ESHID-603888

Los Alamos
NATIONAL LABORATORY

Waste Management Programs

Los Alamos National Laboratory
P.O. Box 1663, MS K491
Los Alamos, NM 87545
505-667-5466

Symbol: EWP-24-015
Date: June 19, 2024
LA-UR-24-25884

Submitted at https://www.regulations.gov

Sasha Lucas-Gerhard
Paul Diss
U.S. Environmental Protection Agency
EPA Docket Center
1200 Pennsylvania Avenue NW
Washington, DC 20460

Subject: Comment *References* from Triad National Security, LLC, Managing and Operating Contractor of the Los Alamos National Laboratory, on Proposed Rule: Revisions to Standards for the Open Burning/Open Detonation of Waste Explosives, 89 Fed. Reg. 19952 (March 20, 2024), Docket ID No. EPA-HQ-OLEM-2021-0397; RIN 2050-AH24

Dear Ms. Lucas-Gerhard and Mr. Diss,

Triad National Security, LLC (Triad) submits the enclosed comment *References* in response to the Environmental Protection Agency's (EPA) proposed alterations to the regulatory standards for the open burning and open detonation (OB/OD) of waste explosives. Triad appreciates the opportunity to provide these comment References for consideration.

Triad, the managing and operating contractor of the Los Alamos National Laboratory (Laboratory), separately submitted:

> **Comments from Triad National Security, LLC, Managing and Operating Contractor of the Los Alamos National Laboratory, on Proposed Rule: Revisions to Standards for the Open Burning/Open Detonation of Waste Explosives, 89 Fed. Reg. 19952 (March 20, 2024), Docket ID No. EPA-HQ-OLEM-2021-0397; RIN 2050-AH24**

In its Comments, the Laboratory identified documentation in the **REFERENCES** section that supports the Laboratory's Comments and/or should be considered in evaluating the proposed alterations to the regulatory standards for the OB/OD of waste explosives. In particular, certain of these References demonstrate that thermal treatment, or OB/OD, can be performed in a manner protective of human health and the environment.

Sincerely,

JEANNETTE HYATT (Affiliate)
Digitally signed by JEANNETTE HYATT (Affiliate)
Date: 2024.06.19 13:49:59 -06'00'

Jeannette T. Hyatt
Senior Director
Environment and Waste Programs

Attachment: Comment *References* from Triad National Security, LLC, Managing and Operating Contractor of the Los Alamos National Laboratory, on EPA Proposed Rule: Revisions to Standards for the Open Burning/Open Detonation of Waste Explosives (LA-UR-24-25884)

Copy: eshq-dcrm@lanl.gov
epccorrespondence@lanl.gov

Comment *References* from Triad National Security, LLC, Managing and Operating Contractor of the Los Alamos National Laboratory, on EPA Proposed Rule: Revisions to Standards for the Open Burning/Open Detonation of Waste Explosives

Submitted June 19, 2024.

Docket ID No. EPA-HQ-OLEM-2021-0397;
RIN 2050-AH24

89 Fed. Reg. 19952 (March 20, 2024)

1. DOE (U.S. Department of Energy), November 2019. *DOE Technical Standard Explosives Safety. DOE-STD-1212-2019*. (DOE 2019)

2. DOE (U.S. Department of Energy), March 2022. *Interim Hazard Classification for Waste Solids Contaminated with Dispersed Explosives (2016-61 Renew-6 Revision)*. (DOE March 2022)

3. DOE (U.S. Department of Energy), April 2022. *Interim Hazard Classification for the Disposal of Trace Explosives in Flammable Liquids (2020-08 Renew-2)*. (DOE April 2022)

4. DOT (U.S. Department of Transportation), November 2014. *Department of Transportation – Special Permit 15448 (Third Revision)*. (DOT 2014)

5. EPA (U.S. Environmental Protection Agency), 2008. *Basic Concepts in Environmental Sciences, Module 6: Air Pollutants/Control Techniques* (Last Updated April 4, 2008). (EPA 2008)

6. Fresquez, P.R., May 2011. *Chemical Concentrations in Field Mice Collected from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 At Los Alamos National Laboratory*. LA-UR-11-10614. Copy available at http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-11-10614. (Fresquez 2011)

7. Fresquez, P.R., L. Hansen, and C. Hathcock, 2013. *Chemical Concentrations in Field Mice/Voles Collected from an Open-Burn Site at Technical Area 16 at Los Alamos National Laboratory, Revision 1*. LA-UR-13-20040. Copy available at https://permalink.lanl.gov/object/tr?what=info:lanl-repo/eprr/ERID-250074. (Fresquez *et al.* 2013)

8. Gadek, C.R. and M.S. Velardi, October 2021. *2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory*. LA-UR-21-30407. Copy available at https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-21-30407. (Gadek & Velardi 2021)

9. Gadek, C.R., M.S. Velardi, and E.J. Abeyta, January 2023. *2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory*. LA-UR-23-20631. (Gadek *et al*. 2023)

10. Gaukler, S.M. and J.E. Stanek, June 2019. *Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory*. LA-UR-19-25647. OSTI Identifier 1529507. Copy available at https://www.osti.gov/biblio/1529507. (Gaulker & Stanek 2019)

11. Gaukler, S.M. and J.E. Stanek, March 2020. *2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-20-22529. OSTI Identifier 1607903. Copy available at https://www.osti.gov/biblio/1607903. (Gaulker & Stanek 2020)

12. Gaukler, S.M. and J.E. Stanek, March 2021. *2020 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical*

Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory. LA-UR-21-22303. OSTI Identifier 1770094. Copy available at https://www.osti.gov/biblio/1770094. (Gaulker & Stanek 2021)

13. Gaukler, S.M. and J.E. Stanek, March 2022. *2021 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-22-21423. OSTI Identifier 1846122. Copy available at https://www.osti.gov/biblio/1846122. (Gaulker & Stanek 2022)

14. Gaukler, S.M. and J.E. Stanek, February 2023. *2022 Results for Avian Monitoring of Inorganic Elements and Organic Chemical Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-23-20968. (Gaulker & Stanek 2023)

15. Green, A. and S. Allen, 2011. *Open Detonation Air Sampling Summary for Resource Conservation and Recovery Act (RCRA) Permitting at Los Alamos National Laboratory*. LA-UR-11-03249. Copy available at https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-11-03642. (Green & Allen 2011)

16. Hathcock, C.D., April 2014. *Avian Monitoring at the TA 36 Minie Site, TA-39 Point 6 Site, and TA 16 Burn Ground*. LA-UR-13-27825. Copy available at http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-13-27825. (Hathcock & Fair 2013)

17. Hathcock, C.D., October 2014. *Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-14-28161. OSTI Identifier 1160102. Copy avilable at https://www.osti.gov/biblio/1160102. (Hathcock 2014)

18. Hathcock, C.D., October 2015. *Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-15-28296. (Hathcock 2015)

19. Hathcock, C.D., B.E. Thompson, and J. T. Berryhill, April 2017. *2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-17-20359. OSTI Identifier 1340948. Copy avilable at https://www.osti.gov/biblio/1340948. (Hathcock *et al.* 2017)

20. Hathcock, C.D., A.W. Bartlow, and B.E. Thompson, April 2018. *2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-18-22897. OSTI Identifier 1435543. Copy avilable at https://www.osti.gov/biblio/1435543. (Hathcock *et al.* 2018)

21. Hathcock, C.D., *et al*., May 2019. *2018 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-19-24156. OSTI Identifier 1514915. Copy avilable at https://www.osti.gov/biblio/1514915. (Hathcock *et al.* 2019)

22. Hites, D.A., 2011. *Dioxins: An Overview and History*. Envt'l Science & Tech, Vol. 45, No. 1. (Hites 2011)

23. Huang, H., and A. Buekens, 1995. *On the Mechanisms of Dioxin Formation in Combustion Processes*. Chemosphere, Vol. 31, No. 9. (Huang *et al*. 1995)

24. Kulkarni, P.S., *et al.*, July 2008. *Dioxins sources and current remediation technologies--A review*. Environment International, Vol. 34, Issue 1, Pages 139-153. Available at https://www.sciencedirect.com/science/article/pii/S0160412007001390?via%3Dihub. (Kulkarni *et al*. 2008)

25. LANL (Los Alamos National Laboratory), June 2020c. Supplement 4-3 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Screening Level Air Modeling Analysis and Risk Evaluation for Open Detonation Operations*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 60 to 144). (LANL 2020c)

26. LANL (Los Alamos National Laboratory), June 2020f. Supplement 4-7 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Open Detonation Unit at Technical Area 36 Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 448 to 545). (LANL 2020f)

27. LANL (Los Alamos National Laboratory), June 2020g. Supplement 4-8 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Open Detonation Unit at Technical Area 39 Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 546 to 636). (LANL 2020g)

28. LANL (Los Alamos National Laboratory), June 2020k. Supplement 4-12 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Screening Level Air Modeling Analysis and Risk Evaluation for Open Burning Operations at Los Alamos National Laboratory*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 784 to 856) (last accessed August 2023). (LANL 2020k)

29. LANL (Los Alamos National Laboratory), June 2020l. Supplement 4-14 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Thermal Measurements at the TA-16-388 Flash Pad*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 874 to 922). (LANL 2020l)

30. LANL (Los Alamos National Laboratory), June 2020n. Supplement 4-16 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515 (LANL Part B Application-Volume 2_june 2020.pdf). *Technical Area 16 - Open Burn/Open Detonation (OB/OD) Area - Technical Area 16-388 Flash Pad Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. Available at https://cloud.env.nm.gov/waste/pages/view.php?ref=15167&search=%21collection5316&order_by=relevance&sort=DESC&offset=0&archive=0&k=e3b22cd65c&curpos=1&restypes= (PDF pp. 1030 to 1090) (last accessed August 2023). (LANL 2020n)

31. LANL (Los Alamos National Laboratory), May 2022. *Open Detonation Unit at Technical Area 36 Human Health and Ecological-Risk Screening Assessments*. (LANL WMP 2022)

32. LANL (Los Alamos National Laboratory), May 2022. *Open Detonation Unit at Technical Area 39 Human Health and Ecological-Risk Screening Assessments*. (LANL 2022)

33. Leininger, L.D., *et al.*, May 2020. *IHE Material and IHE Subassembly Qualification Test Description and Criteria*, Vol. 14.7. LLNL-TR-679331-REV-1. LA-UR-15-29238. OSTI Identifier 1635762. (Leininger *et al*. 2020)

34. Mason, N.M. *et al.*, May 2024. *2023 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory*. LA-UR-24-21036. (Mason *et al*. 2024)

35. Mitchell, W.J. and J.C. Suggs, August 1998. *Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD)*. EPA/600/R-98/103. (Mitchell *et al*. 1998)

36. Oxley, J.C., 1998. *The Chemistry of Explosives*, Chapter 5. (Oxley 1998)

37. Rodriguez, J.M. and E.J. Abeyta, March 2021. *2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory*. LA-UR-21-22304. OSTI Identifier 1773305. Available at https://www.osti.gov/biblio/1773305. (Rodriguez & Abeyta 2021)

38. Sanchez, A.A., C.D. Hathcock, and B.E. Thompson, February 2020. *2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at the Los Alamos National Laboratory*. LA-UR-20-20436. OSTI Identifier 1597317. Copy available at https://www.osti.gov/biblio/1597317. (Sanchez *et al*. 2020)

1. DOE (U.S. Department of Energy), November 2019. *DOE Technical Standard Explosives Safety. DOE-STD-1212-2019*. (DOE 2019)

TS

MEASUREMENT
SENSITIVE

DOE-STD-1212-2019
November 2019

DOE TECHNICAL STANDARD

EXPLOSIVES SAFETY

U.S. Department of Energy
Washington, D.C.20585

AREA SAFT

(This page left intentionally blank.)

FOREWORD

1. This Department of Energy (DOE) Standard has been approved to be used by DOE, including the National Nuclear Security Administration, and their contractors.
2. Comments (recommendations, additions, and deletions) and data, that may be of use in improving this document, should be e-mailed to thomas.garcia@nnsa.doe.gov or sent to:

   NA-513
   U.S. Department of Energy
   National Nuclear Security Administration
   P.O. Box 5400
   Albuquerque, NM 87185-5400

3. This Standard is the successor to DOE-STD-1212-2012. It provides requirements for an Explosives Safety Program.
4. This official version of the Standard may be found online at:

   https://www.standards.doe.gov/standards-browse

(This page left intentionally blank.)

Table of Contents

(This page left intentionally blank.)

1. SCOPE/PURPOSE

1.1. This Technical Standard provides the basic technical requirements for an explosives safety program necessary to ensure safe operations involving explosives, explosives assemblies, pyrotechnics and propellants, and assemblies containing these materials.

1.2. This Technical Standard establishes safety controls and standards not addressed in other existing DOE or non-DOE regulations and is intended to close the safety gap created by DOE's unique activities to govern the DOE explosives safety process and ensure explosives safety is commensurate with the risk.

1.3. This Technical Standard is based on the Cardinal Principle of Explosives Safety, which is to limit exposure to a minimum number of personnel, for a minimum amount of time, to a minimum amount of explosives, consistent with safe and efficient operations.

2. APPLICABILITY

2.1. This Technical Standard applies to all DOE sites engaged in any of the following activities involving explosives, pyrotechnics, or propellants as well as assemblies containing these materials:

- Developing
- Manufacturing
- Handling
- Storing
- Transporting
- Processing
- Testing

2.2. Existing facilities that do not meet the requirements of this technical standard may continue to be used for the balance of their functional lives if the following two conditions are met and documented:

2.2.1. The current operation presents no significantly greater risk than that assumed when the facility was originally designed.

2.2.2. It can be demonstrated clearly that a modification to bring the facility into compliance is not feasible.

3. ADMINISTRATION AND MANAGEMENT

3.1. NA-513 *Office of Worker Safety and Health Services* is the National Nuclear Security Administration (NNSA) Office of Primary Interest (OPI) for this Technical Standard. NA-513 shall act as the Preparing Activity for this Technical Standard. The DOE/NNSA Explosives Safety Committee (ESC) shall review, evaluate, and recommend proposed changes to this Technical Standard. The changes shall be consonant with state-of-the-art technical changes in the field and include lessons learned from DOE/NNSA, other Governmental, and Industry experience and mishaps. NA-513 shall evaluate proposed changes to this Technical Standard on an annual basis. The OPI may decide to submit a section into RevCom for review and approval.

3.1.1. The DOE/NNSA ESC shall evaluate proposed changes at the request of the OPI.

3.1.2. Throughout this Standard, requirements are denoted by the words “shall” and “should.”

Note: The use of the word “may” with reference to application of a procedure or method denotes an acceptable means of performing the task.

3.1.2.1. “Shall” requirements are mandatory.

Note 1: Relief from a "shall" requirement requires an exemption (see section 3.2 of this chapter).

Note 2: A contractor may use an approved equivalency as an alternative approach to meet a "shall" requirement, (see section 3.3 of this chapter).

3.1.2.2. “Should” requirements are advisory.

Note: Relief from a “should” requirement requires a waiver (see section 3.4 of this chapter).

3.2. Exemption

3.2.1. Exemptions are the release from requirements in this Standard.

3.2.2. Exemptions are approved by the Head of DOE Field Element (DOE/NNSA Field/Operations/ Production Office) or designee, and documented for the OPI in a memorandum.

3.2.3. Central Technical Authority (CTA) or designee concurrence is required prior to the granting of exemptions for nuclear safety directives or successor documents identified in the current version of DOE O 410.1, Central Technical Authority Responsibilities Regarding Nuclear Safety

Requirements. CTA or designee concurrence is required for exemptions involving hazard category 1, 2, or 3 nuclear facilities.

3.2.4. Exemptions are processed by the Head of the DOE Field Element or designee. Follow DOE-O-251.1D Appendix E for the Exemption Process.

3.3. Equivalency

3.3.1. Equivalencies represent an alternative approach to meeting a “shall” requirement of the Standard intended to achieve an equivalent level of safety.

3.3.2. Required documentation for an equivalency:

- Description of the condition.
- Requirement(s) being affected.
- Reason why requirement cannot be achieved.
- Alternate approach.
- Contractor Explosives Safety Authority Having Jurisdiction (AHJ) determination of equivalent safety.
- Contractor Explosives Safety AHJ explanation of additional risk (if applicable).

3.3.3. The Contractor Explosives Safety AHJ shall evaluate, determine, and document that the proposed alternate approach complies with the intent of the provisions of this Standard.

3.3.4. The Contractor Explosives Safety AHJ shall provide a determination of equivalent safety.

3.3.4.1. If the equivalency introduces additional risk, the Contractor Explosives Safety AHJ shall include an explanation of the additional risk.

3.3.5. Equivalencies shall be coordinated with the Federal Explosives Safety Subject Matter Expert (SME) (DOE/NNSA Sites).

3.3.6. Equivalencies that do not introduce additional risk are approved by the Contractor Facility Manager.

3.3.6.1. Equivalencies that introduce additional risk are approved by the Head of DOE Field Element.

3.4. Waiver

3.4.1. A Waiver provides relief from a “should” requirement.

3.4.2. A Waiver is where the conditions, practices, means, methods, or processes to be used are determined to be safe and necessary.

3.4.3. The Contractor Explosives Safety AHJ shall evaluate, determine, and document that the proposed waiver complies with the intent of the provisions of this Standard. This documentation shall include a determination regarding the safety and necessity of the waiver.

3.4.4. Waivers are approved by Contractor Facility Management.

3.4.5. Required documentation for a waiver:

- Description of the condition.
- Requirement being affected.
- Reason why compliance is not achieved.
- Compensatory measures taken to provide protection.
- Any proposed corrective actions and schedule.
- Contractor Explosives Safety AHJ determination.
- Duration of the waiver.

4. EXPLOSIVES SAFETY PROGRAM (ESP) REQUIREMENTS

4.1. All DOE sites within the scope of this Technical Standard shall establish and maintain a site-specific ESP based on the requirements in this Technical Standard and 10 CFR 851.24. ESPs shall address all applicable explosives operations and activities. The ESP shall include:

4.1.1. The organizational structure for site Explosives Safety operations and activities. Address the following committees as they apply:

4.1.1.1. A Contractor Explosives Development Committee to approve each phase of an explosives development program.

4.1.1.2. A Contractor Explosives Storage Review Committee to establish and approve storage review intervals for all bulk explosives stored at the facility.

4.1.2. The process to resolve technical conflicts between Explosives Safety requirements and other functional area technical requirements.

4.1.3. The process to apply specific Explosives Safety provisions to meet Level-of-Protection criteria.

4.1.4. The process to interact with other safety disciplines supporting explosives operations and activities performed at the site.

4.1.5. The hazard analysis process in support of explosives operations and activities, with a graded approach.

4.1.6. The training and qualification program to support explosives operations and activities.

5. ROLES AND RESPONSIBILITIES

5.1. NNSA Associate Administrator for Safety, Infrastructure, and Operations.

5.1.1. Designates Explosives Approval Authority (EAA) to approve qualification of Insensitive High Explosive (IHE) Material and/or Subassembly.

5.1.2. Exercises responsibilities delegated by the Administrator under this Standard.

5.2. Central Technical Authority (CTA)

5.2.1. Concurs with exemptions to this Technical Standard involving hazard category 1, 2, or 3 nuclear facilities.

5.3. Explosives Approval Authority (EAA)

5.3.1. Approves Qualification of Insensitive High Explosive Material and/or Subassembly.

5.4. Head of DOE Field Element (DOE/NNSA Field/Operations/Production Office).

5.4.1. Verifies that the facilities, activities, and programs under their purview operate in compliance with the requirements of this Technical Standard.

5.4.2. Approves exemptions to this Technical Standard.

5.4.2.1. Exemptions involving hazard category 1, 2, or 3 nuclear facilities require CTA concurrence.

5.4.3. Approves equivalencies to this Technical Standard that introduce additional risk.

5.4.4. Approves Explosives Safety Site Plans.

5.4.5. Approves site and general construction plans for explosives facilities.

5.4.6. Provides oversight of the Contractor ESP.

5.4.7. Appoints a primary and alternate field element representative to the DOE/NNSA Explosives Safety Committee (ESC). Ensures an appointed member attends each DOE/NNSA ESC Meeting.

5.5. Federal Explosives Safety Subject Matter Expert (SME) (DOE/NNSA Sites).

5.5.1. Reviews and recommends approval or disapproval to the Head of DOE Field Element or designee for:

5.5.1.1. Exemptions to this Technical Standard.

5.5.1.2. Equivalencies to this Technical Standard that introduce additional risk.

5.5.2. Reviews the Explosives Safety Site Plans (ESSP) and recommends approval or disapproval to the Head of DOE Field Element or designee.

5.5.3. Performs assessments of the Contractor ESP in accordance with DOE O 226.1, Implementation of Department of Energy Oversight Policy (current version).

5.5.4. Familiarizes themselves with the Contractor ESP and the explosives operations and activities under their contract.

5.6. DOE/NNSA ESC Chair.

5.6.1. Performs duties identified in this Technical Standard and the approved DOE/NNSA ESC Charter.

5.7. Contractor Facility Manager

5.7.1. Establishes and maintains a site-specific ESP.

5.7.2. Assigns a Contractor Explosives Safety Program Manager.

5.7.3. Appoints a primary and alternate Explosives Safety Subject-Matter-Expert as the Contractor Explosives Safety AHJ and Voting Member on the DOE/NNSA Explosives Safety Committee. Ensures an appointed member attends each DOE/NNSA ESC Meeting.

5.7.4. Approves equivalencies that provide equivalent safety.

5.8. Contractor Facility Management

5.8.1. Implements the Explosives Safety requirements of this Technical Standard into operations and activities involving explosives.

5.8.2. Verifies that the site training and qualification program addresses explosives workers.

5.8.3. Verifies that explosives-related activities performed on-site by entities other than DOE/NNSA contractors/subcontractors are coordinated through the Contractor Explosives Safety AHJ.

5.8.4. Transmits the ESSP to the Head of DOE Field Element or Designee for review and approval.

5.8.5. Selects hazard analysis methodology and addresses the results.

5.8.6. Approves explosives area electrical hazard classification analyses.

5.8.7. Establishes the levels of approval required for operating procedures, based on the operation’s inherent risk.

5.8.8. Establishes the frequency/interval of inspections, operational checks, storage review, and other items as identified in this Technical Standard.

5.8.9. Approves waivers.

5.9. Contractor Explosives Safety Program Manager

5.9.1. Assists Contractor Facility Management in implementing the requirements of this Technical Standard.

5.9.2. Performs site-specific explosives safety assessments to verify compliance with the requirements of this Technical Standard.

5.9.3. Recommends approval of the ESSP to Contractor Facility Management.

5.10. Contractor Explosives Safety Authority Having Jurisdiction (AHJ)

5.10.1. Assists Contractor Facility Management so that the level of explosives safety provided to site-specific explosives operations and activities is commensurate with the requirements of this Technical Standard.

5.10.2. Provides site-specific determinations, interpretations, and clarifications to the requirements of this Technical Standard.

5.10.3. Interfaces with other disciplines to resolve site-specific conflicts between national codes and standards and this Technical Standard.

5.10.4. Reviews and recommends approval of electrical hazard classification analyses.

5.10.5. Provides documented determinations and recommendations to Contractor Facility Management regarding proposed equivalencies and waivers to the requirements of this Technical Standard.

6. GENERAL OPERATIONAL SAFETY

6.1. Cardinal Principle

6.1.1. The Cardinal Principle of Explosives Safety is to limit exposure to a minimum number of personnel, for a minimum amount of time, to a minimum amount of explosives, consistent with safe and efficient operations.

6.1.2. The Cardinal Principle shall be observed at any location or in any operation involving explosives.

6.2. Protection of Explosives

6.2.1. Explosives are energetic materials that can react violently and should be protected from abnormal stimuli or environments, including:

- Friction forces;
- Excessive pressures and temperatures;
- Impact, shock, and pinching;
- Deformation;
- Electrical sparks, abrasive or welding sparks, and open flame;
- Contamination; and
- Contact with incompatible materials.

6.3. Equipment Checks

6.3.1. Before being used in the explosives process, and at established intervals, processing and test equipment shall be checked for:

- Proper design;
- Proper function;
- Specified clearances between parts in relative motion;
- Abnormal metal to metal rubbing of moving parts potentially contacting explosive materials;
- Cracks, voids, or screw threads where explosives may accumulate; and
- Contamination that is incompatible with the process materials.

6.3.2. This checkout may require the use of mock explosives in process or test conditions.

6.3.3. Explosive materials shall not be pinched or confined between equipment lids or covers and their mating surfaces. These surfaces shall be cleaned before cover placement. This includes pressing operations.

6.4. Inspection Frequency

6.4.1. When this Technical Standard calls for an inspection, but the inspection interval is not specified, Contractor Facility Management shall establish the inspection interval.

6.4.2. Inspection intervals shall be modified when operational experience dictates a need.

6.5. Hazard Identification and Communication

6.5.1. Contractor Facility Management shall identify and maintain a current list of explosives and other hazardous materials used in conjunction with their operations.

6.5.2. Contractor Facility Management shall educate and train employees in the hazards and precautions required for handling explosives and materials used in conjunction with explosives.

6.6. Work Environment

6.6.1. Where solid bare explosive pieces are handled:

6.6.1.1. The floor should be resilient or covered with a resilient material.

6.6.1.2. All hard objects that explosives could strike in a handling incident should be covered with a resilient material where practical.

Note: Physical safety systems demonstrated to preclude the explosives from being dropped or struck could meet these requirements.

6.6.2. A procedure should be established to account for hand tools that may be inadvertently dropped into an explosives processing operation, thus creating a hazard.

6.6.3. Personnel shall be assigned in such a manner that each worker’s presence is monitored frequently and assistance can be provided or aid summoned in the event of an emergency.

6.7. General Explosives Area Controls

6.7.1. Smoking, Matches, Lighters, Metal Articles

6.7.1.1. There shall be no smoking in explosives storage, processing, or test areas, except in designated locations.

6.7.1.2. No matches, lighters, or other fire, flame, or spark producing devices shall be taken into an explosives control area except with written authorization. If authorized to be carried, matches shall be contained in a metal carrying device too large to fit into pockets. “Strike anywhere” matches shall not be used.

6.7.1.3. Operating personnel should not carry metal articles (e.g., keys, jewelry, knives, coins) in explosives processing areas where such items could constitute a hazard if dropped into the process.

6.7.2. Cooking and Eating

6.7.2.1. Food or beverages shall not be consumed in explosives buildings, except in designated areas.

6.7.2.2. There shall be no personal dishes or utensils in an explosives building, except in designated eating areas.

6.7.2.3. Coffee pots, hot plates, ovens (including microwaves), and portable electric heaters shall not be permitted in rooms where:

- Explosives may be present.
- Combustible vapors or dust may be present.
- Electrical classification of appliances is not compatible with the area.

6.7.3. Access to Explosives Areas

6.7.3.1. Access control procedures shall be established for entry to all explosives areas.

6.8. Concurrent Contact Operations

6.8.1. The preferred setup for explosives operations is to perform each operation in a separate location to preclude any adverse operation interaction. Because such an arrangement is frequently impractical, concurrent operations may be permitted if the following conditions exist:

6.8.1.1. Potential equipment-operator interactions between the two operations have been analyzed and the risk is not appreciably greater than that for both operations considered separately.

6.8.1.2. Explosive materials in either operation are not exposed to stress conditions such as elevated temperature (melting or heat conditioning), elevated pressures (pressing or extruding), or deformation/shear (machining or cutting).

6.8.1.3. Mixing of materials in the concurrent operations does not create compatibility problems.

6.8.1.4. Each operator is aware at all times of concurrent operations in his or her area.

6.9. Contamination Prevention

6.9.1. Precautions shall be taken to avoid mutual contamination when two or more incompatible explosives or materials are handled on a single line or within one building or room.

Note: This includes vacuum systems and explosives scrap collection.

Note: Inadvertent mixing of incompatible explosives materials can be hazardous not only to manufacturing facilities and personnel but also to the user if such materials are loaded into explosives devices.

6.9.2. When two or more explosives are used in a line or within a building and mixing is not intended, the materials shall be segregated in separate locations.

6.9.2.1. Containers shall be clearly marked with the weight and contents identified.

6.9.2.2. Care shall be exercised to properly segregate material in service magazines and in operating buildings.

6.9.3. When a different explosive is to be used in process equipment, the equipment shall be thoroughly cleaned, and excess explosive from the previous job should be removed from the bay.

Note: This eliminates the hazards caused by mixing materials.

6.9.4. In any explosives operation, permanent service lines shall be labeled as to their contents.

6.9.4.1. Valves and switches on service lines whose operation can result in a hazardous situation shall be labeled as to their function.

7. EXPLOSIVES FACILITY DESIGN/SITE CRITERIA

7.1. Explosive Facilities

7.1.1. Permanent explosives facilities shall comply with Unified Facilities Criteria (UFC) 3-340-02.

7.1.1.1. DOE/TIC-11268 may be used as a supplement as it often resolves some special DOE design considerations and may result in a more economical design.

Note: As an example, it describes how to reduce blast overpressure from an explosion due to a high-altitude location.

7.1.2. Portable magazines should be ventilated and resistant to water, fire, and theft.

7.1.2.1. Portable magazines may be made of any material that meets these requirements.

Note: Type 2 portable magazines that comply with 27 Code of Federal Regulations (CFR) Part 555.208 meet these criteria.

7.1.3. Portable magazines shall be sited per Department of Defense Explosives Safety Regulation (DESR) 6055.09 as aboveground magazines.

7.2. Blast Resistant Design

7.2.1. Blast-resistant design for personnel and facility protection shall be based on the TNT (Trinitrotoluene) equivalency of the maximum quantity of explosives and propellants.

7.2.2. TNT equivalency shall be increased by 20% for design purposes in accordance with UFC 3-340-02.

7.3. Criteria for Lightning Protection Systems

7.3.1. Lightning protection shall be designed in accordance with National Fire Protection Association (NFPA) 780, Standard for the Installation of Lightning Protection Systems, and Chapter 42 of this Technical Standard.

7.4. Unproven Facility Design

7.4.1. For an unproven facility design, either a validated model or full-scale test is required to validate structural adequacy unless a high degree of confidence can be provided by calculations or other technical bases.

7.4.1.1. Prior to full-scale testing, test plans shall be provided to the Head of DOE Field Element (DOE/NNSA Field/Operations/Production Office) for concurrence.

7.5. Design of New Facilities

7.5.1. The design of new explosives facilities and major modifications to existing explosives facilities shall conform to the following:

7.5.1.1. The requirements established in this Technical Standard.

7.5.1.2. The methods of analysis and design, as well as protective design features specified in UFC 3-340-02.

Note: It is not intended that existing physical facilities be changed arbitrarily to comply with these provisions, except as required by law.

7.5.1.3. The following documents may be used to assist the design and analysis of blast-resistant design. The most current and updated version should be used.

- DOE/TIC-11268
- Department of Defense Explosives Safety Board (DDESB) TP-12
- DDESB TP-13
- DDESB TP-15
- DDESB TP-16
- DDESB TP-17

7.5.2. Studies necessary to provide the technical basis for location, engineering, design, and operation (under normal and potential design basis accident conditions) of buildings shall follow the stricter of this Technical Standard or DESR 6055.09 for establishing explosives quantity-distance (QD) separation.

7.5.3. To maintain maximum, long-term flexible use of facilities, Contractor Facility Management is encouraged to consider installing dual-rated (i.e., Class I, Division 1 and Class II, Division 1) permanent wiring and equipment in explosives operating rooms. As a minimum, installation should allow for easy conversion to dual-rated wiring and equipment.

7.6. Site and General Construction Plans

7.6.1. Site and general construction plans for explosives facilities, as well as plans for changes in utilization of facilities or mission changes that adversely affect the explosives QD requirements, shall be submitted to the Head of DOE Field Element (DOE/NNSA Field/Operations/Production Office) for review and approval. Plans shall be forwarded for:

7.6.1.1. New construction or major modifications of facilities for explosives activities.

Note: When modifications or rehabilitation plans for existing facilities do not introduce additional hazards or do not increase the net explosives capacity or chemical agent hazard for which the facility was designed or sited, site and general construction plans are not required to be submitted to the Head of DOE Field Element (DOE/NNSA Field/Operations/Production Office) for review.

7.6.1.2. Facilities for activities not involving explosives that are in such proximity to explosives as to be exposed to hazards or for which a reasonable doubt may exist regarding possible exposure to hazards.

7.6.1.3. Facilities for activities not involving explosives that become exposed to blast, fire, or fragment hazards; or potential toxic chemical agent release due to change in facility mission or facilities usage.

7.6.2. When the review of site and general construction plans is required, Contractor Facility Management shall:

7.6.2.1. Indicate specifically in the letter of transmittal its approval of the proposal, along with changes, modifications, or specific precautionary measures considered necessary.

7.6.2.2. Comply with applicable requirements of DESR 6055.09 for site plan submission.

7.6.2.3. Retain a copy of the complete site plan and the final safety submission, together with DOE/NNSA Field/Operations/Production Office letter(s) of approval, as a permanent record at the facility/site of origin.

7.6.2.4. Keep facility maps current with the latest site plan approval and reconciled with the facility master planning document.

7.6.3. DESR 6055.09 identifies minimum distances for protection from fragment hazards and blast overpressure.

7.6.3.1. The methods of calculation presented in DDESB TP-13 may be used to establish a smaller fragment exclusion zone.

Note: It is not intended that these minimum fragment distances be applied to operating facilities or dedicated support functions within an operating line. For these exposures, the DOE criteria presented in this Technical Standard for Class I, II, III, or IV Level-of-Protection activities with appropriate QD separations are the required protection levels.

7.6.4. In addition to this Technical Standard, the following are resource documents for the siting and design of explosives facilities:

- DOE Order 420.1
- DOE Order 430.1
- 10 CFR Part 830
- UFC 3-340-02
- DOE/TIC-11268
- DESR 6055.09
- DDESB TP-13
- AMCR 385-100
- TR-828
- AD 411445
- AFWL-TR-74-102
- HNDM-1110-01-2

8. HAZARD ANALYSIS

8.1. Hazard Analysis

8.1.1. Before starting any operation involving explosives, a documented hazard analysis shall be performed per 10 CFR 851.21.

8.1.1.1. Hazard analyses shall be performed using a graded approach applicable to the specific explosives operation.

8.1.2. When an explosives operation changes, new hazards shall be addressed in a supporting hazard analysis which then becomes part of the original hazard analysis.

8.1.3. When modifying facility or process equipment, a documented analysis shall be performed to validate uniform standards are adhered to throughout the facility.

8.1.4. Contractor Facility Management shall address the results of a hazard analysis. Hazard prevention and abatement shall be conducted per 10 CFR 851.22.

8.2. Similar Processes

8.2.1. A single hazard analysis may be performed for similar processes performed in a single facility, provided that the “worst case” process is the basis for the hazard analysis.

8.2.1.1. Selection criteria for the worst-case process are:

- Sensitivity of materials;
- Quantity of materials;
- Number of personnel potentially affected; and
- Impact on other operations and activities.

8.2.1.2. As a new process is considered for inclusion under an existing hazard analysis, each step of the new process shall be evaluated to determine if it is within the scope of the existing hazard analysis, and to identify any hazards not addressed in the existing hazard analysis.

8.3. High Risk

8.3.1. Hazard analysis supporting explosives synthesis, formulation, manufacturing, testing, or disposal operations shall be performed and revalidated as a team effort. The team shall consist of a minimum of three personnel, to include at least one technical member and one operator. The following makeup is recommended:

- Team Leader, who is familiar with the analysis methodology used.
- Technical Member(s), who is familiar with the process being analyzed.
- Scribe, who writes notes of meetings and interviews and drafts reports.
- Operator who actually performs the work being analyzed.
- Explosives Safety Subject Matter Expert.

Note: A technical member is an individual who has expertise in a particular technical discipline (e.g. engineering, chemistry, physics, and safety).

8.3.2. Contractor Facility Management shall select the analysis methodology used (e.g., What if Analysis, Fault Tree Analysis, Event Tree Analysis).

8.3.3. Employees and employee representatives shall be consulted on the hazard analysis.

8.3.4. The result of the hazard analysis shall be provided to employees involved in or affected by the operation.

8.3.5. The hazard analysis shall be updated and revalidated at least every five years.

8.4. Electrical Hazard Classification Analysis

8.4.1. If a documented analysis is used to determine the electrical hazard classification for areas where explosives operations or activities are conducted, the analysis shall be reviewed by the Contractor Explosives Safety AHJ and approved by Contractor Facility Management.

8.4.2. The scope of the analysis shall identify the specific location and specific explosives operation or activity.

8.4.3. The analysis should be limited to the following:

- Enclosed areas, (e.g. rooms, bays, chambers).
- Normal operating conditions.

8.4.4. The analysis should consider the following:

- The physical configuration of the explosives, (encased, bare, consolidated, powder, packaged, unpackaged).
- The explosives operation or activity being conducted.
- Other activities or operations being conducted in the same area.
- Migration of explosive or ignitable gases, vapors or dust mixtures to or from adjacent areas.

Note: The analysis shall be updated and revalidated if any of these change.

9. OPERATING PROCEDURES

9.1. Procedures

9.1.1. Operating procedures shall be written and approved for each operation involving explosives.

9.1.2. Operating procedures shall implement all applicable controls derived from supporting hazard analysis prior to the procedure being approved for use.

Note: Operating procedures that were not prepared using the current hazard analysis shall be evaluated to verify that all applicable controls (new or revised) derived from the current hazard analysis are implemented prior to the procedure being approved for use.

9.2. Approval

9.2.1. New or revised operating procedures shall be reviewed and approved prior to use.

9.2.2. Contractor Facility Management should establish levels of approval based on the operation’s inherent risk.

9.2.3. The review and approval process shall include line and safety organizations.

9.3. Operating Procedures Content

9.3.1. The introduction to the procedure should include the following:

9.3.1.1. A statement of the scope, nature of the operation and its objectives, and defining what facilities and equipment are covered.

9.3.1.2. The name of the department responsible for the operation and the procedure.

9.3.1.3. If the procedure serves as the basis for an exemption, equivalency, or waiver from the requirements of this Technical Standard, a statement to this effect and a specific reference shall be included.

9.3.2. The materials and equipment section should present the following information:

9.3.2.1. All significant tools, supplies, chemicals, and equipment necessary to perform the operation should be listed in the procedure or in a separate required document.

9.3.2.2. Specifications for approved chemicals, supplies, tooling, and equipment should be referenced where applicable.

9.3.2.3. An explanation of any specific hazard involved in the handling of chemicals or explosives, or a reference to a document that describes the hazards.

9.3.3. The safety section of the procedure should present the following information or reference a safety document that specifies the requirements:

9.3.3.1. General safety rules to be observed and techniques to be applied that verify safety of operations, prevent personnel injury or illness, and prevent equipment damage.

9.3.3.2. Additional or specific emergency controls not addressed by the facility emergency plan.

9.3.3.3. Protective equipment used during the operation.

9.3.3.4. The number of personnel (workers and casuals) and explosives weight limits associated with the operation being conducted.

9.3.4. The operations section should consist of sequential directions written or pictured in clear, concise steps that describe how to perform a particular operation:

9.3.4.1. General directions for operation of all major explosives handling equipment.

9.3.4.2. Particular emphasis should be placed on safety interlocks and controls, and their proper use.

9.3.4.3. If a particular operation requires that no other operation be performed concurrently in the same work area, this requirement shall be stated clearly in the procedure.

9.4. Special or Experimental Procedures

9.4.1. In addition to the applicable requirements listed for Operating Procedures, the following shall also be addressed:

9.4.1.1. Field operations (remote to normally occupied areas) shall include procedures to verify prompt response of both fire and emergency medical services.

9.4.1.2. Personnel involved with the operation shall be briefed or trained on any unique aspects of the operation and emergency procedures.

9.4.2. When a special or experimental operation shall be conducted a number of times, an Operating Procedure should be written and approved.

10. TRAINING

10.1. Explosives Safety Training

10.1.1. Personnel shall be properly trained before they are assigned to explosives operations or operate any explosives transport vehicle.

10.1.2. The training for explosives work serves to assist in conducting work safely and developing safety awareness and shall verify that personnel:

- Develop and maintain a safe attitude towards work with explosives.
- Define and understand the potential hazards involved.
- Learn correct skills to perform tasks safely.
- Are prepared for unexpected hazardous conditions.
- Read and understand the appropriate operating procedures.

10.2. Training and Qualification Programs

10.2.1. Each Site's Training and Qualification Program shall address Explosives Safety training.

10.2.2. An employee shall not be permitted to continue working with explosives if the supervisor, with counsel from medical personnel, determines that he or she is unable to perform the task safely. Possible reasons include:

- Physical injury or illness.
- Disease.
- Mental or emotional disturbances.

10.3. Unexploded Ordnance (UXO) Qualification

10.3.1. Personnel in charge of UXO removal/disposal should be US citizens and have successfully completed training at a US Military Explosives Ordnance Disposal (EOD) school.

10.3.1.1. Personnel shall provide documentation of completed training and have a minimum of 18 months operational EOD experience.

10.3.2. Personnel performing UXO removal or disposal shall have completed training at a US Military EOD school or have equivalent training or experience.

10.3.3. All other personnel engaged in UXO operations shall be trained thoroughly in applicable UXO recognition and Explosives Safety.

10.3.4. Personnel requiring access to areas known or suspected to contain UXOs shall be required to complete UXO awareness training and comply with any site-specific additional UXO area access requirements.

10.3.5. Sites containing UXOs shall establish site-specific UXO awareness training.

11. QUANTITY-DISTANCE

11.1. Explosives Safety Site Plan Submission and Approval

11.1.1. Contractor Facility Management shall verify that ESSPs are submitted to the Head of DOE Field Element (DOE/NNSA Field/Operations/Production Office) for review and approval.

11.1.2. Where there is an increase in risk, an ESSP shall be resubmitted and approved prior to start of operations for the following conditions:

- There is an increase in explosive weight.
- The facility undergoes a major modification.
- The required Level-of-Protection changes.

11.1.3. Risk based explosives siting, as described in DDESB TP-14 is another tool to address explosives QD determinations of equivalency of safety.

11.1.4. The site plan package shall contain the following:

11.1.4.1. A QD Chart containing the following:

- Each sited facility potential explosion site (PES) listing maximum net explosives weight (NEW) for each applicable Hazard Division (HD).
- Actual and required distance to exposed sites (ES).
- QD criteria used for siting each PES - ES relationship.

11.1.4.2. Map(s) showing each PES, its clear zone, and all ESs within the clear zone.

11.1.4.3. Personnel limits for the explosives facility.

11.1.4.4. Description(s) of explosives and non-explosives operations within the clear zone.

11.1.4.5. Justification(s) for facilities not meeting current criteria for the operation that address:

- Bringing the facility up to current standards is not feasible, and
- Operations present no significantly greater risk than that assumed when the facility was originally constructed.

11.1.5. If the siting has any unique characteristics, explain what they are and what criteria is being applied.

Note: If a facility is built to control blast effects and fragments, QD to other facilities do not apply.

11.1.6. A letter of transmittal shall accompany each site plan or group of site plans. The letter shall contain the following:

11.1.6.1. Reason for submittal (preliminary or final siting of new facility, site plan/plans for grandfathered facility/facilities, change in operation with increased or decreased QD requirement).

11.1.6.2. Request for site plan approval.

11.1.6.3. For a grandfathered facility, note whether the facility meets current criteria for the operation being conducted.

11.2. Quantity-Distance Criteria

11.2.1. QD criteria shall account for the types and severity of hazards each explosive material presents, the construction and orientation of facilities to which the criteria are applied, and the degree of protection desired for personnel and facilities adjacent to the explosives operations.

Note: The United Nations (UN) hazard classification system defines the types and severities of explosives hazards.

11.2.2. Hazard Divisions

11.2.2.1. Explosives shall be classified based on their reactions to specific initiating influences.

11.2.2.2. Personnel shall use the UN hazard classification system for DOE explosives classification, Table 11.1 lists the hazard divisions of Class 1.

Table 11.1 Division of Class 1

HD Designators	Hazards
1.1	Mass detonating
1.2.1	Non-mass explosion, fragment producing with NEW for QD > 1.6 lbs
1.2.2	Non-mass explosion, fragment producing with NEW for QD ≤ 1.6 lbs
1.2.3	Non-mass explosion, fragment producing based on single package test only No reaction greater than burning from the external fire test, bullet impact test or slow cook-off test
1.3	Mass fire, minor blast or fragment
1.4	Moderate fire, no significant blast or fragment
1.5	Explosive substance, very insensitive (with a mass explosion hazard)
1.6	Explosive article, extremely insensitive

11.2.2.3. Classification tests (described by TB 700-2) and additional tests (as desired), including UN ST/SG/AC/10/1 and UN ST/SG/AC/10/11, shall be used to assign energetic materials to the appropriate HD SCG (Storage Compatibility Group). Supplemental tests may be used for additional characterization when material properties or anticipated material environments are expected to significantly influence the explosives classification.

11.2.2.4. Although Department of Transportation (DOT) hazard classifications require the use of the Bureau of Explosives' (BOE) Impact Apparatus to determine impact sensitivity, other impact apparatus may be used, providing:

- Test results for at least two reference explosives are compared to results for the reference explosives on the BOE Impact Apparatus; and
- A minimum of 10 trials each is run for the reference explosives and the explosives being classified.

11.2.3. The principles and tables presented in DESR 6055.09 shall be used to determine the total quantities of explosives in adjacent magazines, operating buildings, or other explosive facilities that shall be applied to QD tables, and inert storage locations.

Note 1: When the levels of protection required by this Technical Standard differ from the requirements of DESR 6055.09, this Technical Standard shall take precedence.

Note 2: The minimum separation distances required for the facilities are based on the desired Level-of-Protection and total quantities of explosives.

Note 3: The total quantity of explosives is determined by defining and examining the maximum credible event (MCE). If an explosives event occurs, the MCE is the largest credible amount of explosives that could be involved (not necessarily the total quantity of explosives present).

Note 4: Requirements for onsite de minimis or residual quantities of explosives can be found in Section 17.7.

11.2.4. Transport Vehicles

11.2.4.1. Explosives loaded vehicles in holding yards are considered aboveground magazines for QD purposes. They shall be kept in groups, and each group shall be limited to a maximum of 250,000 lbs (113,398 kg) of high explosives (HE).

11.2.4.2. When a classification yard, interchange yard, inspection station or specified location is the site where explosives are interchanged between the common carrier and facility transportation, QD provisions do not apply provided that vehicles are moved expeditiously to a suitable location.

11.2.5. Utilities Installations

11.2.5.1. Permanent DOE controlled underground utilities installations (excluding building service lines) should be separated from explosives locations containing HD 1.1 materials (see Table 11.2).

Table 11.2 QD Separation for Protection of Underground Service Installations

Quantity of explosives (Maximum)		**Distance**	
Lbs.	**(kg)**	**Feet**	**(Meters)**
≤ 10,000	(4,535.9)	80	(26)
20,000	(9,071.8)	85	(28)
50,000	(22,679.6)	110	(36)
100,000	(45,359.2)	140	(46)
250,000	(113,398.1)	190	(62)

Note: If the potential donor building is designed to contain the effects of an explosion, the formula: $D=3.0\ W^{1/3}$ can be used to determine separation distances for less than 20,000 lbs (9,071.8 kg).

11.2.5.2 Privately owned or operated utilities installations (aboveground and underground) shall be separated from explosives locations by at least public traffic route distances. Installations that include structures should be separated from explosives facilities by inhabited building distance.

11.2.5.3. Certain auxiliary power facilities, transformer stations, etc., present fire hazards to explosives facilities. Transformers and associated electrical switching apparatus serving one explosives facility or complex that do not present a fire hazard to the facility (i.e., dry type, "less flammable" oil insulated) shall be located as specified in NFPA 70 and FMDS 5-4/14-18.

11.2.5.4. Normal oil insulated transformers shall be located at least 50 ft from an explosives facility or as specified in DESR 6055.09.

Note: See Section 36.3 for additional electrical supply system requirements.

11.2.6. Storage Tanks for Petroleum and Hazardous Materials

11.2.6.1. Storage tanks for petroleum and hazardous materials shall be sited using Storage Tanks for Hazardous Materials criteria as specified in DESR 6055.09.

11.2.7. Small Quantities of HD 1.1 Explosive Substances

11.2.7.1. Use Table 11.3 to determine distances for small quantities of explosive substances.

Note: For many situations, it can be demonstrated that adequate personnel protection is provided at distances considerably less than those distances identified in DESR 6055.09.

Table 11.3 Minimum QD Requirements for Small Amounts of Explosive Substances Having HD 1.1 Classification

NEW	Inhabited Building Distance	Public Traffic Route Distance	Intraline Distance
Less than 0.0066 lb	0 ft	0 ft	0 ft
(0.003 kg)	(0 m)	(0 m)	(0 m)
0.0066 lb – 0.022 lb	16.40 ft	9.84 ft	6.56 ft
(0.003 kg – 0.01 kg)	(5 m)	(3 m)	(2 m)
0.022 lb – 0.55 lb	49.21 ft	29.52 ft	16.40 ft
(0.01 kg – 0.25 kg)	(15 m)	(9 m)	(5 m)

12. LEVEL-OF-PROTECTION CRITERIA

12.1. Required Level-of-Protection

12.1.1. The Level-of-Protection required for an explosives activity is based on the hazard class (accident potential) of the explosives activity involved.

12.1.2. Each bay (i.e., storage, handling, or processing building) that houses an explosives activity shall have a Level-of-Protection based on the hazard class determined for the activity.

12.1.3. Level-of-Protection may be provided by equipment design, structural design, operation separation, or provision of operational shields.

12.2. Hazard Class 0

12.2.1. Explosives operations involve the intentional initiation of explosives materials or articles.

Note: Examples are explosives testing, firing activities associated with training, and destruction of explosives by detonation.

12.2.2. Areas used to conduct Class 0 activities shall protect all personnel from injury due to blast, fragments, and structural collapse of buildings. This protection may be achieved by measures (or combination of measures) to include control of fragments and overpressure by suppression, containment, or distance (location) as follows:

12.2.2.1. No structural damage to any facility due to overpressure, fragments, or debris.

12.2.2.2. No fragment or debris impact to operators.

12.2.2.3. Operator protection from any injurious thermal flux.

12.2.2.4. Overpressure, fragment, and debris impact to surrounding areas limited to approved site plans and DESR 6055.09 for intentional detonation of explosives criteria.

12.3. Hazard Class I

12.3.1. Explosives operations involve activities with a high accident potential where: (1) energies approach the upper safety limits, (2) loss of control of interfacing energy is likely to exceed safety limits, and (3) research and development where safety implications have not been fully characterized.

Note: Examples are screening, blending, pressing, extrusion, drilling of holes, dry machining, machining explosives and metal in combination, some environmental testing, new explosives development and processes, explosives disposal by burning and some destructive testing.

12.3.2. Operations shall be conducted remotely because any personnel exposure is unacceptable.

12.3.3. Bays for Class I activities shall comply with the requirements for Class II bays, and, in addition, provide protection to prevent serious personal injuries to personnel performing the activity and personnel in other occupied areas. This protection can be achieved by controlling blast and debris through suppression, containment, or establishing an exclusion area with positive access control. Serious injury prevention is satisfied when personnel are not exposed to:

12.3.3.1. Overpressures greater than 5 psi maximal effective pressure, which should not exceed 2.3 psi peak positive incident pressure (2.3 psi is specified in the DESR 6055.09 as required protection for all personnel exposed to remote operations).

12.3.3.2. Structural collapse of a facility or building from overpressure or debris impact. Structural collapse is a structural component's failure as a direct result of loss of structural integrity. This collapse does not result in explosion propagation, fatalities, or severe personal injuries.

12.3.3.3. Hazardous fragment or debris having an impact energy greater than 11 ft lbs.

12.3.3.4. Thermal fluxes are limited to prevent the onset of second-degree burns. This value is specified in DESR 6055.09, as required protection for all personnel assigned to perform remote operations.

12.3.3.5. Transients shall be protected as specified in DESR 6055.09 using "Accidental Ignition or Initiation of Explosives" criteria.

12.4. Hazard Class II

12.4.1. Explosives operations involve activities with moderate accident potential due to the explosives type, condition of the explosives, or nature of the operations. These activities involve energies that do or may interface with the explosives are normally well within the safety boundaries for the explosives involved, but where the loss of control of these energies could approach the safety limits.

Note: Examples are weighing, some wet machining, assembly and disassembly, some environmental testing, and some packaging operations.

12.4.2. Class II activities have an accident potential greater than Class III activities, but personnel exposure in contact operations is acceptable.

12.4.3. For Class II operations, access ramps and site roads are not considered occupied areas.

12.4.4. Bays for Class II activities shall comply with the requirements for Class III bays, and, in addition, provide protection to prevent fatalities and severe personnel injuries in all occupied areas other than the bay of occurrence. Prevention of fatalities and severe injuries is satisfied when personnel in occupied areas other than the bay of occurrence are not exposed to the following:

12.4.4.1. Overpressures greater than 15 psi maximal effective pressure. The threshold pressure for eardrum rupture is 5 psi; one-half of the threshold pressure for lung damage is 15 psi (see chapter I-11.1 of UFC 3-340-02).

12.4.4.2. Structural collapse resulting from overpressure or debris impact. Structural collapse is a structural component's failure as a direct result of a facility losing structural integrity. This collapse does not result in explosives propagation, fatalities, or severe personnel injuries.

12.4.4.3. Hazardous fragments or debris generated in acceptor-occupied areas having an impact energy of 58 ft-lbs or greater, (see chapter I-11.3 of UFC 3-340-02).

12.5 Hazard Class III

12.5.1. Explosives operations involve activities with low accident potential.

Note: Examples are activities during storage and operations incidental to storage or removal from storage.

12.5.2. Bays for Class III activities shall provide protection from explosion propagation from bay to bay within buildings and between buildings that are located at intraline or intermagazine distance.

12.5.3. If intermediate storage of explosives is within an operating building containing Class II or Class I operations, the intermediate storage or staging bay shall require Class II Level-of-Protection.

12.5.4. Minimum separation distances may be reduced when explosives bays are designed to adequately contain the effects of an accident (blast pressures and missiles).

12.6. Hazard Class IV

12.6.1. Explosives operations involve activities with IHE or IHE subassemblies where the probability of accidental initiation or transition from burning to detonation is negligible.

Note: Examples are processing and storage activities with IHE and IHE subassemblies.

12.6.2. The following explosives activities with IHE and IHE subassemblies shall remain Class I:

- Pressing.
- Some machining (see Paragraph 24.2.4).
- Dry blending.
- Dry milling.

- Dry screening.

12.6.3. Bays for Class IV activities shall provide protection from fire hazards effects.

12.6.3.1. This protection may be achieved by HD 1.3 aboveground magazine distance separation or by a design that contains the effects of an accident.

12.6.3.2. Because accidental detonation is not considered credible, Class IV bays shall be sited and designed as acceptors rather than donors for the effects of blast overpressure, structural collapse, and missiles (hazardous fragments).

13. REMOTE OPERATIONS

13.1. Personnel Protection

13.1.1. Explosives operations that present a high accident potential as defined in Paragraph 12.3.1 shall be performed remotely.

13.1.2. Personnel involved in remote operations shall be provided the required Level-of-Protection for the hazard class of the operation.

13.1.3. Transient personnel shall be provided protection in accordance with the requirements in DESR 6055.09.

13.2. Access and Equipment Controls

13.2.1. Administrative and/or engineered controls shall be used to prevent entry into a hazardous location in which a remote operation is occurring or to prevent the operation from proceeding when personnel enter.

13.2.1.1. Roads shall be blocked at a minimum public traffic route distance (K24) or hazardous fragment distance from buildings where hazardous (remote) operations are being performed, whichever is greater.

Note: Hazardous fragment distance may be satisfied by providing equivalent protection.

13.2.1.2. Corridors leading to bays in which hazardous (remote) operations are being performed shall be marked to warn of the danger with established barriers.

13.2.1.3. When practical, visual methods should be used to monitor remote operations to enable viewing of the operating area conditions before entering. Audio monitoring and video recording should also be considered.

13.2.1.4. Remote operating equipment should be interlocked to access doors for each remote operation.

13.2.1.5. Lights or similar warning devices shall conspicuously identify locations where remote operations are performed to indicate when remote operations are under way.

14. LIMITS AND CONTROL

14.1 Explosives Limits

14.1.1. The quantity of explosives at an operating location shall be the minimum necessary to carry out the operation safely and efficiently.

14.1.1.1. When practical, this quantity shall be subdivided and separated to prevent propagation of detonation.

14.1.1.2. Supplies exceeding this minimum quantity shall be removed from the operating area.

14.1.2. In no case shall the quantity of explosives permitted in an operating building exceed the maximum permitted by QD criteria.

14.1.3. QD criteria and requirements for application of these criteria are presented in Chapter 11.

14.1.4. IHE limits for pressing, dry blending, dry milling, dry screening, and certain machining operations (see Paragraph 24.2.4) should be the same as those established for HE operations.

14.2. Personnel Limits

14.2.1. The number of personnel at an operating location shall be the minimum consistent with safe and efficient operation.

14.2.2. Only jobs necessary to the performance of a hazardous explosives operation should be performed in the same location as the hazardous operation.

14.2.3. Only personnel needed for hazardous operations shall be allowed in hazardous locations.

14.2.4. Personnel limits shall allow for necessary casuals.

14.2.5. Sufficient personnel shall be available to perform a hazardous operation safely and to obtain help and aid the injured if an accident occurs.

14.2.6. Contractor Facility Management shall specify explosives activities that may be performed alone.

14.2.6.1. No person shall perform explosives work with a high risk of serious injury alone.

14.2.6.2. Prompt and easy communications with other employees shall be provided.

14.3. Limit Control

14.3.1. Posting and Recording

14.3.1.1. All rooms, bays, and buildings containing explosives shall have, posted in a conspicuous place, a standardized posting stating the maximum amount of explosives and the maximum number of workers and casuals permitted in the controlled area at any one time.

14.3.1.2. Maximum explosives and personnel limits for all buildings and bays for each explosives area shall be documented and maintained on file.

14.3.2. Limit Review and Approvals

14.3.2.1. Contractor Facility Management personnel with authority and jurisdiction over an operating bay or building shall review explosives and personnel limits for each location periodically and recommend changes as required.

14.3.2.2. When the use of a location changes, personnel and explosives limits shall be reviewed and limits reestablished as required.

14.3.2.3. Changes in explosives and personnel limits shall be reviewed and approved in the same manner as operating procedures (see Chapter 9).

14.3.2.4. A procedure shall be established for the approval of temporary changes in explosives and personnel limits for an operating location.

14.3.3. Personnel Controls

14.3.3.1. A system shall be established to control the presence of personnel within explosives operating areas.

14.3.3.2. The movement of transients in the vicinity of an explosives operating area should be controlled when their presence creates a congestion problem or other safety concern.

14.3.4. Explosives Controls

14.3.4.1. A verifiable system shall be established to control the amount of explosives present in an explosives facility.

15. PERSONAL PROTECTIVE EQUIPMENT

15.1. Clothing

15.1.1. Flame-retardant clothing may be desired for explosives operations with the potential for flash fire.

15.1.1.1. The clothing shall not have cuffs.

15.1.1.2. The clothing should not have metallic fasteners.

15.1.2. Operating procedures shall include protective clothing requirements.

15.1.3. Cotton or other antistatic outer and undergarments, including socks, should be worn where generation of static electricity would create a hazard.

15.2. Footwear

15.2.1. Personnel working in areas where electrostatic sensitive explosive powders or materials are handled shall wear conductive, non-sparking footwear.

Note: Exception: Personnel working on electrical or electronic equipment shall not wear conductive footwear unless protected by insulated mats, ground fault circuit interrupters (GFCI), etc.

15.2.2. When conductive footwear is worn, the conductivity shall be tested immediately prior to each use.

15.2.3. Personnel working in areas where explosives contamination may be present shall wear non sparking footwear or bootie shoe coverings.

15.3. Wristbands

15.3.1. When conductive wristbands are worn, the conductivity shall be tested immediately prior to each use.

16. INSENSITIVE HIGH EXPLOSIVES QUALIFICATION

16.1. Revisions to Insensitive High Explosives (IHE) Test Description and Criteria

16.1.1. Revisions to LLNL-TR-679331/LA-UR-15-29238, “IHE Material and IHE Subassembly Qualification Test Description and Criteria” shall be approved by the proponent organizations (Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Pantex) and shall be reviewed for concurrence by the DOE/NNSA Explosives Safety Committee. Once concurrence is obtained, the Chair shall issue a letter of concurrence to the submitting organization.

16.2. Insensitive High Explosive (IHE) Materials

16.2.1. In scales that are conservative to the relevant nuclear weapon application, IHEs shall meet the following requirements:

Note: For more information refer to Attachment A of this chapter - IHE QUALIFICATION BACKGROUND

16.2.1.1. Does not transition from deflagration to detonation (DDT).

16.2.1.2. Does not transition from shock to detonation (SDT).

- Under 3.5 GPa, 3 μs 1-dimensional shock insult at 25°C.
- Under 5.3 GPa, 0.5 μs 1-dimensional shock insult at 25°C.
- Under 1.5 GPa, 3 μs 1-dimensional shock insult when heated to 10°C below the cook-off temperature of the explosive.

16.2.1.3. Passes IHE criteria outlined in LLNL-TR-679331/LA-UR-15-29238, "IHE Material and IHE Subassembly Qualification Test Description and Criteria."

- Skid test
- Bullet test

16.2.2. The qualification and approval process described herein is limited to DOE and nuclear weapons applications.

16.3. IHE Qualification Testing

16.3.1. Any explosive that is a candidate for classification as an IHE shall be subjected to the DOE qualification tests listed in Table 16.1.

Note: This includes three tiers of tests. Test procedures are contained in LLNL-TR-679331/LA-UR-15-29238.

Table 16.1 Required Testing to Qualify IHE Materials

Tier 1: Prerequisites	Tier 2: IHE Material Qualification	Tier 3: Demonstration Tests[1]
Interim Hazard Classification	DDT Test and SDT Test	Skid Test and Bullet Test

[1] Minimum of 20 drops per test series

16.3.2. Some or all of the test requirements of this section may be met by analogy as indicated below:

16.3.2.1. The DOE/NNSA Explosives Safety Committee determines the acceptability of analogy in lieu of test data.

16.3.2.2. Analogy submitted in lieu of test data shall include rationale.

16.3.2.3. Approved IHEs (listed in Table 16.2) with complete test data shall be used for baseline comparison purposes.

16.3.3. The DOE/NNSA Explosives Safety Committee may request additional information depending on circumstances surrounding the analogous information submitted.

16.3.4. A candidate IHE can be placed in one of the following analogy categories to define required tests depending on the type and extent of change in the candidate IHE relative to the baseline IHE and the potential effects of these changes on specific initiation mechanisms (shock, thermal, mechanical, impact):

16.3.4.1. If the analogy can be fully credited, no testing is required.

Note: For example; the candidate IHE involves the same energetic and inert components as the approved baseline IHE, the only change being a volume-percent decrease in the energetic component content.

16.3.4.2. If the analogy can be partially credited, partial testing is required. Sufficient testing is required to verify that no chemical or physical incompatibilities have been introduced that would de-stabilize the base IHE.
Note 1: For example; the candidate IHE formulation modifies an inert component of the approved baseline IHE.

Note 2: In this case, test data normally generated by the requesting facility during their explosive development scale-up phasing process may be submitted in lieu of the qualification tests of Table 16.1.

Note 3: During the development phase, the Contractor Explosives Development Committee (EDC), or equivalent, may dictate restrictions consistent with an IHE that are internal to their facility only.

16.3.4.3. If the analogy cannot be credited, full testing is required.

Note: For example; the candidate IHE involves the addition of an untested (IHE tests) energetic component to the approved baseline IHE.

16.4. IHE Qualification Process

16.4.1. IHE Materials qualified by previous methods shall remain qualified and are listed in Table 16.2

Table 16.2 Approved IHEs

TATB
TATB/KEL-F (or equivalent) Formulations

16.4.2. The organization with the need for IHE determination (hereafter shall be referred to as the Requestor) shall perform or have performed the appropriate tests in accordance with the requirements of LLNL-TR-679331/LA-UR-15-29238, after coordinating need for material qualification with the appropriate Headquarters (HQs) Program Office (e.g., NA-11, NA-12, or NA-19).

16.4.3. The Requestor submits the test data, for the candidate explosive, to the DOE/NNSA ESC Chair.

16.4.4. The DOE/NNSA ESC Chair assigns a Task Group for review and recommendation of approval/disapproval of the candidate explosives material.

16.4.5. If the request is not recommended for approval, the Task Group documents the rationale and requirements that were not met and provides this information to the DOE/NNSA ESC Chair who then communicates with the Requester through the DOE/NNSA ESC Chair.

16.4.6. If the request is recommended for approval, the Task Group assembles the test data and provides this information to the DOE/NNSA ESC Chair with a recommendation to approve the candidate explosive.

16.4.7. The DOE/NNSA ESC Chair prepares a written recommendation on the approval of the candidate explosive, and submits it along with the supporting explosives package to the NNSA/NA-50 Associate

Administrator for Safety, Infrastructure, and Operations; the Explosives Approval Authority (EAA) or designee.

16.4.8. The NNSA/NA-50 EAA approves or denies the candidate explosive for qualification as an IHE, and provides written documentation of their decision to the DOE/NNSA ESC Chair.

16.4.9. The DOE/NNSA ESC Chair provides documentation of the EAA's decision to requestor, and if approved, the IHE is added to Table 16.2.

16.5. IHE Subassemblies Testing

16.5.1. IHE Subassemblies are composed of IHE hemispheres or spheres with booster charges, with or without detonators that, as an assembly are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible, and therefore meet IHE criteria at a system-relevant scale.

16.5.2. Main charge materials that do not qualify as IHE materials in Section 16.3 may be used as main charges in an IHE Subassembly, provided they meet IHE criteria at a smaller, system-relevant scale.

16.5.3. Any explosive Subassembly that is a candidate for classification as an IHE Subassembly shall be subjected to DOE qualification tests as listed in Table 16.3. These tests shall be planned with consideration of worst-case scenarios. Testing approaches and methods are contained in LLNL-TR- 679331 / LA-UR-15-29238. The qualification approach evaluates each material in the assembly as follows:

16.5.4. Verify main charge is incapable of DDT and therefore meets IHE criteria for a material

16.5.4.1. Verify main charge meets IHE material criteria for SDT, as shown in Table 16.1, Tier 2 and defined in LLNL-TR-679331/LA-UR-15-29238.

16.5.4.2. Verify detonator material is incapable of DDT in a scale conservative to its relevant application.

Note: Electrical threat to detonator is not part of this qualification.

16.5.4.3. Verify booster is incapable of DDT in a scale conservative to its relevant application

Table 16.3 DOE Qualification Tests for IHE Subassemblies*

Test	Results
DDT	No DDT in main charge, booster, and detonator materials tested at scales relevant to application, plus margin for conservatism.
SDT	No SDT in main charge material per tests in Table 12.1 for both ambient and heated materials.
Multiple Bullet Impact	No detonation or violent reaction of main charge with a 3-round bullet impact burst in worst-case configuration.
Skid Test	No burning or violent reaction of main charge (as evidenced by visible fireball) up to a specified height and test angle using Subassembly configuration modified for impact in worst-case geometry.

* Tests are not required for subassemblies when main charge and booster charge explosives have been qualified as IHE by tests in Table 16.1.

Note: The test plan shall specify applicable testing for cased and/or uncased configurations with or without detonators.

16.5.5. Some or all of these test requirements may be met by analogy as indicated below:

16.5.5.1. The DOE/NNSA Explosives Safety Committee determines the acceptability of analogy in lieu of test data.

16.5.5.2. Analogy submitted in lieu of test data shall include rationale.

16.5.5.3. Approved IHE Subassemblies with complete test data shall be used for baseline comparison purposes.

16.5.6. The DOE/NNSA Explosives Safety Committee may request additional information depending on circumstances surrounding the analogous information submitted.

16.5.7. A candidate IHE Subassembly can be placed in one of the following analogy categories to define required tests depending on the type and extent of change in the candidate IHE Subassembly relative to the baseline IHE Subassembly and the potential effects of these changes on specific initiation mechanisms (shock, thermal, mechanical, impact):

16.5.7.1. If the analogy can be fully credited, no testing is required.

Note: For example; materials and scales remain the same and only minor changes that do not affect explosive characteristics.

16.5.7.2. If the analogy can be partially credited, partial testing is required.

Note: For example; minor changes to explosive materials or components.

16.5.7.3. If the analogy cannot be credited, full testing is required.

Note: For example; a significant change to materials or configurations.

16.6. IHE Subassembly Qualification Process

16.6.1. IHE Subassemblies qualified by previous methods shall remain qualified and are listed in Table 16.4.

16.6.2. The Requestor submits a test plan to the DOE/NNSA ESC Chair and the test plan shall be coordinated with the appropriate DOE/NNSA site, after coordinating need for subassembly qualification with the appropriate HQs Program Office (e.g., NA-11, NA-12, or NA-19).

16.6.3. The DOE/NNSA ESC Chair assigns a Task Group for review and approval/disapproval of the test plan.

16.6.4. The ESC Task Group reviews the test plan for compliance with the IHE subassembly requirements and provides input (if necessary), and approves/denies the test plan. They then communicate their decision to the DOE/NNSA ESC Chair.

16.6.5. The DOE/NNSA ESC Chair communicates the approval/disapproval to the Requestor.

16.6.6. If the test plan is approved, the Requestor submits the test data, for the candidate subassembly, to the DOE/NNSA ESC Chair.

16.6.7. The DOE/NNSA ESC Chair submits the test data to the Task Group for review and recommendation of approval/disapproval of the candidate subassembly.

16.6.8. If the request is not recommended for approval, the Task Group documents the rationale and requirements that were not met and provides to the Requestor through the DOE/NNSA ESC Chair.

16.6.9. If the request is recommended for approval, the Task Group provides the DOE/NNSA ESC Chair with recommendation to approve the candidate subassembly.

16.6.10. The DOE/NNSA ESC Chair prepares a written recommendation on the approval of the candidate subassembly, and submits it along with the supporting subassembly package to the NNSA/NA-50 EAA.

16.6.11. The NNSA/NA-50 EAA approves or denies the candidate subassembly for qualification as an IHE subassembly.

16.6.12. The EAA provides written documentation of their decision to the DOE/NNSA ESC Chair.

16.6.13. If approved, the DOE/NNSA ESC Chair provides documentation of the EAA's decision to requestor. If approved, the IHE Subassembly is added to Table 16.4.

Table 16.4 Approved IHE Subassemblies

B61*3/4/6/7/8/10/11/12	W80*	W81*	B83*
W84	W87	W89	

*** Approval limited to boosters of the size tested or smaller.**

Note: Any redesign that dimensionally increases the booster size requires resubmission of an experimental plan and additional testing as another IHE Subassembly.

16.7. IHE Weapons

16.7.1. IHE weapons are those weapons listed in JNWPS TP-20-7, and are exempt from storage and transportation limits when stored or transported alone or in combination with each other.

Note: This classification is valid only if storage containers provide adequate spacing between individual units. JNWPS TP-20-7 specifies the spacing requirements for materials stored or transported out of containers.

Attachment A – IHE QUALIFICATION BACKGROUND

BACKGROUND

The DOE IHE definition differs from that of Department of Defense (DoD)/UN Extremely Insensitive Substance (EIS) due to different risks and consequences associated with nuclear weapons application. The critical difference in risk is the possibility of special nuclear material (SNM) dispersal.

Detonation is the response that impacts nuclear safety. Inadvertent nuclear yield should not be possible in modern weapons, so SNM dispersal is the critical nuclear safety improvement that IHE enables. SNM dispersal requires shock from explosive in direct contact, according to DOE-HDBK-3010-94 and NUREG/CR-6410. Absence of a detonation greatly reduces the likelihood of dispersal. A shock from any High Explosive violent reaction (HEVR) scenario, such as a violent deflagration, would be weak.

Prompt Shock-to-Detonation Transition (SDT) cannot be excluded under all conditions because an IHE shall detonate to function as designed. The threshold should be clearly defined because nuclear safety requires that we know the SDT characteristics of an explosive. It is also important to confirm that the SDT characteristics are reasonably consistent across the lifecycle temperature range. SDT insults are generated with a gas gun which develops a sustained, 1D, shock pulse. These 1D shock pulses do not have a system-relevant scale, so all IHE materials and subassemblies undergo the same test.

Deflagration-to-Detonation Transition (DDT) is the build-up of a burning reaction to a detonation. Ignition is a complex phenomenon governed by many competing processes. We assume ignition of a burning reaction in qualification testing since we cannot guarantee that ignition shall never occur in the various relevant hazard scenarios. Whether the ignited materials transition to a detonation is equally complex but is controlled by a few key variables, including the strength of confinement, charge size, and the state of the explosive. The DDT test is a large test with high confinement, and large margin. Deliberate ignition verifies DDT is not possible in the material in any scale relevant to a nuclear weapon. The inclusion of DDT testing eliminates the need for many standard ignition and reaction violence tests like ODTX, Susan, Spigot, Friction, Bonfire, and Slow Cookoff.

Unknown to Detonation Transition (XDT). In some hazard scenarios with detonable solid rocket motors, initiation has been observed under conditions that are insufficient to develop either an SDT or DDT initiation. This response mode is termed XDT, where “X” stands for the unknown transition to detonation. It is believed that the XDT mechanism is the result of a process that includes severe damage and break-up of a bare energetic material in an unconfined space, expansion of this damaged material, and subsequent re-compaction of damaged material to develop ignition or initiation. The process is known to be highly complex and geometry dependent. There are no credible threats to nuclear weapons that include a geometry that allows this process to progress. Also, the final stage of both DDT and XDT is facilitated by the same underlying mechanism, shock initiation of damaged explosives. If an HE passes a conservatively-designed DDT test, then we can be confident that XDT is not a possibility under similar stimulus and geometry. Therefore, a test for XDT does not need to be included as a qualification test.

High explosive violent reaction (HEVR) is a commonly used term to describe an unacceptable level of reaction. There is, however, no clear definition, either theoretically or empirically, of HEVR. DOE Order 452.1E and the D&P Manual both refer to HEVR as "ranging from a fast deflagration of the high explosive up to and including a detonation of the high explosive". There is no threshold for what might constitute a fast deflagration. In other cases, including dispersal of material outside a facility perimeter, HEVR is essentially being defined in terms of causing a secondary effect rather than in terms of the phenomenon itself.

Without a clear or consistent definition, it is impossible to define one or more tests with meaningful criteria to evaluate the candidate explosive for its propensity to undergo HEVR. Hence the absence of that specific term in the definition of IHE. Historical IHE test definitions similarly did not exclude the possibility of HEVR in an IHE.

We can make some observations on the implications of the new definition to the potential for HEVR: the material properties that underlie DDT behavior also underlie HEVR responses, including the propensity for thermal ignition, deflagration rate, and shock sensitivity. Therefore, an explosive that meets the DDT criteria in the new definition is likely to be relatively benign in any HEVR.

DEFINITIONS

Scales conservative to a relevant nuclear weapon application: The scale of a given experiment is related to HE configuration in US nuclear weapons. This is related to the main charge with a margin of conservatism. The scale is not the same as classified scaled weapons experiments.

Scales conservative to its relevant application: The scale of a given experiment is related to the HE configuration and confinement of the given application. For example, a booster application has a shorter run length and lower confinement relative to a main charge.

REFERENCE DOCUMENTS

The following documents set forth some of the procedures to be referenced when planning the IHE and IHE subassembly testing required by Table 16.1 and Table 16.3:

- TB 700-2
- MHSMP-84-22 Rev.1
- UN ST/SG/AC.10/11/Rev.1
- LLNL-TR-679331, LA-UR-15-29238, 2015
- DOE HDBK-3010
- NUREG-1320
- JNWPS TP-20-7

17. LABORATORY OPERATIONS

17.1. Operational Requirements

17.1.1. Laboratory personnel shall conduct work involving explosives materials in accordance with approved operating procedures supported by documented hazard analysis.

17.1.2. The quantity of explosives present in a laboratory shall be the minimum required for the operations and should be at or below assigned limits.

17.1.3. Storage of explosives not in process is allowed provided the explosives are secured when the laboratory is unoccupied.

17.1.4. Explosives shall be configured to preclude exceeding the maximum credible event (MCE).

17.1.5. Open flames shall be prohibited in laboratories where explosives or flammable solvent vapors are or may be present unless allowed by an approved hazard analysis or procedure.

17.1.6. Disposal of explosives through laboratory drains shall be forbidden unless the drain plumbing has no traps and is designed to handle explosives (i.e., is provided with a sump or other device for the collection of solids).

Note 1: Even if a drain is designed to handle explosives, deliberate disposal of explosives in these drains should be avoided. These drains should be used only to clean up explosives spills.

Note 2: Special care should be exercised to prevent entrance of compounds into drains that may react with iron or rust to form sensitive salts (e.g., picrates and picric acid).

17.1.7. Suitable guards shall be provided for all glass or fragile equipment that shall withstand reduced or elevated pressure.

17.2. Blast Shields

17.2.1. If determined through a documented hazard analysis that a laboratory operation presents a credible risk of explosives initiation, controls shall be incorporated, such as the use of blast shields or performing the operation remotely. Table 17.1 lists shields that have been tested and found acceptable for the indicated quantities of explosive.

17.2.2. If an experiment poses a metal-fragment hazard (as opposed to a glass-fragment hazard) and the experiment cannot be conducted remotely, the proposed shield should be tested and approved under conditions simulating an explosion in the experimental setup but with at least 125% of the anticipated explosive content.

17.2.3. The shield shall be anchored to the hood frame or bench top when it is being used for protection against more than 0.16 oz (5 grams) of TNT equivalent.

Note: Shields listed in Table 17.1 were not tested for metal-fragment penetration (unless specifically indicated) and thus may not offer effective protection when the explosive is closely confined in a heavy-walled metal container ("heavy-walled" is defined here as wall thickness to diameter ratio greater than 0.01).

17.2.4. Other blast shields may be approved for use after successfully passing a test of 125% of the rated explosive charge.

17.2.5. For confined areas, a blast vent having less strength than the shield should be provided.

17.2.6. When explosives operations require personnel to reach around a shield to manipulate equipment, exposure shall be minimized.

Table 17.1 Blast Shields for Laboratory Operations

Shield	Minimum distance from explosive	Explosives limit
Leather gloves, jackets, or coats, and plastic face shields	----	**50 mg**
3 mm tempered glass	**8 cm**	**50 mg**
7 mm Lucite/equivalent material	**15 cm**	**2.5 g**
20 mm Lucite/equivalent material	**15 cm**	**10 g**
15 mm laminated resistant glass	**20 cm**	**20 g**
25.4 mm Lexan/Lexguard	**30 cm**	**50 g**
2 units each of **25.4 mm** plate glass laminated with **12.4 mm** polycarbonate with a **9.5 mm** air gap between units (glass sides facing the explosive)	**30 cm**	**50 g** (steel confined)

Note 1: Blast testing has shown that laminated tempered glass is superior to monolithic tempered glass, and polycarbonate is superior to acrylic plastics, such as Lucite. Laminated tempered glass is recommended instead of monolithic tempered glass and polycarbonate is recommended in lieu of acrylic.

Note 2: The shields are recommended to be of equal or greater thickness than those listed in the table.

Note 3: Proof testing is highly recommended.

Note 4: When designing and/or replacing a blast shield with a polycarbonate, it should be UV stabilized, treated for abrasion resistance, and have met Mil Spec P-46144C.

Note 5: When designing or replacing a blast shield with laminated glass, it should be coated with a 0.1 mm fragment-resistant film on the viewer's side to minimize spalling.

Note 6: The shield, shield frame, and anchoring system shall be designed to resist maximum credible overpressure and fragments.

17.3. Heating Operations

17.3.1. During synthesis, formulation, or experimental work, heat may be applied to initiate or maintain reaction, to increase solubility, etc.

17.3.2. Heat shall be applied indirectly using steam, a water bath, oil bath, or an approved laboratory electrical heating device such as a mantle.

17.3.3. Caution shall be exercised to verify that reactive material does not come in direct contact with the heating elements.

17.3.4. If an experiment requires a blast shield, any heating device shall be mounted so that temperature can be controlled from the operator side of the shield.

17.3.5. If an experiment requires a blast shield, any heating device should be mounted so it can be separated quickly from the reaction vessel without operator exposure.

Note: During design of the experiment, consideration should be given to providing emergency cooling for the reaction vessel or its contents.

17.3.6. Heating systems that are operated unattended shall have dual controls, an override shutoff, or some other protection against failure of the primary heating control.

17.3.6.1. Heating of explosives with devices without these controls shall be monitored at all times

Note: If the operator leaves for any reason, the heating device should be turned off.

17.3.7. Requirements in paragraph 17.3.6. may not apply to systems capable of totally containing the effects of an explosion.

17.3.8. Periodic checks should be made to verify that an experiment is proceeding satisfactorily and that the apparatus is not boiling dry, malfunctioning, etc.

17.3.9. In the case of remotely controlled operations, provisions shall be made for observation using mirrors, television monitors, etc.

17.4. Laboratory Setups

17.4.1. Equipment and apparatus shall be clean, in good condition, and in good working order.

17.4.2. All glassware and apparatus shall be inspected for cracks, defects, etc., before use.

17.4.3. Defective or damaged equipment shall be removed from service.

17.4.4. Setups shall be geometrically and structurally stable.

17.4.5. Work areas should be neat and uncluttered.

17.5. Low Concentration of Explosives in Solution

17.5.1. After explosives are in dilute solution (less than 25% explosives by weight), the primary hazard shall be considered as that associated with the solvent and not the explosive.

Note: Where supported by technical data and approved by the EDC, a solvent/ explosives solution greater than 25% may also be similarly classified.

17.5.2. If the explosive recrystallizes or precipitates out of solution, safety requirements for explosives shall apply.

17.6. Explosives Sample Control

17.6.1. Samples shall be delivered to a laboratory only at specific designated locations.

17.6.2. Each sample shall be properly identified and labeled.

17.6.3. Upon completion of required tests or analyses, the sample should be removed from the laboratory.

17.6.4. A safety information sheet should accompany all samples of new experimental explosive material submitted to a laboratory for analysis.

17.7. De minimis or Residual Quantities

17.7.1. Based on a total mass size less than the critical diameter, primary explosives 1 mg or less and secondary explosives 10 mg or less are considered non-detonable by abnormal stimuli or environment (see Paragraph 6.2.1). Locations with explosives in these quantities are therefore exempt from the following requirements.

- Electrical equipment requirements.
- Posting of fire symbol signs and placards.
- Quantity/distance requirements.
- Posting of explosives limits.
- Personnel Limits.

17.8. Laboratory Wiring and Equipment

17.8.1. Permanent wiring and equipment for existing laboratory areas are not required to meet the requirements of Chapter 36.

17.8.2. Process equipment used for synthesis, heating, drying, mechanical mixing, and blending shall be dual-rated (Class I, Division 1 and Class II, Division 1).

17.8.3. Weighing equipment shall be Class II, Division 1 or mechanical.

17.8.4. Synthesis, heating, drying, mechanical mixing, blending, and weighing operations shall be isolated from non-rated wiring, electrical equipment, and instrumentation in a manner that prevents dust or vapors reaching an ignition source.

17.8.5. When laboratory equipment cannot meet the requirements of Paragraphs 17.8.2, 17.8.3, and 17.8.4, apply Paragraphs 36.4.3 and 36.4.4.

18. INSPECTION

18.1. Inspections

18.1.1. Explosives shall be inspected to verify proper identification.

18.1.2. Incoming explosives raw materials shall be inspected for foreign bodies that could cause operating or safety problems in processing operations.

18.1.3. Pressed explosive billets shall be inspected for foreign bodies, voids, or cracks that could cause operating or safety problems in processing operations.

18.1.4. Explosives pieces and assemblies shall have their physical parameters measured where improper dimensions could cause safety problems in processing operations.

18.2. Inspection Methods

18.2.1. The following are examples of acceptable inspection methods:

- Screening
- Visual inspection
- Magnetic separation
- Radiography
- Chemical analysis
- Physical dimension

18.3. Equipment Inspection Design and Operation

18.3.1. Pinch points shall be eliminated or steps taken to preclude explosives contamination of pinch points.

18.3.2. Threaded fasteners or threads of measuring equipment shall be protected from explosives contamination.

18.3.3. Care shall be taken to prevent parts of the measuring or handling equipment from becoming loose and getting into the explosives.

18.3.4. Inspection fixtures shall be designed to secure the explosives piece or assembly effectively to prevent toppling, rolling, or dropping during measurement operations.

Note: This is especially critical if the explosives assembly is in motion (e.g., spinning, vibrating) during measurement.

19. EXPLOSIVES DEVELOPMENT AND FORMULATION SCALEUP

19.1. Contractor Explosives Development Committee (EDC)

19.1.1. A committee shall be established at each DOE/NNSA facility engaged in explosives development to be the approving authority for each phase of an explosives development program.

19.1.2. This committee is referred to in this Technical Standard as the EDC, but it may have a different name at each DOE/NNSA facility.

19.1.3. Individuals selected to serve on the EDC should have considerable experience in explosives handling, processing, chemistry, sensitivity and safety.

19.1.4. The EDC shall approve phase-by-phase, modified formulations and sensitivity data as follows:

19.1.4.1. Shall review and approve data generated in each phase of a development project that involves a new explosive or new explosive formulation before the next phase begins.

19.1.4.2. Shall review and approve compositional modifications to previously evaluated explosive formulations and may approve minor modifications to the explosives formulation for a given phase of development without requiring all of the developmental steps and tests.

19.1.4.3. May waive some developmental phase tests if comparable sensitivity data for the subject material are available from another source.

19.2. Development Process

19.2.1. All DOE/NNSA explosives handling facilities shall establish an administrative process that defines the basic steps for developing and evaluating new explosives and explosive formulations.

19.2.2. The process shall require that each development effort proceed in phases from small to large quantities. The quantities of materials that may be handled in each phase shall be limited as specified below in Table 19.1.

19.2.3. The EDC shall be responsible for establishing criteria for acceptable explosive behavior in each test of each phase of the explosives development process.

19.2.4. The development process should consist of three phases plus sensitivity and compatibility testing, when required.

Table 19.1 Scaleup Process Guidelines for New Explosives and Formulations

Quantity of New Material[a]	Recommended Data[a]	Data Desired	Additional Recommendations
Synthesis			
Specified by the lab performing the synthesis	Impact, friction, spark, thermal stability	Before using the new ingredient in a formulation	----
Formulation			
Compatibility Testing: 2 g	Thermal compatibility of new ingredient with other ingredients of formulation	Before proceeding to Phase I	Materials should be processed remotely
Phase I			
10 g	Impact, friction, thermal stability	Before non-remote processing and handling in Phase I or scaleup to Phase II	Materials should be processed remotely before passing sensitivity and stability tests
Phase II			
500 g[b]	Compatibility [c], impact, friction, spark, thermal stability, thermal characterization before elevated temperature pressing	[d, e]	[f]
Phase III			
Specified by EDC	Compatibility, high-speed machining, drop, skid	Before Phase III machining or handling of billets 7 kg or greater	Composition of formulation shall be fixed

a. Quantities and recommended data apply to both new formulations and explosive ingredients.
b. The EDC may allow more than 500 g in Phase II where larger quantities are needed for some tests.
c. Compatibility of explosives and formulations with materials contacting the explosives in test and production assemblies.
d. Before proceeding to Phase II if the composition of a formulation is modified so that the composition is no longer within the limits specified by the EDC.
e. Before proceeding to Phase III if:
  1. The formulation to be scaled up to Phase III differs from that tested in Phase I, or
  2. The explosive or formulation prepared for Phase II development is produced by techniques different from those used in Phase I.
f. Materials investigated in this phase should be produced by techniques similar to those that shall be used to produce larger batches in a subsequent phase.

19.3. Sensitivity Testing

19.3.1. Before mixing a new explosive with other materials, the sensitivity and stability of the explosive should be determined and should comply with the criteria set by the EDC. Recommended tests include the following:

- Drop-weight impact
- Friction

- Spark
- Thermal stability

Note: Thermal stability tests should include two or more of the following:

- Differential thermal analysis or differential scanning calorimetry
- Thermal gravimetric analysis
- Gas evolution rate at elevated temperature (chemical reactivity test, vacuum stability)
- Time-to-explosion analysis

19.4. Compatibility Testing

19.4.1. If a proposed formulation contains new ingredients (explosive or non-explosive), the new ingredients should be tested for compatibility with the other ingredients before preparing batches for Phase I testing.

19.4.2. Compatibility tests should include any of the stability tests listed under Paragraph 19.3.1.

19.4.3. No more than 2g of the new formulation should be prepared, handled, or stored before compatibility testing.

19.4.4. Formulations for compatibility testing should be processed remotely, whenever possible.

19.5. Phase I—Preliminary Development

19.5.1. Whenever possible, material should be processed remotely.

19.5.2. The total quantity of material that may be processed, handled, or stored at any one time in Phase I should not exceed 10g.

19.5.3. The new explosive or formulation should be subjected to sensitivity and stability tests.

Note 1: As a minimum, drop-weight impact, friction, spark sensitivity, and thermal stability tests should be performed.

Note 2: Thermal stability testing need not be performed here if one or more of the compatibility tests listed under Paragraph 19.3.1 have already been conducted on the new formulation.

19.5.4. If the new explosive or formulation has acceptable sensitivity and compatibility results, it may be scaled up to Phase II.

Note: The EDC may impose handling or processing restrictions or precautions on the material if its performance in any of the above tests is questionable.

19.5.5. After Phase I testing of a formulation is complete, the EDC shall define, on the basis of the test results, what variations in composition are permissible during Phase II development without retesting.

19.6. Phase II—Experimental Characterization and Development

19.6.1. The total quantity of materials processed or handled at any one time in Phase II should not exceed 500g.

Note: No limit exists on the quantity that may be stored, other than the storage facility limits for Group L explosives.

19.6.2. Materials investigated in Phase II should be produced by techniques similar to those that shall be used to produce larger batches in a subsequent scaleup phase.

19.6.3. A thermal characterization test and evaluation should be run before pressing the new material at elevated temperature.

19.6.4. The Phase I sensitivity and stability tests should be rerun in Phase II if any of the following conditions apply:

19.6.4.1. The formulation to be scaled up to Phase III differs from that tested in Phase I. In this case, testing should be completed before Phase III scaleup.

19.6.4.2. The explosive or formulation prepared for Phase II development is produced by techniques different than those used in Phase I.

Note: Testing should be completed before Phase III scaleup.

19.6.4.3. During Phase II, the composition of a formulation is modified to an extent that the composition is no longer within the limits specified by the EDC (see Paragraph 19.5.5). Testing should be completed before proceeding with Phase II.

19.6.4.4. The compatibility of explosives and formulations with materials contacting the explosives in test and production devices shall be evaluated before any such device is assembled.

Note: If compatibility testing is required, one or more of the tests listed under Paragraph 19.3.1 should be recommended.

19.7. Phase III—Full-Scale Testing and Production Development

19.7.1. The maximum quantity of materials processed or handled in Phase III shall be defined in the EDC grant of authorization to proceed with Phase III.

Note: No limit is imposed for storage facilities except the limits imposed by the QD tables.

19.7.2. All additional testing necessary to define storage compatibility grouping should be completed before committing bulk quantities of the material to storage (see Section 32.4).

19.7.3. During Phase III development, the composition of all formulations should be fixed.

19.7.4. Any new explosive material that is to be contact machined shall be subjected to a machining overtest.

Note: Reaction threshold should be determined if possible.

19.7.5. If billets of 7kg or greater are to be produced in Phase III, skid testing should be performed and EDC criteria for this test should be met.

19.7.6. Paragraph 19.6.4 should also apply to Phase III development.

20. SYNTHESIS AND FORMULATION

20.1. Synthesis

20.1.1. Synthesis operations are conducted both on laboratory and pilot scales. The EDC shall approve new operations and materials. In the laboratory, the new material shall initially be prepared on a small scale and characterized as to sensitivity, physical, and explosive properties. Also, the laboratory shall develop processing techniques for the material. If laboratory studies determine that the explosive is of continuing interest, it may be advanced to the Pilot Plant where processing techniques shall be refined and scaled up. The Pilot Plant shall produce sufficient material for larger scale physical, explosive, and sensitivity characterizations.

20.1.2. Laboratory Scale Synthesis

20.1.2.1. Before initiation of work, the subject matter expert who is directing or conducting the synthesis shall analyze each explosives or potential explosives experiment for the type and magnitude of hazards. They shall be responsible for planning the proper selection of conditions, quantity of explosives, and safety devices to be employed.

20.1.2.2. Experiments should be designed to minimize the amount of explosives involved and to use the mildest conditions that yields the desired information.

20.1.2.3. New explosives materials shall be afforded extra protection against impact, pinching, friction, pressure, sparks, contamination, and deterioration.

Note: If it is necessary to subject explosives to any of these conditions, the operation shall be conducted remotely or adequate personnel shielding shall be provided.

20.1.3. Pilot or Processing Scale Synthesis

20.1.3.1. Alarms should be provided for coolant flow to the reactor, for reaction vessel agitation, and for reactor temperature. These alarms should be energized whenever coolant supply or agitation is critical to prevent a runaway reaction.

20.1.3.2. When agitation is critical, the reactor should be equipped with at least two sources of power to maintain agitation in the event of failure. For example, a reactor might employ an air or inert gas bubble tube as a backup for a mechanical agitator.

20.1.3.3. The reaction vessel should be equipped with an emergency system that automatically cools the vessel or opens or closes a vessel dump valve as required by the process.

Note: Contact operations should be conducted with a means to activate the emergency system manually.

20.1.3.4. An alarm or monitor should be provided for the critical exhaust ventilation system to warn operating personnel if airflow rates drop below a predetermined level.

20.1.3.5. Emergency plans shall be established for the synthesis area, specifying action to be taken in the event an alarm sounds.

20.1.3.6. Before operations begin, all equipment shall be set up and checked for proper function.

20.1.3.7. Prior to use with any hazardous material, new or infrequently used equipment shall be tested in a “dry run.”

20.1.3.8. Before starting any process operation, the transfer lines to be used should be properly labeled and their function specified in the operating procedure.

20.1.3.9. All control valves shall be correctly identified according to function.

20.1.3.10. Safety equipment and clothing shall be worn as defined in operating procedures.

20.1.3.11. Explosives warning signs shall be conspicuously displayed on any processing vessel in which explosive materials are to be left overnight.

20.1.3.12. All explosives synthesis process equipment shall be maintained routinely.

20.1.3.13. Equipment with defects that could affect safe operations shall be tagged to prevent its use until repairs are completed.

20.1.3.14. Transfer hoses and portable equipment not involved in the process shall be removed from the work area and stored in their proper places.

20.1.3.15. Agitator blades on reactors and mixers shall be inspected regularly for proper clearance to verify that there is no pinch point or metal to metal contact.

20.1.3.16. Any vessel that can be sealed and that can operate above atmospheric pressure shall be equipped with overpressure protection.

20.1.3.17. All closed vessels should be purged with inert gas before flammable liquids are introduced.

20..1.3.18. Inert gas pressure should be used to transfer flammable liquids when gravity flow or pumping is not practical.

20.2. Formulation

20.2.1. Formulation operations considered in this section involve combining compounds or mixtures when one or more of the ingredients are explosive.

20.2.2. Explosives should be loaded into mixers, mills, and deaerators as an operator attended, contact operation. However, the starting, operating, and stopping of such equipment with explosives present shall be accomplished remotely. As an exception, mixing type operations involving a low-energy transfer may be allowed as a contact operation (e.g., slurry coating and melt agitation).

20.2.3. Equipment used for explosives formulation shall be checked for proper operation before adding explosives.

20.2.4. Equipment shall be examined for proper clearances and for metal-to-metal rubbing of moving parts with the potential to contact explosives.

20.2.5. Bearings should be sealed to preclude explosives contamination.

20.2.6. Fast action deluge systems shall be considered for equipment (e.g., mixers, mills, and deaerators) used for easily ignitable explosives formulations.

20.2.7. Hot water, cold water, or steam may be applied to mixers and mills. Heating fluid temperatures shall not exceed known safe operating temperatures for the explosives involved. When roll milling, allowance shall also be made for viscous shear heating of the explosives in process. Heated systems shall comply with the requirements of Paragraphs 21.3.1 and 21.3.4.

20.2.8. Mixing

20.2.8.1. Mixer seals and gaskets shall be checked on a regular schedule and cleaned or replaced as required.

20.2.8.2. Checks should be made to verify that maximum particle sizes of ingredients or hard agglomerates of proposed mixes are less than the blade to blade or blade to bowl clearances.

20.2.8.3. Initial cleaning with solvents used for dissolving or suspending the explosives residues shall be done remotely (except for melt mix or slurry coating vessels).

20.2.8.4. Explosive powders and plastic bonded explosives formulations should be mixed wet in a contact operation. This can be accomplished if the wet mixture cannot be initiated with energy sources available, the viscosity is kept low, and the possibility of isolated portions of the mix becoming dry is precluded.

20.2.9. Ball or Jar Milling

20.2.9.1. Balls that are porous or contain cavities shall not be permitted in mills for grinding explosives.

20.2.9.2. Grinding media contaminated with explosives slurry shall be protected from excessive impact when emptying of the mill.

20.2.9.3. After grinding, a careful inspection shall be made to verify that the explosive is free of grinding media. Dispose of any explosives contaminated with broken media.

20.2.9.4. After separating the explosive, the grinding media shall be thoroughly cleaned and inspected before reuse or disposal.

20.2.10. Roll Milling

20.2.10.1. Positive stops should be installed on roll mills to prevent rolls from rubbing against each other.

20.2.10.2. Before starting a milling operation on a roll mill, the contact of the scraper blade with the roll should be adjusted to the minimum pressure necessary to perform the operation.

20.2.10.3. Roll gaps should be set as wide as possible while still allowing adequate working of the material. The minimum gap setting shall be 0.1 mm.

20.2.10.4. Roll rpm should be held at the minimum required to process the material adequately.

20.2.10.5. All roll mills that should be contact operated (e.g., with nonexplosive materials) shall be equipped with emergency stop devices (breaker bar or chain) within easy reach of the operator.

21. HEATING, DRYING, AND THERMAL CONDITIONING

21.1. Hazards of Heating Explosives

21.1.1. Elevated temperature may increase an explosive’s sensitivity to other stimuli such as impact, shock, friction and static electricity.

Note: A runaway chemical reaction may occur at or above the explosive’s critical temperature that can produce an explosion or fire.

21.1.2. Elevated temperature of an explosive in a sealed container may cause gas generation and pressure rupture of the containment even at temperatures below the critical temperature.

21.1.3. Chemically incompatible or reactive materials, which may be present as accidental contaminants, as components of the formulation, or in external contact with the explosive, may intensify the preceding dangers or cause them to occur at lower temperatures.

21.1.4. Non-uniform heating can cause excessively hot regions in the explosives. Causes may include inadequate agitation of fluid explosives, non-uniform heaters, and non-uniform heat conduction.

21.2. Critical Temperature and Thermal Analysis Methodology

21.2.1. Critical temperature is a system property that depends on a combination of the explosive's chemical decomposition reactions, its mass and shape, heat transfer and other thermal characteristics of the system, and the confinement or pressure of decomposition products, especially gases. Several different methods of thermal analysis may be used to determine or estimate the critical temperature. The process is typically quite complex because of the complexity of normally occurring chemical reactions.

21.2.2. For operational safety, a conservative estimate (i.e., lower limit) of the critical temperature for a heating operation shall be made (uncertainties of 18°F to 45°F (10°C to 25°C) being common).

Note: Analogy of one explosive or system to another similar system with a reliable thermal analysis should be used to determine safe heating temperatures and heating times (heating limits).

21.2.3. The differential thermal analysis (DTA), differential scanning calorimetry (DSC), or other comparable techniques may be used to measure the temperature of the onset of an exothermic reaction in an explosive. The test results may be used to rank the thermal stability of explosives and as part of a thermal analysis. Because of the complexity of chemical decomposition, however, the DTA/DSC exotherm has no systematic relationship to the critical temperature and is unreliable for estimating safe heating limits. Exotherm temperature is always considerably above critical temperature and usually increases with the heating rate of the test.

21.2.3.1. Where the DTA/DSC exotherm is specified as a standard for temperature control, the test heating rate shall not exceed 18°F (10°C) per minute.

21.2.3.2. DTA/DSC shall not be used as a sole means for establishing heating limits.

21.2.4. Each facility shall conduct or obtain thermal analysis of any explosives system before the explosive is heated in a contact operation or in association with hazardous radioactive materials as described in Section 29.4.

21.2.5. From this analysis, a heating limit for the explosives system shall be established which the EDC shall approve.

21.2.5.1. All factors in Sections 21.1 and 21.2 shall be considered.

21.2.5.2. Any significant change in the geometry or an increase in mass should be considered a new explosives system.

21.2.5.3. For a contact operation, the maximum temperature should be set at least 18°F (10°C) below the critical temperature.

21.2.5.4. For heating explosives in association with hazardous radioactive materials, the maximum temperature should be set at least 36°F (20°C) below the critical temperature.

21.2.5.5. Contractor Facility Management should approve heating to a temperature greater than the above specifications if a documented analysis of the explosive's thermal characteristics indicates that an acceptable time or temperature safety factor is still present for a specific operation.

21.2.5.6. These operations shall be conducted remotely.

21.2.6. Heating controls for each operation shall be established and specified in written operating procedures.

21.2.6.1. Specified conditions should be set at the lowest temperatures and heating times to do the job efficiently. Temperatures should not exceed the heating limit for the explosives system.

21.2.6.2. Factors to consider when establishing heating controls include:

- The heating limit and accuracy of the estimated critical temperature.
- Accuracy of the temperature control equipment.
  The likelihood of incompatible chemical contamination and other operational parameters.

21.3. Heating and Drying Equipment

21.3.1. Heat should be supplied by steam, hot water, friction air, electrically heated transfer fluid, or electrical resistance elements.

21.3.2. Redundant, automatic heat controls shall limit temperatures.

21.3.3. Explosives heated using electrical resistance elements shall be separated from electrical resistance elements to avoid any possible contact.

21.3.4. In systems heated by steam only, the requirements for redundant, automatic heat controls shall be satisfied if a pressure reducing valve, pressure relief valve, and thermostatic valve on the system control the steam pressure.

21.3.5. In electricity heated systems, a manual reset secondary over-temperature system consisting of a controller, failsafe sensor, and an interrupting device shall be provided to interrupt the heat supply source if the primary system fails.

21.3.5.1. The secondary interrupter shall be separate from the primary interrupter.

21.3.5.2. The upper limit of the primary controller is determined by the desired operating temperature limit.

21.3.5.3. The secondary (override) controller is set at a higher temperature but should not exceed the maximum temperature determined by the heating limit specified for the explosives system as determined in Paragraph 21.2.4.

21.3.6. Visual and/or audible alarms should be provided to alert operating personnel to abnormal temperature conditions.

21.3.6.1. The heating of explosives should be monitored at all times.

21.3.7. The air or gas used to condition exposed explosives shall not be recirculated if directly heated by electrical resistance elements.

21.3.8. Drying or heating ovens should be vented to a safe location outdoors. Water wash or filtration of the exhaust may be required.

21.3.8.1. If exhaust fans are used, they shall be interlocked with the heat source.

21.4. Heating and Drying Operations

21.4.1. Heating and drying shall be performed under the mildest set of conditions to accomplish the task safely and efficiently.

21.4.2. A thermal analysis shall be made and a written procedure prepared consistent with Section 21.2.

21.4.3. The operating procedure shall include controls on the mass and geometry (thickness of the layer) of the material that may be heated.

21.4.4. Except as described in Paragraph 21.4.5, drying shall be achieved by circulating a warm, dry gas—either air or inert—over or through the material.

21.4.5. Small samples may be dried by placement in desiccators or by subjecting them to vacuum.

21.4.5.1. Vacuum drying of larger items should be preceded by drying at atmospheric pressure to remove quantities of moisture or solvent before vacuum is applied to remove the final traces of moisture or solvent.

21.4.5.2. Explosives having a vapor pressure exceeding 0.013 Pa (1 x 104 mm Hg) at the drying temperature shall not be subjected to vacuum drying.

21.4.5.3. A cold trap shall be used for vacuum drying where the vapor pressure of the explosives is unknown.

21.4.6. A vapor air mixture within explosive concentration limits shall be avoided.

21.4.6.1. Such a vapor air mixture can be controlled by providing sufficient airflow to maintain a vapor concentration well below the lower flammability limit or by using an inert atmosphere.

21.4.6.2. For inert atmosphere, positive purge shall be used to preclude oxygen leakage into the unit.

21.4.6.3. If vapor concentrations approaching a flammable level are anticipated, they shall be monitored.

21.4.6.4. Airflow shall be controlled to prevent dusting.

21.4.7. When heating explosives whose vapor pressure may cause undesired condensation of explosives on equipment parts, heating shall be conducted in a manner to control condensation of the explosive material.

21.4.7.1. This control should be accomplished by heating the exhaust system or by circulating the air at a rate that shall keep the explosives concentration below the level at which condensation could occur.

21.4.8. The proper operation of heater controls shall be verified on a regular schedule established by Contractor Facility Management.

22. DRY SCREENING, BLENDING, AND MELTING

22.1. Dry Screening

22.1.1. Use of magnetic separators is often advisable to remove ferrous materials that may have passed through the screens.

22.1.2. Operations using mechanical screens shall be performed remotely.

22.1.3. Screening small samples may be performed as a contact operation in accordance with approved operating procedures.

22.1.4. Operating areas and equipment therein shall be cleaned frequently to avoid accumulation of explosives dust.

22.1.5. Operations and equipment shall be set up to minimize and control dust generation.

22.1.6. Equipment shall be designed and operations performed to avoid subjecting explosive materials to pinching, friction, or impact.

22.1.7. Precautions shall be taken to prevent metals from rubbing together when the screens vibrate.

22.1.8. Vibrating equipment shall be inspected frequently for developing cracks subject to contamination by explosives.

22.1.9. Equipment shall be electrically bonded and grounded. Resistance to ground shall be 10 ohms or less and shall be inspected as established by Contractor Facility Management.

22.1.10. Equipment used to transfer electrostatic sensitive explosives to or from screens shall be conductive and electrically bonded to the screen during transfer.

22.2. Blending

22.2.1. Dry blending of explosives shall be performed remotely.

22.2.2. Dry, hand blending of small samples may be performed as a contact operation in accordance with approved operating procedures.

22.2.3. Equipment should be designed and operations performed to minimize generation and dispersion of explosives dust.

22.2.4. Equipment shall be electrically bonded to provide a continuous path to ground.

22.2.4.1. Resistance to ground shall be 10 ohms or less and shall be inspected as established by Contractor Facility Management.

22.2.5. Equipment used to transfer electrostatic sensitive explosives to or from blenders shall be conductive and electrically bonded to the blender during transfer.

22.3. Melting

22.3.1. The heat for melting explosives shall be supplied by saturated steam, hot water, or another temperature controlled medium. The steam pressure shall be controlled in accordance with Paragraph 21.3.4.

22.3.2. Temperatures for contact melting of TNT based explosives (except those containing PETN (Pentaerythritol Tetranitrate), e.g., pentolite) and keeping them molten shall not exceed 249.8°F (121°C).

22.3.2.1. The temperature limit for TNT explosives containing PETN shall be 228.2°F (109°C).

22.3.3. Alarms shall be provided on the melt temperature and on melt kettle agitation when the operation shall be left unattended.

22.3.3.1. Alarms shall sound if the temperature exceeds the specifications of Paragraph 22.3.2 above, or if agitation ceases.

22.3.4. Provisions should be made for emergency emptying of melt kettles in the event of temperature control problems or power failures.

22.3.5. Feeding of the melt kettle and the melting operation shall be controlled or regulated to prevent the formation of large chunks of explosives.

22.3.6. Wherever possible, valves, piping, and threaded bolts and fasteners should be eliminated from melted explosives handling systems.

22.3.7. Melt kettles shall be constructed with corrosion resistant materials.

22.3.7.1. Construction shall not contain blind holes, threads, or cracks in areas exposed to melted explosives.

22.3.7.2. Welds shall be inspected and found free of cracks and porosity.

23. PRESSING AND EXTRUDING

23.1. Pressing

Note: Explosives pressing operations subject explosives to high pressures to achieve a physical change. Pressing of explosives formulations is done routinely to consolidate explosive materials into configurations required for test assemblies or weapon systems. Two common types of pressing operations commonly performed are isostatic/hydrostatic and punch and die. The following requirements apply to these types of pressing operations.

23.1.1. Explosives pressing operations shall be conducted remotely.

23.1.2. The correct functioning of press interlock systems shall be verified at intervals established by Contractor Facility Management.

23.1.3. Pressing mandrels, punches, and dies used in explosives operations shall be examined regularly during periods of use for evidence of structural failure.

23.1.3.1. Suitable nondestructive test methods shall be used to perform the examination.

23.1.3.2. Contractor Facility Management shall establish intervals between inspections for each tooling design before committing the tooling to use.

23.1.3.3. The inspection interval and updating should be based on experience with similar tooling designs and configurations.

23.1.4. All new or modified mandrels, punches, and dies shall be inspected before their first use.

23.1.4.1. At least one pressing cycle shall be completed with mock explosives before proceeding to explosives.

23.1.5. Pressure controllers and indicators shall be calibrated periodically to verify accurate control and monitoring of pressing operations.

23.1.6. Press parts that contact explosive materials shall be cleaned thoroughly to remove residual explosives before use with a different explosive formulation.

23.1.7. Temperature control for heated presses and dies shall comply with the requirements of Paragraphs 21.3.1 and 21.3.4.

23.1.8. All pressing assemblies shall be designed or procedural controls established to minimize or eliminate the extrusion of explosives between two mating metal surfaces during the pressing operation.

23.1.9. Operations with explosive powders should be performed in a manner that reduces the release of explosives dust and thereby reduces operator exposure and general room contamination.

23.1.9.1. For operations involving large amounts of powders, local exhaust ventilation with a dust collection system should be provided.

23.1.9.2. Respiratory protection to prevent inhalation of explosives dust may be required when adequate ventilation is not available.

23.1.10. Isostatic/Hydrostatic Pressing

23.1.10.1. Before an elastomeric container or mandrel constructed of a new material is introduced into a pressing operation (where it shall contact explosives), the material shall be evaluated for compatibility with the explosives.

23.1.10.2. All pressing vessels shall be examined for evidence of cracking or other signs of incipient structural failure at regular use intervals by suitable nondestructive test methods. Contractor Facility Management shall establish examination intervals.

23.1.10.3. Before large scale pressings of new explosives or explosives formulations, the materials shall be evaluated for thermal stability (see scaleup procedures in Chapter 19).

Note 1: “New explosives or explosives formulations” refer to those that are “new” to large scale pressing.

Note 2: Stability test results shall be used to assist in establishing safe pressing conditions for the specific pressing size.

23.1.10.4. For isostatic pressing, procedural controls shall be established to validate that:

- An acceptable vacuum can be obtained on the mandrel assembly to prevent adiabatic heating during pressing; and
- Air is bled out of the press before pressurization.

23.1.10.5. Consideration should be given to the use of fire resistant hydraulic fluids.

Note: New fluids shall be checked to verify compatibility with the explosives used.

23.1.11. Punch and Die Pressing

23.1.11.1. All pressing punches and dies shall be inspected visually for damage, deformation, and cleanliness before installation on a press.

Note: Any questionable condition shall be resolved before the pressing proceeds to verify that the operation's safety is not compromised.

23.1.11.2. All punches, dies, and press attachment fixtures shall be designed to minimize the possibility of the punch being misaligned with the die (resulting in gouging of a die surface during pressing).

Note: Press setup procedures shall provide for operator verification of proper alignment before pressing.

23.1.11.3. The responsible user of a gauging section capable of performing the necessary measurements shall control punches and dies.

Note: Punches and dies should be maintained in matched sets.

23.1.11.4. A group other than the user shall check critical punch and die dimensions before initial use and at suitable intervals thereafter.

Note: Suitable check intervals for each punch and die design should be determined as in Paragraph 23.1.4.

23.2. **Extruding**

23.2.1. Extrusion operations shall be conducted remotely.

23.2.2. Contact extrusion should be performed only when extruding nonexplosive or mock materials or when hand extruding small quantities with no metal to metal contact.

23.2.3. Precautions shall be taken to prevent personnel from being injured by the rupture of pressurized equipment.

23.2.4. The explosive shall be protected against extrusion beyond the tooling cavity.

23.2.5. Precautions shall be taken to prevent foreign material from entering the explosives.

23.2.6. New designs and significant design changes in equipment, tooling or components shall be tested by mock explosives extrusion before actual explosives extrusion.

23.2.7. Pressure controllers and indicators shall be calibrated periodically to validate that proper sealing and extrusion pressures are maintained.

23.2.8. Extrusion press parts shall be cleaned thoroughly of residual explosives remaining from the previous operation before the press is loaded with a different explosive formulation.

23.2.9. Hand loading of extrudable explosives is covered in Section 28.3.

24. MACHINING

24.1. Equipment Requirements

24.1.1. Interlocks shall be provided for wet machining operations to verify coolant flow before machine operation.

24.1.1.1. The coolant flow shall be monitored and the equipment automatically and safely shut down if loss of coolant flow is detected.

24.1.1.2. The coolant interlocks shall be protected from tampering and unauthorized disabling by physical means, or supervisory control.

24.1.2. The vacuum on vacuum chuck holding fixtures shall be monitored and interlocked with the equipment for automatic shutdown of machining in the event of vacuum loss.

24.1.3. Tool path controls (stops, limits, design patterns) shall be provided to prevent the unplanned travel path of a tool or work piece.

24.1.4. Positive means or secondary verification shall control and limit equipment speed and feed rates.

24.1.5. Pressure-relief devices should be installed on pneumatically or hydraulically powered equipment to provide for safe operation.

24.1.6. Metal chip waste from machining operations should be kept separate from explosives waste.

24.1.6.1. When this is not possible, mixed explosives and metal waste should be completely segregated from unmixed waste and held for separate disposal.

24.1.7. A cutting tool inspection and control program shall be established for explosives machining operations.

24.1.8. Dull or damaged tools shall not be used.

24.1.9. Consideration shall be given to additional safety control devices (e.g., design patterns, safety templates, chip thickness sensors, tool pressure sensors), depending on the type of machining operations, size of explosives pieces, types of explosives, and other factors.

24.1.10. The "machining over-test" shall be considered a testing operation (see Paragraph 24.4.13) and is exempt from equipment requirements.

24.2. Contact or Remote Operations

24.2.1. The following explosives may be contact machined if a compatible, nontoxic, noncombustible coolant is used. Explosives not listed below shall be machined remotely.

- Amatol
- Baratol
- Boracitol
- Explosive D
- Octol with no more than 75% HMX (Cyclotetramethylene Tetranitramine)
- Pentolite with no more than 50% PETN
- RDX/TNT compositions with no more than 75% RDX (Cyclotrimethylene Trinitramine). These compositions include Composition B, Composition B-3, and 75/25 Cyclotol
- TATB (Triamino Trinitrobenzene) and TATB compositions with an inert plastic binder
- TNT

24.2.2. Explosive assemblies composed of any combination of explosives listed in the Paragraph 24.2.1 and the following non-explosive materials may be contact machined if a compatible, nontoxic, noncombustible coolant is used.

- Foamed plastics
- Solid plastics
- Adhesives
- Amorphous graphite
- Calcium sulfate casting powder
- Explosives mockup

24.2.3. If an assembly contains an explosive not listed in Paragraph 24.2.1 or a nonexplosive material not listed in Paragraph 24.2.2, the assembly shall be machined remotely.

24.2.4. On any explosive, with certain exceptions for TATB and TATB/KEL-F (or equivalent) formulations and explosives machined by fluid jet (see Paragraph 24.2.6), the following operations shall be performed remotely:

- Drilling of holes smaller than 5cm in diameter (except for TATB and TATB/KEL-F (or equivalent) formulations, where drilling of holes smaller than 5 mm).
- Coring operations (except contact operations on those explosives listed in Paragraph 24.2.1, when the requirements of Section 24.6 are met and a coolant is used).
- Machining of any metal/explosives interface.
- Machining TATB and TATB/KEL-F (or equivalent) formulations subassemblies with HD 1.1 boosters installed.
- Machining of explosives in Phase II or earlier stage of scaleup (see Chapter 19).
- Dry machining

Note: TATB and TATB/Kel-F (or equivalent) formulations booster pellets may be contact machined provided a dust collection system is used.

24.2.5. Machining of primary explosives shall be avoided. Consider other methods, such as forming or pressing to final dimensions, to achieve the desired shape.

24.2.6. IHE, PBX 9404 (Plastic Bonded Explosive), and LX-10 may be contact machined by high-pressure fluid jet.

24.2.6.1. The fluid jet system pressure shall not exceed 20,000psig.

24.2.6.2. The velocity of the fluid jet shall not exceed 520m/sec (theoretical).

24.2.6.3. The jet nozzle orifice diameter shall not exceed 0.01in.

24.2.6.4. The system machining fluid shall be water and shall not contain any abrasives.

Note: See Chapter 25 for use of low-pressure fluids.

24.2.7. Concurrent contact machining operations in the same bay should not be permitted. However, concurrent TATB and TATB/KEL-F (or equivalent) formulations contact machining is permitted when other explosives are not present.

24.2.8. Provisions shall be made to monitor remote machining operations visually. Consideration should be given to video recording and audio monitoring.

24.3. Setup and Preparation Prior to Machining

24.3.1. Before setting up the explosive work piece, the equipment shall be checked for proper function and the absence of interference between stationary and moving parts.

24.3.2. An inert shape (e.g., wax, Lexan (polycarbonate), or mock explosive) should be used to test the equipment function of any operation using new tooling or new part programs.

24.3.3. The explosive component to be machined shall be inspected by radiography or other suitable nondestructive test methods for cracks, voids, and high-density foreign objects.

24.3.4. The explosive component shall be checked for proper size.

24.3.5. Caution shall be exercised during setup and adjustment to avoid pinching, dropping, crushing, or otherwise applying abnormal forces to explosives present.

24.3.6. Special care shall be given to mounting and centering a part on a vacuum chuck.

24.3.7. Special attention shall be given to the proper functioning of the vacuum system and its surface holding area.

24.3.8. Limits on machine speed, depth of cut, and feed rate shall be set before the machine is activated.

24.3.9. Interlocks shall be functional before the machine is used to machine explosives. They should be tested once per shift.

24.4. Operations Requirements

24.4.1. The minimum tool speed necessary for safe and efficient operation should be maintained. The following maximums shall apply:

- The relative velocity between the explosives surface and the cutting tool shall not exceed 65m/min;
- Work pieces or cutting tools shall not be rotated at speeds exceeding 525rpm; and
- The feed rate of the cutting tool or work piece shall not exceed 1mm per revolution.

24.4.2. The work piece, fixture, cutting tools, equipment, floor, troughs, drains, etc., should be cleaned frequently to prevent accumulation of explosive wastes.

24.4.3. Approved measures should be taken to prevent rust and minimize deterioration of precision surfaces.

24.4.4. All tools, equipment, fixtures, and parts should be cleaned before removal from the work area for storage.

24.4.5. Coolant shall be used to aid in removing heat and cutting waste for contact machining operations.

24.4.6. Coolant should be used for remote operations when practical.

24.4.7. Coolant should be used on explosives/inert assemblies.

24.4.8. When the explosives portion is included in the cut, coolant shall be used for contact machining.

24.4.9. Coolant is not required if the explosives portion of the assembly is contained (no bare explosives) and is not included in the cut, or the machining is conducted remotely.

24.4.10. Spray mist coolant may be used during machining of the explosive-containing assemblies if the explosives portion is not included in the cut.

24.4.11. All visible explosives shall be removed from the machine before maintenance or repairs.

24.4.12. No safeguards or interlocks shall be removed or made inoperative, except by authorized personnel.

24.4.13. Before submitting an explosive for contact machining approval, a machining over-test shall be conducted to identify the machinability and associated hazards.

24.4.13.1. Machining over-test should be performed in facilities set aside for this purpose.

24.4.13.2. Machining over-test shall be conducted remotely.

24.4.13.3. Operations performed during sample preparation may include gaging and assembly, but shall not include any contact cutting, scraping, or other material-removing operations on explosives specimens.

24.5. Drilling

24.5.1. Drilling operations should be set up to maximize the ease of achieving and maintaining proper alignment and to facilitate removal of explosives chips, fines, and powder.

24.5.2. The fluting length on the drill bit shall exceed the depth of the hole to be drilled by a minimum of 1.3cm or one-hole diameter, whichever is greater.

24.5.3. The depth of a hole shall not be extended more than 1.5 times the hole diameter (up to a maximum of 2cm) during a single insertion of the drill into the material.

Note: After each insertion, it may be advisable to withdraw the drill completely and remove loose explosives from the cavity and drill bit before reinserting.

24.5.4. Coolant flow (when used) shall be directed to the explosives/cutting edge interface.

24.5.5. Drill bits larger than 0.25in (6mm) should have a coolant channel to the tip of the drill.

Note: Bits 0.25in (6mm) or less in diameter do not need coolant channels, but should limit the depth of each pass to no more than ½ the diameter of the bit to verify that the coolant flow is capable of keeping the hole clean.

24.5.6. Pulsating pressure types of coolant supplies are recommended for drills of 0.25in (6 mm) diameter or less to remove drill fines.

24.6. Coring

Note: A machining operation that removes material in the form of a cylinder by cutting at the circumference to create a hole or recover the material from the center of the cut.

24.6.1. Coolant flow (when used) shall be directed at the explosives/cutting edge interface.

24.6.2. If the hole is not positioned to provide continuous breakout, the coring shall be accomplished incrementally.

24.6.3. When done in increments, no more than 1.5 times the diameter of the hole shall be cored at one time.

24.6.3.1. Before the maximum distance has been cored, the tool shall be totally retracted from the hole and cleaned.

24.6.3.2. The hole shall be flushed with coolant.

24.7. Sawing

24.7.1. The feed rate of the saw blade or work piece shall not exceed 7.5cm/min.

24.7.2. For band saws, coolant flow should be directed onto the saw blade at the cutting interface, guide rollers, and the drive wheel/saw blade interface.

24.7.3. For circular saws, the coolant flow should be directed at the explosives/cutting edge interface.

25. LOW PRESSURE FLUIDS

25.1. Use of Low Pressure Fluids

25.1.1. Low pressure fluids may be handled in explosives contact operations to aid in the following:

- Dissolution
- Rinsing
- Flushing, or
- Similar operations

25.1.2. The fluid system shall have a pressure relief device installed to prevent system over pressurization.

25.1.3. Low pressure fluid operations may be used with those explosives whose impact sensitivity is less than PETN.

Note: Such operations may be used on other explosives only after analyzing the energies involved.

25.1.4. Solvents shall be compatible with the explosive material.

Note: Controls for their use shall be specified in operating procedures.

26. LASER ABLATION

26.1. Laser Ablation Operations

26.1.1. Laser ablation shall be conducted as a Hazard Class 1 Level-of-Protection Activity.

26.1.2. During set-up, when personnel are exposed to the explosives hazard, the ablation laser beam shall not be able to reach the explosives or assembly containing explosives.

Note: Low-power alignment lasers may be used.

26.1.3. Before setting up the explosive work piece, the equipment shall be checked for proper function and the absence of interference between stationary and moving parts.

26.1.4. Caution shall be exercised during setup and adjustment to avoid pinching, dropping, crushing, or otherwise applying abnormal forces to explosives present.

26.1.5. Interlocks shall be functional before the laser is used to ablate explosives.

26.1.6. During laser ablation operations, the operator should be provided an immediate means to block the laser beam from reaching the explosives.

27. HAND CUTTING AND FINISHING

27.1. Hand-Cutting and Finishing Operations

27.1.1. Hand-cutting and finishing of explosive materials shall be performed using the mildest energy input that shall accomplish the task safely and efficiently.

27.1.2. These activities may include:

- Cutting
- Trimming
- Coring
- Lapping (surface polishing)

27.1.3. The Contractor EDC shall review and approve the safety of hand-cutting and finishing operations, which shall then be incorporated into an operating procedure before starting the operation.

28. ASSEMBLY AND DISASSEMBLY

28.1. Tools

28.1.1. Hand tools and electrical and pneumatic tools that may subject the explosives to abnormal frictional forces, pinching, or excessive pressure, or cause significant deformation, shall not be used during assembly or disassembly.

Note: Tools may be used on nonexplosive components.

28.2. Assembly Operations

28.2.1. Operators need to be alert for mismated parts and misaligned components during assembly operations.

28.2.2. Hard surfaces that contact explosives shall be precisely machined to mate with the explosives, lined with cushioning material, or otherwise configured to keep sharp corners or projections from being forced into explosives.

28.3. Loading Assemblies with Plastic or Extrudable Explosives

28.3.1. Contamination of these explosives with abrasive or foreign substances shall be avoided.

28.3.2. The assembly shall be loaded with small increments of explosives and may be tamped with suitable nonmetallic tools to eliminate air voids.

28.3.3. Plastic explosive compositions C-3 and C-4 may be softened by warming to between 69.8°F (21°C) and 100.4°F (38°C) before working.

28.3.4. Extrudable explosives LX-13 and XTX should be kept as cool as practical to prevent premature curing.

28.4. Disassembly Operations

28.4.1. Before beginning disassembly, the device’s condition shall be assessed to determine if it can be safely handled.

28.4.2. Disassembly operations shall be planned before actual disassembly. Possible problem areas caused by method of construction or physical condition shall be considered.

28.4.3. Approved operating procedures shall be used for each unique disassembly.

28.4.4. If disassembly would normally cause release of pressure or if a credible hazard exists of pressure causing components to fly apart, before beginning disassembly, pressurized units shall be thoroughly depressurized.

28.4.5. If approved for use, compressed air shall be applied cautiously during disassembly to avoid causing device components to fly apart.

28.4.5.1. This may require remote operation.

28.4.5.2. Use hydraulic pressure if possible.

28.5. Personnel Protection for Disassembly Operations

28.5.1. Operators and all other personnel shall be provided complete protection from disassembly operations involving conditions known or expected to require the use of abnormal force.

28.5.1.1. Such operations require either remote operation or the use of an operational shield.

28.5.2. When required, shielding shall be designed to protect personnel at other operations or locations from blast and fragments arising from a possible explosion.

28.5.3. When disassembly requires that the operator be protected by an operational shield, disassembly shall be defined as complete separation (threads or other connections) of component parts.

Note: For example, parts shall not be loosened or separated while the operator is unprotected.

29. TESTING

29.1. Test Planning

29.1.1. All explosives testing involving the intentional initiation of explosives materials or articles shall be considered Class 0 operations and shall comply with the requirements of Chapter 12 of this Technical Standard.

29.1.2. Proposed testing programs shall undergo a hazard analysis based upon the maximum credible event.

29.1.2.1. This shall be done with knowledge of the construction and operation of all standard and nonstandard equipment to be used, as well as the type of explosives involved.

29.1.3. Large-scale tests with the potential to propel fragments off DOE testing locations shall receive a formal risk analysis of the worst-case conditions for each test type.

29.1.3.1. Such analysis shall address the probability and potential severity of hazards with respect to injury and property damage.

29.2. Firing Areas

29.2.1. A secured firing area (danger zone) shall be established for each test to protect personnel from hazardous blast overpressure, firebrands (burning or hot fragment), fragments, or projectiles from an explosives shot or gun firing.

29.2.1.1. The danger zone shall be determined by the application of the principles outlined in DESR 6055.09.

29.2.2. Selected firing areas shall minimize the potential for secondary fires and adverse effects to the environment.

29.3. Checkout of Dynamic Engineering Test Equipment for Explosive Assemblies

29.3.1. To minimize the possibility of an incident during dynamic testing of explosive assemblies, load-bearing members of the test equipment or explosive assembly should be proof-tested and examined if:

29.3.1.1. The test equipment is new or has undergone a design modification;

29.3.1.2. Existing test equipment is to be used under unusually severe test conditions (i.e., conditions of velocity, vibration, pressure, load); or

29.3.1.3. A new or modified explosive assembly is to be tested that affects the loading characteristics of the equipment.

29.3.2. Proof-testing of the explosive assembly or test equipment should be conducted before running tests involving systems with explosives.

29.3.3. At a minimum, proof-testing should consist of the following sequence of checkouts:

29.3.3.1. Check out load-bearing members (lifting devices, hold-down mechanisms, fixtures, vehicle cases) to at least 125% of rated load using simulated loads.

29.3.3.2. “Dry run” tests of actual systems with mock materials in place of explosives and hazardous radioactive materials.

29.3.4. If a part failure occurs in either of the checkout tests in Paragraphs 29.3.3.1 or 29.3.3.2, tests involving explosives or radioactive material shall not be run until additional checkout tests have demonstrated that the cause of failure has been eliminated.

29.4. Testing of Explosives and Hazardous Radioactive Materials

29.4.1. Explosives and hazardous radioactive materials (e.g., plutonium, enriched uranium) shall not be included in the same test or operation if the test or operation is not contained and involves any of the following:

Note 1: Depleted uranium and natural thorium are not considered hazardous radioactive materials for this purpose.

Note 2: Nuclear Explosive Operations, covered by DOE Order 452.2 are exempted from this requirement.

29.4.1.1. Application of high-energy stimuli (e.g., high shock, impact, or friction levels) to the explosive.

29.4.1.2. Heating the explosive to within 18°F (10°C) of the heating limit determined for the explosive system without hazardous radioactive materials consistent with Paragraph 21.2.4.

29.4.1.3. Intimate contact of incompatible material with the explosive as determined by compatibility testing.

29.5. Heating of Explosives Test Specimens

29.5.1. Before heating an explosive, a thermal analysis shall be conducted and a written procedure prepared consistent with Section 21.1.

29.5.2. For requirements on heating equipment see Section 21.3.

29.5.3. Contact operations on explosives specimens undergoing thermal conditioning may be permitted if:

29.5.3.1. The specimen is not subjected to excessive friction, impact, or spark stimuli during normal operations or during a credible accident scenario.

29.5.3.2. The explosive involved has satisfied appropriate scale-up sensitivity and stability criteria (see Chapter 19) and has sufficient handling history to reveal any special characteristics affecting safe use.

29.5.4. If an explosives test specimen in a contact operation is discovered to have exceeded the established heating limit for the explosive system, the test shall be terminated and the specimen cooled to ambient temperature.

Note: An operating procedure should be prepared and approved for the required corrective action (i.e., disassembly or disposal).

29.6. Instrumentation

29.6.1. Instrumentation directly applied to explosives in a test specimen shall be physically disconnected, isolated, or grounded before personnel may enter the test cell.

29.6.1.1. Only instrumentation channels that contain devices that limit the current below the level capable of initiating the explosive are exempt.

29.6.2. Environmental control transducer leads, not attached to the test specimen and permanently installed in an approved control system, do not need to be grounded or disconnected.

29.7. Explosives Accumulation Limits

29.7.1. Explosives specimens shall not be permitted to accumulate in a test cell beyond the quantity required to sustain the test.

29.7.1.1. For short-term testing (less than one day), specimens present shall not exceed a 4-hr supply.

30. TEST FIRING

30.1. General Range Standards

30.1.1. Each DOE explosives test site shall establish procedures to verify that personnel are not exposed to firebrands (burning or hot fragment), fragments, or excessive blast overpressure from a test shot.

30.1.2. During test operations, personnel access to each test site shall be controlled.

30.1.2.1. Unattended roadblocks, gates, or doors used to prevent personnel from entering the danger zone during a test should be interlocked or locked with specially controlled keys.

Note: In locations where interlocks or locks are not practicable, appropriate barriers and signage may be applied.

30.1.3. Before test firing, all firing site personnel and visitors shall be accounted for and in a safe place.

30.1.4. A visual inspection of the danger zone shall be performed immediately before each test shot or series of shots as applicable, to verify that no transients are present.

30.1.5. The danger zone shall be free of service personnel (e.g., telephone repairmen, surveyors, road maintenance crews) during test operations.

30.1.6. The control point shall notify service personnel of the specific requirements under which they may safely work in the area when testing is not in progress.

30.1.7. The control point shall notify firing site personnel of the presence and location of service personnel in their areas.

30.1.8. Clearance for a test or test series shall be coordinated with all test sites and other areas that could be affected.

30.1.9. A warning shall be provided to every affected area to warn personnel of an impending test firing.

Note 1: This warning shall include standard audible signals.

Note 2: Detonation of very large explosive shots, numerous smaller shots, or gun firings could exceed the DOE allowable limits for impulse noise.

30.1.10. During test operations, all personnel assigned to the test area shall be continuously alert for movement of personnel, vehicles, and aircraft.

30.1.11. Test firings often create hazardous conditions for aircraft operating in the airspace near the danger zone. If this airspace is subject to air traffic, precautions shall be taken to verify that the airspace is clear of traffic at the time of firing.

30.1.12. Each firing site shall establish personnel limits based on the number of people actually needed to conduct an operation and the number of casuals that should be present. The responsible person at the firing site shall enforce these personnel limits.

30.1.13. Testing of explosives can result in personnel exposure to toxic decomposition products such as carbon monoxide, hydrogen chloride, hydrogen fluoride, hydrogen cyanide, and nitrogen oxides.

30.1.13.1. Allow the detonation cloud to disperse before leaving protective bunkers.

Note: Fragment-danger-zone distances are normally adequate to allow cloud dispersal and protect outside personnel from excessive exposure.

30.1.14. For testing that can result in abnormally long hazardous conditions following the test, the procedure shall require a suitable waiting period before personnel leave their shelter or safe haven area.

30.2. **Grass Fires**

30.2.1. Before conducting a test shot at an outside firing pad, an evaluation shall be made to determine the need to control grass fires that the test may initiate.

30.3. **Test Setup**

30.3.1. Test setup work should be done before receipt of explosives. When possible the following activities should be performed:

30.3.1.1. Firing site safety devices (at both the bunker and remote from the firing bunker) shall be checked as established by Contractor Facility Management.

Note: Safety devices include warning lights, door and gate firing circuit interlocks, emergency firing circuit cutoff switches, and grounding.

30.3.1.2. Firing pad and shot stand setup work that require power tools or other potential spark-producing devices should be completed.

Note: Special precautions and procedures shall be developed and implemented if power tools or other spark producing devices are needed after explosives are delivered to the firing pad.

30.3.1.3. The firing pad shall be cleared of all unnecessary equipment.

30.3.1.4. When possible, all diagnostic equipment shall be set up, checked, and tested in a “dry run.”

30.3.1.5. If a special structure is required, as much work as possible should be accomplished on the structure, including assembly of all materials.

30.4. Pin Switches and Other Non-initiating Circuits

30.4.1. Whenever pin switches and other non-initiating circuits are checked (such as for charging current or leakage) and are in contact with or in close proximity to explosives, the check should be performed remotely.

30.4.2. Other non-initiating electrical circuits include strain gauges, pressure transducers, thermocouples, etc., that may be affixed to or close to the explosives within an assembly.

30.4.2.1. A continuity-only (resistance) check may be accomplished as a contact operation with an electrical instrument approved for use with the particular explosive device.

30.4.3. When low-firing-current actuators are involved, consider conducting these tests remotely (see Section 37.4).

30.5. Low-Energy Electro-explosive Devices

30.5.1. Procedures shall be established to verify that Radio Frequency (RF), Frequency Modulation (FM), and television transmitters with sufficient output energy to initiate an electro-explosive devices (EED) at the test site are either restricted to a safe distance from the site or not operated.

30.5.2. Appropriate separation distances from Electromagnetic Radiation (EMR) transmitters shall be determined per Paragraph 38.1.3.

30.5.3. Low-firing-current igniters or detonators shall be kept separate from explosives at all times, except during actual test charge assembly and setup.

30.5.4. At all times, wiring systems for the explosive charge and any low-firing-current initiators shall be kept insulated from all sources of extraneous current unless the weapon components have an exposed electrical ground by design.

30.5.5. Connections made using weapon wiring connectors or cables are acceptable without further modification.

30.5.6. Shunts shall be left on low-energy initiators or lead wires until connections are made.

30.5.7. Connections shall be taped or otherwise insulated.

30.5.8. Test units containing low-firing-current actuators or detonators shall be clearly marked.

30.5.8.1. No contact operations involving electrical testing shall be permitted on this type of unit unless an electrical meter for the specific application is used.

30.6. Explosives Storage in Firing Areas

30.6.1. Explosives or ammunition storage at a firing area shall be located such that ignition, explosion, or detonation is improbable if a fire, unplanned explosion, or detonation occurs in the area.

30.6.2. Tests that require storage of explosives or ammunition at the firing site beyond a day’s event shall conform to the requirements of Chapter 32.

30.7. Firing Leads

30.7.1. All detonator lead wires shall be electrically insulated.

30.7.2. During setup on the firing point, firing leads or cables of low-energy detonators for explosive assemblies shall be kept shorted.

30.8. Unattended Test Assemblies (during off-shift hours, when necessary)

30.8.1. If explosives are present, appropriate safety warning signs shall be displayed at all entrances to the firing pad.

30.8.2. Protective services and fire department personnel shall be notified of the explosives location.

30.8.3. This location shall be in a controlled-access or secured area.

30.8.4. If low-energy detonators are present on the assembly, their leads or cables shall be shorted.

30.9. Firing Control Circuit Criteria

30.9.1. The criteria in this section apply to electrical circuits used to initiate EEDs used for test firing.

Note 1: These criteria apply regardless of whether the circuit is energized using an internal or external power source.

Note 2: A Firing Circuit shall be treated as capable of firing without warning as soon as it is coupled to an EED.

Note 3: A Firing Circuit that is connected to explosives shall not be armed during contact operations.

30.9.2. Firing Control Circuits shall be documented, reviewed, and approved for safety and operational control purposes.

30.9.2.1. Documentation shall include complete wiring diagrams, electrical schematics, and cable function lists.

30.9.3. All Firing Control Circuits, including changes and modifications, shall be reviewed for safety and compliance with Section 30.9, and approved by Contractor Facility Management prior to use with explosives.

30.9.4. Firing Control Circuits not meeting the safety criteria of Section 30.9 may be used with explosives only if equivalent safety is provided as determined by a documented analysis reviewed by the Contractor Explosives Safety AHJ, and approved by Contractor Facility Management.

30.9.5. Firing Control Circuits shall include both an arm and a fire control.

30.9.5.1. For low-energy EEDs, the safe mode of the arming circuit shall interrupt the firing circuit, short-circuit the EED terminals, and should ground the EED terminals.

Note: Manual shorting and grounding is permitted.

30.9.6. Each Firing Control Circuit shall include an interlock device which prevents unauthorized or inadvertent energization of a firing circuit.

30.9.6.1. The interlock device shall be unique for its application.

30.9.6.2. If key-operated controls are used, they shall be designed to lock in the safe (Off) position when the control key is removed.

30.9.6.3. Duplicate keys, safety plugs, or other interlock devices shall not be permitted in any single test area.

30.9.6.4. During shot preparation, the key, safety plug, or other interlock device, whichever is used, shall be in the control of the lead operator at all times.

30.9.7. Each Firing Control Circuit shall be isolated from all other circuits so as to prevent inadvertent energization by other circuits.

30.9.8. Firing Control Circuits shall be failsafe. Failure of any single component shall not result in inadvertent initiation of the EED prior to arming.

30.9.9. Firing Control Circuits shall be marked clearly or otherwise distinctively identified.

30.9.10. Developmental and/or Self-Contained Firing Circuits designed to initiate EEDs shall meet the requirements of Section 30.9 before being used with explosives.

30.10 Test Firing in Containment Apparatus (Tanks, Chambers, or Vessels)

30.10.1. Explosives may be detonated in containment apparatus.

30.10.2. All containment components shall be capable of withstanding and confining the effects of the explosion.

30.10.3. When new firing containment apparatus are designed and put into service, a safety factor to their operational explosives weight limit shall be included during certification testing.

30.10.3.1. This over-test load should be based on a percentage of the operational explosives weight limit.

Note: For example, a certification test should be performed with an appropriate explosive material weighing at least 125% TNT equivalency of the intended operating limit.

30.10.4. The firing circuit should be interlocked with the containment apparatus access door latch so that the door shall be closed and latched before the explosive can be fired.

30.10.5. Qualified engineering personnel shall periodically inspect the containment apparatus to verify that its structural integrity is maintained after repeated detonations.

30.10.6. Test firing is often conducted inside large containment apparatus that allow personnel entry but provide a confined working space and limited egress.

30.10.6.1. The operating procedure shall include requirements for ventilating and evaluating the containment apparatus' atmosphere before personnel entry.

30.11. Gun Firings

30.11.1. The gun shall be rigidly mounted so that the impact area is defined and controlled.

30.11.2. The target shall have an adequate backstop.

30.11.3. Provision should be made to remotely move the gun, remotely remove the propellant charge, or remove the explosives from the line of fire if the gun misfires, unless the hazardous effects of an accidental detonation of the explosive target is contained or effectively shielded from personnel.

30.11.4. Provisions shall be made to collect and remove undetonated explosives from the chamber or area.

30.11.5. Work, adjustment, or observation shall not be permitted on a gun while a live round is in the firing chamber. The only exception is to check azimuth and elevation.

30.11.6. Precautions shall be taken to protect personnel or equipment against hazards resulting from errors in assembly or preparation of equipment and ammunition. In particular, the following areas shall be checked:

- Fluid level of hydraulic recoil mechanisms.
- Function of the firing mechanisms.
- Absence of obstructions in the bore.

30.11.7. Firing mechanisms, particularly electric firing mechanisms, shall be tested before use to verify that merely inserting a round or closing of the breech does not result in firing.

30.11.8. Test weapons other than manually-fired small arms should be equipped for remote control of the safety and for remote cocking.

Note: The safety shall not be advanced to the fire position and the weapon shall not be cocked until all personnel are in a safe location.

30.11.9. When using hydrogen gas to fire a light gas gun, the operation shall be remote while hydrogen is present in the gun pressure tanks or in the gun barrel and catch tank after firing.

30.11.9.1. The hydrogen shall be purged from the entire system with inert gas and the atmosphere checked before personnel are allowed to reenter the gun bay.

30.12. Drop Testing

30.12.1. After an explosives drop test, personnel shall wait a minimum of 5 minutes before leaving the control bunker to inspect the test pad.

30.12.1.1. If smoke or flame is observed at the drop test area, entry shall not be permitted until at least 30 minutes after all visual signs have disappeared.

30.13. Post-firing Controls

30.13.1. If the firing appears to be normal, test personnel shall remain in the protective shelter for a suitable waiting period.

30.13.1.1. The test procedure shall specify the waiting period, which shall be sufficient to verify adequate dissipation of smoke and dust.

Note: In some cases, developing and analyzing the diagnostic film for misfires may be helpful.

30.13.2. During the waiting period, all power to the firing units shall be turned off or disconnected.

30.13.2.1. Whenever possible, detonator cables should be disconnected from the firing units and shunted and grounded, and the firing unit capacitor grounded.

30.13.3. After the waiting period, one qualified person (or more, when required by a documented hazard analysis) shall physically inspect the firing pad to determine the results of the shot before other personnel leave the shelter.

30.13.3.1. When a partial detonation or a test misfire occurs or is suspected, the firing area shall be inspected for unreacted explosives (see Chapter 31).

30.13.3.2. If the inspection confirms that safe conditions exist, the lead person shall signal “all clear.”

30.13.4. Recovered explosives from a destructive test shall be placed in an explosives storage magazine as Storage Compatibility Group L unless a documented analysis determines that the explosives do not present a special risk.

30.14. Contamination of Firing Areas

30.14.1. A contamination zone for each firing area shall be established and permanently documented.

30.14.2. Personnel access to explosives-contaminated areas shall be controlled.

Note: Unless determined unnecessary, through documented analysis reviewed by the Contractor Explosives Safety AHJ and approved by Contractor Facility Management.

30.14.3. Service personnel shall not work in the area without the permission of testing-area management and only when supervised by a management-approved person.

Note: Unless determined unnecessary, through documented analysis reviewed by the Contractor Explosives Safety AHJ and approved by Contractor Facility Management.

31. TEST FAILURES AND MISFIRES

31.1. Explosives Misfire

31.1.1. If no audible detonation is heard after once pulsing the firing circuit, the firing circuitry and detonators may be checked for continuity. These checks shall be accomplished from within the control bunker or from a protected location. If the firing circuits and detonators appear operative, additional attempts to fire may be made.

31.1.2. If the shot still does not fire, the following precautions shall be taken:

31.1.2.1. Disconnect and de-energize all electrical power sources connected to the shot.

31.1.2.2. Verify that all personnel in the danger zone are aware of the misfire and that they shall remain under cover until released.

31.1.2.3. Before personnel are permitted to leave the cover of the bunker, a pre-established waiting period shall be observed.

Note: A minimum 30 minute waiting period is advised.

31.1.2.4. A carefully prepared review of the situation should be initiated in consultation with another knowledgeable person.

31.1.2.5. After an agreement has been reached and before other personnel are permitted to leave the cover of the bunker, one qualified person should carefully approach and examine the setup to verify that it is safe.

31.2. Misfire of a Remotely Fired Gun

31.2.1. When a misfire occurs, several more attempts to fire the gun may be made. If subsequent attempts are also unsuccessful, the following precautions should be taken:

31.2.1.1. Disconnect all electrical circuitry to the gun so the firing system cannot be energized.

31.2.1.2. Before approaching a light-gas-driven gun, verify that it is in a safe condition by venting all pressure in the gun breech.

31.2.1.3. To reduce the risk of a gas explosion if the driving gas is flammable, the gun breech shall be purged with inert gas after venting.

31.2.1.4. A minimum waiting period of 10 minutes shall be observed before permitting personnel to approach to the gun.

31.2.1.5. When approaching the gun, if there is any indication that powder is burning, personnel shall return to a safe area and observe an additional waiting period of at least 20 minutes.

31.2.1.6. The gun shall not be approached within the known recoil distance behind the breech or from the front. Approach to and work on the gun shall be from the sides.

31.2.1.7. For separate loading guns (i.e., propellant charge is loaded separate from projectiles), the propellant igniter shall be disconnected from the firing mechanism and removed from the gun before any other gun operations.

31.2.1.8. If possible, the powder chamber of the gun shall be checked for the presence of pressure and vented to the atmosphere before opening the chamber.

31.2.2. If an unforeseen failure situation arises (e.g., the explosive projectile is stuck in the bore), an emergency procedure shall be prepared and followed to resolve the situation.

32. EXPLOSIVES STORAGE

32.1. **Storage Magazine Facilities**

32.1.1. Permanent Facilities and Portable Magazines

32.1.1.1. New permanent explosives facilities shall comply with UFC 3-340-02, *Unified Facilities Criteria*.

Note: DOE/TIC-11268 may be used as supplemental guidance.

32.1.1.2. Legacy facilities with an approved QD site plan may continue to be used as explosives facilities (see Chapter 11).

32.1.1.3. Portable magazines should be ventilated and resistant to water, fire and theft. They may be made of any material that meets these requirements.

Note: Portable facilities that comply with 27 CFR Part 555.203, 27 CFR Part 555.207, 27 CFR Part 555.208, 27 CFR Part 555.209, 27 CFR Part 555.210, or 27 CFR Part 555.211 meet these requirements.

32.1.1.4. Portable magazines shall be sited per DESR 6055.09 as above ground magazines.

32.1.2. Placards shall be posted on or near each magazine door, specifying explosive and personnel limits and general safety precautions that should be observed during work in the magazine.

32.1.3. Vegetation around storage magazines should be controlled to minimize potential damage to the magazine (Section 40.1).

32.1.4. At least two fire extinguishers, minimum rating 2A-10BC should be provided for immediate use by personnel working around a magazine.

32.1.5. Rated telephone or other emergency communication equipment should be provided in magazine storage areas.

32.1.6. All communication equipment located outdoors should be protected from the weather.

32.1.7. Temperature control.

32.1.7.1. In general, storage magazines should not be heated unless heating is necessary to prevent damage caused by sudden temperature changes or when dimensional changes of components are undesirable.

32.1.7.2. Magazines requiring heat should be heated with steam, hot water, or electrically heated hot water.

32.1.7.3. Magazines with temperature control requirements, may require both heating and air conditioning.

32.1.7.4. Electrical systems with forced air through ducts may be allowed if the systems are located exterior to any explosive hazard.

32.1.7.5. Heating coils shall be arranged so that explosives material cannot come into contact with the coils. They shall be equipped with covers designed to prevent storage of materials on top of the coils.

32.1.7.6. Maximum and minimum temperature monitors should be provided in all heated magazines.

32.2. Storage Magazine Operations

32.2.1. Explosives items shall be properly packaged and stored in either DOT-approved manufacturers’ containers/packages or in approved onsite containers (see Section 32.5).

32.2.2. Explosives may be stored on magazine shelves.

32.2.2.1. The bottom of the container should not be more than 2m off the floor, except as permitted by Section 32.2.3.

32.2.3. Explosives and explosives containers in storage shall be positioned safely and securely. If explosives containers are stacked, they shall be placed in stable arrays.

32.2.4. Load limits shall be established for shelving in magazines.

32.2.4.1. If overloading is possible, the loading conditions shall be posted.

32.2.5. Materials shall not be left suspended by booms, cranes, or hoists in any explosives storage facility.

32.2.6. Stacks of explosives should be arranged so that air freely circulates to all parts of the stack.

32.2.6.1. To prevent moisture accumulation, pallets or appropriate dunnage should be used so containers are not stacked directly on the magazine floor.

32.2.7. Aisles shall be wide enough to accommodate inspection, inventory, sampling, and materials handling operations of the stored explosives containers.

32.2.8. Crews shall not be permitted to work in a position that requires passing the work aisle or the position of a second crew to reach the exit.

32.2.9. Each crew working in a magazine shall have their own exit route that does not interfere with exit routes for other crews (see Chapter 41).

32.2.10. Magazines shall be locked at all times except when permissible operations are in progress or when opened for ventilation.

32.2.11. Personnel shall be present while the magazine is open for ventilation.

32.2.12. All exit doors shall be unlocked and open when personnel are working in the magazine.

32.2.13. Each magazine shall be inventoried at least annually to determine the total weight of explosives present.

Note: For the purpose of inventories, “annually” refers to the one-year anniversary of the last inventory or inspection plus or minus 30 days.

32.2.13.1. Materials that are not properly identified or labeled shall be dispositioned.

32.2.14. The liquid level in storage containers for wetted explosives shall be checked and replenished as necessary at least once a year.

32.2.14.1. A log of the checks shall be maintained.

32.2.15. Empty containers, tools, conveyors, lift trucks, skids, etc., should not be stored in a magazine containing explosives.

32.2.16. Combustible materials such as excess dunnage, packing material, and boxes shall not be stored in a magazine containing explosives.

32.2.17. Flammable liquids shall not be stored or used in explosives magazines unless the liquid is an explosive, is needed as an explosives-wetting agent, or is an integral part of an explosives device.

32.2.18. Explosives-handling operations shall not be performed when magazine entranceways are icy or do not provide adequate footing for any other reason.

32.2.19. Operations involving hazardous materials shall not be permitted in any magazine with the following exceptions:

32.2.19.1. Those operations incident to storage or removal from storage.

32.2.19.2. Inspection and surveillance sampling of compatibility Group D materials, and Group C materials consisting of bulk propellants and IHE, provided that each storage container sampled is in good condition (i.e., the container is not leaking, no evidence exists of explosives contamination at the closure or of seal failure, and the closure is mechanically sound and free of excessive corrosion).

32.2.19.3. Only one container of explosives shall be opened at one time in a magazine.

32.2.19.4. Adding liquid to adjust the liquid composition level in which a Group D explosive is stored (water and alcohol mixtures may be used). If only water is added to the explosive, the water should be distilled or de-ionized (bacteria present in untreated water may produce gas during storage).

32.3. **Storage Review Program**

32.3.1. Contractor Facility Management shall establish a program to review stored explosive materials. Explosives may degrade during prolonged storage, increasing the hazards of handling or use.

Note: An example storage review program is provided in Attachment A of this chapter.

32.4. **Storage Compatibility**

32.4.1. Explosives shall not be stored with materials or items that increase the risk of initiation or decomposition.

Note: Examples are mixed storage of explosives with flammable or combustible materials, acids, or corrosives.

32.4.2. Different types of explosives may be stored in the same magazine if they are compatible.

32.4.2.1. Explosives shall be assigned to a storage compatibility group (SCG) when they can be stored together without significantly increasing either the probability of an accident or, for a given quantity of explosive, the magnitude of such an accident.

32.4.3. Each type of explosive shall be assigned to an appropriate SCG (A through G, L, and S) for the purpose of storage at DOE facilities. The groups are defined in the following sections.

Note 1: These definitions and Table 32.1 are in accordance with the principles and tables in DESR 6055.09.

Note 2: Table 32.1 presents some examples of commonly used materials that are assigned to each storage compatibility group. This list does not enumerate all materials that may be included in each group.

32.4.3.1. Group A: Initiating explosives. Bulk initiating explosives that have the necessary sensitivity to friction, heat, or shock to make them suitable for use as initiating elements in an explosives train.

Note: Examples are lead azide, lead styphnate, mercury fulminate, and tetracene.

32.4.3.2. Group B: Detonators and similar initiating devices not containing two or more independent safety features. Items containing initiating explosives that are designed to initiate or continue the functioning of an explosives train.

Note: Examples are detonators (all types, excluding Exploding Bridge Wires (EBW) and slappers), blasting caps, small arms primers, and fuses.

32.4.3.3. Group C: Bulk propellants, propellant charges, and devices containing propellant with or without their own means of initiation. Items that shall deflagrate, explode, or detonate upon initiation.

Note: Examples are single-, double-, triple-base, and composite propellants, rocket motors (solid propellant), and ammunition with inert projectiles.

32.4.3.4. Group D: High explosives (HE) and devices containing explosives without their own means of initiation and without a propelling charge, or articles containing a primary explosives substance and containing two or more effective protective features.

Note: Example includes explosives and ammunition that can be expected to explode or detonate when any given item or component thereof is initiated.

32.4.3.5. Group E: Explosives devices without their own means of initiation and with propelling charge (other than one containing a flammable or hypergolic liquid).

Note: Examples are artillery ammunition and rockets.

32.4.3.6. Group F: Explosives devices with their own means of initiation and with or without propelling charge.

Note: Examples are offensive and fragmentation grenades.

32.4.3.7. Group G: Pyrotechnic materials and devices containing pyrotechnic materials.

Note: Examples are devices that, when functioning, result in an incendiary, illumination, lachrymatory, smoke, or sound effect.

32.4.3.8. Group H: Ammunition containing both explosives and White Phosphorus or other pyrophoric material. Ammunition in this group contains fillers, which are spontaneously flammable when exposed to the atmosphere.

Note: Examples are White Phosphorus, Plasticized White Phosphorus (PWP), or other ammunition containing pyrophoric material.

32.4.3.9. Group J: Ammunition containing both explosives and flammable liquids or gels. Ammunition in this group contains flammable liquids or gels other than those that are spontaneously flammable when exposed to water or the atmosphere.

Note: Examples are liquid or gel filled incendiary ammunition, fuel-air explosive (FAE) devices, flammable liquid fueled missiles, and torpedoes.

32.4.3.10. Group K: Ammunition containing both explosives and toxic chemical agents. Ammunition in this group contains chemicals specifically designed for incapacitating effects more severe than lachrymation.

Note: Examples are artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent.

32.4.3.11. Group L: Explosives or ammunition not included in other compatibility groups that present a special risk, requiring isolation of each type. This group shall include explosives or ammunition having characteristics that do not permit storage with other similar or dissimilar materials.

Note 1: Examples are damaged explosives; suspect explosives; and explosives, explosive devices, or containers that have undergone severe testing unless documented determination is made that these items do not present a special risk; fuel/air explosive devices, and water-activated devices.

Note 2: Also included are experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and salvaged explosives until they have been established to be compatible with the original materials. Types presenting similar hazards may be stored together.

32.4.3.12. Group N: HD 1.6 ammunition containing only extremely insensitive detonating substances (EIDS).

Note: Examples are IHE missiles and bombs.

32.4.3.13. Group S: Explosives, explosive devices, or ammunition presenting no significant hazard. Explosives or ammunition so designed or packed that when in storage any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder firefighting.

Note: Examples include explosive switches or valves and small arms ammunition.

32.4.4. Mixing of storage compatibility groups may be permitted as indicated in Table 32.2.

32.4.4.1. When using the “Z” mixing authorized by Table 32.2, items shall be stored in approved containers and the net quantity of explosives for that location shall not exceed 1,000 lbs.

32.4.4.2. SCG B and SCG F articles shall be segregated in storage from those of other compatibility groups by means that shall prevent propagation of those articles.

32.4.5. Newly synthesized compounds and mixtures shall be stored in Group L storage facilities. After a complete evaluation, the EDC shall assign those compounds or mixtures of continuing interest (see Section 19.1) to the appropriate compatibility group, and stored according to the following considerations:

32.4.5.1. The material’s sensitivity to initiating stimuli (e.g., friction, impact, spark, shock, and thermal) is similar to that of other explosives in the group.

32.4.5.2. The material’s reactions and the effects of these reactions, in the event of application of initiating stimuli, are similar to other members of the group.

32.4.5.3. The material is chemically compatible with other materials in the group. Sensitivity and compatibility testing is described in Sections 19.3 and 19.4.

32.4.6. The material shall be stored in separate cubicles in one of the following categories:

- High explosives
- Propellants
- Detonators, actuators, and similar devices
- Primary and static-sensitive explosives

Note: As an alternate to Table 32.1 and Table 32.2, samples of explosives up to 4.4 lbs. total may be stored in the same cubicle if the cubicle walls are designed to prevent propagation.

32.5. Onsite Containers

32.5.1. Explosives containers used for handling, transportation (including transportation to disposal sites), and storage shall be designed and constructed to prevent:

- Leakage or spills
- Excessive movement of contents
- Effects of external stimuli
- Contamination

32.5.2. When screw-type closures are used, the ingress of explosive substances into the threading shall be prevented.

32.5.3. Explosives containers should be constructed of, or lined with, nonabsorbent materials that are compatible with the explosive contents.

32.5.4. Use of glass containers is discouraged, except for small samples, and shall be used only when the explosive reacts with other materials or when a high degree of purity is required.

32.5.5. Metal containers for materials that are potential dust producers shall be constructed without seams or rivet heads. Seams or rivet heads can provide locations for dust accumulation.

32.5.6. Containers for cast or pressed explosives pieces that are larger than 1 ft at their greatest dimension or weigh more than 11 lbs. loaded should be provided with handles or some other type of handhold.

32.5.6.1. If the loaded container weighs more than 110lbs., provisions should be made to allow handling by mechanical handling equipment.

32.5.7. Containers shall be labeled with the applicable UN hazard classification code and clearly marked to identify the contents.

32.5.8. Whenever possible, explosive pellets and items containing small quantities of explosives (e.g., detonators) shall be packaged in containers constructed so the functioning of one item does not propagate to the remaining items in the container.

Note: When a non-propagating array is not possible, the pellets or detonators shall be stored inside a closed container and shall be labeled to indicate the total weight of the explosive contents.

32.5.9. Container closures shall be the type that shall not apply excessive pinching or rubbing forces to explosives during closing and opening.

32.5.10. The closures and surfaces of container openings shall be kept clean of explosives contamination to minimize any hazard during closing and opening.

32.5.11. Explosives and ammunition in damaged containers shall not be stored in a magazine with other explosives and ammunition.

Note: Damaged containers shall be repaired, or the contents transferred to new or undamaged containers, or the container plus contents moved to a Group L storage magazine.

32.5.12. Open containers and containers with covers not securely fastened shall not be stored in magazines.

Note: Containers that have been opened shall be properly closed before being returned to storage.

32.6. Storage in Buildings Other Than Storage Magazines

32.6.1. Packing and Shipping Buildings (Designed for Packing & Shipping)

32.6.1.1. Incoming shipments shall be distributed as soon as practical after receipt and shall not be allowed to accumulate.

32.6.1.2. Items for outgoing shipments should not be accumulated before receipt of orders covering each specific shipment.

32.6.1.3. Separate rooms shall be provided for the temporary storage of explosives awaiting shipment and for their preparation for shipment (i.e., assembling, crating, marking).

Note: The rooms shall be divided by walls or separated to prevent an explosion in the preparation area from propagating to the temporary storage area.

32.6.1.4. The combined total amount of explosives permitted in shipping/receiving buildings, platforms, and transportation vehicles shall be based on QD constraints.

Note: When an adequate barricade (sufficient to prevent sympathetic detonation) is in place between transportation vehicles and the adjoining building or platform, quantities on each side of the barricade may be considered individually to determine QD requirements.

32.6.1.5. If required by operational necessity, explosives and pyrotechnics that are part of the work in process within the building may be stored during non-operational hours in operating buildings provided:

- Explosives limits are not exceeded.
- Containers of bulk explosives or pyrotechnics are properly secured and covered.
- Processing equipment, such as hoppers and pipelines, is empty.

32.6.2. Service Magazines

Note: The requirements for storage magazines presented in Sections 32.1 through 32.5 of this chapter shall also apply to service magazines, except as modified below.

32.6.2.1. An explosives item should be stored for no longer than necessary in a service magazine (with a maximum of 180 days).

32.6.2.2. Service magazine inventory should be reviewed every three months.

Note: Any material that has been in the service magazine for a period approaching 180 days and is not expected to be used immediately should be disposed of or removed to an appropriate storage magazine.

32.6.2.3. When practical, store explosives in service magazines in approved containers.

32.6.2.4. A documented hazard analysis shall be performed for activities involving unpackaged explosives or explosives-containing devices, unsealed explosives containers, as well as their associated packaging and unpackaging.

32.6.2.5. Unpackaged explosives or explosives-containing devices and unsealed explosives containers shall be stored in a manner that renders them stable and unlikely to be dropped or spilled.

32.6.2.6. Packaging material shall not be stored in a service magazine.

32.6.2.7. Minimum/maximum temperature monitors are not normally required for service magazines.

32.6.3. Warehouses

32.6.3.1. HD 1.4 materials (see Paragraph 11.2.2) packaged as HD SCG 1.4S, may be stored in warehouses if they are placed in segregated and specifically designated areas.

32.6.3.2. Articles in HD SCG 1.4S are considered inert for storage purposes and are not subject to QD requirements as long as they are stored with inert items or other HD SCG 1.4S items only.

Note 1: This applies only if HD SCG 1.4S articles remain in their original packaging container or are proven to be self-contained.

Note 2: When stored with items in a storage compatibility group other than S, normal QD requirements shall be observed.

32.6.4. Service Bays

32.6.4.1. Service bays should not be used for long term storage/staging of explosives or explosives components.

32.6.4.2. If intermediate storage/staging of explosives is within an operating building containing Class II or Class I operations, the intermediate storage/staging bay shall require Class II Level-of-Protection.

32.6.4.3. Explosives items shall be properly packaged and stored/staged in either DOT-approved containers/packages or in specified onsite containers (see Section 32.5).

32.6.4.4. The storage of containers shall comply with the requirements of Paragraph 32.2.6.

32.6.4.5. An explosives item shall be stored/staged for no longer than necessary in a service bay (with a maximum of 180 days).

32.6.4.6. Any material that has been in the service bay for a period approaching 180 days and is not expected to be used immediately shall be disposed of or removed to a storage magazine.

32.6.4.7. Contractor Facility Management shall provide a method to verify the explosives limit and the 180-day limit are not exceeded.

32.6.4.8. Explosives containers shall be positioned safely and securely.

32.6.4.9. Aisles shall be wide enough to accommodate operations. Unobstructed aisles shall be maintained to permit rapid exit of personnel and to facilitate safe and efficient operations.

32.6.4.10. Along with operations incident to storage or removal from storage, the following are allowed in service bays:

- Material handling,
- Visual inspection,
- Surveillance, and
- Inventory operations.

32.6.4.11. Empty containers, tools, pallet jacks, pallets, etc., should not be stored in a service bay containing explosives.

32.6.4.12. Combustible materials such as excess dunnage, packing material, and boxes shall not be stored in a service bay containing explosives.

32.6.4.13. Flammable liquids shall not be stored or used in a service bay containing explosives.

Table 32.1 Storage Compatibility Groups for Explosives and Explosive-Containing Devices

Group A Initiating explosives.

- CP (5-Cyanotetrazolpentaamine Cobalt III Perchlorate)
- HMX (Cyclotetramethylene tetranitramine) (dry)
- Lead azide
- Lead styphnate
- Mercury fulminate
- PETN (Pentaerythritol tetranitrate) (dry)
- RDX (Cyclotrimethylene trinitamine) (dry)
- TATNB (Triaziodotrinitrobenzene)
- Tetracene

Group B Detonators and similar initiating devices.

- MDF (mild detonating fuse) detonator assemblies
- Detonators excluding EBWs and slappers
- Explosive bolts
- Fragmenting actuators

Igniters

- Blasting caps
- Pressure cartridges
- Small arms primers
- Squibs

Group C Bulk propellant, propellant charges, and devices containing propellants with or without their own means of initiation. This Group also includes some IHEs.

- Smokeless powder
- Pistol and rifle powder
- Rocket-motor solid propellants
- TATB (Triamino trinitrobenzene)
- LX-17
- PBX-9502

Group D High explosives (HE) and devices containing explosives without their own means of initiation and without a propelling charge or articles containing a primary explosive substance and containing two or more effective protective features.

- Ammonium picrate
- Baratol
- Black Powder
- Boracitol
- Compositions A, B, and C (all types)
- Cyclotols (not to exceed a maximum of 85% RDX)
- DATB (diaminotrinitrobenzene)
- Detasheet
- Detonating cord (primacord or mild detonating fuse)
- Bis-Dinitropropyl adipate
- Bis-Dinitropropyl glutarate
- Bis-Dinitropropyl maleate
- Dinitropropane
- Dinitropropanol
- Dinitropropyl acrylate monomer (DNPA)
- Dinitropropyl acrylate polymer (PDNPA)
- EBW and slapper detonators
- Elastomeric plastic bonded explosives
- Explosive D
- HMX (Cyclotetramethylene tetranitramine) (wet)
- HMX/wax (formulated w/ at least 1% wax)
- HNS (Hexanitrostilbene)
- Linear-shaped charge
- Methyl dinitorpentanoate
- Nitroguanidine
- Octol
- Pentolite
- PETN (Pentaerythritol tetranitrate) (wet)
- PETN/extrudable binder
- Plastic Bonded Explosives, PBX (a Group
- D explosive formulated w/ a desensitizing
- plastic binder)
- Potassium picrate
- RDX (Cyclotrimethylene trinitramine) (wet)
- TATB/DATB mixtures
- Tetryl
- TNT (Trinitrotoluene)

Group E Explosives devices without their own means of initiation and with propelling charge.

- Fixed Artillery ammunition
- Rockets (e.g., 66mm LAW)

Group F Explosives devices with their own means of initiation and with or without propelling charge.

- Hand Grenade, fragmentation

Table 32.1 Storage Compatibility Groups for Explosives and Explosive-Containing Devices (cont.)

Group G	**Pyrotechnic material and devices that produce an incendiary, illumination, lachrymatory, smoke, or sound effect.** • Smoke pots • Flares • Incendiary ammunition
Group K	**Ammunition containing both explosives and toxic chemical agents.** • Artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent.
Group L	**Explosives or ammunition not included in other compatibility groups that present a special risk requiring isolation of each type.** • Damaged or suspect explosives, explosive devices or containers. • Experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and some salvaged explosives.
Group N	**HD 1.6 articles containing only extremely insensitive detonating substances (EIDS).** • IHE missiles and bombs
Group S	**Explosives and Ammunition that presents no significant hazard. Items are packaged or designed so that any hazardous effects from accidental functioning are limited to the extent that they do not significantly hinder firefighting. Examples include the following:** • Cable cutters • Cartridge actuated valves • Linear actuators (e.g., dimple, piston, bellows motors) • Safety fuze • Small arms ammunition
	Materials and Systems that need not be stored or labeled as explosives unless they are near other explosives that could initiate them. When near explosives, these materials become Group D, unless otherwise indicated. • FEFO/SOL (35% weight or less FEFO in ethyl acetate) • FEFO/solution • Group D explosives in inert solvents (explosive concentration not exceeding 25% weight) • Nitrates; treat as Group C when with other explosives • Perchlorates; treat as Group C when with other explosives • Materials received as ORM-D (Other Regulated Material-D) are to be relabeled and stored as Classification Code 1.4C in accordance with the requirements of TB 700-2. Authorized on-site classifiers may assign an alternate classification and SCG as appropriate for on-site storage and use.

Table 32.2. Storage Compatibility Mixing Chart

Groups	A	B	C	D	E	F	G	H	J	K	L	N	S
A	X	Z											
B	Z	X	Z	Z	Z	Z	Z					X	X
C		Z	X	X	X	Z	Z					X	X
D		Z	X	X	X	Z	Z					X	X
E		Z	X	X	X	Z	Z					X	X
F		Z	Z	Z	Z	X	Z					Z	X
G		Z	Z	Z	Z	Z	X					Z	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	Z	Z					X	X
S		X	X	X	X	X	X	X	X			X	X

Notes:

1. An “x” in a block of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to the following sections.
2. A “z” in a block of the above chart indicates that when warranted by operational considerations or magazine availability, and when safety is not sacrificed, these groups may be combined in storage. Combinations that violate the principles of Paragraph 33.4.4 require justification by an exemption.
3. No mark in a block indicates that combined storage is not permitted. L compatibility group types presenting similar hazards may be stored together but not mixed with other groups.
4. K compatibility group requires not only separate storage from other groups, but also may require separate storage within the group.

Attachment A – Example Storage Review Program

1. A storage review date is assigned to each bulk explosive placed in storage. The storage review date is shown on or adjacent to the identification tag or sticker attached to every container or package of explosive in storage or listed in the inventory records.

2. Storage review intervals are based, whenever possible, on stability data. A safe storage interval is considered as that time period, at maximum anticipated storage temperature, during which an explosive material can be conservatively expected to show an acceptable level of decomposition.

3. Contractor Facility Management designates or creates an Explosives Storage Review Committee (SRC) to establish and approve storage review intervals for all explosives stored at the DOE facility. Also, the SRC prescribes for each explosive appropriate tests to evaluate the safety of handling and processing the material after it has exceeded its storage review interval. These tests are referred to as “stability tests,” although sensitivity, or other types of testing, could be included in the material evaluation program. In some cases, the SRC simply requires periodic stability testing rather than establishing a storage review interval (e.g., nitrocellulose, single- and double-base propellants).

4. To store a new explosive, to increase (or decrease) the review interval for a previously approved material, or to use different stability test data for an explosive, the following procedure could be used:

   - A responsible person should communicate the request to the SRC.
   - If the request concerns storage of a new explosive, the individual recommends a storage review interval and stability-evaluation testing.
   - Supporting data is supplied with the recommended review interval and proposed stability tests for the explosive.
   - The SRC reviews the request and supporting data and then prescribes a storage review interval and stability tests as appropriate.
   - A new explosive is assigned an interim storage review and stability test interval before Phase II scale-up (see Chapter 19).
   - The following general guidelines are offered to assist the SRC in establishing review intervals when there is insufficient stability information to predict storage life.
     - If no information is available on a new material relative to storage stability, a review interval of 90 days or less is assigned.
     - A new formulation is assigned a storage review interval not exceeding that of its least stable component.
     - If the compound or formulation is new to DOE but DoD agencies have extensive experience with it, the DoD information is used conservatively.
     - For a formulation or ingredient with a manufacturer-assigned shelf life, a review interval that exceeds the recommended shelf life is not assigned unless additional stability tests indicate such storage is warranted.

5. A storage review interval of up to 20 yrs is permissible for an explosive if a conservative evaluation of stability data indicates that such an interval is justified.

33. TRANSPORTATION

33.1. Explosives Transportation

Note 1: Onsite movements of explosives shall be in accordance with this Technical Standard, local onsite packaging, and the site's motor vehicle safety program.

Note 2: Explosives containing items transported by Federal Agents within the Office of Secure Transportation are governed by DOE Order 452.2 and DOE Order 460.1.

Note 3: Section 161.K of The Atomic Energy Act of 1954 as amended and Title 18 United States Code (USC), Chapter 40, section 845 govern security and emergency vehicles carrying explosives in support of approved contingency plans.

33.1.1. Qualified explosives handlers shall load and unload explosives (see Chapter 10).

33.1.2. When transferring explosives within facilities, open body vehicles (other than flatbed types) shall have sides and tailgates or rear doors that are strong and securely fastened to safely retain the explosives.

33.1.3. The cargo on partly or completely loaded vehicles (including flatbed types) shall be blocked, braced, chocked, tied down, or otherwise secured to prevent shifting during transit.

33.1.4. Precautions shall be taken to prevent the exhausts of motor vehicles from igniting explosive material.

33.1.4.1. When a motor vehicle approaches within 25 ft of the doors of a structure through which a shipment is to be moved, the doors shall be kept closed until the motor has been turned off, unless the vehicle is equipped with an exhaust spark arrestor or there are no explosives exposed.

Note: Explosives packaged in DOT or onsite containers are not considered exposed.

33.1.5. No explosives shall be loaded or unloaded from a motor vehicle while the motor is running unless the motor is required to provide power to vehicle accessories used in loading and unloading operations and is equipped with an exhaust spark arrestor.

33.1.6. During loading and unloading, explosives laden vehicles shall have their emergency brakes set and wheels chocked to prevent inadvertent vehicle movement.

33.2. Onsite Shipments

33.2.1. Hazard Division Placards are required for all shipments of HD 1.1, 1.2, and 1.3 explosives (excluding de minimis quantities) and shall be plainly visible from all directions.

33.2.2. Hazard Division Placards are required for HD 1.4, 1.5, and 1.6 explosives when the gross weight exceeds 1000 lbs.

33.2.3. Motor vehicles used to transport explosives onsite should be equipped with the following:

33.2.3.1. Adequate tie-down bolts, rings, and straps to secure the explosives load.

33.2.3.2. The cargo area where the explosives are loaded shall be void of any sharp projections.

Note: Non-sparking lining is desirable when hauling explosives in transfer containers that are not DOT approved.

33.2.3.3. A quick-disconnect switch on the battery, if explosives are left loaded on the vehicle overnight.

33.2.3.4. Two fully charged and serviceable fire extinguishers with a minimum rating of 2A-10BC, with one extinguisher mounted on the outside of the vehicle.

Note: Only one extinguisher is required for the transport of HD 1.4 explosives.

33.2.3.5. Rear view mirrors on both sides of the vehicle.

33.2.3.6. One pair of chock blocks.

33.2.4. Normal shipments of explosive materials on site shall be packaged in DOT approved containers/packages or in approved onsite containers (see Section 32.5).

33.2.5. Onsite shipments of explosive-designed systems related to experiments or tests that, by their nature, are not conducive to the requirements of Paragraph 33.2.4 shall be governed by Section 29.1. and the following:

33.2.5.1. For shipping purposes, placards and labels shall reflect the appropriate Hazard Division as assigned by the designated onsite classification authority.

33.2.5.2. The appropriate authority shall review and approve the designed method of transport for the system.

33.2.5.3. Drivers shall be knowledgeable of the unique aspects of the system being transported or shall be accompanied by an explosives handler qualified by training and experience to handle the system.

33.2.6. After the EDC has determined that new or developmental explosives meet the necessary testing to establish that they are not forbidden explosives and are at the proper phase of development for the quantity of material being requested, onsite transport shall conform to Paragraph 33.2.4. or 33.2.5.

33.3. Materials Handling Equipment

33.3.1. Industrial trucks shall not be used in locations where high concentrations of dusts or sublimation of explosives occur (e.g., screening buildings, pouring bays, melt-pour units, drilling bays, consolidating bays, explosive washout facilities).

33.3.2. Gasoline-powered or diesel-powered materials-handling equipment (e.g., forklifts) should be used only in areas where all explosives are properly packaged and only if equipped in the following manner.

33.3.2.1. Backfire deflectors shall be the oil-bath or screen type (certain types of air cleaners shall serve the purpose) and shall be attached securely on the throat of the carburetor.

33.3.2.2. A tight-fitting, properly vented cap, shall be in place on the gasoline fill pipe at all times (except during refueling).

33.3.2.3. A flame arrestor shall be installed in the fill pipe.

33.3.2.4. If necessary, a deflector plate shall be installed to prevent any gasoline tank overflow from reaching the motor or the exhaust pipe.

33.3.2.5. On gravity feed systems or on pump systems where siphoning might occur, a shutoff valve shall be installed at the fuel tank or in the feed line to permit shutting off the flow of gasoline in an emergency or a break in the fuel line or carburetor.

33.3.2.6. Provisions shall be made to prevent fuel lines from rupturing due to vibration.

33.3.3. Battery-powered handling equipment shall only be used in hazardous areas for which it is specifically rated (e.g., types E, EE, ES, EX rated).

33.4. General Operation Requirements

33.4.1. The operator of an explosives-transport vehicle shall have training in the general safety precautions for explosives handling.

33.4.2. Congested areas should be avoided when determining explosives routes.

33.4.3. No personnel shall ride in the cargo area. Loose items (e.g., handling gear) in the cargo compartments are prohibited.

33.4.4. No smoking is allowed in or within 25 ft of any vehicle containing explosives.

33.4.5. Matches, lighters, or other fire-, flame-, or spark-producing devices shall not be in the vehicle or carried by personnel in the vehicle containing explosives.

33.4.6. Other than when opened for inspection at an authorized location, containers of explosives shall not be opened or repaired on any transportation vehicle.

33.4.7. Refueling or maintenance shall not be performed on vehicles containing explosives.

33.4.8. Each site’s traffic rules shall address the operation of explosives-transport vehicles and the operation of other vehicles in the vicinity of explosives-transport vehicles.

33.5. Hazardous Conditions

33.5.1. Explosives should not be transported in hazardous conditions (e.g., storms, icy roads, or poor visibility), unless an emergency plan is in effect to provide instruction and guidelines while an explosives-transport vehicle is in transit. The plan should address the following issues:

- Parking the vehicle.

- Safeguarding the vehicle from other traffic.
- Notifying appropriate authorities of the emergency situation.
- Leaving the vehicle unattended.

33.5.2. A plan shall be prepared to address mechanical breakdowns. The plan shall address the following issues:

- Removing the vehicle from the road as far as practical.
- Posting emergency reflectors, signals, etc. (carrying flares on the vehicle is not permitted).
- Reporting the problem.
- Maintaining surveillance of the vehicle.
- If necessary, removing the vehicle load to facilitate repair of the vehicle.

33.5.3. If an explosives-carrying vehicle is involved in an accident, the following steps should be taken:

33.5.3.1. Inspect the load for evidence of fire.

Note 1: If there is a fire, but the explosives material is not presently or imminently involved, attempt to prevent the fire from spreading to the load.

- The fire may be fought using the vehicle’s fire extinguishers.
- Verify the security of explosives items removed from the vehicle.

Note 2: If a fire presently or imminently involves the explosives load.

- Evacuate all personnel to a pre-established safe distance.
- Block or divert traffic from the vicinity of the accident.

Note 3: Unless the explosive cargo is imminently involved in fire, the operator is to stay with the vehicle until the cargo is properly dispositioned.

Note 4: Notify the fire department or fire brigade of the accident immediately and inform them of the general type and approximate quantity of explosives involved.

33.5.3.2. Inform the proper authorities of the accident.

34. MATERIALS RECEIPT

34.1. Motor Vehicles

34.1.1. A qualified person using an approved checklist at a designated inspection station shall carefully inspect all incoming motor vehicles loaded with explosives in HD 1.1, 1.2, and 1.3.

Note: Inspections requiring opening or moving explosives shipping containers or removing bracing or blocking shall be done at a location sited for explosives operations as specified in DESR 6055.09.

34.1.1.1. When an inspection reveals that an incoming tractor is in unsatisfactory condition, the tractor should be disconnected from the trailer at the inspection station and moved to a position where it does not endanger any other explosives.

34.1.1.2. When an inspection reveals that a trailer or its load is in an unsatisfactory condition, the trailer shall be moved to a location that is at least inhabited-building distance for the particular material involved from administration areas, hazardous locations, and the facility boundary.

Note 1: At this location, the unsatisfactory condition shall be corrected before the vehicle is moved to its destination within the facility.

Note 2: When moving from the inspection station to the isolated location, the route should be as far as possible from built-up areas and areas with high personnel concentrations.

34.1.1.3. Vehicles that cannot be immediately dispatched to points where they are to be unloaded should be moved to a location sited in accordance with Paragraph 11.2.4.

34.1.2. Vehicles shall not be backed up to a dock on which explosives are resting and could be damaged.

34.1.3. The receiving facility’s doors should be closed while the motor vehicle is in motion or the engine is running.

Note: This requirement does not apply to vehicles equipped with spark arrestors or when no exposed explosives are present.

34.1.4. Once the vehicle is in position, the engine shall be shut off, the brakes set, and the wheels chocked.

34.1.5. After unloading, the vehicle shall be inspected for loose explosives materials.

Note 1: Any spilled material shall be cleaned up after the inspection.

Note 2: Spills involving liquid explosives or explosives in solution shall be reported immediately to the building supervisor.

Note 3: Approved cleanup procedures shall be used.

34.2. Damaged Shipments

34.2.1. Explosives shipments shall be inspected for damage before storage.

34.2.2. Contents of a damaged or broken container shall be removed to another container. Spilled materials shall be cleaned up before continuing with loading or unloading.

34.2.3. Any shipment received in damaged condition as a result of inadequate or improper blocking and bracing or as a result of not being loaded in accordance with DOT requirements shall not be reshipped until the damage is corrected.

35. MATERIALS HANDLING

35.1. Material Handling

35.1.1. The distance that explosive materials can fall, if accidentally dropped during handling, shall be maintained at a minimum.

35.1.2. Hard surfaces and edges that could be accidentally struck by dropped consolidated explosives should be padded with cushioning mats or coverings when practical and needed.

Note: Protective padding includes sheet material on work surfaces, equipment, and approved floor coverings.

35.1.3. Explosives handling shall be permitted only in areas free of obstructions and where the walkway surfaces provide positive footing with no slipping or tripping hazards (i.e., snowy or icy walkways).

35.1.4. Explosives and incompatible materials shall not be handled together.

35.1.5. Detonators, actuators, EEDs, and other items normally shipped as HD 1.4 explosives should be kept in non-propagating trays or containers unless handled individually.

35.1.6. Dry explosive materials that generate dust shall be transported in closed containers.

35.1.7. Containers of explosives or explosive assemblies shall be labeled to identify contents during handling, storage, and transportation.

35.1.8. Explosives items that cannot be identified and labeled shall be stored as HD SCG 1.1L.

35.1.8.1. A material analysis shall be performed to identify the material before it is returned to inventory or disposed of in accordance with regulatory requirements.

35.1.9. Components or devices that contain explosives should not be labeled or marked “inert” or “dummy.”

35.1.10. Nonconforming items shall be labeled/tagged indicating that they contain explosives.

Note: The marking requirements of this paragraph are not applicable to items subject to the current DOE O 452 series of directives.

35.2. Manual Handling of Bare Consolidated Explosives

35.2.1. Operations shall be arranged to minimize the handling distance in all manual explosives handling situations.

35.2.1.1. Explosive items that cannot be securely gripped should not be manually handled.

35.2.2. Explosives should not be carried up or down stairs except when in protective containers.

35.3. Carts or Hand Trucks

35.3.1. Explosives that cannot be handled manually shall be moved only on suitable carts or hand trucks.

35.3.2. Carts used to handle bare explosives shall be provided with a padded surface to support the explosives.

35.3.3. The carts shall be equipped with either a lip, sides of sufficient height, or tie-down straps to prevent the explosives from sliding or rolling off the cart.

35.3.4. The cart-explosive load combination shall have a center of gravity low enough to prevent tipping if the cart suddenly stops.

35.3.5. Explosives handling carts or hand trucks should be equipped with brakes.

35.3.6. Carts containing explosives shall be positively secured (e.g., setting wheel brakes or chocking) when the cart is stationary.

35.4. Vacuum Handling

35.4.1. Any mechanical handling where a loss of vacuum would allow the explosive to drop an excessive distance shall incorporate a safety device (e.g., collar, net, or strap) to prevent dropping.

Note 1: “Excessive distance” shall be defined as a distance greater than the minimum drop height giving drop-skid “initiation” for the explosive being handled. “Initiation” in the drop-skid test refers to any indication of sample decomposition.

Note 2: An alternative method of protection can be a resilient surface under the explosives and over all items that may be struck by falling explosives.

36. ELECTRICAL

36.1. Electrical Equipment and Wiring

Note 1: The use of rated wiring, fixtures, equipment, and instrumentation provides additional safety for work with explosives materials by

- Restricting electrical ignition sources such as sparks and electrical faults (shorts, power surges),
- Controlling surface temperatures of electrical items, and
- Reducing the potential for electrically initiated fires.

Note 2: Although NFPA 70 does not specifically address explosives, NFPA 70 Article 500, Hazardous (Classified) Locations, requirements for the design and installation of electrical equipment and wiring in electrical hazard classified locations is recommended as guidance for the installation of rated equipment and fixtures where required by this chapter.

Note 3: Explosives do not normally fit the NFPA 70 definitions for groupings, classes, divisions, and area classifications. In order to apply NFPA 70 Article 500 as a guide, vapors containing explosives shall be treated as Group D (unless NFPA 70 requires a higher classification because of other components of the vapor) and dusts of explosives or solid explosives shall be treated as Group G. Maximum temperature limits shall be based on the thermal analysis of the explosives used in the operation. Division 1 items can be substituted for Division 2 items, but never Division 2 for Division 1 items.

Note 4: Electrical requirements for outdoor test areas shall be determined by hazard analysis.

36.1.1. Areas where explosives operations and activities are conducted shall be evaluated and classified.

36.1.2. Electrical equipment and wiring shall be properly classified, designed and installed to minimize the possibility of ignition.

36.1.3. Rated wiring (permanent and temporary), fixtures, equipment, and instrumentation shall be used for explosives operations and activities appropriate to the electrical hazard classification.

36.1.4. Rated wiring, equipment and instruments shall be approved for use by a Nationally Recognized Testing Laboratory.

36.1.5. Rated items shall have labels and/or clearly identifiable markings to show Class, Division, Group, and Temperature Range for which they are approved.

36.1.6. Equipment approved for one Hazard Class is not interchangeable with another Hazard Class.

36.1.7. Where rated items are required but not available, substitute items may be approved as per Paragraphs 36.4.3. and 36.4.4.

36.2. Electrical Hazard Classification for Explosives Operations or Activities

36.2.1. Contractor Facility Management shall assign an electrical hazard classification for all designated areas, (e.g. rooms, bays, chambers) where explosives operations or activities are conducted.

36.2.2. Area classification shall be in accordance with the recommendations of Table 36.1 or through documented analysis as described in Section 8.4.

Table 36.1 Recommended Explosives Area Electrical Hazard Classifications

Normal Operating Condition	Area Classification
1. Activities involve flammable gases or chemicals/materials expected to produce flammable vapors with explosives present.	Class I, Division 1
2. Activities are expected to produce explosives dust, or ignitable dust mixtures with explosives present, that is suspended in the air. *Examples are; screening, grinding, blending, pressing, dry machining explosives, and weighing of explosives powders.*	Class II, Division 1
3. Activities involve vapors and dust as described in numbers 1 and 2 of this table. *Examples are; synthesis, formulation, mixing, wet blending, and casting explosives, heating/drying of uncased explosives, plus any explosives processing that is expected to produce sublimation.*	Class I, Division 1 and Class II, Division 1 (dual rated)
4. Activities are expected to produce explosives dust that can accumulate on electrical equipment or apparatus. *Examples are; inspection of explosives powders and wet machining of explosives.*	Class II, Division 2 (Class II, Division 1 or dual rated equipment and wiring can be substituted)
5. Activities are not expected to produce flammable vapors or explosives dust. *Examples are; operations with fully encased explosives, explosives packaged in approved containers, and areas in explosives facilities where no explosives are present such as offices, control rooms, halls, rest rooms, and mechanical equipment rooms.*	General Purpose (See Note 1 and 2)

Note 1: General Purpose Areas may be established in explosives locations if Contractor Facility Management can determine, based on a documented analysis of the processes involved and the separation between explosives operations requiring Class I or Class II rated electrical wiring, fixtures, process equipment, and instrumentation and the General Purpose Area is established and maintained such that:

- Migration of explosive or ignitable gasses, vapors or dust mixtures into the General Purpose Area from the rated area does not occur under normal operating conditions.
- Ignition energy (arcing, sparking from General Purpose wiring, equipment, fixtures, and instrumentation) that may be developed in the General Purpose Area is not transferred to the rated area.

Note 2: Where specifically permitted in NFPA 70 Articles 501 through 503, General Purpose equipment or equipment in General Purpose enclosures shall be permitted to be installed in Division 2 locations if the equipment does not constitute a source of ignition under normal operating conditions.

36.3. Electrical Supply System

36.3.1. Mutual hazards may exist where explosives facilities are located near electrical supply lines and stepping equipment. To protect against these hazards, NFPA 70 and the following requirements apply to all new construction or major modifications, and should be considered for existing facilities.

Note 1: QD requirements are based on air blast overpressure only, and fragment distances are not considered.

Note 2: Electric supply lines that can be interrupted without loss of power (i.e., power is rerouted through existing lines and/or networks) can be separated from explosives sites in accordance with Paragraph 36.3.7.

Note 3: Electrical supply lines are classified by purpose as to transmission, distribution, or service.

36.3.2. Electrical supply lines which jointly supply power (regardless of voltage) to offsite, non-facility locations shall be considered transmission lines for QD purposes.

36.3.3. Electric transmission lines and the tower or poles supporting them shall be located no closer to explosives facilities than:

- Inhabited-building distance if the line in question is part of a grid/system serving a large, offsite area.
- Public traffic route distance if loss of the line does not create serious social or economic hardships to offsite areas.

36.3.4. Electrical distribution lines and the tower or poles supporting them shall be located no closer to explosives facilities than public traffic route distance.

36.3.5. Electrical distribution lines that exclusively support a storage/operation area and the loss of the lines is acceptable, separation is in accordance with service line criteria, Paragraph 36.3.7.

36.3.6. Unmanned privately owned or contractor-owned electrical substations (not to include building transformers and associated switch gear) shall be no closer to explosives facilities than public traffic route distances.

36.3.7. Electric service lines required to be in close proximity to a combustible constructed or uncovered explosives facility shall be no closer to that facility than the length of the lines between the poles or towers supporting the lines.

Note: An alternate effective means can be provided so that broken, energized lines cannot come into contact with the facility or its appurtenances (e.g., geographic terrain features, instantaneous circuit interrupters, cable trays, linking lines together).

36.3.8. Equivalent underground electrical service lines shall be located as specified in Paragraph 11.2.5 and Table 11.2.

36.3.9. Electrical service lines shall be installed underground from a point not less than 50 ft away from such facilities.

36.3.10. Surge arrestors or capacitors shall be provided on the supply side of the main service disconnect.

36.3.11. Lightning arrestors, surge arrestors, surge capacitors, service entrance ground, and building ground shall be interconnected outside the building.

36.4. Electrical Equipment and Instrumentation

36.4.1. Non-permanent process instrumentation and process equipment should be rated for the actual environment based on the explosives operation being performed (as defined in Section 36.2).

36.4.2. Group G or Group D equipment shall not have a surface temperature exceeding the lowest onset of the exotherm of the explosive.

36.4.2.1. When the thermal rating of the equipment is inadequate, additional protection shall be provided or the equipment shall be excluded from the hazardous location.

36.4.2.2. Equipment afforded additional protection shall be administratively controlled and marked accordingly.

36.4.3. When Hazard Class I or II equipment is required but not available, alternate equipment should be:

- Purged or pressurized in accordance with NFPA 496, or
- Sealed to prevent explosives contamination for Hazard Class II locations, or
- Determined intrinsically safe (without regard to voltage) in accordance with NFPA 70 Article 504/ANSI 913.

36.4.3.1. When the equipment is purged or sealed, the surface temperature shall not exceed 248°F (120°C) for normal operations, or 329°F (165°C) for overload conditions.

36.4.3.2. When the equipment is purged, the airflow shall be monitored per NFPA 496 and interlocked to the equipment, or alarmed when operator shutdown of the machine can be reliably performed immediately upon receipt of that alarm.

36.4.4. All electrical equipment or instrumentation in hazardous locations that do not meet the above requirements shall be evaluated and documented as to their suitability for use in the specific area and operation. The following are suggested areas for evaluation:

- Malfunction of electrical equipment or process instrumentation.
- Consequences of electrical initiated fire.

- Initiation of explosives by electrical current.
- Breach of containment resulting in exposed explosives or spillage of explosives.
- Ignition sources arising from physical damage to the wiring method used (e.g., crushing by forklift or other material handling equipment, frayed cords).
- Exposed electrical conductors or connectors that could make contact with leg wires or cables of explosive devices during routine handling.
- Exposed electrical conductors or connectors on which explosives dust or vapors could collect.
- Collection of explosives dust on or in the equipment.
- Sensitivity to heat and spark, and thermal stability of explosives involved.

36.4.5. Watertight equipment (that would pass a NEMA 4 hose test) should be provided in those locations where water-explosives mixtures may come in contact with the electrical equipment and wiring.

36.5. Hand-held, Battery-Powered Lights and Instruments

36.5.1. Hand-held, battery-operated equipment shall not come in direct or indirect contact with bare explosives, unless they are evaluated and approved by Contractor Facility Management prior to use.

36.5.2. Batteries shall not be removed or replaced in hazard rated areas.

36.5.3. Flashlights and hand lanterns powered by low-voltage dry cell batteries and “miner cap lamps” approved as permissible by the U.S. Mine Safety and Health Administration (MSHA), Underwriters Laboratory (UL), or those previously approved by the U.S. Bureau of Mines, for NEC Class I hazardous locations, are authorized for use in both Class I and Class II locations.

36.5.4. Devices that provide “cold light” through chemical action are acceptable for use in any location.

36.5.5. The following electric items powered by low voltage dry cell batteries are authorized for use in the vicinity of Hazard Class II, Division 2 rated hazardous operations and during setup of Hazard Class I or Class II, Division 1 hazardous operations:

- Hand-held instruments
- Watches
- Calculators
- Personal medical devices
- Cameras

- Self-contained flashes
- Scanners
- Communication devices

36.5.5.1. Prior to use of the above items, during Hazard Class I or Class II, Division 1 hazardous operations, they shall be evaluated as to their intrinsic safety and approved by Contractor Facility Management.

36.6. Non-Rated Extension Lighting

36.6.1. When it is necessary to use extension lights within 10 ft of exposed explosives, where no airborne dust exists, the following requirements shall apply:

36.6.1.1. Lights shall be positioned outside the fall-down distance to the explosives.

36.6.1.2. Lights shall be mounted on heavy tripod stands.

36.6.1.3. The lights shall be fitted with exterior globes to prevent the falling of hot sparks or particles that might ignite the explosives.

36.6.1.4. The lights shall be fitted with adequate guards to protect the globes from physical damage.

36.6.1.5. The wire providing power to the lights shall be positioned so as to prevent vehicles and personnel damaging the cord.

36.6.1.6. The light stand shall be secured to prevent tipping.

36.6.1.7. Neither the light nor the power cord shall be allowed to come in direct or indirect contact with the explosives.

37. ELECTRICAL TEST INSTRUMENTS

Note: This chapter does not address those instruments covered by DOE O 452.2E or successor document.

37.1. Terminology Specific to this Chapter

37.1.1. Approval: An instrument design, as designated by a manufacturer model or part number, is approved for use with explosives systems after it has been evaluated according to the requirements of this chapter.

37.1.2. Certification: A specific instrument, as designated by a serial number, is certified for use with explosives systems after the model or part number has been approved and the instrument has been inspected, calibrated, and labeled according to the requirements of this chapter.

37.1.3. 1A/1W no-fire criterion: The 1 Amp/1 Watt no-fire criterion specifies that the initiator does not fire within 5 minutes when subjected to a current of 1 amp minimum per bridge with an associated power of 1 watt minimum per bridge, whichever is most conservative.

Note: In reference to “per bridge” above, the information is based on MIL-DTL-23659F, Detail Specification: Initiators, Electric, General Design Specifications For (10 June 2010), section 3.4.3.2.1.

37.1.4. Fail-safe current: The fail-safe current of an instrument is the maximum output current through zero resistance given any single failure; at least two independent failure modes must occur before this current can be exceeded.

37.2. Classification

37.2.1. Test instruments shall be classified based on electrical characteristics that affect safe use with explosives systems, as noted below.

37.2.1.1. Type 1: Are used with low-energy EEDs that comply with the 1A/1W no-fire criterion, and with high-energy initiators. Other uses shall be evaluated according to Paragraph 37.4.1.3.

37.2.1.2. Type 2: Are used with high-energy initiators. Other uses shall be evaluated according to Paragraph 37.4.1.3.

37.2.1.3. Type 3: Are used on non-initiating electrical circuits. Applications shall be evaluated according to Section 37.5.

37.2.2. Test instruments not meeting the safety criteria may be used on an explosive system only if the activity is considered a remote operation and adequate personnel shielding or separation distance is provided.

37.3. Approval and Certification

37.3.1. Each DOE facility where electrical test instruments are used on explosives systems shall establish a formal system for approving and certifying these instruments.

37.3.2. Procedures should be established for marking instruments to show approved uses and restrictions.

37.3.3. Each test instrument used on explosives systems shall be certified.

37.3.4. Each certified test instrument shall be prominently labeled with its approved use and with a warning if its use is restricted.

37.3.5. Each DOE facility using electrical instruments to test explosives systems shall maintain records of all instrument types approved for use with initiating circuits.

37.3.5.1. These records should include type, manufacturer, model, electrical specifications, wiring diagrams, and failure mode analyses.

37.3.6. Contractor Facility Management shall notify the DOE/NNSA Explosives Safety Committee Chair in writing when new electrical instruments have been approved for use with initiating systems.

37.4. Electrical Instruments for Use with Initiating Electrical Circuits

37.4.1. Instruments used with electrical initiation circuits connected to EEDs are either Type 1 or Type 2. Test instruments used for this purpose shall be current limited. Before being approved for use on initiating circuits, each instrument wiring diagram and internal circuitry design shall be analyzed and examined for the following:

37.4.1.1. For Type 1 instruments, the fail-safe current shall not exceed 10 mA.

37.4.1.2. For Type 2 instruments, the fail-safe current shall not exceed 100 mA.

37.4.1.3. Where a Type 1 or Type 2 instrument cannot be used for a particular application, the maximum fail-safe current should not exceed 3% and shall not exceed 10% of the no-fire rating of the initiator being tested.

37.4.1.4. The current-limiting features of test instruments shall be internal to the instrument and shall not depend on test circuit load characteristics.

37.4.1.5. The current-limiting components should be identified and documented for reference during certification.

37.4.1.6. Circuit measurements that verify proper functioning of the current-limiting components should be documented for reference during certification.

37.4.2. An instrument is certified for use on initiating circuits when:

37.4.2.1. Its current-limiting circuitry has been inspected, measured, and found to be consistent with the approved design; and

37.4.2.2. It has been inspected, calibrated, and labeled with the instrument Type and optionally the maximum fail-safe current.

37.4.3. Certified instruments shall be inspected and calibrated at prescribed intervals or whenever the instrument is opened for servicing or repair.

37.4.3.1. Access to internal circuitry of certified instruments shall be controlled to prevent unauthorized repairs, maintenance, or alteration.

37.5. Electrical Instruments for Use with Non-Initiating Electrical Circuits

37.5.1. Instruments used with electrical circuits connected to strain gages, pin switches, pressure transducers, thermocouples, electrical components, etc., that are affixed to or within an assembly with explosives are classified as Type 3. These instruments shall meet the following requirements:

37.5.1.1. Each specific use of the instrument shall be analyzed so no credible scenario exists whereby the normal test energy from the instrument can ignite explosives charges or initiators in the test.

Note: Operational requirements are contained in Sections 30.4 and 29.6.

37.5.1.2. Where an instrument is used to make measurements on sensors directly applied to explosives (e.g., bonded strain gages or pin switches), a safe current limit and an instrument fail-safe current shall be determined and documented.

Note: The design shall be approved in accordance with Paragraphs 37.4.1.4., 37.4.1.5., and 37.4.1.6., and the instrument shall be certified in accordance with Paragraphs 37.4.2 and 37.4.3.

37.5.1.3. Instruments used with non-initiating electrical circuits shall be marked prominently with the instrument Type and any restrictions on use.

Note: Many of these instruments do not meet the requirements for use with initiating systems and shall be marked to prevent their use on this type of circuit.

38. ELECTRO-EXPLOSIVE DEVICES

38.1. Protection from Electromagnetic Radiation

38.1.1. EEDs should be left inside their containers until ready for use.

38.1.2. Shorting clips or other safety devices should not be removed until the EED is ready for use.

38.1.3. AFMAN 91-201, NAVSEAOP 3565/NAVAIR 16-1-529, or the Pantex V Curve formula should be used for establishing minimum separation distance between EMR sources and EEDs.

Note 1: EEDs are vulnerable to initiation from a variety of sources. One potential hazard associated with EEDs is the accidental initiation by stray electromagnetic energy. This hazard exists when an electromagnetic field of sufficient intensity is generated to induce or otherwise couple currents and/or voltages of magnitudes large enough to initiate EEDs or other sensitive explosive components of weapon systems, or other explosive devices. This unintended actuation could have safety (premature firing) or reliability (dudding) consequences.

Note 2: The degree to which EEDs are susceptible to unintentional initiation by exposure to the radiated fields of RF emitters depends on many variables. These variables include the ability of the leads, circuit, or installation to capture RF energy; the type and characteristics of RF energy; and methods of coupling that can introduce this energy into the EED.

Note 3: Some EEDs are initiated by low levels of electrical energy and are susceptible to unintentional initiation by many forms of direct or induced stray electrical energy, such as from lightning discharges, static electricity, or tribo-electric (friction generated) effects, and radio frequency (RF) energy.

Note 4: Lightning protection systems and requirements normally preclude the inadvertent initiation of EEDs by direct lightning strikes.

Note 5: Stray energy, such as transients and other forms of induced energy, can be imposed on circuits affecting EEDs from other subsystems by various methods. Examples are inductive or capacitive coupling; sneak ground circuits; defective components or wiring; and errors in design, modification, or maintenance.

Note 6: Emitter operating frequencies, power levels, modulation, and illumination angles are some of the factors that affect the vulnerability of EEDs to RF energy.

39. STATIC ELECTRICITY

39.1. Bonding and Grounding of Equipment

39.1.1. All equipment requiring grounding shall be interconnected if a structure is equipped with a lightning protection system.

39.1.1.1. Wires used as static ground conductors should be at least No. 10 AWG.

39.1.1.2. Static grounds shall not be made to gas, steam, or air lines; dry pipe sprinkler systems; or air terminals of lightning protection systems.

Note 1: Bonding straps may be used to bridge locations where electrical continuity can be broken by the presence of oil on bearings, paint, or rust at any contact point.

Note 2: Pressure contact alone is not adequate grounding for permanent equipment in contact with conductive floors or tabletops.

Note 3: Static grounds can be made to water pipes, ground cones, buried copper plates, or driven ground rods of lightning protection systems.

39.2. Testing Bonded Equipment Grounds

39.2.1. Grounding systems shall be tested for electrical resistance and continuity after installation has been completed and, in the case of active equipment, intervals are determined by Contractor Facility Management.

39.2.1.1. If the equipment has been inactive for more than one month, the ground system shall be visually inspected for continuity before reactivation of the system. All exposed explosives or hazardous materials shall be removed before testing.

39.2.1.2. When testing for resistance-to-ground, equipment should be considered as a unit except in the case of an electrically isolated device or a belt-driven machine.

Note: In measuring the total resistance-to-ground for belt-driven machinery resistance of the belting is to be excluded.

39.2.2. In hazardous locations (operations where a static spark discharge may be dangerous), all conductive parts of equipment shall be bonded.

39.2.2.1. In the case of grounded equipment, bonding shall be such that resistance to ground does not exceed 25 ohms, unless resistance is not to exceed 10 ohms because of a lightning protection installation.

39.2.3. For existing equipment, the rate of static generation should be considered before making changes in grounding systems.

39.3. Conductive Floors, Shoes, Mats and Wristbands

39.3.1. In areas where personnel come into the proximity of (i.e., possible contact with) static-sensitive explosives or vapors, conductive floors shall be installed except where adequate housekeeping, dust collection, ventilation, or solvent recovery methods eliminate the hazards of dust-air or flammable vapor-air mixtures.

39.3.2. Conductive floors and shoes should be used for grounding personnel in operations involving explosives (propellants, pyrotechnics, lead azide, lead styphnate, mercury fulminate, CP) that are sensitive to initiation by human electrostatic discharge.

Note: Conductive floors may also be required in areas where operations involve static sensitive EEDs.

39.3.3. Conductive floors are not required throughout an entire building or room if the hazard is localized. In such cases, conductive mats or runners may be used where required.

39.3.3.1. These mats or runners shall meet all specifications and test requirements that apply to conductive floors.

Note: Conductive wristbands may be substituted for conductive mats and footwear at fixed, grounded or bonded workstations or outdoor locations.

39.3.4. Where conductive floors and shoes are required, tabletops on which exposed explosives or dusts are encountered should be covered with a properly grounded or bonded conductive material that meets the same requirements as those for flooring.

39.4. Conductive Floor, Shoes, Work Surface, Wristband, and Rubber Hose Specifications

39.4.1. Conductive floors shall be made of non-sparking material such as conductive rubber or conductive flooring composition.

39.4.2. The flooring shall provide for electrical resistance not to exceed 1,000,000 ohms.

39.4.3. The surface of the installed floor shall be free from cracks and reasonably smooth. The material shall not slough off, wrinkle, or buckle under operating conditions.

Note: Conductive tiles are not recommended for use in areas where explosives dust can cause contamination. The large number of joints and the tendency of tiles to loosen provide areas in which explosive dust can become lodged, making normal cleanup procedures difficult.

39.4.4. Conductive floors shall be compatible with the explosive materials to be processed.

39.4.5. Conductive shoes shall provide for electrical resistance not to exceed 1,000,000 ohms.

39.4.6. Conductive wristbands shall not exceed a resistance between the wearer and ground or bonding point of 1,200,000 ohms.

39.4.7. Wristbands shall be of a design that maintains electrical contact with the wearer when used.

39.4.8. Table-top work surface mats shall have a resistance not to exceed 1,200,000 ohms.

39.4.9. The resistance of conductive rubber hose should not exceed 250,000 ohms.

39.5. Conductive Floor, Shoes, Work Surface, and Wristband Tests

39.5.1. Test instruments shall be used only when the room is free from exposed explosives and flammable gas mixtures.

39.5.1.1. Each electrode shall weigh 2.3kg and shall have a dry, flat, circular contact area 6.5cm in diameter, which shall comprise a surface of aluminum or tinfoil 1.3 to 2.5mm thick, backed by a layer of rubber 0.6 to 0.65cm thick and measuring between 40 and 60 durometer hardness as determined with a Shore Type A durometer (ASTM D-2240).

39.5.2. Initial tests shall be made of all conductive floors, and subsequent tests shall be made at least semi-annually.

39.5.3. Maximum floor resistance shall be measured with an ohmmeter that operates on a normal open circuit output voltage of 500 volts DC and a short circuit current of 2.5 milliamperes with an effective internal resistance of approximately 200,000 ohms.

39.5.4. The floor shall be clean and dry. “Electrode jelly” such as brushless shaving soap or saline solution shall not be used.

39.5.5. The resistance of the floor shall be more than 5,000 ohms in areas with 110-volt service and 10,000 ohms in areas with 220-volt service, and less than 1,000,000 ohms in all areas, as measured between a permanent ground connection and an electrode placed at any point on the floor and also as measured between two electrodes placed 3 ft apart at any points on the floor.

Note: Measurements shall be made at five or more locations in each room. If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 seconds shall be considered as the measured value.

39.5.6. Where conductive floors and shoes are required, resistance between the ground and the wearer shall not exceed 1,000,000 ohms.

39.5.7. Conductive wristbands shall not exceed a resistance between the wearer and ground or bonding point of 1,200,000 ohms.

39.5.8. Table-top work surface mats that are not part of a total conductive system shall have a resistance not to exceed 1,200,000 ohms.

39.6. Humidification

39.6.1. Humidification to prevent static electricity accumulations and subsequent discharges is usually effective if the relative humidity is above 60%.

Note: Due to the possibility of spontaneous ignition, certain materials such as metallic powders and some pyrotechnic mixtures cannot be exposed to air with 60% relative humidity.

39.6.2. Where this technique is used to prevent static electricity accumulations, a daily preoperational check of the humidity levels shall be accomplished before work starts.

40. FIRE PROTECTION

40.1. Vegetation Control

40.1.1. Vegetation around storage magazines and explosives operating facilities should be controlled to minimize potential damage to the magazine or facility from erosion or grass, brush, or forest fires.

40.1.2. A firebreak at least 50 ft wide and free from combustible material should be maintained around each aboveground magazine or explosives operating facility.

40.1.2.1. If an aboveground magazine or explosive facility exterior is fire resistant, the firebreak can have vegetation, but the growth shall be controlled to prevent rapid transmission of fire to the magazine or facility.

40.1.3. Maintaining the firebreaks around earth-covered magazines and cutting grass covering these structures is only required 5 ft from ventilators to prevent transmission of a fire into a structure.

40.2. Fire Protection Criteria

40.2.1. The following fire protection criteria shall be required for all new facilities or redesign of existing facilities where changes in activities shall result in a higher hazardous classification.

40.2.1.1. Automatic fire suppression systems shall be installed in all buildings containing HE and plutonium, except storage magazines, firing chambers, or rooms used as firing chambers within explosives operating buildings.

40.2.1.2. Where fire suppression is required, each explosives bay shall have an individual feed with its controls protected outside the bay and located to enable system operation if a detonation occurs in any bay.

40.2.1.3. Transmitted fire alarms shall distinguish between explosives and non-explosives areas through the use of annunciator panels at safe locations; small non-HE areas do not need separately transmitted alarms.

41. FACILITY EGRESS

41.1. Personnel Protective Restrictions and Requirements

41.1.1. DOE occupancies containing high explosives dictate that personnel be protected from blast overpressures and fragments (and spread of plutonium in some occupancies) from an accidental detonation.

Note: Accidental detonation of explosives is usually the result of stimuli other than a fire.

41.1.2. Non-compliance with some means of egress provisions (such as those covering exit doors, exit travel distance, number and location of exits, and common path of travel to exits), is permitted where required to provide protection from blast overpressure and fragments.

Note: Justification for non-compliance shall be documented.

41.1.3. When means of egress requirements are not met, the following additional personnel-protective restrictions or requirements should be imposed:

41.1.3.1. The building and means of egress should be protected by supervised automatic sprinkler systems connected to sound evacuation alarms.

41.1.3.2. Explosives operating buildings and their means of egress should have automatic, early warning fire detection systems connected to sound evacuation alarms where such early warning might reasonably aid in prevention or mitigation of personnel injury.

Note: This requirement is not applicable to explosives storage magazines, firing chambers, or rooms used as firing chambers within explosives operating buildings.

41.1.3.3. Personnel limits within the explosives work area (bay, cell) shall be established and controlled. These should not exceed 20 for reduced hazard occupancies or 6 for high hazard occupancies.

41.2. Requirements for Existing Facilities

41.2.1. Existing facilities may deviate from current means of egress requirements in the following situations:

41.2.1.1. Code requirements are not part of the defined code-of-record.

41.2.1.2. Deviations were made to meet Level-of-Protection and design criteria.

41.2.1.3. Building construction predates both current and Level-of-Protection criteria, but a hazard analysis has shown the risk of operations to be acceptable.

41.3. Requirements for New Facilities

41.3.1. If deviations from means of egress requirements are made, the following aspects related to each explosives operation, bay, and/or workroom where a deviation exists shall be reviewed and documented (e.g., Fire Hazard Analysis, Fire Protection Facility Assessment) by a qualified Fire Protection Engineer (see DOE-STD-1066).

41.3.2. The criteria considered acceptable for the Fire Protection Engineer review are:

41.3.2.1. No obstruction shall limit the width of the pathway to less than 36 in.

41.3.2.2. Combustible and flammable material quantities shall be minimized, justified, documented, and reviewed by site fire protection personnel and approved by line management. Ignition sources shall be identified and eliminated where possible.

41.3.2.3. The total time for six people to exit the workroom or bay, including the opening of doors where necessary is 30 seconds or less.

41.3.2.4. The total time for 20 people to exit the workroom or bay is 90 seconds or less. Noncompliance with this criterion shall be evaluated and justified during the conceptual design review.

41.4. Single Exits

41.4.1. Where means of egress requires at least two exits, but provisions for personnel protection from an explosion do not permit at least two exits from a room or structure, a single exit is acceptable, provided the following are met:

41.4.1.1. The path of exit travel shall be arranged so it is not through or toward a hazardous operation.

41.4.1.2. A room containing a high hazard explosive occupancy shall not exceed 500 ft^2, and the occupant load of the room shall be restricted to two operators and two casuals.

41.4.1.3. A room containing a reduced hazard explosive occupancy shall not exceed 1,000 ft^2.

41.4.2. Explosives storage magazines may have only single exits for the purpose of maintaining integrity of design.

Note: The conditions of this chapter do not apply to these magazines.

41.5. Blast Resistant Doors

41.5.1. Blast resistant doors required to protect personnel from the effects of an accidental detonation may be located in the means of egress, provided the requirements of Sections 41.1 through 41.3 and the following are met:

41.5.1.1. Where power operated doors are required to accomplish unlatching and opening, they shall have redundant features or be capable of being opened manually (to permit exit travel) or closed where necessary to safeguard exits.

41.5.1.2. The time required to fully open or close a door shall be as short as reasonably possible.

41.5.1.3. A revolving door is acceptable if a secondary means of escape (with swinging doors) is provided at the same location.

Note: The revolving door shall be prevented from rotating at too rapid a rate to permit orderly exit of personnel.

41.5.1.4. The following exceptions to means of egress requirements are permitted with documented justification:

- Swinging doors may exceed 48 in wide.
- Swinging doors adjacent to a revolving blast door can be omitted.
- Revolving blast doors need to be designed to collapse into book fold position.
- Where fire rated doors are required, blast doors are considered to have the required fire rating.
- A vestibule with two or more doors that is intended during routine operations to prevent continuous and unobstructed passage by allowing the release of only one door at a time shall be permitted in a means of egress.

  Note: In such cases, there shall be provisions to allow for continuous and unobstructed travel during an emergency egress condition.

- Panic hardware is not required on blast doors.

41.6. Slide Escapes

41.6.1. Slide escapes should be provided for elevated explosives operating locations from which rapid exit may be vital and cannot be obtained by other means.

41.6.2. Slide escapes should be located on opposite sides of the explosives operation to reduce the likelihood of personnel being trapped by fire between them and a single slide.

41.6.3. Exits to slide escapes shall open onto platforms that are not less than 3 ft^2 and the platforms shall be equipped with guardrails.

41.6.4. The slides shall begin at the outside edge of the platform, not at the edge of the buildings.

41.6.5. Slide escape landings shall be located at selected places leading directly to escape routes that are free from tripping hazards, low guy lines, drains, ditches, or other obstructions.

41.6.6. Manually or automatically controlled devices (trips) that sound an alarm in the operating building shall be installed at or near the entrances to slide escapes.

Note: These devices may also actuate deluge valves and water curtains in the building or room affected. Recommended slide escape specifications:

41.6.7. Recommended slide escape specifications:

- Angle, 40 to 50 degrees horizontal.
- Slide depth, 24 in.
- Radius at bottom of slide, 12 in.
- Height at lower end of slide, not over 24 in. above the landing.

41.6.8. If necessary, the end of the slide shall have a horizontal run sufficient to prevent employee injury from exit speed without the use of landing cushions, which are unsatisfactory in cold weather.

41.6.8.1. One foot of horizontal run is required for a 15 ft. long slide.

41.6.8.2. One additional foot of horizontal run shall be provided for each additional 5 ft. of slide length.

41.6.8.3. The juncture of the two sections shall be well rounded.

41.6.8.4. Metal sheets constructing the slide shall overlap in the direction of travel.

42. LIGHTNING PROTECTION

42.1. Lightning Protection Systems

42.1.1. All explosives structures shall be protected by a lightning protection system (LPS) that is compliant with the code-of-record version of NFPA 780 unless not required as noted in this chapter.

42.1.2. Sideflash (Arcing) Protection.

42.1.2.1. NFPA 780 shall be used to determine sideflash protection for all structures other than those with a Faraday like shield LPS.

Note: For Faraday like shield structures, in general, explosives and dunnage should be in contact with no more than one interior surface, this contact surface is normally the floor, shelf, or workbench.

42.1.3. Sideflash separation distance as determined by NFPA 780, shall be applied as given below:

42.1.3.1. All sideflash separation distances shall be measured from the outermost surface of the container, packing, device or equipment holding the explosive that is nearest the structural surface, or penetration extension in question.

Note: Measure from the surface of the explosive itself only when the explosive is bare.

42.1.3.2. When sideflash separation distance from structural elements and penetrations are maintained, approved explosives storage containers provide adequate protection from effects of lightning current flow.

Note: Containers are authorized to be in direct contact with each other.

42.2. Conditions Where Lightning Protection Is Not Required

42.2.1. A documented analysis reviewed by the Contractor Explosives Safety AHJ and approved by Contractor Facility Management demonstrates that the cumulative annual risk of a lightning strike to the structure in question or to any of the metallic penetrations of that structure is low.

Note: Methods for determining cumulative annual risk can be found in NFPA 780 Annex L. Equivalent methods may also be used.

42.2.2. Explosives operations served by a local lightning warning system (LWS) where:

42.2.2.1. Contractor Facility Management accepts, in the event lightning does strike the unprotected structure or the structure's penetrations, the potential damage, the loss of use of the structure, and the impact on other explosives operations at the facility; and

42.2.2.2. Contractor Facility Management accepts the impact of pausing all operations in other structures and the area within public traffic route (remote) distance of the structure without an operable LPS during a lightning threat; and

42.2.2.3. The Facility has a local effective LWS and lightning warning plan.

42.3. Lightning Warning and Protection Plan

42.3.1. Each site's Lightning Warning and Protection Plan shall take into consideration additional hazards due to the presence of explosives as identified in this chapter.

42.4. Lightning Threat Actions

42.4.1. Each site shall establish specific documented criteria for continuation or pause of explosives operations at the receipt of lightning threat notifications.

Note: These criteria should be based on the sensitivity of operations involved and the amount of time required to safely pause operations.

42.4.2. Contractor Facility Management shall evaluate their explosives operations to determine the time required to:

42.4.2.1. Safely pause explosive operations where required.

42.4.2.2. Evacuate personnel from the areas specified in Paragraph 42.4.6 to safe locations, or

42.4.2.3. Relocate explosives to a safe sideflash separation (standoff) distance.

42.4.3. Contractor Facility Management shall determine in advance of any lightning threat those activities that shall be paused and at what threat level the pause for each identified activity shall begin.

42.4.4. For a lightning threat alert, Contractor Facility Management shall evaluate pausing the following activities:

42.4.4.1. Activities involving AC powered electrical equipment in direct or indirect contact with explosives regardless of the form of LPS installed.

42.4.4.2. Explosives operations in an unprotected building or outside (some activities may be safer to proceed to a planned detonation or to a safe mode for the explosive).

42.4.4.3. Work with exposed electrostatic discharge sensitive (0.1 joule or less) EEDs in structures not equipped with a Metallic (Faraday-Like) Cage.

42.4.4.4. Explosives work in structures not equipped with a Metallic (Faraday-Like) Cage and where any explosives are at a sideflash separation distance less than that specified above or by NFPA 780.

42.4.5. For a lightning threat warning, Contractor Facility Management shall evaluate pausing the following activities in addition to those specified in the lightning threat alert.

42.4.5.1. Outside activities involving explosives.

42.4.5.2. Activities where extensions of penetrations, bonded or not, are in direct or indirect contact with the explosives.

42.4.5.3. Positions of hoists, without non-conductive links, and other movable conductive projections into a facility that can be moved or retracted to a maximum distance from explosives or explosive devices.

42.4.5.4. Explosives operations in structures not equipped with a LPS.

42.4.6. Contractor Facility Management shall determine in advance of any lightning threat notification those structures and areas that shall be evacuated and at what threat level the evacuation should begin. Contractor Facility Management should evaluate evacuating the following areas as a minimum:

42.4.6.1. Explosives structures without an LPS.

42.4.6.2. Magazine areas.

42.4.6.3. Structures not equipped with a Faraday like shield LPSs and containing exposed electrostatic discharge sensitive (0.1 joule or less) EEDs.

42.4.6.4. Structures not equipped with a Faraday like shield LPS and containing exposed electrostatic discharge sensitive (0.1 joule or less) explosives.

42.4.6.5. Parked, explosives-laden vehicles.

42.4.6.6. All buildings and areas within public traffic route distance (based on a 2.3 psi as given in DESR 6065.09 of an explosive structure not equipped with a LPS.

42.4.7. When Contractor Facility Management determines that evacuation of personnel from and around explosives structures is required, the following shall apply:

42.4.7.1. DOE/NNSA personnel and contractor/subcontractor personnel in the identified buildings and areas shall be evacuated to at least public traffic route distance.

42.4.7.2. Other personnel shall be evacuated to at least inhabited-building distance.

42.4.7.3. The evacuation distances shall be based on the maximum operating quantities and Hazard Division of explosives approved for the structure and on applicable psi and fragment distances as given in DESR 6055.09.

42.4.7.4. In lieu of evacuation, personnel are authorized to take shelter in a room or building that provides protection from overpressures in excess of 2.3 psi, fragments, and structural collapse in event of an explosion of any adjacent structure containing explosives.

42.4.7.5. During evacuation periods, personnel are allowed, at Contractor Facility Management's discretion, to pass within the specified distance of explosives structures not equipped with a LPS if required for evacuation or to gain access to or leave other operating areas.

42.5. Pause of Operations

42.5.1. When operations are being paused during lightning threat notifications, the following should apply:

42.5.1.1. Process equipment containing explosives should be stopped as soon as safety permits.

42.5.1.2. If a building or bay is being evacuated, the minimum number of personnel needed to safely pause operations that cannot be paused immediately are authorized to remain at the building. As soon as operations are paused, they shall evacuate.

42.5.1.3. Explosives testing can continue as long as personnel are not required to leave the test shelter.

Note: Operations at test firing areas shall be paused during lightning threat warning when explosives are present. Completion of a test after receiving a lightning threat alert may be allowed if test preparation has progressed to the point that discontinuing testing represents a greater personnel exposure than completing testing.

42.5.1.4. Actions required to be taken by personnel transporting explosives on site should be specified.
Note: Safe parking areas should be identified.

43. BUILDING AND EQUIPMENT MAINTENANCE

43.1. Cleaning

43.1.1. To maintain safe conditions, building interiors shall be cleaned regularly to prevent the accumulation of explosives dust and waste on exposed surfaces (e.g., structural members, floors, radiators, heating coils, utility lines, equipment, electrical fixtures).

43.1.1.1. These cleaning activities should not be conducted as a concurrent operation during hazardous operations.

43.1.1.2. Floors should be cleaned with hot water or a water steam mix wherever practical. Non-abrasive sweeping compounds that are compatible with the explosives involved may be used when a water steam mix or hot water is not practical.

Note 1: Such sweeping compounds may be combustible but shall not be volatile (closed cup flash point shall not be lower than 230°F (110°C)).

Note 2: Sweeping compounds containing wax shall not be used on conductive flooring.

Note 3: Where nitrated organic explosives (which may form sensitive explosive compounds with some alkalis) are involved, the use of cleaning agents containing those alkalis is prohibited.

43.1.2. Before resuming operations following maintenance, the area shall be cleaned and approved by the Supervisor.

43.2. Maintenance and Repair

43.2.1. Maintenance operations involving major repairs, changes, or the use of hazardous equipment should not be performed in work areas while explosives are present.

Note 1: Before beginning such maintenance, explosives should be removed and the area prepared.

Note 2: An approved procedure shall be established to verify that the area has been inspected and is safe for these operations.

43.2.2. Non-facility personnel performing maintenance or construction operations shall be at least intraline distance from any explosives operation and should be at least intraline distance from any building containing explosives.

Note 1: This requirement does not apply to personnel making job site inspections or equipment repairs requiring less than eight hours (e.g., technical representatives, architect engineering surveyors).

Note 2: Transportation of explosives is permitted on roadways at less than intraline distance.

43.2.3. Contractor Facility Management shall determine the minimum practical distance by which non-facility personnel (e.g., technical representatives, service representatives, architect engineering surveyors) shall be separated from explosives operations while making job site inspections or equipment repairs requiring less than eight hours.

43.2.3.1. The rationale for establishing the minimum practicable distance and additional control measures taken shall be documented and maintained until operations have been completed and personnel have permanently vacated the work site.

43.2.3.2. All such personnel shall be informed of the risk of working at less than intraline distance and shall agree to accept such risk.

43.2.4. New equipment or equipment subjected to major repair or modification shall be test operated, and handling equipment shall be tested before being returned to operations.

43.3. Hot Work Permits

43.3.1. In explosives work areas, a written permit shall be completed for the temporary use of portable, heat producing equipment that generates temperatures higher than 228°F (109°C).

43.3.2. Explosives decontamination of the immediately affected work areas and explosives removal shall be required before beginning hot work operations.

44. DECONTAMINATION AND CLEANING

44.1. Cleaning Operations

44.1.1. Operating procedures shall specifically cover decontamination.

Note 1: These procedures should cover methods, inspection, marking, control, dismantling, maintenance, final disposition, etc.

Note 2: Reference TB 700-4 for decontamination methods and marking.

44.1.2. Hot water or steam may be used to clean or remove explosives contamination from equipment.

44.1.3. When required, solvents that have been tested for and are compatible with explosives can be used.

Note: Operating procedures shall specify controls for their use.

44.1.4. When cleaning or removing explosives material from equipment, work surfaces, and floors, only clean cloth rags, paper wipes, and approved non-metallic brushes or scrapers should be used in conjunction with hot water, steam, and solvents.

44.1.5. Items to be cleaned should be positioned so that water and residue shall drain directly into an approved collection system. See Chapter 47 for waste collection and Chapter 48 for waste disposal.

44.1.6. Disposal of waste generated shall be coordinated with site environmental/waste management personnel.

44.1.7. Exhaust ventilation may be required to remove toxic explosives fumes, vapors, or steam from the cleaning area.

44.2. Cleaning Screw Threads

44.2.1. To avoid the necessity of cleaning explosives from threads, explosives processing techniques shall be designed to prevent explosives from being deposited on threaded fasteners.

44.2.2. When screw threads are required, covering or protection (e.g., sealant, cement) over the exposed threads should be provided.

44.2.3. Threads should be cleaned using approved non-metal “picks,” solvent, hot water, or steam.

Note: Soaking in solvents and applying penetrating oil may be useful.

44.2.4. After cleaning exposed threads of screws, bolts, pipe, etc., operator protection may still be required to facilitate safe disassembly.

44.3. Final Decontamination and Disposal of Equipment

44.3.1. If the item to be decontaminated has only smooth, flat surfaces (i.e., no cracks, seams, voids, or other places where explosive residue may be inaccessible), hot water, steam, or solvents may be employed to accomplish decontamination.

Note: Any explosives contamination of concern shall be visible to the unaided eye and shall have dimensions (length, width, and depth).

44.3.2. If the item to be decontaminated has tight places where explosives may remain lodged following normal cleaning procedures, the item shall be subjected to final decontamination techniques that may include partial disassembly.

44.3.2.1. Before subjecting an item to final decontamination by thermal or chemical techniques, as much explosive as possible shall have been removed by approved means (hot water, steam, and approved solvents in conjunction with cloth or paper wipes and non-metallic brushes or scrapers).

44.3.2.2. Items undergoing final decontamination by thermal techniques shall be subjected to sustained heating at a temperature at least 108ºF (60°C) higher than required for decomposition of the most thermally stable explosive substance present.

Note 1: The item shall be kept at that temperature for a sufficient period so that all parts have reached the temperature and all explosives material is decomposed.

Note 2: Thermal decomposition is usually accomplished by placing the items to be decontaminated in a high-temperature sustained fire (see TB 700-4). This operation shall be conducted remotely or with operator protection.

44.3.2.3. Final decontamination also may be accomplished by immersing the item in a chemical cleaning agent.

Note 1: The period of immersion shall be sufficient so that all explosive material is chemically decomposed.

Note 2: The chemical cleaning agent shall be one that TM 9-1300-214 has approved for use.

Note 3: Chemical cleaning agents for decontamination or destruction of explosives should not be used for more than about 1 oz of explosives.
Note 4: Reference TM 9-1300-214 for decontaminating chemicals for explosives and for color tests for identification of energetic materials.

44.4. Inspection

44.4.1. After decontamination procedures are complete and before transfer to a nonexplosive area, the item shall be inspected.

44.4.2. The degree of decontamination shall be determined/documented and the item shall be labeled to indicate its decontaminated state.

44.4.3. Representatives of at least two departments, such as operations or safety, should accomplish the inspection.

44.5. Identification and Control of Decontaminated Items

44.5.1. Decontaminated items shall be marked to indicate the degree of decontamination and stored separately from non-contaminated items until final disposition is made.

44.5.2. Degrees of decontamination shall be designated and all items shall be tagged and/or marked with this designation.

44.5.3. Guidelines for establishing a system to designation degrees of decontamination are provided below.

44.5.3.1. X—A single X indicates that the facilities or equipment have been partially decontaminated. Additional decontamination processes are required before facilities or equipment are moved or any maintenance, repair, etc., is performed. The X rating would apply to facilities, rooms, bays, or equipment that have been subjected to routine decontamination performed by an operator at the close of the workday.

44.5.3.2. XXX—Three Xs indicate that the equipment or facilities have been examined and decontaminated by approved procedures; no contamination of concern (see Note under Paragraph 44.3.1) can be detected by appropriate instrumentation, test solutions, or by visual inspection on easily accessible surfaces or in concealed housings, etc., and are considered safe for the intended use. Items decontaminated to this degree cannot be furnished to qualified DOE, DoD, or industry users or be in direct contact with an open flame (cutting, welding, high temperature heating devices), or operations which generate extreme heat, such as drilling and machining unless the following two conditions are met:

- It has been determined that decontamination to the XXXXX level shall destroy the item’s usefulness.
- Decontamination to a degree less than XXXXX in combination with administrative and technical safeguards shall eliminate risk of injury. As a minimum, an approved operating procedure setting forth the specific operational limitations, precautions, and monitoring necessary to assure safety shall be available and decontamination shall be performed under the direction of the inspectors who shall certify decontamination.

44.5.3.3. XXXXX—Five Xs indicate the equipment or facilities are decontaminated, free of explosives hazards, and may be released for general use or to the general public.

44.5.3.4. 0—A zero indicates the item, although located in a contaminated area, was never directly exposed to contamination.

45. COLLECTION SYSTEMS

45.1. Vacuum Equipment

45.1.1. Precautions shall be taken to prevent explosives from entering any vacuum system not specifically designed to collect explosives.

45.1.2. All vacuum lines used for explosives operations should be labeled to warn maintenance personnel that explosive residue may be present in these lines.

Note: A suggested label is:

DANGER, MAY CONTAIN EXPLOSIVES

45.1.3. All vacuum lines that are potentially contaminated with explosives shall be disassembled according to approved operating procedures.

45.1.3.1. Disassembly should be accomplished at flanged connections or elastomeric tubing whenever practical.

45.1.3.2. No attempt should be made to disassemble a vacuum line at a threaded connection.

45.1.4. The design or installation of any new vacuum lines associated with processes capable of generating explosives contamination of concern shall not employ demountable, internal screwed, or threaded fittings or connections unless welded or fixed permanently in place.

45.1.5. Vacuum systems used to evacuate processes for explosives operations that are capable of generating explosives contamination of concern shall be equipped with primary and secondary intake line traps or filters to prevent explosives from contaminating the pump.

45.2. Explosives Dust Exhaust Ventilation and Collection Systems

45.2.1. Exhaust ventilation should be used to control explosives dust.

45.2.2. Exhaust ventilation used to remove explosives dust requires an approved dust collection system to prevent the release of the dust outside the building.

45.2.3. Exhaust ventilation and collection systems that control explosives dust and materials associated with explosives production shall be designed to meet minimum requirements in the American Conference of Government Industrial Hygienists (ACGIH) Ventilation Manual and this Technical Standard.

45.2.4. A “wet collector” that moistens the dust close to the point of origin and keeps it wet until the dust is removed for disposal is preferred.

Note: A “dry type collector” is permitted when authorized by an approved operating procedure.

45.2.5. Dust collectors shall be designed to prevent explosives dust from reaching any mechanical power source of the collection system.

45.2.6. All conductive portions of the collection system shall be grounded and bonded.

45.2.7. A dust collection system shall not have screw threads, recesses, or cracks that may be exposed to explosives contamination.

45.2.8. Dust collection lines should be equipped with flanged connectors and inspection ports.

45.2.9. Pipes or ducts through which explosives are conveyed shall be designed using one of the following methods:

45.2.9.1. The pipes or ducts shall be designed to avoid dead spots or propagation of detonation.

45.2.9.2. The design shall establish pipe characteristics including materials selection, diameter and turn radius in relation to the material being transferred, its ignition and detonation characteristics, and transfer rates.

45.2.9.3. The pipes and ducts shall have long radius bends with a centerline radius at least four times the diameter of the ducts or pipes.

45.2.10. Dust collectors shall be emptied and cleaned on a regular basis as system use warrants and shall be inspected periodically.

45.2.11. Wherever practical, dry type explosives dust collection chambers should be located outside operating buildings, in the open, or in buildings exclusively set aside for the purpose.

45.2.12. Stationary and portable wet type collectors may be placed in the explosives operating bays or cubicles, provided the quantity of explosives in the collectors does not exceed 2 kg.

46. DRAINS AND SUMPS

46.1. Collection

46.1.1. All drain lines handling explosive wastes shall be provided with sumps, clarifiers, weirs or basins of adequate design and capacity for removal of explosives by settling.

46.1.2. The drains shall be of adequate capacity, free of pockets, and have sufficient slope (at least ¼ in./ft.) to prevent the settling out of explosives in the line until it reaches the sump, clarifier, weir or other settling basin.

46.1.3. Drain gutters within buildings may be constructed with a slope of ⅛ in/ft.

46.1.3.1. Drain gutters shall be cleaned periodically.

46.1.4. Sumps shall be designed to prevent suspended and settleable solid explosive material from being carried in the wash waters beyond the sumps.

46.1.4.1. The design shall allow sufficient settling time on the basis of the settling rate of the material and the usual flow rate.

46.1.4.2. Sumps shall be constructed so that the overflow does not disturb any floating solids.

46.1.4.3. The design shall also permit easy removal of collected explosives and retention of those explosives that float on water (until they can be skimmed off).

46.1.5. When using settling basins to supplement sumps, they shall be cleaned periodically.

46.1.6. The following requirements apply to sumps and associated equipment:

46.1.6.1. Explosives collection trays for sumps shall be constructed of nonferrous metal.

46.1.6.2. Hoisting equipment used to lift trays shall be designed to prevent the trays from binding on the sides of the sump.

46.1.6.3. Bolted sump tanks or other types of construction that permit the explosives to settle in obscure or hidden spaces shall not be used.

46.1.7. Drains between the source of explosive and the sump shall be troughs with rounded bottoms and removable ventilated covers to facilitate inspection for accumulation of explosives.

46.1.7.1. This requirement applies to all new construction and major modifications and should be considered for existing facilities.

46.1.8. Short sections of closed pipe or trough are permitted if they can be visually inspected for blockage or explosives buildup.

46.1.9. Explosives or explosives contaminated waste liquids shall not be released into closed drains and sewers.

46.1.10. Drains shall be inspected periodically and necessary steps taken to prevent the buildup of explosive deposits.

46.2. Effluent

46.2.1. Drains containing explosive waste materials shall not be connected in a manner that allows such wastes to empty into the normal sewage systems carrying inert or sanitary wastes.

46.2.2. Care shall be taken to avoid the possibility of deposition of explosives from sump effluent due to drying, temperature changes, or interaction with other industrial contaminations.

46.2.3. When handling explosives that are appreciably soluble in water, sweeping and other dry collecting measures shall be used to keep such out of the drainage system.

46.2.4. The combination of sumps, settling ponds, and other systems shall remove explosives so that outflows meet environmental standards.

47. WASTE COLLECTION

47.1. Removal of Explosives Waste

47.1.1. Provision shall be made to remove explosives waste from areas where it is generated.

47.1.2. Removal of explosives waste may be accomplished by (see also Chapters 45 and 46):

- Collecting dust/fines or chips in a wet or dry vacuum system
- A slurry of water or nonflammable solvent
- By collecting solid waste in receptacles

47.1.3. Explosives waste shall be collected and maintained separately from conventional waste.

47.1.4. Mixing of incompatible explosive waste shall be avoided.

47.1.5. Receptacles shall be clearly labeled to indicate the type of waste permissible.

47.2. Solid Wastes

47.2.1. Areas where solid explosives wastes are not removed by vacuum or liquid systems shall be equipped with a seamless or lined receptacle to collect explosives wastes.

47.2.2. Explosives waste shall be removed from the collection point at an interval to keep aggregate levels within explosive weight limits.

47.2.3. Conventional waste not contaminated by explosives or containing noncombustible materials shall not be placed in an explosives waste receptacle.

47.2.4. Explosives-contaminated waste shall be segregated as combustibles and non-combustibles.

47.2.5. Before being transported, explosives waste shall be packaged to prevent spills, leaks, or exposure to initiation stimuli.

47.2.5.1. Incompatible materials shall not be packaged together.

47.2.5.2. All packages of explosives waste shall be labeled clearly to indicate the nature and approximate quantity of contents.

47.3. Vacuum Collection of Explosives Dusts

47.3.1. Explosives dusts should be collected by a vacuum system, preferably the wet type.

47.3.1.1. Dust in a wet vacuum should be maintained in wet form using a wetting agent that is kept close to the point of origin and kept wet in the collection system until removed for disposal.

47.3.1.2. Water-soluble explosives such as Explosive D should be collected in a dry vacuum system.

47.3.2. SCG A explosives may be collected by a wet vacuum system, provided they are maintained in a wet form using a wetting agent that is kept close to the point of intake.

47.3.2.1. Use of a vacuum system to collect these more sensitive materials should be limited to operations involving small quantities of explosives.

47.3.3. Dry-type dust collection chambers, except portable units, should be located in the open, outside operating buildings, or may be inside if adequate shielding is provided.

47.3.3.1. The quantity of explosives collected shall not exceed the capacity of the shielding to protect operating personnel.

Note: The degree of barricading and the appropriate intraline distance shall determine this limit.

47.3.4. If dry dust collection outside a building is not practical, a separate room or shielded area within the building shall be designated for this purpose.

47.3.4.1. This room or shielded area shall not contain other operations or be used as a communicating corridor or passageway between other operating locations within the building when explosives are being collected.

47.3.5. Stationary and portable wet-type collectors may be placed in the explosives operating bays or cubicles if the quantity of explosives in the collectors does not exceed 4.4 lbs.

47.3.5.1. If placed in separate cubicles, the explosive weight limits may be increased by an amount determined by the extent of the cubicle walls' capabilities to serve as operational shields.

47.3.6. Collection systems and chambers shall be designed to prevent explosives from being pinched between metal parts. See Chapter 46 for additional design information.

47.3.7. Two collection chambers shall be installed ahead of the pump or exhauster in series to prevent explosives dust from entering the vacuum producer in dry vacuum collection systems.

47.3.7.1. In addition, non-sparking fans and dust-tight motors shall be used.

47.3.8. Dry-type portable vacuum collectors shall not be located in bays or cubicles where explosives are present or in enclosed ramps, but may be positioned outside the building or in a separate cubicle.

47.3.8.1. The building or cubicle walls shall provide adequate shielding for at least 4.4 lbs. of explosives.

Note: Shielding and QD constraints shall define the explosives limits.

47.3.9. Explosives dust shall be removed from the collection chamber periodically to eliminate unnecessary and hazardous explosives concentrations.

47.3.9.1. The entire system should be cleaned at intervals established by Contractor Facility Management, dismantling the parts if necessary.

47.3.9.2. A cleaning schedule shall be established for the collection chamber and the entire system using the operating hours as a basis.

47.3.10. The entire explosives-dust collecting system shall be electrically bonded and grounded with resistance-to-ground not exceeding 10 ohms.

47.3.10.1. The grounds shall be tested at intervals established by Contractor Facility Management.

47.4. Explosives Slurries

47.4.1. Machine tools shall be fitted with wet boxes to catch and direct water and explosives fines to an explosives waste gutter system.

47.4.2. Wastewater that might contain explosives materials shall be kept from contaminating potable water or conventional wastewater systems.

47.4.3. Settling tanks shall be inspected regularly to monitor the waste accumulation.
47.4.3.1. Records of waste removal shall be kept.

47.4.4. When pumping settled explosives from a slurry-settling tank, the operation shall be arranged to preclude exposure of the explosive material to pinching.

47.4.5. Explosives materials in settling basins shall be kept wet until removed.

47.4.5.1. The materials shall be maintained wet until spread out for disposal.

47.4.5.2. Explosives materials containing powdered metals shall be kept sufficiently wet to prevent a dangerous temperature rise resulting from a reaction of the metal with water.

Note 1: The possibility of hydrogen generation in this situation is anticipated.

Note 2: If an explosive or flammable gas can be generated, then proper ventilation shall be supplied to prevent an explosive or flammable mixture from accumulating.

47.5. Metal Scrap

47.5.1. Metal scrap shall be inspected to detect explosives contamination.

47.5.2. When scrap is found to contain explosives contamination of concern, it shall be decontaminated in accordance with final decontamination procedures (see Chapter 44).

47.6. Salvaged Explosives

47.6.1. Salvaged explosives materials shall be thoroughly inspected by operating supervisors and reused, screened, reprocessed, or destroyed as the situation warrants.

47.6.2. Salvaged explosives materials shall be classified as SCG L until they have been established to be compatible with the original material.

48. WASTE DISPOSAL

48.1. Preparation for Open Burning

48.1.1. Preparations to burn or place explosives waste on a pad or in a pit shall not begin until 24 hours after the previous burn at the same burning point.

Note 1: The only exceptions are if the burn area has been thoroughly soaked with water and inspected by a qualified person(s) or the temperature of the burning tray/surface has been measured and inspected by a qualified person(s) to achieve personnel safety during subsequent burning operations.

Note 2: The burning point shall be inspected for residual embers or hot spots before loading with explosives.

48.1.2. Before beginning preparations, firing controls shall be disconnected from power sources and circuits shunted and grounded.

48.1.3. Some explosives give off toxic vapors or fumes when destroyed by burning. Refer to section 8.1.4 for hazard prevention and abatement requirements.

48.1.4. Incompatible explosives materials shall not be in the same pit or on the same pad at the same time.

48.1.5. Personnel engaged in burning explosives should be provided with non-static-producing cotton clothing.

48.1.6. Containers of explosives materials shall not be opened less than 10 ft from each other.

48.1.7. Empty explosives waste containers that are to be reused shall be situated an adequate distance from the burning point to prevent charring or damage during the destruction operation.

48.1.8. Based on past experience or analysis, a layer of excelsior or similar material may need to be placed on the bottom of the pit or pad where the explosives waste shall be placed.

48.1.9. Powdered, granular, or slurry form explosives should be placed in a layer not more than 8 cm thick.

48.1.10. Water-wet initiating explosives (SCG A) shall not be allowed to dry completely.

48.1.11. Wood, heating oil, liquid propane, or natural gas may be used to allow complete combustion of the explosives waste material.

48.1.12. The ignition train should be set up to burn upwind, except that the ignition train for burning IHE may be set to burn downwind.

48.1.13. The firing circuit shall require a key for completion. Only one copy of the firing key shall exist, and it shall be in the lead operator’s possession.

48.1.14. Radio transmitters and cellular phones in the control shelter and vehicles at the burning site shall be turned off during setup and firing of low-energy electrical squibs to provide protection against radio frequency currents.

48.1.15. Precautions shall be taken to verify that extraneous electrical currents from any source do not unintentionally activate the firing system.

48.1.16 The burn shall be primed after all other preparation work is complete and with a minimum number of personnel present.

48.1.17. Ignition shall be accomplished remotely.

48.2. Destruction by Burning or Flashing

48.2.1. Explosives waste may be destroyed by remote burning if it can be done with little chance of detonation.

48.2.2. Explosives-contaminated waste may be burned remotely in a wire cage.

48.2.3. An open furnace or burning area for explosives should be used to destroy wet-machining cuttings and classified parts.

Note: The same furnace or burning area may also be used for flashing casings after washout of an explosive charge.

48.2.4. Explosives in closed containers or casings likely to detonate should not be burned.

48.2.5. Large pieces likely to detonate should not be burned.

48.2.6. Special attention should be given to the placement and orientation of large pieces and those in closed containers or casings.

48.2.7. Approved incinerators may be used to destroy small devices such as detonators, actuators, etc.

48.2.8. Concurrent burning operations shall not be conducted within 150 ft. of each other.

48.2.9. When several pads are burned, the downwind pad shall be ignited first, followed by the others in succession.

48.3. Ignition System Malfunctions

48.3.1. If the ignition system fails to fire, treat it the same as an explosives misfire (see Section 31.1).

48.3.2. If the squibs fire but fail to ignite the ignition train, remotely survey the area, and wait at least 30 minutes.

Note: When it appears safe to emerge from the control shelter, disconnect, shunt, and ground the firing circuit, and inspect the squibs, firing system, or ignition train.

48.4. Post-burn Operations

48.4.1. No entry should be allowed into the disposal area until eight hours have elapsed unless it can be determined visually that all explosives have been destroyed.

48.4.2. Squib firing lines shall be disconnected, shunted, and grounded before personnel can enter the burn area.

48.4.3. Unburned or partially burned explosives material remaining in the pit or pad may be moved or repositioned for further burning with the following controls:

48.4.3.1. The material shall not be raked or otherwise insulted.

48.4.3.2. The burning operation shall be repeated to destroy any remaining explosive waste.

48.4.4. At least 24 hours shall elapse before ashes are collected.

Note: The only exceptions are if the burn area has been thoroughly soaked with water and inspected by a qualified person(s) or the temperature of the burning tray/surface has been measured and inspected by a qualified person(s) to provide personnel safety.

48.5. Disposal Area

48.5.1. Explosives waste destruction operations shall be separated from magazines, inhabited buildings, public traffic routes, and occupied operating buildings so that personnel and facilities are not exposed to hazardous blast overpressure, fire brands, fragments, or projectiles from burning or detonation of explosives.

48.5.1.1. For destruction by open burning or flashing, the minimum separation distance from unprotected personnel and from facilities not associated with the operation shall be Hazardous Fragment Distance in DESR 6055.09, unless carried out in pits or with other aids for limiting the range of fragments and debris if an accidental detonation occurs.

48.5.1.2. Sites should be located taking into account the direction of the prevailing winds to prevent sparks from being blown toward explosives locations.

48.5.1.3. The size of the danger zone for destruction by open detonation shall be determined by one of the following formulas:

- $D(\text{ft.}) = 328\ W^{1/3}$
- $D(\text{m}) = 131\ Q^{1/3}$

48.5.1.4. Minimum separation distances shall be based on requirements outlined in DESR 6055.09 for areas used for intentional detonations.

48.5.1.5. Self-contained destruction facilities are exempt from the above requirements.

48.5.2. The maximum quantity of explosives that may be destroyed at one time shall be determined by starting with a small quantity, gradually increasing until an optimum amount, consistent with safe and efficient operation, is reached.

48.5.3. Explosives waste and ordinary rubbish shall not be destroyed in the same destruction area at the same time.

48.5.4. During destruction operations, the area within 200 ft of the destruction point shall be kept clear of dry grass, leaves, and other extraneous combustible material.

Note: This clearance may be reduced to fire brand distance if aids to limit the range of fragments and debris are provided for the destruction points used within the disposal area.

48.5.5. Explosive waste awaiting destruction shall be stored at least intraline distance from the explosives being destroyed.

48.5.6. When unloading explosives from vehicles at the burning grounds, explosives containers shall be distributed to trays or other disposal locations.

48.5.6.1. Vehicles shall be moved to a safe location as soon as explosives items have been removed.

48.5.6.2. Explosives containers shall not be opened until vehicles have been withdrawn.

48.5.7. Provisions for emergency firefighting shall be readily available at the waste disposal area.

48.5.8. The burning grounds shall be serviced with telephones or two-way radio communication.

48.6. Destruction by Detonation

48.6.1. Cased explosives should be removed from cases and burned or the cased item destroyed by detonation.

48.6.2. Detonators, primary explosives, and other explosives that might detonate, if burned, should be destroyed by detonation.

48.6.3. The destruction by detonation of any explosives material or article shall be considered a Class 0 operation.

48.6.4. A high-energy detonator (e.g., an EBW) or nonelectric detonator should initiate the detonation.

48.7. Use of Solvents

48.7.1. Solvent immersion may be used to prepare small quantities of explosives and explosive detonators for destruction.

48.7.2. Items to be destroyed shall be soaked in suitable, compatible solvents until all the explosives material is dissolved.

48.7.3. Saturated solvent solutions shall not be reused.

48.7.4. Solvent-explosives mixtures shall be destroyed by burning.

49. EMERGENCY CONTROL

49.1. Placards and Fire Symbols

49.1.1. Placards and fire symbols as specified in DESR 6055.09 shall be displayed on either buildings, work areas, or multi-building areas to warn of potential hazards from explosives and to provide information for emergency situations.

49.1.2. These placards and symbols shall be readily visible upon approach.

49.2. Emergency Plans

49.2.1. Each site's emergency plan shall take into consideration additional hazards due to the presence of explosives.

50. SECURITY RESPONSE FORCE AMMUNITION

50.1. Recommendations for security vehicles and personnel carrying HD 1.1/1.2 ammunition are included in Attachment A of this chapter.

50.2. Security Ammunition Surveillance

50.2.1. Ammunition used by the security forces, stored for contingency plans, and for other types of operations should be reviewed periodically for serviceability, safety, and any specific lot restrictions or suspensions issued by DoD, other Government agencies, or commercial sources.

50.3. Pre-positioned Storage

50.3.1. When HD 1.2 ammunition is stored inside or at less than inhabited-building distance from inhabited buildings, fragment barriers shall be provided.

Note: Minimally acceptable fragment barriers are: ¼ in of mild steel plate, one layer of sand bags, 12 in of loose sand or dirt, or other equivalent protection.

50.4. Security Working Dog Explosives Training Aids

50.4.1. Security Working Dog explosives training aids (including HD 1.1) may be transported and handled by qualified personnel in areas that provide realistic and effective training per the requirements of AFMAN 91-201 and AFI 31-202.

Attachment A – Recommendations for Security Vehicles and Personnel Carrying HD 1.1/1.2 Ammunition.

1. While performing their duties, security forces are often required to carry HD 1.1/1.2 ammunition in their vehicles and/or on their persons exempt from QD and Level-of-Protection requirements. In the case of an accident or fire, the presence of HD 1.1/1.2 ammunition present significant explosives blast and fragment hazards.

2. The following Explosives Safety recommendations are provided to assist Security Response Force Planners when preparing contingency plans involving the transportation of HD 1.1/1.2 ammunition.

3. The intent of providing these recommendations is that they be applied to routine (non-emergency) security activities when and where deemed appropriate by Security Response Force Management.

Recommendation 1: Apply the Cardinal Principle:
- Carry the minimum quantity of HD 1.1/1.2 munitions needed to support security duties and contingency plans.
- Whenever practicable, pre-position HD 1.1/1.2 ammunition in readily accessible magazines.

Recommendation 2: Additional controls for vehicles carrying HD 1.1/1.2 ammunition:
- Carry no more than 25 lbs NEW of 1.1/1.2 munitions in any individual security response force vehicle.
- Secure the ammunition in the vehicle to prevent excess movement.
- Do not use the vehicle for administrative purposes.
- When temporarily out of security service, separate the vehicle from inhabited facilities and property lines by a minimum of 125 ft.
- If the vehicle is to be parked in excess of one shift, download the ammunition to properly sited magazines or approved facilities.
- Prior to repairing or performing maintenance on the vehicle, download the ammunition into properly sited magazines or approved facilities.

Recommendation 3: Additional controls for personnel carrying HD 1.1/1.2 ammunition:
- Place ammunition temporarily removed from an individuals’ uniform/load bearing equipment in approved locations.

References

1. 50 U.S.C. 2401, National Nuclear Security Administration Act.
2. Title 41, Code of Federal Regulations (CFR), Part 102-193, Creation, Maintenance, and Use of Records.
3. DOE O 226.1B, Implementation of Department of Energy Oversight Policy.
4. DOE O 251.1D, Departmental Directives Program.
5. DOE O 410.1, Central Technical Authority Responsibilities Regarding Nuclear Safety Requirements.
6. NNSA SD 410.1A, Implementation of National Nuclear Security Administration Central Technical Authority Responsibilities Regarding Nuclear Safety Requirements.

APPENDIX A. Acronyms

ACGIH	American Conference of Government Industrial Hygienists
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
BOE	Bureau of Explosives
CFR	Code of Federal Regulations
CP	5-Cyanotetrazolpentaamine Cobalt III Perchlorate
DDESB	Department of Defense Explosives Safety Board
DDT	Deflagration to Detonation Transition
DESR	Department of Defense Explosives Safety Regulation
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSC	Differential Scanning Calorimetry
DTA	Differential Thermal Analysis
EAA	Explosives Approval Authority
EBW	Exploding Bridge Wire
EDC	Explosives Development Committee
EED	Electro-explosive Device
EIDS	Extremely Insensitive Detonating Substance
EIS	Extremely Insensitive Substance
EMR	Electromagnetic Radiation
EOD	Explosive Ordnance Disposal

ES	Exposed site
ESC	Explosives Safety Committee
ESP	Explosives Safety Program
ESSP	Explosives Safety Site Plan
GFCI	Ground Fault Circuit Interrupters
HD	Hazard Division
HDBK	Handbook
HE	High Explosive
HEVR	High Explosive Violent Reaction
HMX	Cyclotetramethylene Tetranitramine
IHE	Insensitive High Explosive
LLNL	Lawrence Livermore National Laboratories
LPS	Lightning Protection System
LWS	Lightning Warning System
MCE	Maximum Credible Event
MSHA	Mine Safety and Health Administration
NA	Nuclear Administration
NEW	Net Explosive Weight
NFPA	National Fire Protection Association
NNSA	National Nuclear Security Administration
OPI	Office of Primary Interest
PBX	Plastic Bonded Explosive
PES	Potential Explosion Site

PETN	Pentaerythritol Tetranitrate
PTRD	Public Traffic Route Distance
QD	Quantity-Distance
RDX	Cyclotrimethylene Trinitramine
RF	Radiofrequency
SDT	Shock to Detonation Transition
SCG	Storage Compatibility Group
TATB	Triamino Trinitrobenzene
TNT	Trinitrotoluene
UFC	Unified Facilities Criteria
UL	Underwriters Laboratory
UN	United Nations
USC	United States Code
UXO	Unexploded Ordnance
XDT	Unknown to Detonation Transition

APPENDIX B. Definitions

ARM. A general term that implies the energizing of electronic and electrical circuitry, which in turn controls power sources or other components used to initiate explosives. The arming operation completes all steps preparatory to electrical initiation of explosives except the actual fire signal.

BARRICADE. An intervening approved barrier, natural or artificial, of such type, size, and construction as to limit in a prescribed manner the effect of an explosion on nearby buildings or personnel.

BAY. A location (e.g., room, cubicle, cell, or work area) containing a single type of explosives activity, which affords the required protection specified for appropriate hazard classification of the activity involved.

BLENDING. The mixing of solid materials (usually dry) by gravity flow, usually induced by vessel rotation.

BONDED (BONDING). Connected to establish electrical continuity and conductivity.

BOOSTER. Explosives used in an explosive train to amplify the shock output of the initiating device and cause detonation of the main explosive charge.

CARDINAL PRINCIPLE. The Cardinal Principle of Explosives Safety is to limit exposure to a minimum number of personnel, for a minimum amount of time, to a minimum amount of explosives, consistent with safe and efficient operations.

CASUAL. A person other than an operator who intermittently visits an explosives operation for the purpose of supervision, inspection, maintenance, etc. Casuals do not perform hands-on work with explosives but are otherwise involved with the explosives operation being performed. Casuals are accounted for in the established personnel limits for the area and are provided a Level-of-Protection consistent with the explosion hazard of operations in adjacent areas.

CLEAR ZONE. The required minimum distance for the protection of personnel and facilities from the PES.

COMPATIBILITY. The chemical property of materials to coexist without adverse reaction for an acceptable period of time. Compatibility in storage exists when storing materials together does not increase the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Storage compatibility groups are assigned to provide for segregated storage.

CONCURRENT OPERATIONS. Operations performed simultaneously and in close enough proximity that an incident with one operation could adversely influence the other.

CONTACT OPERATIONS. An operation in which an operator and an explosive item are both present with no operational shield.

CONTAMINATION OF CONCERN. Explosives contamination that is visible to the unaided eye and has dimensions (length, width, and depth).

CONTRACTOR EXPLOSIVES DEVELOPMENT COMMITTEE. A committee established at each DOE/NNSA facility engaged in explosives development to be the approving authority for each phase of an explosives development program.

CONTRACTOR EXPLOSIVES SAFETY AUTHORITY HAVING JURISDICTION (AHJ). An Explosives Safety Subject Matter Expert who is appointed by the M&O Contractor Facility Manager to provide day-to-day support to ongoing and planned explosives operations and activities.

CONTRACTOR EXPLOSIVES SAFETY PROGRAM MANAGER. A manager assigned by the M&O Contractor Facility Manager who assists Contractor Facility Management in implementing the requirements of this Technical Standard.

CONTRACTOR FACILITY MANAGEMENT. Management staff of the M&O contractor responsible for explosives facilities at the site.

CONTRACTOR FACILITY MANAGER. The senior M&O manager at the site.

CRITICAL TEMPERATURE. Temperature above which the self-heating of an explosive causes a runaway reaction. It is dependent on mass, geometry, and thermal boundary conditions.

DANGER ZONE. That area around a test site where personnel could be in physical jeopardy due to overpressure, fragments, or firebrands released during an explosive test.

DEFLAGRATION. A rapid chemical reaction in which the output of heat is sufficient to enable the reaction to proceed and be accelerated without input of heat from another source. Deflagration is a surface phenomenon with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction, and temperature and may cause transition into a detonation.

DETONATION. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure. A detonation is a reaction that proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium, forming a propagating shock wave that is originally of supersonic velocity. When the material is located on or near the surface of the ground, a detonation is normally characterized by a crater.

DIFFERENTIAL SCANNING CALORIMETRY (DSC). A technique in which the difference in energy inputs into a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program, or are held isothermally. The record is the differential scanning calorimetry or DSC curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal DTA curve.

DIFFERENTIAL THERMAL ANALYSIS (DTA). A technique in which the temperature difference between a substance and a reference material is measured as a function of temperature or time while the substance and the reference material are subjected to a controlled temperature program or are held isothermally. The record is the DTA curve. The energy input is substituted for ΔT and is plotted in the same manner as a normal DTA curve.

DIRECT CONTACT WITH EXPLOSIVES. Physical contact between an electrical instrument or equipment to bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device.

DUAL RATED. Equipment and wiring which can be used for both Class I, Division 1 and Class II, Division 2 electrical hazard areas.

DRYING. The removal of volatiles from ingredients or mixtures.

ELECTRO-EXPLOSIVE DEVICE (EED). A device containing some reaction mixture (explosive or pyrotechnic) that is electrically initiated. The output of the initiation is heat, shock, or mechanical action. See also LOW-ENERGY EED.

ENERGIZED. A circuit is energized when any part of it is connected to an electrical energy source.

EXPERIMENTAL PROCEDURE. A procedure prepared for conducting a specific experiment a limited number of times under close technical supervision.

EXPLODING BRIDGEWIRE (EBW). An EED that is initiated by the discharge of a high current through the device bridgewire, causing the wire to explode and produce a shockwave. An EBW as defined herein is a device containing no primary explosive.

EXPLOSIVE. Any chemical compound or mechanical mixture that is designed to function as an explosive, or chemical compound that functions through self-reaction as an explosive, and that, when subjected to heat, impact, friction, shock, or other suitable initiation stimulus, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases that exert pressures in the surrounding medium. The term applies to materials that either detonate or deflagrate.

DOE explosives may be dyed various colors except pink, which is reserved for mock explosive.

EXPLOSIVES APPROVAL AUTHORITY (EAA). NA-51 Deputy Associate Administrator for Safety fills this role.

EXPLOSIVE DECONTAMINATION. The removal of hazardous explosive material.

EXPLOSIVES FACILITY. A structure or defined area used for explosives storage or operations. Excluded are explosives presenting only localized, minimal hazards as determined by the Contractor Explosives Safety Authority Having Jurisdiction. Examples of excluded items may include user quantities of small arms ammunition, commercial distress signals, or cartridges for cartridge actuated tools, etc.

EXPLOSIVES SAFETY SITE PLAN. A formal package of explosives facility and operations safety documents to be prepared by Facility Management for DOE/NNSA approval of explosives facilities siting and operations before the operation starts. This package becomes part of the basis for explosives facility operations.

EXPLOSIVES SAFETY SUBJECT MATTER EXPERT (SME). The DOE Site or Field Office person responsible for Explosives Safety Oversight.

EXPOSED SITE. A magazine, cell, stack, truck or trailer loaded with ammunition, explosives workshop, inhabited building, assembly place or public traffic route, which is exposed to the effects of an explosion (or fire) at the PES under consideration.

EXTRUDING. Forcing a plastic-type material, under pressure, into a confined space or through a confined opening to produce a desired configuration.

FIRING CIRCUIT. A firing circuit is a component of a Firing Control Circuit. It is intended to transmit energy to an EED to reliably initiate it. A firing circuit usually includes the final energy storage device and the last switch that releases energy to the EED.

FIRING CONTROL CIRCUIT. An electrical circuit designed to reliably initiate EEDs) while preventing unintentional initiations. The firing control circuit includes everything electrically associated with the circuit providing energy to the EED being initiated, (e.g. the firing circuit, safety interlocks, diagnostic interfaces, controls and switches, power supplies, transmitters, receivers).

FIRING PAD. The prepared site where explosive items are fired for test data acquisition.

FLAMMABLE LIQUID. Any liquid having a flash point below 60°C and a vapor pressure not exceeding 280 kPa (41 psia) at 37.8°C. This is the definition as applied in this Technical Standard; it includes some materials defined as combustible liquids by the Department of Transportation (DOT) and/or NFPA 70, Flammable and Combustible Liquids Code.

FLASH POINT. The temperature at which a liquid or volatile solid gives off a vapor sufficient to form an ignitable mixture with air near the surface of the material or within the test vessel.

FORMULATION. (1) The operation of combining ingredients to produce a mixture of a final desired composition possessing specific physical and explosive properties. (2) An explosives composition.

GROUNDING. Providing an electrical path to the earth, generally to the facility grounding electrode system.

HAZARD ANALYSIS. The identification of risks associated with the tasks being performed. It focuses on the relationship between the worker, the task, the tools, and the work environment.

HAZARDOUS FRAGMENT DISTANCE. The distance at which the areal density of hazardous fragments or debris becomes one per 600 ft^2 ($55.7m^2$).

HEAD OF DOE FIELD ELEMENT. Manager in charge of a DOE Site, Field Office Manager or designated Operations or Production Office Manager

HEATING LIMITS. The conditions established for safely heating an explosive system (maximum temperature, heating time, heating rate, etc.). These limits are based on the estimated critical temperature of the explosive system with a suitable margin of safety.

HEAVY-WALLED. A wall thickness to diameter ratio greater than 0.01.

HIGH-ENERGY INITIATOR. Exploding bridgewire systems, slapper detonators, and EEDs with similar energy requirements for initiation.

HOLE (as applied to machine explosives). Any cavity that is more than one-half diameter deep, being cut by any tool with the direction of feed along the axis of rotation.

HOT WORK (thermal). Any operation requiring the use of a flame-producing device, an electrically heated tool producing a temperature higher than 109°C, or a mechanical tool that can produce sparks or heat explosives or explosives contamination to provide an initiation stimulus.

HYDROSTATIC PRESSING. The operation of compacting a material that is confined in a press by a diaphragm by hydraulically applying pressure to the diaphragm.

INDIRECT CONTACT WITH EXPLOSIVES. Contact between bare explosives, the metallic casing of an explosive, or the firing leads of an explosive device and electrical instruments or equipment through electrically conductive equipment or surfaces other than the equipment leads.

INERT MATERIALS. Materials that show no exothermic decomposition when tested by DSC or DTA. Moreover, when tested by recognized compatibility tests, the inert material will not show any incompatibility with energetic material with which it may be combined. Inert material will neither alter the onset of exotherm of the DSC or DTA trace of the energetic material nor increase the rate of decomposition or gas evolution of the energetic material.

INHABITED-BUILDING DISTANCE. The minimum distance permitted between explosives locations and inhabited buildings, administrative areas, site boundaries, main power stations, and other facilities of vital or strategic nature.

INITIATION, WITH ITS OWN MEANS. Explosives or ammunition having their normal initiating device (e.g., detonators or squibs) assembled to them so that this device is considered to present a significant risk of activation during storage.

INITIATION, WITHOUT ITS OWN MEANS. Explosives or ammunition that (1) are not stored with an initiating device assembled to them; or (2) have the initiating device assembled to them, but (a) safety features preclude initiation of the explosives filler of the end item in the event of accidental functioning of the initiating device, or (b) the initiating device does not contain any primary explosives and has a high threshold of initiation (e.g., EBW or slapper detonators). The power source for the initiator should not be present within the assembly or system. If the initiator’s power source is present, two or more management-certified safety devices connected in series will be present to interrupt any flow of energy from the power source to the initiator.

INTENTIONAL INITIATION. This operation involves intentionally initiating explosives materials or articles for the purpose of testing, training, demonstration, or destruction.

INTERMAGAZINE DISTANCE. The minimum distance permitted between any two storage magazines. The distance required is determined by the type(s) of magazine and also the type and quantity of explosives stored therein.

INTRALINE DISTANCE. The minimum distance permitted between any two operating buildings or sites within an operating line, at least one of which contains, or is designed to contain, explosives.

INTRINSICALLY SAFE. An apparatus or system whose circuits are incapable of producing any spark or thermal effect capable of causing ignition of a mixture of flammable or combustible material under test conditions described in ANSI/UL 913.

ISOSTATIC PRESSING. The operation of compacting a material in a sealed flexible container. The container is submerged in a pressure vessel, and the vessel is pressurized with liquid.

LABORATORY OPERATIONS. Experimental study, testing, and analysis of small quantities of energetic materials. Manufacturing processes with small quantities of materials are not included.

LASER ABLATION. The removal of material using a laser.

LOW-ENERGY EED. All EEDs except EBW detonators and slapper detonators.

LOW PRESSURE. Gas less than 150 psig (1 MPa gauge); liquid less than 1,500 psig (10 MPa gauge).

MACHINING OVERTEST. A test to evaluate the susceptibility of an explosive material to initiation during machining.

MAXIMUM CREDIBLE EVENT (MCE). The MCE from a hypothesized accidental explosion or fire is the worst single event that is likely to occur from a given quantity and disposition of explosives or explosives devices. The event must be realistic with a reasonable probability of occurrence considering the explosive propagation, burning rate characteristics, and physical protection given to the items involved.

MELTING. Operations involving change in the physical state of explosives from solid to liquid.

MISFIRE. An explosive charge that has partially or completely failed to initiate as planned.

MIXING. A mechanical operation that combines dissimilar materials.

MOCK EXPLOSIVE. Substances bearing similar physical properties (texture, density, cohesion, etc.) to an explosive material. They are non-detonable; however, some are exothermic materials that will burn. Mock explosives are used to represent explosives for purposes such as dry run testing of equipment. DOE mock explosives are normally pink in color.

NEW (OR EXPERIMENTAL) EXPLOSIVES. Explosive, explosive mixture, or explosive and binder mixture that the EDC has not characterized.

NON-FACILITY PERSONNEL. Construction or maintenance personnel who do not have a continuing contract with DOE or NNSA or their agents at the facility/site concerned where construction or maintenance activities occur.

OCCUPIED AREA. Any work area that can be reasonably considered integral to an explosives operating area to which personnel are assigned or in which work is performed, however intermittently. Examples of areas to be considered as occupied are assembly/disassembly cells or bays, explosives operating bays, radiography control and film processing rooms, offices, break areas, and rest rooms.

OPERATIONAL SHIELD. A barricade constructed to protect personnel, material, or equipment from the effects of a possible fire or explosion occurring at a particular operation.

PENETRATION. A conductive object that passes through the zone of protection or exterior surface of an LPS.

PERMANENT WIRING. Facility wiring that includes installed electrical wiring, communications wiring, security systems wiring, and fire protection systems alarm and response wiring.

PERMANENT EQUIPMENT. Equipment that includes the installed electrical fixtures and equipment associated with permanent wiring. Permanent equipment also includes equipment such as HVAC, hoods, vacuum pumps, hydraulic pumps, etc.

POTENTIAL EXPLOSION SITE (PES). The location of a quantity of ammunition and explosives that will create a blast, fragment, thermal, or debris hazard in the event of an accidental explosion of its contents.

PRESSING. The operation of increasing the density of explosive material by applying pressure.

PRIMARY EXPLOSIVE. A sensitive explosive that nearly always detonates by simple ignition from such means as a spark, flame, impact and other primary heat sources of appropriate magnitude. Examples are mercury fulminate, lead azide, lead styphnate, and other materials of similar sensitivities.

PROPELLANT. Explosive composition used to propel projectiles and rockets and to generate gases for powering auxiliary devices.

PUBLIC TRAFFIC ROUTE DISTANCE. The minimum separation distance required between a potential explosion site and any public street, road, highway, passenger railroad, or navigable waterway (including roads on DOE-controlled land open to public travel).

PUNCH AND DIE PRESSING. The operation of compacting a material confined by a die by forcing a punch or punches into the die and against the material.

PYROTECHNIC MATERIAL. Physical mixtures of finely divided fuels and oxidizer powders; may include various organic binders and color intensifiers. The material is intended to produce an effect by heat, light, sound, gas or smoke, or a combination of these as the result of non-detonative, self-sustaining exothermic chemical reactions.

QUALIFIED PERSON. A person assigned by Contractor Facility Management who has the appropriate level of training and experience in the explosives operation or activity.

QUANTITY-DISTANCE (QD). The quantity of explosive material and distance separation relationships that provide defined levels of protection. The relationships are based on levels of risk considered acceptable for specific exposures and are tabulated in applicable QD tables. These separation distances do not provide absolute safety or protection. Greater distances than those in the QD tables should be used if practical.

REMOTE OPERATION. An operation performed in a manner that will protect personnel in the event of an accidental explosion. (Remote operations involve protection from accidental (not intentional) initiations. See Intentional Firing in this section and Class 0 operations in Chapter VI for operations involving intentional initiation).

RESILIENT MATERIAL. An engineered product that is manufactured using various types of flexible bouncy and elastic material (e.g., cork, linoleum, rubber, sheet vinyl, vinyl composition tile).

RESISTANCE. The property of a conductor to oppose the flow of an electric current and change electric energy into heat. For lightning protection purposes, low resistance values are desired. Resistance is measured in ohms.

SCREENING. An operation using screens to separate particles of differing sizes.

SECONDARY EXPLOSIVES. An explosive substance that is relatively insensitive (when compared to primary explosives) and is usually initiated by primary explosives with or without the aid of boosters or supplementary charges. Such explosives may react as a deflagrating or as a detonating explosive. Examples are TNT, plastic bonded formulations, and other materials of similar sensitivity.

SERVICE BAY. A designated room, area or vault within an operating building for the intermediate storage/staging of explosives or explosives components awaiting either processing performed in that facility or transportation once intermediate or final processing in that facility is complete.

SERVICE MAGAZINE. An auxiliary building or suitable designated room (vault) used for the intermediate storage of explosives materials not exceeding the minimum amount necessary for safe and efficient operation.

SHUNT. An electrical interconnection of various portions of EED circuitry to prevent the development of an electrical charge differential between the parts.

SIDEFLASH. (1) The phenomena in which lightning current will jump through a non-conductive medium to attach to improperly bonded metallic objects. (2) An electrical spark, caused by differences of potential, which occurs between conductive metal bodies or between conductive metal bodies and a component of an LPS or ground.

SLAPPER DETONATOR. An EED initiated by a rapid discharge of a high current through a metal foil. The expansion of the metal vapor causes a plastic or metal covering to be propelled across an air gap and detonate a high-density explosive pellet.

SMALL ARMS AMMUNITION. (1) Ammunition designed to be fired from a pistol, revolver, rifle, or shotgun held by the hand or to the shoulder. (2) Ammunition of caliber less than 20 mm with incendiary, solid, inert, or empty projectiles (with or without tracers) designed to be fired from machine guns or cannons. (3) Blank cartridges.

STATIC GROUND. An electrical path to ground intended to reduce the potential for static-generated sparks and arcs.

STORAGE MAGAZINE. A structure designed or specifically designated for the long-term storage of explosives or ammunition.

SYNTHESIS. The chemical operation or operations required to produce a desired chemical compound.

TARGET. The area, structure, or material into which a projectile is fired.

TNT EQUIVALENT. A measure of the blast effects from explosion of a given quantity of material expressed in terms of the weight of TNT that would produce the same blast effects when detonated.

TRANSIENT. Any person within inhabited-building distance but not inside an explosives bay or other occupied areas (offices, break areas, shops, etc.). A transient’s presence within IBD of an explosives operation is transitory in nature, or to complete a relatively short-term, non-explosives-related work assignment in an area in which personnel are not permanently assigned, such as a building corridor, access ramp, or roadway. Transients are not accounted for in established personnel limits for any explosives operating area and are afforded a Level-of-Protection only from Class I explosion hazard activities.

UNEXPLODED ORDNANCE (UXO). Explosive ordnance which has been primed, fuzed, armed, or otherwise prepared for action, and which has been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material and remains unexploded either by malfunction, design, or for any other cause.

UNOCCUPIED AREA. Locations where occupancy is of a transitory nature such as building corridors, access ramps, and facility roads.
Note: Examples are locations such as mechanical equipment rooms, equipment/parts staging/storage areas, decontamination areas and janitor's closets, which typically have a low personnel density and an intermittent and relatively short-term duration of occupancy for assigned work but in which personnel are not normally permanently assigned.

APPENDIX C. Measurement Abbreviations

°C	degrees Celsius
cm	Centimeters
°F	Degrees Fahrenheit
ft	Feet
ft-lbs	Foot Pounds
ft^2	Square Feet
GPa	Gigapascals
g	Grams
hr	Hour
in	Inches
kg	Kilograms
kPa	Kilopascals
L	Liters
lbs	Pounds
m	Meters
µs	Microseconds
mg	Milligrams
min	Minute
mm	Millimeters
mm Hg	Millimeters of Mercury
oz	Ounces
Pa	Pascals

psi	Pounds per Square Inch
psig	Pounds per Square Inch, Gauge Pressure
rpm	Revolutions per Minute
sec	Seconds
m^2	Square Meters
yrs	Years
%	Percent

APPENDIX D. References

10 CFR Part 830: *Nuclear Safety Management*

10 CFR Part 851: *Worker Safety and Health Program*

27 CFR Part 555.203: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Types of Magazines*

27 CFR Part 555.207: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Construction of Type 1 Magazines*

27 CFR Part 555.208: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Construction of Type 2 Magazines*

27 CFR Part 555.209: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Construction of Type 3 Magazines*

27 CFR Part 555.210: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Construction of Type 4 Magazines*

27 CFR Part 555.211: *Bureau of Alcohol, Tobacco, Firearms, and Explosives, Department of Justice, Commerce in Explosives, Construction of Type 5 Magazines*

60-Series Publications: *Explosive Ordnance Disposal Procedures*, Technical Manual (TM) (Army), Technical Order (TO) (Air Force), EOD Bulletin (Navy), Commanding Officer, Naval Explosive Ordnance Disposal Technology Division, 20008 Stump Neck Road, Indian Head, Maryland 20640-5070, (current versions)

ACGIH Ventilation Manual: *Industrial Ventilation: A Manual of Recommended Practice*,(current version); ACGIH, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240

AD 411445: *Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations*, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314 (current version)

AFWL-TR-74-102: *The Air Force Manual for Design and Analysis of Hardened Structures*, Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, NM 87117; ADB004152, Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314, (current version)

AFMAN 91-201: *Explosives Safety Standards*, Secretary of the Air Force (current version)

AMCR 385-100: *AMC Safety Manual*, Headquarters, United States Army Material Command, 5001 Eisenhower Avenue, Alexandra, Virginia 22333, (current version).

ANSI/UL 913: *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations*, (current version)

ASCE/SEI 7-10: *Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers*, (with errata) (current version)

ASTM D-2240-68: *Standard Method for Rubber Property—Durometer Hardness, American Society for Testing and Materials*, (current version)

DDESB TP-12: *Department of Defense Explosives Safety Board Technical Paper 12: Fragment and Debris Hazards*, (current version)

DDESB TP-13: *Department of Defense Explosives Safety Board Technical Paper 13: Prediction of Building Debris for Quantity-Distance Siting*, (current version)

DDESB TP-14: *Department of Defense Explosives Safety Board Technical Paper 14: Approved Methods and Algorithms for DoD Risk-Based Explosives Siting*, (current version)

DDESB TP-15: *Department of Defense Explosives Safety Board Technical Paper 15, Approved Protective Construction*, (current version)

DDESB TP-16: *Department of Defense Explosives Safety Board Technical Paper 16, Approved Protective Construction*, (current version)

DDESB TP-17: *Department of Defense Explosives Safety Board Technical Paper 17, DDESB Blast Effects Computer*, (current version) User's Manual and Documentation, with accompanying program entitled DDESB Blast Effects Computer (BEC), (current version)

Defense Logistics Agency, Industrial Engineering Study to Establish Safety Design Criteria for Use in Engineering of Explosives Facilities and Operations, AD, 411445, Process Engineering Branch, APMED Picatinny Arsenal, Dover, NJ; Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314

DESR 6055.09, *Defense Explosives Safety Regulation* (current version)

DoD Instruction 4140.62, *Material Potentially Presenting an Explosive Hazard*, (current version)

DOE HDBK-3010: *DOE Handbook, Airborne Release Fractions / Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, (current version)

DOE Order 252.1: *Technical Standards Program*, (current version)

DOE Order 420.1: *Facility Safety*, U. S. Department of Energy (current version)

DOE Order 430.1: *Real Property Asset Management*, U. S. Department of Energy, Office of Project and Facilities Management, (current version)

DOE Order 452.1E: *Nuclear Explosive and Weapon Surety Program*, U.S. Department of Energy, (current version)

DOE Order 452.2: *Nuclear Explosive Safety*, U. S. Department of Energy, (current version)

DOE Order 460.1: *Packaging and Transportation Safety*, U.S. Department of Energy, (current version)

DOE/TIC-11268: *A Manual for the Prediction of Blast and Fragment Loading of Structures*, U.S. Department of Energy, Albuquerque Operations, Amarillo Area Office, Facilities and Maintenance Branch, P.O. Box 30030, Amarillo, TX 79120, (current version)

FMDS 5-4/14-18: *Factory Mutual Data Sheet 5-4/14-18*, (current version)

HNDM-1110-01-2: *Suppressive Shields, Structural Design and Analysis Handbook*, U.S. Army Corps of Engineers, U.S. Army Corps of Engineering, Huntsville Division, HNDED-CS, P.O. Box 1600, Huntsville, AL 35807, (current version)

JNWPS TP-20-7: *Joint Nuclear Weapons Publication System, Technical Manual, Nuclear Safety Criteria*, (current version)

LLNL-TR-679331, LA-UR-29238: *IHE Material and IHE Subassembly Qualification Test Description and Criteria*, Maienschein, Leininger, Hooks, 2015

MHSMP-84-22: *IHE Material Qualification Tests, Description and Criteria*, Mason & Hanger-Silas Mason Publication, Rev 1, July 1985, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161

Mil Spec P-46144C: *Specification for Polycarbonate, Type I, Class 1*, (current version)

National Electrical Code: (see NFPA 70)

NAVSEAOP 3565/NAVAIR 16-1-529: *Electromagnetic Radiation Hazards (U)(Hazards to Personnel, Fuel and Other Flammable Material)* (U), Naval Sea Systems Command, Volume 1, Fifth Revision, Dated 15 July 1982, (current version)

NFPA 70: *National Electrical Code*, National Fire Protection Association, (version detailed in 10 CFR 851)

NFPA 496: *Purged and Pressurized Enclosures for Electrical Equipment*, National Fire Protection Association, (current version)

NFPA 780: *Lightning Protection Code*, National Fire Protection Association, (current version)

NUREG-1320: *U.S. Nuclear Regulatory Commission, “Nuclear Fuel Cycle Facility Accident Analysis Handbook*, (current version)

TB 700-4: *Technical Bulletin, Decontamination of Facilities and Equipment,* Department of the Army, (October 1978)

TB 700-2: *Technical Bulletin, Department of Defense Ammunition and Explosives Hazard Classification Procedures* (TB 700-2, NAVSEA INST 8020.8A, TO 11A-1-47, DLAR 8220.1), Departments of the Army, the Navy, the Air Force, and the Defense Logistics Agency, Washington, DC, (current version)

The Atomic Energy Act of 1954: 42 USC 2011, Nuclear Regulatory Legislation, Office of the General Counsel, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001

Title 18 USC: *Crimes and Criminal Procedure*, Title 18 of the United States Code

TM 9-1300-214: *Technical Manual, Military Explosives*, Department of the Army, Department of the Army, (current version)

TR-828: *Technical Report, Blast Environment from Fully and Partially Vented Explosions in Cubicles*, Keenan, W.A. and J.E. Tancreto, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043

UFC 3-340-02: *Unified Facilities Criteria (UFC) Structures to Resist the Effects of Accidental Explosions* (formerly TM 5-1300), (current version)

UN ST/SG/AC/10/1: *Transportation of Dangerous Goods, Model Regulations*, United Nations Publications, (current version)

UN ST/SG/AC/10/11: *Transportation of Dangerous Goods, Test Manual,* United Nations Publications, (current version)

2. DOE (U.S. Department of Energy), March 2022. *Interim Hazard Classification for Waste Solids Contaminated with Dispersed Explosives (2016-61 Renew-6 Revision)*. (DOE March 2022)

Department of Energy
National Nuclear Security Administration
P.O. Box 5400
Albuquerque, NM 87185

March 23, 2022

MEMORANDUM FOR TERESA ROBBINS
MANAGER, NNSA PRODUCTION OFFICE (NPO)

PATRICK MOSS
ASSISTANT DEPUTY MANAGER FOR FIELD OPERATIONS, NA-LA

FROM: RONALD D. WILCOX
EXPLOSIVES HAZARD CLASSIFIER, NA-531

Ronald Wilcox
Digitally signed by Ronald Wilcox
Date: 2022.03.23 15:41:26 -06'00'

SUBJECT: Interim Hazard Classification for Waste Solids Contaminated with Dispersed Explosives (2016-61 Renew-6 Revision)

1. The following Interim Hazard Classification (IHC) is issued for Waste Solids Contaminated with Dispersed Explosives:

   Department of Transportation (DOT)
   Hazard Class/Division: Not regulated as an explosive

   Packaging note: The explosive substances contaminating the waste solids shall be less than 0.5% by weight, be explosives with an energy density equal to or less than that of PETN and be homogenous within the package. Packaging will be compliant with the Hazardous Materials Regulations (49 CFR) if any regulated hazardous material is present.

2. This IHC is granted for shipment of explosives on behalf of the Department of Energy (DOE). This IHC is not applicable for shipment of explosives by private contractors for non-DOE contracts.

3. The IHC is valid until March 22, 2023.

4. The IHC has been assigned in accordance with 49 CFR 173.56(b)(3), DOT-SP 15448, dated November 12, 2014, with grantee letter dated July 5, 2019, and TB 700-2, Chapter 3, dated July 30, 2012. Transportation carriers used to carry the above explosives must have a copy of this IHC and DOT-SP 15448, dated November 12, 2014, with grantee letter dated July 5, 2019, onboard the conveyance.

5. Questions concerning this IHC should be directed to my office at (505) 845-5113 or my telework number, (505) 712-9009.

cc:

T. Benoit, NA-LA
W. Gentile, NA-LA
B. Bailey, NPO
W. Shoemaker, NPO
C. Carlton, CNS
C. Carthel, CNS
A. Maes, CNS
P. Moon, CNS
M. Griego, LANL
J. Kelly, LANL
R. Murphy, LANL
L. Wedgeworth, LANL
NPO-Correspondence@npo.doe.gov
pnt@lanl.gov
L. Hay, PNNL

3. DOE (U.S. Department of Energy), April 2022. *Interim Hazard Classification for the Disposal of Trace Explosives in Flammable Liquids (2020-08 Renew-2)*. (DOE April 2022)

Department of Energy
National Nuclear Security Administration
P.O. Box 5400
Albuquerque, NM 87185

April 25, 2022

MEMORANDUM FOR THOMAS GRIM
ASSISTANT MANAGER FOR ENVIRONMENTAL SAFETY AND HEALTH, NA-LL

TERESA ROBBINS
MANAGER, NNSA PRODUCTION OFFICE

PATRICK MOSS
ASSISTANT MANAGER FOR OPERATIONS, NA-LA

WILL ORTIZ
ACTING ASSISTANT MANAGER FOR OPERATIONS, NA-SN

FROM: RONALD D. WILCOX
EXPLOSIVES HAZARD CLASSIFIER, NA-531

Ronald Wilcox

Digitally signed by Ronald Wilcox
Date: 2022.04.25 10:04:34 -06'00'

SUBJECT: Interim Hazard Classification for the Disposal of Trace Explosives in Flammable Liquids (2020-08 Renew-2)

1. The following Interim Hazard Classification (IHC) is issued for the Disposal of Trace Explosives in Flammable Liquids:

Department of Transportation (DOT) Hazard Class/Division:	3
Identification Number:	UN3379
Proper Shipping Name:	Desensitized explosive, liquid, n.o.s. (As indicated)
DOT Container Marking:	DESENSITIZED EXPLOSIVE, LIQUID, N.O.S. (As indicated) UN 3379
DOT Label:	FLAMMABLE LIQUID 3
Net Explosive Weight:	Not to exceed 5 % explosive

2. These liquids are required to be packaged in accordance with 49 CFR 173.201.

3. The following restrictions are applicable to this IHC:
    a. Explosive constituents are limited to those with energy density less than CL-20.
    b. The explosive must be completely dissolved in the solvent and not precipitate at anticipated shipping temperatures.
    c. The solvent must not freeze during shipment.

4. This IHC is granted for shipment of explosives on behalf of the Department of Energy (DOE). This IHC is not applicable for shipment of explosives by private contractors for non-DOE contracts.

5. The IHC is valid until April 24, 2023.

6. The IHC has been assigned in accordance with 49 CFR 173.56(b)(3), DOT-SP 15448, dated November 12, 2014, with grantee letter dated July 5, 2019, and TB 700-2, Chapter 3, dated July 30, 2012. Transportation carrier used to carry the above explosives must have a copy of this IHC and DOT-SP 15448, dated November 12, 2014, with grantee letter dated July 5, 2019, onboard the conveyance.

7. Questions concerning this IHC should be directed to my office at (505) 845-5113 or my telework number, (505) 712-9009.

cc:
T. Benoit, NA-LA
W. Gentile, NA-LA
N. Balaban, NA-LL
K. Lee, NA-LL
R. Lybarger, NA-SN
B. Bailey, NPO
W. Shoemaker, NPO
C. Carlton, CNS
P. Moon, CNS
J. Abeyta, LANL
M. Griego, LANL
R. Murphy, LANL
L. Wedgeworth, LANL
C. Hachmann, LLNL
D. Schneider, LLNL
S. Colborg, SNL
D. Finfrock, SNL
D. Saiz, SNL
pnt@lanl.gov
L. Hay, PNNL

4. DOT (U.S. Department of Transportation), November 2014. *Department of Transportation – Special Permit 15448 (Third Revision)*. (DOT 2014)

November 12, 2014

U.S. Department
of Transportation

**Pipeline and Hazardous
Materials Safety Administration**

East Building, PHH-30
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

DOT-SP 15448
(THIRD REVISION)

(FOR RENEWAL, SEE 49 CFR 107.109)

1. GRANTEE: (See Individual Authorization Letter)

2. PURPOSE AND LIMITATION:

a. This special permit authorizes the transportation in commerce of certain Class 1 materials under an Interim Hazard Classification. This special permit provides no relief from the Hazardous Materials Regulations (HMR) other than as specifically stated herein. The most recent revision supersedes all previous revisions.

b. The safety analyses performed in the development of this special permit only considered the hazards and risks associated with the transportation in commerce.

c. Unless otherwise stated herein, this special permit consists of the special permit authorization letter issued to the grantee together with this document.

3. REGULATORY SYSTEM AFFECTED: 49 CFR Parts 106, 107 and 171-180.

4. REGULATIONS FROM WHICH EXEMPTED: 49 CFR §§ 172.320 in that each package containing Class 1 material must be marked with an EX number, 173.51 and 173.56 in that an explosive must be approved prior to being transported, 173.57 and 173.58 in that an explosive must be subjected to the prescribed testing prior to being transported, and 173.60(b)(14) and 173.62(c)(5) in that the proposed packaging must be approved by the Associate Administrator, except as provided herein.

5. BASIS: This special permit is based on the application of U.S. Department of Defense dated May 1, 2014, submitted in accordance with § 107.105 and the public proceeding thereon.

6. HAZARDOUS MATERIALS (49 CFR 172.101):

Hazardous Materials Description			
Proper Shipping Name	**Hazard Class/ Division**	**Identification Number**	**Packing Group**
As appropriate	1.1, 1.2, 1.3, 1.4, 1.5, 1.6	As appropriate	II
As appropriate	2.1, 2.2, 2.3	As appropriate	N/A
As appropriate	3	As appropriate	As appropriate
As appropriate	4.1, 4.2, 4.3	As appropriate	As appropriate
As appropriate	5.1, 5.2	As appropriate	As appropriate
As appropriate	6.1, 6.2	As appropriate	As appropriate
As appropriate	7	As appropriate	N/A
As appropriate	8	As appropriate	As appropriate
As appropriate	9	As appropriate	As appropriate
N/A	Not Regulated (N.R.)	N/A	N/A

7. SAFETY CONTROL MEASURES:

a. PACKAGING - Prescribed packaging, marking, and labeling is as required by the HMR and the Joint Technical Bulletin 700-2 Department of Defense Ammunition and Explosives Hazard Classification Procedures, hereby referred to as the TB 700-2. Packagings which fall under § 173.62(c), Packaging Instruction 101, must be approved by one of the organizations listed under paragraph 7.c. of this Special Permit.

b. Operational Controls - All Grantees must follow the TB 700-2.

c. Each Interim Hazard Classification (IHC) must be approved (by signature) by a designated Federal employee of one of the following organizations:

- US Army Technical Center for Explosives Safety
- US Navy Naval Ordnance Safety and Security Activity
- US Air Force Safety Center
- US Department of Energy National Nuclear Security Administration Associate Administrator for Safety and Health

d. Each organization listed above is authorized to delegate IHC approval authority to specific Federal employees within supplementary DOD and Department of Energy (DOE) organizations.

e. Any delegation of authority will be in writing and will be made available upon request to a DOT Pipeline Hazardous Materials Safety Administration (PHMSA) Federal employee by the Surface Deployment and Distribution Command (SDDC) Safety Office for the DOD, or by the National Nuclear Security Administration Office of the Associate Administrator for Safety and Health for the DOE.

f. Upon request by a DOT PHMSA Federal employee, the SDDC Safety Office for the DOD or the National Nuclear Security Administration Office of the Associate Administrator for Safety and Health for the DOE, must provide a copy of all

IHCs currently valid for domestic transport in commerce.

g. Every approved IHC is only valid for transport in commerce executed on behalf of the DOD or the DOE as prescribed in the TB 700-2.

h. The duration of the IHC and the procedures for renewal will be governed by the TB 700-2.

i. If an unusual or non-customary need for IHC issuance arises, the DOD or DOE, via email as required, will notify the Associate Administrator through the Approvals and Permits Division of that occurrence and the circumstances.

8. SPECIAL PROVISIONS:

a. A person who is not a holder of this special permit who receives a package covered by this special permit may reoffer it for transportation provided no modification or change is made to the package and it is reoffered for transportation in conformance with this special permit and the HMR.

b. A current copy of this special permit must be maintained at each facility where the package is offered or reoffered for transportation.

9. MODES OF TRANSPORTATION AUTHORIZED: As authorized by the HMR.

10. MODAL REQUIREMENTS: A current copy of this special permit must be carried aboard each cargo vessel, aircraft, or motor vehicle used to transport packages covered by this special permit. The shipper must furnish a copy of this special permit to the air carrier before or at the time the shipment is tendered.

11. COMPLIANCE: Failure by a person to comply with any of the following may result in suspension or revocation of this special permit and penalties prescribed by the Federal hazardous materials transportation law, 49 U.S.C. 5101 et seq:

o All terms and conditions prescribed in this special permit and the Hazardous Materials Regulations, 49 CFR Parts 171-180.

- Persons operating under the terms of this special permit must comply with the security plan requirement in Subpart I of Part 172 of the HMR, when applicable.
- Registration required by § 107.601 et seq., when applicable.

Each "Hazmat employee", as defined in § 171.8, who performs a function subject to this special permit must receive training on the requirements and conditions of this special permit in addition to the training required by §§ 172.700 through 172.704.

No person may use or apply this special permit, including display of its number, when this special permit has expired or is otherwise no longer in effect.

Under Title VII of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—"The Hazardous Materials Safety and Security Reauthorization Act of 2005" (Pub. L. 109-59), 119 Stat. 1144 (August 10, 2005), amended the Federal hazardous materials transportation law by changing the term "exemption" to "special permit" and authorizes a special permit to be granted up to two years for new special permits and up to four years for renewals.

12. REPORTING REQUIREMENTS: Shipments or operations conducted under this special permit are subject to the Hazardous Materials Incident Reporting requirements specified in 49 CFR §§ 171.15 Immediate notice of certain hazardous materials incidents, and 171.16 Detailed hazardous materials incident reports. In addition, the grantee(s) of this special permit must notify the Associate Administrator for Hazardous Materials Safety, in writing, of any incident involving a package, shipment or operation conducted under terms of this special permit.

Issued in Washington, D.C.:

for Dr. Magdy El-Sibaie
Associate Administrator for Hazardous Materials Safety

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Pipeline and Hazardous Material Safety Administration, U.S. Department of Transportation, East Building PHH-30, 1200 New Jersey Avenue, Southeast, Washington, D.C. 20590.

Copies of this special permit may be obtained by accessing the Hazardous Materials Safety Homepage at http://hazmat.dot.gov/sp_app/special_permits/spec_perm_index.htm. Photo reproductions and legible reductions of this special permit are permitted. Any alteration of this special permit is prohibited.

PO: BV/TG

5. EPA (U.S. Environmental Protection Agency), 2008. *Basic Concepts in Environmental Sciences, Module 6: Air Pollutants/Control Techniques*. (EPA 2008)

Jump to main content.

BCES: Module 6: Air Pollutants/Control Techniques

Contact Us **Search:** ○ All EPA ○ This Area Go

- You are here: EPA Home
- Air & Radiation
- Air Quality Planning & Standards
- Air Pollution Training Institute
- Basic Concepts in Environmental Sciences
- Module Contents
- Module 6: Air Pollutants and Control Techniques
- Particulate Matter
- Control Techniques

Module 6: Air Pollutants and Control Techniques - Particulate Matter - Control Techniques

Features

- Quick Reference
- Glossary
- Calculators
- Help
- A-Z Index
- Full Contents

Objectives

1. Describe the basic designs of five different categories of particle control devices and the collection mechanisms they use.
2. Given a description of particulate matter and gas stream conditions, select appropriate particulate control devices for the situation.

Introduction

Within each of the five main categories of particulate control techniques, there are many different design types:

- Gravity settling chamber
- Mechanical collectors
- Particulate wet scrubbers
- Electrostatic precipitators
- Fabric filters

Gravity Settling Chambers

As the name implies, this category of control devices relies upon gravity settling to remove particles from the gas stream. Gravity settling chambers are used only for very large particles in the upper end of the supercoarse size range (approximately 75 micrometers and larger). The very low terminal settling velocities of most particles encountered in the field of air pollution limit the usefulness of gravity settling chambers. (See the lesson on Control Techniques in Module 3 for more information about terminal settling velocities.)

The stringent control requirements adopted in the late 1960s through early 1970s have resulted in a sharp decline in the use of this type of collector. There are very few gravity settling chambers still in commercial use.

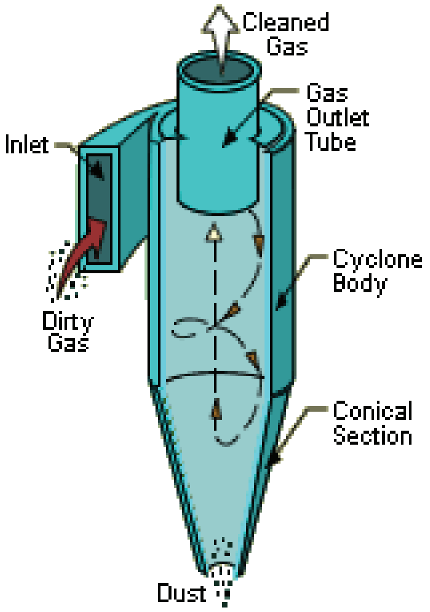
Mechanical Collectors

Mechanical collectors use the inertia of the particles for collection. The particulate-laden gas stream is forced to spin in a cyclonic manner. The mass of the particles causes them to move toward the outside of the vortex. Most of the large-diameter particles enter a hopper below the cyclonic tubes while the gas stream turns and exits the tube.

There are two main types of mechanical collectors: (1) large-diameter cyclones, and (2) small-diameter multi-cyclones. Large-diameter cyclones are usually one to six feet in diameter; while small-diameter multi-cyclones usually have diameters between 3 and 12 inches.

A typical large-diameter cyclone system is shown in Figure 1. The gas stream enters the cyclone tangentially and creates a weak vortex of spinning gas in the cyclone body. Large-diameter particles move toward the cyclone body wall and then settle into the hopper of the cyclone. The cleaned gas turns and exits the cyclone. Large-diameter cyclones are used to collect particles ranging in diameters from one-sixteenth inch to more than 6 inches.

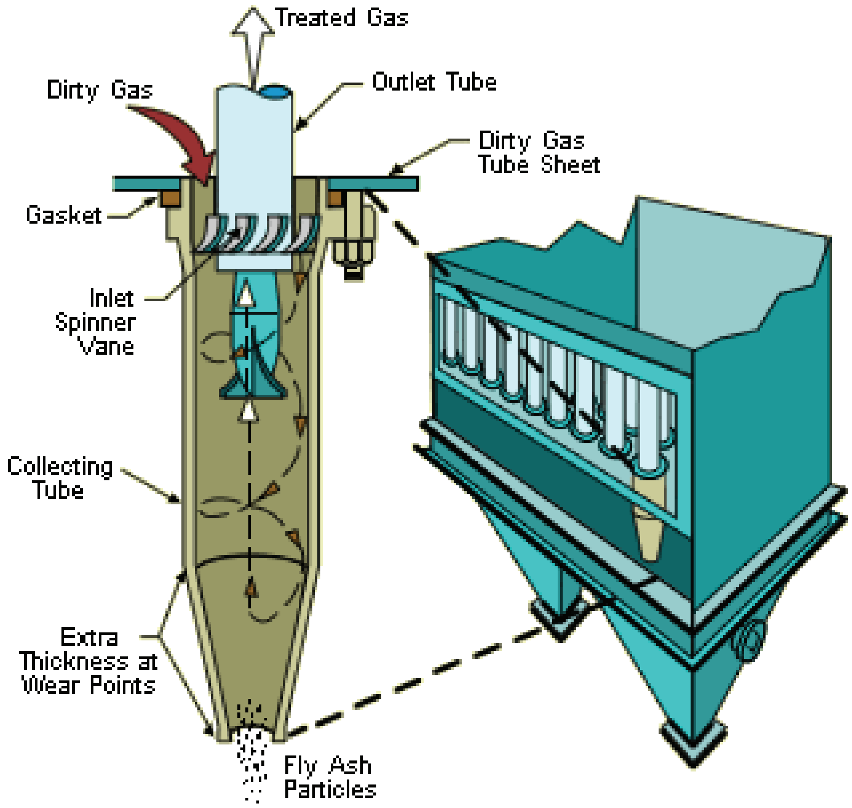
Figure 1. Top-Inlet Large-Diameter Cyclone



In systems where the large-diameter cyclone is located after the fan (positive pressure), the treated gas is usually discharged directly from the cyclone. In systems where the cyclone is located before the fan (negative pressure), the gas stream is either exhausted from a separate stack or from the discharge duct of the fan itself. In negative pressure systems, a solids discharge valve is used to prevent air infiltration up through the hopper area.

A small-diameter cyclone tube is shown in Figure 2. Vanes located on the inlet of each of the tubes create the spinning movement of the gas stream. Most of the commercial tubes are six, nine, or twelve inches in diameter. Due to the limited gas handling capacity of each tube, large numbers of tubes are mounted in parallel in a single collector.

Figure 2. Small-Diameter Multi-Cyclone Collector

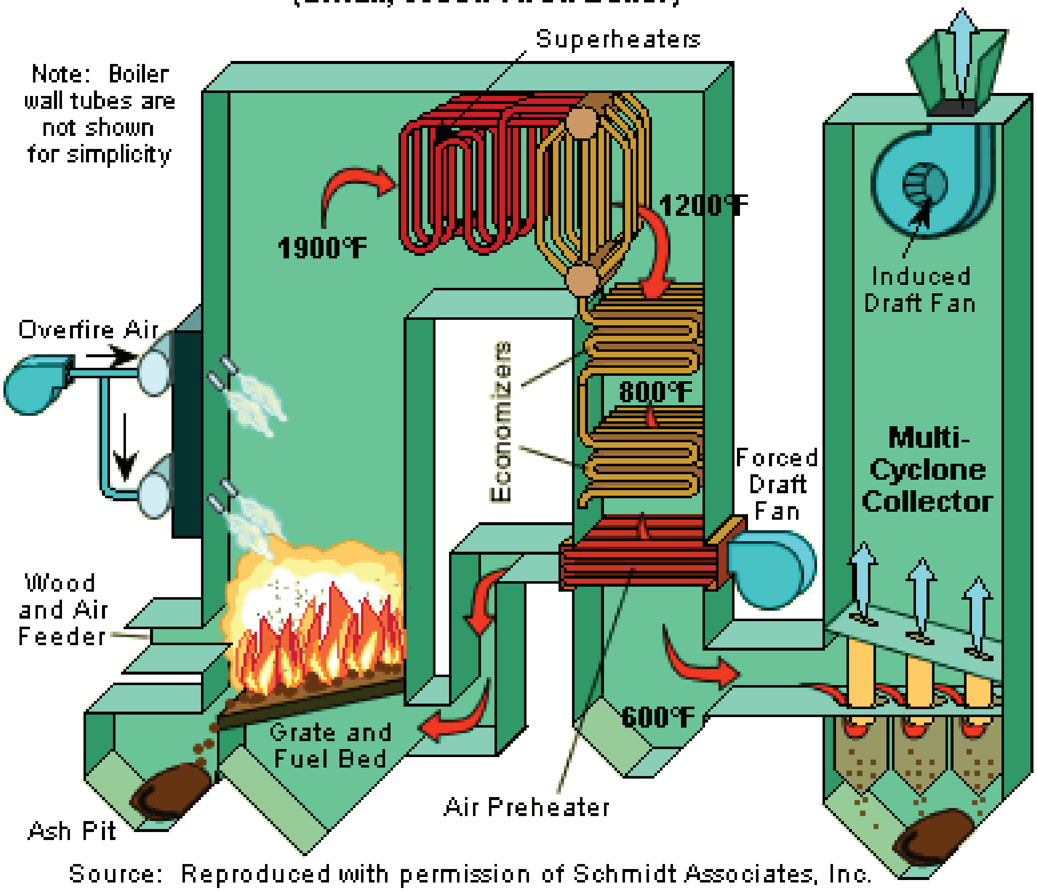


The small-diameter of the cyclone tube creates more rapid spinning of the gas stream than is possible in large-diameter cyclones. Furthermore, the particles moving outward in the spinning gas stream have a relatively shorter distance to travel in a small-diameter multi-cyclone tube before they reach the cyclone body wall. These features allow small-diameter multi-cyclones to collect considerably smaller particles than large-diameter cyclones can. Small-diameter multi-cyclones, such as the one shown in Figure 2 are capable of removing particles having diameters down to 5 micrometers. Conversely, the small-diameter multi-cyclones are not generally used for very large diameter material, such as one-eighth inch and above, because large particles may plug the spinner vanes in the multi-cyclone tubes.

Some mechanical collectors are specially designed to provide high-efficiency particulate matter collection down to a particle size of one micrometer. These have higher gas velocities within the cyclone tubes and different cyclone geometries than those shown in Figure 2.

A typical application of a conventional multi-cyclone collector is shown in Figure 3. In this example, the multi-cyclone is located after a small, wood-fired boiler and is used as a precollector for the fabric filter.

Figure 3. Small-Diameter Multi-Cyclone Collector (Small, Wood-Fired Boiler)



Source: Reproduced with permission of Schmidt Associates, Inc.

Mechanical collectors are used whenever the particle size distributions generated by the process are relatively large (greater than 5 micrometers) and/or the control efficiency requirements are in the low-to-moderate range of 50 to 90%.

They are also used as the pre-collector of large-diameter embers generated in some combustion systems. Removal of the embers is necessary to protect high-efficiency particulate control systems downstream from the mechanical collectors.

Most mechanical collectors are not applicable to industrial sources that generate sticky and/or wet particulate matter. These materials can accumulate on the cyclone body wall or the inlet spinner vanes of conventional multi-cyclone collectors.

Particulate Wet Scrubbers

There are a number of major categories of particulate wet scrubbers. The list provided below is not exhaustive (nor is it listed in order of efficiency).

- Venturis

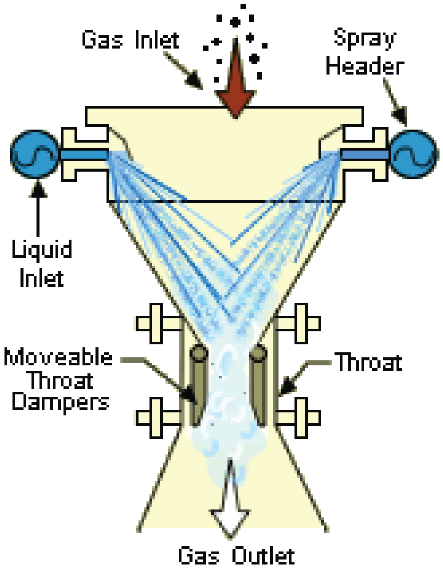
- Impingement and Sieve Plates
- Spray Towers
- Mechanically Aided
- Condensation Growth
- Packed Beds
- Ejector
- Mobile Bed
- Caternary Grid
- Froth Tower
- Oriented Fiber Pad
- Wetted Mist Eliminators

This lesson discusses only three of the above types of scrubbers: venturis, impingement plate scrubbers, and spray towers.

Venturi Scrubbers

A typical venturi throat is shown in Figure 4. Particulate matter, which accelerates as it enters the throat, is driven into the slow moving, large water droplets that are introduced near the high velocity point at the inlet of the venturi throat. The adjustable dampers in the unit illustrated are used to adjust the open cross-sectional area and thereby affect the speed of the particles entrained in the inlet gas stream.

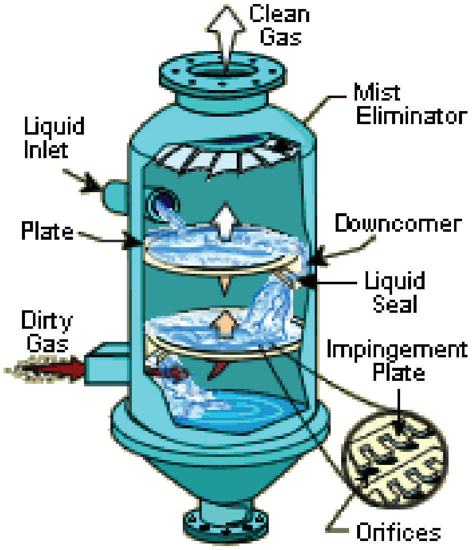
Figure 4. Adjustable-Throat Venturi Scrubber



Impingement Plate Scrubbers

An impingement plate scrubber is shown in Figure 5. These scrubbers usually have one to three horizontal plates, each of which has a large number of small holes. The gas stream accelerating through the holes atomizes some water droplets in the water layer above the plate. Particles impact into these water droplets.

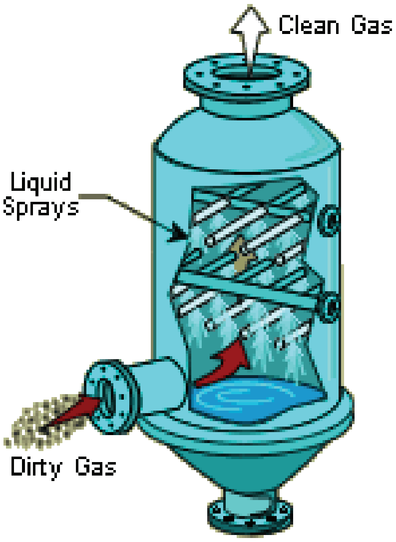
Figure 5. Impingement Plate Scrubber



Spray Tower Scrubbers

A typical spray tower scrubber is shown in Figure 6. This is the simplest type of particulate wet scrubber in commercial service. Sets of spray nozzles located near the top of the scrubber vessel generate water droplets that impact with particles in the gas stream as the gas stream moves upwards.

Figure 6. Spray Tower Scrubber



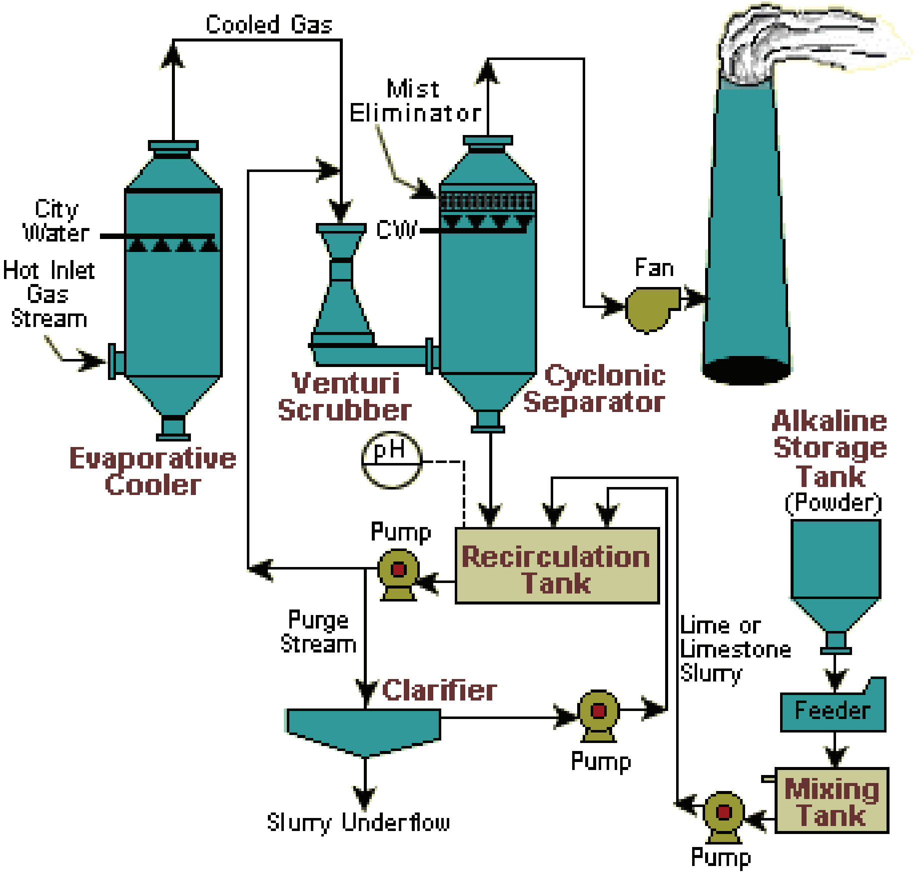
Each of the categories of particulate wet scrubbers listed earlier has a large number of different design types. For example, venturi scrubbers include the following different design types: (1) fixed throat, (2) adjustable throat, (3) collision (opposed-adjustable), (4) single rod decks, and (5) multiple rod decks. Spray tower scrubbers include these design types: (1) open, (2) cyclonic, and (3) baffled spray towers. The scrubber categories listed above comprise more than fifty different types of scrubbers in common commercial use. Scrubbers are by far the most diverse group of air pollution control devices used for particulate control.

Wet Scrubbing Systems

Each particulate wet scrubber vessel is part of a large, and sometimes complex, wet scrubbing system. For example, Figure 7 illustrates a venturi scrubber in a scrubbing system. The evaporative cooler, located before the venturi scrubber in the system, cools the gas stream, which serves the following purpose:

1. It protects the construction materials of the venturi throat.
2. It helps to homogeneously and heterogeneously nucleate vapor phase material emitted from the process before it reaches the scrubbing system.
3. It prevents the water droplets from evaporating and inhibiting inertial impaction.

Figure 7. Example of a Particulate Wet Scrubbing System



Located after the venturi scrubber, the cyclonic separator removes entrained water droplets from the gas stream leaving the venturi. The cyclonic separator consists of a cyclonic vessel and a horizontal mist eliminator. The overall scrubbing system includes pumps for liquid recirculation, a tank to treat the liquid being recirculated, an alkali addition unit to control the liquid pH, a purged liquid treatment unit, a fan for gas movement, and a stack. There are a wide variety of wet scrubber system designs; however, these components are present in many systems, regardless of which type of particulate matter scrubber is used.

Scrubber Operating Principles

The numerous different types of particulate wet scrubbers mentioned earlier have some important common characteristics, which allow for a general discussion about wet scrubber operating principles and applicability. All particulate wet scrubber designs utilize particle and/or droplet inertia as the fundamental force to transfer particles from the gas stream to the liquid stream. Within the scrubber, particle-laden air is forced to contact the liquid droplets, sheets of liquid on a packing material, or jets of liquid from a plate. Particles with too much inertia impact on the water droplet, water sheet, or water jet instead of passing around the "target" with the gas stream.

Note: Two important particle collection mechanisms for scrubbers, inertial impaction and interception, are discussed in the lesson on Collection Mechanisms in Module 3.

The ability of a particulate wet scrubber to remove particles depends on two or more of the following variables:

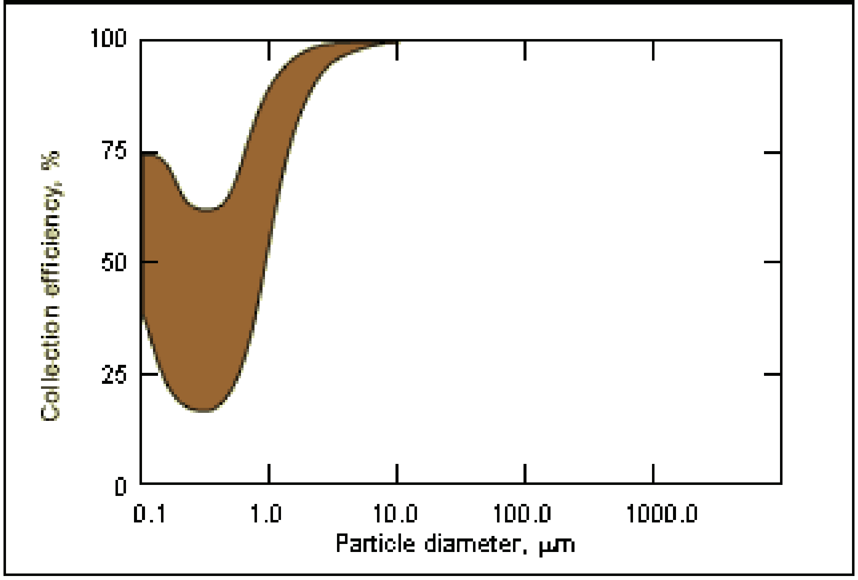
- The size (aerodynamic diameter) of the particle
- The velocity of the particle
- The velocity of the droplet, sheet, or jet

The venturi scrubber throat shown in Figure 4 illustrates these principles. The collection efficiency increases as the gas stream accelerates upon entering the throat. The large, 100- to 1,000-micrometer water droplets formed from the inlet stream move relatively slowly compared with the small-diameter particles in the accelerating gas stream. Due to the difference in the velocities of the particles and droplets, inertial impaction and interception occur in the venturi throat. The effectiveness of the impaction increases for larger particles. The importance of the difference in velocity and the particle size is discussed in more detail in Module 3. (See the section on Inertial Impaction and Interception in the lesson on Collection Mechanisms.)

Collection Efficiency of Wet Scrubbers

All of the particulate wet scrubbers in commercial use depend on inertial impaction. However, the velocities of the particle-laden gas stream and the liquid targets vary substantially. Accordingly, there are substantial differences in the ability of particulate wet scrubbers to collect particles less than approximately 5 micrometers. This is illustrated in Figure 8. If a significant portion of the particulate matter mass is composed of particles less than 5 micrometers, care is needed to select the type of scrubber that is effective in this size range.

Figure 8. Efficiency of Several Types of Particulate Wet Scrubbers



It should be noted that some types of wet scrubbers have limited capability to remove particles in the less than 0.3-micrometer range. Methods of particle collection in this very small size range take advantage of these particles' tendencies to diffuse slowly due to their interactions with gas molecules (Brownian diffusion). In other words, these particles are so small that their movement is influenced by collisions with individual molecules in the gas stream.

Advantages and Disadvantages of Scrubbers

Many types of particulate wet scrubbers can provide high efficiency control of particulate matter. One of the main advantages of particulate wet scrubbers is that they are often able to simultaneously collect particulate matter and gaseous pollutants. Also, wet scrubbers can often be used on sources that have potentially explosive gases or particulate matter. They are compact and can often be retrofitted into existing plants with very limited space.

One of the main disadvantages of particulate wet scrubbers is that they require make-up water to replace the water vaporized into the gas stream and lost to purge liquid and sludge removed from the scrubber system. Wet scrubbers generate a waste stream that must be treated properly.

Electrostatic Precipitators

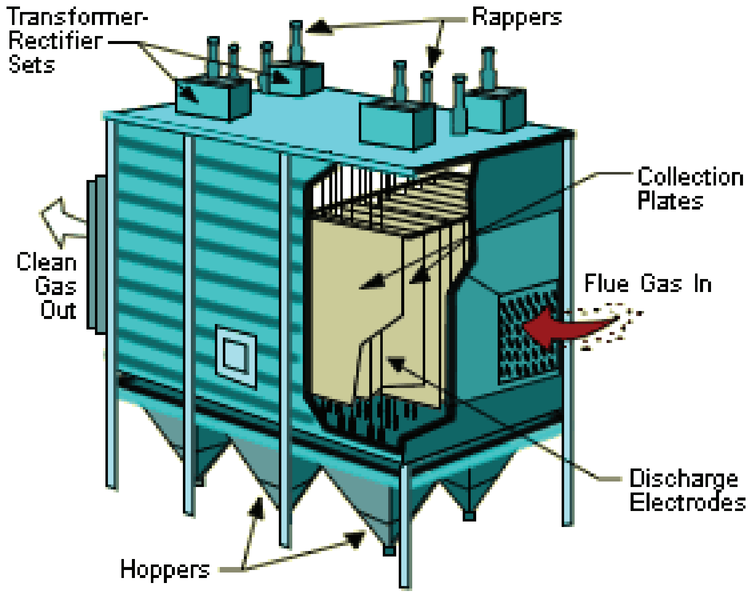
Types of Electrostatic Precipitators

An electrostatic precipitator (ESP) uses nonuniform, high-voltage fields to apply large electrical charges to particles moving through the field. The charged particles move toward an oppositely charged collection surface, where they accumulate.

There are three main styles of electrostatic precipitators: (1) negatively charged dry precipitators, (2) negatively charged wetted-wall precipitators, and (3) positively charged two-stage precipitators. The negatively charged dry precipitators are the type most frequently used on large applications such as coal-fired boilers, cement kilns, and kraft pulp mills. Wetted-wall precipitators (sometimes called wet precipitators) are often used to collect mist and/or solid material that is moderately sticky. The positively charged two-stage precipitators are used only for the removal of mists. In the remainder of this section, the discussions will focus only on negatively charged dry precipitators because these are the most common types of precipitators.

Figure 9 shows the scale of a typical electrostatic precipitator used at a coal-fired boiler.

Figure 9. Conventional Electrostatic Precipitator



Essentially all of these units are divided into a number of separately energized areas that are termed **fields** (see Figure 10). Most precipitators have between three and ten fields in series along the gas flow path. On large units, the precipitators are divided into a number of separate, parallel chambers, each of which has an equal number of fields in series. There is a solid partition or physical separation between the 2 to 8 chambers that are present on the large systems.

Figure 10. Arrangements of Fields and Chambers in an ESP

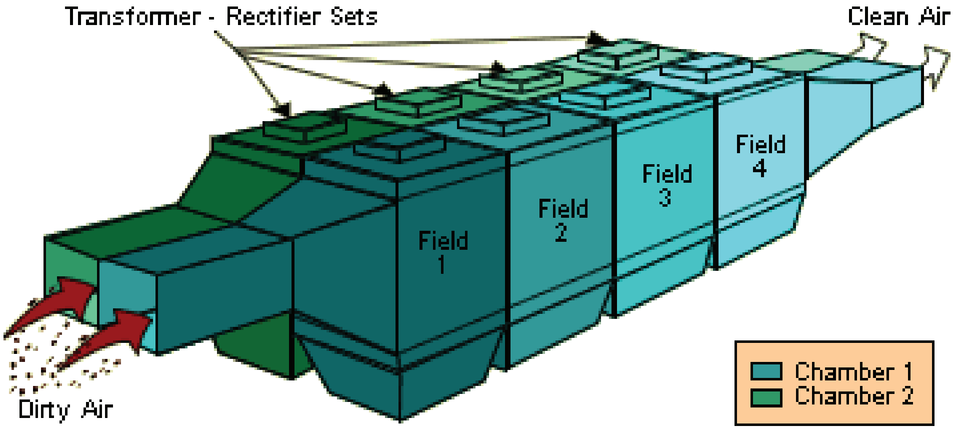


Figure 11 shows a single gas passage in a typical electrostatic precipitator. A high-voltage electrical charge is applied to the small-diameter electrode shown in the center of the picture. The large vertical surfaces on both sides of the electrode are electrically grounded collection plates. The particles in the gas stream, which is moving horizontally through the unit (into the photograph shown in Figure 11), become charged and then move to either side.

Figure 11. Single Nine-Inch Gas Passage (ESP)

Advantages and Disadvantages of ESPs

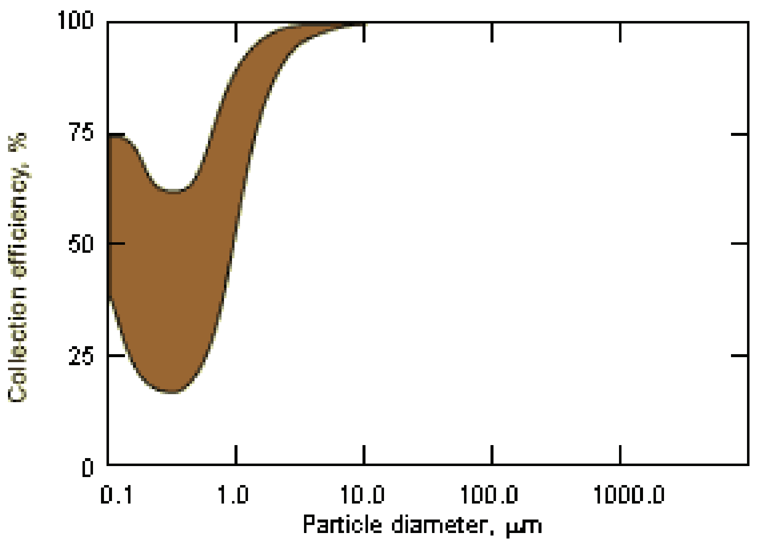
Electrostatic precipitators can have very high efficiencies due to the strong electrical forces applied to the small particles. These types of collectors can be used when the gas stream is *not* explosive and does *not* contain entrained droplets or other sticky material.

The composition of the particulate matter is very important because it influences the electrical conductivity within the dust layers on the collection plate. **Resistivity**, an important concept associated with electrostatic precipitators, is a measure of the ability of the particulate matter to conduct electricity and is expressed in units of ohm-cm. As the resistivity increases, the ability of the particulate matter to conduct electricity decreases. Precipitators can be designed to work in any resistivity range; however, they usually work best when the resistivity is in the moderate range (10^8 to 10^{10} ohms-cm).

Collection Efficiency of ESPs

The typical Particle Size - Collection Efficiency curve for a properly sized and operated electrostatic precipitator is shown in Figure 12. The efficiency is usually at a minimum in the range of 0.1 to 0.5 micrometers. The shape of the efficiency curve is the combined effect of two particle electrical charging mechanisms, neither of which is highly effective in this particle size range. It should be noted that this decrease in efficiency occurs in the same particle size range as for particulate wet scrubbers. However, the reason for this decreased efficiency zone is entirely different than that for particulate wet scrubbers.

Figure 12. Particle Size-Efficiency Curve for ESPs



Fabric Filters

Operating Principles

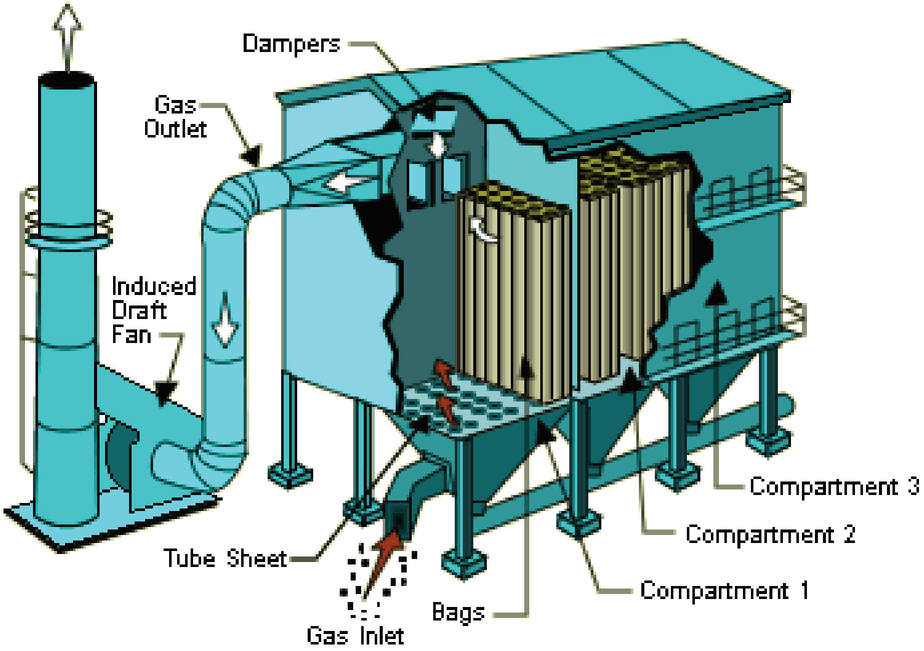
Fabric filters collect particulate matter on the surfaces of filter bags. Most of the particles are captured by inertial impaction, interception, Brownian diffusion, and sieving on already collected particles that have formed a dust layer on the bags. (Inertial impaction, interception, and Brownian diffusion are discussed further in the lesson on Collection Mechanisms in Module 3.) The fabric material itself can capture particles that have penetrated through the dust layers. Electrostatic attraction may also contribute to particle capture in the dust layer and in the fabric itself. Due to the multiple mechanisms of particle capture possible, fabric filters can be highly efficient for the entire particle size range of interest in air pollution control.

Types of Fabric Filters

A **reverse-air-type fabric filter**, shown in Figure 13, is one of the major categories of fabric filters. It is used mainly for large industrial sources. In this type of unit, the particle-laden gas stream enters from the bottom and passes into the inside of the bags. The dust cake accumulates on the inside surfaces of the bags. Filtered gas passes through the bags and is exhausted from the unit.

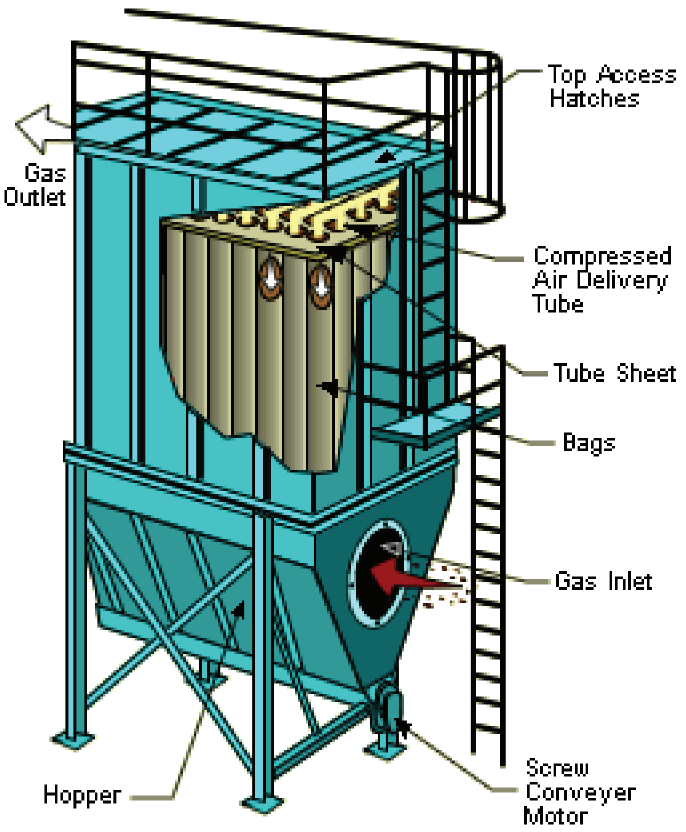
When cleaning is necessary, dampers are used to isolate a compartment of bags from the inlet gas flow. Then, some of the filtered gas passes in the reverse direction (from the outside of the bag to the inside) in order to remove some of the dust cake. The gas used for reverse air cleaning is re-filtered and released.

Figure 13. Reverse Air Fabric Filter



Another common type of fabric filter is the **pulse jet** shown in Figure 14. In this type of unit, the bags are supported on metal wire cages that are suspended from the top of the unit. Particulate-laden gas flows around the *outside* of the bags, and a dust cake accumulates on the exterior surfaces. When cleaning is needed, a very-short-duration pulse of compressed air is injected at the top inside part of each bag in the row of bags being cleaned. The compressed air pulse generates a pressure wave that moves down each bag and, in the process, dislodges some of the dust cake from the bag.

Figure 14. Pulse Jet Fabric Filter



Advantages and Disadvantages of Fabric Filters

Fabric filters are used in a wide variety of applications where high efficiency particulate collection is needed. The control efficiencies usually range from 99% to greater than 99.5% depending on the characteristics of the particulate matter and the fabric filter design. As mentioned earlier, fabric filters can be very efficient at collecting particles in the entire size range of interest in air pollution control.

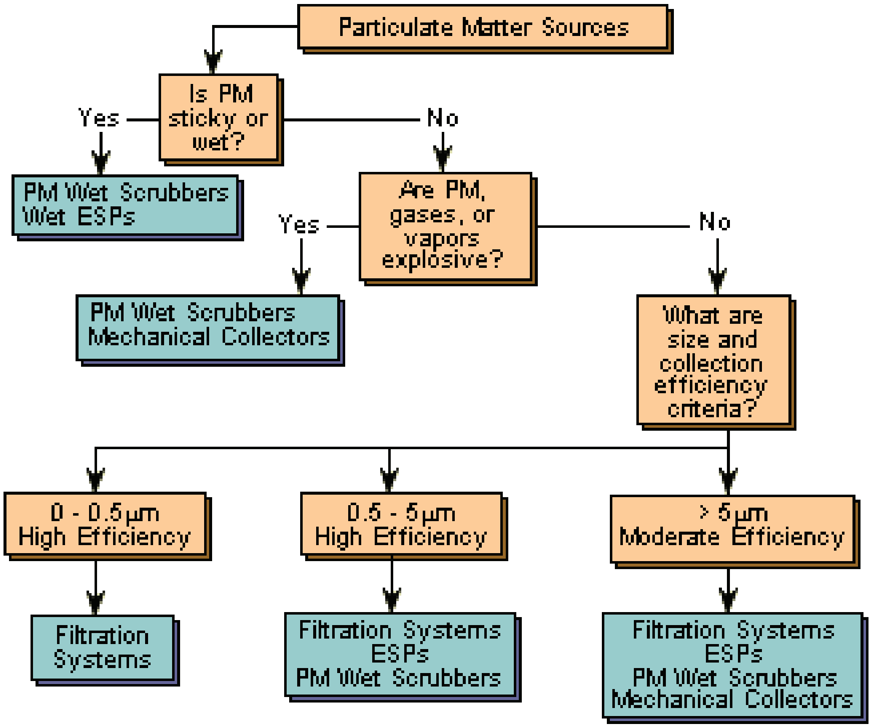
The performance of fabric filters is usually independent of the chemical composition of the particulate matter. However, they are not used when the gas stream generated by the process equipment includes corrosive materials that could chemically attack the filter media. Fabric filters are also not used when there are sticky or wet particles in the gas stream. These materials accumulate on the filter media surface and block gas movement.

Fabric filters must be designed carefully if there are potentially combustible or explosive particulate matter, gases, or vapors in the gas stream being treated. If these conditions are severe, alternative control techniques, such as wet scrubbers, are often used.

General Applicability of Particulate Control Systems

Particulate matter control systems are often selected based on the general criteria listed in Figure 15.

Figure 15. General Applicability of Particulate Control Systems



If there is a high concentration of wet and/or sticky particulate matter, either a particulate wet scrubber or a wet electrostatic precipitator is used. If wet or sticky materials are present with combustible materials or explosive gases or vapors, the particulate wet scrubber is most appropriate.

If the particulate matter is primarily dry, mechanical collectors, particulate wet scrubbers, conventional electrostatic precipitators, and fabric filters can be used. The next step in the selection process is to determine if the particulate matter and/or gases and vapors in the gas stream are combustible or explosive. If so, then mechanical collectors or particulate wet scrubbers can be used because both of these categories of systems can be designed to minimize the risks of ignition. In some cases, a fabric filter can also be used if it includes the appropriate safety equipment. An electrostatic precipitator is not used due to the risk of ignition caused by electrical sparking in the precipitator fields. When selecting between mechanical collectors and wet scrubbers, mechanical collectors are the more economical choice. They have a lower purchase cost and a lower operating cost than wet scrubbers.

If the dry particulate matter is present in a gas stream that is not combustible or explosive, the selection depends on the particle size range and the control efficiency requirements. If a significant portion of the gas stream is in the less than 0.5-micrometer size range, and high efficiency control is needed, a fabric filter is the most common choice. If a significant portion of the particulate matter is in the 0.5- to 5-micrometer size range, and high efficiency control is needed, fabric filters, electrostatic precipitators, or particulate wet scrubbers (certain types) could be used. If most of the particulate matter is larger than 5 micrometers, any of the four main types of particulate control systems could be used.

There are numerous exceptions to the general applicability information presented above due to site-specific process conditions and unique particulate matter control systems. Nevertheless, this chart provides a general indication of the uses and limitations of many commercially available particulate matter control systems.

Practice Problems
Particulate Matter - Control Techniques

Instructions:

Complete the Practice Problems before proceeding to the next lesson. Click on the button below.

Practice Problems

Previous Section
Particulate Matter: Formation Mechanisms

Next Lesson
Sulfur Oxides: Contents

APTI Virtual Classroom

Local Navigation

- Module 6:
  Air Pollutants and Control Techniques
- Particulate Matter
- Sulfur Oxides
- Ozone
- Volatile Organic Compounds
- Incompletely Oxidized Compounds

- Dioxins and Furans
- Halogens
- Review Exercises

- EPA Home
- Privacy and Security Notice
- Contact Us

- Share
  - Del.icio.us
  - Digg
  - Facebook
  - reddit
  - Slashdot
  - StumbleUpon
  - What is this?

Last updated on Friday, April 4th, 2008.

http://www.epa.gov/apti/bces/module6/matter/control/control.htm

Print As-Is

Jump to main content.

6. Fresquez, P.R., May 2011. *Chemical Concentrations in Field Mice Collected from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 At Los Alamos National Laboratory*. LA-UR-11-10614. (Fresquez 2011)

LA-UR-11-10614

Title:	Chemical Concentrations in Field Mice from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory
Author(s):	Fresquez, Philip R.
Intended for:	Report

Contents

List of Figures

List of Tables

CHEMICAL CONCENTRATIONS IN FIELD MICE COLLECTED FROM OPEN-DETONATION FIRING SITES TA-36 MINIE AND TA-39 POINT 6 AT LOS ALAMOS NATIONAL LABORATORY

P.R. Fresquez

ABSTRACT

Field mice (mostly *Peromyscus* spp.) were collected at two open-detonation (high explosive) firing sites—Minie at Technical Area (TA) 36 and Point 6 at TA-39—at Los Alamos National Laboratory in August of 2010 and in February of 2011 for chemical analysis. Samples of whole body field mice from both sites were analyzed for target analyte list elements (mostly metals), dioxin/furans, polychlorinated biphenyl congeners, high explosives, and perchlorate. In addition, uranium isotopes were analyzed in a composite sample collected from TA-36 Minie. In general, all constituents, with the exception of lead at TA-39 Point 6, in whole body field mice samples collected from these two open-detonation firing sites were either not detected or they were detected below regional statistical reference levels (99% confidence level), biota dose screening levels, and/or soil ecological chemical screening levels. The amount of lead in field mice tissue collected from TA-39 Point 6 was higher than regional background, and some lead levels in the soil were higher than the ecological screening level for the field mouse; however, these levels are not expected to affect the viability of the populations over the site as a whole.

INTRODUCTION

Small mammal mark-recapture studies were conducted at Los Alamos National Laboratory (LANL) at two open-detonation high explosive research and development firing sites—Minie at Technical Area (TA) 36 and Point 6 at TA-39—during August of 2010 (Bennett and Robinson 2011). The purpose of the mark-recapture studies was to evaluate the small mammal (field mice) species occurrence and population abundance at the open-detonation firing sites when compared to an undeveloped (control) site. Based on population abundance, species diversity and composition, sex ratios, and weights, the open-detonation firing sites do not appear to be adversely affecting small mammal population dynamics when compared to the undeveloped background site.

On the final day of trapping for the population study at the two detonation sites in 2010, all animals were euthanized and submitted for chemical analysis to investigate the concentrations of various chemicals, particularly dioxin and furans, associated with open-detonation activities at LANL. Additional samples for chemical analyses were collected at both firing sites in February 2011. This chemical uptake analysis was conducted to gather information on the potential impact that the open-detonation operations conducted at TA-36 Minie and TA-39 Point 6 may have historically had on the sites. Field mice are effective indicators of contaminant presence due to their feeding and activity habits (i.e., burrowing) (Arthur et al. 1987), and at LANL they are used as the biota (radionuclide) dose (McNaughton 2006) and (chemical) uptake (Fresquez et al. 2010) models for terrestrial mammals because they have the smallest home range (~100 m^2).

METHODOLOGY

Site Descriptions

LANL is situated in northern New Mexico on the Pajarito Plateau (Figure 1), a series of finger-like mesas speared by east-to-west-oriented canyons. The mesa tops slope eastward from approximately 2377 m (7800 ft) to 1890 m (6200 ft). The surrounding land is largely undeveloped, including large tracts held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, and San Ildefonso Pueblo.

The firing sites are in remote locations and specialize in experimental studies of the dynamic properties of high explosive materials under high-pressure and temperature conditions. The facilities that make up the explosives testing operations are used primarily for research, development, test operations, and detonator development and testing related to the US Department of Energy Stockpile Stewardship Program (DOE 2008).

TA-36 Minie (Solid Waste Management Unit [SWMU] 36-004[c]) is located near the head of Fence Canyon (Figure 2). TA-39 Point 6 (SWMU 39-004[c]) is located in the bottom of Ancho Canyon (Figure 3). Both of the firing sites involved within this study have been in use since the 1950s. The vegetation consists of piñon (*Pinus edulis* Engelm.)

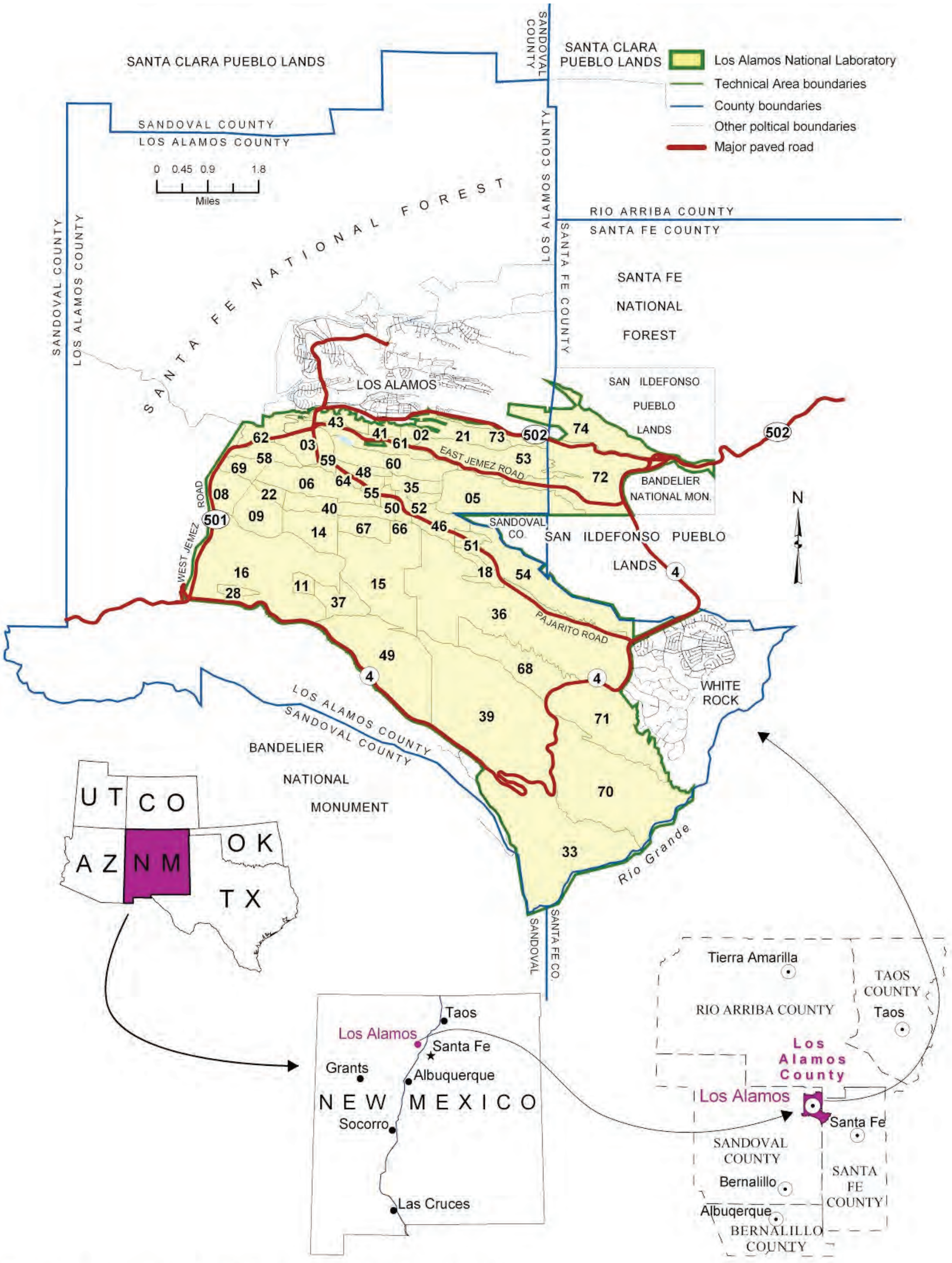


Figure 1. Location of Los Alamos National Laboratory (from Bennett and Robinson 2011)

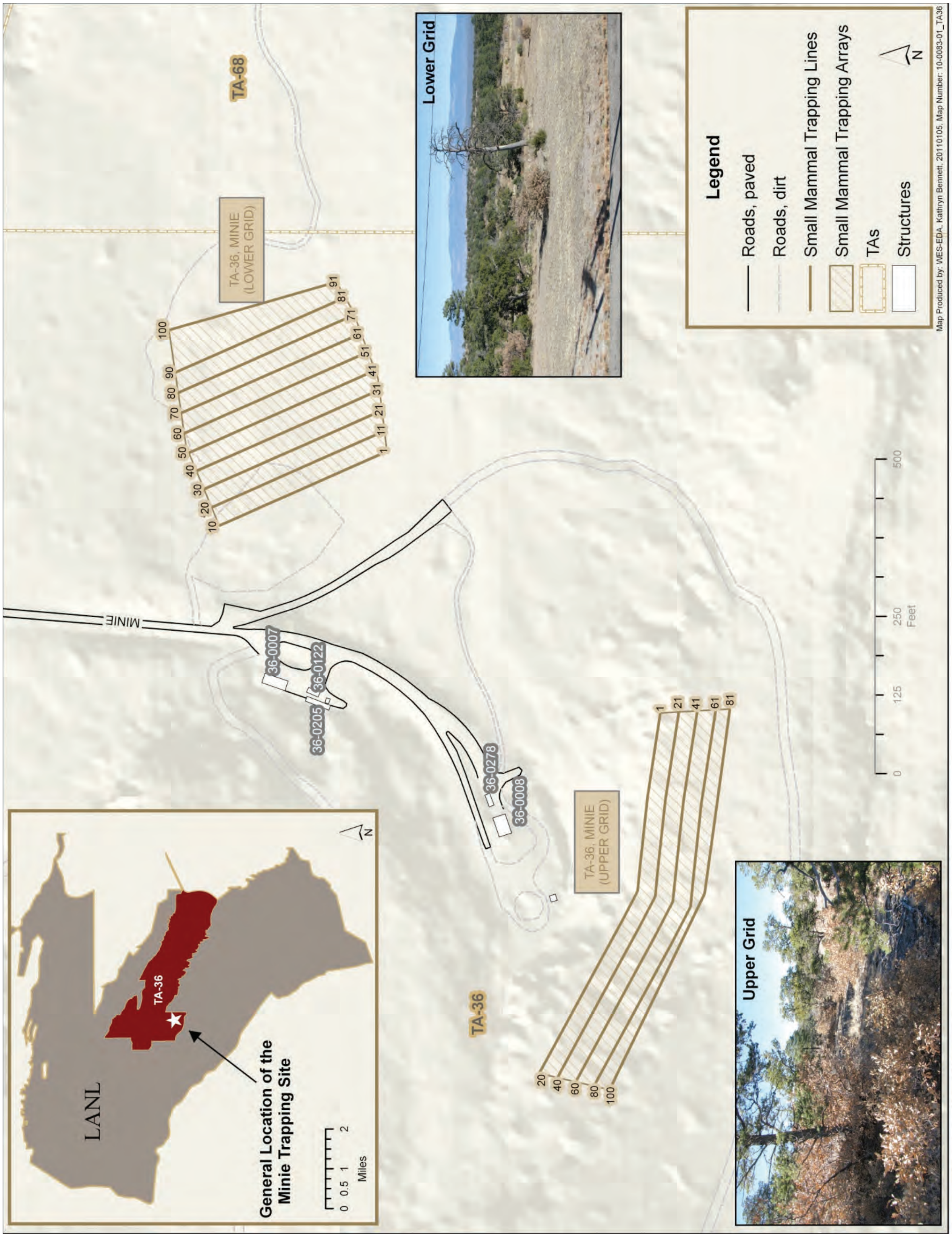


Figure 2. TA-36 Minie trapping location (from Bennett and Robinson 2011)

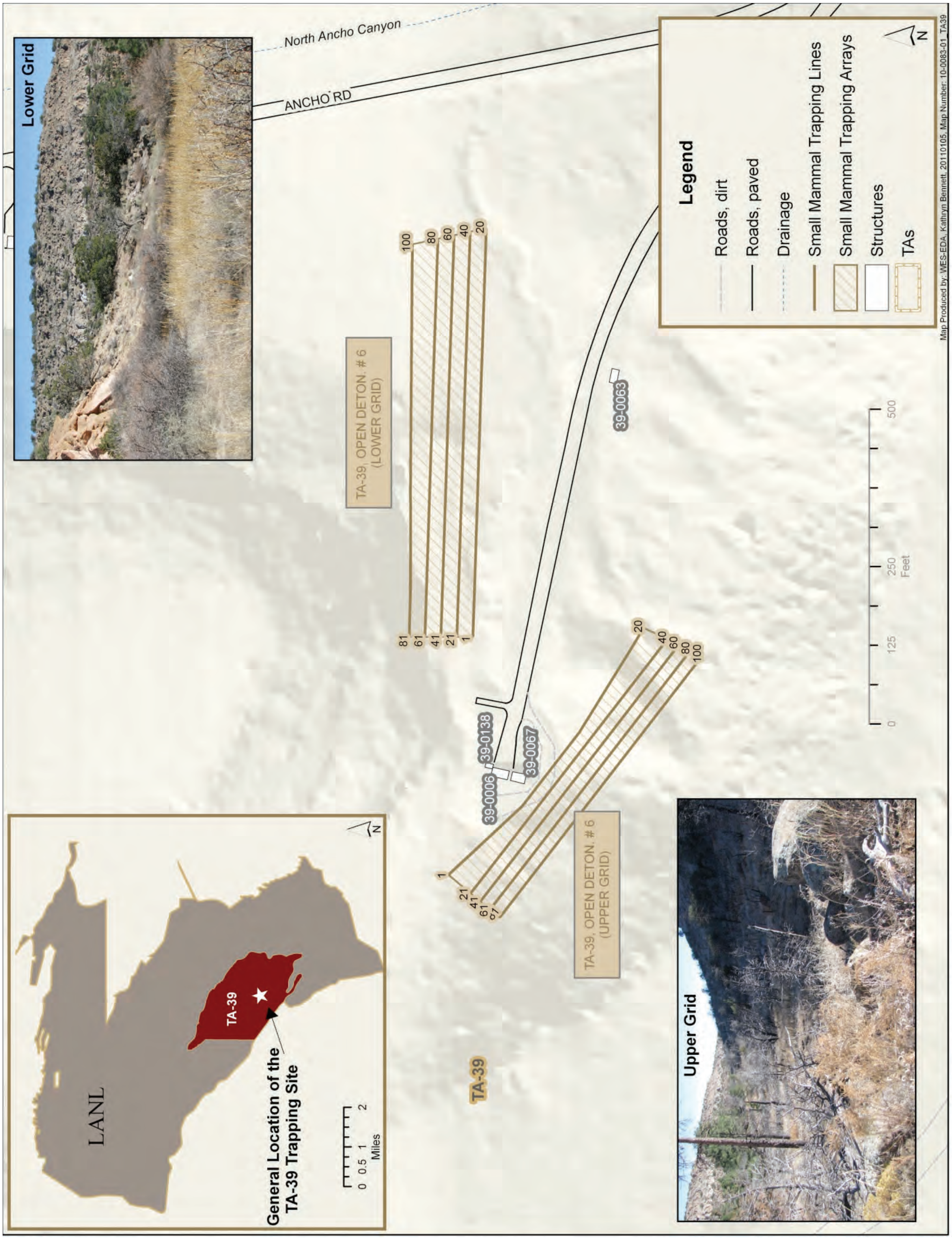


Figure 3. TA-39 Point 6 trapping location (from Bennett and Robinson 2011)

-(*Juniperus monosperma* [Englem.] Sarg.) with interspersed ponderosa pine (*Pinus ponderosa* C. Lawson) and gambel oak (*Quercus gambelii* Nutt.).

Small Mammal Trapping

Trapping grids, for the population study, were set up at TA-36 Minie and TA-39 Point 6 (see Figures 2 and 3). Each firing site was assigned two grids—lower and upper—with grid configuration based on topography of each site. The lower grids consisted of 10 lines of 10 traps with spacing of 10 m per trap and 10 m between each line, and these grids were situated downgradient of the firing site. The upper grids consisted of five lines of 20 traps with spacing of 10 m per trap and 10 m between each line, and these grids were situated adjacent and upgradient to the firing site. Each grid had 100 traps.

Trapping at each location took place over four consecutive nights. Traps were baited in the late afternoon with a molasses-coated horse feed and checked early each morning. Animals were collected and taken to a central location for processing. At the processing location, field mice were identified to species, weighed, sexed, and measured (total body, tail, hind foot, and ear). These data can be found in Bennett and Robinson (2011). Each animal was ear tagged and released. On the final day of trapping in 2010, all animals were euthanized, placed in double zip lock bags, and stored in a freezer at 4 degrees C. Additional samples for chemical analysis were collected in February 2011. All sample information can be found in the Appendix; the most common sample consisted of deer mice (*Peromyscus maniculatus*).

Captured mouse being weighed.

ALS (formally Paragon Analytics) Group analyzed the field mice (whole body) samples collected from TA-36 (Minie) for uranium-234, uranium-235, and uranium-238; and for target analyte list (TAL) elements (aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, zinc, antimony, arsenic, cadmium, lead, selenium, silver, thallium, and mercury) from both sites. Polychlorinated biphenyls (PCBs) (congeners, homologs, and totals) and dioxin/furans in whole body field mice from both sites were analyzed by Cape Fear Analytical Laboratory, Inc., and General Engineering Laboratories analyzed the samples for high explosives and perchlorate.

Biota Comparison Levels

Radionuclides and chemical concentrations in biota from Laboratory areas are first compared to regional statistical reference levels (RSRLs). RSRLs, which represent natural and fallout levels, are the upper-level background concentrations (mean plus three standard deviations = 99% confidence level) for radionuclides and chemicals calculated from biota that was collected from regional locations away from the influence of the Laboratory (over nine miles away) (DOE 1991). For radionuclides, TAL elements, high explosives, dioxin/furans, perchlorate, and PCBs in whole body field mice, RSRLs can be found in Fresquez (2009, 2011).

If the levels of radionuclides in field mice collected from potentially impacted areas are higher than the RSRLs, the concentrations are compared to (tissue) screening levels (SLs) and then to standards. Biota SLs were set at 10% (0.01-rad/day) of the standard for terrestrial animals (0.1-rad/day) (DOE 2002) by the dose assessment team at the Laboratory to identify the potential contaminants of concern (McNaughton 2006).

There are no regulatory SLs for chemicals in tissues of biota; so if chemicals in biota are higher than the RSRLs then the chemical concentration in the soil at the place of collection are compared with ecological screening levels (ESLs) (LANL 2010). ESLs are LANL derived and are designed to reflect the concentration of a chemical in the soil that is not expected to produce any adverse effects on selected biota receptors that commonly come into contact with soil or ingest biota that live in or on soil (i.e., they are the concentrations that are protective of ecological receptors under chronic exposure conditions).

RESULTS

TA-36 Minie

<u>a. Uranium Isotopes</u>. The concentration of uranium-238 in a composite whole body field mouse sample (n = 5 subsamples) was the only uranium isotope out of the three that was detected in higher amounts than the RSRL (Table 1). The amount of uranium-238, however, was two orders of magnitude below the biota dose screening level. Based on the isotopic distribution of uranum-234 and uranium-238, the source of uranium was depleted uranium.

Table 1. Uranium isotopes (pCi/g ash) in a composite whole body field mouse sample (n = 5) collected from TA-36 Minie in 2010. (Bold values are higher than 3TPU and the RSRL.)

Radionuclide[a]	**Sample #3214**	**3TPU**[b]	**RSRL**[c]	**SL**[d]
Uranium-234	0.066	0.025	0.11	46
Uranium-235/236	0.0055	0.0069	0.0092	46
Uranium-238	**0.261**	0.072	0.098	46
	DU[e]			

[a] Method was by alpha spectrometry.

[b] Values are the total propagated uncertainty at the 99% confidence level.

[c] Regional Statistical Reference Level; this is the upper-limit regional background concentration (mean + 3 std dev) based on Fresquez (2009).

[d] Screening Level is based on 0.01 rad/day.

[e] DU = depleted uranium based on the distribution of U-234 to U238.

Sample #SFB-10-11-3214 contained five mice—three from the upper grid and two from the lower grid.

<u>b. TAL Elements</u>. Most TAL elements in field mice (n = 3) collected from TA-36 Minie were below RSRLs (Table 2). The only two elements that were higher than the RSRLs were barium in two out of the three samples and lead in three out of the three samples. However, based on the highest concentration of barium in the soil at TA-36 Minie (204 mg/kg) (Vigil-Holterman and Juarez 2011a), the level was below the ESL of 1800 mg/kg for the field mouse (LANL 2010). Similarly, the highest lead concentration detected in soil at TA-36 Minie was 44 mg/kg (Vigil-Holterman and Juarez 2011a) and is lower than the ESL for the field mouse of 120 mg/kg (LANL 2010).

Table 2. TAL elements (mg/kg wet) in whole body field mice collected from TA-36 Minie and TA-39 Point 6 in 2010. (Bold values are higher than the RSRL.)

	TA-36 OD Minie			TA-39 OD Point 6			
Element[a]	**3202/U[d]**	**3203/L**	**3204/U**	**3215/L**	**3216/U**	**3217/L**	**RSRL[b]**
Aluminum	6.0	13	8.9	11	17	13	73
Barium	**5.6**	3.6	**5.8**	**8.6**	**5.2**	2.0	5.1
Beryllium[c]	0.00065	0.0015	0.00095	0.00090	0.00085	0.00075	0.016
Calcium	6800	6000	7700	8000	8100	7000	12624
Chromium	0.21	0.23	0.32	0.23	0.37	0.26	0.40
Cobalt	0.021	0.023	0.016	0.018	0.025	0.015	0.072
Copper	2.6	1.9	1.8	2.6	2.0	1.5	6.2
Iron	40	52	57	53	59	53	140
Magnesium	200	270	230	270	220	160	544
Manganese	0.94	1.7	0.94	1.5	1.2	0.97	7.6
Nickel	0.042	0.083	0.035	0.046	0.057	0.074	0.11
Potassium	2600	2600	2900	2400	2900	1700	3677
Sodium	1300	1000	1300	1100	1200	860	1920
Vanadium	0.0076	0.024	0.0064	0.013	0.027	0.015	0.14
Zinc	35	77	100	35	36	83	119
Antimony	0.034	0.084	0.030	0.043	0.066	0.12	0.17
Arsenic	0.0076	0.014	0.011	0.0060	0.0093	0.010	0.089
Cadmium	0.035	0.0039	0.0071	0.0020	0.010	0.015	0.039
Lead	**0.50**	**0.66**	**0.99**	**3.0**	**1.0**	**0.82**	0.49
Selenium	0.32	0.27	0.28	0.27	0.34	**0.42**	0.40
Silver	0.00087	0.0014	0.0010	0.00081	0.00087	0.0012	0.020
Thallium	0.0012	0.0020	0.0018	0.0027	0.0023	0.0027	0.0055
Mercury	0.0047	0.0017	0.0037	0.0013	0.0042	0.0017	0.013

---

[a] Al to Zn by method SW6010B and analyzed by inductively coupled plasma; Sb to Tl by method SW6020B and analyzed by inductively coupled plasma mass spectroscopy; Hg by method SW7471 and analyzed by cold vapor atomic adsorption.

[b] Regional Statistical Reference Level; this is the upper-limit regional background concentration (mean + 3 std dev) based on Fresquez (2009).

[c] All U flagged undetected (<minimum detection limit [MDL]) TAL elements were reported as one-half the MDL; all B flagged estimated values (>MDL but <RL) were reported.

[d] Sample number/grid location (U = upper, L = lower)

c. Dioxin and Furans. There were no dioxin or furan concentrations that were detected above the standard quantification limit (SQL) (i.e., reporting level) in any of the eight whole body field mouse samples (Table 3).

d. High Explosives and Perchlorate. There were no detections of high explosives above the SQL in any of the four whole body field mice samples at TA-36 Minie (Table 4). Similarly, all field mouse samples (n = 4) contained perchlorate concentrations below the RSRL.

e. Polychlorinated Biphenyls. Total PCBs in three of the five whole body field mice samples collected from TA-36 Minie were slightly higher than the RSRL calculated from non-urban sites (undisturbed grasslands) but quite lower than the RSRL estimated from field mice collected near an urban waste transfer station in Española, NM (Table 5). Nevertheless, the highest PCB amounts detected in soil at TA-36 Minie (Aroclor 1248 = 0.0054 mg/kg, Aroclor 1254 = 0.0036 mg/kg, and Aroclor 1260 = 0.021 mg/kg) (Vigil-Holterman and Juarez 2011a) were all below the ESLs for the deer mouse (Aroclor 1248 = 0.014 mg/kg, Aroclor 1254 = 0.88 mg/kg, and Aroclor 1260 = 20 mg/kg) (LANL 2010).

TA-39 Point 6

a. TAL Elements. Most TAL elements in whole body field mice from TA-39 Point 6 (n = 3) were below or similar to the RSRLs (see Table 2). As in field mice from TA-36 Minie, the only two TAL elements that were found to be higher than the RSRLs were barium in two of the three samples and lead in all three samples. Based on the highest barium concentration in soil at TA-39 Point 6 measured in 1995 (302 mg/kg) (LANL PRS Database) and in 2010 (99 mg/kg) (Vigil-Holterman and Juarez 2011b), the levels are well below the ESL of 1800 mg/kg for field mice (LANL 2010). Conversely, the highest lead concentrations detected in soil at TA-39 Point 6 in 1995 (978 mg/kg) (LANL PRS Database) and in 2010 (375 mg/kg) (Vigil-Holterman and Juarez 2011b) were higher than the ESL of 120 mg/kg (LANL 2010). Undoubtedly, the highest lead concentrations in soil at TA-39 Point 6 were probably associated with samples collected on or near the firing pad; however, based on the average soil lead concentration from two sampling

Table 3. Dioxin and furan concentrations (pg/g wet) in whole body field mice samples collected from TA-36 Minie in 2010/11.

	Aug-10										Feb-11					
Dioxin/Furan[a]	**3205/L[bc]**	**Lab Q**	**3206/L**	**Lab Q**	**3207/U**	**Lab Q**	**3208/U**	**Lab Q**	**3209/U**	**Lab Q**	**5081/L**	**Lab Q**	**5083/L**	**Lab Q**	**5085/L**	**Lab Q**
Dioxins																
Tetrachlorodibenzodioxin[2,3,7,8-]	0.175	U	0.501	U	0.173	U	0.482	U	0.535	U	0.084	U	0.0668	U	0.0734	U
Tetrachlorodibenzodioxins (Total)	0.175	U	0.501	U	0.173	U	0.482	U	0.535	U	0.084	U	0.0668	U	0.0734	U
Pentachlorodibenzodioxin[1,2,3,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Pentachlorodibenzodioxins (Total)	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzodioxins (Total)	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	1.04	J	0.474	U	0.478	U	0.726	U	0.622	J	0.42	U	0.334	U	0.367	U
Heptachlorodibenzodioxins (Total)	4.6	J	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.412	J
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.59	J	1.67	J	0.956	U	1.45	U	1.61	J	0.896	J	0.668	U	1.25	J
Furans																
Tetrachlorodibenzofuran[2,3,7,8-]	0.165	J	0.258	J	0.222	J	0.311	J	0.359	J	0.257	J	0.156	J	0.211	J
Tetrachlorodibenzofurans (Totals)	0.379	J	0.493	J	0.468	J	0.311	J	0.698	J	0.464	J	0.289	J	0.188	J
Pentachlorodibenzofuran[1,2,3,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Pentachlorodibenzofuran[2,3,4,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Pentachlorodibenzofurans (Totals)	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U

Table 3 (cont.)

	Aug-10										Feb-11					
Furans (cont.)	**3205/L**[bc]	**Lab Q**	**3206/L**	**Lab Q**	**3207/U**	**Lab Q**	**3208/U**	**Lab Q**	**3209/U**	**Lab Q**	**5081/L**	**Lab Q**	**5083/L**	**Lab Q**	**5085/L**	**Lab Q**
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Hexachlorodibenzofurans (Total)	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Heptachlorodibenzofurans (Total)	0.496	U	0.474	U	0.478	U	0.726	U	0.557	U	0.42	U	0.334	U	0.367	U
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.992	U	0.949	U	0.956	U	1.45	U	1.11	U	0.84	U	0.668	U	0.734	U

[a] Method blank corrected data.

[b] Sample number/grid location (U = upper, L = lower).

[c] Results as related to the Laboratory Qualifier: Result followed by a blank space is a Detected value = result was above the reporting limit (RL); Result followed by a U is an Undetected value = result was below the minimum detectable level (MDL) (Shown); Result followed by a J is an Estimated value = result was above the MDL but below the RL.

Table 4. High explosives (µg/kg wet) and perchlorate (mg/kg wet) in whole body field mice collected from TA-36 Minie and TA-39 Point 6 in 2010. (Bold values are higher than the RSRL.)

		TA-36 OD Minie				TA-39 OD Site 6		
High Explosives/Perchlorate	**RL[a]**	**3210/U[b]**	**3211/L**	**3212/L**	**3213/U**	**3221/L**	**3222/U**	**RSRL[c]**
2,4-Diamino-6-nitrotoluene	2000	U[d]	U	U	U	U	U	
2,6-Diamino-4-nitrotoluene	2000	U	U	U	U	U	U	
3,5-Dinitroaniline	1000	U	U	U	U	U	U	
Amino-2,6-dinitrotoluene[4-]	500	U	U	U	U	U	U	
Amino-4,6-dinitrotoluene[2-]	500	U	U	U	U	U	U	
Dinitrobenzene[1,3-]	500	U	U	U	U	U	U	
Dinitrotoluene[2,4-]	500	U	U	U	U	U	U	
Dinitrotoluene[2,6-]	500	U	U	U	U	U	U	
HMX	500	U	U	U	U	U	U	
Nitrobenzene	500	U	U	U	U	U	U	
Nitrotoluene[2-]	500	U	U	U	U	U	U	
Nitrotoluene[3-]	500	U	U	U	U	U	U	
Nitrotoluene[4-]	500	U	U	U	U	U	U	
PETN	1000	U	U	U	U	U	U	
RDX	500	U	U	U	U	U	U	
TATB	1000	U	U	U	U	U	U	
Tetryl	500	U	U	U	U	U	U	
Trinitrobenzene[1,3,5-]	500	U	U	U	U	U	U	
Trinitrotoluene[2,4,6-]	500	U	U	U	U	U	U	
Tris (o-cresyl) phosphate	1000	U	U	U	U	U	U	
Perchlorate	0.0040	0.028	0.012	0.012	0.096	0.12	0.088	0.19

---

[a] Reporting level (standard quantification limit).

[b] Sample number/grid location (U = upper, L = lower).

[c] Regional Statistical Reference Level; this is the upper-level background concentration (mean + 3 SD) based on data from Fresquez (2011).

[d] Laboratory Qualifier. (Detected) = result was above the reporting limit (RL); U (Undetected) = result was below the minimum detectable level (MDL); J (Estimated) = result was above the MDL but below the RL.

Table 5. Polychlorinated biphenyl (PCB) homologs and totals (pg/g wet) in whole body field mice collected from TA-36 Minie in 2010/2011. (Total PCBs highlighted in bold are higher than the RSRL.)

	Aug-10				Feb-11						RSRL[c]	
PCB Homolog/Total	**3205/L[ab]**	**Lab Q**	**3206/L**	**Lab Q**	**5080/L**	**Lab Q**	**5084/L**	**Lab Q**	**5082/L**	**Lab Q**	**Non-Urban**	**Urban**
Total monoCB	5.62	U	5.69	U	6.76	U	5.36	U	5.1	U		
Total diCB	5.62	U	5.69	U	6.76	U	5.36	U	5.1	U		
Total triCB	26.3		5.69	U	6.76	U	5.36	U	5.1	U		
Total tetraCB	5.62	U	5.69	U	6.76	U	5.36	U	5.1	U		
Total pentaCB	73.8		93.2		19.7		36.8		15.2			
Total hexaCB	1140		1860		147		443		82.1			
Total heptaCB	1500		4120		163		428		88.4			
Total octaCB	540		1850		48.2		164		11.4			
Total nonaCB	130		146		6.76	U	12		5.1	U		
Total decaCB	66.2		30.1		6.76	U	5.36	U	5.1	U		
Total PCB	3470		8100		378		1080		197		885	28000

---

[a] Sample number/grid location (U = upper, L = lower).

[b] Result as related to Laboratory Qualifiers: Result followed by a blank space is a Detected value = result was above the standard quantification limit (SQL); Result followed by a U is an Undetected value = result was below the minimum detectable level (MDL) (shown); Result followed by a J is an Estimated value = result was above the MDL but below the SQL.

[c] Regional Statistical Reference Level; this is the upper-limit regional background concentration (mean + 3 std dev) based on Fresquez (2011).

periods over the entire site, the amount (82 mg/kg; n = 57) (LANL PRS Database, Vigil-Holterman and Juarez 2011b) was lower than the ESL for field mice.

b. Dioxin and Furans. Out of the six field mice samples collected in August of 2010 and February of 2011, only one sample and for only one compound, pentachlorodibenzofuran [2,3,4,7,8-], was detected above the SQL (Table 6). The amount (5.26 pg/g wet weight), however, was just above the reporting limit of 4.8 pg/g wet weight, and there were no detections of this compound above the reporting limit in soil samples collected from the site (Vigil-Holterman and Juarez 2011b); thus, these data in the tissue of one field mouse sample out of six may be a false positive.

c. High Explosives and Perchlorate. There were no detections of high explosives above the SQLs in any of the field mice samples (n = 2) collected at TA-39 Point 6 (see Table 4). Similarly, the amounts of perchlorate (n = 2) were below the RSRL.

d. Polychlorinated Biphenyls. Two out of five whole body field mouse samples collected from TA-39 Point 6 were higher in total PCBs than either of the RSRLs (Table 7). These two samples were collected from the upper grid, which is closer to the firing site, as compared to the other three samples being collected at the lower grid, which is further away. Nevertheless, the highest PCB amounts detected in soil at TA-39 Point 6 (Aroclor 1254 = 0.042 mg/kg and Aroclor 1260 = 0.018 mg/kg) (Vigil-Holterman and Juarez 2011b) were still below the ESLs for the deer mouse (Aroclor 1254 = 0.88 mg/kg and Aroclor 1260 = 20 mg/kg) (LANL 2010).

CONCLUSIONS

The tissues of the biota collected from TA-36 Minie indicated that analyzed concentrations were below the RSRLs or applicable SLs or soil comparisons. Similarly, at TA-39 Point 6, with the exception of lead, there were no detections of inorganic and organic chemicals in whole body tissues of field mice above RSRLs or applicable SLs or soil comparisons. Additionally, average lead concentrations over the TA-39 Point 6 site indicate that the site as a whole is not above ESLs for the field mouse. In conclusion, none of whole body tissue concentrations within the samples collected from TA-36 Minie or from TA-39 Point 6 appear to significantly impact the field mice population. In fact,

Table 6. Dioxin and furan concentrations (pg/g wet) in whole body field mice samples collected from TA-39 Point 6 in 2010/2011.

	Aug-10						Feb-11					
Dioxin/Furan[a]	3218/L[b,c]	Lab Q	3219/U	Lab Q	3220/U	Lab Q	5548/L	Lab Q	5550/L	Lab Q	5552/L	Lab Q
Dioxins												
Tetrachlorodibenzodioxin[2,3,7,8-]	0.442	U	0.287	U	0.245	U	0.081	U	0.0845	U	0.0692	U
Tetrachlorodibenzodioxins (Total)	0.442	U	0.287	U	0.245	U	0.081	U	0.0845	U	0.0692	U
Pentachlorodibenzodioxin[1,2,3,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Pentachlorodibenzodioxins (Total)	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzodioxins (Total)	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.487	U	1.1	J	0.495	U	0.405	U	0.402	U	0.346	U
Heptachlorodibenzodioxins (Total)	0.487	U	1.1	J	0.495	U	0.405	U	0.402	U	0.346	U
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1.07	J	2.06	J	1.03	J	0.81	U	0.803	U	0.728	J
Furans												
Tetrachlorodibenzofuran[2,3,7,8-]	0.345	J	0.323	J	0.655	J	0.177	J	0.169	J	0.208	J
Tetrachlorodibenzofurans (Totals)	0.633	J	0.434	J	0.655	J	0.499	J	0.492	J	0.421	J
Pentachlorodibenzofuran[1,2,3,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Pentachlorodibenzofuran[2,3,4,7,8-]	0.489	J	**5.26**		0.773	J	0.405	U	0.402	U	0.346	U
Pentachlorodibenzofurans (Totals)	0.489	J	**5.26**		0.773	J	0.405	U	0.402	U	0.346	U
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U

Table 6 (cont.)

	Aug-10						Feb-11					
Furans (cont.)	**3218/L[b,c]**	**Lab Q**	**3219/U**	**Lab Q**	**3220/U**	**Lab Q**	**5548/L**	**Lab Q**	**5550/L**	**Lab Q**	**5552/L**	**Lab Q**
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.487	U	0.571	J	0.495	U	0.405	U	0.402	U	0.346	U
Hexachlorodibenzofurans (Total)	0.487	U	0.571	J	0.495	U	0.405	U	0.402	U	0.346	U
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Heptachlorodibenzofurans (Total)	0.487	U	0.484	U	0.495	U	0.405	U	0.402	U	0.346	U
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.974	U	0.968	U	0.989	U	0.81	U	0.803	U	0.692	U

[a] Method blank corrected data.

[b] Sample number/grid location (U = upper, L = lower).

[c] Results as related to the Laboratory Qualifier: Result followed by a blank space (Detected) = result was above the reporting limit (RL); Result followed by a U (Undetected) = result was below the minimum detectable level (MDL) (Shown); Result followed by an J (Estimated) = result was above the MDL but below the RL.

Table 7. Polychlorinated biphenyl (PCB) homologs and totals (pg/g wet) in whole body field mice collected from TA-39 Point 6 in 2010/2011. (Total PCBs highlighted in bold are higher than the RSRL.)

	Aug-10				Feb-11						RSRL[c]	
PCB Homolog/Total	**3219/U[ab]**	**Lab Q**	**3220/U**	**Lab Q**	**5549/L**	**Lab Q**	**5551/L**	**Lab Q**	**5553/L**	**Lab Q**	**Non-Urban**	**Urban**
Total monoCB	4.77	U	3.42	U	5.99	U	5.97	U	5.6	U		
Total diCB	4.77	U	3.42	U	5.99		5.97	U	5.6			
Total triCB	5.06	B	49.8		5.99		5.97		5.6			
Total tetraCB	9.72	B	41.5	B	5.99		5.97		5.6			
Total pentaCB	3370		12100		65.1		34		5.6			
Total hexaCB	44900		16400		471		189		65.9			
Total heptaCB	9820		4070		313		71.7		39.2			
Total octaCB	1020		802		130		33.2		10.7			
Total nonaCB	86.2		90.1		19.3		5.97	U	5.6	U		
Total decaCB	8.58		3.42	U	5.99	U	5.97	U	5.6	U		
Total PCB	**59300**		**33600**		998		328		116		857	28000

[a] Sample number/grid location (U = upper, L = lower).

[b] Result as related to Laboratory Qualifiers: Result followed by a blank space is a Detected value = result was above the standard quantification limit (SQL); Result followed by a U is an Undetected value = result was below the minimum detectable level (MDL) (shown); Result followed by a J is an Estimated value = result was above the MDL but below the SQL.

[c] Regional Statistical Reference Level; this is the upper-limit regional background concentration (mean + 3 std dev) based on Fresquez (2011).

B = blank corrected.

Bennett and Robinson (2011) reported that the populations from these two detonation sites were similar to an undisturbed background location.

We acknowledge that the sample numbers for chemical analysis in some cases may be small and recommend more sampling over time.

ACKNOWLEDGMENTS

Thanks to Rhonda Robinson, Chuck Hathcock, Kathy Bennett, Leslie Hansen, Dave Keller, Lauren Maestas, and Alex Johnson for their assistance in the collection of the small mammal samples. In addition, thanks to Hector Hinojosa for his assistance in the review and final preparation of the manuscript.

REFERENCES

Arthur, W.J., O.D. Markham, C.R. Groves, and B.L. Keller. 1987. Radionuclide Export by Deer Mice at a Solid Radioactive Waste Disposal Area in Southeastern Idaho. Health Physics 52(1).

Bennett, K. and R. Robinson. 2011. Small Mammal Sampling at Open-Detonation Firing Sites. Los Alamos National Laboratory report LA-UR-11-00717.

Fresquez, P.R. 2009. The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice Collected from Regional Background Areas. Los Alamos National Laboratory report LA-UR-09-07580.

Fresquez, P.R. 2011. The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice Collected from Regional Background Areas: Revision 1. Los Alamos National Laboratory report (unpublished).

Fresquez, P.R., C. Hathcock, D. Keller, and G. Gonzales. 2010. Foodstuffs and Biota Monitoring. pp. 279–304. In: Environmental Surveillance at Los Alamos during 2009. Los Alamos National Laboratory report LA-14427-ENV.

Los Alamos National Laboratory. 2010. ECORISK Database: Version 2.5. Los Alamos National Laboratory report LA-UR-10-6898.

McNaughton, M. 2006. Calculating Dose to Non-Human Biota. Los Alamos National Laboratory, Meteorology and Air Quality Group procedure ENV-MAQ-514, R1.

US Department of Energy. 1991. Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance. US Department of Energy report DOE/EH-0173T.

US Department of Energy. 2002. A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. US Department of Energy Standard DOE-STD-1153-2002.

US Department of Energy. 2008. Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico. US Department of Energy report DOE/EIS-0380, Albuquerque, New Mexico.

Vigil-Holterman, L. and C. Juarez. 2011a. Soil Sampling Results Summary Report for TA-36-8 Open Detonation Unit. Los Alamos National Laboratory report (unpublished).

Vigil-Holterman, L. and C. Juarez. 2011b. Soil Sampling Results Summary Report for TA-39-6 Open Detonation Unit. Los Alamos National Laboratory report (unpublished).

APPENDIX

Information on field mice collected at open-detonation firing sites TA-36 Minie and TA-39 Point 6

							Constituents Analyzed				
TA	**Species Name**	**Ear Tag #**	**Date Collected**	**Weight (g)**	**Sample #**	**Grid Location**	**Uranium Isotopes**	**Dioxin/ Furans**	**PCB Congeners**	**HE/ Perchlorate**	**TAL Elements**
					SFB10-11-						
36	REME	4033	8/13/10	20	3202	Upper					X
36	PEMA	4040	8/13/10	10.5	3203	Lower					X
36	PEMA	2	8/13/10	17	3204	Upper					X
36	PEMA	4029	8/10/10	17	3205	Lower		X	X		
36	PEMA	4028	8/13/10	17.5	3206	Lower		X	X		
36	REME	4036	8/13/10	11	3207	Upper		X			
36	REME	3	8/13/10	7	3208	Upper		X			
36	REME	4034	8/13/10	8.5	3209	Upper		X			
36	REME		8/10/10	14.5	3210	Upper				X	
36	PETR	1	8/13/10	25	3211	Lower				X	
36	PETR	4027	8/13/10	34	3212	Lower				X	
36	PEMA	4037	8/13/10	19	3213	Upper				X	
36	4 PEMA 1 NEME	4043, 4032, 4030, 4035, 4048	8/13/10	Composite	3214	3U, 2L	X				
					MICE36-11-						
36	PETR		2/17/11	10	5080	Lower			X		
36	PEMA		2/15/11	15	5084	Lower			X		
36	PEBO		2/15/11	19	5085	Lower		X			
36	REME		2/17/11	11.5	5081	Lower		X			
36	PEMA		2/17/11	17	5082	Lower			X		
36	PEMA		2/17/11	15.5	5083	Lower		X			

39	PEMA	4098	8/26/10	16.5	3215	Lower				X
39	PEBO	2602	8/26/10	19.5	3216	Upper				X
39	PEMA	4085	8/26/10	27	3217	Lower				X
39	PEMA	2603	8/26/10	10.5	3218	Lower	X			
39	PEMA	4080	8/23/10	17	3219	Upper	X	X		
39	PEMA	4083	8/26/10	25	3220	Upper	X	X		
39	PEMA	4090	8/26/10	15.5	3221	Lower			X	
39	PEMA	4082	8/26/10	12.5	3222	Upper			X	
39	PEMA		2/24/11	12.5	MICE39-11-5550	Lower	X			
39	PEMA		3/1/11	19	5553	Lower		X		
39	PEMA		2/23/11	17	5549	Lower		X		
39	PEMA		2/23/11	12	5548	Lower	X			
39	PEMA		2/24/11	16	5551	Lower		X		
39	PEMA		2/24/11	13.5	5552	Lower	X			

PEMA = deer mouse (*Peromyscus maniculatus*)
PETR = pinyon mouse (*Peromyscus truei*)
REME = western harvest mouse (*Reithrodontomys megalotis*)
PEBO = brush mouse (*Peromyscus boylii*)
NEME = Mexican wood rat (*Neotoma mexicana*)
Sample Coordinates:
TA-36, upper grid (X = 1631558 and Y = 1756103) and lower grid (X = 1632355 and Y = 1756697)
TA-39, upper grid (X = 1636020 and Y = 1746329) and lower grid (X = 1636562 and Y = 1746542)

7. Fresquez, P.R., L. Hansen, and C. Hathcock, 2013. *Chemical Concentrations in Field Mice/Voles Collected from an Open-Burn Site at Technical Area 16 at Los Alamos National Laboratory, Revision 1*. LA-UR-13-20040. (Fresquez *et al*. 2013)

LA-UR-13-20040

Title:

CHEMICAL CONCENTRATIONS IN FIELD MICE/VOLES COLLECTED FROM AN OPEN-BURN SITE AT TECHNICAL AREA 16 AT LOS ALAMOS NATIONAL LABORATORY: REVISION 1

Author(s): P.R. Fresquez, L. Hansen, and C. Hathcock

Intended for: Report

PREFACE

The purpose of this revision was to increase the data base for small mammal collections at the TA-16 burning grounds. In addition to inorganic elements and dioxin/furan concentrations in field mice/voles collected in 2011, the population parameters of field mice around the TA-16 burn ground site were estimated and samples were analyzed for polychlorinated biphenyls, high explosives, and perchlorate.

CHEMICAL CONCENTRATIONS IN FIELD MICE/VOLES COLLECTED FROM AN OPEN-BURN SITE AT TECHNICAL AREA 16 AT LOS ALAMOS NATIONAL LABORATORY: REVISION 1

P.R. Fresquez, L. Hansen, and C. Hathcock

ABSTRACT

Field mice and voles were collected around an open-burn (high-explosive waste) site, TA-16-388 (flash pad), at Technical Area 16 at Los Alamos National Laboratory in March of 2011 for the analysis of 23 target analyte list (TAL) elements (mostly metals) and 17 dioxin/furan chemicals. In July of 2012, small mammal community and population parameters were estimated across the site, and samples were analyzed for polychlorinated biphenyl's (PCBs), high explosives (HEs), and perchlorate. All TAL elements in whole-body field mouse samples (n=3) were either similar to regional statistical reference levels (RSRLs) or below ecological screening levels. Dioxins and furans (n=6) and HEs (n=2) were not detected in any of the whole-body field mouse/vole samples. Perchlorate concentrations (n=2) were below the RSRL. One out of the two small mammal samples contained PCB Arochlor-1260 above non-urban RSRLs; the amount, however, was similar to the urban RSRL. There was no adverse effect of burning ground operations on local small mammal populations.

INTRODUCTION

Two open-burn treatment units (burn units), the TA-16-388 Flash Pad and the TA-16-399 Burn Tray, located at Technical Area 16 (TA-16) at Los Alamos National Laboratory (LANL or the Laboratory), are used for the destruction of high explosives (HE), HE machining wastes, and wastes contaminated with HE (LANL 2003) **(Figures 1 and 2)**. The burn units have been in operation since the late 1950s and have been authorized to operate under an interim basis by the State of New Mexico since 1980. Currently, the Laboratory is in the process of applying for a hazardous waste permit for the open-burning treatment of HE wastes at TA-16. The public has voiced concern about potential effects from releases of chemicals, particularly dioxins and furans on the surrounding environment (New Mexico Environment Department [NMED] 2010).

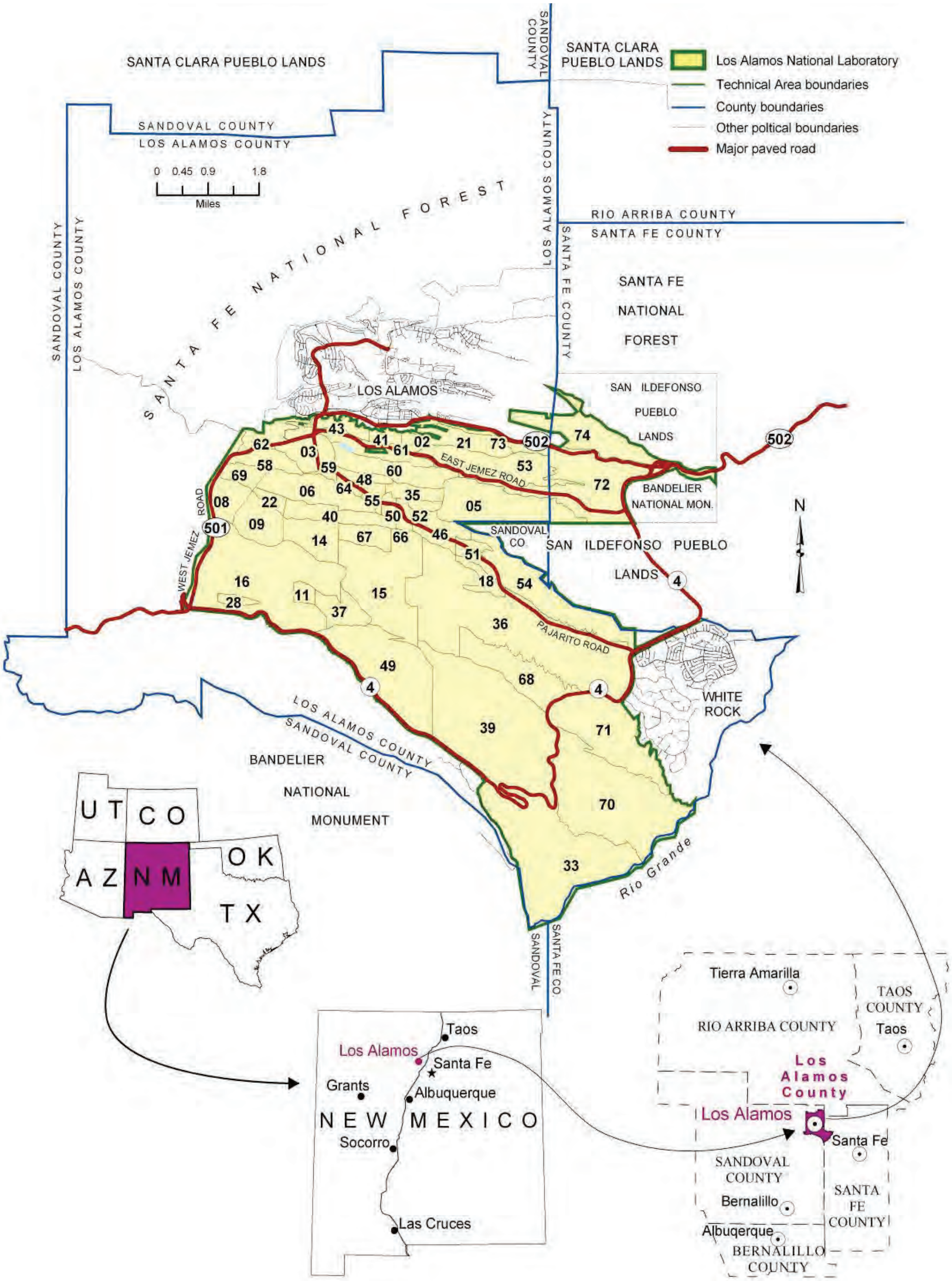


Figure 1. Location of Los Alamos National Laboratory.

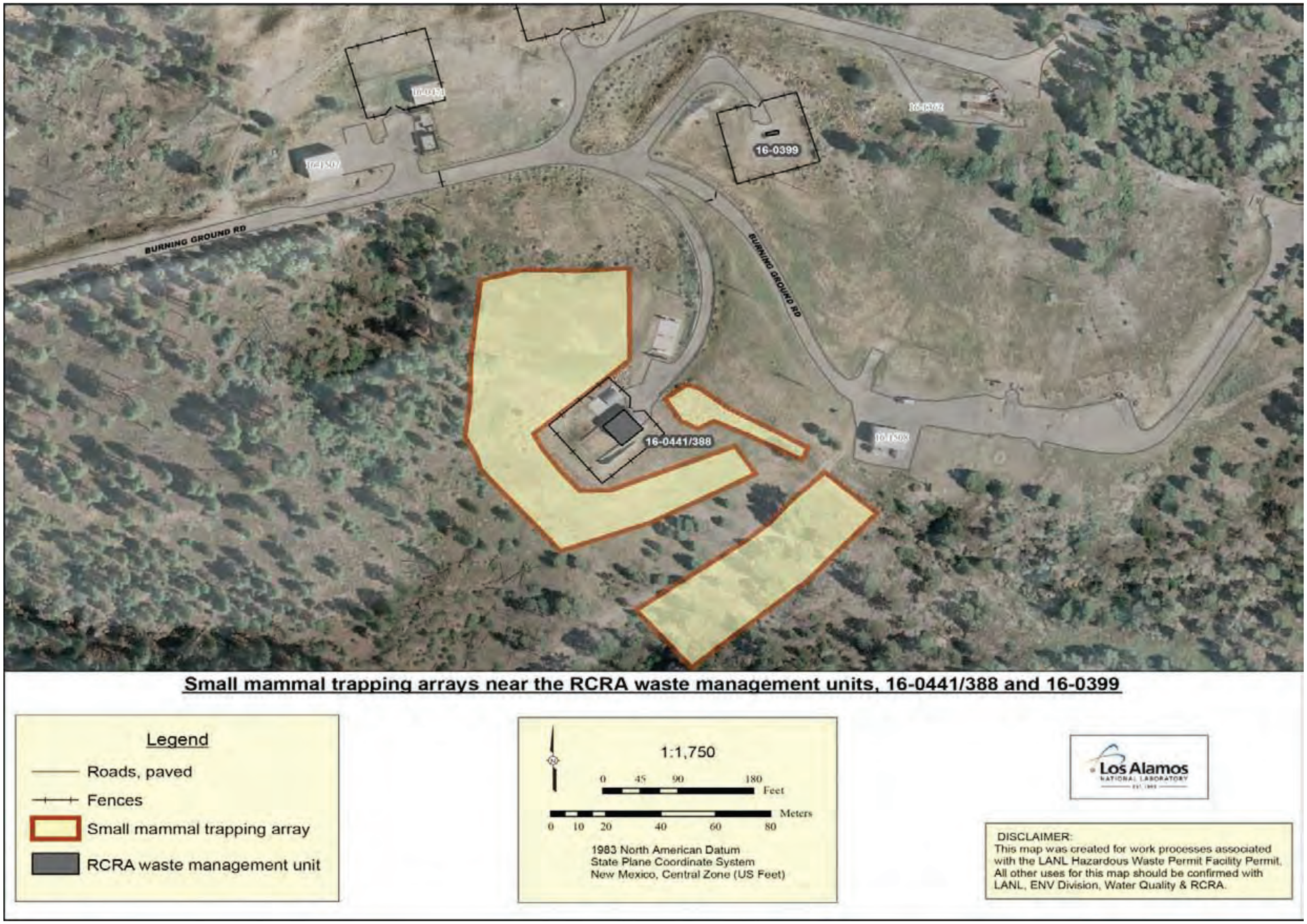


Figure 2. Location of burn units (referred to as the RCRA waste management units) and sampling arrays at TA-16 in 2011.

An analysis of Resource Conservation and Recovery Act (RCRA) metals and dioxin/furan chemicals in soil samples (n=37) collected in proximity to the two burn units at TA-16 showed that some elements like barium, cadmium, and silver were detected above background and each sample contained from 3 to 17 dioxin/furan chemicals. The human health and ecological risk analyses concluded that no risks to human or ecological receptors above acceptance thresholds are present at the site (LANL 2010a).

The purpose of the present study was to gain more information on any food-chain transfer of the chemicals of potential ecological concern at the burn units to a low-trophic-level animal receptor (e.g., field mice) to verify the results of the ecological risk analysis. In general, field mice are effective biomonitors because of their ease of collection, feeding habits (e.g., omnivore), limited home range, and association with the soil (e.g., burrowing) (Arthur et al. 1987, Talmage and Walton 1991, Smith et al., 2002). At LANL, field mice are used as the biota (radionuclide) dose (McNaughton 2006) and chemical (Fresquez et al. 2010) uptake models for terrestrial mammals because they have the smallest home range (0.089 to 1.5 acres) (Wood et al. 2010).

METHODOLOGY

Site Description

The Laboratory is situated in northern New Mexico on the Pajarito Plateau, a series of fingerlike mesas separated by east-to-west-oriented canyons. The mesa tops slope eastward from approximately 2377 m (7800 ft) to 1890 m (6200 ft). The surrounding land is largely undeveloped, including large tracts held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, and San Ildefonso Pueblo. The open-burn sites are located in a remote location at TA-16 and vegetation consist of mostly ponderosa pine (*Pinus ponderosa* C. Lawson), gambel oak (*Quercus gambelii* Nutt) and open field grasses.

Small Mammal Trapping

2011 Study. Large snap traps were set in three arrays (north/west/south, east, and southeast) around the most often used burn unit, TA-16-388 (Flash Pad), in March-April 2011 **(Figure 2)**. Traps were baited in the late afternoon with molasses-coated oat bait and checked early each morning. A total of nine field mice/voles were collected over the sampling period; three samples were used for target analyte list (TAL) analysis, and six samples were used for dioxin/furan analysis. The samples for TAL analysis were each placed in double ziplock bags, whereas the dioxin/furan samples were each placed into 250-mL amber glass jars. All samples were secured with chain-of-custody tape, transported in an ice cooler, and stored in a freezer until they were submitted to the Laboratory's Sample Management Office. Samples consisted of deer mice (*Peromyscus maniculatus*) (PEMA), brush mice (*Peromyscus boylii*) (PEBO), and long-tailed voles (*Microtus longicaudus*) (MILO) (Appendix A).

ALS Group (formerly Paragon Analytics) analyzed the whole-body (carcass plus pelt) field mouse samples for TAL elements (aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, zinc, antimony, arsenic, cadmium, lead, selenium, silver, thallium, and mercury). Seventeen dioxin/furan congeners in whole-body field mice/voles were analyzed by Cape Fear Analytical, LLC.

2012 Study. Small mammal trapping was conducted near TA-16-399 (Flash Pad) on July 2-3, using Sherman live traps. The objective of the sampling was to evaluate the status of the small mammal community and to collect samples for the analysis of polychlorinated biphenyls (PCBs), high explosives (HEs), and perchlorate. A trap web was set up with 12 spokes and 10 traps per spoke (Parmenter et al. 2003) **(Figure 3)**. Traps were baited on July 2nd, and checked on July 3rd. Six samples were collected, processed, and submitted similar to the 2011 study, but for organic chemical analyses.

Measures of abundance (captures per 100 trap nights), species richness, and species diversity for all captured animals; and average weight, male:female sex ratios; and indicators of reproductive activity (presence of pregnant females or juveniles) for the two most commonly trapped species, PEBO and PEMA, were determined. A comparison of these metrics to results from 21 other locations sampled between 2001 and 2010 on or near LANL using Sherman live traps during summer time periods (July through September) was conducted. Comparison trapping locations ranged from mesa tops to canyon bottoms and from pinyon-juniper to riparian, ponderosa pine, and mixed conifer habitats. Box and whisker plots were plotted for the number of captures per 100 trap nights, the species' sex ratios, the species' average nonpregnant adult weights, and community diversity, as indexed by Shannon' H metric (Shannon 1948). Sex ratios were not

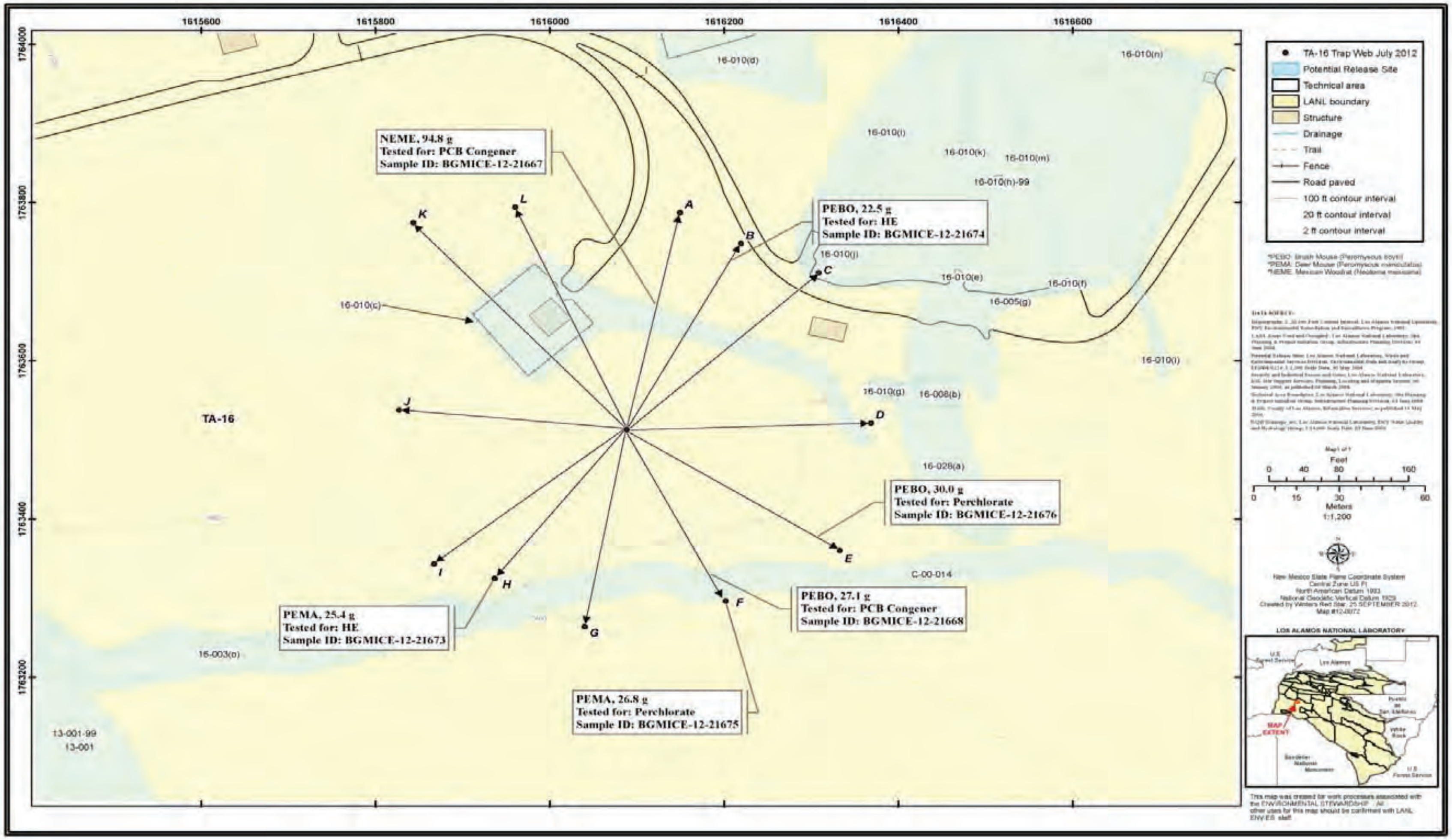


Figure 3. Map of the trapping web used to sample small mammals at the TA-16 burning grounds during July 2012. NEME = *Neotoma Mexicana*; PEBO = *Peromyscus boylii*; PEMA = *Peromyscus maniculatus*; PCB = polychlorinated biphenyl; HE = high explosives.

calculated if only one gender was captured in the trapping effort. The box and whisker plots represent the minimum value, the 25th percentile, the median, the 75th percentile, and the maximum value.

Biota Comparison Levels

Chemical concentrations in field mice/voles from Laboratory areas are first compared with regional statistical reference levels (RSRLs). RSRLs, which represent natural and fallout levels of chemicals, are the upper-level bounds of background concentrations (mean plus three standard deviations = 99% confidence level) calculated from field mice that were collected from regional locations away from the influence of the Laboratory (over 9 miles away) (U. S. Department of Energy [DOE] 1991). For TAL elements, dioxins/furans, PCBs, and perchlorate in whole-body field mice, RSRLs can be found in Fresquez (2009, 2011a). HEs are not naturally produced or commonly released, so the small mammals collected from regional locations should not contain these chemicals.

There are no regulatory screening levels for chemicals in tissues of field mice, so if chemicals in field mice are higher than the RSRLs, then the average chemical concentration in the soil at the place of collection is compared with ecological screening levels (ESLs) (LANL 2010b). ESLs are derived by the Laboratory from the literature and are designed to reflect the concentration of a chemical in the soil that is not expected to produce any adverse effects on selected biota receptors that commonly come into contact with soil or ingest biota that live in or on soil (i.e., they are the concentrations that are protective of ecological receptors under chronic exposure conditions).

RESULTS

2011 Study: Of the 23 TAL elements, barium, nickel, and cadmium were the only chemicals in whole-body field mice collected from around a burn unit at TA-16 (TA-16-388) that were detected in higher concentrations than the RSRLs in two or more samples **(Table 1)**. (Note that barium and cadmium were also detected above background concentrations in soil samples.) Nickel and cadmium in whole-body field mice were just above the RSRLs, whereas barium was substantially higher (15 to 27 mg/kg) than the field mouse RSRL (5.1 mg/kg). Nevertheless, the average concentration of barium in soil (519 mg/kg) from across the site (n=32) (LANL 2010a) was still below the ESL of 1800 mg/kg for the field mouse (LANL 2010b). Dioxins and furans

Table 1. TAL Elements (mg/kg wet) in Whole-Body Field Mice Collected from Burn Site at TA-16 in 2011.

Element[a]	9125[b] (brush mouse)	9131 (deer mouse)	9132 (deer mouse)	RSRL[c]
Aluminum	11	21	14	73
Barium	**15**	**27**	**22**	5.1
Beryllium[d]	0.0022	0.0019	0.0023	0.016
Calcium	11000	10000	11000	12624
Chromium	0.22	0.23	0.23	0.40
Cobalt	0.035	0.049	0.048	0.072
Copper	2.8	3.4	3.8	6.2
Iron	61	84	79	140
Magnesium	280	300	360	544
Manganese	3.1	2.6	2.4	7.6
Nickel	**0.14**	**0.12**	**0.18**	0.11
Potassium	2800	2700	2700	3677
Sodium	1300	1200	1200	1920
Vanadium	0.029	0.052	0.036	0.14
Zinc	23	23	25	119
Antimony	0.032	0.041	0.057	0.17
Arsenic	0.026	0.028	0.022	0.089
Cadmium	**0.048**	**0.040**	0.035	0.039
Lead	**0.59**	0.49	0.19	0.49
Selenium	0.29	0.39	0.39	0.40
Silver	0.0085	0.0068	0.0076	0.020
Thallium	0.0018	0.0017	0.0018	0.0055
Mercury	0.012	0.0081	0.0023	0.013

Note: Bold values are higher than the RSRL.

[a] Al to Zn by method SW6010B and analyzed by the inductively coupled plasma (ICP) technique; Sb to Tl by method SW6020B and analyzed by ICP/mass spectrometry; Hg by method SW7471 and analyzed by cold vapor atomic absorption.

[b] Sample number.

[c] The RSRL is the upper-limit regional background concentration (mean + 3 std dev) based on Fresquez 2009.

[d] All U flagged undetected (<method detection limit [MDL]) TAL elements were reported as one-half the MDL; all B flagged estimated values (>MDL but <reporting limit) were reported.

Table 2. Dioxin and Furan Concentrations (pg/g wet) in Whole-Body Field Mouse/Vole Samples Collected from Open-Burn Site TA-16 in 2011.

Dioxins/Furans[a]	9126[b] (MILO)	RQ[c]	9127 (MILO)	RQ	9128 (MILO)	RQ	9129 (MILO)	RQ	9130 (PEMA)	RQ	9133 (PEMA)	RQ
Dioxins												
Tetrachlorodibenzodioxin[2,3,7,8-]	0.0847	U	0.0843	U	0.084	U	0.0831	U	0.134	J	0.0837	U
Tetrachlorodibenzodioxins (Total)	0.0847	U	0.0843	U	0.084	U	0.0831	U	0.134	J	0.0837	U
Pentachlorodibenzodioxin[1,2,3,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.791	J	0.418	U
Pentachlorodibenzodioxins (Total)	0.423	U	0.422	U	0.42	U	0.416	U	0.791	J	0.418	U
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.46	J	0.418	U
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.734	J	0.418	U
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Hexachlorodibenzodioxins (Total)	0.423	U	0.422	U	0.42	U	0.416	U	1.19	J	0.418	U
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	1.97	J	0.418	U
Heptachlorodibenzodioxins (Total)	0.423	U	0.422	U	0.42	U	0.416	U	2.87	J	0.418	U
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.847	U	0.843	U	1.7	J	0.831	U	7.73	J	0.837	U

Table 2. Continued.

Dioxins/Furans[a]	9126[b]	RQ[c]	9127	RQ	9128	RQ	9129	RQ	9130	RQ	9133	RQ
Furans												
Tetrachlorodibenzofuran[2,3,7,8-]	0.246	U	0.268	U	0.282	U	0.299	U	0.197	U	0.244	U
Tetrachlorodibenzofurans (Total)	0.442	J	0.449	J	0.282	U	0.519	J	0.197	U	0.395	J
Pentachlorodibenzofuran[1,2,3,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Pentachlorodibenzofuran[2,3,4,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Pentachlorodibenzofurans (Total)	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.776	J	0.418	U
Hexachlorodibenzofurans (Total)	0.423	U	0.422	U	0.42	U	0.416	U	0.776	J	0.418	U
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.423	U	0.422	U	0.42	U	0.416	U	0.753	J	0.418	U
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.423	U	0.422	U	0.42	U	0.416	U	0.418	U	0.418	U
Heptachlorodibenzofurans (Total)	0.423	U	0.422	U	0.42	U	0.416	U	0.753	J	0.418	U
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.847	U	0.843	U	0.84	U	0.831	U	0.836	U	0.837	U

[a] Method was by 8290; blank corrected data.

[b] Sample number.

[c] Results as related to the reporting qualifier (RQ). Result followed by a blank space is a detected value = result was above the standard quantification limit (SQL); result followed by a U is an undetected value = result was below the method detection limit (MDL) (shown); result followed by a J is an estimated value = result was above the MDL but below the SQL.

were not detected above the analytical limit of quantification (detection limit) in any of the whole-body field mice/voles collected around the burn site, TA-16-388, at TA-16 **(Table 2)**. These data are similar to other dioxin/furan field-mouse uptake studies at the local (Fresquez 2011b) and national (Krouskop et al., 1991) levels and suggest that dioxins and furans, at least in the parts per trillion range (pg/g) in soil under natural field conditions, are not significantly assimilated, either by ingestion and/or by surface contact modes, to field mice/voles; possibly because of the adsorption of the chemical to soil surfaces or because of oxidation/reduction changes.

2012 Study: Trapped animals included one Mexican woodrat (*Neotoma mexicana*) (NEMA), three brush mice (PEBO) and two deer mice (PEMA). This resulted in a species richness of three, a capture rate of 4.2 animals per 100 trap nights, and a species diversity of 1.01. Species richness was within the range of normally observed results for LANL trapping efforts **(Figure 4)**. Captures per 100 trap nights and species diversity values were in the middle 50 percent of the data values for all trapping locations **(Figures 5 and 6)**.

Only two adult male PEMA were captured, so no pregnant females or juveniles were recorded for that species. There was evidence of reproduction in the captured PEBO **(Figure 7)**. Male:female sex ratios for PEBO at TA-16 were in the middle 50 percent of the data values for all trapping locations **(Figure 4)**. Average nonpregnant adult weights at the TA-16 burning grounds were above the 75th percentile for all species/gender combinations captured, and for PEBO and PEMA males, they were the highest values recorded at any of the LANL trapping locations **(Figure 8)**.

There were no HEs detected in any of the field mice collected around the burn unit and the perchlorate concentrations were similar to the RSRL **(Table 3).** One out of the two small mammals (brush mouse>wood rat) collected was higher in PCBs than the RSRL for undisturbed (non-urban) sites **(Table 4)**. PCB concentrations differ between small mammal species and may be attributed to differences in habitat use and foraging strategies (Johnson et al., 1996, Smith et al., 2006). Nevertheless, the highest PCB amount recorded (26,500 pg/g) was still similar to PCBs in field mice collected from around the perimeter of a public waste (garbage) transfer station (28,000 pg/g) (Fresquez 2011) and was far below the average (whole-body) amount (2.3E06 pg/g) that resulted in population alterations by decreasing reproductive capability and changes in liver, spleen, and adrenal function in field mice (Battey et al., 1990).

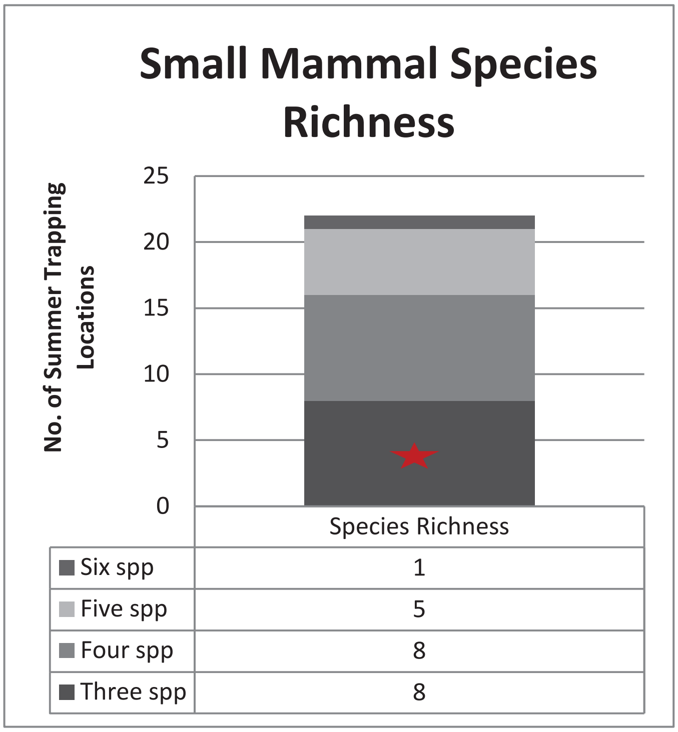


Figure 4. Species richness of small mammal communities sampled at LANL during summer between 2001 and 2012. The red star indicates the sampled species richness of three at the TA-16 burning grounds.

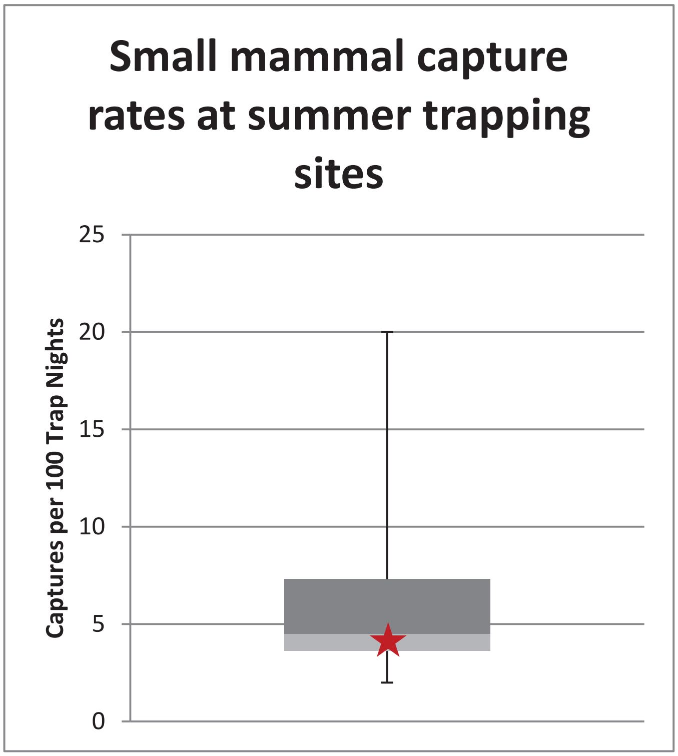


Figure 5. Capture rates of small mammal communities sampled at LANL during summer between 2001 and 2012. The red star indicates the sampled capture rate of 4.2 captures per 100 trap nights at the TA-16 burning grounds.

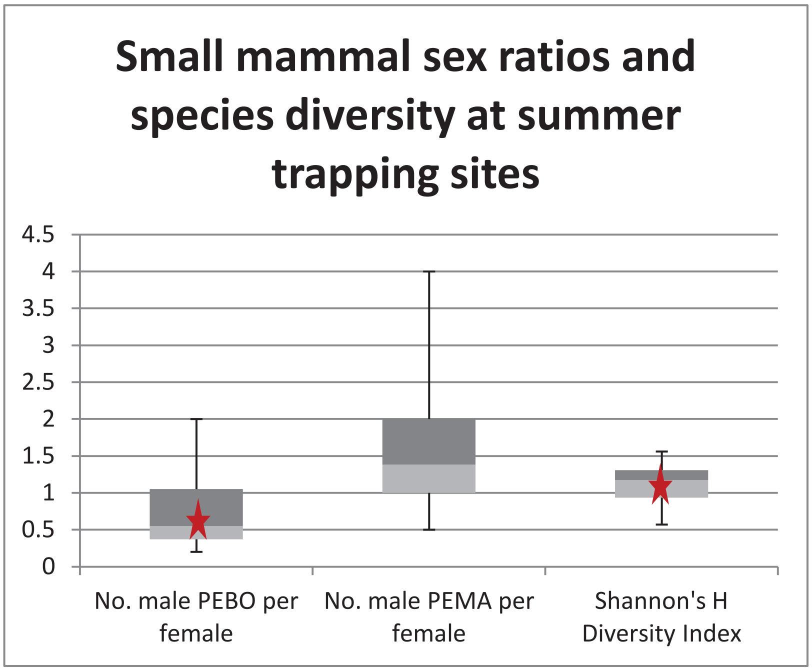
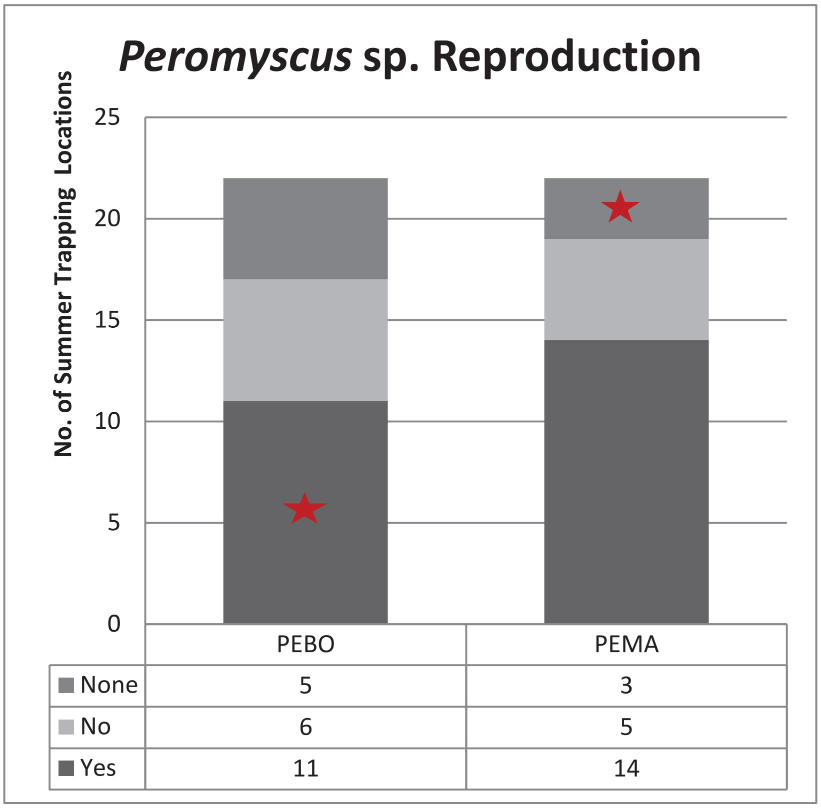


Figure 6. Sex ratios (males per female) and species diversity (Shannon's H index) for small mammals sampled at LANL during summer between 2001 and 2012. The red star indicates the sampled values at the TA-16 burning grounds of 0.5 male PEBO (*P. boylii*) per female, and a Shannon's H value of 1.01. No female PEMA (*P. maniculatus*) were captured, so no sex ratio was calculated for that species during this trapping effort.



	PEBO	PEMA
None	5	3
No	6	5
Yes	11	14

Figure 7. Evidence of reproduction (pregnant females or juveniles) in PEBO (*P. boylii*) and PEMA (*P. maniculatus*) populations sampled at LANL during summer between 2001 and 2012. Yes indicates the presence of either pregnant females or juveniles; No indicates only nonpregnant adult females present; and, None means that no adult females or juveniles of that species were captured. The red star indicates the sampling results at the TA-16 burning grounds of "Yes" for PEBO and "None" for PEMA.

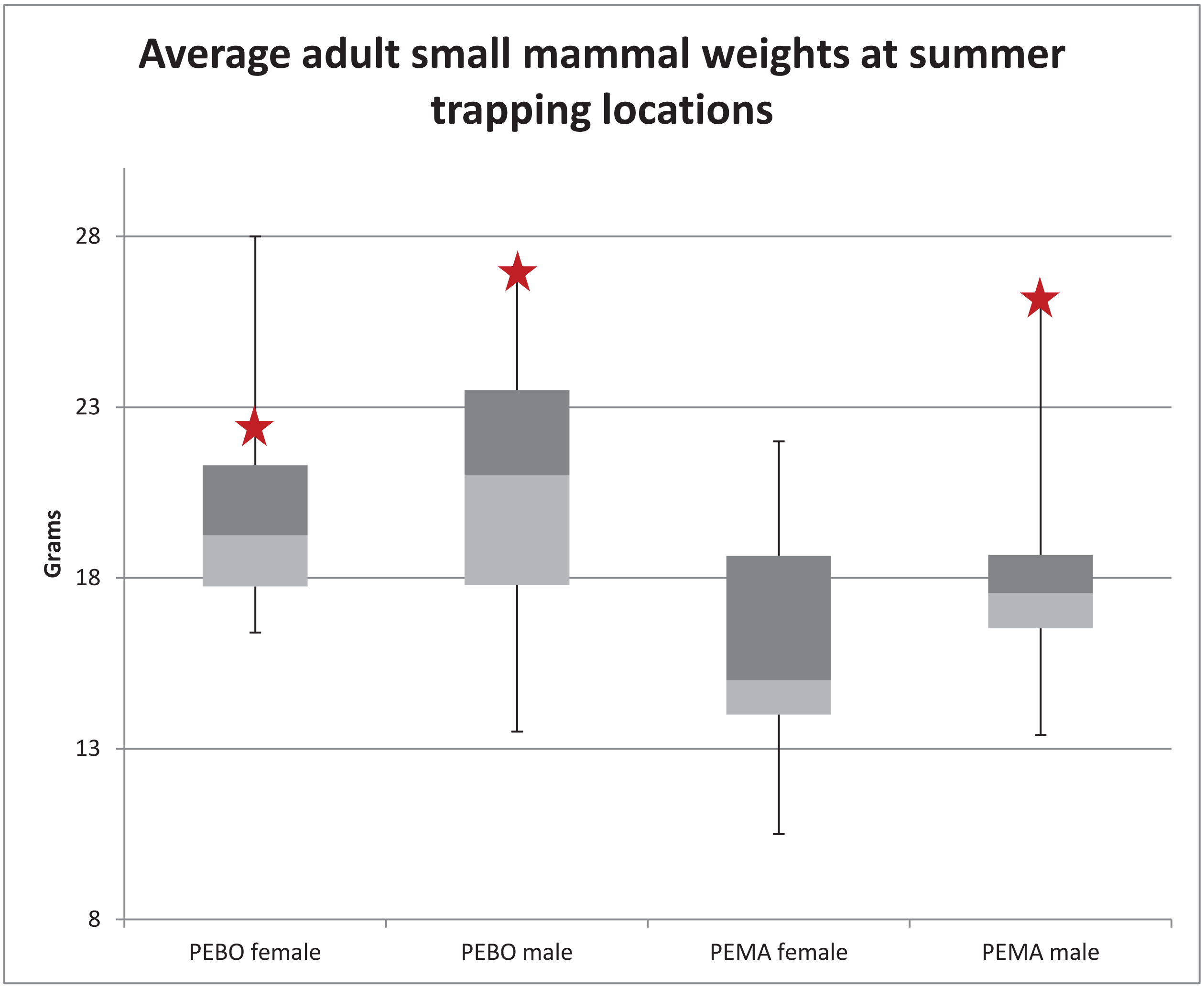


Figure 8. Average weight of adult nonpregnant female and of male PEBO (*P. boylii)* and PEMA (*P. maniculatus)* sampled at LANL during summer between 2001 and 2012. The red star indicates the sampling results at the TA-16 burning grounds of 22.5 g for female PEBO, 27.1 g for male PEBO, and 26.1 g for male PEMA. No female PEMA were captured during this trapping effort.

Table 3. High explosive concentrations (µg/kg wet) and perchlorate (mg/kg wet) in whole body field mice samples collected from TA-16 in 2012.

High Explosive/Perchlorate	12-21673[a] (deer mouse)	12-21674[a] (brush mouse)	
Trinitrotoluene[2,4,6-]	U	U	
Dinitrotoluene[2,4-]	U	U	
RDX	U	U	
Amino-2,6-dinitrotoluene[4-]	U	U	
HMX	U	U	
TATB	U	U	
Amino-4,6-dinitrotoluene[2-]	U	U	
Tetryl	U	U	
2,6-Diamino-4-nitrotoluene	U	U	
Dinitrotoluene[2,6-]	U	U	
3,5-Dinitroaniline	U	U	
2,4-Diamino-6-nitrotoluene	U	U	
PETN	U	U	
Tris (o-cresyl) phosphate	U	U	
Nitrotoluene[2-]	U	U	
Nitrobenzene	U	U	
Nitrotoluene[3-]	U	U	
Trinitrobenzene[1,3,5-]	U	U	
Dinitrobenzene[1,3-]	U	U	
Nitrotoluene[4-]	U	U	
	12-21675[a] (deer mouse)	**12-21676[a] (brush mouse)**	**RSRL[b]**
Perchlorate	0.0216	0.0032	0.19

[a] Sample number.

[b] Regional Statistical Reference Level; this is the upper-level background concentration (mean + 3 SD) based on data from Fresquez 2011a.

U (Undetected)=result was below the minimum detectable level.

Table 4. Polychlorinated biphenyl (PCB) homologs and totals (pg/g wet) in whole body field rat/mice collected from TA-16 in 2012.

PCB Homolog/Total[a]	12-21667[b] (wood rat)	12-21668[b] (brush mouse)	RSRL[c] Non-Urban	RSRL[c] Urban
Mono PCBs	0	0		
Di PCBs	0	0		
Tri PCBs	0	0		
Tetra PCBs	0	0		
Penta PCBs	23	1600		
Hexa PCBs	263	11100		
Hepta PCBs	146	10400		
Octa PCBs	91	2760		
Nona PCBs	7.5	511		
Deca PCB	0	49		
Total PCBs	531	26500	885	28000

[a] Method was by 1668A; blank corrected data.

[b] Sample number

[c] Regional Statistical Reference Level is the mean plus three standard deviations (99% confidence level) from Fresquez 2011a.

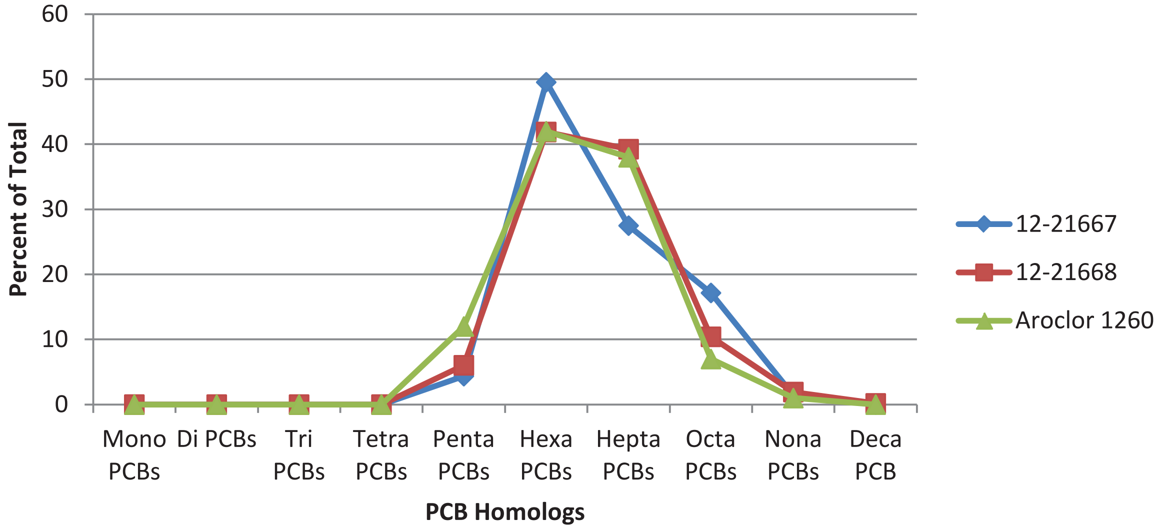


Figure 9. PCB homolog distribution of whole-body field wood rat (#21667)/brush mouse (#21668) samples collected from the TA-16 burning grounds in 2012 compared with Arochlor-1260.

The PCB homolog distribution of the field (brush) mouse collected near the TA-16 burn unit overlaps the distribution pattern of Archlor-1260 almost perfectly **(Figure 9)**.

Overall, both inorganic and organic data from whole-body field mice/voles collected at the burn unit site at TA-16 support the results of the ecological risk assessment conducted for this site. These data support the conclusion that there is no adverse effect of burn unit operations on local small mammal populations.

ACKNOWLEDGMENTS

Thanks to Rhonda Robinson, Sherri Sherwood, Dave Keller, and Beth Norris for sampling support; Kathy Bennett for preparing Figure 2; and Anne Garnett and Pamela Maestas for assistance in the editing and formatting of the manuscript, respectively.

REFERENCES

Arthur, W.J., O.D. Markham, C.R. Groves, and B.L. Keller. 1987. “Radionuclide Export by Deer Mice at a Solid Radioactive Waste Disposal Area in Southeastern Idaho,” Health Physics 52(1).

Batty, J., Leavitt, R.A., Biondao, N. and D. Polin. 1990. An Ecotoxicological Study of a Population of the White-Footed Mouse (*Peromyscus leucopus*) Inhabiting a Polychlorinated Biphenyls-Contaminated Area. Archives of Environmental Contamination and Toxicology, 19:283-290.

Clark Jr., Foerster, K.S., Marn, C.M., and R.L. Hothem. 1992. Uptake of Environmental Contaminants by Small Mammals in Pickleweed Habitats at San Francisco Bay, California. Archives of Environmental Contamination and Toxicology, 22:389-396.

DOE. 1991. “Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance,” US Department of Energy report DOE/EH-0173T (January 1991).

Fresquez, P.R. 2009. “The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice Collected from Regional Background Areas,” Los Alamos National Laboratory report LA-UR-09-07580.

Fresquez, P.R. 2011a. “The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice Collected from Regional Background Areas: Revision 1,” Los Alamos National Laboratory report LA-UR-11-11687.

Fresquez, P.R. 2011b. “Chemical Concentrations in Field Mice Collected from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory,” Los Alamos National Laboratory report LA-UR-11-10614.

Fresquez, P.R., C. Hathcock, D. Keller, and G. Gonzales. 2010. “Foodstuffs and Biota Monitoring,” pp. 279–304. In “Environmental Surveillance at Los Alamos during 2009,” Los Alamos National Laboratory report LA-14427-ENV.

Johnson, M.S., R.T. Leah, L. Connor, C. Rae and S. Saunders. 1996. Polychlorinated Biphenyls in Small Mammals from Contaminated Landfill Sites. Environmental Pollution, 92(2):185-191.

Krouskop, K.J., K.C. Ayers, and J.L. Proctor. 1991. “Multimedia Sampling for Dioxin at a Strip Mine Reclaimed with Sludge from Bleached Kraft Wastewater Treatment,” Tappi Journal, 74(4):235–240.

LANL. 2003. “Los Alamos National Laboratory Technical Area 16, Part B Permit Renewal Application, Revision 4.0.” Los Alamos National Laboratory report LA-UR-03-3903.

LANL. 2010a. “Human Health and Ecological Screening Assessment for the TA-16 Burn Ground: Revision 2,” Los Alamos National Laboratory report LA-UR-10-02042.

LANL. 2010b. “ECORSK Database: Version 2.5,” Los Alamos National Laboratory report LA-UR-10-6898.

Linzey, A.V. 1987. Effects of Chronic Polychlorinated Biphenyls exposure on Reproductive Success of White-Footed Mice (*Peromyscus leucopus*). Archives of Environmental Contamination and Toxicology, 16:455-460.

Linzey, A. and D.M. Grant. 1994. Characteristics of a White-Footed Mouse Population Inhabiting a Polychlorinated Biphenyls Contaminated Site. Archives of Environmental Contamination and Toxicology, 27:521-526.

McNaughton, M. 2006. “Calculating Dose to Non-Human Biota,” Los Alamos National Laboratory, Meteorology and Air Quality Group procedure ENV-MAQ-514, R1.

NMED. 2010. Order Granting Applicants' Motion for Partial Reconsideration: In the Matter of Application of the United States Department of Energy and Los Alamos National Security, LLC, for a Hazardous Waste Facility Permit for Los Alamos National Laboratory and the Notice of Intent to Deny a Permit for Open Burn Units TA-16-399 and TA-16-388 for the Los Alamos National Laboratory. Hazardous Waste Bureau—New Mexico Environment Department. December 21, 2010.

Parmenter, R.R., T.L. Yates, D.R. Anderson, K.P. Burnham, J.L. Dunnum, A.B. Franklin, M.T. Friggens, B.C. Lubow, M. Miller, G.S. Olson, C.A. Parmenter, J. Pollard, E. Rexstad, T.M. Shenk, T.R. Stanley, and G.C. White. 2003. “Small-mammal density estimation: a field comparison of grid-based vs. web-based density estimators,” Ecological Monographs 73(1): 1-26.

Shannon, C.E. 1948. “A mathematical theory of communication,” Bell System Tech. J. 27:379-423.

Talmage, S.S. and B.T. Walton. 1991. “Small Mammals as Monitors of Environmental Contaminants,” Reviews of Environmental Contamination and Toxicology 119:47–145.

Wood, B.A., L. Cao, and M.D. Dearing. 2010. “Deer Mouse (*Peromyscus maniculatus*) Home-Range Size and Fidelity in Sage-Steppe Habitat,” Western North American Naturalist 70(3):345–354.

APPENDIX A: Sample Information

Species	Array Location	Sample Number	Date Collected	Weight (grams)	TAL	Dioxins/ Furans	PCBs	HE	Perchlorate
PEMA[a]	N/W/S	MICEBURN-11-9133	3/17/11	21		X[b]			
PEMA	N/W/S	9132	3/17/11	13.5	X				
PEMA	SE	9131	3/18/11	16.5	X				
PEMA	N/W/S	9130	3/22/11	19.5		X			
MILO	N/W/S	9129	3/22/11	24		X			
MILO	N/W/S	9128	3/23/11	21.5		X			
MILO	N/W/S	9127	3/24/11	20.5		X			
MILO	N/W/S	9126	3/24/11	21		X			
PEBO	SE	9125	4/1/11	15	X				
NEME	A	BG-MICE-12-21667	7/3/12	94.8			X		
PEBO	B	21674	7/3/12	23.5				X	
PEBO	E	21676	7/3/12	30					X
PEBO	F	21668	7/3/12	27.1			X		
PEMA	F	21675	7/3/12	26.8					X
PEMA	H	21673	7/3/12	25.4				X	

Note: Coordinates are as follows: X = 1615893.65 and Y = 1763660.03.

[a] PEMA = Deer mouse (*Peromyscus maniculatus*), MILO = Long-tailed vole (*Microtus longicaudus*), PEBO = Brush mouse (*Peromyscus boylii*), NEME=Mexican wood rat.

[b] X = Analyzed.

8. Gadek, C.R. and M.S. Velardi, October 2021. *2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory*. LA-UR-21-30407. (Gadek & Velardi 2021)

LA-UR-21-30407

Title: 2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Author(s): Gadek, Chauncey Ryland
Velardi, Milu Sue

Intended for: Environmental Regulatory Document

Issued: 2021-10-29 (rev.1)

LA-UR-21-30407
October 2021
Approved for public release;
distribution is unlimited.

2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY

Prepared by: **Chauncey Gadek and Milu Velardi, Environmental Protection and Compliance Division, Environmental Stewardship Group, Los Alamos National Laboratory**

Los Alamos
NATIONAL LABORATORY

Contents

Figures

Tables

Executive Summary

Los Alamos National Laboratory (LANL) biologists in the Environmental Protection and Compliance Division initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. In this annual report we compare monitoring results from these efforts among years to assess trends in local migratory bird communities. The objectives of this study are to 1) determine whether LANL operations impact bird abundance, species richness, or diversity, and 2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. LANL biologists completed the ninth year of this effort in 2021.

Between May and July 2021, we completed three avian point count surveys at each of the treatment sites which are the Technical Area (TA)-36 Minie site, the TA-39 point 6, and the TA-16 burn ground. We recorded a total of 778 birds representing 58 species at the three treatment sites and compared these results to data from their associated control sites. We also compared occupancy and nest success data from nestboxes at treatment sites with the overall avian nestbox monitoring network.

In 2021, abundance and species richness at treatment and control sites continued to trend similarly from year to year with minor random deviations. Though richness remained stable across all sites, three new bird species were observed at the treatment sites: Blue Grosbeak, White-crowned Sparrow, and Willow Flycatcher indicative of a healthy avian community. The species diversity at the TA-36 Minie site and TA-39 were statistically higher than their associated controls. The species diversity at all three treatment sites has been consistently lower at control relative to treatment sites, likely due to subtle habitat differences. The slightly elevated diversity at treatment sites in 2021 is not unexpected and shows no clear pattern of diverging with diversity at treatment sites. Overall diversity remains high across all sites relative to similar habitats.

Nestbox occupancy and success continue to fluctuate annually, though all three treatment sites experienced decreases in nest success between 2020 and 2021, likely driven by extremely low precipitation levels during winter of 2020.

The overall results from 2021 continue to indicate that operations at the three treatment sites are not negatively affecting bird populations. This long-term project will continue to monitor for any changes over time.

This page intentionally left blank.

Introduction

As part of the Resource Conservation and Recovery Act permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites, Technical Area (TA)-36 Minie site and TA-39 point 6, and one open burn site, TA-16 burn ground (hereafter referred to as Minie, TA-39, and TA-16, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017, 2018, 2019; Sanchez et al. 2020; Rodriguez and Abeyta 2021). The objectives of this long-term monitoring program are to (1) determine whether LANL operations impact bird abundance, species richness, or diversity, and (2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. This involves comparing community and nestbox metrics at treatment sites with control sites of similar habitat that LANL biologists have surveyed since 2011 (Hathcock et al. 2011).

LANL biologists used standard point count methodology to record avian abundance, richness, and diversity along transects at the three treatment sites and their associated control sites during the summer of 2021. Summer surveys provide information about which bird species are breeding at each site. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

In addition to avian point counts, LANL biologists monitored nestboxes around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared to the overall avian nestbox monitoring network, which was established in 1997 (Fair and Myers 2002).

Methods

Field Methods for Point Count Surveys

LANL biologists conducted the point count surveys along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon (*Pinus edulis*) – juniper (*Juniperus monosperma*) woodland (PJ) for Minie (Figure 1) and TA-39 (Figure 2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 3). The habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (Figure 4) are monitored annually. The control sites were originally established in 2011 (Hathcock et al. 2011). Each habitat type control contained two replicate transects that LANL biologists monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects are monitored randomly.

The treatment sites at Minie and TA-39 were similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was in an undeveloped area.

Transects were approximately 2.0 to 2.5 km in length with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys is May 11 through July 9. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site conducted between 0.5 hours before sunrise and four hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for five minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected is point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an “unlimited-distance circular plot”; however, surveyors record the distance to each bird out to an estimated 100 m. A range finder should be used if available. Surveyors avoid re-counting individuals between points.
- While walking between points, surveyors record any obvious species not recorded at the previous point that also wouldn’t be counted at the next point. Surveyors do not spend excess time looking for birds between points.
- Surveys are not conducted during rain events or winds greater than 24 kph.
- Surveyors use the “NOTES” section to indicate any additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Surveyors record other wildlife or unusual sightings that could be used for other projects.

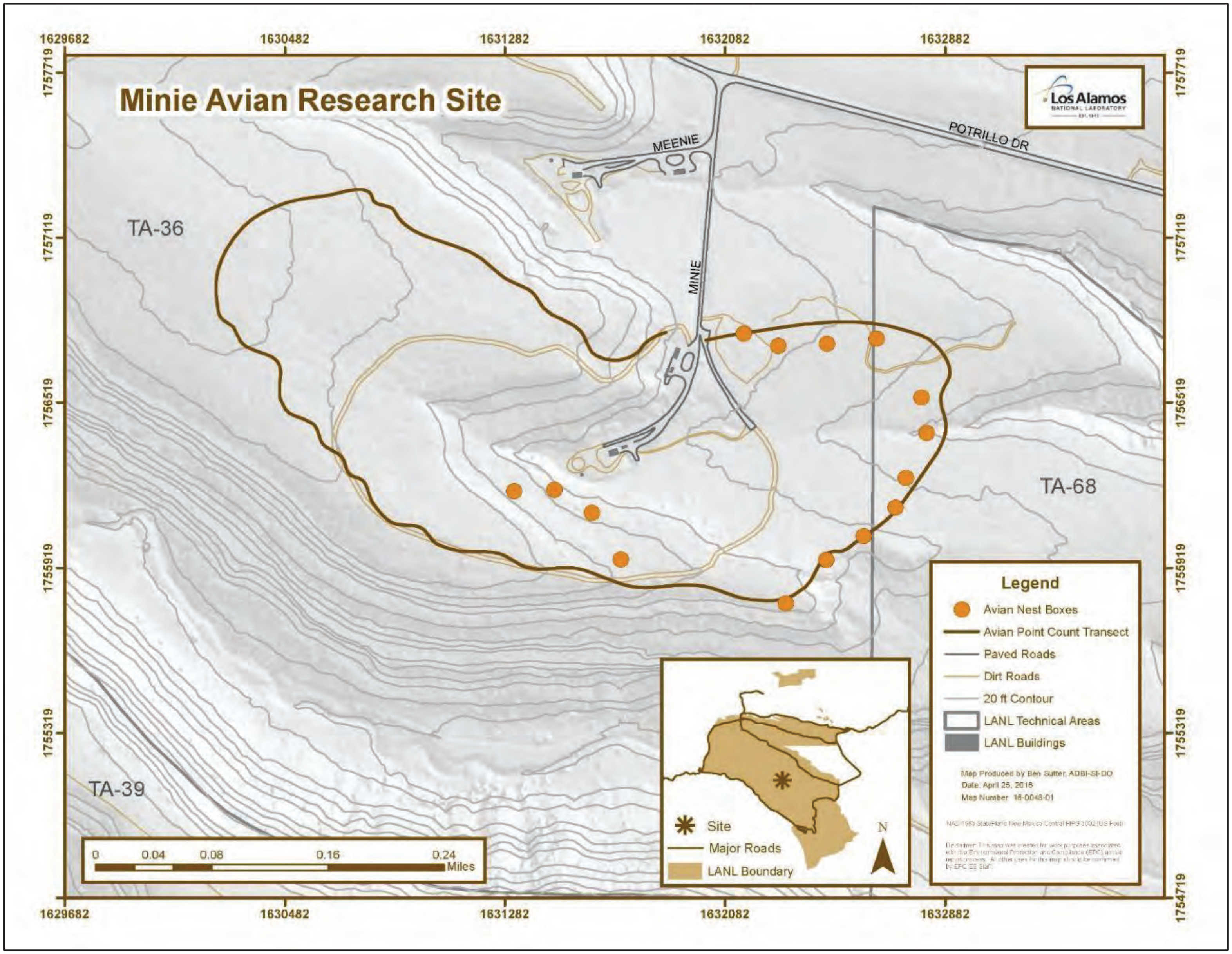


Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie Site

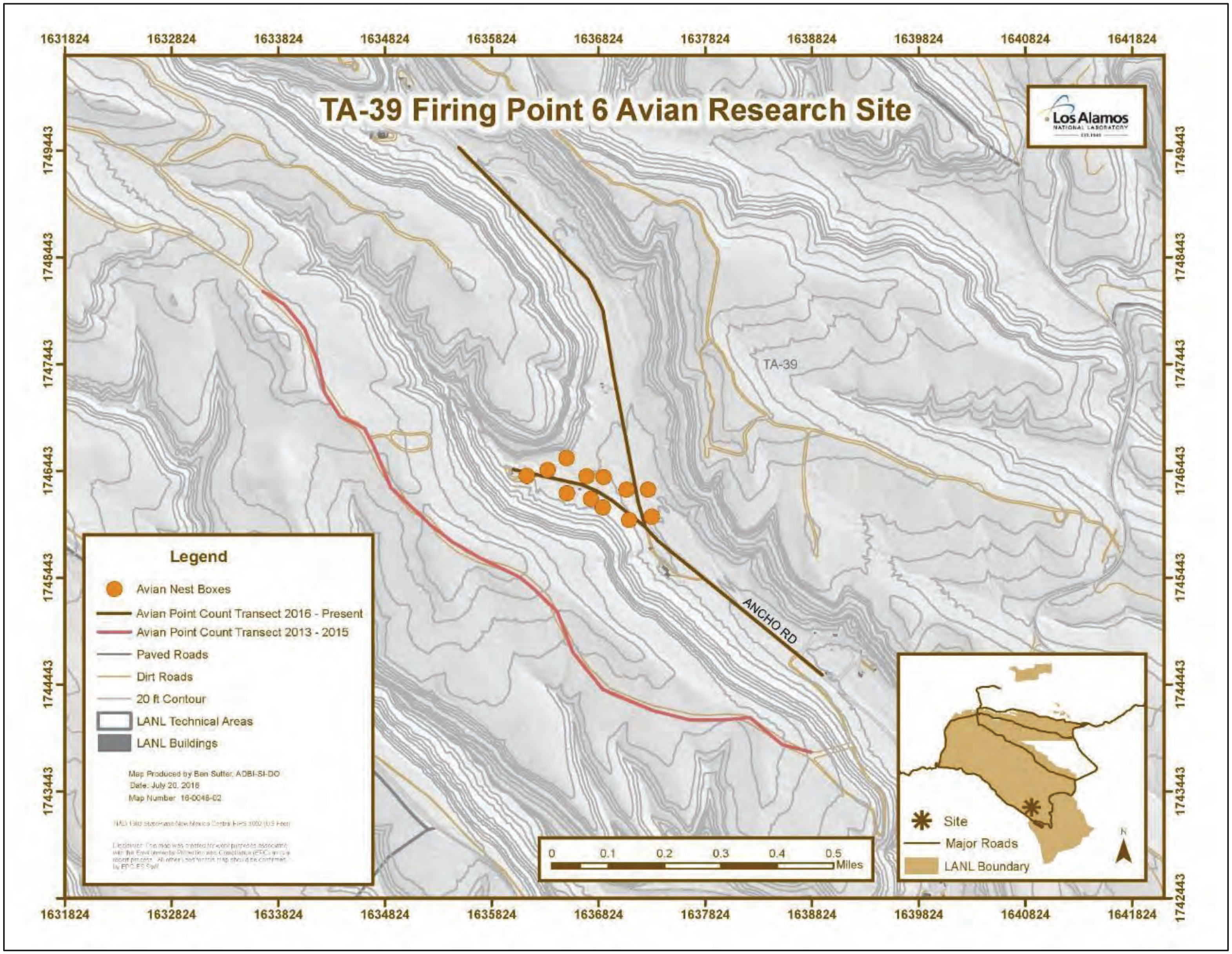


Figure 2. Breeding bird survey transect and nestbox locations around TA-39 Point 6

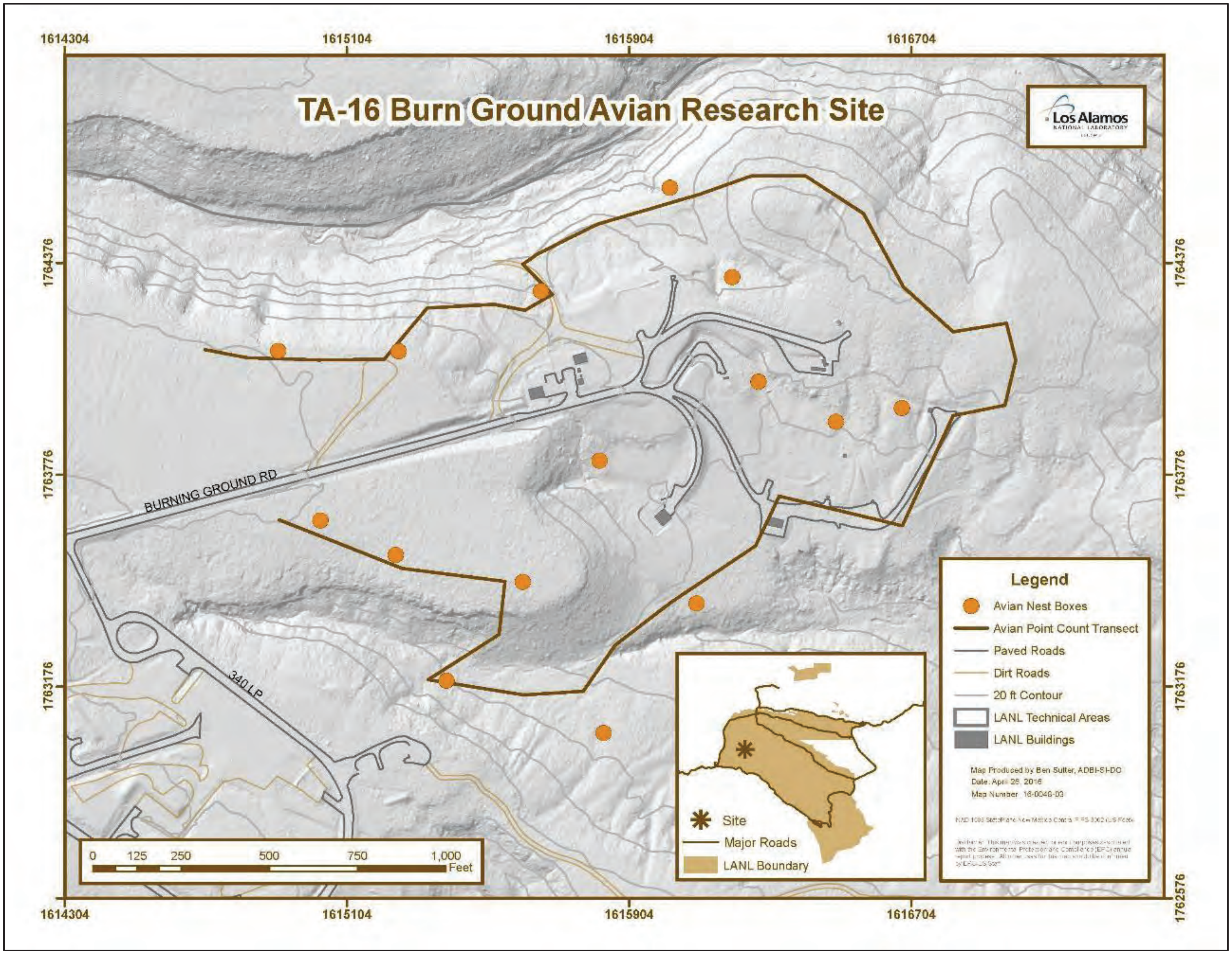


Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 Burn Ground

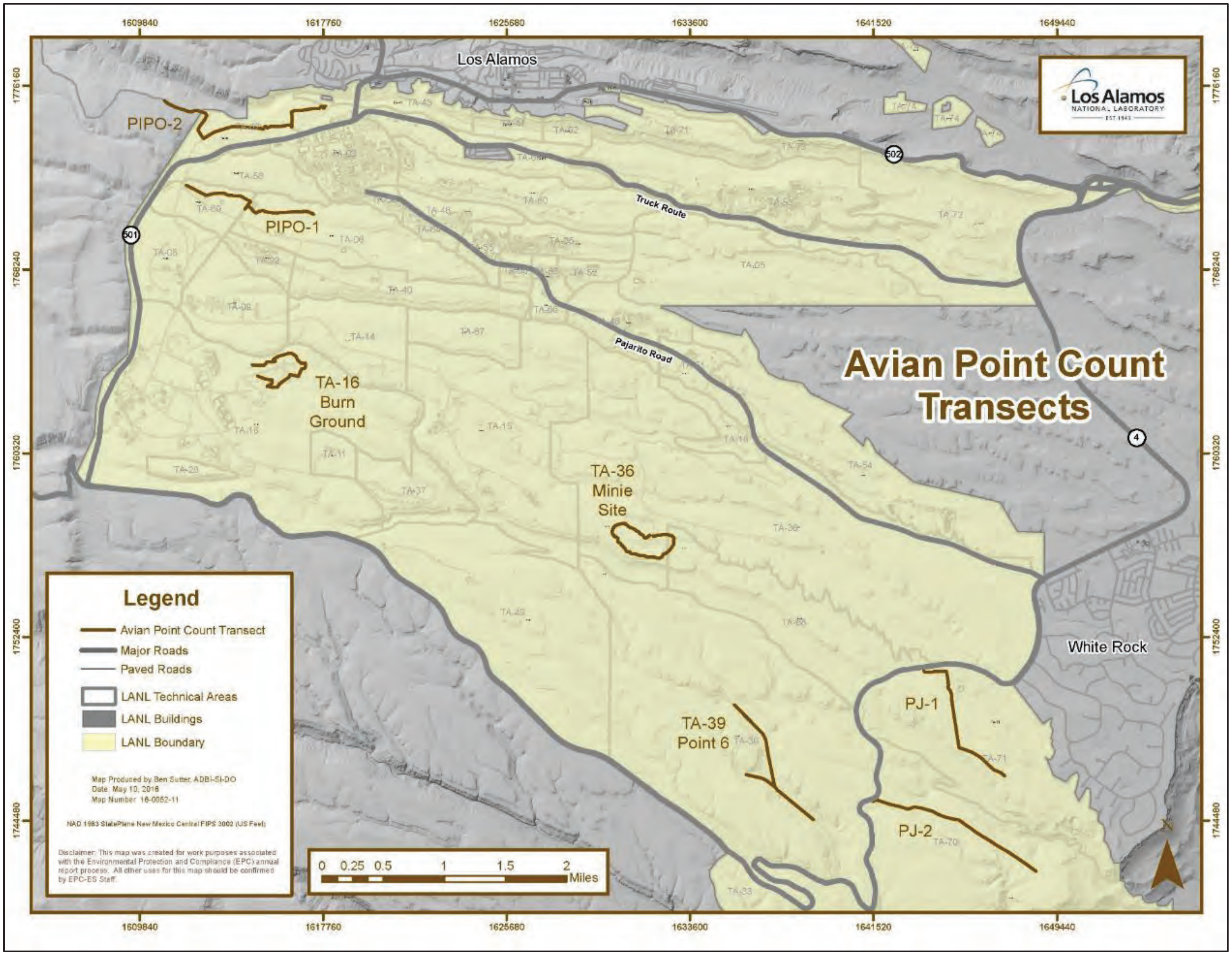


Figure 4. All avian point count transects around LANL

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Statistical Methods for Point Counts

We summarized these data to compare abundance, species richness, and diversity between treatment and control sites and over time. We considered each treatment site and control to be individual communities. Abundance is the total number of individuals recorded of a given species (Gotelli and Colwell 2011). Species richness is the number of different species represented in an ecological community and is simply a count of species (Boulinier et al. 1998). Species diversity is a measure that takes into account species richness and the overall abundance to compare evenness across a community (Tramer 1969). As a species diversity metric, we used Shannon's diversity index which measures the probability that two individuals randomly selected from a sample will belong to different species (Shannon and Weaver 1949).

We calculated species richness, diversity, and abundance using the statistical software R (version 4.1.0; R Core Team 2021) and the package *vegan* (Dixon 2003). We used the Shannon's diversity index to compare diversity between habitats (Clarke et al. 2014). Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5, and are rarely greater than 4.5, where high values indicate high diversity. We used a Hutcheson's T-test in the R package *ecolTest* (Salinas and Ramirez-Delgado 2021) to test for differences between treatment and combined control site diversity each year.

In September of 2020, biologists and concerned citizens documented a large avian mortality event across New Mexico (NMDGF 2020). While researchers have yet to determine the causal factors of the die-off, an anomalous early cold front and record breaking wildfires along the Pacific coast coincided with the event. In 2021, LANL biologists predicted to see a decrease in species richness due to the mass mortality event in 2020. To test for a signal of the avian mortality event, we looked for differences in richness and abundance between 2020 and 2021 using a repeated measures ANOVA framework with transect as a repeated measurement in the R package *lme4* (Bates et al. 2015). Because bird species recovered from the 2020 mortality event tended to be insectivores (D'Ammassa 2020), we also binned all species in two major summer feeding guilds (insectivores and omnivores) in the ANOVAs.

Field Methods for Nestbox Monitoring

In 2011, LANL biologists added nestboxes to Minie and TA-39 (Figures 1 and 2). In 2015, biologists added nestboxes to TA-16 (Figure 3). We monitored nestboxes every one to two weeks for active nests. When an active nest was found, we monitored it more frequently to determine whether the nest failed or successfully fledged young. We also banded nestlings and determined the sex after the age of 10 days. We compared the data from the nestboxes at the treatment sites to the data from the overall nestbox network at LANL.

Statistical Methods for Nestboxes

We calculated occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. We compared the 2021 data from the three treatment sites with the overall avian nestbox network at LANL which was established in 1997 (Fair and Myers 2002).

Results and Discussion

Point Count Surveys-Year 2021

LANL biologists completed three surveys at each of the three treatment sites and the associated control sites between May and July 2021. Table 1 summarizes the species richness, diversity, and abundance for 2021 for each treatment and control site. A total of 778 birds representing 58 species were recorded at the three treatment sites. A full account of the 2013 – 2021 data is detailed in Appendix 1.

Table 1. The species richness, diversity, and abundance recorded at all treatment and control sites in 2021

	Minie	*TA-39*	*PJ Control 1*	*PJ Control 2*	*TA-16*	*PIPO Control 1*	*PIPO Control 2*
Richness	33	38	33	25	37	36	44
Diversity	3.00	3.03	2.82	2.54	3.20	3.01	3.22
Abundance	209	286	225	159	283	349	448

Abundance

Overall bird abundance has trended similarly for both treatment and control sites (Figure 5 & Table 2). Overall abundance has tended to increase since 2013 with minor fluctuations. The fluctuations in bird abundances were not alarming, and abundances at treatment sites and control sites have continued to trend together (Figure 5). Bird abundances seems to partially track winter precipitation levels with 2015-2017 representing the wettest winters in our dataset (NOAA 2021). Abundance values marginally decreased in 2021, with the exception of Minie and PIPO-2 sites, potentially driven by extreme drought conditions during winter 2020 and spring 2021 (NOAA 2021).

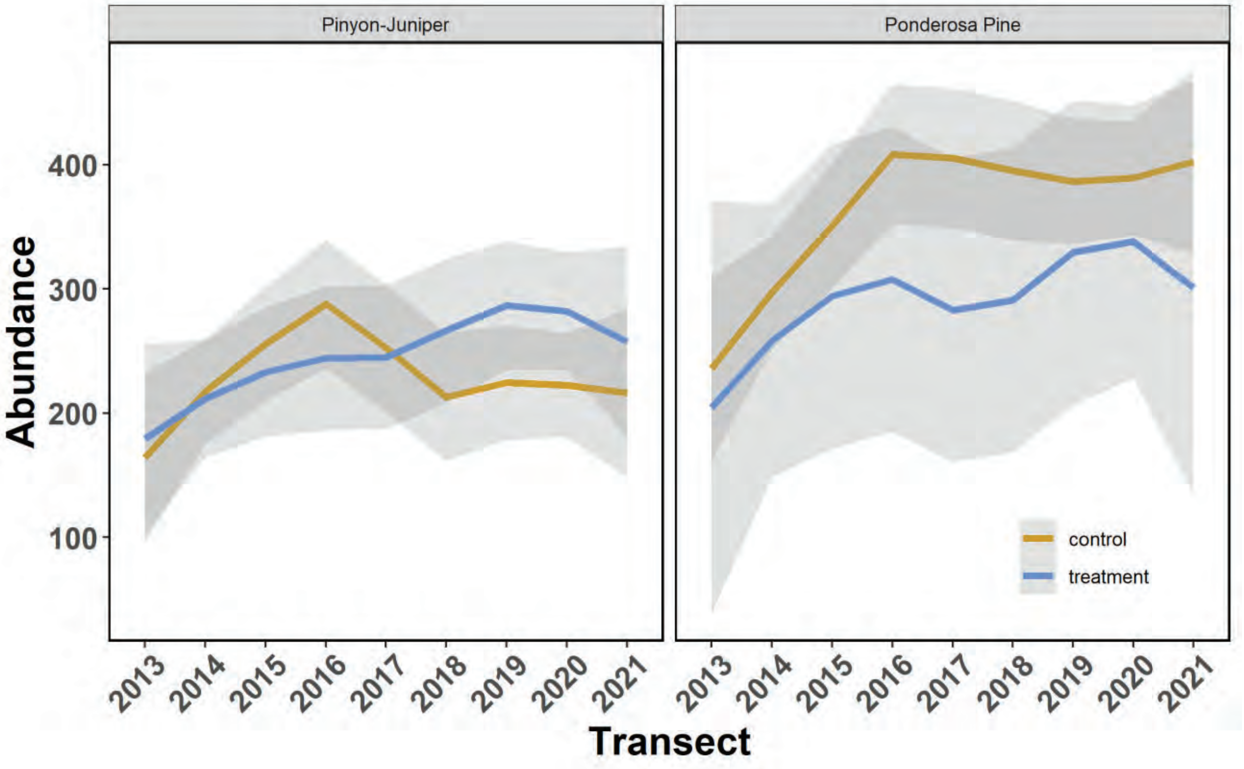


Figure 5. Abundance values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 2. Changes in species abundance over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Minie	193	186	275	210	222	242	245	203	209
TA-39	177	193	260	249	261	315	298	413	286
PJ Control 1	187	157	269	312	240	235	226	292	225
PJ Control 2	181	177	301	228	300	168	187	269	159
TA-16	220	209	347	271	302	285	310	389	283
PIPO Control 1	258	223	432	323	447	374	364	373	349
PIPO Control 2	256	254	371	396	449	366	394	429	448

Species Richness

Figure 6 & Table 3 illustrate changes in species richness over time at the treatment and individual control sites. Overall the mean richness at treatment sites has remained stable with small annual fluctuations since monitoring began (Figure 6 & Table 3). Species richness at both treatment and control sites have largely trended together with average richness at treatment sites slightly increasing in 2015- 2017, similar to abundance values, suggesting richness may also be influenced by winter precipitation.

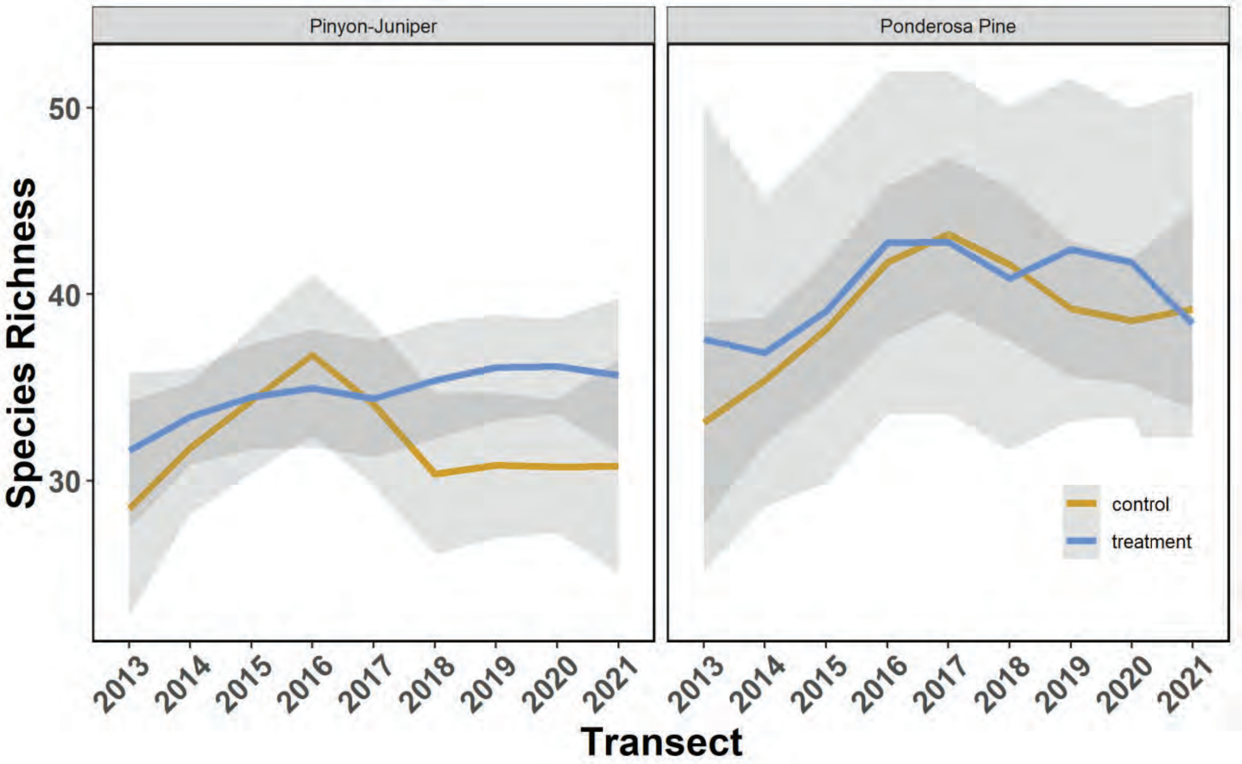


Figure 6. Species richness values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 3. Changes in species richness over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Minie	33	33	34	30	35	35	34	33	33
TA-39	31	31	39	38	34	36	38	40	38
PJ Control 1	29	30	33	36	37	30	30	37	33
PJ Control 2	30	29	37	33	39	23	33	32	25
TA-16	39	33	40	44	41	43	39	46	37

PIPO Control 1	34	34	30	40	46	40	41	33	36
PIPO Control 2	33	36	43	43	44	39	40	40	44

Diversity

Figure 7 and Tables 4 – 6 compare the species diversity over time between the treatment site and the combined controls. We combined the two control sites to analyze diversity because we were interested in the relative abundances among species. Significant differences in diversity between sites by year are indicated in bold font with a darker shading. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Even though we see significant differences, the bird diversity at all sites is around 3, which—compared with ecological systems in general—is very high.

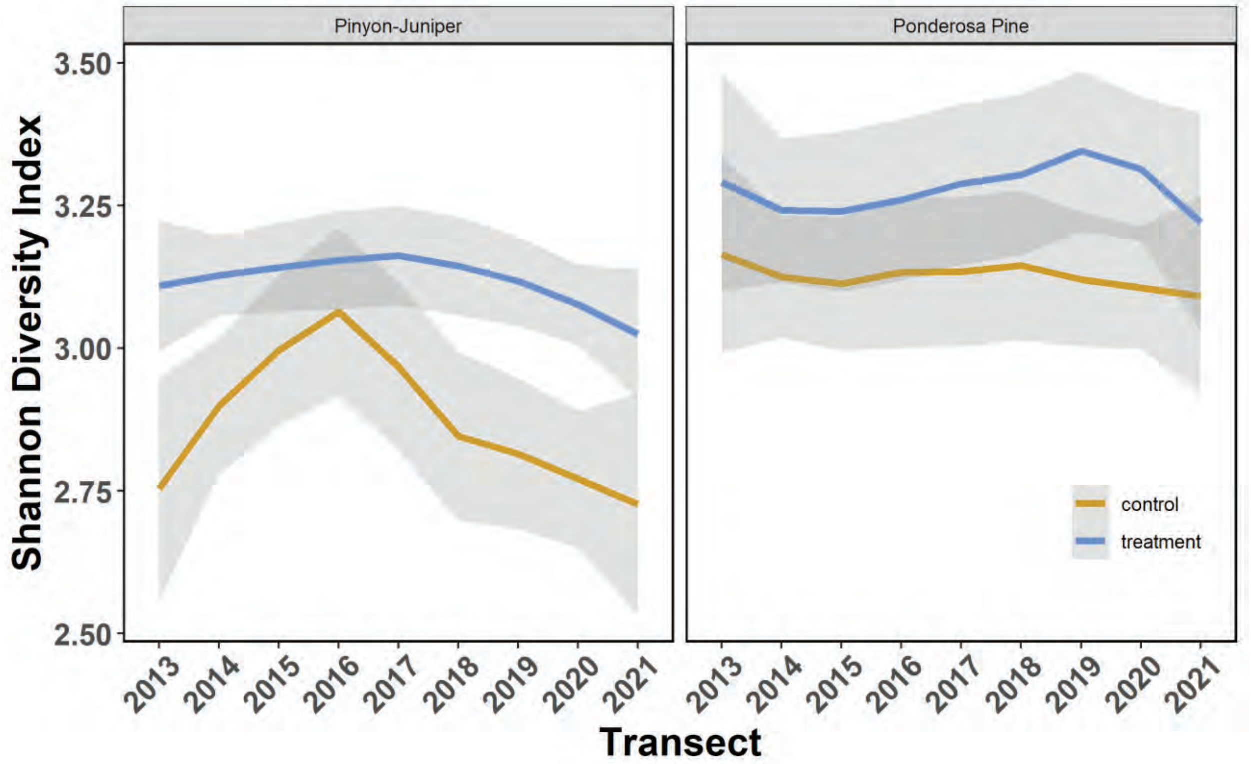


Figure 7. Shannon diversity index values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 4. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Minie	3.14	3.14	3.19	2.97	3.13	3.21	3.06	3.13	3.00
PJ Control	2.88	2.99	3.16	3.07	3.24	2.94	2.97	2.98	2.80
Hutcheson's t-test	**t = 3.34** **df = 523** **p < 0.001**	t = 1.97 df = 468 p = 0.05	t = 0.55 df = 683 p = 0.58	t = -1.34 df = 473 p = 0.18	t = -1.53 df = 515 p = 0.13	**t = 4.07** **df = 599** **p < 0.0001**	t = 1.29 df = 634 p = 0.20	**t = 2.23** **df = 528** **p = 0.03**	**t = 2.41** **df = 532** **p = 0.02**

Table 5. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
TA-39	3.09	3.07	3.13	3.32	3.18	3.13	3.08	3.07	3.03
PJ Control	2.88	2.99	3.16	3.07	3.24	2.94	2.97	2.97	2.80
Hutcheson's t-test	**t = 2.64** **df = 481** **p < 0.01**	t = 1.08 df = 488 p = 0.28	t = -0.28 df = 492 p = 0.78	**t = 3.91** **df = 690** **p < 0.00001**	t = -1.00 df = 693 p = 0.32	**t = 2.83** **df = 702** **p < 0.01**	t = 1.46 df = 673 p = 0.15	t = 1.49 df = 945 p = 0.14	**t = 2.73** **df = 644** **p < 0.01**

Table 6. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
TA-16	3.30	3.21	3.23	3.29	3.24	3.36	3.29	3.36	3.20
PIPO-Control	3.26	3.22	3.16	3.21	3.20	3.17	3.31	3.18	3.22
Hutcheson's t-test	t = 0.71 df = 419 p = 0.48	t = -0.28 df = 517 p = 0.78	t = 1.30 df = 702 p = 0.20	t = 1.18 df = 524 p = 0.24	t = -0.91 df = 549 p = 0.36	**t = 3.07** **df = 598** **p < 0.005**	t = -0.46 df = 659 p = 0.65	**t = 3.42** **df = 842** **p < 0.001**	t = -0.24 df = 583 p = 0.81

Detecting 2020 Mass Mortality Event

Though upwards of 100,000 birds are thought to have died in the mass mortality event last September (NMDGF 2020), repeated measures ANOVAs between years and foraging guilds, controlled for transect, showed no significant difference in abundance or richness between 2020 and 2021 (Figure 8). It is likely that most of the birds involved in the die-off, were migrants flying through New Mexico and therefore did not contribute to local breeding populations.

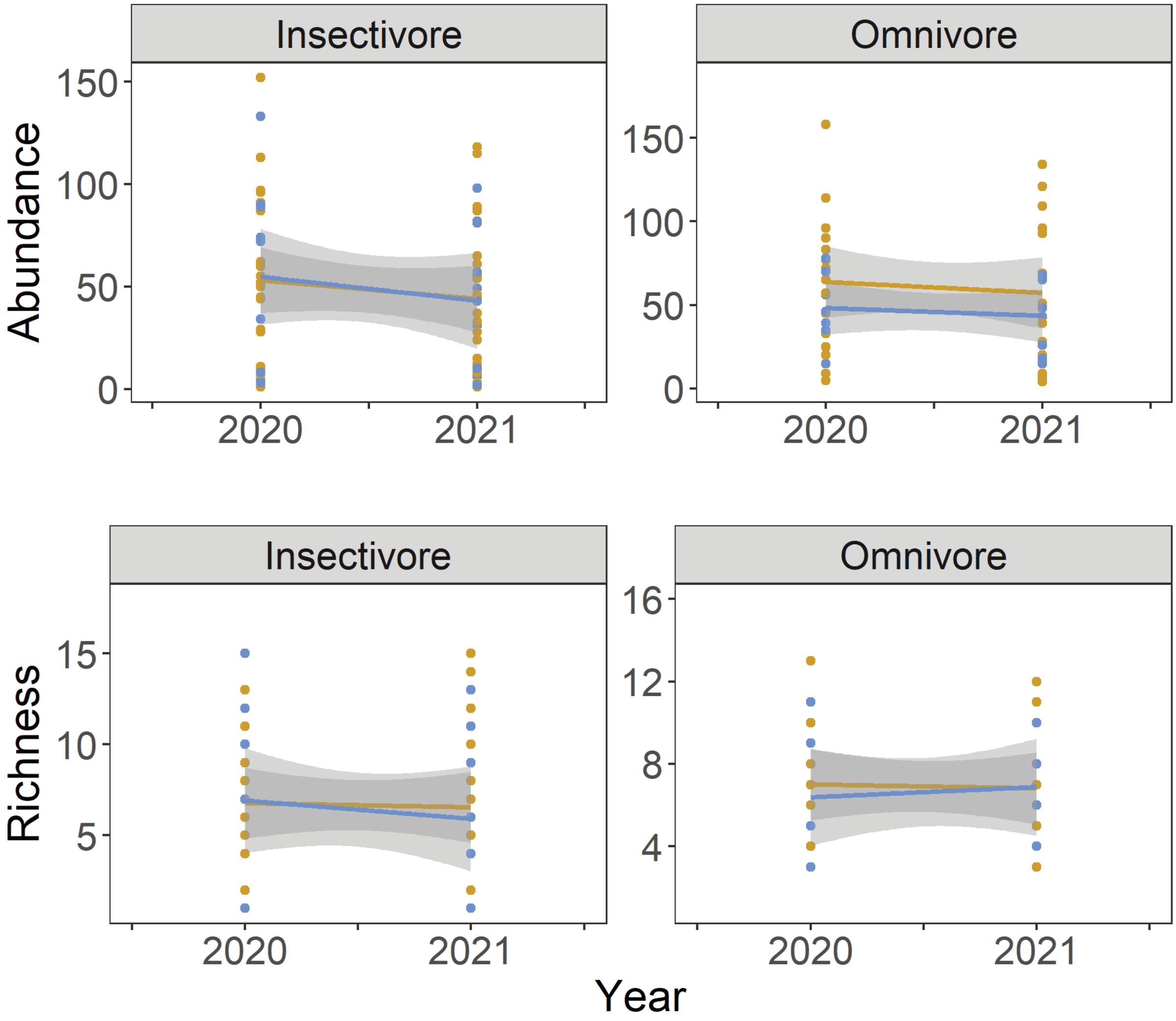


Figure 8. Richness compared between 2020 and 2021 for two major summer foraging guilds between control sites (orange) and treatment sites (blue).

Nestboxes

During the 2021 nesting season, LANL biologists actively monitored 15 nestboxes at each treatment site and a total of 365 nestboxes throughout the overall avian nestbox network. Of those, 110 contained active nests and 49 of those nests fledged young successfully for an overall occupancy rate of 30% and a 45% success rate. Both the occupancy and success rates for 2021 were the lowest recorded since the start of the nestbox monitoring at firing sites in 2015 (Tables 7 & 8). Figure 9 and Tables 7 and 8 compare the occupancy and nest success rates for each treatment site and the overall nestbox network since 2015.

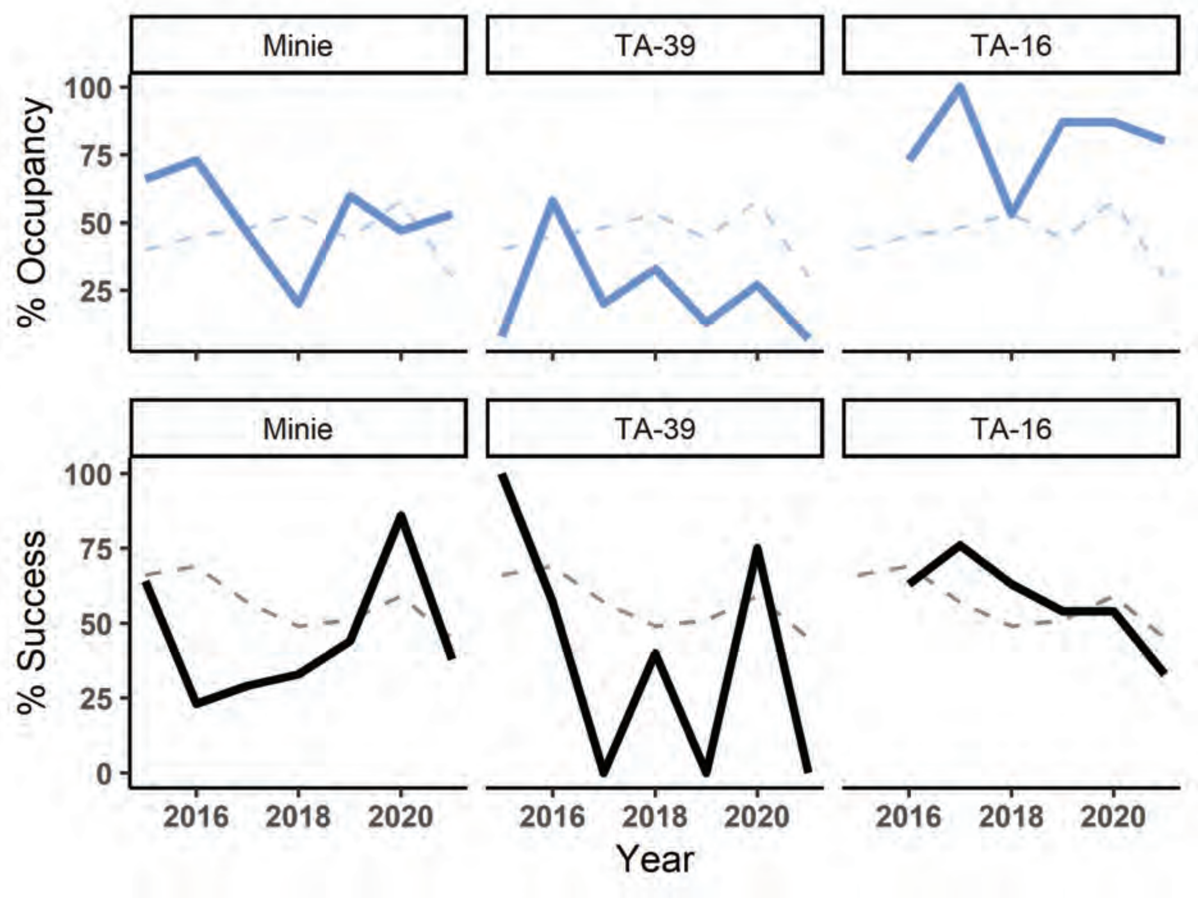


Figure 9. Nestbox occupancy (blue line; top) and success (black line; bottom) plotted by year for the three treatment sites. Dashed lines are global yearly mean for occupancy and success combined across all sites.

Table 7. Comparison of occupancy for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Overall Network	40%	45%	48%	53%	44%	58%	30%
Minie	66%	73%	46%	20%	60%	47%	53%
TA-39	8%	58%	20%	33%	13%	27%	7%

TA-16	-	73%	100%	53%	87%	87%	80%

Table 8. Comparison of nest success for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Overall Network	66%	69%	57%	49%	51%	59%	45%
Minie	64%	23%	29%	33%	44%	86%	38%
TA-39	100%	57%	0%	40%	0%	75%	0%
TA-16	-	63%	76%	63%	54%	54%	33%

In 2021, there were three successful nests that fledged young at Minie, four at TA-16, and zero at TA-39. Occupancy at TA-39 was also low relative to the other treatment sites and the overall network. The nest success rate at TA-39 has been highly variable since monitoring began in 2015 ranging between 0% and 75%. TA-39 is the lowest elevation treatment site and occupancy has been decreasing over time at this site and surrounding areas of the avian nestbox network (Figure 9 & Table 7). Wysner et al. (2019) found that Western Bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. Western Bluebirds have the highest occupancy rates throughout the nestbox network, and shifts in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the Minie treatment site have fluctuated annually and have not displayed a decreasing trend over time, though the success rate dropped substantially between 2020 and 2021 (Figure 9 & Table 8). While occupancy has been relatively high and naturally fluctuating at TA-16, the success rate has been decreasing since 2017 with the largest decrease in success occurring in 2021.

Decreases in occupancy and nest success were pervasive across both control and treatment sites between 2020 and 2021 with 79% of all nestbox sites showing a decrease in occupancy and 86% showing a decrease in nesting success (Figure 10 & Table 9). These decreases are likely driven by extreme low precipitation values winter 2020 and spring 2021 (NOAA 2021). Decreases in precipitation have been linked to declines in body mass which may indirectly impact reproductive success (Smith et al. 2010).

In 2021, LANL biologists submitted nonviable eggs collected from nestboxes at the treatment sites and the rest of the nestbox network to an analytical lab for chemical analyses. These data will be presented in a separate report.

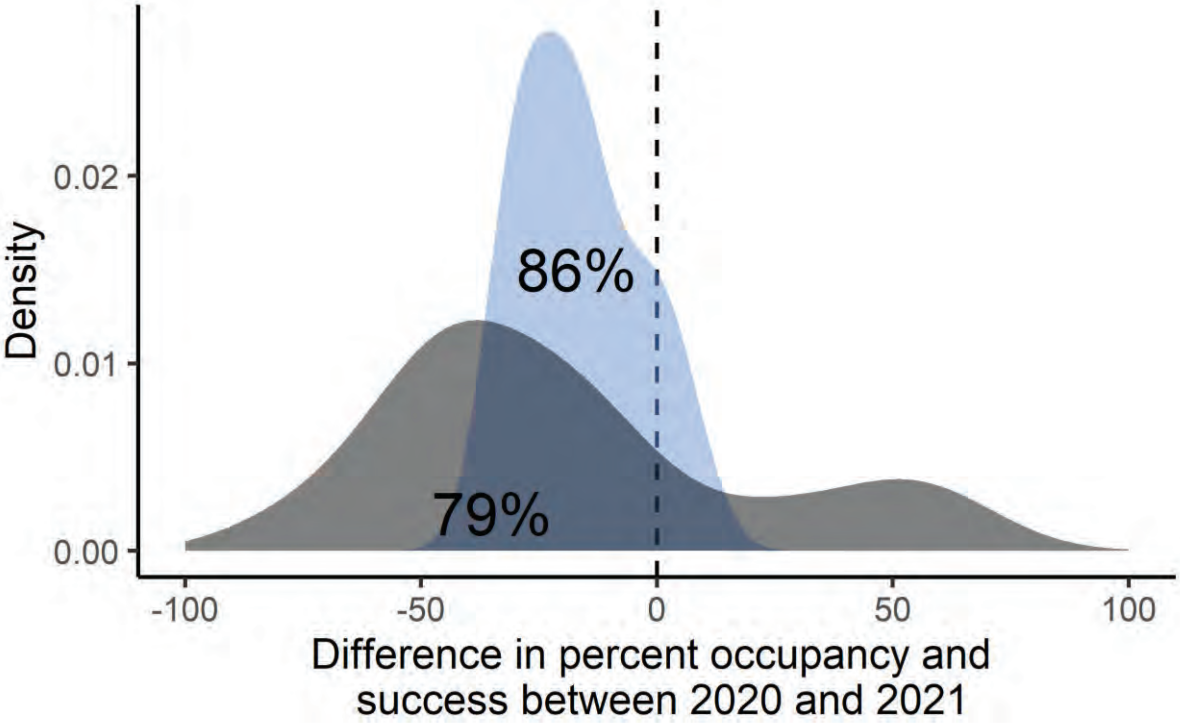


Figure 10. Distribution of between-year comparisons of percent occupancy (grey) and success (blue) between 2020 and 2021. Shaded area to left of dashed line illustrates number of sites that had a reduction in percent occupancy or success in 2021 compared to 2020. Percentages indicate number of comparisons falling below zero.

Table 9. Results from best fit repeated measures ANOVA for comparison between 2020 and 2021 abundance and richness binned by foraging guild and using transect as repeated measure.

Insectivore			
Abundance ~ Year + Site Cat	**df**	**t**	**P value**
Year	20	-1.320	0.20
Site Category (Treatment/Control)	12	0.823	0.43
Richness ~ Year + Site Cat	**df**	**t**	**P value**
Year	21	-0.728	0.48

Site Category (Treatment/Control)	13	0.780	0.45
Omnivore			
Abundance ~ Year + Site Cat	**df**	**t**	**P value**
Year	12	-1.532	0.15
Site Category (Treatment/Control)	12	0.036	0.97
Richness ~ Year + Site Cat	**df**	**t**	**P value**
Year	12	-0.628	0.54
Site Category (Treatment/Control)	12	0.674	0.51

Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Over the 9 year study period LANL biologists have documented sensitive species from the Sensitive Species Best Management Practices Source Document (Berryhill et al. 2020) and the Birds of Management Concern and Focal Species list (USFWS 2021) at the treatment sites. Those species are the Cassin's Finch, Juniper Titmouse, Grace's Warbler, Virginia's Warbler, Black-throated Gray Warbler, Evening Grosbeak, Peregrine Falcon, and the Mourning Dove. The Gray Vireo is the only sensitive species documented in only control sites. Of the 79 species detected at the three treatment sites, the Migratory Bird Treaty Act protects all but one species. The Eurasian Collared-Dove is not native and therefore not protected under the Migratory Bird Treaty Act.

Continuing to document migratory bird occurrences and nest success across treatment and control sites, provides a long-term dataset to assess the ecological health of avifauna at the three treatment sites at LANL. In addition, this research contributes to meeting the Department of Energy's commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and it allows LANL to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Thanks to the following individuals for technical and field support work in 2021: Andrew Bartlow, Jesse Berryhill, Chuck Hathcock, Audrey Sanchez, Jenna Stanek, Brent Thompson, Luciana Vigil-Holterman, and former staff and interns that helped in previous years.

Literature Cited

Bates, D., M. Mächler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67(1). https://doi.org/10.18637/jss.v067.i01

Berryhill, J.T., J.E. Stanek, E.J. Abeyta, and C.D. Hathcock. 2020. Sensitive Species Best Management Practices Source Document, Revision 5. Los Alamos National Laboratory report number LA-UR-20-24514, Los Alamos, New Mexico.

Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Polluck. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79(3):1018–1028.

Clarke, K.R., R.N. Gorley, P.J. Somerfield, and R. Warwick. 2014. Change in marine communities; an approach to statistical analysis and interpretation, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262pp.

D'Ammassa, A. 2020. 'Hundreds of thousands, if not millions': New Mexico sees massive migratory bird deaths. Las Cruces Sun News.

Dixon, P. 2003. VEGAN, a package of R functions for community ecology. Journal of Vegetation Science 14(6):927–930.

Fair, J.M., and O.B. Myers. 2002 Early reproductive success of western bluebirds and ash-throated flycatchers: a landscape-contaminant perspective. Environmental Pollution 118:321–330.

Gotelli, N.J. and R.K. Colwell. 2011. Estimating species richness. Biological diversity: Frontiers in Measurement and Assessment 12:39–54.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. Los Alamos National Laboratory report number LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. Los Alamos National Laboratory report number LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill. 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-18-22897, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow, A.A. Sanchez, J. Stanek, and B.E. Thompson. 2019. 2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-19-24156, Los Alamos, New Mexico.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. Los Alamos National Laboratory report number LA-14029, Los Alamos, New Mexico.

New Mexico Department of Game and Fish (NMDGF). 2020. Starvation, unexpected weather to blame in mass migratory songbird mortality. http://www.wildlife.state.nm.us/starvation-unexpected-weather-to-blame-in-mass-migratory-songbird-mortality/. Accessed February 2021.

NOAA (National Oceanic and Atmospheric Administration). September 2021. Climate at a Glance: Global Mapping, retrieved on September 14, 2021 from https://www.ncdc.noaa.gov/cag/

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Rodriguez, J.M. and E.J. Abeyta. 2021. 2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los

Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-21-22304, Los Alamos, New Mexico.

Salinas, H. and D. Ramirez-Delgado. 2021. ecolTest: Community Ecology Tests. URL https://cran.r-project.org/web/packages/ecolTest/index.html.

Sanchez, A.A., C.D. Hathcock, and B.E. Thompson. 2020. 2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-20-20436, Los Alamos, New Mexico.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, USA. 127pp.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874–2882.

Tramer, E.J. 1969. Bird species diversity: components of Shannon’s formula. Ecology 50(5):927–929.

U.S. Fish and Wildlife Service (USFWS). 2021. Birds of conservation concern. United States Department of Interior, Fish and Wildlife Service, Migratory Bird Program, Arlington, Virginia. 48 pp.

Wysner, T.E., A.W. Bartlow, C.D. Hathcock, and J.M. Fair. 2019. Long-tern phenology of two North American secondary cavity-nesters in response to changing climate conditions. The Science of Nature 106:54. doi:10.1007/s00114-019-1650-9.

Appendix 1. All birds recorded at the three treatment sites from 2013–2021

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
Species	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Acorn Woodpecker																			5		3	2	3	5	3	5	1
American Crow																							1	1		1	1
American Kestrel				1				1	1	1			2					2									
American Robin	1	1	2		2					1	1		2		4	2			7		9	4	4	6	12	6	14
Ash-throated Flycatcher	11	5	14	13	13	10	17	12	12	19	11	30	12	8	8	6	11	4	3	5	6	2	3	8	4	6	6
Audubon's Warbler		2				5							2				5		6	5	1	6		1	11	14	9
Bewick's Wren	4	8	9	9	14	14	5	10	4	3	10	15	9	2	8	1	2										
Black-chinned Hummingbird		1	1				1	2	1	3	2				1	2	3		1		1		1		1	12	1
Black-headed Grosbeak	1	3				1	1	2	1		2	4	1		3	2	1	1			1	2		2		1	1
Black-throated Gray Warbler			1		2			2		5	6	4															
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	11	8	2		7	5	4	2	13	5	2		6	2	1	3	6	4	9	3
Blue Grosbeak																		1									
Broad-tailed Hummingbird	2	1	3		1		3	2		3	1	2		3	1	2	9	3	5	11	11	5	7	10	8		
Brown Creeper																			1								
Brown-headed Cowbird	1								1			2			3	2	10	3	4	1			4	2	8	4	4
Bushtit		2		2		11				2	14			1	12		2										
Canada Goose												16				2											
Canyon Towhee	2		5	3	6	2	3	5	3	1	1	2	10	13	19	6	3	9	1			1		1			
Canyon Wren					1							2	3	8	6	2	4				2						
Cassin's Finch						4																					1
Cassin's Kingbird	6	13	13	5	2	5	6	5	4	7	6	2	21	21	32	37	49	14				1				2	
Chipping Sparrow	3	16	17	29	6	22	10	10	10	6	6	5	8	15	25	27	24	16	1	5	3	10	5	21	8	32	6
Clark's Nutcracker																				4		1					
Common Nighthawk	6		5	2	4	4	1	5		5	1	3	2	7	5	7	3	1			1	2	2			1	
Common Raven	2	5	1		1	2	3			1		2	1		1	2	5		5	6	2	2	5	5	7	4	2
Cooper's Hawk					1														1			1			1		
Cordilleran Flycatcher																			5	10	6	3	3	1	2	4	
Dark-eyed Junco															1	1			6	2	4		5	2		2	3
Downy Woodpecker				1									1	2		1	2	1		1		1	1	1			
Dusky Flycatcher				1								1		1												2	1
Eurasian Collared-Dove	3													4			2							1			
Evening Grosbeak	3		4						1			8							5		29			1			
Grace's Warbler							1								2	4	1	6	6	4	4	8	5	8	22	12	17
Gray Flycatcher	12	6	5	7	3	6	3	2	4	10	10	11	10	5	8	3	14	5									

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
Species	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Great Horned Owl		3								1																	
Green-tailed Towhee	3	1								1																1	
Hairy Woodpecker			2	1		1		1	1			5	3			1	1	4	1	1		1	1	2	1	1	
Hammond's Flycatcher																			8	9	12	5	7	5	10	5	7
Hepatic Tanager									2			1	2	1	2			1				1					
Hermit Thrush						1														4	6	1	2	2	5	5	2
House Finch	16	17	26	17	12	18	17	11	11	21	4	23	9	30	44	50	53	22	16	2	5	5	12	7	12	18	11
House Wren																1			1	1		2	2	6	8	2	1
Juniper Titmouse	12		7	6	9	3	26	8	20	11	13	18	6	1			3	2									
Lesser Goldfinch	2	6	7	4	9	12	8	4	4	4	12	9	10	14	19	15	27	8	3		8	9	4	8	5	6	2
MacGillivray's Warbler																						1	3			1	
Mountain Bluebird		2	20	10	11	1	9	3	2		4						2	1			4	4	4	7	4	5	
Mountain Chickadee	5	2	1	2									1	1		1			5	8	9	6	8	9	1	4	6
Mourning Dove	17	17	13	5	8	8	11	9	7	13	22	10	3	15	11	8	10	9	4		1	3	17	3	5	17	5
Northern Mockingbird					2		1	4			1							2									
Northern Rough-winged Swallow						3																					
Orange-crowned Warbler																										1	
Peregrine Falcon									1			1						1									
Pine Siskin	10	2		5	1			1		6		3	3						12	4	5		4	2		6	
Plumbeous Vireo	10	10	7	3	9	9	15	3	3	1		1	6	6	5	5	12	4	11	16	15	14	11	18	16	24	17
Pygmy Nuthatch				2		2	3		1			2	4	12	9	11	10	1	11	13	26	29	41	20	16	23	5
Red Crossbill					1						2						1			2	9	13	9		6	26	1
Red-shafted Flicker	3	1	3	2	5	2	1		1	3	2	4	8		3	2	2		3	4	11	11	5	5	2	7	5
Red-tailed Hawk							1	2	1			1	1	1	1												
Rock Wren	3	3	4		2	10	11	10	4	7	10	4	12	14	14	12	20	15	1	2	2	6			4	1	
Ruby-crowned Kinglet																								2			1
Savannah Sparrow																										1	
Say's Phoebe	2	1	2		2	5	1	1	2	2	1		5	2	4		6	5	1		1	3	3	4	1	1	4
Scaled Quail			1																								
Spotted Towhee	17	8	19	27	32	24	19	20	17	12	6	33	16	12	16	15	20	14	11	18	16	14	21	22	34	24	16
Steller's Jay							1												3	2	5	6	3	4	4	2	1
Townsend's Solitaire	1																						1				
Turkey Vulture					1			2									1		1					1			
Vesper Sparrow																									1		
Violet-green Swallow		5	7	1	3	2	1	6		6	4	1	9	6	6	9	47	5		2	19	2	2	4	2	7	6
Virginia's Warbler					1	3	1					1	2	4		5		2	17	11	21	13	7	5	5	8	3

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
Species	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Warbling Vireo						2													2	9	7	6	5	4	6	3	7
Western Bluebird	15	11	18	17	16	19	21	23	8	5	19	12	21	13	6	7	17	3	20	20	49	37	32	27	20	27	8
Western Tanager		2	3		1						2	1	1	2	2	6	1	2	2	3	7	2	4	6	16	10	7
Western Wood-Pewee	10	8	18	11	10	7	18	14	10		4	2	10	8	11	12	18	12	15	10	16	14	22	20	24	28	25
White-breasted Nuthatch	1	4	9	10	13	5	2	1	2			2	4	4	2	6	3	2	9	8	7	9	20	10	10	8	10
White-crowned Sparrow																		1									
White-throated Swift											1						2										
White-winged Dove	1	5	9	2		3	2	1	1	7	5	6	16	15	15	5	2	5			1	2			1		
Willow Flycatcher																		1									
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	10	10	8	10	4	8	6	4	5		2	1								

9. Gadek, C.R., M.S. Velardi, and E.J. Abeyta, January 2023. *2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory*. LA-UR-23-20631. (Gadek *et al*. 2023)

ESHID-603740

LA-UR-23-20631

Approved for public release; distribution is unlimited.

Title:	2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory
Author(s):	Gadek, Chauncey Ryland Velardi, Milu Sue Abeyta, Elisa Janelle
Intended for:	Report
Issued:	2023-01-24

January 2023

2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY

Prepared for: U.S. Department of Energy/National Nuclear Security Administration,
Los Alamos Field Office

Prepared by: Chauncey Gadek, Milu Velardi, and Elisa Abeyta
Environmental Protection and Compliance Division
Environmental Stewardship Group (EPC-ES)
Los Alamos National Laboratory

Editing and Layout by: Tamara Hawman, Communications Specialist
Technical Editing and Communications (CEA-TEC)
Los Alamos National Laboratory

Cover photo: A Violet-green Swallow (*Tachycineta thalissina*) captured during a Monitoring Avian Productivity and Survivorship (MAPS) banding session in Sandia Canyon June 2022. Photo credit: Elisa Abeyta.

Contents

Figures

Tables

EXECUTIVE SUMMARY

Los Alamos National Laboratory (LANL) biologists in the Environmental Protection and Compliance Division initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property, with additional monitoring beginning in 2017 at a third firing site. In this annual report, we compare monitoring results from these efforts among years to assess trends in local migratory bird communities. The objectives of this study are

- to determine whether LANL operations impact bird abundance, species richness, or diversity; and
- to examine occupancy and nest success of secondary-cavity nesting birds that use nest boxes.

LANL biologists completed the tenth year of this effort in 2022.

Between May and July 2022, biologists completed three avian point count surveys at each of the treatment sites:

- Technical Area (TA)-36 Minie site,
- TA-39 Point 6,
- TA-16 Burn Ground, and
- Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT).

We recorded a total of 1,182 birds representing 63 species at the four treatment sites and compared these results with data from their associated control sites. We also compared occupancy and nest success data from nest boxes at treatment sites with the overall avian nest box monitoring network and against a subset of relevant control sites.

In 2022, abundance and species richness at treatment and control sites continued to trend similarly from year to year with minor random deviations, indicative of a stable avian community. Though richness remained stable across all sites, two new bird species were observed at the treatment sites—Bullock's Oriole and Painted Redstart. The species diversity at the TA-36 Minie site, TA-39, and DARHT were statistically higher than their associated controls. The species diversity at all three treatment sites has been consistently lower at control relative to treatment sites, likely due to subtle habitat differences. Annual diversity at treatment sites in 2022 remains stable relative to past years. Overall diversity remains high across all sites relative to similar habitats.

Nest box occupancy and success continue to fluctuate annually; however, a long-term discrepancy between occupancy and nest success at treatment sites in ponderosa pine habitat warrants further data collection and analyses.

The overall results from 2022 continue to suggest that operations at the four treatment sites are not negatively impacting bird populations. This long-term project will continue to monitor for any changes over time.

1 Introduction

As part of the Resource Conservation and Recovery Act permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites—Technical Area (TA)-36 Minie site and TA-39 Point 6; and one open burn site—TA-16 Burn Ground (hereafter referred to as Minie, TA-39, and TA-16, respectively; or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock, Thompson, and Berryhill 2017; Hathcock, Bartlow, and Thompson 2018; Hathcock et al. 2019; Sanchez, Hathcock, and Thompson 2020; Rodriguez and Abeyta 2021). LANL biologists have been conducting point counts and monitoring nest boxes near an additional firing site, the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) since 2017. Results for DARHT are included in this report. The objectives of this long-term monitoring program are

- to determine whether LANL operations impact bird abundance, species richness, or diversity; and
- to examine occupancy and nest success of secondary-cavity nesting birds that use nest boxes.

This effort involves comparing community and nest box metrics at treatment sites with control sites of similar habitat that LANL biologists have surveyed since 2011 (Hathcock, Zemlick, and Norris 2011).

LANL biologists used standard point count methodology to record avian abundance, richness, and diversity along transects at the three treatment sites and their associated control sites during the summer of 2022. Summer surveys provide information about which bird species could be breeding at each site. These surveys are most valuable when they are conducted over multiple years because they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

Although point counts are a reliable way to assess community level metrics, their utility in detecting fine-scale landscape differences may be limited (Ralph, Sauer, and Droege 1995). Point counts cannot distinguish between birds that use the local habitat to breed versus itinerant individuals that migrate through or temporarily forage locally. Assessing the success of birds known to nest in close proximity to firing (treatment) sites and those that nest in similar habitats away from firing (control) sites provides increased power to connect local environmental disturbances with local biology. To perform this assessment, LANL biologists monitored nest boxes around all four treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared with the overall avian nest box monitoring network, which was established in 1997 (Fair and Myers 2002), and a subset of sites of similar habitat type and nest box number.

2 Methods

2.1 Field Methods for Point Count Surveys

LANL biologists conducted the point count surveys along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 2-1 through 2-5). The habitat types around the sites are a pinyon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodland (PJ) at Minie (Figure 2-1) and TA-39 (Figure 2-2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 2-3) and DARHT (2-4). The habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (5) are monitored annually. The control sites were originally established in 2011 (Hathcock, Zemlick, and Norris 2011). Each habitat type control contained two replicate transects that LANL biologists monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects are surveyed in a random order. Note that due to fire restrictions in 2022, biologists were unable to survey PJ control transects in June.

The treatment sites at Minie and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 is in the canyon bottom, whereas the controls are on mesa tops. The treatment sites at TA-16 and DARHT are similar in elevation and overstory vegetation to the PIPO control sites, and all are on mesa tops. One of the PIPO control transects is adjacent to development, and the other transect is in an undeveloped area.

Transects are approximately 2.0 to 2.5 km in length, with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The timeframe for breeding bird surveys is May 11 through July 9. Ideally, the breeding bird surveys should take place during the second week of May, June, and July. This protocol requires a total of three surveys per site conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for 5 minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected is point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an “unlimited-distance circular plot”; however, surveyors record the distance to each bird out to an estimated 100 m. A range finder should be used if available. Surveyors avoid re-counting individuals between points.
- While walking between points, surveyors record any obvious species not recorded at the previous point that also would not be counted at the next point. Surveyors do not spend excess time looking for birds between points.
- Surveyors do not conduct surveys during rain events or during winds greater than 24 kph.
- Surveyors use the “NOTES” section to document additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Surveyors also record other wildlife or unusual sightings that could be useful for other projects.

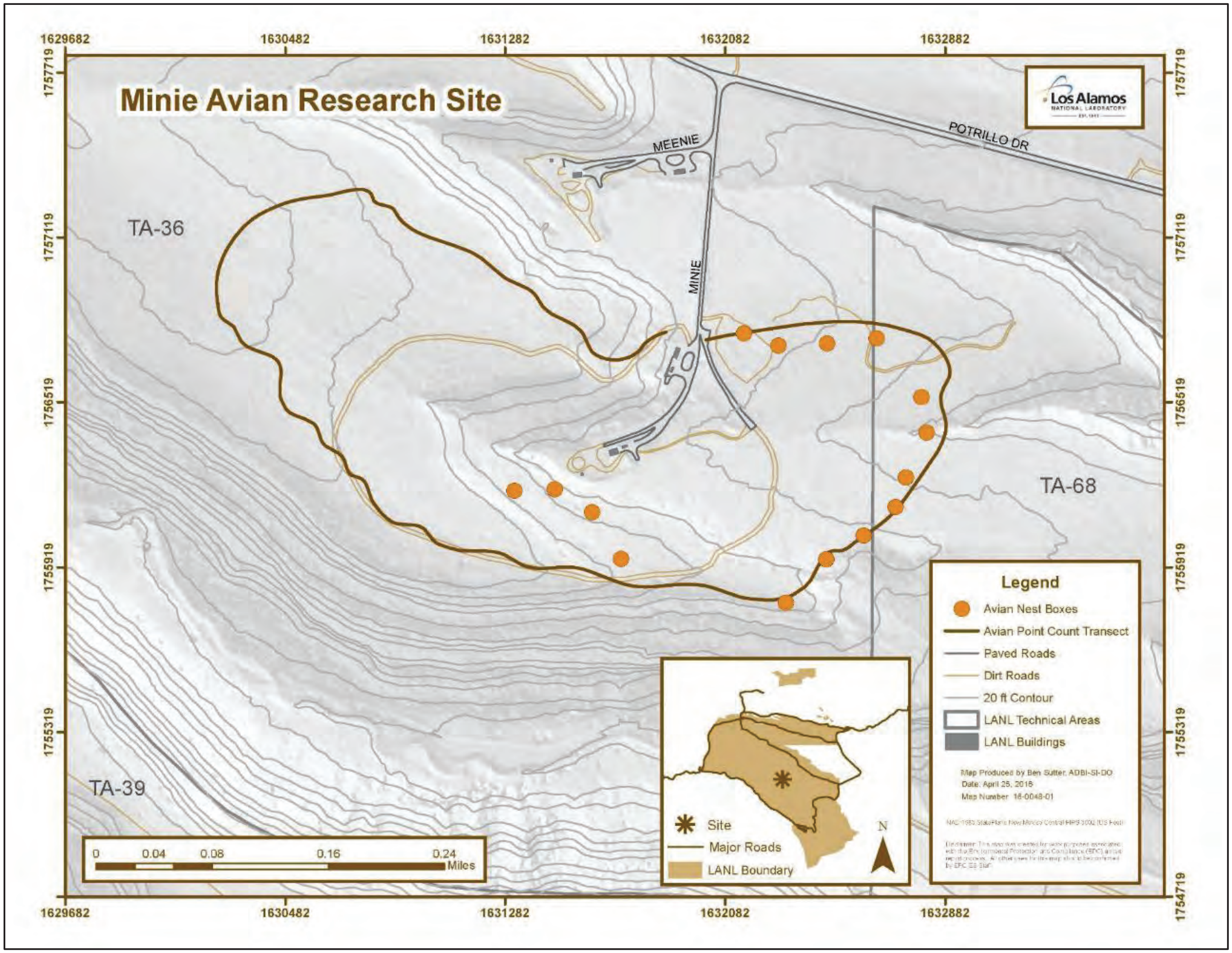


Figure 2-1. Breeding bird survey transect and nest box locations around TA-36 Minie Site.

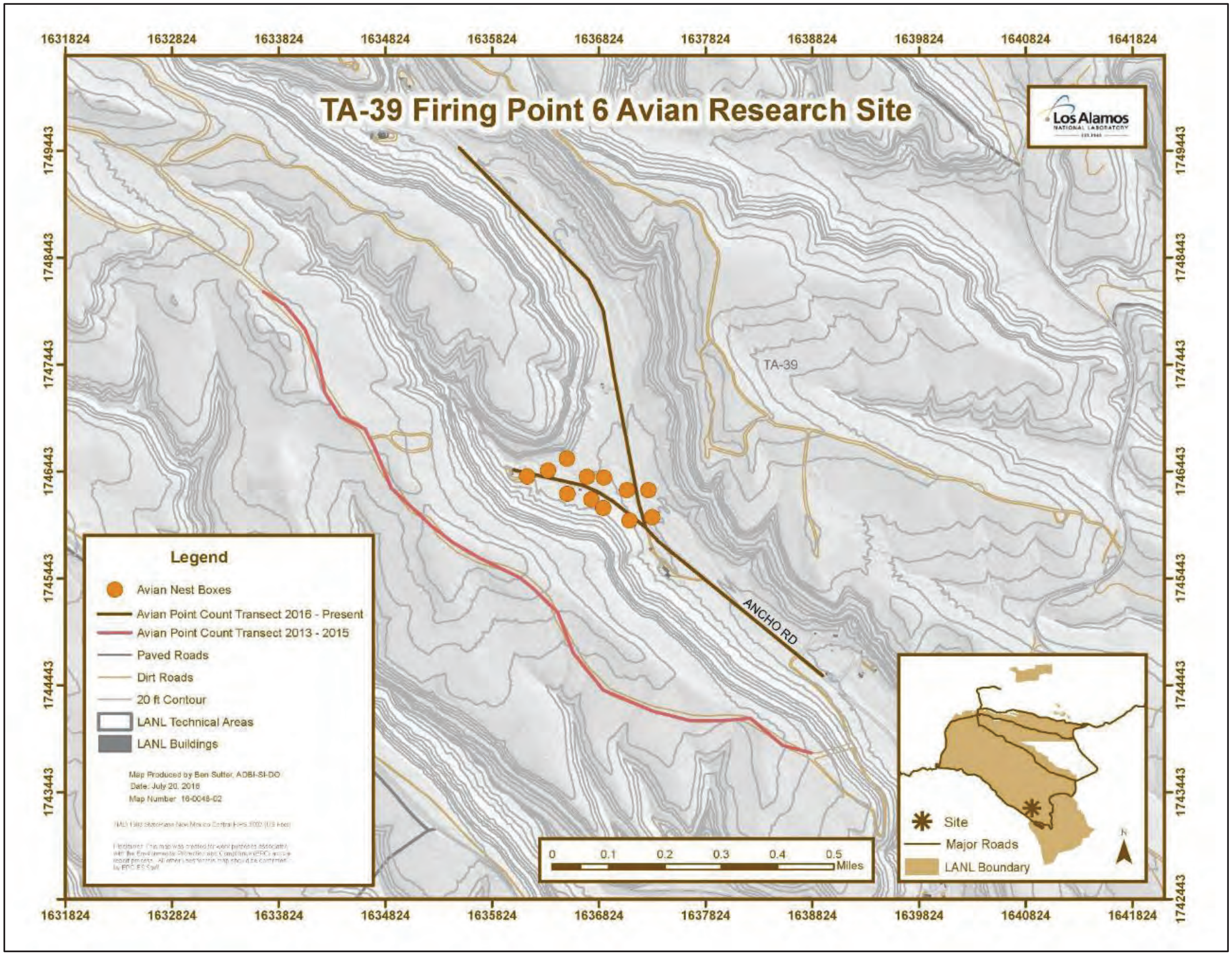


Figure 2-2. Breeding bird survey transect and nest box locations around TA-39 Point 6.

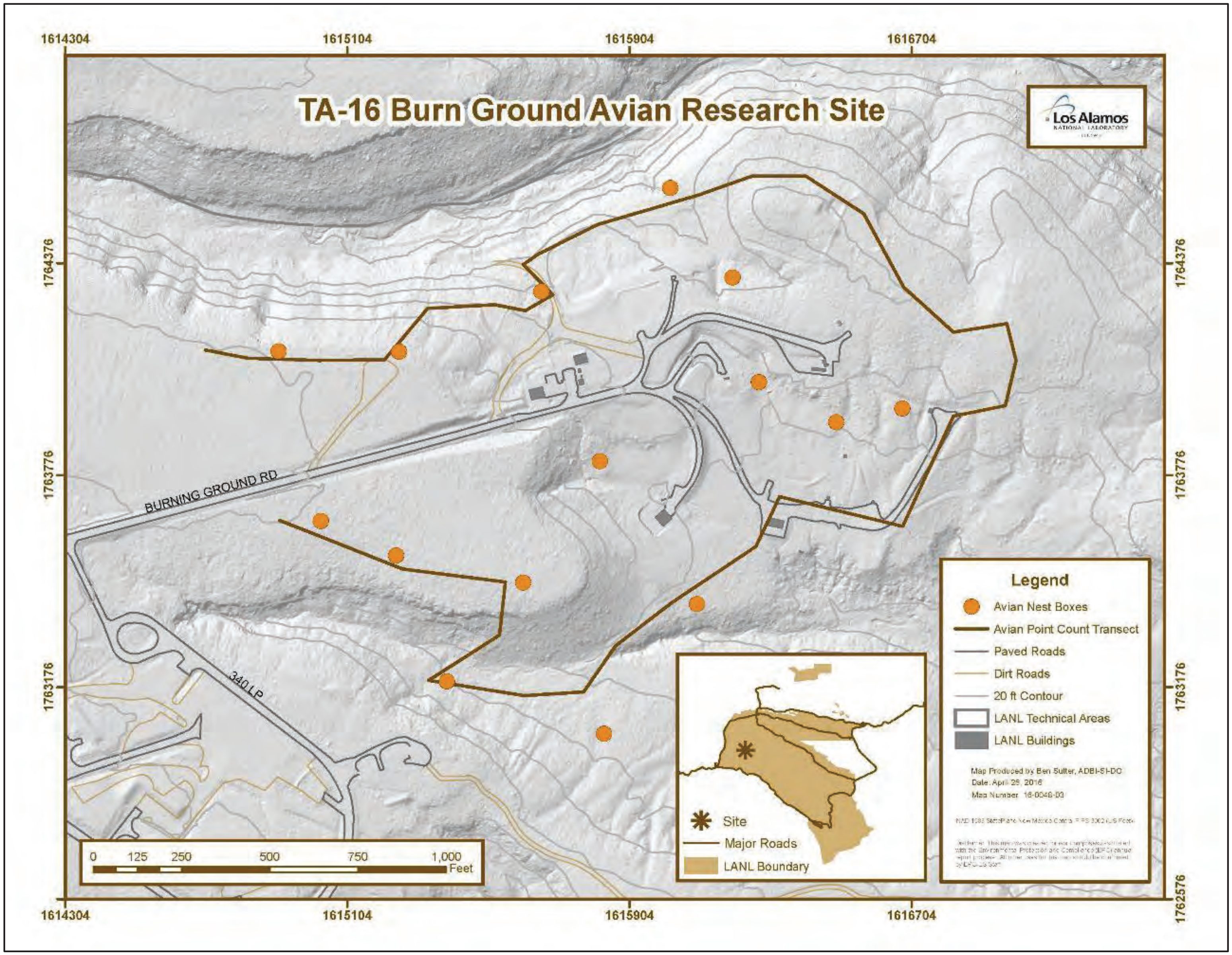


Figure 2-3. Breeding bird survey transect and nest box locations around TA-16 Burn Ground.

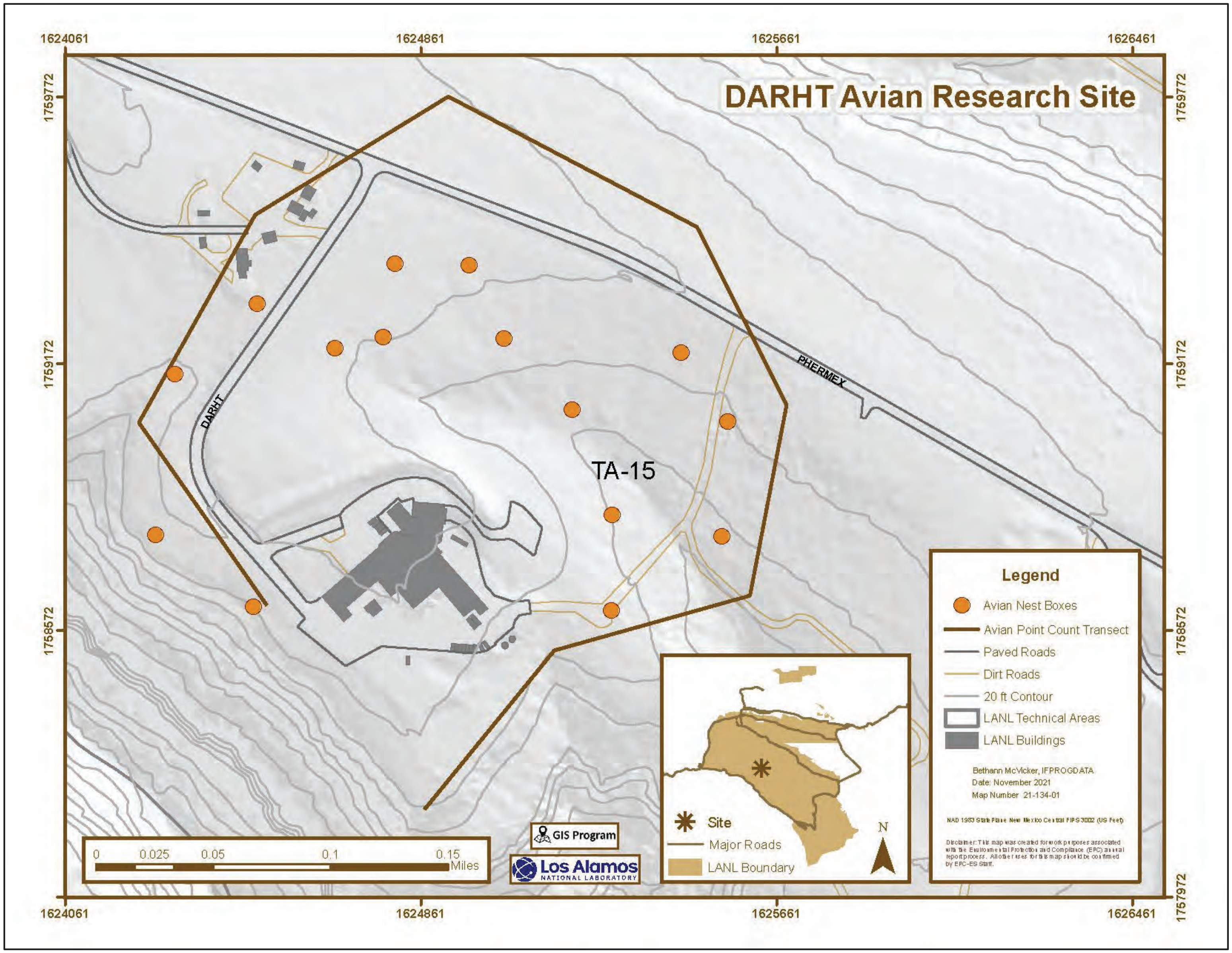


Figure 2-4. Breeding bird survey transect and nest box locations around DARHT.

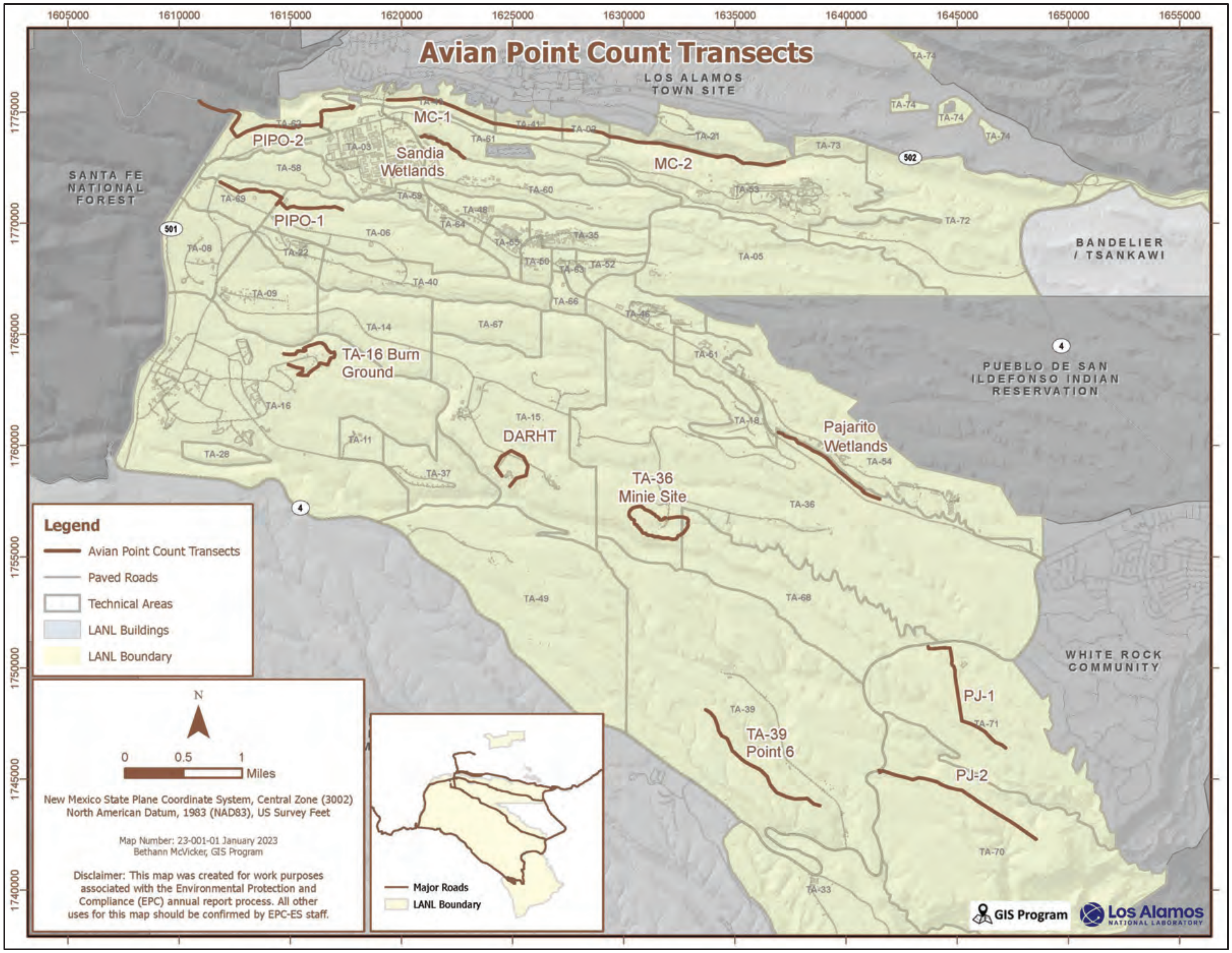


Figure 2-5. All avian point count transects around LANL ponderosa pine forest (PIPO); pinyon-juniper woodland (PJ).

2.2 Statistical Methods for Point Counts

We summarized breeding bird survey data to compare abundance, species richness, and diversity between treatment and control sites and over time. We considered each treatment site and control to be individual communities and compared averaged metrics by combining treatment and control sites within the same habitat class.

Abundance is the total number of individuals recorded of a given species (Gotelli and Colwell 2011). Species richness is the number of different species represented in an ecological community and is simply a count of species (Boulinier et al. 1998). Species diversity is a measure that considers species richness and the overall abundance to compare evenness across a community (Tramer 1969). As a species diversity metric, we used Shannon's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species (Shannon and Weaver 1949; Clarke et al. 2014). We used the diversity index to compare diversity between treatment and control sites. Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5 and are rarely greater than 4.5, where high values indicate high diversity.

We calculated all community metrics using the statistical software R (version 4.2.2; R Core Team 2022 and the package *Vegan* (Dixon 2003) and used simple linear models to estimate coarse trends across the study period. We used Hutcheson's t-tests in the R package *ecolTest* (Salinas and Ramirez-Delgado 2021) to test for differences between treatment and combined (averaged species abundances) control site diversity for each year from 2013 to 2022.

2.3 Field Methods for Nest Box Monitoring

In 2011, we added nest boxes to Minie and TA-39 (Figure 2-1 and Figure 2-2). In 2015, we added nest boxes to TA-16 (Figure 2-3). In 2017, we added 15 nest boxes to DARHT (Figure 2-4). Beginning in May, we monitored nest boxes every 1 to 2 weeks for active nests. When an active nest was found, we monitored it more frequently to determine whether the nest failed or successfully fledged young. We also banded nestlings and determined the sex after the age of 10 days.

2.4 Statistical Methods for Nest Boxes

We calculated occupancy and nest success rates of the nest boxes at the four treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nest boxes divided by the total number of nest boxes. Similarly, the nest success rate was the number of nest boxes that successfully fledged young divided by the number of active nest boxes. We compared the 2022 data from the four treatment sites with the overall avian nest box network at LANL, which was established in 1997 (Fair and Myers 2002). Because the overall nest box network comprises habitats and conditions not present at treatment sites, we also selected control sites that closely matched habitat type and nest box number of comparable treatment sites to examine nesting success metrics in a more balanced design. We calculated and plotted mean nest occupancy and success estimates by treatment and control sites between habitats across all study years.

3 Results and Discussion: Point Count Surveys for Year 2022

LANL biologists completed three surveys at each of the three treatment sites and PIPO control sites between May and July 2022. Because of fire restrictions, the PJ habitat was not surveyed in June 2022. Table 3-1 summarizes the species richness, diversity, and abundance for 2022 for each treatment and control site. A total of 1,182 birds representing 63 species were recorded at the treatment sites. A full account of the 2013–2022 data is detailed in Appendix A.

Table 3-1. Species Richness, Diversity, and Abundance Recorded during 2022 at All Treatment and Control Sites

	Minie	TA-39	PJ Control 1	PJ Control 2	TA-16	DARHT	PIPO Control 1	PIPO Control 2
Richness	37	36	36	22	41	45	36	37
Diversity	3.31	3.11	2.96	2.27	3.18	3.33	2.86	3.06
Abundance	229	339	209	142	340	274	337	334

3.1 Abundance

Overall bird abundance has trended similarly for both treatment and control. Figure 3-1 and Table B-1 detail abundance measured across all years for all sites. Overall abundance has tended to increase since 2013, with minor fluctuations. These fluctuations show no clear pattern that indicates bird numbers are reduced at treatment sites (Figure 3-1, Table 3-1, and Table B-1). Although mean annual abundance estimates trended higher at PIPO control sites than the comparable firing sites, there was substantial overlap in many years when considering per-survey variation in abundances. Mean annual abundance estimates at PJ controls and treatment sites have trended together across the study period, with treatment sites showing a modest but significant increase over time (t = 3.31, p = 0.01) (Figure 3-1).

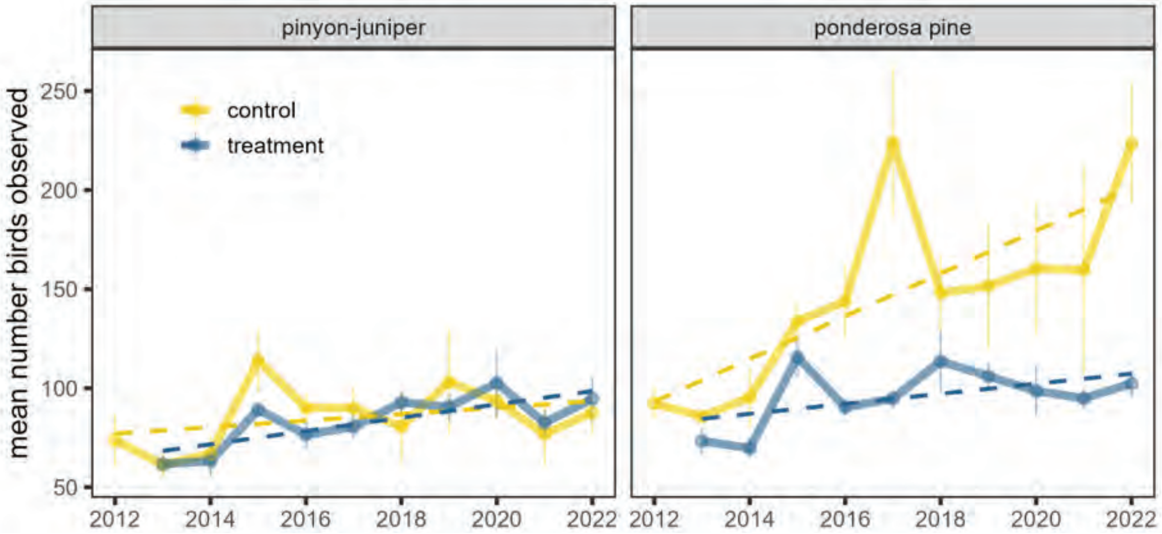


Figure 3-1. Mean bird abundances across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean abundance from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.2 Species Richness

Figure 3-2 and Table B-2 illustrate changes in species richness over time at the treatment and individual control sites. Overall, the mean richness at treatment sites has marginally increased with annual fluctuations since monitoring began (Figure 3-2 and Table B-2). The only significant increase across all years occurred at PJ treatment sites (t = 2.81, p = 0.02). Species richness at both treatment and control sites has partially trended together with average richness slightly higher than at control sites for most years. Per-survey species richness has markedly diverged between treatment and control sites since 2020 in PIPO habitat (Figure 3-2). Though slight increasing trends seem promising, it cannot be ruled out that survey effort and detectability has changed across the study period, leading to increased identification ability. Future data collection should include surveyors' names to control surveyor variability in ongoing analyses.

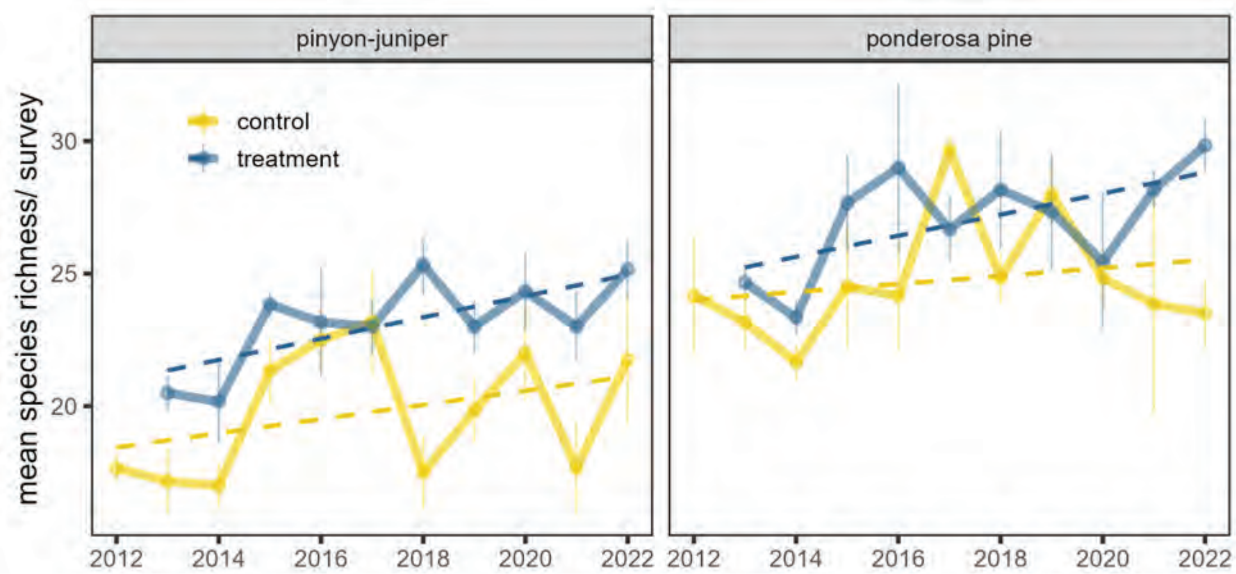


Figure 3-2. Mean bird species richness across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean richness from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.3 Diversity

Figure 3-3 and Table B-3 through Table B-10 illustrate variation in species diversity over time between the treatment and control sites. Both treatment sites in PJ habitat and DARHT in PIPO habitat had significantly higher total diversity than the comparable control sites in 2022 (Table B-3 through Table B-10). Across the entire study window in all significantly different comparisons, the diversity was significantly higher at the treatment site than the combined controls (Table B-3 through Table B-10). Though we see significant differences, the total bird diversity at all sites has remained stable at around 3. Per-survey diversity indices between treatment and control sites in ponderosa pine habitat clearly diverge in 2017, likely driven by the addition of DARHT surveys (Figure 3-3). The generally low ambient disturbance conditions at Weapons Facilities Operations relative to control sites may be driving the higher diversity we observed at treatment sites.

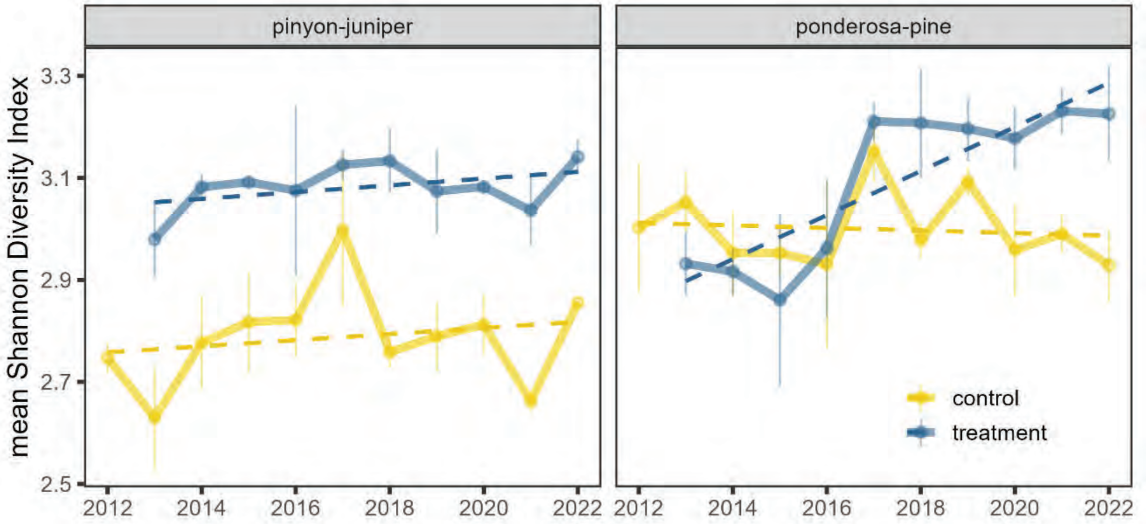


Figure 3-3. Mean Shannon Diversity Index across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean diversity from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.4 Nest Boxes

During the 2022 nesting season, LANL biologists actively monitored 15 nest boxes at each treatment site and a total of 333 nest boxes throughout the overall avian nest box network. Of those, 110 contained active nests, and 49 of those nests fledged young successfully, for an overall occupancy rate of 41 percent and a success rate of 42 percent. Though occupancy rate increased from a historic low in 2021, nesting success rate for 2022 continued to drop to a new recorded low since data collection began in 2015 (Table B-11 and Table B-12). Figure 3-4, Table B-11, and Table B-12 compare the occupancy and nest success rates for each treatment site and the overall nest box network since 2015.

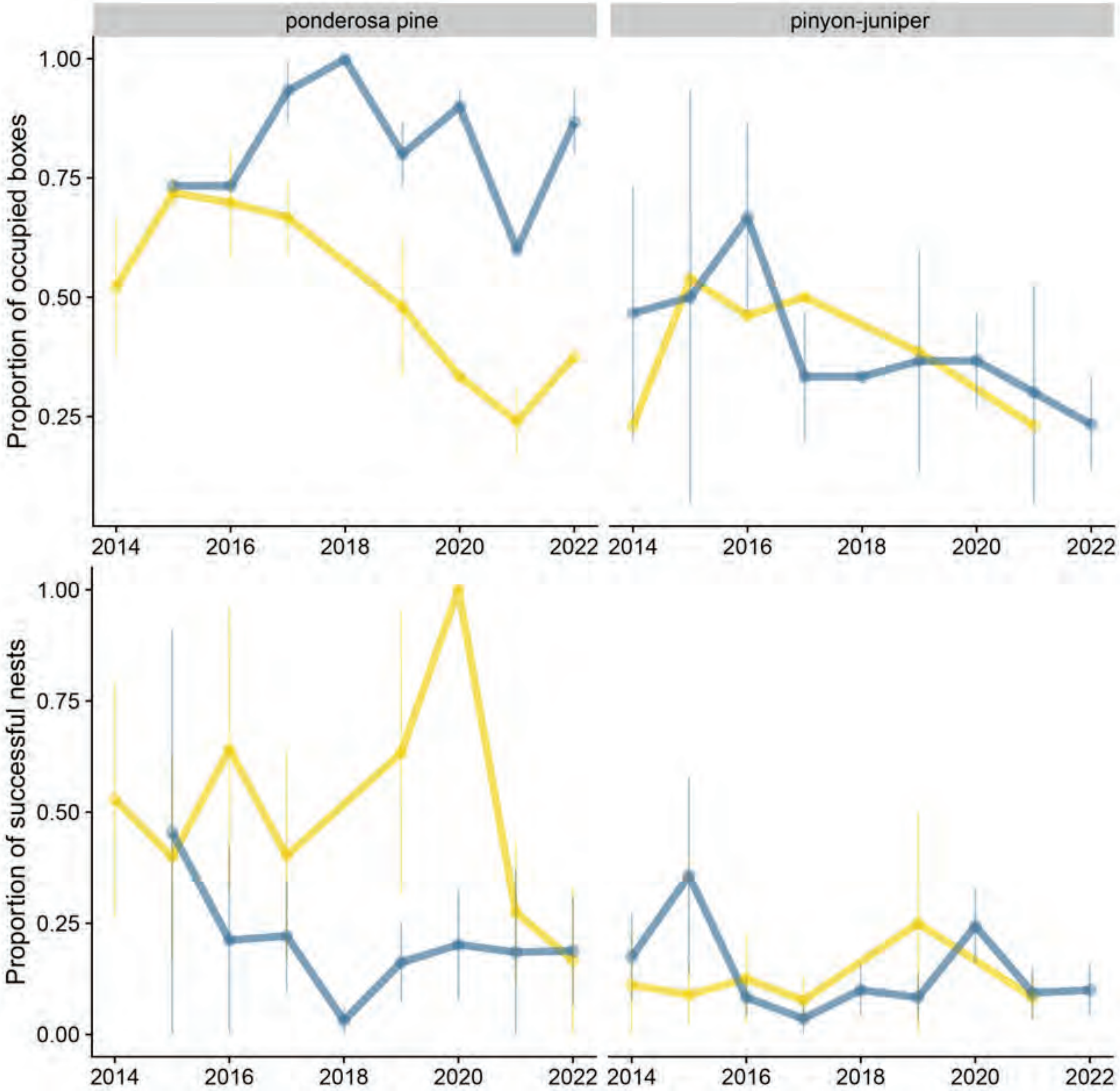


Figure 3-4. Mean proportion occupancy and success across study period for treatment sites (blue) and control sites (yellow) in ponderosa pine habitat (left panels) and pinyon-juniper habitat (right panels). Lines connecting sequential year's values to illustrate trends. Vertical lines represent standard error around mean values.

In 2022, two successful nests fledged young at Minie, five at TA-16, and zero at TA-39. Occupancy at TA-39 continues to be low relative to the other treatment sites and the overall network. The nest success rate at TA-39 has been highly variable since monitoring began in 2015, ranging between 0 percent and 100 percent. TA-39 is the lowest elevation treatment site, and occupancy has been decreasing over time at this site and surrounding areas of the avian nest box network (Table B-11). Wysner et al. (2019) found that Western Bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. Western Bluebirds have the highest occupancy rates throughout the nest box network, and shifts in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the Minie treatment site have fluctuated annually and have not displayed a decreasing trend over time, though the success rate dropped substantially after 2020 and does not appear to have recovered (Table B-12). While occupancy has been relatively high and naturally fluctuating at TA-16, the success rate has shown a decreasing trend since 2017, with the largest decrease in success occurring in 2021 (Table B-12). These decreases are likely driven by low precipitation values from winter 2020 through spring 2022 (NOAA 2022). Decreases in precipitation have been linked to declines in body mass, which could indirectly impact reproductive success (Smith, Reitsma, and Marra 2010).

After establishing more appropriate control sites for productivity comparisons, an interesting trend emerged. Comparative site occupancy patterns varied between habitat types (Figure 3-4). Proportion site occupancy across all years was substantially higher in PIPO treatment sites than controls ($t = 4.84$, $df = 21.7$, $p < 0.001$), representing a difference of 31 percent mean proportion occupancy. Conversely, PJ habitat showed no difference in occupancy combined across all years ($t = 0.12$, $df = 17.9$, $p = 0.92$) (Figure 3-4).

Proportion nest success also varied between habitat types but contradicted the within-habitat-type nest success patterns (Figure 3-4). In PIPO habitat, the proportion of nest success across all years compared with reduced and relevant control sites was significantly lower at treatment sites (TA-16 and DARHT; $t = -2.59$, $df = 37.6$, $p = 0.01$). There was no discernable difference across all years in PJ habitat ($t = 0.68$, $df = 49.5$, $p = 0.50$). The pattern suggests that in PIPO treatment sites, the local habitat is attractive to cavity nesting birds, but their success rates are substantially lower—roughly equivalent to those in the PJ habitats.

In 2022, LANL biologists submitted nonviable eggs and nestlings collected from nest boxes at the treatment sites and the rest of the nest box network to an analytical lab for chemical analyses. These data will be presented in a separate report. A total of 7 nonviable eggs and 1 nestling were collected from treatment sites compared with 18 nonviable eggs and 2 nestlings across all control sites in 2022.

4 Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Over the 10-year study period, LANL biologists have documented sensitive species from the Sensitive Species Best Management Practices Source Document (Berryhill et al. 2020) and the Birds of Management Concern and Focal Species list (USFWS 2021) at the treatment sites. Those species are Cassin’s Finch, Juniper Titmouse, Grace’s Warbler, Virginia’s Warbler, Black-throated Gray Warbler, Evening Grosbeak, Peregrine Falcon, and Mourning Dove. The Gray Vireo is the only sensitive species documented in only control sites. Of the 81 species detected at the three treatment sites, the Migratory Bird Treaty Act protects all but one species. The Eurasian Collared-Dove is not native and is therefore not protected under the Migratory Bird Treaty Act.

Overall comparisons provide mixed evidence for and against firing sites’ potential negative impact on birds. Through further data collection and refining analyses to appropriately control for uneven sampling and site-specific variation, we gain to sharpen our understanding of differences between bird communities and productivity at treatment and control sites. For example, is it valid to compare TA-16 Burn Site, where noise disturbances could be relatively minimal to open firing sites like Minie and TA-39? It is likely that a complex interaction of local habitat, climate trends, and disturbance levels interact in ways that might obscure signals in the absence of large, long-term datasets. Continuing to document migratory bird occurrences and nest success among treatment and control sites will only increase our ability to uncover such signals should they exist, allowing LANL biologists to assess the ecological health of avifauna at the three firing sites and one open burn site at LANL.

Anthropogenic noise variation has been documented to affect bird behavior (Derryberry et al. 2020; Bernat-Ponce, Gil-Delgado, and López-Iborra 2021). Because a primary disturbance of concern at the open firing sites is intermittent noise, we suggest measuring sound metrics of the local bird communities between and during firing operations and compare those levels against appropriate controls using passive acoustic recording devices.

This research contributes to meeting the Department of Energy's commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service. It also allows LANL to contribute to national goals in avian conservation monitoring and research.

5 Acknowledgments

Thanks to the following individuals for technical and field support work in 2022: Andrew Bartlow, Jesse Berryhill, Audrey Sanchez, Jenna Stanek, Brent Thompson, Luciana Vigil-Holterman, Jadzia Rodriguez, and former staff and interns who helped in previous years.

6 Literature Cited

Bernat-Ponce, Edgar, José A. Gil-Delgado, and Germán M. López-Iborra. 2021. "Recreational Noise Pollution of Traditional Festivals Reduces the Juvenile Productivity of an Avian Urban Bioindicator," Environmental Pollution 286 (October): 117247. https://doi.org/10.1016/j.envpol.2021.117247

Berryhill, J. T., J. E. Stanek, E. J. Abeyta, and C. D. Hathcock. 2020. "Sensitive Species Best Management Practices Source Document, Revision 5," Los Alamos National Laboratory report LA-UR-20-24514, Los Alamos, New Mexico.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Polluck. 1998. "Estimating species richness: the importance of heterogeneity in species detectability," Ecology 79(3):1018–1028.

Clarke, K. R., R. N. Gorley, P. J. Somerfield, and R. Warwick. 2014. *Change in marine communities; an approach to statistical analysis and interpretation*, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262pp.

Derryberry, Elizabeth P., Jennifer N. Phillips, Graham E. Derryberry, Michael J. Blum, and David Luther. 2020. "Singing in a Silent Spring: Birds Respond to a Half-Century Soundscape Reversion during the COVID-19 Shutdown," Science 370 (6516): 575–79. https://doi.org/10.1126/science.abd5777

Dixon, P. 2003. "Vegan, a package of R functions for community ecology," Journal of Vegetation Science 14(6):927–930.

Fair, J. M., and O. B. Myers. 2002. "Early reproductive success of western bluebirds and ash-throated flycatchers: a landscape-contaminant perspective," Environmental Pollution 118:321–330.

Gotelli, N. J. and R. K. Colwell. 2011. "Estimating species richness," Biological diversity: Frontiers in Measurement and Assessment 12:39–54.

Hathcock, C. D., K. Zemlick, and B. Norris. 2011. "Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011," Los Alamos National Laboratory report LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C. D. and J. M. Fair. 2013. "Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds," Los Alamos National Laboratory report LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C. D. 2014. "Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C. D. 2015. "Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C. D., B. E. Thompson, and J. T. Berryhill. 2017. "2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C. D., A. W. Bartlow and B. E. Thompson. 2018. "2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-18-22897, Los Alamos, New Mexico.

Hathcock, C. D., A. W. Bartlow, A. A. Sanchez, J. Stanek, and B. E. Thompson. 2019. "2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-19-24156, Los Alamos, New Mexico.

McKown, B., S. W. Koch, R. G. Balice, and P. Neville. 2003. "Land cover classification map for the Eastern Jemez Region," Los Alamos National Laboratory report LA-14029, Los Alamos, New Mexico.

NOAA (National Oceanic and Atmospheric Administration). September 2022. "Climate at a Glance: Global Mapping," retrieved on October 18, 2022 from https://www.ncdc.noaa.gov/cag/

Ralph, C. John, John R. Sauer, and Sam Droege. 1995. "Monitoring Bird Populations by Point Counts," Pacific Southwest Research Station.

R Core Team. 2022. "R: A language and environment for statistical computing," R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Rodriguez, J. M. and E. J. Abeyta. 2021. "2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-21-22304, Los Alamos, New Mexico.

Salinas, H. and D. Ramirez-Delgado. 2021. *ecolTest*: Community Ecology Tests. URL https://cran.r-project.org/web/packages/ecolTest/index.html

Sanchez, A. A., C. D. Hathcock, and B. E. Thompson. 2020. "2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-20-20436, Los Alamos, New Mexico.

Shannon, C. E. and W. Weaver. 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana, IL, USA. 127 pp.

Smith, J. A. M., L. R. Reitsma, and P. P. Marra. 2010. “Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird,” Ecology 91(10):2874–2882.

Tramer, E. J. 1969. “Bird species diversity: components of Shannon’s formula,” Ecology 50(5):927–929.

USFWS (U.S. Fish and Wildlife Service). 2021. “Birds of conservation concern,” United States Department of Interior, Fish and Wildlife Service, Migratory Bird Program, Arlington, Virginia. 48 pp.

Wysner, T. E., A. W. Bartlow, C. D. Hathcock, and J. M. Fair. 2019. “Long-term phenology of two North American secondary cavity-nesters in response to changing climate conditions,” The Science of Nature 106:54. doi:10.1007/s00114-019-1650-9.

7 Acronyms and Abbreviations

Acronym	Definition
DARHT	Dual-Axis Radiographic Hydrodynamic Test Facility
LANL	Los Alamos National Laboratory
PIPO	ponderosa pine (forest)
PJ	pinyon-juniper (woodland)
TA	Technical Area

Appendix A Tables of 2013–2022 Species Abundances among Firing Sites

Table A-1. Detected Species Abundances at TA-36 Minie Site (Pinyon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker										
American Crow										
American Kestrel				1				1	1	
American Robin	1	1	2		2					5
Ash-throated Flycatcher	11	5	14	13	13	10	17	12	12	7
Audubon's Warbler		2				5				1
Bewick's Wren	4	8	9	9	14	14	5	10	4	5
Black-chinned Hummingbird		1	1				1	2	1	2
Black-headed Grosbeak	1	3				1	1	2	1	
Black-throated Gray Warbler			1		2			2		
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	11	8	14
Blue Grosbeak										
Broad-tailed Hummingbird	2	1	3		1		3	2		5
Brown Creeper										
Brown-headed Cowbird	1								1	
Bullock's Oriole										
Bushtit		2		2		11				12
Canada Goose										
Canyon Towhee	2		5	3	6	2	3	5	3	
Canyon Wren					1					
Cassin's Finch						4				
Cassin's Kingbird	6	13	13	5	2	5	6	5	4	
Chipping Sparrow	3	16	17	29	6	22	10	10	10	
Clark's Nutcracker										
Common Nighthawk	6		5	2	4	4	1	5		
Common Raven	2	5	1		1	2	3			12

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cooper’s Hawk					1					
Cordilleran Flycatcher										
Dark-eyed Junco										
Downy Woodpecker				1						
Dusky Flycatcher				1						
Eurasian Collared-Dove	3									
Evening Grosbeak	3		4						1	
Grace’s Warbler							1			
Gray Flycatcher	12	6	5	7	3	6	3	2	4	8
Great Horned Owl		3								
Green-tailed Towhee	3	1								1
Hairy Woodpecker			2	1		1		1	1	1
Hammond’s Flycatcher										
Hepatic Tanager									2	
Hermit Thrush						1				
House Finch	16	17	26	17	12	18	17	11	11	17
House Wren										
Juniper Titmouse	12		7	6	9	3	26	8	20	3
Lark Sparrow										2
Lesser Goldfinch	2	6	7	4	9	12	8	4	4	8
MacGillivray’s Warbler										0
Mountain Bluebird		2	20	10	11	1	9	3	2	5
Mountain Chickadee	5	2	1	2						5
Mourning Dove	17	17	13	5	8	8	11	9	7	9
Northern Mockingbird					2		1	4		8
Northern Rough-winged Swallow						3				
Olive-sided Flycatcher										
Orange-crowned Warbler										
Painted Redstart										
Peregrine Falcon									1	
Pine Siskin	10	2		5	1			1		
Plumbeous Vireo	10	10	7	3	9	9	15	3	3	7

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Pygmy Nuthatch				2		2	3		1	
Red Crossbill					1					
Red-shafted Flicker	3	1	3	2	5	2	1		1	1
Red-tailed Hawk							1	2	1	
Rock Wren	3	3	4		2	10	11	10	4	5
Ruby-crowned Kinglet										
Savannah Sparrow										
Say's Phoebe	2	1	2		2	5	1	1	2	2
Scaled Quail			1							
Spotted Towhee	17	8	19	27	32	24	19	20	17	18
Steller's Jay							1			
Townsend's Solitaire	1									1
Turkey Vulture					1			2		2
Vesper Sparrow										
Violet-green Swallow		5	7	1	3	2	1	6		3
Virginia's Warbler					1	3	1			
Warbling Vireo						2				
Western Bluebird	15	11	18	17	16	19	21	23	8	11
Western Tanager		2	3		1					
Western Wood-Pewee	10	8	18	11	10	7	18	14	10	13
White-breasted Nuthatch	1	4	9	10	13	5	2	1	2	1
White-crowned Sparrow										
White-throated Swift										
White-winged Dove	1	5	9	2		3	2	1	1	
Willow Flycatcher										
Wilson's Warbler										
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	10	10	7

Table A-2. Detected Species Abundances at TA-39 Point 6 (Pinyon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker										
American Crow										
American Kestrel	1			2					2	
American Robin	1	1		2		4	2			
Ash-throated Flycatcher	19	11	30	12	8	8	6	11	4	7
Audubon's Warbler				2				5		3
Bewick's Wren	3	10	15	9	2	8	1	2		1
Black-chinned Hummingbird	3	2				1	2	3		
Black-headed Grosbeak		2	4	1		3	2	1	1	1
Black-throated Gray Warbler	5	6	4							
Blue-gray Gnatcatcher	2		7	5	4	2	13	5	2	13
Blue Grosbeak									1	
Broad-tailed Hummingbird	3	1	2		3	1	2	9	3	2
Brown Creeper										
Brown-headed Cowbird			2			3	2	10	3	12
Bullock's Oriole										1
Bushtit	2	14			1	12		2		
Canada Goose			16				2			
Canyon Towhee	1	1	2	10	13	19	6	3	9	5
Canyon Wren			2	3	8	6	2	4		
Cassin's Finch										
Cassin's Kingbird	7	6	2	21	21	32	37	49	14	41
Chipping Sparrow	6	6	5	8	15	25	27	24	16	20
Clark's Nutcracker										
Common Nighthawk	5	1	3	2	7	5	7	3	1	6
Common Raven	1		2	1		1	2	5		2
Cooper's Hawk										
Cordilleran Flycatcher										
Dark-eyed Junco						1	1			
Downy Woodpecker				1	2		1	2	1	
Dusky Flycatcher			1		1					1

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove					4			2		
Evening Grosbeak			8							
Grace’s Warbler						2	4	1	6	3
Gray Flycatcher	10	10	11	10	5	8	3	14	5	6
Great Horned Owl	1									
Green-tailed Towhee	1									
Hairy Woodpecker			5	3			1	1	4	
Hammond’s Flycatcher										
Hepatic Tanager			1	2	1	2			1	
Hermit Thrush										
House Finch	21	4	23	9	30	44	50	53	22	41
House Wren							1			
Juniper Titmouse	11	13	18	6	1			3	2	3
Lark Sparrow										
Lesser Goldfinch	4	12	9	10	14	19	15	27	8	31
MacGillivray’s Warbler										
Mountain Bluebird		4						2	1	
Mountain Chickadee				1	1		1			
Mourning Dove	13	22	10	3	15	11	8	10	9	16
Northern Mockingbird		1							2	19
Northern Rough-winged Swallow										
Olive-sided Flycatcher										
Orange-crowned Warbler										
Painted Redstart										
Peregrine Falcon			1						1	
Pine Siskin	6		3	3						1
Plumbeous Vireo	1		1	6	6	5	5	12	4	9
Pygmy Nuthatch			2	4	12	9	11	10	1	8
Red Crossbill		2						1		
Red-shafted Flicker	3	2	4	8		3	2	2		4
Red-tailed Hawk			1	1	1	1				
Rock Wren	7	10	4	12	14	14	12	20	15	14

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet										
Savannah Sparrow										
Say's Phoebe	2	1		5	2	4		6	5	
Scaled Quail										
Spotted Towhee	12	6	33	16	12	16	15	20	14	20
Steller's Jay										
Townsend's Solitaire										
Turkey Vulture								1		
Vesper Sparrow										
Violet-green Swallow	6	4	1	9	6	6	9	47	5	
Virginia's Warbler			1	2	4		5		2	3
Warbling Vireo										
Western Bluebird	5	19	12	21	13	6	7	17	3	4
Western Tanager		2	1	1	2	2	6	1	2	4
Western Wood-Pewee		4	2	10	8	11	12	18	12	16
White-breasted Nuthatch			2	4	4	2	6	3	2	3
White-crowned Sparrow									1	
White-throated Swift		1						2		
White-winged Dove	7	5	6	16	15	15	5	2	5	7
Willow Flycatcher									1	
Wilson's Warbler										
Woodhouse's Scrub-Jay	8	10	4	8	6	4	5		2	3

Table A-3. Detected Species Abundances at TA-16 Burn Grounds (Ponderosa Pine Forest Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker	5		3	2	3	5	3	5	1	
American Crow					1	1		1	1	5
American Kestrel										
American Robin	7		9	4	4	6	12	6	14	
Ash-throated Flycatcher	3	5	6	2	3	8	4	6	6	11
Audubon’s Warbler	6	5	1	6		1	11	14	9	5
Bewick’s Wren										
Black-chinned Hummingbird	1		1		1		1	12	1	
Black-headed Grosbeak			1	2		2		1	1	1
Black-throated Gray Warbler										
Blue-gray Gnatcatcher		6	2	1	3	6	4	9	3	9
Blue Grosbeak										
Broad-tailed Hummingbird	5	11	11	5	7	10	8			11
Brown Creeper	1									
Brown-headed Cowbird	4	1			4	2	8	4	4	3
Bullock’s Oriole										
Bushtit										
Canada Goose										
Canyon Towhee	1			1		1				
Canyon Wren			2							
Cassin’s Finch									1	
Cassin’s Kingbird				1				2		1
Chipping Sparrow	1	5	3	10	5	21	8	32	6	19
Clark’s Nutcracker		4		1						
Common Nighthawk			1	2	2			1		
Common Raven	5	6	2	2	5	5	7	4	2	9
Cooper’s Hawk	1			1			1			
Cordilleran Flycatcher	5	10	6	3	3	1	2	4		2
Dark-eyed Junco	6	2	4		5	2		2	3	3
Downy Woodpecker		1		1	1	1				
Dusky Flycatcher								2	1	1

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove						1				
Evening Grosbeak	5		29			1				
Grace's Warbler	6	4	4	8	5	8	22	12	17	11
Gray Flycatcher										
Great Horned Owl										
Green-tailed Towhee								1		
Hairy Woodpecker	1	1		1	1	2	1	1		
Hammond's Flycatcher	8	9	12	5	7	5	10	5	7	1
Hepatic Tanager				1						
Hermit Thrush		4	6	1	2	2	5	5	2	2
House Finch	16	2	5	5	12	7	12	18	11	20
House Wren	1	1		2	2	6	8	2	1	2
Juniper Titmouse										
Lark Sparrow										
Lesser Goldfinch	3		8	9	4	8	5	6	2	9
MacGillivray's Warbler				1	3			1		1
Mountain Bluebird			4	4	4	7	4	5		
Mountain Chickadee	5	8	9	6	8	9	1	4	6	6
Mourning Dove	4		1	3	17	3	5	17	5	2
Northern Mockingbird										
Northern Rough-winged Swallow										
Olive-sided Flycatcher										
Orange-crowned Warbler								1		1
Painted Redstart										1
Peregrine Falcon										
Pine Siskin	12	4	5		4	2		6		1
Plumbeous Vireo	11	16	15	14	11	18	16	24	17	19
Pygmy Nuthatch	11	13	26	29	41	20	16	23	5	21
Red Crossbill		2	9	13	9		6	26	1	
Red-shafted Flicker	3	4	11	11	5	5	2	7	5	7
Red-tailed Hawk										1
Rock Wren	1	2	2	6			4	1		

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet						2			1	
Savannah Sparrow								1		
Say's Phoebe	1		1	3	3	4	1	1	4	
Scaled Quail										
Spotted Towhee	11	18	16	14	21	22	34	24	16	23
Steller's Jay	3	2	5	6	3	4	4	2	1	
Townsend's Solitaire					1					
Turkey Vulture	1					1				
Vesper Sparrow							1			
Violet-green Swallow		2	19	2	2	4	2	7	6	7
Virginia's Warbler	17	11	21	13	7	5	5	8	3	4
Warbling Vireo	2	9	7	6	5	4	6	3	7	7
Western Bluebird	20	20	49	37	32	27	20	27	8	32
Western Tanager	2	3	7	2	4	6	16	10	7	
Western Wood-Pewee	15	10	16	14	22	20	24	28	25	47
White-breasted Nuthatch	9	8	7	9	20	10	10	8	10	9
White-crowned Sparrow										
White-throated Swift										
White-winged Dove			1	2			1			
Willow Flycatcher										
Wilson's Warbler										
Woodhouse's Scrub-Jay	1									

Table A-4. Detected Species Abundances at Dual-Axis Radiographic Hydrodynamic Test Facility (Ponderosa Pine Forest Habitat)

Species	2017	2018	2019	2020	2021	2022
Acorn Woodpecker		1	1	1		2
American Crow						
American Kestrel						1
American Robin	1		9	2	6	3
Ash-throated Flycatcher	7	2	2	5	4	2
Audubon’s Warbler		4	12	2	3	2
Bewick’s Wren						
Black-chinned Hummingbird		1				1
Black-headed Grosbeak		3	1			3
Black-throated Gray Warbler						
Blue-gray Gnatcatcher	5	8	16	17	4	9
Blue Grosbeak						
Broad-tailed Hummingbird	3	4	5	10	1	7
Brown Creeper						
Brown-headed Cowbird		5	2	7	6	8
Bullock’s Oriole						
Bushtit						
Canada Goose						
Canyon Towhee						
Canyon Wren						
Cassin’s Finch						
Cassin’s Kingbird	9	14	13	1	15	10
Chipping Sparrow	16	31	21	17	30	18
Clark’s Nutcracker		1				
Common Nighthawk						
Common Raven	10	1	5	5	6	4
Cooper’s Hawk						
Cordilleran Flycatcher		1	1			3
Dark-eyed Junco						
Downy Woodpecker						
Dusky Flycatcher						2

Species	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove						
Evening Grosbeak						
Grace's Warbler	6	8	12	4	7	6
Gray Flycatcher			1		3	
Great Horned Owl			2		2	
Green-tailed Towhee						
Hairy Woodpecker		1				
Hammond's Flycatcher	1					1
Hepatic Tanager	1		1			2
Hermit Thrush	1	1				1
House Finch	30	20	25	27	23	17
House Wren						
Juniper Titmouse						2
Lark Sparrow	1	2			1	
Lesser Goldfinch	19	12	20	25	5	9
MacGillivray's Warbler						
Mountain Bluebird	7	8	7	7	4	1
Mountain Chickadee	3		7	7	4	1
Mourning Dove	1	1	5	5	7	6
Northern Mockingbird		1		1	2	5
Northern Rough-winged Swallow			1			
Olive-sided Flycatcher		1	1		3	
Orange-crowned Warbler						
Painted Redstart						
Peregrine Falcon						
Pine Siskin	1				3	
Plumbeous Vireo	11	14	19	14	9	12
Pygmy Nuthatch	9	13	13	3	4	6
Red Crossbill	4					4
Red-shafted Flicker	8	10	3	1	3	2
Red-tailed Hawk	1		1			1
Rock Wren	2	1		1	2	

Species	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet						
Savannah Sparrow						
Say’s Phoebe	8	1	5	2	2	1
Scaled Quail						
Spotted Towhee	28	22	22	27	31	27
Steller’s Jay	1					
Townsend’s Solitaire		1				1
Turkey Vulture	2	1		1		
Vesper Sparrow						
Violet-green Swallow	9	12	32	20	28	15
Virginia’s Warbler	12	8	4	1	8	2
Warbling Vireo						
Western Bluebird	15	24	25	32	12	26
Western Tanager	2	1	4	6	6	3
Western Wood-Pewee	14	19	22	14	17	25
White-breasted Nuthatch	5	7	7	4	6	3
White-crowned Sparrow						
White-throated Swift	8					3
White-winged Dove		4	1	2		1
Willow Flycatcher						
Wilson’s Warbler		2				
Woodhouse’s Scrub-Jay	3					7

Appendix B Supplemental Tables

Table B-1. Changes in Species Raw Abundance over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie	193	186	275	210	222	242	245	203	209	229
TA-39	177	193	260	249	261	315	298	413	286	339
PJ Control 1	187	157	269	312	240	235	226	292	225	209
PJ Control 2	181	177	301	228	300	168	187	269	159	142
TA-16	220	209	347	271	302	285	310	389	283	340
PIPO Control 1	258	223	432	323	447	374	364	373	349	337
PIPO Control 2	256	254	371	396	449	366	394	429	448	334

Table B-2. Changes in Raw Species Richness over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie	33	33	34	30	35	35	34	33	33	37
TA-39	31	31	39	38	34	36	38	40	38	36
PJ Control 1	29	30	33	36	37	30	30	37	33	40
PJ Control 2	30	29	37	33	39	23	33	32	25	30
TA-16	39	33	40	44	41	43	39	46	37	40
PIPO Control 1	34	34	30	40	46	40	41	33	36	37
PIPO Control 2	33	36	43	43	44	39	40	40	44	39

Table B-3. Changes in Species Diversity over Time Comparing Minie Site with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie		3.14	3.14	3.19	2.97	3.13	3.21	3.06	3.13	3.00	3.31
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson’s t-test	t	−3.93	−3.06	−2.10	−0.68	−1.73	−4.38	−3.31	−2.99	−1.87	−3.59
	df	327	272	534	511	450	458	392	493	419	331
	p-value	<0.01	<0.01	0.04	0.50	0.08	<0.01	<0.01	<0.01	0.06	<0.01

Table B-4. Changes in Species Diversity over Time Comparing Minie Site with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69
PJ Control 2		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson’s t-test	t	−3.64	−2.94	−2.06	0.81	0.88	−7.20	−1.81	−3.42	−4.46	−7.49
	df	337	328	563	436	490	312	346	471	299	252
	p-value	<0.01	<0.01	<0.01	0.42	0.38	<0.01	0.07	<0.01	<0.01	<0.01

Table B-5. Changes in Species Diversity over Time Comparing TA-39 with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson’s t-test	t	−3.36	−2.42	−1.12	−5.34	−2.40	−3.27	−3.37	−2.52	−2.15	−1.31
	df	330	268	509	540	425	497	444	561	462	361
	p-value	<0.01	0.02	0.26	0.00	0.02	<0.01	<0.01	0.01	0.03	0.19

Table B-6. Changes in Species Diversity over Time Comparing TA-39 with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11
PJ Control 2		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69
Hutcheson’s t-test	t	−3.04	−2.22	−1.13	−3.89	0.31	−6.21	−1.94	−2.92	−4.70	−4.90
	df	337	325	542	440	561	325	396	578	319	279
	p-value	<0.01	0.03	0.26	<0.01	0.76	<0.01	0.05	<0.01	<0.01	<0.01

Table B-7. Changes in Species Diversity over Time Comparing TA-16 with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18
PIPO Control 1		3.14	3.12	2.91	3.14	3.13	3.04	3.13	2.90	3.01	2.96
Hutcheson’s t-test	t	−2.42	−1.21	−5.22	−2.01	−1.41	−4.55	−2.38	−6.95	−2.85	−3.12
	df	470	424	742	574	706	644	668	725	632	668
	p-value	0.02	0.23	<0.01	0.04	0.16	<0.01	0.02	<0.01	<0.01	<0.01

Table B-8. Changes in Species Diversity over Time Comparing TA-16 with PIPO Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18
PIPO Control 2		3.20	3.16	3.26	3.11	3.23	3.10	3.29	3.18	3.22	3.05
Hutcheson’s t-test	t	−1.58	−0.67	0.43	−2.40	−0.11	−3.85	−0.08	−3.15	0.18	−1.98
	df	445	463	714	621	630	634	661	817	664	667
	p-value	0.11	0.50	0.67	0.02	0.91	<0.01	0.94	<0.01	0.86	0.05

Table B-9. Changes in Species Diversity over Time Comparing DARHT with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33
PIPO Control 1		-	-	-	-	3.13	3.04	3.13	2.90	3.01	2.96
Hutcheson’s t-test	t	-	-	-	-	−0.72	−2.73	−0.24	−3.59	−3.40	−4.85
	df	-	-	-	-	687	621	679	665	613	599
	p-value	-	-	-	-	0.47	0.01	0.81	0.00	0.00	0.00

Table B-10. Changes in Species Diversity over Time Comparing DARHT with PIPO Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33
PIPO Control 2		-	-	-	-	3.23	3.10	3.29	3.18	3.22	3.05
Hutcheson's t-test	t	-	-	-	-	−2.05	2.43	0.16	−0.70	−3.86	−2.05
	df	-	-	-	-	609	686	640	593	572	609
	p-value	-	-	-	-	0.04	0.02	0.87	0.49	<0.01	0.04

Table B-11. Comparison of Occupancy for Treatment Sites and Overall Nest Box Network over Time

	2015	2016	2017	2018	2019	2020	2021	2022
Overall Network	40%	45%	48%	53%	44%	58%	30%	41%
Minie	66%	73%	46%	20%	60%	47%	53%	33%
TA-39	8%	58%	20%	33%	13%	27%	7%	13%
TA-16	-	73%	100%	53%	87%	87%	80%	93%
DARHT	-	-	87%	99%	73%	93%	64%	80%

Table B-12. Comparison of Nest Success for Treatment Sites and Overall Nest Box Network over Time

	2015	2016	2017	2018	2019	2020	2021	2022
Overall Network	66%	69%	57%	49%	51%	59%	45%	42%
Minie	64%	23%	29%	33%	44%	86%	38%	40%
TA-39	100%	57%	0%	40%	0%	75%	0%	0%
TA-16	-	63%	76%	63%	54%	54%	33%	36%
DARHT	-	-	62%	6.3%	45%	31%	56%	58%

10. Gaukler, S.M. and J.E. Stanek, June 2019. *Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory*. LA-UR-19-25647. OSTI Identifier 1529507.

(Gaulker & Stanek 2019)

LA-UR-19-25647

Title: Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory

Author(s): Gaukler, Shannon Marie
Stanek, Jenna

Intended for: Report

Issued: 2019-06-18

LA-UR-19-xxxx

Approved for public release;
distribution is unlimited.

June 2019

Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory

Prepared by: Shannon Gaukler and Jenna Stanek
Environmental Protection and Compliance Division,
Environmental Stewardship

Prepared for: U.S. Department of Energy, National Nuclear Security Administration,
Los Alamos Field Office

An Affirmative Action/Equal Opportunity Employer

Contents

ACRONYMS AND TERMS

ALS	Australian Laboratory Services
EPA	Environmental Protection Agency
LOAELs	lowest observable adverse effect levels
mg/kg	milligrams per kilogram
RSRLs	regional statistical reference levels
TA	Technical Area
TAL	total analyte list

SUMMARY

In 2018, nonviable avian eggs were opportunistically collected at Los Alamos National Laboratory near open detonation sites at Technical Area (TA) 36 and TA-39 and near the TA-16 burning grounds and were evaluated for inorganic elements (mostly metals). A total of eight western bluebird *Sialia mexicana*) and ash-throated flycatcher (*Myiarchus cinerascens*) egg samples were collected among the three locations of interest. Due to the small sample size, statistical comparisons could not be made. However, concentrations of inorganic elements observed in this study were compared with the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval; regional statistical reference level [RSRL]). Several inorganic elements were not detected in avian eggs and the majority of inorganic elements detected were below the RSRL. The few elements that exceeded the RSRL were below the lowest observable adverse effect level (LOAEL), when available. These data suggest that inorganic element concentrations in eggs observed here are not of ecological concern. As these data are preliminary, more data are needed to make a robust assessment, including additional background samples.

INTRODUCTION

Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of nonviable eggs and/or nestlings that die of natural causes is noninvasive and is nondestructive to populations. Inorganic elements and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

Sources of inorganic elements include both anthropogenic and natural sources and birds can be exposed through a number of routes including diet, ingestion of soil, drinking water, and inhalation. Inorganic elements (mostly metals) and dioxins and furans are of interest at open-detonation firing sites (TA-36 and TA-39) and at the burn grounds at TA-16 (Fresquez 2011).

OBJECTIVES

The objective of this study is to document chemical concentrations in eggs and nestlings collected near TAs 36, 39, and 16 and to compare concentrations of inorganic elements observed in this study with the upper-level bounds of background concentrations.

METHODS

Sample Collection

Eggs were collected from nest boxes when they were determined to be nonviable due to documented timing of known incubation periods for the species. In 2018, two nonviable egg samples were collected from TA-36, two egg samples from TA-39, and four samples from TA-16. All egg samples were either western bluebirds (*Sialia mexicana*) or ash-throated flycatchers (*Myiarchus cinerascens*) and were collected in June and July of 2018. No nestling samples were obtained in 2018 because the nest boxes located in the areas of interest did not have nestlings that died of natural causes that could be collected opportunistically.

Chemical Analyses

Due to limited sample mass, nonviable eggs were analyzed for TAL only and were analyzed at ALS (Australian Laboratory Services, formerly Paragon Analytics, Inc.) in Fort Collins, Colorado. The two samples collected near TA-36 and submitted for analyses consisted of one individual western bluebird egg and one composite of six western bluebird eggs. The two samples collected near TA-39 and submitted for analyses consisted of one individual ash-throated flycatcher egg and one composite of three western bluebird eggs. The four samples collected near TA-16 and submitted for analyses consisted of two individual western bluebird eggs, one composite of four western bluebird eggs, and one composite of two ash-throated flycatcher eggs.

Antimony, arsenic, cadmium, lead, selenium, silver, and thallium concentrations were measured by inductively coupled plasma mass spectrometry (Environmental Protection Agency [EPA] SW-846 Method 6020A), and aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were measured by inductively coupled plasma atomic emission spectrometry (EPA SW-846 Method 6010B). Mercury was measured by cold-vapor atomic absorption procedure (EPA SW-846 Method 7471A). All metal results were reported on an mg/kg (milligram per kilogram) dry weight basis.

Analyses of Chemical Levels

The 2018 results could not be statistically compared with background data due to small sample sizes; more data are needed to enable a robust evaluation of open detonation sites and background locations. However, results from 2018 were compared with the regional statistical reference levels (RSRL), which represents natural and fallout levels of chemicals, and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Regional statistical reference levels were calculated from nonviable eggs of western bluebirds and ash-throated flycatchers at background locations from Bandelier National Monument in 2016 and 2018 (n=8). Results were also compared with the lowest observable adverse effect levels (LOAEL) from peer reviewed literature, when available.

PRELIMINARY RESULTS AND DISCUSSION

Many of the inorganic elements assessed in this study were not detected in passerine egg samples. Elements that are not (or very little is) maternally transferred into eggs or do not accumulate in eggs include cadmium (Leach et al. 1979; Stoewsand et al. 1986), lead (Pattee 1984), vanadium (White and Dieter 1978), and silver (Schwarzbach et al. 2006; Seiler and Skorupa 2001).

Minie Firing Site (TA-36)

The two western bluebird egg samples collected from TA-36 did not have detectable levels of several elements including aluminum, antimony, arsenic, beryllium, cadmium, lead, nickel, silver, or vanadium. Detectable concentrations of barium, calcium, chromium, cobalt, iron, magnesium, manganese, mercury, potassium, selenium, sodium, thallium, and zinc were all below the RSRL and the LOAEL (when available). One egg sample contained copper concentrations of 4.1 mg/kg that was higher than the RSRL of 3.6 mg/kg (Table 1).

The elevated copper in western bluebird egg samples observed in 2018 at TA-36 and TA-39 (see below) are similar with previous observations (Gaukler, 2017) and could be from some high-explosives testing. Copper has historically been detected above soil screening levels at Technical Area 39 (Juarez and Vigil-holterman 2011). Contrarily, copper soil levels at Technical Area 36, near the firing site were below the RSRL in 2018. No reliable screening levels exists for egg tissues, although it has been suggested that birds are relatively resistant to copper toxicity when compared with other taxa (Eisler 1998).

TA-39

Two egg samples collected from nest boxes at TA-39 did not contain detectable concentrations of aluminum, antimony, arsenic, beryllium, cadmium, chromium, lead, nickel, silver, thallium, or vanadium. Detectable concentrations of barium, cobalt, and zinc were all below the RSRL. One western bluebird egg sample contained higher concentrations of calcium, copper, iron, magnesium, manganese, mercury, potassium, selenium, and sodium compared with RSRLs (Table 2). Although calcium, magnesium, potassium, and sodium were higher in eggs collected at Technical Area 39 compared with the RSRL, these elements are macronutrients, which are required by living organisms in large quantities. Copper, iron, manganese and selenium are essential micronutrients to living organisms in small concentrations, but can become toxic at high enough levels. No reliable screening levels are available for copper, iron, and manganese; however, both mercury and selenium egg concentrations were below the LOAELs for these elements (Heinz et al 1996; Thompson et al 1996)

TA-16 Burn Grounds

Western bluebird and ash-throated flycatcher eggs collected from nest boxes at TA-16 did not contain detectable concentrations of aluminum, arsenic, beryllium, cadmium, lead, nickel, thallium or vanadium. One sample out of the four collected contained higher concentrations of antimony (0.21 mg/kg) compared with the RSRL (0.11 mg/kg). Two samples out of four collected contained higher concentrations of mercury (0.23 and 0.25 mg/kg) compared with RSRLs (0.18 mg/kg; Table 3). However, both of the samples were below the LOAEL for mercury (1.67 mg/kg, converted from wet to dry weight), suggesting that adverse health effects are not expected at the observed concentrations (Thompson et al 1996). No reliable screening levels are available for antimony; therefore, it is unknown at what concentrations adverse effects could be expected.

CONCLUSIONS

The overall results indicate that the levels of inorganic elements in the eggs of western bluebirds and ash-throated flycatcher are not likely to cause adverse effects in breeding bird populations. Most constituents were not detected in the nonviable egg samples collected near firing sites at TA-36 and TA-39 and the burning grounds at TA-16. Most constituents that were detected were below RSRLs and all were below the LOAELs (when available). These data suggest that egg elements concentrations observed here are not of ecological concern. As these data are preliminary, more data from nonviable eggs and nestlings are needed to make a robust assessment, including additional background samples. Evaluating avian nestling samples for high explosives is also of interest for future work as those data become available.

REFERENCES

Becker, P. H. (2003). Biomonitoring with birds. Trace Metals and other Contaminants in the Environment, 6(C), 677–736. doi:10.1016/S0927-5215(03)80149-2.

Eisler, R. (1998). Copper hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Geological Survey, Biological Resources Division, Biological Science Report.

Fresquez, P. (2011). Chemical Concentrations in Field Mice from Open-detonation firing sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory. LA-UR-11-10614.

Gaukler, S. and C. Hathcock. (2017). Chemical concentrations in passerine eggs and nestlings collected near the Dual-Axis Radiographic Hydrodynamic Test Facility and Technical Areas 36, 39, and 16 at Los Alamos National Laboratory. LA-UR-17-31033.

Gochfeld, M., & Burger, J. (1998). Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in New York. Environmental Research, 77(1), 36–42. doi:10.1006/enrs.1997.3802.

Heinz, G. (1996). Selenium in Birds. In W. Beyer, G. Heinz, & A. Redmon-Norwood (Eds.), Environmental Contaminants in Wildlife Interpreting Tissue Concentrations (1st ed., pp. 447–458). Boca Raton, Florida: CRC Press, Inc.

Jones, K.C. and de Voogt, P. (1999). Persistent Organic Pollutants (POPs): State of the Science. Environmental Pollution, 100, 209-221.

Juarez, C. L., & Vigil-holterman, L. R. (2011). Soil Sampling Results Summary Report for the Open Detonation Units at Technical Area (TA) 36-8 and TA-39-6. LA-UR-11-03156.

Leach, R., Wang, K., & Baker, D. (1979). Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. The Journal of Nutrition, 109(3), 437–443.

Pattee, O. H. (1984). Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Archives of Environmental Contamination and Toxicology, 13, 29–34. doi:10.1007/BF01055643.

Schwarzbach, S. E., Albertson, J. D., & Thomas, C. M. (2006). Effects of Predation, Flooding, and Contamination Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk, 123(1), 45–60.

Seiler, R. L., & Skorupa, J. P. (2001). National Irrigation Water Quality Program Data-Synthesis Data Base. Carson City, NV.

Stoewsand, G. S., Bache, C. A., Gutenmann, W. H., & Lisk, D. J. (1986). Cocentration of Cadmium in Coturnix Quail Fed Earthworms. Journal of Toxicology and Envrionmental Health, 18, 36–376.

Thompson, D. (1996). Mercury in Birds and Terrestrial Mammals In W. Beyer, G. Heinz, & A. Redmon-Norwood (Eds.), Environmental Contaminants in Wildlife Interpreting Tissue Concentrations (1st ed., pp. 341–356). Boca Raton, Florida: CRC Press, Inc.

White, D. H., & Dieter, M. P. (1978). Effects of Dietary Vanadium in Mallard Ducks. Journal of Toxicology and Envrionmental Health, 4, 43–50.

Table 1. Inorganic element concentrations (mg/kg dry weight) detected in eggs collected near the Minie Firing Site (TA-36) compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2018 (n=8).

Element	Western bluebird (n=1) SFB-18-160523	Western bluebird (n=6) SFB-18-160524	RSRL
Barium	19	12	35
Calcium	3100	3200	4983
Chromium	ND	0.22	1.3
Cobalt	ND	0.03	0.6
Copper	2.8	**4.1**	3.6
Iron	160	130	250
Magnesium	390	350	447
Manganese	1.6	2.9	4.5
Mercury	0.04	0.08	0.18
Potassium	7500	7500	12040
Selenium	1.9	2.1	3.2
Sodium	7300	7600	10299
Thallium	ND	0.0019	0.0192
Zinc	46	51	78

ND = nondetect

Bold values indicate a detectable concentration that is higher than the RSRL.

Table 2. Inorganic element concentrations (mg/kg dry weight) detected in eggs collected near TA-39 compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2018 (n=8).

Element	Western bluebird (n=3) SFB-18-160525	Ash-throated flycatcher (n=1) SFB-18-160526	RSRL
Barium	11	7.9	35
Calcium	**8900**	2400	4983
Cobalt	0.15	0.06	0.6
Copper	**9.2**	2.4	3.6
Iron	**350**	86	250
Magnesium	**1100**	330	447
Manganese	**6.5**	0.78	4.5
Mercury	**0.62**	0.15	0.18
Potassium	**27000**	7600	12040
Selenium	**8.3**	2.6	3.2
Sodium	**24000**	9200	10299
Zinc	150	33	78

ND = nondetect

Bold values indicate a detectable concentration that is higher than the RSRL.

Table 3. Inorganic element concentrations (mg/kg dry weight) detected in eggs collected near TA-16 burning grounds compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2018 (n=8).

Element	Western bluebird (n=1) SFB-18-160510	Ash-throated flycatcher (n=2) SFB-18-160520	Western bluebird (n=1) SFB-18-160521	Western bluebird (n=4) SFB-18-160522	RSRL
Antimony	**0.21**	ND	ND	ND	0.11
Barium	15	6.8	12	9.8	35
Calcium	600	3700	2900	2900	4983
Chromium	ND	ND	ND	0.28	1.3
Cobalt	ND	0.07	ND	0.04	0.6
Copper	3.2	3.1	2.2	2.5	3.6
Iron	38	150	87	190	250
Magnesium	420	320	290	320	447
Manganese	1.3	2.3	1.8	3.1	4.5
Mercury	**0.23**	**0.25**	0.16	0.13	0.18
Potassium	11000	8200	8400	8200	12040
Selenium	1.3	3.2	2.9	2.7	3.2
Silver	ND	0.026	ND	ND	0.04
Sodium	8700	7600	9100	6700	10299
Zinc	8.7	50	30	54	78

ND = nondetect

Bold values indicate a detectable concentration that is higher than the RSRL.

11. Gaukler, S.M. and J.E. Stanek, March 2020. *2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-20-22529. OSTI Identifier 1607903.

(Gaulker & Stanek 2020)

LA-UR-20-22529

Title: 2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Author(s):
Gaukler, Shannon Marie
Stanek, Jenna Elizabeth

Intended for: Report

Issued: 2020-03-25

LA-UR-20-xxxx

Approved for public release;
distribution is unlimited.

March 2020

2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Shannon Gaukler and Jenna Stanek
Environmental Protection and Compliance Division,
Environmental Stewardship

Prepared for: U.S. Department of Energy, National Nuclear Security Administration, Los Alamos Field Office

An Affirmative Action/Equal Opportunity Employer

CONTENTS

ACRONYMS AND TERMS

ALS	Australian Laboratory Services
EPA	Environmental Protection Agency
LANL	Los Alamos National Laboratory
LOAEL	slowest observable adverse effect levels
mg/kg	milligrams per kilogram
pg/g	picograms per gram
PCBs	polychlorinated biphenyls
RSRLs	regional statistical reference levels
TA	Technical Area
TCDD	tetrachlorodibenzodioxin-2,3,7,8
TEF	toxic equivalent factors
TEQ	toxic equivalents
WHO	World Health Organization

1.0 SUMMARY

In 2019, non-viable avian eggs and one nestling were opportunistically collected at Los Alamos National Laboratory (LANL) near open detonation sites located at Technical Area (TA) 16 burn grounds, TA-36 Minie, and TA-39 Point 6. These samples were evaluated for inorganic elements (mostly metals), polychlorinated biphenyls (PCBs), dioxins, and furans. A total of 26 western bluebird (*Sialia mexicana*) and five mountain bluebird (*Sialia currucoides*) egg samples and one non-viable ash-throated flycatcher (*Myiarchus cinerascens*) nestling were collected among the three locations of interest. Concentrations of inorganic elements observed in this study were compared with the regional statistical reference level (RSRL) which is the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Several inorganic elements were not detected in avian eggs and the majority of inorganic elements detected were below the RSRL. The few elements that exceeded the RSRL were below the lowest observable adverse effect level (LOAEL), when available. One nestling collected from TA-16 contained detectable concentrations of some dioxin and furan congeners. Octachlorodibenzodioxin-1,2,3,4,6,7,8,9 concentration exceeded the RSRL, but did not exceed the calculated tetrachlorodibenzodioxin-2,3,7,8 (TCDD) toxic equivalent LOAEL. PCBs were also detected in the nestling sample and were above the RSRL but below the LOAEL. These data suggest that inorganic and organic element concentrations in eggs and nestlings are not of ecological concern. More data are needed to make a robust assessment and to evaluate trends over time.

2.0 INTRODUCTION

In support of the Resource Conservation and Recovery Act (RCRA) permit process, Los Alamos National Laboratory (LANL) began annual avian monitoring in 2013 around TA-16 burn grounds and at two firing sites, TA-36 Minie and TA-39 Point 6. Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of non-viable eggs and/or nestlings that die of natural causes is noninvasive and is nondestructive to populations. Inorganic elements and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

Several congeners of PCBs, dioxins, and furans elicit similar toxic effects (i.e., immunotoxicity, carcinogenicity, and endocrine disruption) as those caused by tetrachlorodibenzodioxin-2,3,7,8 (TCDD), the most potent in this class of chemicals (Van den Berg et al. 2006). These congeners, like TCDD, have a high binding affinity to the aryl hydrocarbon receptor (Van den Berg et al. 2006). The World Health Organization (WHO) developed toxic equivalency factors (TEFs) for TCDD-like compounds that can be used to determine the relative potency, or toxic equivalents (TEQs), of dioxin-like compounds for different classes of animals (i.e., fish, birds, and mammals), as well as to facilitate risk assessment for TCDD-like exposure (Van den Berg et al. 2006).

Sources of inorganic elements include both anthropogenic and natural sources; birds can be exposed through a number of routes, including diet, ingestion of soil, drinking water, and inhalation. Inorganic elements (mostly metals), dioxins, and furans are of interest at open-detonation firing sites (TA-36 and TA-39) and at the burn grounds at TA-16 (Fresquez 2011).

3.0 OBJECTIVES

The objective of this study is to document chemical concentrations in eggs and nestlings collected near TA-16 burn grounds, TA-36 Minie, and TA-39 Point 6 and to compare concentrations of inorganic elements, polychlorinated biphenyls (PCBs), dioxins, and furans observed in this study with the upper-level bounds of background concentrations.

4.0 METHODS

4.1. Sample Collection

Eggs and nestlings were collected from nest boxes when they were determined to be non-viable, based on documented timing of known incubation periods for the species. In 2019, warm temperatures in the early spring and then a period of very cold temperatures led to higher than usual numbers of non-viable eggs. We collected a total of 31 non-viable eggs at LANL near the TA-16 burn grounds (Figure 1) and near open detonation sites TA-36 Minie (Figure 2) and TA-39 Point 6 (Figure 3). At TA-16, 22 non-viable western bluebird (*Sialia mexicana*) samples and one non-viable ash-throated flycatcher (*Myiarchus cinerascens*) nestling sample were collected and submitted as six composite samples and one individual sample, respectively. At TA-36, five non-viable mountain bluebird (*Sialia currucoides*) eggs were collected and submitted as one composite sample. At TA-39, four non-viable western bluebird eggs were collected and submitted as one composite sample. All samples were collected May through July of 2019. Concentrations of chemicals in eggs and nestlings have been monitored annually at these locations since 2014.

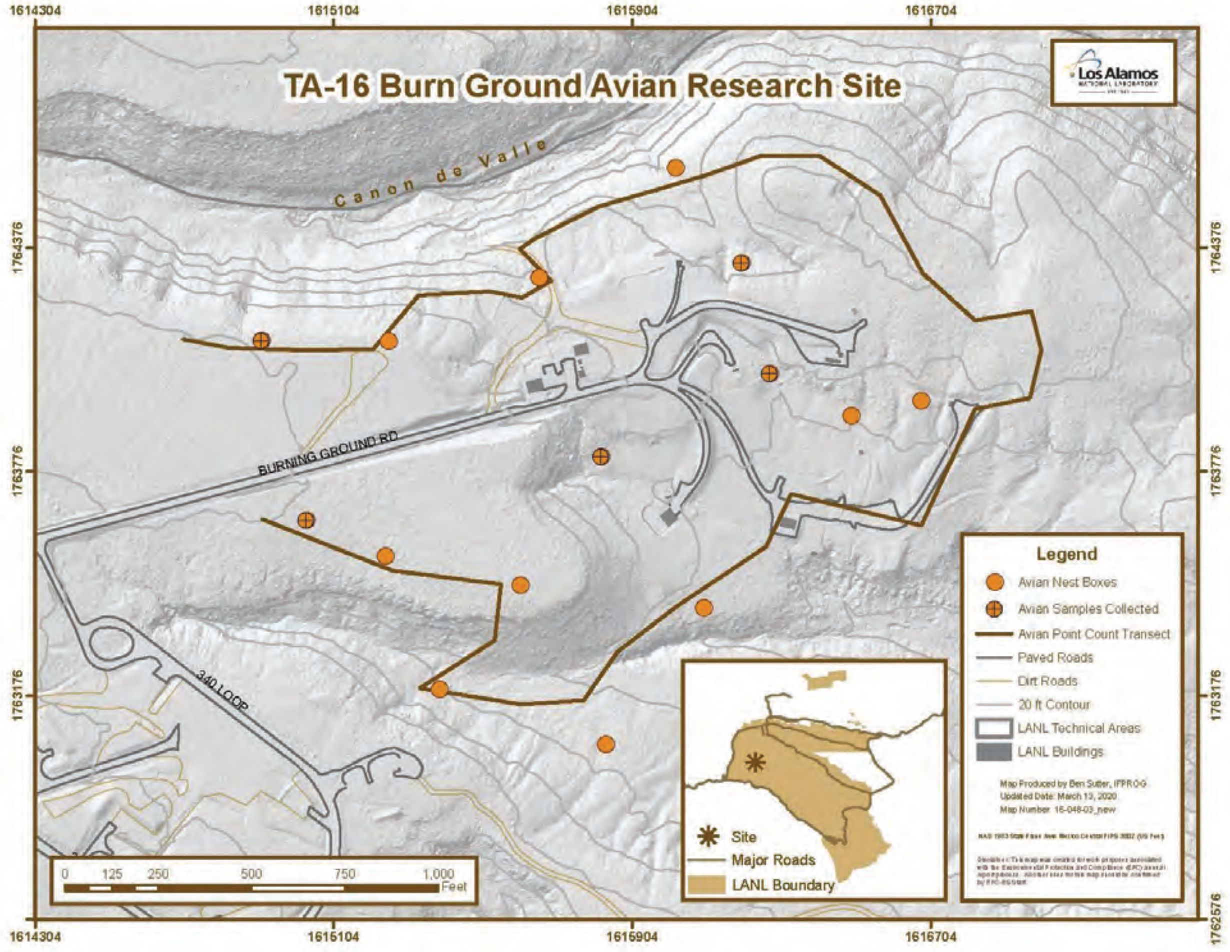


Figure 1. Avian nest box locations around TA-16 burn grounds.

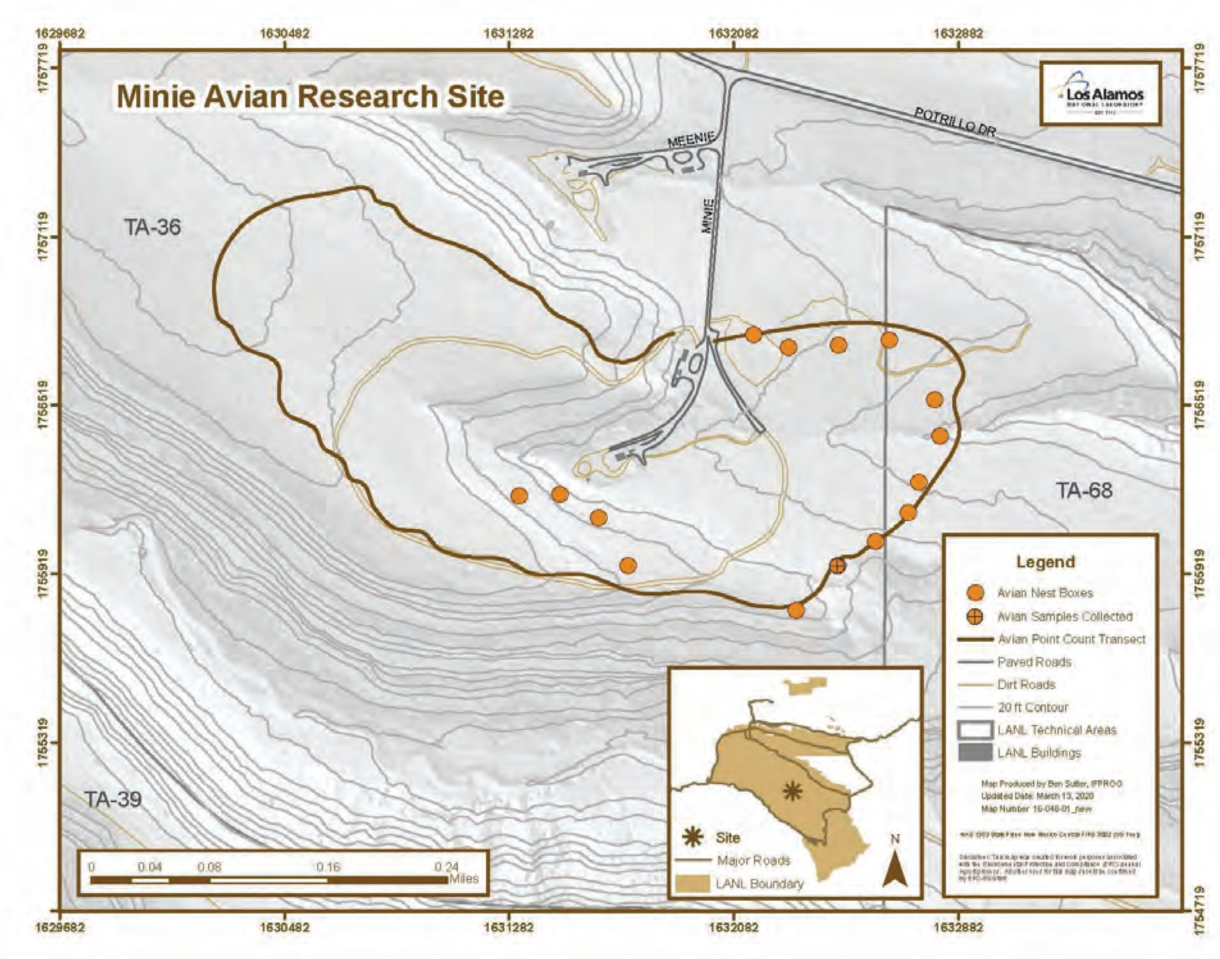


Figure 2. Avian nest box locations around TA-36 Minie.

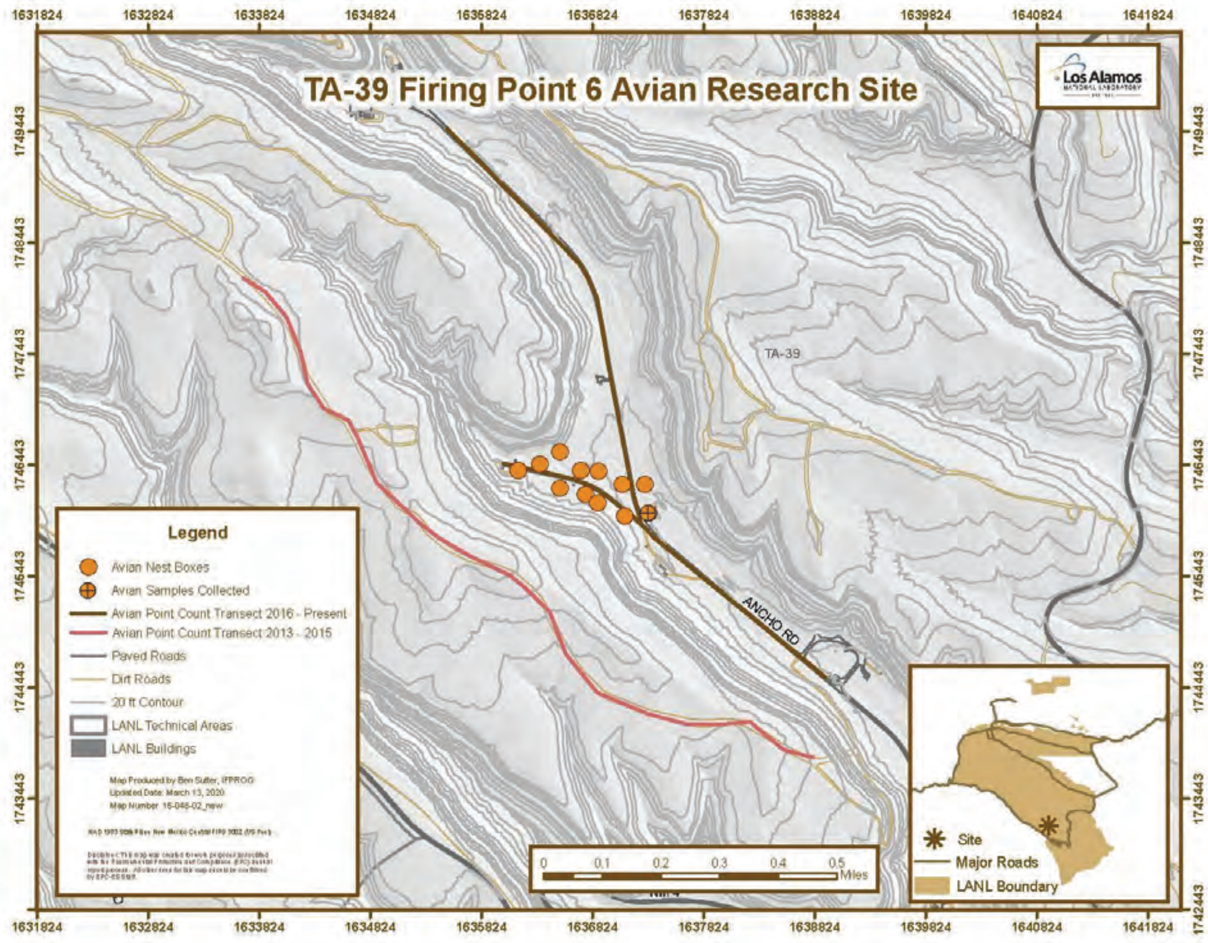


Figure 3. Avian nest box locations around TA-39 Point 6.

4.2. Chemical Analyses

Due to limited sample mass, non-viable eggs were analyzed for total analyte list (mostly inorganic metals) only and were analyzed at ALS (Australian Laboratory Services, formerly Paragon Analytics, Inc.) in Fort Collins, Colorado. Antimony, arsenic, cadmium, lead, selenium, silver, and thallium concentrations were measured in egg samples by inductively coupled plasma mass spectrometry (Environmental Protection Agency [EPA] SW-846 Method 6020A), and aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were measured by inductively coupled plasma atomic emission spectrometry (EPA SW-846 Method 6010B). Mercury was measured by cold-vapor atomic absorption procedure (EPA SW-846 Method 7471A). All inorganic element results were reported on an mg/kg (milligram per kilogram) dry weight basis.

The non-viable nestling sample collected near TA-16 was analyzed for PCB congeners by EPA Method 1668A and dioxin/furan congeners by EPA SW-846 Method 8290 at Cape Fear Analytical LLC, Wilmington, North Carolina. All organic chemical results are reported on a wet weight basis.

4.3. Statistical Methods

The 2019 results were compared with the regional statistical reference levels (RSRL), which represents natural and fallout levels of chemicals, and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Regional statistical reference levels were calculated from non-viable eggs of western bluebirds and ash-throated flycatchers collected from Bandelier National Monument from 2016 through 2019 (n = 23). Non-viable egg results are also compared with the lowest observable adverse effect levels (LOAEL) from peer reviewed literature, when available.

In the nestling, TCDD-like TEQs were calculated for all aryl hydrocarbon–binding PCB, dioxin, and furan congeners; these include:

- non-*ortho*-substituted PCB congeners 77, 81, 126, and 169
- mono-*ortho*-substituted PCB congeners 105, 114, 118, 123, 156, 157, 167, and 189
- tetrachlorodibenzodioxin-2,3,7,8
- pentachlorodibenzodioxin-1,2,3,7,8
- hexachlorodibenzodioxin-1,2,3,4,7,8
- hexachlorodibenzodioxin1,2,3,6,7,8
- hexachlorodibenzodioxin-1,2,3,7,8,9
- heptachlorodibenzodioxin-1,2,3,4,6,7,8
- octachlorodibenzodioxin-1,2,3,4,6,7,8,9
- tetrachlorodibenzofuran-2,3,7,8
- pentachlorodibenzofuran-1,2,3,7,8
- pentachlorodibenzofuran-2,3,4,7,8
- hexachlorodibenzofuran-1,2,3,4,7,8
- hexachlorodibenzofuran-1,2,3,6,7,8
- hexachlorodibenzofuran-1,2,3,7,8,9
- hexachlorodibenzofuran-2,3,4,6,7,8
- heptachlorodibenzofuran-1,2,3,4,6,7,8
- heptachlorodibenzofuran-1,2,3,4,7,8,9
- octachlorodibenzofuran-1,2,3,4,6,7,8,9

Each congener was multiplied by its respective avian-specific WHO TEF (Van den Berg et al. 2006), and added together for a total TEQ for the nestling sample. PCB congeners 156 and 157 co-eluted, and therefore were treated as one; the WHO TEFs were the same for both PCB congeners.

Nestling sample results of PCBs, dioxin, furans, and TEQs were compared with RSRLs and LOAELs, when available. The nestling RSRL was calculated from non-viable nestlings of western bluebirds and ash-throated flycatchers at background locations from Bandelier National Monument in 2018 and 2019 (n = 4 samples).

5.0 RESULTS AND DISCUSSION

Similar with previous years, many of the inorganic elements assessed in this study were not detected in passerine egg samples. Several elements are not (or very little is) maternally transferred into eggs or do not accumulate in eggs and include cadmium (Leach et al. 1979; Stoewsand et al. 1986), lead (Pattee 1984), vanadium (White and Dieter 1978), and silver (Schwarzbach et al. 2006; Seiler and Skorupa 2001), which may explain why these elements were mostly not detected.

Similarly, most dioxins and furans were not detected in the nestling sample collected from TA-16 burn grounds. Most constituents that were detected in eggs and the nestling were below RSRLs, and all constituents were below the LOAELs, when available.

5.1. TA-16 Burn Grounds

Western bluebird eggs collected from nest boxes at TA-16 burn grounds did not contain detectable concentrations of aluminum, arsenic, beryllium, cadmium, nickel, or vanadium. Of the elements containing detectable concentrations in eggs, only antimony, barium, and selenium were detected at concentrations above the RSRLs (Table 1). One sample out of the six collected contained slightly higher concentrations of antimony (0.27 mg/kg) compared with the RSRL (0.26 mg/kg). No reliable screening levels were available for antimony. One sample out of six collected contained higher concentrations of selenium (3.5 mg/kg) when compared with the RSRL (3.3 mg/kg dry weight). Selenium is an essential micronutrient and needed by living organisms. Additionally, the selenium concentration was far below the LOAEL of 10 mg/kg dry weight (Heinz et al. 1989).

Two samples out of six collected contained higher concentrations of barium (68 and 210 mg/kg) when compared with RSRL (31 mg/kg; Table 1). Legacy barium in the canyon sediment is known to occur in the area (Reid 2003) and has been detected in water samples near Cañon de Valle, which may suggest that birds may be exposed by direct drinking of water, and then the constituent is maternally transferred to their eggs. No reliable screening levels were available for barium; therefore, it is unknown at what concentrations adverse effects could be expected. However, of the non-viable egg samples collected at TA-16 burn grounds since 2016 ($n = 17$), only five of them contained barium concentrations above their respective RSRLs. Additionally, percentages of eggs hatched in nest boxes at TA-16 burn grounds ($n= 48$) compared with nest boxes at the background location ($n = 120$) were not statistically different (Mann-Whitney U test; $p > 0.05$). The hatching success in nest boxes at TA-16 burn grounds ($n = 48$) was 74.5% and was consistent with those reported previously for the area (Fair and Myers 2002). Barium did not have a negative impact on eggshell thickness when TA-16 burn grounds ($n = 40$) data was compared with background locations ($n = 54$; mixed-effects regression model; $p > 0.05$). These results suggest that adverse effects at the population level are unlikely to occur.

PCBs were detected in the nestling sample at 0.0126 mg/kg and were above the RSRL of 0.0045 mg/kg but well below the LOAEL in avian eggs of 3.0 mg/kg (Hoffman et al. 1996). Thus, even though the PCB concentrations were higher than the RSRL, these levels are not expected to negatively impact the bird population.

Most dioxins and furans were not detected in the nestling sample collected from TA-16 burn grounds. The nestling contained detectable concentrations of octachlorodibenzodioxin-1,2,3,4,6,7,8,9 of 7.65 mg/kg, which exceeds the RSRL of 2.42 mg/kg. Lowest observable adverse effect levels were not available for each dioxin and furan congener. However, the most potent dioxin congener, TCDD, is found to induce toxic effects in eastern bluebirds (*Sialia sialis*) when egg concentrations are between 0.001 and 0.01 mg/kg (Thiel et al. 1988). The TCDD toxic equivalency factor of octachlorodibenzodioxin-1,2,3,4,6,7,8,9 for avian species is 0.0001 (Van den Berg et al. 2006). Multiplying the detectable concentration of 7.65 mg/kg by the toxic equivalency factor yields a value of 0.000765 mg/kg, which was much less than the TCDD

LOAEL observed in eastern bluebird eggs. Total toxic equivalents (dioxin-like PCB, dioxin, and furan congeners) were 13.63 pg/g and were well below the RSRL of 23.51 pg/g.

5.2. TA-36 Minie

The one mountain bluebird egg sample, collected from TA-36 Minie, did not have detectable levels of several elements, including aluminum, antimony, arsenic, beryllium, cadmium, nickel, silver, or vanadium. Detectable concentrations of barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, potassium, selenium, sodium, thallium, and zinc were all below the RSRL (Table 2). Mercury and selenium concentrations were well below LOAELs (Heinz et al. 1989, Thompson 1996); no other LOAELs were available.

5.3. TA-39 Point 6

One egg sample collected from a nest box at TA-39 Point 6 did not contain detectable concentrations of aluminum, arsenic, beryllium, cadmium, chromium, lead, nickel, silver, thallium, or vanadium. Detectable concentrations of antimony, barium, calcium, cobalt, copper, iron, magnesium, manganese, mercury, potassium, selenium, sodium, and zinc were all below the RSRLs (Table 3). Mercury and selenium concentrations were well below LOAELs (Heinz et al. 1989, Thompson 1996); no other LOAELs were available.

6.0 CONCLUSIONS

The overall results indicate that the levels of constituents detected in the eggs and nestlings are not likely to cause adverse effects in breeding bird populations. Several constituents were not detected in the non-viable egg and nestling samples collected near TA-16 burn grounds, TA-36 Minie, and TA-39. Most constituents that were detected were below RSRLs and all were below the LOAELs, when available. These results suggest that the detectable concentrations observed here were not of ecological concern. More data from non-viable eggs and nestlings are needed to make a robust assessment and to examine trends over time. Evaluating avian nestling samples for high explosives are also of interest for future work as those data becomes available.

7.0 REFERENCES

Becker, P. H. (2003). Biomonitoring with birds. Trace Metals and other Contaminants in the Environment, 6(C), 677–736. doi:10.1016/S0927-5215(03)80149-2.

Fair, J. M. and O. B. Myers (2002). Early Reproductive Success of Western Bluebirds and Ash-throated Flycatchers: a Landscape-contaminant Perspective. Environmental Pollution, 118, 321-330.

Fresquez, P. (2011). Chemical Concentrations in Field Mice from Open-detonation firing sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory. LA-UR-11-10614.

Gochfeld, M. and Burger, J. (1998). Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in New York. Environmental Research, 77(1), 36–42. doi:10.1006/enrs.1997.3802.

Heinz, G. H., D. J. Hoffman, and L.G. Gold. (1989). Impaired Reproduction of Mallards Fed an Organic form of Selenium, The Journal of Wildlife Management, 53:418-428.

Hoffman, D. J., C. P. Rice, and T. J. Kubiak.”PCBs and Dioxins in Birds,” in Environmental Contaminants in Wildlife Interpreting Tissue Concentrations, 1st Edition. Editors Nelson Beyer, W., Heinz, G. H. and A. W. Redmon-Norwood. CRC Press, Inc., Boca Raton, Florida, 165–207.

Jones, K. C. and de Voogt, P. (1999). Persistent Organic Pollutants (POPs): State of the Science. Environmental Pollution, 100, 209-221.

Leach, R., Wang, K., and Baker, D. (1979). Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. The Journal of Nutrition, 109(3), 437–443.

Pattee, O. H. (1984). Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Archives of Environmental Contamination and Toxicology, 13, 29–34. doi:10.1007/BF01055643.

Reid, K. (2003). Barium and High Explosives in a Semiarid Alluvial Systme, Cañon de Valle, New Mexico. LA-UR-03-9094.

Schwarzbach, S. E., Albertson, J. D., and Thomas, C. M. (2006). Effects of Predation, Flooding, and Contamination Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk, 123(1), 45–60.

Seiler, R. L. and Skorupa, J. P. (2001). National Irrigation Water Quality Program Data-Synthesis Data Base. Carson City, NV.

Stoewsand, G. S., Bache, C. A., Gutenmann, W. H., and Lisk, D. J. (1986). Cocentration of Cadmium in Coturnix Quail Fed Earthworms. Journal of Toxicology and Envrionmental Health, 18, 36–376.

Thompson, D. 1996. Mercury in Birds and Terrestrial Mammals in W. Beyer, G. Heinz, & A. Redmon-Norwood (Eds.), *Environmental Contaminants in Wildlife Interpreting Tissue Concentrations* (1st ed., pp. 341–356). Boca Raton, Florida: CRC Press, Inc.

Thiel, D., Martin, S., Duncan, J., Lemke, M., Lance, W. and Peterson, R. (1988). Evaluation of the effects of dioxin-contaminated sludges on wild birds. In Proceedings, TAPPI environmental Conference, Norcross, GA (pp. 487–506).

Van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson. (2006). The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, Toxicological Sciences 93(2):223–241.

White, D. H. and Dieter, M. P. (1978). Effects of Dietary Vanadium in Mallard Ducks. Journal of Toxicology and Envrionmental Health, 4, 43–50.

Table 1. Inorganic element concentrations (mg/kg dry weight) detected in single or composite egg samples collected near TA-16 burn grounds compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2019 (n = 23).

Element	Western bluebird (n = 2) SFB-19-184785	Western bluebird (n = 5) SFB-19-184786	Western bluebird (n=1) SFB-19-184787	Western bluebird (n=4) SFB-19-184788	Western bluebird (n=4) SFB-19-184789	Western bluebird (n=4) SFB-19-184790	RSRL
Antimony	0.110	0.057	0.069	**0.270**	0.076	0.081	0.264
Barium	24	**68**	**210**	17	11	34	31
Calcium	2,700	2,500	3,800	3,800	2,900	2,600	5,637
Chromium	ND	0.20	ND	ND	ND	0.22	1.74
Cobalt	ND	0.089	0.077	0.046	0.041	0.063	0.354
Copper	3.10	2.30	2.80	3.90	3.30	2.80	4.85
Iron	180	170	100	130	120	150	274
Lead	ND	0.028	ND	ND	0.030	0.029	0.405
Magnesium	380	320	340	380	370	320	436
Manganese	2.80	2.70	2.00	1.20	2.40	3.40	4.47
Mercury	0.032	0.061	0.042	0.110	0.064	0.038	0.143
Potassium	7,400	6,700	6,800	8,200	7,000	6,200	11,035
Selenium	2.7	**3.5**	2.7	2.9	2.9	2.7	3.3
Silver	ND	ND	ND	ND	0.005	ND	0.040
Sodium	7,200	9,100	7,700	8,900	8,600	6,800	10,561
Thallium	ND	0.0076	0.0120	ND	0.0052	0.0090	0.0222
Zinc	65.0	65.0	43.0	62.0	51.0	52.0	95.8

ND = non-detect
Bold values indicate a detectable concentration that are higher than the RSRL.

Table 2. Inorganic element concentrations (mg/kg dry weight) detected in a mountain bluebird composite egg sample collected near the TA-36 Minie compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2019 (n = 23). No values were above the RSRL.

Element	Mountain bluebird (n = 5) SFB-19-184791	RSRL
Barium	15	31
Calcium	3,100	5,637
Chromium	0.20	1.74
Cobalt	0.049	0.354
Copper	2.90	4.85
Iron	140	274
Lead	0.042	0.405
Magnesium	330	436
Manganese	3.40	4.47
Mercury	0.011	0.143
Potassium	7,200	11,035
Selenium	2.0	3.3
Sodium	9,000	10,561
Thallium	0.0082	0.0222
Zinc	54.0	95.8

Table 3. Inorganic element concentrations (mg/kg dry weight) detected in a western bluebird composite egg sample collected near TA-39 Point 6 compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2016-2019 (n=23). No values were above their respective RSRL.

Element	Western bluebird (n = 4) SFB-19-184792	RSRL
Antimony	0.130	0.264
Barium	10	31
Calcium	3,100	5,637
Cobalt	0.043	0.354
Copper	2.70	4.85
Iron	110	274
Magnesium	360	436
Manganese	2.20	4.47
Mercury	0.059	0.143
Potassium	6,900	11,035
Selenium	2.3	3.3
Sodium	7,200	10,561
Zinc	55.0	95.8

12. Gaukler, S.M. and J.E. Stanek, March 2021. *2020 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-21-22303. OSTI Identifier 1770094.

(Gaulker & Stanek 2021)

LA-UR-21-22303

Title: 2020 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Author(s): Gaukler, Shannon Marie
Stanek, Jenna Elizabeth

Intended for: Report

Issued: 2022-02-22 (rev.1)

LA-UR-21-22303

22 February 2022

2020 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory: Revision 1

Los Alamos
NATIONAL LABORATORY
EST. 1943

A note from the authors regarding the revision: In report number LA-UR-21-22303, inorganic element results were reported on a wet weight basis when after further review, we have concluded that the results are consistent with dry weight values. This change does not affect the observations, the comparisons, or conclusions of the study.

Prepared by: Shannon Gaukler and Jenna Stanek
Environmental Protection and Compliance Division,
Environmental Stewardship

Prepared for: U.S. Department of Energy, National Nuclear Security Administration, Los Alamos Field Office

*An Affirmative Action/Equal Opportunity Employe*r

CONTENTS

ACRONYMS AND TERMS

ALS	Australian Laboratory Services
EPA	Environmental Protection Agency
LANL	Los Alamos National Laboratory
LOAEL	slowest observable adverse effect levels
mg/kg	milligrams per kilogram
pg/g	picograms per gram
PCBs	polychlorinated biphenyls
RSRLs	regional statistical reference levels
TA	Technical Area
TCDD	tetrachlorodibenzodioxin-2,3,7,8
TEF	toxic equivalent factors
TEQ	toxic equivalents
RCRA	Resource Conservation and Recovery Act
WHO	World Health Organization

1.0 SUMMARY

In 2020, non-viable avian eggs and two nestling were opportunistically collected at Los Alamos National Laboratory (LANL) near open detonation sites located at Technical Area (TA) 16 burn grounds, TA-36 Minie, and TA-39 Point 6. These samples were evaluated for inorganic elements (mostly metals), dioxins, and furans. A total of six eggs and two deceased western bluebird (*Sialia mexicana*) nestling samples were collected among the three locations of interest. Concentrations of inorganic elements observed in this study were compared with the regional statistical reference level (RSRL) which is the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Several inorganic elements were not detected in avian eggs and all inorganic elements detected were below the RSRL and the lowest observable adverse effect level (LOAEL), when available. One nestling collected from TA-39 contained detectable concentrations of two dioxin congeners. Heptachlorodibenzodioxin-1,2,3,4,6,7,8 and octachlorodibenzodioxin-1,2,3,4,6,7,8,9 concentration exceeded the RSRL, but did not exceed the calculated tetrachlorodibenzodioxin-2,3,7,8 (TCDD) toxic equivalent LOAEL. These data suggest that inorganic and organic element concentrations in eggs and nestlings are not of ecological concern. More data are needed to make a robust assessment and to evaluate trends over time.

2.0 INTRODUCTION

In support of the Resource Conservation and Recovery Act (RCRA) permit process, Los Alamos National Laboratory (LANL) began annual avian monitoring in 2013 around TA-16 burn grounds and at two firing sites, TA-36 Minie and TA-39 Point 6. Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of non-viable eggs and/or nestlings that die of natural causes is non-invasive and is non-destructive to populations. Inorganic elements and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

Several congeners of polychlorinated biphenyls (PCBs), dioxins, and furans elicit similar toxic effects (i.e., immunotoxicity, carcinogenicity, and endocrine disruption) as those caused by tetrachlorodibenzodioxin-2,3,7,8 (TCDD), the most potent in this class of chemicals (Van den Berg et al. 2006). These congeners, like TCDD, have a high binding affinity to the aryl hydrocarbon receptor (Van den Berg et al. 2006). The World Health Organization (WHO) developed toxic equivalency factors (TEFs) for TCDD-like compounds that can be used to determine the relative potency, or toxic equivalents (TEQs), of dioxin-like compounds for different classes of animals (i.e., fish, birds, and mammals), as well as to facilitate risk assessment for TCDD-like exposure (Van den Berg et al. 1998).

Sources of inorganic elements include both anthropogenic and natural sources; birds can be exposed through a number of routes, including diet, ingestion of soil, drinking water, and inhalation. Inorganic elements (mostly metals), dioxins, and furans are of interest at open-detonation firing sites (TA-36 and TA-39) and at the burn grounds at TA-16 (Fresquez 2011).

3.0 OBJECTIVES

The objective of this ongoing study is to document chemical concentrations in eggs and nestlings collected near TA-16 burn grounds, TA-36 Minie, and TA-39 Point 6 and to compare concentrations of inorganic elements, PCBs, dioxins, and furans observed in this study with the upper-level bounds of background concentrations.

4.0 METHODS

4.1. Sample Collection

Eggs and nestlings were collected from nest boxes when they were determined to be non-viable, based on documented timing of known incubation periods for the species. We collected a total of six non-viable eggs and two deceased nestlings at LANL near the TA-16 burn grounds (Figure 1) and near open detonation sites TA-36 Minie (Figure 2) and TA-39 Point 6 (Figure 3). At TA-16, five non-viable western bluebird (*Sialia mexicana*) eggs and one deceased nestling samples were collected and submitted as one composite sample and four individual samples. At TA-36, one non-viable western bluebird egg was collected and submitted and at TA-39, one deceased western bluebird nestling was collected and submitted. All samples were collected May through July of 2020. Concentrations of chemicals in eggs and nestlings have been monitored annually at these locations since 2014.

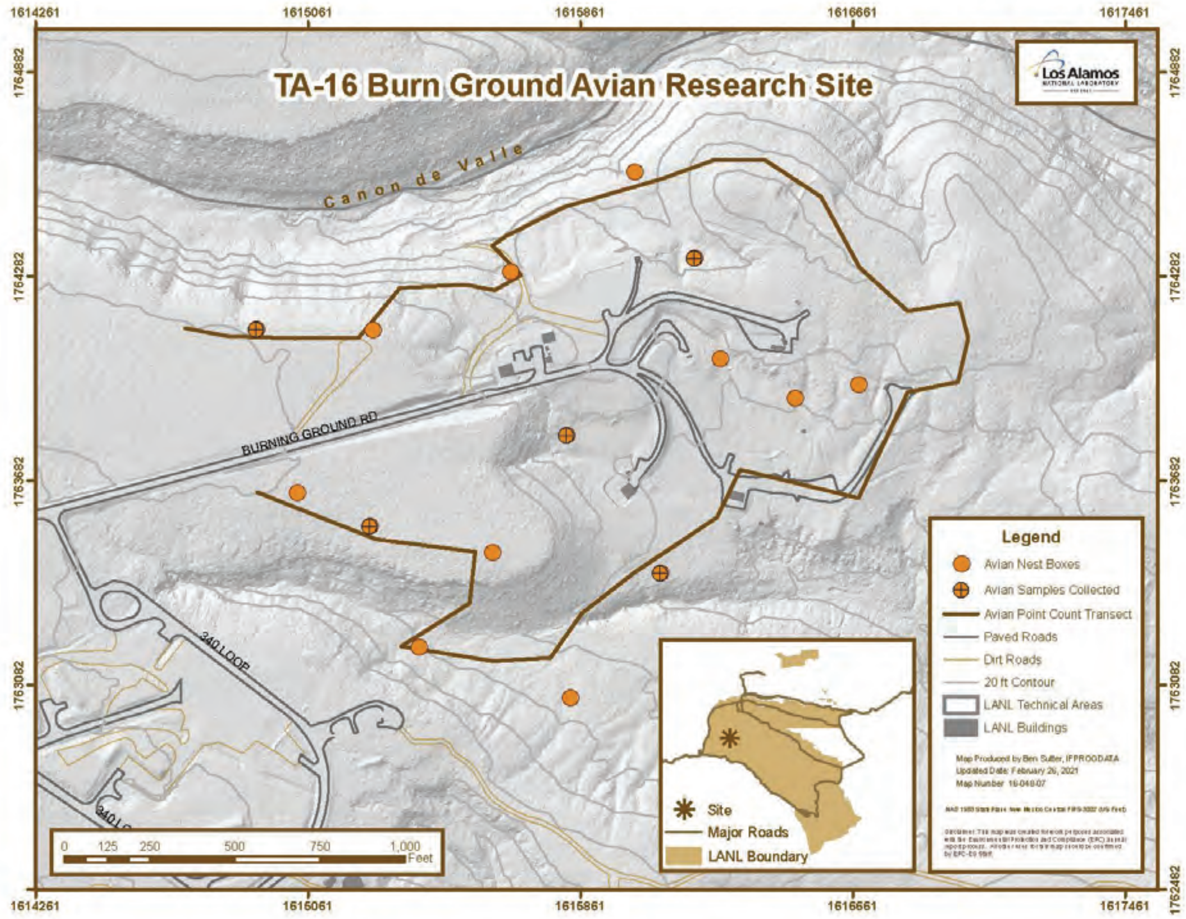


Figure 1. Avian nest box locations around TA-16 burn grounds.

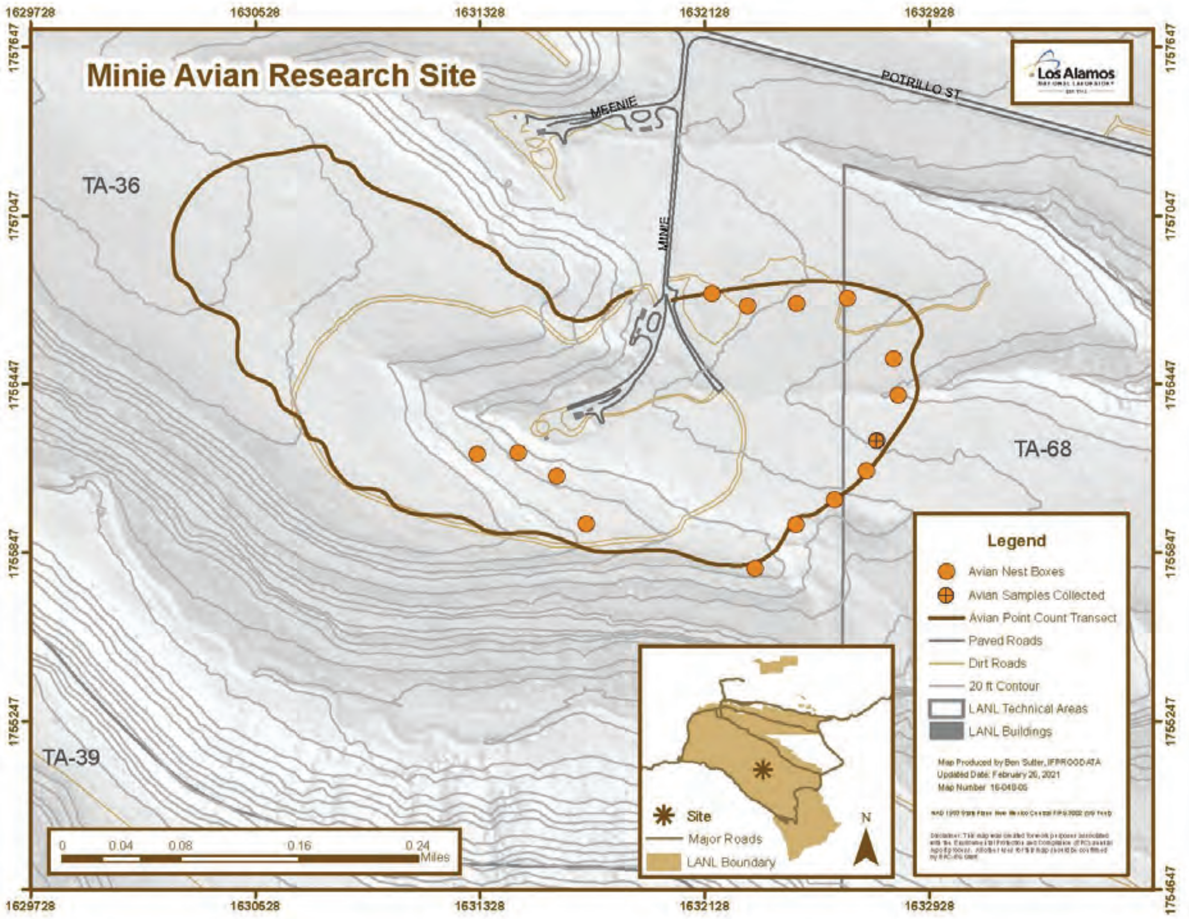


Figure 2. Avian nest box locations around TA-36 Minie.

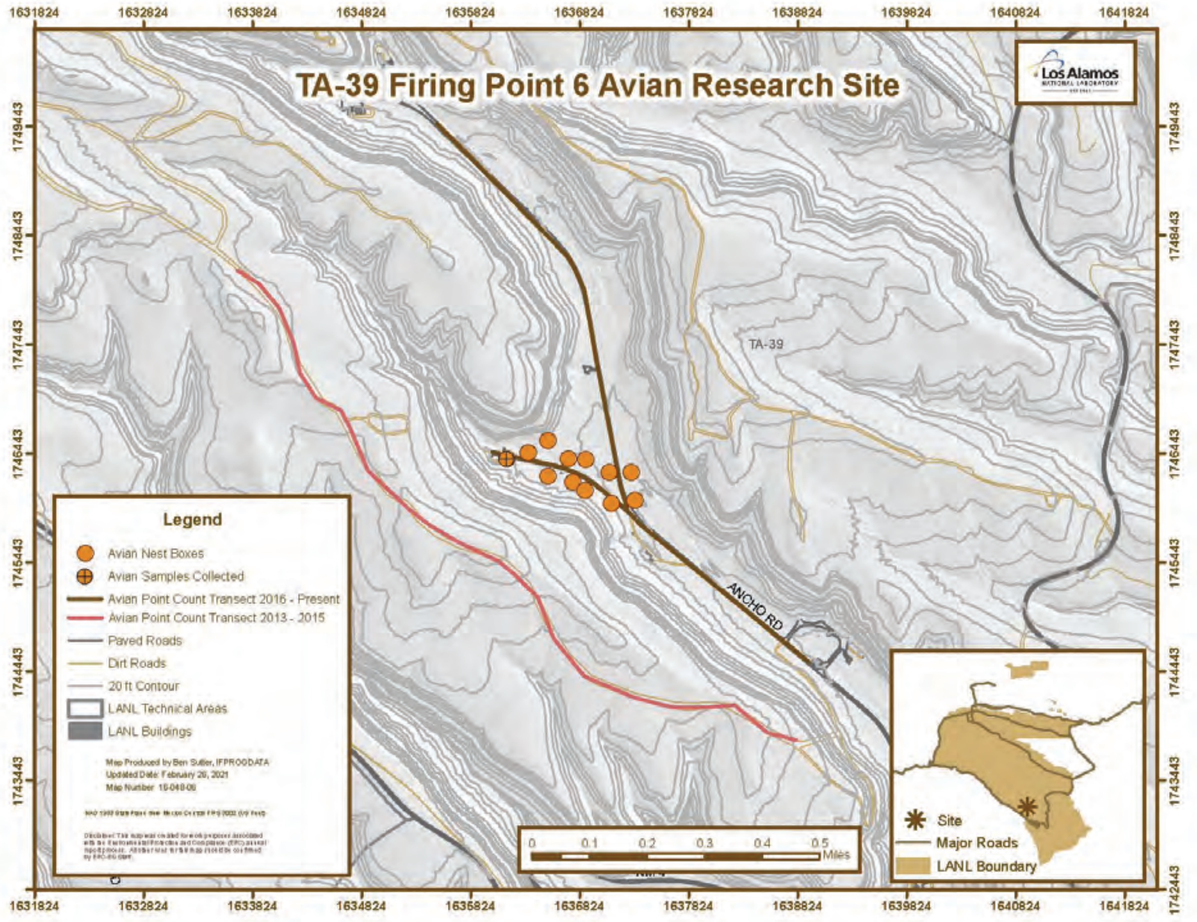


Figure 3. Avian nest box locations around TA-39 Point 6.

4.2. Chemical Analyses

Due to limited sample mass, non-viable eggs and one nestling sample were analyzed for total analyte list (mostly inorganic metals) only and were analyzed at ALS (Australian Laboratory Services, formerly Paragon Analytics, Inc.) in Fort Collins, Colorado. Antimony, arsenic, cadmium, lead, selenium, silver, and thallium concentrations were measured in egg samples by inductively coupled plasma mass spectrometry (Environmental Protection Agency [EPA] SW-846 Method 6020A), and aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were measured by inductively coupled plasma atomic emission spectrometry (EPA SW-846 Method 6010B). Mercury was measured by cold-vapor atomic absorption procedure (EPA SW-846 Method 7471A). All inorganic element results were reported on an mg/kg (milligram per kilogram) dry weight basis.

The non-viable nestling sample collected near TA-39 was analyzed for dioxin and furan congeners by EPA SW-846 Method 8290 at Cape Fear Analytical LLC, Wilmington, North Carolina. All organic chemical results are reported on a wet weight basis.

4.3. Statistical Methods

The 2020 results were compared with the regional statistical reference levels (RSRL), which represents natural and fallout levels of chemicals, and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Regional statistical reference levels were calculated from non-viable eggs of western bluebirds and ash-throated flycatchers (*Myiarchus cinerascens*) collected from Bandelier National Monument in 2020 (n = 7 samples). Non-viable egg results are also compared with the lowest observable adverse effect levels (LOAEL) from peer reviewed literature, when available.

Nestling sample results of dioxin and furans, were compared with RSRLs and LOAELs, when available. The nestling RSRL was calculated from non-viable nestlings of western bluebirds and ash-throated flycatchers at background locations from Bandelier National Monument in 2018 and 2019 (n = 5 samples). Nestling sample results of TAL were compared directly with one sample collected from background locations.

5.0 RESULTS AND DISCUSSION

Similar with previous years, many of the inorganic elements assessed in this study were not detected in passerine egg samples. Several elements are not (or very little is) maternally transferred into eggs or do not accumulate in eggs and include cadmium (Leach et al. 1979; Stoewsand et al. 1986), lead (Pattee 1984), vanadium (White and Dieter 1978), and silver (Schwarzbach et al. 2006; Seiler and Skorupa 2001), which may explain why these elements were mostly not detected.

Similarly, most dioxins and furans were not detected in the nestling sample collected from TA-39 burn grounds. Overall, most constituents that were detected in egg and the nestling samples were below RSRLs, and all constituents were below the LOAELs, when available.

5.1. TA-16 Burn Grounds

Western bluebird eggs collected from nest boxes at TA-16 burn grounds did not contain detectable concentrations of aluminum, arsenic, beryllium, cadmium, chromium, cobalt, nickel, silver, or vanadium. Of the elements containing detectable concentrations in eggs, all concentrations were below the RSRLs (Table 1). Mercury and selenium concentrations were well below LOAELs (Ohlendorf and Heinz, 2011, Shore et al. 2011); no other LOAELs were available.

Many inorganic elements were not detected in the non-viable nestling sample from TA-16 burn grounds. Detections patterns and concentrations of inorganic elements between the nestling from TA-16 and the nestling sample from a background location are similar.

5.2. TA-36 Minie

The one western bluebird egg sample collected from TA-36 Minie, did not have detectable levels of several elements, including aluminum, arsenic, beryllium, cadmium, chromium, cobalt, lead, nickel, silver, thallium, or vanadium. Detectable concentrations of antimony, barium, calcium, copper, iron, magnesium, manganese, mercury, potassium, selenium, sodium, and zinc were all below the RSRL (Table 2). Mercury and selenium concentrations were well below LOAELs (Ohlendorf and Heinz, 2011, Shore et al. 2011); no other LOAELs were available.

5.3. TA-39 Point 6

Most dioxins and furans were not detected in the nestling sample collected from TA-39. The sample contained detectable concentrations of 1,2,3,4,6,7,8,9-octachlorodibenzodioxin at 4.51 pg/g (picograms per gram) and 1,2,3,4,6,7,8-heptachlorodibenzodioxin at 1.83 pg/g, which exceeds the RSRL of 2.36 pg/g and 1.43 pg/g, respectively. Lowest observable adverse effect levels are not available for each dioxin and furan congener. However, TCDD, the most potent dioxin congener, induces toxic effects in avian eggs at concentrations between 1,000 to 10,000 pg/g wet weight (Harris and Elliott 2011). Toxic equivalent factors can be used to calculate the toxic equivalent values of dioxin-like compounds. The toxic equivalent factor for 1,2,3,4,6,7,8,9-octachlorodibenzodioxin and 1,2,3,4,6,7,8-heptachlorodibenzodioxin for avian species is 0.0001 and 0.001, respectively (Van den Berg et al. 1998). Multiplying the detectable concentration by the toxic equivalent factors yield values that are orders of magnitude less than the lowest observable adverse effect level for TCDD observed in avian eggs (Harris and Elliott 2011).

6.0 CONCLUSIONS

The overall results indicate that the levels of constituents detected in the eggs and nestlings are not likely to cause adverse effects in breeding bird populations. Several constituents were not detected in the non-viable egg and nestling samples collected near TA-16 burn grounds, TA-36 Minie, and TA-39. Most constituents that were detected were below RSRLs and all were below the LOAELs, when available. These results suggest that the detectable concentrations observed here were not of ecological concern. More data from non-viable eggs and nestlings are needed to make a robust assessment and to examine trends over time. Evaluating avian nestling samples for high explosives are also of interest for future work as those data become available.

7.0 REFERENCES

Becker, P. H. (2003). Biomonitoring with birds. Trace Metals and other Contaminants in the Environment, 6(C), 677–736. doi:10.1016/S0927-5215(03)80149-2.

Fresquez, P. (2011). Chemical Concentrations in Field Mice from Open-detonation firing sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory. LA-UR-11-10614.

Gochfeld, M. and Burger, J. (1998). Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in New York. Environmental Research, 77(1), 36–42. doi:10.1006/enrs.1997.3802.

Harris, M., and Elliott, J. (2011) Effects of Polychlorinated Biphenyls, Dibenzo-p-Dioxins, and Dibenzofurans, and Polybrominated Diphenyl Ethers in Wild Birds, Pp. 477-528 in Beyer W., and Meador, J. eds. Environmental Contaminants in Biota Interpreting Tissue Concentrations, 2nd Edition. CRC Press Boca Raton, Florida.

Jones, K. C. and de Voogt, P. (1999). Persistent Organic Pollutants (POPs): State of the Science. Environmental Pollution, 100, 209-221.

Leach, R., Wang, K., and Baker, D. (1979). Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. The Journal of Nutrition, 109(3), 437–443.

Ohlendorf, H., and Heinz, G. (2011). Selenium in Birds, Pp. 669-701 in Beyer, W., and Meador, J. eds. Environmental Contaminants in Biota Interpreting Tissue Concentrations, 2nd Edition. CRC Press Boca Raton, Florida.

Pattee, O. H. (1984). Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Archives of Environmental Contamination and Toxicology, 13, 29–34. doi:10.1007/BF01055643.

Schwarzbach, S. E., Albertson, J. D., and Thomas, C. M. (2006). Effects of Predation, Flooding, and Contamination Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk, 123(1), 45–60.

Seiler, R. L. and Skorupa, J. P. (2001). National Irrigation Water Quality Program Data-Synthesis Data Base. Carson City, NV.

Shore, R., Pereira, M., Walker, L., and Thompson, D. (2011) Mercury in Nonmarine Birds and Mammals. Pp. 609-624 in Beyer, W., and Meador, J. eds. Environmental Contaminants in Biota Interpreting Tissue Concentrations, 2nd Edition. CRC Press Boca Raton, Florida.

Stoewsand, G. S., Bache, C. A., Gutenmann, W. H., and Lisk, D. J. (1986). Cocentration of Cadmium in Coturnix Quail Fed Earthworms. Journal of Toxicology and Envrionmental Health, 18, 36–376.

Van den Berg M., Birnbaum, L., Bosveld, A., Brunstrom, B., Cook, P., Feely, M., Giesy, J., Hanberg, A., Hasegawa, R., Kennedy, S., Kubiak, T., Laresn, J., Rolaf van Leeuwen, F., Liem, A., Nolt, C., Peterson, R., Poellinger, L., Safe, S., Schrenk, D., Tillitt, D., Tysklind, M. Younes, M., Waern, F., and Zacharewski, T. (1998). Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife, Environmental Health Perspectives, 106: 775-792.

Van den Berg, M., Birnbaum, L., Denison, M., De Vito, M., Farland, W., Feeley, M., Fiedler, H. Hakansson, H., Hanberg, A., Haws, L., Rose, M., Safe, S., Schrenk, D., Tohyama, C., Tritscher, A., Tuomisto, J., Tysklind, M., Walker, N., and Peterson, R. (2006). The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, Toxicological Sciences 93(2):223–241.

White, D. H. and Dieter, M. P. (1978). Effects of Dietary Vanadium in Mallard Ducks. Journal of Toxicology and Envrionmental Health, 4, 43–50.

Table 1. Inorganic element concentrations (mg/kg dry weight) detected in single or composite egg samples collected near TA-16 burn grounds compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2020 (n = 7). No values were above the RSRL.

Element	Western bluebird (n = 1) SFB-20-206077	Western bluebird (n = 1) SFB-20-206078	Western bluebird (n=1) SFB-20-206079	Western bluebird (n=2) SFB-20-206080	RSRL
Antimony	0.140	0.140	0.130	0.087	0.228
Barium	95	55	8	85	124
Calcium	1,900	3,300	3,600	2,500	18,838
Copper	3.70	3.00	2.20	2.60	4.65
Iron	150	150	280	150	292
Lead	0.39	ND	ND	ND	0.43
Magnesium	300	270	360	380	620
Manganese	1.80	1.50	1.70	2.00	3.88
Mercury	0.072	0.057	0.060	0.180	0.192
Potassium	9,700	9,100	7,900	7,800	11,225
Selenium	2.6	2.6	3.2	2.6	4.0
Sodium	9,400	10,000	8,300	8,300	11,221
Thallium	ND	ND	ND	0.0076	0.0263
Zinc	44.0	39.0	42.0	51.0	61.9

ND = non-detect

Table 2. Inorganic element concentrations (mg/kg dry weight) detected in a western bluebird egg sample collected near the TA-36 Minie compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data from 2020 (n = 7). No values were above the RSRL.

Element	Western bluebird (n = 1) SFB-20-206081	RSRL
Antimony	0.19	0.228
Barium	17	124
Calcium	17,000	18,838
Copper	4.10	4.65
Iron	150	292
Magnesium	530	620
Manganese	2.80	3.88
Mercury	0.021	0.192
Potassium	10,000	11,225
Selenium	2.0	4.0
Sodium	9,700	11,221
Zinc	55.0	61.9

13. Gaukler, S.M. and J.E. Stanek, March 2022. *2021 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-22-21423. OSTI Identifier 1846122.

(Gaulker & Stanek 2022)

Title: 2021 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Author(s): Gaukler, Shannon Marie
Stanek, Jenna Elizabeth

Intended for: Report
Environmental Regulatory Document

Issued: 2022-03-16 (rev.2)

Los Alamos
NATIONAL LABORATORY

LA-UR-22-21423

Title:	2021 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory
Author(s):	Gaukler, Shannon Marie Stanek, Jenna Elizabeth
Intended for:	Report
Issued:	2022-02-25 (rev.1)

Los Alamos
NATIONAL LABORATORY

LA-UR-22-21423
*Approved for public release;
distribution is unlimited.*

11 February 2022

2021 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Prepared by: Shannon Gaukler and Jenna Stanek
Environmental Protection and Compliance Division,
Environmental Stewardship

Prepared for: U.S. Department of Energy, National Nuclear Security Administration, Los Alamos Field Office

An Affirmative Action/Equal Opportunity Employer

CONTENTS

ACRONYMS AND TERMS

ALS	Australian Laboratory Services
EPA	Environmental Protection Agency
LANL	Los Alamos National Laboratory
LOAEL	lowest observable adverse effect levels
mg/kg	milligrams per kilogram
PCBs	polychlorinated biphenyls
RSRLs	regional statistical reference levels
TA	Technical Area
TCDD	tetrachlorodibenzodioxin-2,3,7,8
TEF	toxic equivalent factors
TEQ	toxic equivalents
RCRA	Resource Conservation and Recovery Act
WHO	World Health Organization

1.0 SUMMARY

In 2021, non-viable avian eggs and one nestling were opportunistically collected at Los Alamos National Laboratory (LANL) near open detonation sites located at Technical Area (TA) 16 burn grounds and TA-36 Minie. Similar to previous years, nestboxes were monitored at TA-39 Point 6, however, no avian samples were available for opportunistic collection. Samples were evaluated for inorganic elements (mostly metals), dioxins, and furans. One ash-throated flycatcher (*Myiarchus cinerascens*) egg sample was collected from TA-16 burn grounds. One ash-throated flycatcher and one mountain bluebird (*Sialia currucoides)* egg sample and one deceased western bluebird (*Sialia mexicana*) nestling sample were collected from TA-36 Minie. Concentrations of inorganic elements observed in this study were compared with the regional statistical reference level (RSRL) which is the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Several inorganic elements were not detected in avian eggs. Most inorganic elements detected were below the RSRL and all were the lowest observable adverse effect level (LOAEL), when available. The nestling collected from TA-36 did not contain detectable concentrations of dioxin or furan congeners. These data suggest that inorganic and organic element concentrations in eggs and nestlings are not of ecological concern. More data are needed to make a robust assessment and to evaluate trends over time.

2.0 INTRODUCTION

In support of the Resource Conservation and Recovery Act (RCRA) permit process, Los Alamos National Laboratory (LANL) began annual avian monitoring in 2013 around TA-16 burn grounds and at two firing sites, TA-36 Minie and TA-39 Point 6. Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of non-viable eggs and/or nestlings that die of natural causes is non-invasive and is non-destructive to populations. Inorganic elements and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

Several congeners of polychlorinated biphenyls (PCBs), dioxins, and furans elicit similar toxic effects (i.e., immunotoxicity, carcinogenicity, and endocrine disruption) as those caused by tetrachlorodibenzodioxin-2,3,7,8 (TCDD), the most potent in this class of chemicals (Van den Berg et al. 2006). These congeners, like TCDD, have a high binding affinity to the aryl hydrocarbon receptor (Van den Berg et al. 2006). The World Health Organization (WHO) developed toxic equivalency factors (TEFs) for TCDD-like compounds that can be used to determine the relative potency, or toxic equivalents (TEQs), of dioxin-like compounds for different classes of animals (i.e., fish, birds, and mammals), as well as to facilitate risk assessment for TCDD-like exposure (Van den Berg et al. 1998).

Sources of inorganic elements include both anthropogenic and natural sources; birds can be exposed through a number of routes, including diet, ingestion of soil, drinking water, and inhalation. Inorganic elements (mostly metals), dioxins, and furans are of interest at open-detonation firing sites (TA-36 and TA-39) and at the burn grounds at TA-16 (Fresquez 2011).

3.0 OBJECTIVES

The objective of this ongoing study is to document chemical concentrations in eggs and nestlings collected near TA-16 burn grounds, TA-36 Minie, and TA-39 Point 6 and to compare concentrations of inorganic elements, PCBs, dioxins, and furans observed in this study with the upper-level bounds of background concentrations.

4.0 METHODS

4.1. Sample Collection

Eggs and nestlings were collected from nest boxes when they were determined to be non-viable, based on documented timing of known incubation periods for the species. We collected a total of four non-viable eggs and one deceased nestling at LANL near the TA-16 burn grounds (Figure 1) and near open detonation site TA-36 Minie (Figure 2). At TA-16 burn grounds, two non-viable ash-throated flycatcher (*Myiarchus cinerascens*) egg samples were collected and submitted as one composite sample. At TA-36 Minie, one non-viable mountain bluebird egg (*Sialia currucoides)*, one non-viable ash-throated flycatcher egg, and one deceased western bluebird (*Sialia mexicana*) nestling were collected and submitted as individual samples. All samples were collected May through July of 2021. Concentrations of chemicals in eggs and nestlings have been monitored annually at these locations since 2014.

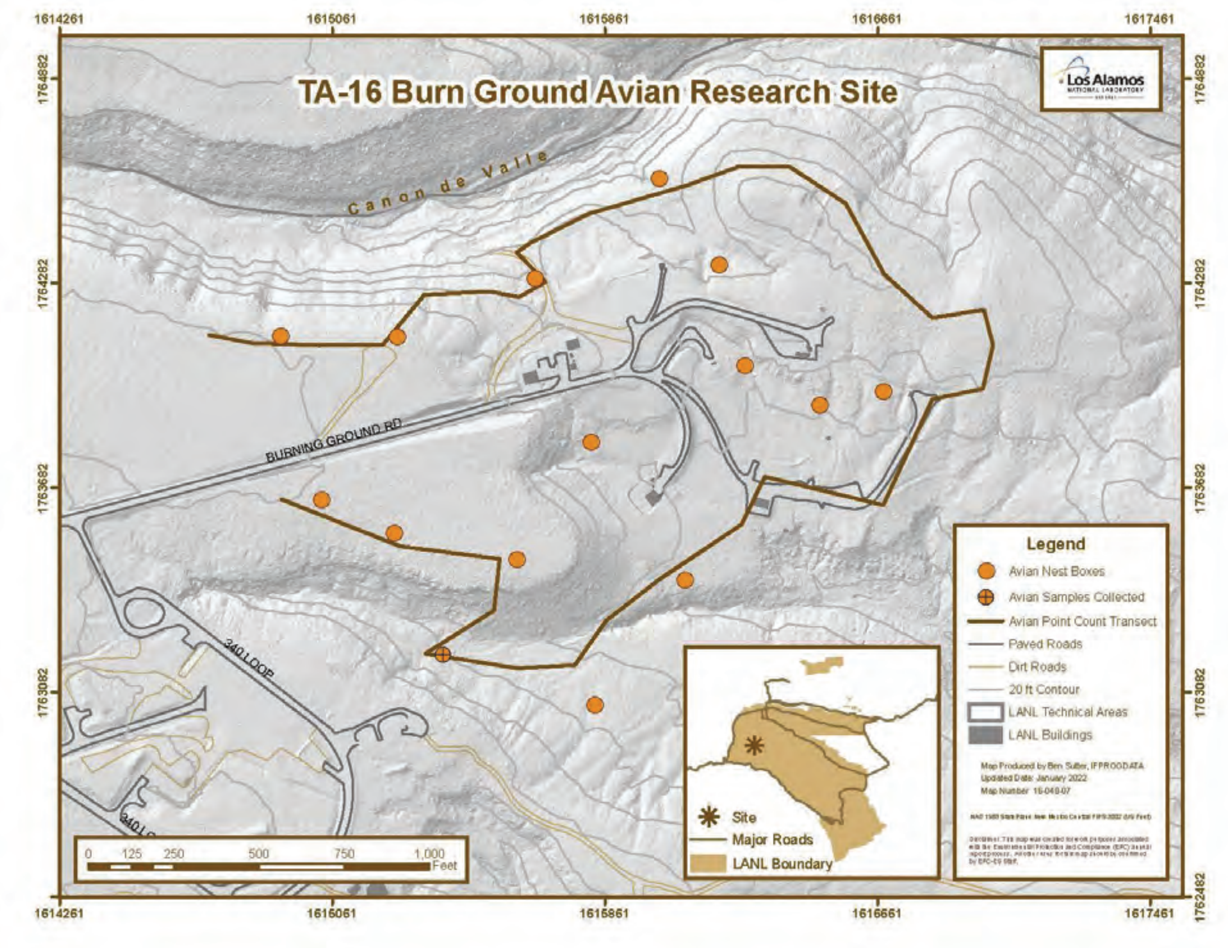


Figure 1. Avian nest box locations around TA-16 burn grounds.

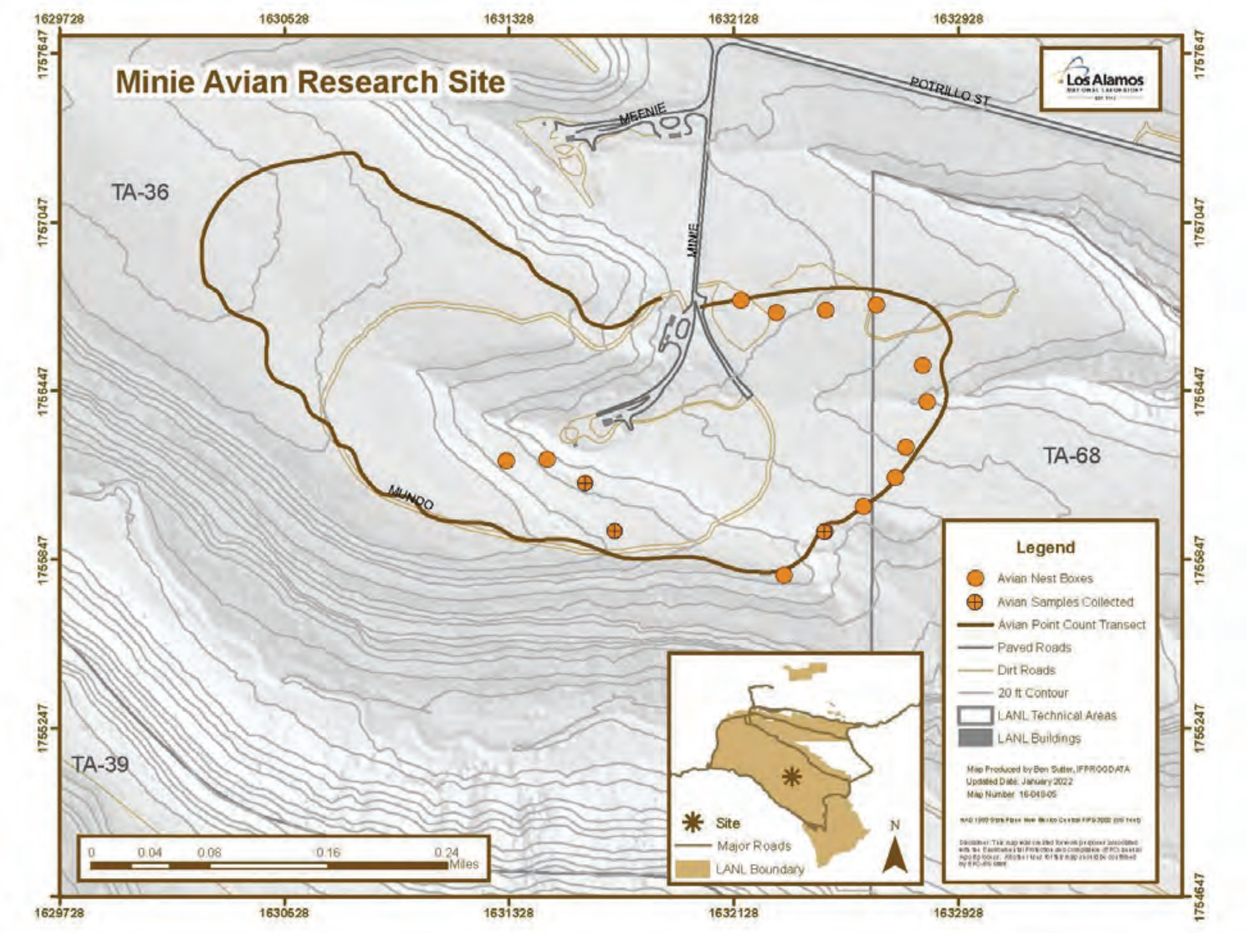


Figure 2. Avian nest box locations around TA-36 Minie.

4.2. Chemical Analyses

Due to limited sample mass, non-viable eggs were analyzed for total analyte list (mostly inorganic metals) only and were analyzed at ALS (Australian Laboratory Services, formerly Paragon Analytics, Inc.) in Fort Collins, Colorado. Antimony, arsenic, cadmium, lead, selenium, silver, and thallium concentrations were measured in egg samples by inductively coupled plasma mass spectrometry (Environmental Protection Agency [EPA] SW-846 Method 6020), and aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were measured by inductively coupled plasma atomic emission spectrometry (EPA SW-846 Method 6010B). Mercury was measured by cold-vapor atomic absorption procedure (EPA SW-846 Method 7471A). All inorganic element results were reported on an mg/kg (milligram per kilogram) wet weight basis.

The non-viable nestling sample collected near TA-36 Minie was analyzed for dioxin and furan congeners by EPA SW-846 Method 8290 at Cape Fear Analytical LLC, Wilmington, North Carolina. All organic chemical results are reported on a wet weight basis.

4.3. Statistical Methods

The 2021 results were compared with the regional statistical reference levels (RSRL), which represents natural and fallout levels of chemicals, and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Regional statistical reference levels were calculated from non-viable eggs of western bluebirds and ash-throated flycatchers collected from Bandelier National Monument from 2021 (n = 10 samples). Non-viable egg results are also compared with the lowest observable adverse effect levels (LOAEL) from peer reviewed literature, when available.

Detectable concentrations of dioxin and furans congeners are compared with RSRLs and LOAELs, when available. The nestling RSRL was calculated from non-viable nestlings of western bluebirds and ash-throated flycatchers at background locations from Bandelier National Monument in 2018 through 2020 (n = 8 samples).

5.0 RESULTS AND DISCUSSION

Similar with previous years, many of the inorganic elements assessed in this study were not detected in passerine egg samples. Several elements are not (or very little is) maternally transferred into eggs or do not accumulate in eggs and include cadmium (Leach et al. 1979; Stoewsand et al. 1986), lead (Pattee 1984), vanadium (White and Dieter 1978), and silver (Schwarzbach et al. 2006; Seiler and Skorupa 2001), which may explain why these elements were mostly not detected. Similarly, no dioxins and furans were detected in the nestling sample collected from TA-36 Minie.

5.1. TA-16 Burn Grounds

The composite ash-throated flycatcher egg sample collected from nest boxes at TA-16 burn grounds did not contain detectable concentrations of aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, nickel, silver, thallium or vanadium. Mercury was detected at a concentration of 0.031 mg/kg and slightly exceeded the RSRL of 0.011 (Table 1), but was far below the LOAEL of 1.9 mg/kg (Shore et al. 2011). The remaining detectable elements were below the RSRLs (Table 1). Selenium concentrations were also below the LOAEL of 2.6 mg/kg (Ohlendorf and Heinz, 2011,); no other LOAELs were available.

5.2. TA-36 Minie

The one mountain bluebird and one ash-throated flycatcher egg sample collected from TA-36 Minie, did not have detectable levels of several elements, including aluminum, arsenic, beryllium, cadmium, chromium, cobalt, lead, nickel, silver, thallium, or vanadium. The mountain bluebird egg sample contained antimony concentrations of 0.024, which slightly exceeded the RSRL of 0.019 mg/kg (Table 2). The ash-throated flycatcher egg sample contained mercury concentrations of 0.019 mg/kg which slightly exceeded the RSRL of 0.011 (Table 2), but was far below the LOAEL of 1.9 mg/kg (Shore et al. 2011). The remaining detectable elements were below the RSRLs (Table 2). Selenium concentrations were also below the LOAEL of 2.6 mg/kg (Ohlendorf and Heinz, 2011,); no other LOAELs were available. No dioxin and furan congeners were detected in the western bluebird nestling sample collected from TA-36 Minie.

6.0 CONCLUSIONS

The overall results indicate that the levels of constituents detected in the eggs and nestlings are not likely to cause adverse effects in breeding bird populations. Several constituents were not detected in the non-viable egg and nestling samples collected near TA-16 burn grounds and TA-36 Minie. The majority of constituents that were detected were below RSRLs and all were below the LOAELs, when available. These results suggest that the detectable concentrations observed here are not of ecological concern. More data from non-viable eggs and nestlings are needed to make a robust assessment and to examine trends over time. Evaluating avian nestling samples for high explosives are also of interest for future work as those data become available.

7.0 REFERENCES

Becker, P. H. (2003). Biomonitoring with birds. Trace Metals and other Contaminants in the Environment, 6(C), 677–736. doi:10.1016/S0927-5215(03)80149-2.

Fresquez, P. (2011). Chemical Concentrations in Field Mice from Open-detonation firing sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory. LA-UR-11-10614.

Gochfeld, M. and Burger, J. (1998). Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in New York. Environmental Research, 77(1), 36–42. doi:10.1006/enrs.1997.3802.

Jones, K. C. and de Voogt, P. (1999). Persistent Organic Pollutants (POPs): State of the Science. Environmental Pollution, 100, 209-221.

Leach, R., Wang, K., and Baker, D. (1979). Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. The Journal of Nutrition, 109(3), 437–443.

Ohlendorf, H., and Heinz, G. (2011). Selenium in Birds, Pp. 669-701 in Beyer, W., and Meador, J. eds. Environmental Contaminants in Biota Interpreting Tissue Concentrations, 2nd Edition. CRC Press Boca Raton, Florida.

Pattee, O. H. (1984). Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Archives of Environmental Contamination and Toxicology, 13, 29–34. doi:10.1007/BF01055643.

Schwarzbach, S. E., Albertson, J. D., and Thomas, C. M. (2006). Effects of Predation, Flooding, and Contamination Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. The Auk, 123(1), 45–60.

Seiler, R. L. and Skorupa, J. P. (2001). National Irrigation Water Quality Program Data-Synthesis Data Base. Carson City, NV.

Shore, R., Pereira, M., Walker, L., and Thompson, D. (2011) Mercury in Nonmarine Birds and Mammals. Pp. 609-624 in Beyer, W., and Meador, J. eds. Environmental Contaminants in Biota Interpreting Tissue Concentrations, 2nd Edition. CRC Press Boca Raton, Florida.

Stoewsand, G. S., Bache, C. A., Gutenmann, W. H., and Lisk, D. J. (1986). Cocentration of Cadmium in Coturnix Quail Fed Earthworms. Journal of Toxicology and Envrionmental Health, 18, 36–376.

Van den Berg M., Birnbaum, L., Bosveld, A., Brunstrom, B., Cook, P., Feely, M., Giesy, J., Hanberg, A., Hasegawa, R., Kennedy, S., Kubiak, T., Laresn, J., Rolaf van Leeuwen, F., Liem, A., Nolt, C., Peterson, R., Poellinger, L., Safe, S., Schrenk, D., Tillitt, D., Tysklind, M. Younes, M., Waern, F., and Zacharewski, T. (1998). Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife, Environmental Health Perspectives, 106: 775-792.

Van den Berg, M., Birnbaum, L., Denison, M., De Vito, M., Farland, W., Feeley, M., Fiedler, H. Hakansson, H., Hanberg, A., Haws, L., Rose, M., Safe, S., Schrenk, D., Tohyama, C., Tritscher, A., Tuomisto, J., Tysklind, M., Walker, N., and Peterson, R. (2006). The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds, Toxicological Sciences 93(2):223–241.

White, D. H. and Dieter, M. P. (1978). Effects of Dietary Vanadium in Mallard Ducks. Journal of Toxicology and Envrionmental Health, 4, 43–50.

Table 1. Detectable inorganic element concentrations (mg/kg wet weight) detected in a composite egg samples collected near TA-16 burn grounds compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data in 2021 (n = 10).

Element	Ash-throated Flycatcher (n = 2) SFB-21-233901	RSRL
Barium	0.47	3.9
Calcium	550	6,588
Copper	0.53	1.71
Iron	23	70
Magnesium	62	130
Mercury	0.031	0.011
Potassium	1,900	3,227
Selenium	0.85	1.0
Sodium	2,400	3,506
Zinc	11	23.1

Table 2. Inorganic element concentrations (mg/kg wet weight) detected in a single egg sample collected near the TA-36 Minie compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data in 2021 (n = 10).

Element	Mountain bluebird (n = 1) SFB-21-233902	Ash-throated flycatcher (n = 1) SFB-21-233903	RSRL
Antimony	0.024	ND	0.019
Barium	1.9	ND	3.9
Calcium	690	640	6,588
Copper	0.45	0.54	1.71
Iron	17	23	70
Magnesium	81	72	130
Manganese	ND	0.36	1.04
Mercury	0.003	0.019	0.011
Potassium	2,000	1,400	3,227
Selenium	0.42	0.64	1.0
Sodium	2,300	1,900	3,506
Zinc	7.4	9.5	23.1

ND = Not detected

14. Gaukler, S.M. and J.E. Stanek, February 2023. *2022 Results for Avian Monitoring of Inorganic Elements and Organic Chemical Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory*. LA-UR-23-20968. (Gaulker & Stanek 2023)

LA-UR-23-20968

ESHID-603744

Approved for public release; distribution is unlimited.

Title: 2022 Results for Avian Monitoring of Inorganic Elements and Organic Chemical Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Author(s): Gaukler, Shannon Marie
Stanek, Jenna Elizabeth

Intended for: Report

Issued: 2023-02-03 (rev.1)

Los Alamos
NATIONAL LABORATORY

LA-UR-23-20968
January 2023

2022 Results for Avian Monitoring of Inorganic Elements and Organic Chemical Concentrations in Passerine Eggs and Nestlings Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY

Prepared for: U.S. Department of Energy/National Nuclear Security Administration,
Los Alamos Field Office

Prepared by: Shannon Gaukler and Jenna Stanek
Environmental Protection and Compliance Division,
Environmental Stewardship (EPC-ES)

Editing and Layout by: Tamara Hawman, Communications Specialist
Technical Editing and Communications (CEA-TEC)

Los Alamos
NATIONAL LABORATORY

Contents

Figures

Tables

1 Summary

In 2022, nonviable avian eggs and one nestling were opportunistically collected at Los Alamos National Laboratory (LANL) near open detonation sites located at Technical Area (TA) 16 burn grounds, TA-36 Minie, and TA-39 Point 6. Samples were evaluated for inorganic elements (mostly metals) or per- and polyfluoroalkyl substances (PFAS).

- Three western bluebird (*Sialia mexicana*) egg samples were collected from TA-16 burn grounds.
- One deceased mountain bluebird (*Sialia currucoides*) nestling sample was collected from TA-36 Minie.
- One ash-throated flycatcher (*Myiarchus cinerascens*) egg sample was collected from TA-39 Point 6.

Concentrations of inorganic elements (i.e., mostly metals) observed in this study were compared with the regional statistical reference level (RSRL), which is the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Several inorganic elements were not detected in avian eggs. All of the inorganic elements that were detected were below the RSRL and the lowest observable adverse effect level (LOAEL), when available. No PFAS compounds were detected in the mountain bluebird nestling sample collected from TA-36, and the majority of PFAS compounds were not detected in the western bluebird egg sample from TA-16. These data suggest that inorganic element and PFAS concentrations in eggs and nestlings are not of ecological concern. More data are needed to make a robust assessment and to evaluate trends over time.

2 Introduction

In support of the Resource Conservation and Recovery Act permit process, LANL began annual avian monitoring in 2013 around TA-16 burn grounds and at two firing sites: TA-36 Minie and TA-39 Point 6. Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of nonviable eggs and/or nestlings that die of natural causes is non-invasive and is non-destructive to populations. Inorganic elements (i.e., mostly metals) and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Birds can be exposed to chemicals through multiple routes, including diet, ingestion of soil, drinking water, and inhalation. Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

Polychlorinated biphenyls (PCBs) are manufactured chemicals that were used in industrial products; commercial production of these chemicals was banned in the late 1970s. Dioxins and furans are not manufactured—they are created as a result of the manufacturing of products (e.g., herbicides) or from the combustion of materials (e.g., coal, woods). Several congeners of PCBs, dioxins, and furans elicit similar toxic effects (i.e., immunotoxicity, carcinogenicity, and endocrine disruption) across several taxa, such as those caused by tetrachlorodibenzodioxin-2,3,7,8 (TCDD), which is the most potent in this class of chemicals (Van den Berg et al. 2006). These congeners, like TCDD, have a high binding affinity to the aryl hydrocarbon receptor (Van den Berg et al. 2006). Several effects have been observed in birds when exposed to PCBs, dioxins, and furans, including effects on reproduction and development (Harris and Elliot 2011). The World Health Organization developed toxic equivalency factors for TCDD-like compounds that can be used to determine the relative potency—or toxic equivalents—of dioxin-like compounds for different classes of animals (i.e., fish, birds, and mammals) as well as to facilitate risk assessment for TCDD-like exposure (Van den Berg et al. 1998).

PFAS are a class of manufactured compounds that are used in many consumer and industrial products, such as cookware, food packaging, stain repellants, paints, and fire-fighting foams. PFAS compounds have useful properties, including repelling oil, stains, grease, and water, which contribute to their widespread use. Several thousand known PFAS compounds exist—some of which have been more widely used and studied than others—and these compounds have been manufactured since the 1940s. PFAS compounds are detected in the environment around the globe and have even been detected in avian tissues in remote areas, such as oceanic environments and from the Arctic region, where global deposition is the primary source of PFAS in the environment (Kannan et al. 2002; Martin et al. 2004). Toxicity data for PFAS compounds in avian ecological receptors are sparse.

Sources of inorganic elements include both anthropogenic and natural sources. Adverse effects, such as those on reproduction, in birds have been observed due to mercury and selenium exposures (Ohlendorf and Heinz 2011; Shore et al. 2011).

Inorganic elements, dioxins, and furans are of interest at open-detonation firing sites (TA-36 and TA-39) and at the burn grounds at TA-16 (Fresquez 2011). PFAS compounds are being monitored to contribute to site-wide characterization at LANL.

3 Objectives

The objective of this ongoing study is to document chemical concentrations in eggs and nestlings collected near TA-16 burn grounds, TA-36 Minie, and TA-39 Point 6 and to compare concentrations of inorganic elements, PCBs, dioxins, furans, and PFAS compounds observed in this study with the upper-level bounds of background concentrations, when available.

4 Methods

4.1 Sample Collection

Eggs and nestlings were collected from nest boxes when they were determined to be nonviable based on documented timing of known incubation periods for the species. In 2022, we collected a total of four nonviable egg samples and a deceased nestling at LANL near the TA-16 burn grounds (Figure 1), near open detonation site TA-36 Minie (Figure 2), and near TA-39 Point 6 (Figure 3). At TA-16 burn grounds, four nonviable western bluebird eggs were collected from one nest and was submitted as one composite sample, and two nonviable western bluebird egg samples collected from two separate nests were submitted as individual samples. At TA-36 Minie, one deceased mountain bluebird nestling was collected and submitted as an individual sample. At TA-39 Point 6, one ash-throated flycatcher egg sample was collected and submitted as an individual sample. All samples were collected June through July of 2022. Concentrations of chemicals in eggs and nestlings have been monitored annually at these locations since 2014.

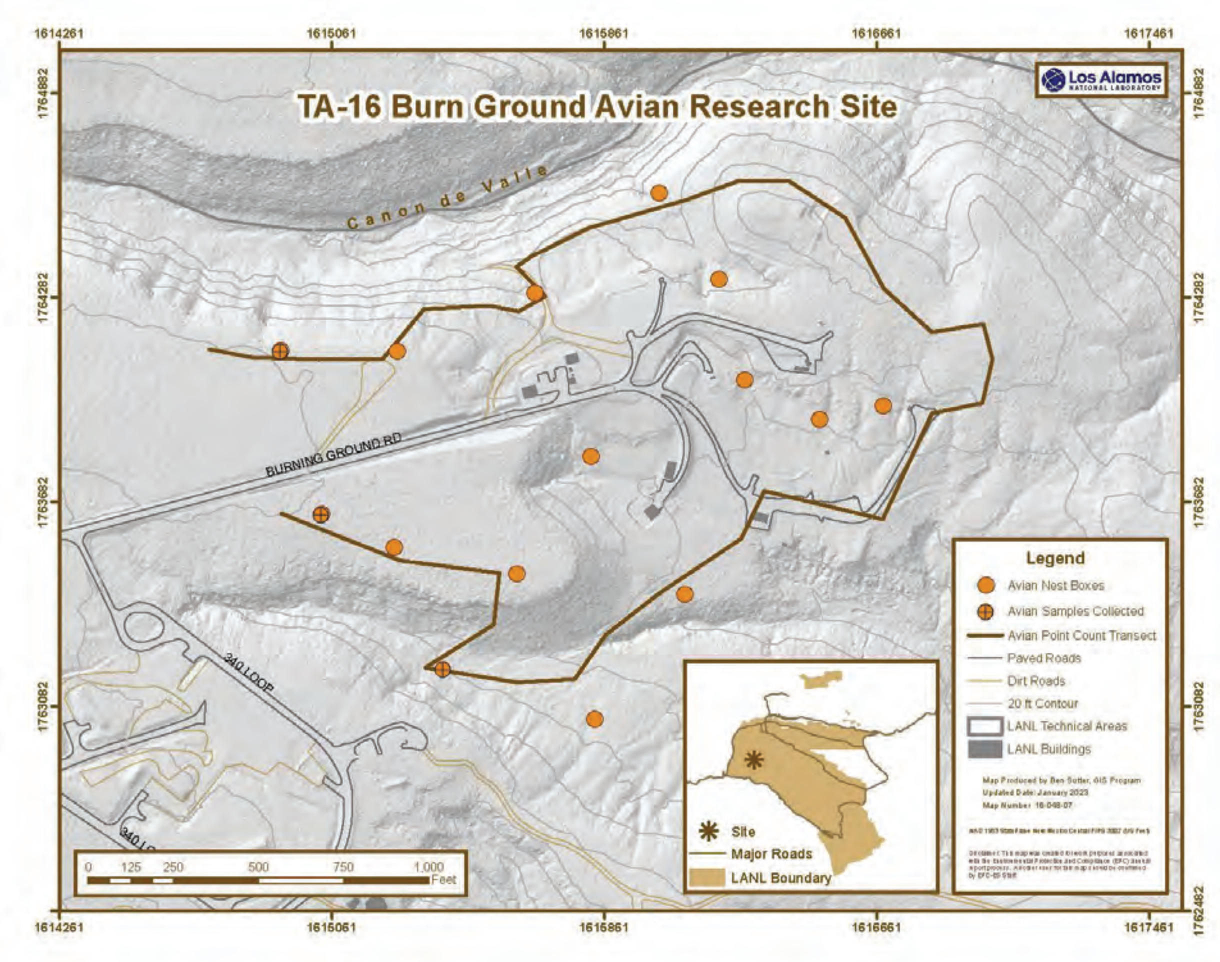


Figure 1. Avian nest box locations around TA-16 burn grounds.

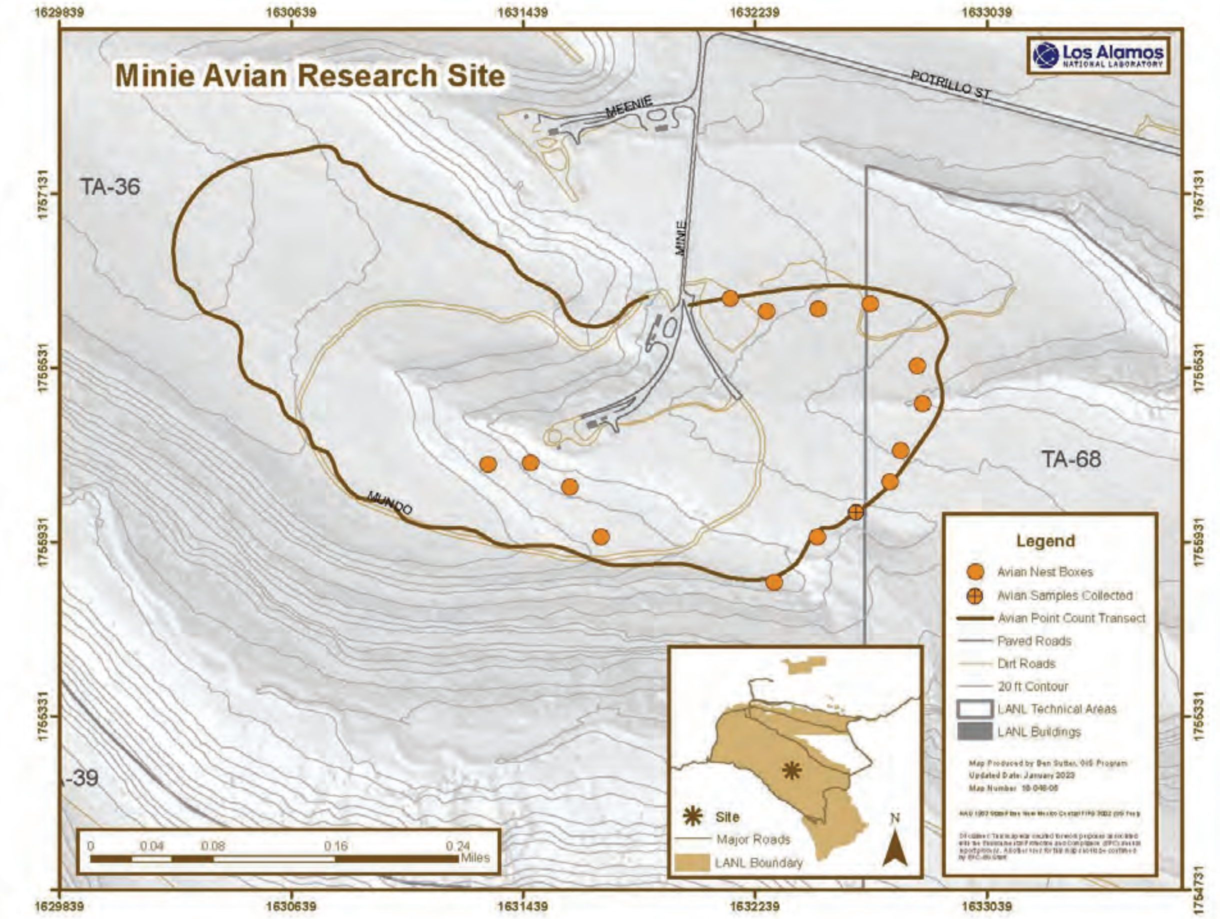


Figure 2. Avian nest box locations around TA-36 Minie.

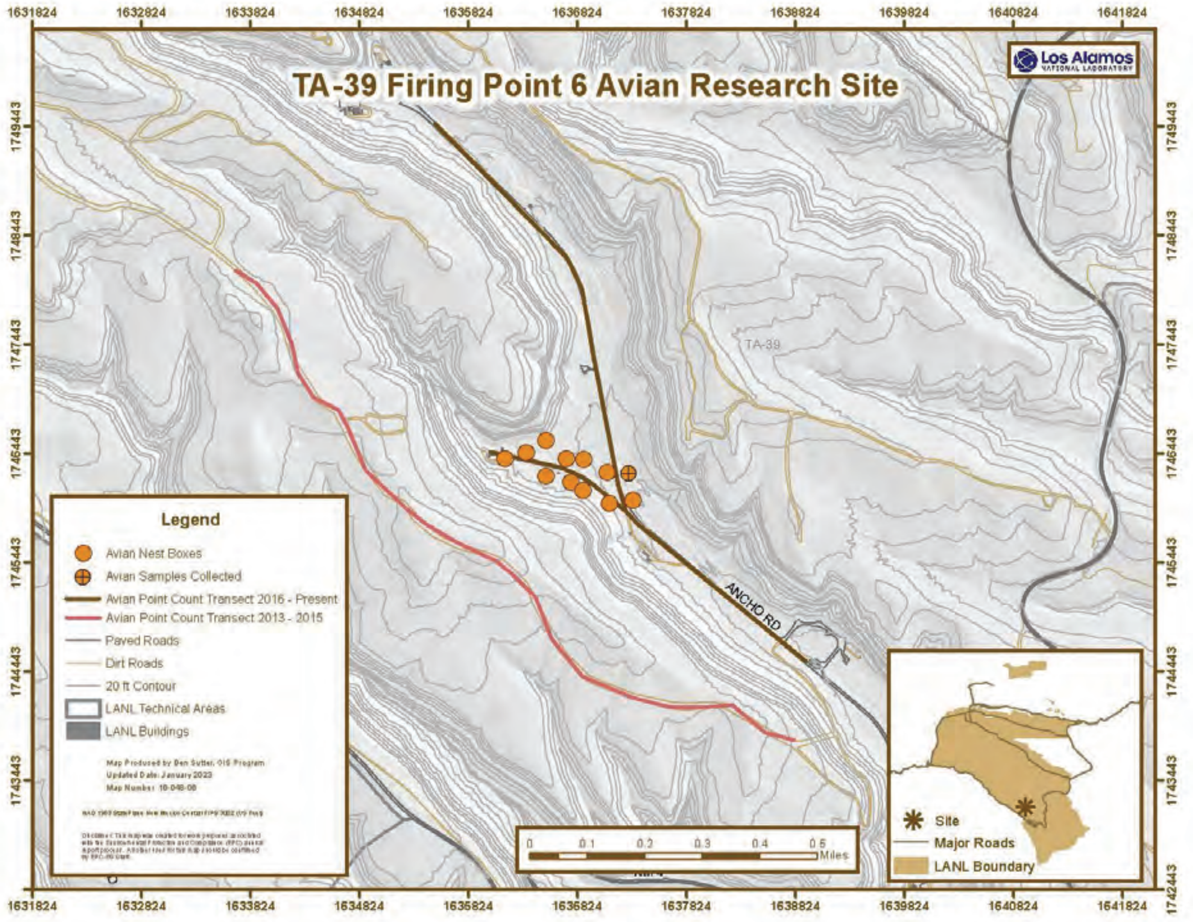


Figure 3. Avian nest box locations around TA-39 Firing Point 6.

4.2 Chemical Analyses

Due to limited sample mass, nonviable eggs were analyzed for total analyte list (inorganic elements) or PFAS only and were analyzed at GEL Laboratories in Charleston, South Carolina.

- Antimony, arsenic, cadmium, lead, selenium, silver, and thallium concentrations were measured in egg samples by inductively coupled plasma mass spectrometry (Environmental Protection Agency [EPA] SW-846 Method 6020).
- Aluminum, barium, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were measured by inductively coupled plasma atomic emission spectrometry (EPA SW-846 Method 6010B).
- Mercury was measured by cold-vapor atomic absorption procedure (EPA SW-846 Method 7471A).
- PFAS compounds were analyzed by liquid chromatograph triple quadrupole mass spectrometry (EPA:537M).

All inorganic element results were reported on an mg/kg (milligram per kilogram) wet weight basis, and PFAS compounds were reported on an ng/g (nanogram per gram) wet weight basis. No dioxin or furan congeners were analyzed due to limited sample masses.

4.3 Data Analyses

The 2022 results were compared with the RSRL, which represents natural and fallout levels of chemicals and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). Regional statistical reference levels were calculated from nonviable eggs of western bluebirds and ash-throated flycatchers collected from Bandelier National Monument in 2021 and 2022 (n = 20 samples). Nonviable egg results were also compared with the LOAEL from peer-reviewed literature, when available.

Detectable concentrations of PFAS were compared with RSRLs, when available. The nestling RSRLs for PFAS were calculated from nonviable nestlings of western bluebirds at background locations from Bandelier National Monument in 2022 (n = 2). RSRLs for nonviable egg samples at background locations from Bandelier National Monument are not yet available due to limited sample size (n = 1).

5 Results and Discussion

Similar to previous years, many of the inorganic elements assessed in this study were not detected in passerine egg samples. Several elements are not maternally transferred (or very little is transferred) into eggs or do not accumulate in eggs, including cadmium (Leach et al. 1979; Stoewsand et al. 1986), lead (Pattee 1984), vanadium (White and Dieter 1978), and silver (Schwarzbach et al. 2006; Seiler and Skorupa 2001), which could explain why these elements were mostly not detected. Similarly, no PFAS were detected in the mountain bluebird nestling sample, and most PFAS assessed in this study were not detected in the western bluebird egg sample.

5.1 TA-16 Burn Grounds

The two separate nonviable western bluebird egg samples collected from nest boxes at TA-16 burn grounds did not contain detectable concentrations of aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, manganese, mercury, nickel, silver, thallium, or vanadium. All of the inorganic elements that were detected in the western bluebird egg samples were below the RSRLs (Table 1). Selenium concentrations were well below the LOAEL of 2.6 mg/kg (Ohlendorf and Heinz 2011). A mercury LOAEL is available of 1.9 mg/kg (Shore et al. 2011), but mercury was not detected in either of the western bluebird egg samples. No other LOAELs are available.

The one western bluebird composite egg sample (n = 4) collected from a nest box at TA-16 burn grounds was tested for 37 PFAS compounds; 4 compounds were detected at very low levels, including

- perfluoroundecanoic acid at 0.307 ng/g,
- perfluorononanoic acid at 0.317 ng/g,
- perfluorotetradeconoic acid at 0.733 ng/g, and
- perfluorotridecanoic acid at 1.02 ng/g.

An RSRL for PFAS in passerine eggs has not yet been calculated because only one egg sample was collected for PFAS from Bandelier National Monument. Although these four PFAS compounds are not as well-studied as other PFAS compounds, such as perfluorooctanesulfonic acid (PFOS), a LOAEL for PFOS in avian eggs was determined at 92.4 ng/g (Dennis et al. 2021). All of the observed concentrations of PFAS compounds in the western bluebird at TA-16 were two orders of magnitude below the PFOS LOAEL. Additionally, the PFAS concentrations observed here are within the ranges observed in avian tissues from published studies, including studies that occurred away from point-source pollution and in the Arctic, where global deposition is the primary source of PFAS in the environment (Kannan et al. 2002; Martin et al. 2005). We are exploring other potential sources for some of the PFAS chemicals detected at LANL. Anticipated sources are atmospheric deposition and historical use of PFAS-containing materials.

Table 1. Detectable inorganic element concentrations (mg/kg wet weight) detected in two separate single egg samples collected near TA-16 burn grounds compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data in 2021 and 2022 (n = 20).

Element	Western bluebird (n = 1) SFB-22-255317	Western bluebird (n = 1) SFB-22-255318	RSRL
Barium	3.42	2.08	6.4
Calcium	1,820	569	9,382
Chromium	0.253	ND	1.18
Iron	43.1	ND	117
Magnesium	68.5	74	236
Potassium	1,680	1,800	4,145
Selenium	0.46	0.40	1.5
Sodium	2,190	1,940	4,029
Zinc	10.9	8.65	37.1

ND = Not Detected

5.2 TA-39 Point 6

The one ash-throated flycatcher egg sample collected from TA-39 Point 6 did not have detectable levels of several elements, including aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, thallium, or vanadium. All of the inorganic elements that were detected in the ash-throated flycatcher egg sample were below the RSRLs (Table 2**Error! Reference source not found.**). Selenium concentrations were well below the LOAEL of 2.6 mg/kg (Ohlendorf and Heinz 2011). A mercury LOAEL is available of 1.9 mg/kg (Shore et al. 2011), but mercury was not detected in the ash-throated flycatcher egg sample. No other LOAELs are available.

Table 2. Inorganic element concentrations (mg/kg wet weight) detected in a single egg sample collected near the TA-39 Point 6 compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs based on data in 2021 and 2022 (n = 20).

Element	Ash-throated flycatcher (n = 1) SFB-22-255320	RSRL
Barium	0.898	6.4
Calcium	643	9,382
Magnesium	64	236
Potassium	1,450	4,145
Selenium	0.48	1.5
Sodium	1,790	4,029
Zinc	5.8	37.1

5.3 TA-36 Minie

The one mountain bluebird nestling sample collected from TA-36 Minie did not contain any detectable levels of the 37 PFAS compounds that were analyzed. Similarly, no PFAS compounds were detected in nestling samples collected from Bandelier National Monument either.

6 Conclusions

The overall results indicate that the levels of constituents detected in eggs and nestlings are not likely to cause adverse effects in breeding bird populations from these study sites. Several constituents were not detected in the nonviable egg and nestling samples collected near TA-16 burn grounds, TA-36 Minie, and TA-39. All of the constituents that were detected were below RSRLs, and all were below the LOAELs, when available. These results suggest that the detectable concentrations observed here are not of ecological concern. More data from nonviable eggs and nestlings are needed to make a robust assessment and to examine trends over time. Evaluating avian nestling samples for high explosives is also of interest for future work as those data become available.

7 References

Becker, P. H. (2003). Biomonitoring with birds. *Trace Metals and other Contaminants in the Environment* 6(C):677–736. doi:10.1016/S0927-5215(03)80149-2.

Dennis, N. M., S. Subbiah, A. Karnjanapiboonwong, M. L. Dennis, C. McCarthy, C. J. Salice, and T. A. Anderson. (2021). Species- and Tissue-Specific Avian Chronic Toxicity Values for Perfluorooctane Sulfonate (PFOS) and a Binary Mixture of PFOS and Perfluorohexane Sulfonate. *Environmental Toxicology and Chemistry* 40(3):899–909.

Fresquez, P. R. (2011). Chemical Concentrations in Field Mice Collected from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory. Los Alamos National Laboratory report LA-UR-11-10614.

Gochfeld, M. and J. Burger (1998). Temporal trends in metal levels in eggs of the endangered roseate tern (*Sterna dougallii*) in New York. *Environmental Research* 77(1):36–42. doi:10.1006/enrs.1997.3802.

Harris, M. L. and J. E. Elliott. (2011). Effects of Polychlorinated Biphenlys, Dibenzo-p-Dioxins and Dibenzofurans, and Polybrominated Diphenyl Ethers in Wild Birds in W. Beyer and J. Meador, eds. *Environmental Contaminants in Biota: Interpreting Tissue Concentrations*, 2nd Edition. CRC Press, Boca Raton, Florida.

Jones, K. C. and P. de Voogt. (1999). Persistent organic pollutants (POPs): state of the science. Environmental Pollution 100(1–3), 209–221.

Kannan, K., S. Corsolini, J. Falandysz, G. Oehme, S. Focardi, and J. Giesy. (2002). Perfluorooctanesulfonate and Related Fluorinated Hydrocarbons in Marine Mammals, Fishes, and Birds from Coasts of the Baltic and the Mediterranean Seas. *Environmental Science and Technology* 36(15):3210–3216.

Leach, R. M. Jr., K. W. Wang, and D. E. Baker (1979). Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. *Journal of Nutrition*, 109(3):437–443.

Martin, J. W., M. M. Smithwick, B. M. Braune, P. F. Hoekstra, D. C. G. Muir, and S. A. Mabury. (2004). Identification of Long-Chain Perfluorinated Acids in Biota from the Canadian Arctic. *Environmental Science and Technology* 38(2):373–380.

Ohlendorf, H. M., and G. H. Heinz. (2011). Selenium in Birds, pp. 669–701 in Beyer, W., and Meador, J. eds. *Environmental Contaminants in Biota: Interpreting Tissue Concentrations*, 2nd Edition. CRC Press Boca Raton, Florida.

Pattee, O. H. (1984). Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. *Archives of Environmental Contamination and Toxicology* 13:29–34. doi:10.1007/BF01055643.

Schwarzbach, S. E., J. D. Albertson, and C. M. Thomas (2006). Effects of Predation, Flooding, and Contamination Reproductive Success of California Clapper Rails (*Rallus longirostris obsoletus*) in San Francisco Bay. *The Auk* 123(1):45–60.

Seiler, R. L. and J. P. Skorupa (2001). National Irrigation Water Quality Program Data-Synthesis Data Base. Carson City, NV.

Shore, R. F., M. G. Pereira, L. A. Walker, and D. R. Thompson (2011) Mercury in Nonmarine Birds and Mammals, pp. 609–624 in W. Beyer and J. Meador, eds. *Environmental Contaminants in Biota: Interpreting Tissue Concentrations*, 2nd Edition. CRC Press, Boca Raton, Florida.

Stoewsand, G. S., C. A. Bache, W. H. Gutenmann, and, D. J. Lisk (1986). Concentration of cadmium in Coturnix quail fed earthworms. *Journal of Toxicology and Envrionmental Health* 18(3):369–376.

Van den Berg M., L. Birnbaum, A. T. Bosveld, B. Brunström, P. Cook, M. Feeley, J. P. Giesy, A. Hanberg, R. Hasegawa, S. W. Kennedy, T. Kubiak, J. C. Larsen, F. X. van Leeuwen, A. K. Liem, C. Nolt, R. E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillitt, M. Tysklind, M. Younes, F. Waern, and T. Zacharewski (1998). Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environmental Health Perspectives* 106(12):775–792.

Van den Berg, M., L. S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R. E. Peterson (2006). The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicological Sciences* 93(2):223–241.

White, D. H. and M. P. Dieter (1978). Effects of dietary vanadium in mallard ducks. *Journal of Toxicology and Envrionmental Health* 4(1):43–50.

8 Acronyms and Abbreviations

Acronym	Definition
EPA	Environmental Protection Agency
LANL	Los Alamos National Laboratory
LOAEL	lowest observable adverse effect level
mg/kg	milligrams per kilogram
ng/g	nanograms per gram
PCBs	polychlorinated biphenyls
PFAS	per- and polyfluoroalkyl substances
PFOS	perfluorooctanesulfonic acid
RSRL	regional statistical reference level
TA	Technical Area
TCDD	tetrachlorodibenzodioxin-2,3,7,8

15. Green, A. and S. Allen, 2011. *Open Detonation Air Sampling Summary for Resource Conservation and Recovery Act (RCRA) Permitting at Los Alamos National Laboratory*. LA-UR-11-03249. (Green & Allen 2011)

LA-UR-11-03249

Open Detonation Air Sampling Summary for Resource Conservation and Recovery Act (RCRA) Permitting at Los Alamos National Laboratory

Andrew Green and Shannon Allen
WES-EDA

During 2010 and 2011 the Environmental Data and Analysis Group (WES-EDA) AIRNET team conducted sampling of suites of dioxins, furans and metals in support of the RCRA permit for Los Alamos National Laboratory (LANL) operated by LANS, LLC.

This document is a brief description of the work that was performed by the AIRNET team. Shannon Allen headed up the field team of Joan Lujan, William Smith and Louis Naranjo. Shannon coordinated the equipment purchase and sample analysis. Andrew Green performed the data analysis with support from Luciana Vigil-Holterman.

Dioxin and Furan Detection Equipment and Methodology

Thirty samples were collected for analysis using the EPA TO-9A method. The samples were collected using appropriate specialized high volume air samplers (Model TE-1000 PUF Poly-Urethane Foam) which were purchased from Tisch Environmental, Inc.

Prior to sample collection the sampling equipment was calibrated as described in the Operations Manual for the TE-1000 PUF. Sample flow volumes were calculated as described in the manual. Average atmospheric pressure and temperature data used in the calculation were obtained from LANL's meteorological tower at TA-54.

Pre-prepared sample media for TO-9A was obtained from Test America. TO-9A filters included a poly-urethane foam filter in a glass cartridge, and an airborne particulate filter. The glass PUF cartridge and the particulate filter were installed in series into the PUF sample module and connected to the sampler.

After collection, samples were returned for analysis to Test America in the original pre-cleaned packaging which consisted of aluminum foil and zip lock bags. Samples were shipped from the LANL Sample Management Office using coolers and ice to preserve samples as required by the TO-9A method.

One field blank was collected for each day of sampling, for a total of 8 blank samples.

Nitrile gloves were used whenever sample media were handled.

Metals Detection Equipment and Methodology

Thirty metals samples were collected using high volume air samplers (Hi-Q Environmental Model HVP-3000 BRL). Polypropylene 8”x10” filters were used, which were pre-cut and sold by Hi-Q Environmental.

Three field blank samples were collected, one for every ten field samples.

Field samples were collected per SOP-5174 Rev. 1, “AIRNET – Using High Volume Samplers”. Samples were shipped by LANL’s Sample Management Office to the analytical laboratory, ALS.

Sampling Location Selection and Methodology

For each shot, two locations were sampled. Each location had one TE-1000 PUF sampler and one high-volume sampler from Hi-Q. Sampler locations were chosen the morning of each shot after observing the predominant wind direction at the site and looking at the wind direction reported on the LANL meteorology site. Samplers were set as closely as possible to the shot location in a down wind direction. Sampling equipment was started approximately 10 to 15 minutes prior to the shot, and run for at least 15 minutes after the shot. All samplers were powered with extension cords; no gas generators were used. Vehicles were not operated in the immediate area (within the shot exclusion zone) during the sampling period. Shots were monitored from inside the bunker, and any observed plume or wind direction during collection was documented in the field notes.

Data Analysis

The field data were coordinated with the data analysis results to derive volume concentrations which were then compared to acute air inhalation exposure concentrations listed in the companion database of the 2005 US Environmental Protection Agency (EPA) *Human Health Hazard Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA530-R-05-006) when available. Other acute inhalation screening levels were identified within the 1999 *Air Toxics Hot Spots Program Risk Assessment Guidelines Part I The Determination of Acute Reference Exposure Levels for Airborne Toxicants,* drafted by the Office of Environmental Health Hazard Assessment of the California Environmental Protection Agency. These comparisons are attached to this document.

Concluding Remarks

Data were collected following the standard protocol for such measurements.

Comparisons with identified screening levels indicate operations that were monitored did not exceed any appropriate state or federal levels specified for the analytes monitored.

====================end of document====================

LA-UR-11-03249

Attachment

Summary of Analytical Results for Air Samples Collected at TA-36 and TA-39 Open Detonation Treatment Operations

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2834	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2824	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2827	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2844	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4185	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	1.2	pg/Filter	0.198	27	5.346	2.24E-01						
RE39-11-2842	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4191	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4187	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4196	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.93	pg/Filter	0.198	36.6	7.2468	1.28E-01						
RE39-11-4518	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE39-11-4522	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2824	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Heptachlorodibenzodioxins (Total)	50	pg/Filter			10.18	4.91E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2826	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2827	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2844	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4185	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Heptachlorodibenzodioxins (Total)	2	pg/Filter	0.198	27	5.346	3.74E-01						
RE39-11-2842	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4191	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4187	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4196	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Heptachlorodibenzodioxins (Total)	0.93	pg/Filter	0.198	36.6	7.2468	1.28E-01						
RE39-11-4518	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Heptachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE39-11-4522	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Heptachlorodibenzodioxins (Total)	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2824	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	1	pg/Filter			10.18	9.82E-02						
RE36-11-2826	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2827	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2830	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2844	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4185	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	1.3	pg/Filter	0.198	27	5.346	2.43E-01						
RE39-11-2842	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4191	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4187	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4196	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter			0							
RE39-11-4522	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-2824	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-2827	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2844	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-4185	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-4191	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-4187	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE36-11-4196	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter			0							
RE39-11-4522	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2824	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Heptachlorodibenzofurans (Total)	1	pg/Filter			10.18	9.82E-02						
RE36-11-2826	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2827	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2844	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4185	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2836	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Heptachlorodibenzofurans (Total)	1.3	pg/Filter	0.198	27	5.346	2.43E-01						
RE39-11-2842	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4191	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4187	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4196	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Heptachlorodibenzofurans (Total)	50	pg/Filter			0							
RE39-11-4522	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Heptachlorodibenzofurans (Total)	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2840	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug $/m^3$)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4193	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4195	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzodioxins (Total)	4	pg/Filter	0.153	39.6	6.0588	6.60E-01						
RE39-11-2845	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzodioxins (Total)	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzodioxins (Total)	1.3	pg/Filter	0.189	44.4	8.3916	1.55E-01						
RE36-11-2833	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzodioxins (Total)	1.5	pg/Filter	0.193	27.6	5.3268	2.82E-01						
RE39-11-2836	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzodioxins (Total)	2.3	pg/Filter	0.189	25.2	4.7628	4.83E-01						
RE39-11-2839	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzodioxins (Total)	2.1	pg/Filter	0.198	27	5.346	3.93E-01						
RE39-11-2842	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzodioxins (Total)	4.4	pg/Filter	0.168	36	6.048	7.28E-01						
RE36-11-4194	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzodioxins (Total)	2.3	pg/Filter	0.198	36.6	7.2468	3.17E-01						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-4518	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzodioxins (Total)	1.3	pg/Filter	0.202	30.6	6.1812	2.10E-01						
RE39-11-4520	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzodioxins (Total)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzodioxins (Total)	2.3	pg/Filter	0.211	28.8	6.0768	3.78E-01		0				0
RE39-11-2834	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter			0							

Sample Name	**Analyte Description**	**Std Result**	**Std Result Unit**	**Flow rate (m^3/min)**	**Flow time (min)**	**Flow vol (m^3)**	**Conc. In Air (pg or ug /m^3)**	**Detection**	**# of Detects per Analyte**	**Acute Inhalation Exposure Conc. (mg/m^3)**	**CA Acute RELs (mg/m^3)**	**Conversion of screening level to ug/m^3**	**# of Exceeds per Analyte**
RE39-11-4522	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzofuran[1,2,3,4,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzofuran[1,2,3,6,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2824	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzofuran[1,2,3,7,8,9-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2828	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzofuran[2,3,4,6,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2824	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Hexachlorodibenzofurans (Total)	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2827	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						

Sample Name	**Analyte Description**	**Std Result**	**Std Result Unit**	**Flow rate (m^3/min)**	**Flow time (min)**	**Flow vol (m^3)**	**Conc. In Air (pg or ug /m^3)**	**Detection**	**# of Detects per Analyte**	**Acute Inhalation Exposure Conc. (mg/m^3)**	**CA Acute RELs (mg/m^3)**	**Conversion of screening level to ug/m^3**	**# of Exceeds per Analyte**
RE36-11-2832	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-2844	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4185	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4191	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4187	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE36-11-4196	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Hexachlorodibenzofurans (Total)	50	pg/Filter			0							
RE39-11-4522	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Hexachlorodibenzofurans (Total)	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	5.9	pg/Filter	0.153	39.6	6.0588	9.74E-01						
RE39-11-2845	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1.8	pg/Filter			0							
RE36-11-2824	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	4	pg/Filter	0.183	33	6.039	6.62E-01						
RE36-11-2825	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.1	pg/Filter			10.18	2.06E-01						
RE36-11-2826	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.4	pg/Filter			0							
RE36-11-2827	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.7	pg/Filter	0.188	29.4	5.5272	6.69E-01						
RE36-11-2828	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.8	pg/Filter	0.186	37.8	7.0308	5.40E-01						
RE36-11-2829	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	4.3	pg/Filter	0.19	22.2	4.218	1.02E+00						
RE36-11-2830	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.178	45	8.01	1.25E+01						
RE36-11-2831	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2	pg/Filter	0.167	28.2	4.7094	4.25E-01						
RE36-11-2832	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	44.4	8.3916	1.19E+01						
RE36-11-2833	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1.3	pg/Filter			0							
RE36-11-2844	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.5	pg/Filter			0							
RE36-11-4185	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.6	pg/Filter	0.178	36	6.408	4.06E-01						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4186	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.7	pg/Filter	0.194	40.8	7.9152	3.41E-01						
RE39-11-2835	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.5	pg/Filter	0.193	27.6	5.3268	6.57E-01						
RE39-11-2836	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3	pg/Filter	0.192	19.2	3.6864	8.14E-01						
RE39-11-2837	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.1	pg/Filter	0.197	31.2	6.1464	5.04E-01						
RE39-11-2838	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.4	pg/Filter	0.189	25.2	4.7628	7.14E-01						
RE39-11-2839	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2	pg/Filter	0.198	30.6	6.0588	3.30E-01						
RE39-11-2840	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.7	pg/Filter	0.191	24	4.584	5.89E-01						
RE39-11-2841	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.4	pg/Filter	0.198	27	5.346	6.36E-01						
RE39-11-2842	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4191	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.196	33	6.468	1.55E+01						
RE36-11-4193	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.3	pg/Filter	0.168	36	6.048	3.80E-01						
RE36-11-4194	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4187	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	8.6	pg/Filter	0.198	23.4	4.6332	1.86E+00						
RE36-11-4188	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	38.4	7.2576	1.38E+01						
RE36-11-4195	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4196	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	7.9	pg/Filter	0.197	101.4	19.9758	3.95E-01						
RE36-11-4198	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.169	111	18.759	5.33E+00						
RE39-11-2843	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.7	pg/Filter	0.198	36.6	7.2468	5.11E-01						
RE39-11-4518	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	4.1	pg/Filter	0.197	34.8	6.8556	5.98E-01						
RE39-11-4519	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.5	pg/Filter	0.202	30.6	6.1812	5.66E-01						
RE39-11-4520	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3.2	pg/Filter	0.189	31.8	6.0102	5.32E-01						
RE39-11-4521	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE39-11-4522	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1.6	pg/Filter	0.186	25.8	4.7988	3.33E-01						
RE39-11-4523	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.8	pg/Filter	0.211	28.8	6.0768	4.61E-01		0				0
RE39-11-2834	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.153	39.6	6.0588	1.65E+01						
RE39-11-2845	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-2824	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.183	33	6.039	1.66E+01						
RE36-11-2825	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			10.18	9.82E+00						
RE36-11-2826	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-2827	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.188	29.4	5.5272	1.81E+01						
RE36-11-2828	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.186	37.8	7.0308	1.42E+01						
RE36-11-2829	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.19	22.2	4.218	2.37E+01						
RE36-11-2830	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.178	45	8.01	1.25E+01						
RE36-11-2831	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.167	28.2	4.7094	2.12E+01						
RE36-11-2832	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	44.4	8.3916	1.19E+01						
RE36-11-2833	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-2844	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	1.6	pg/Filter			0							
RE36-11-4185	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.178	36	6.408	1.56E+01						
RE36-11-4186	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.194	40.8	7.9152	1.26E+01						
RE39-11-2835	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	1.6	pg/Filter	0.193	27.6	5.3268	3.00E-01						
RE39-11-2836	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.192	19.2	3.6864	2.71E+01						
RE39-11-2837	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.197	31.2	6.1464	1.63E+01						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2838	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	25.2	4.7628	2.10E+01						
RE39-11-2839	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.198	30.6	6.0588	1.65E+01						
RE39-11-2840	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.191	24	4.584	2.18E+01						
RE39-11-2841	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.198	27	5.346	1.87E+01						
RE39-11-2842	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4191	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.196	33	6.468	1.55E+01						
RE36-11-4193	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.168	36	6.048	1.65E+01						
RE36-11-4194	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4187	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.198	23.4	4.6332	2.16E+01						
RE36-11-4188	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	38.4	7.2576	1.38E+01						
RE36-11-4195	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE36-11-4196	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.197	101.4	19.9758	5.01E+00						
RE36-11-4198	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.169	111	18.759	5.33E+00						
RE39-11-2843	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.198	36.6	7.2468	1.38E+01						
RE39-11-4518	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.197	34.8	6.8556	1.46E+01						
RE39-11-4519	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.202	30.6	6.1812	1.62E+01						
RE39-11-4520	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.189	31.8	6.0102	1.66E+01						
RE39-11-4521	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter			0							
RE39-11-4522	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.186	25.8	4.7988	2.08E+01						
RE39-11-4523	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	100	pg/Filter	0.211	28.8	6.0768	1.65E+01		0				0
RE39-11-2834	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2824	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2827	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2844	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4185	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2842	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4191	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4187	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4196	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter			0							
RE39-11-4522	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Pentachlorodibenzodioxin[1,2,3,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2824	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Pentachlorodibenzodioxins (Total)	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2827	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-2844	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4185	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Pentachlorodibenzodioxins (Total)	1.8	pg/Filter	0.198	27	5.346	3.37E-01						
RE39-11-2842	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4191	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							

Sample Name	**Analyte Description**	**Std Result**	**Std Result Unit**	**Flow rate (m^3/min)**	**Flow time (min)**	**Flow vol (m^3)**	**Conc. In Air (pg or ug /m^3)**	**Detection**	**# of Detects per Analyte**	**Acute Inhalation Exposure Conc. (mg/m^3)**	**CA Acute RELs (mg/m^3)**	**Conversion of screening level to ug/m^3**	**# of Exceeds per Analyte**
RE36-11-4187	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE36-11-4196	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Pentachlorodibenzodioxins (Total)	1.5	pg/Filter	0.169	111	18.759	8.00E-02						
RE39-11-2843	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Pentachlorodibenzodioxins (Total)	50	pg/Filter			0							
RE39-11-4522	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Pentachlorodibenzodioxins (Total)	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2824	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2827	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-2844	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4185	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4191	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4187	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE36-11-4196	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4198	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter			0							
RE39-11-4522	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Pentachlorodibenzofuran[1,2,3,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2824	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2827	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-2844	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4185	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.192	19.2	3.6864	1.36E+01						
RE39-11-2837	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4191	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4187	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE36-11-4196	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-4520	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter			0							
RE39-11-4522	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Pentachlorodibenzofuran[2,3,4,7,8-]	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0
RE39-11-2834	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.153	39.6	6.0588	8.25E+00						
RE39-11-2845	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-2824	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.183	33	6.039	8.28E+00						
RE36-11-2825	Pentachlorodibenzofurans (Totals)	50	pg/Filter			10.18	4.91E+00						
RE36-11-2826	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-2827	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.188	29.4	5.5272	9.05E+00						
RE36-11-2828	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.186	37.8	7.0308	7.11E+00						
RE36-11-2829	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.19	22.2	4.218	1.19E+01						
RE36-11-2830	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.178	45	8.01	6.24E+00						
RE36-11-2831	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.167	28.2	4.7094	1.06E+01						
RE36-11-2832	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.189	44.4	8.3916	5.96E+00						
RE36-11-2833	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-2844	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-4185	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.178	36	6.408	7.80E+00						
RE36-11-4186	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.194	40.8	7.9152	6.32E+00						
RE39-11-2835	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.193	27.6	5.3268	9.39E+00						
RE39-11-2836	Pentachlorodibenzofurans (Totals)	2.6	pg/Filter	0.192	19.2	3.6864	7.05E-01						
RE39-11-2837	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.197	31.2	6.1464	8.13E+00						
RE39-11-2838	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.189	25.2	4.7628	1.05E+01						
RE39-11-2839	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.198	30.6	6.0588	8.25E+00						
RE39-11-2840	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.191	24	4.584	1.09E+01						
RE39-11-2841	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.198	27	5.346	9.35E+00						
RE39-11-2842	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-4191	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.196	33	6.468	7.73E+00						
RE36-11-4193	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.168	36	6.048	8.27E+00						
RE36-11-4194	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-4187	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.198	23.4	4.6332	1.08E+01						
RE36-11-4188	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.189	38.4	7.2576	6.89E+00						
RE36-11-4195	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE36-11-4196	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.197	101.4	19.9758	2.50E+00						
RE36-11-4198	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.169	111	18.759	2.67E+00						
RE39-11-2843	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.198	36.6	7.2468	6.90E+00						
RE39-11-4518	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.197	34.8	6.8556	7.29E+00						
RE39-11-4519	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.202	30.6	6.1812	8.09E+00						
RE39-11-4520	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.189	31.8	6.0102	8.32E+00						
RE39-11-4521	Pentachlorodibenzofurans (Totals)	50	pg/Filter			0							
RE39-11-4522	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.186	25.8	4.7988	1.04E+01						
RE39-11-4523	Pentachlorodibenzofurans (Totals)	50	pg/Filter	0.211	28.8	6.0768	8.23E+00		0				0

Sample Name	**Analyte Description**	**Std Result**	**Std Result Unit**	**Flow rate (m^3/min)**	**Flow time (min)**	**Flow vol (m^3)**	**Conc. In Air (pg or ug /m^3)**	**Detection**	**# of Detects per Analyte**	**Acute Inhalation Exposure Conc. (mg/m^3)**	**CA Acute RELs (mg/m^3)**	**Conversion of screening level to ug/m^3**	**# of Exceeds per Analyte**
RE39-11-2834	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.153	39.6	6.0588	1.65E+00						
RE39-11-2845	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2824	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.183	33	6.039	1.66E+00						
RE36-11-2825	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			10.18	9.82E-01						
RE36-11-2826	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2827	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.188	29.4	5.5272	1.81E+00						
RE36-11-2828	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.186	37.8	7.0308	1.42E+00						
RE36-11-2829	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.19	22.2	4.218	2.37E+00						
RE36-11-2830	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.178	45	8.01	1.25E+00						
RE36-11-2831	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.167	28.2	4.7094	2.12E+00						
RE36-11-2832	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.189	44.4	8.3916	1.19E+00						
RE36-11-2833	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2844	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4185	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.178	36	6.408	1.56E+00						
RE36-11-4186	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.194	40.8	7.9152	1.26E+00						
RE39-11-2835	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.193	27.6	5.3268	1.88E+00						
RE39-11-2836	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.192	19.2	3.6864	2.71E+00						
RE39-11-2837	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.197	31.2	6.1464	1.63E+00						
RE39-11-2838	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.189	25.2	4.7628	2.10E+00						
RE39-11-2839	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.198	30.6	6.0588	1.65E+00						
RE39-11-2840	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.191	24	4.584	2.18E+00						
RE39-11-2841	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.198	27	5.346	1.87E+00						
RE39-11-2842	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4191	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.196	33	6.468	1.55E+00						
RE36-11-4193	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.168	36	6.048	1.65E+00						
RE36-11-4194	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4187	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.198	23.4	4.6332	2.16E+00						
RE36-11-4188	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.189	38.4	7.2576	1.38E+00						
RE36-11-4195	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4196	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.197	101.4	19.9758	5.01E-01						
RE36-11-4198	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.169	111	18.759	5.33E-01						
RE39-11-2843	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.198	36.6	7.2468	1.38E+00						
RE39-11-4518	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.197	34.8	6.8556	1.46E+00						
RE39-11-4519	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.202	30.6	6.1812	1.62E+00						
RE39-11-4520	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.189	31.8	6.0102	1.66E+00						
RE39-11-4521	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter			0							
RE39-11-4522	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.186	25.8	4.7988	2.08E+00						
RE39-11-4523	Tetrachlorodibenzodioxin[2,3,7,8-]	10	pg/Filter	0.211	28.8	6.0768	1.65E+00		0				0
RE39-11-2834	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.153	39.6	6.0588	1.65E+00						
RE39-11-2845	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-2824	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.183	33	6.039	1.66E+00						
RE36-11-2825	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			10.18	9.82E-01						

Sample Name	**Analyte Description**	**Std Result**	**Std Result Unit**	**Flow rate (m^3/min)**	**Flow time (min)**	**Flow vol (m^3)**	**Conc. In Air (pg or ug /m^3)**	**Detection**	**# of Detects per Analyte**	**Acute Inhalation Exposure Conc. (mg/m^3)**	**CA Acute RELs (mg/m^3)**	**Conversion of screening level to ug/m^3**	**# of Exceeds per Analyte**
RE36-11-2826	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-2827	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.188	29.4	5.5272	1.81E+00						
RE36-11-2828	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.186	37.8	7.0308	1.42E+00						
RE36-11-2829	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.19	22.2	4.218	2.37E+00						
RE36-11-2830	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.178	45	8.01	1.25E+00						
RE36-11-2831	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.167	28.2	4.7094	2.12E+00						
RE36-11-2832	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.189	44.4	8.3916	1.19E+00						
RE36-11-2833	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-2844	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-4185	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.178	36	6.408	1.56E+00						
RE36-11-4186	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.194	40.8	7.9152	1.26E+00						
RE39-11-2835	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.193	27.6	5.3268	1.88E+00						
RE39-11-2836	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.192	19.2	3.6864	2.71E+00						
RE39-11-2837	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.197	31.2	6.1464	1.63E+00						
RE39-11-2838	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.189	25.2	4.7628	2.10E+00						
RE39-11-2839	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.198	30.6	6.0588	1.65E+00						
RE39-11-2840	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.191	24	4.584	2.18E+00						
RE39-11-2841	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.198	27	5.346	1.87E+00						
RE39-11-2842	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-4191	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.196	33	6.468	1.55E+00						
RE36-11-4193	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.168	36	6.048	1.65E+00						
RE36-11-4194	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-4187	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.198	23.4	4.6332	2.16E+00						
RE36-11-4188	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.189	38.4	7.2576	1.38E+00						
RE36-11-4195	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE36-11-4196	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.197	101.4	19.9758	5.01E-01						
RE36-11-4198	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.169	111	18.759	5.33E-01						
RE39-11-2843	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.198	36.6	7.2468	1.38E+00						
RE39-11-4518	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.197	34.8	6.8556	1.46E+00						
RE39-11-4519	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.202	30.6	6.1812	1.62E+00						
RE39-11-4520	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.189	31.8	6.0102	1.66E+00						
RE39-11-4521	Tetrachlorodibenzodioxins (Total)	10	pg/Filter			0							
RE39-11-4522	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.186	25.8	4.7988	2.08E+00						
RE39-11-4523	Tetrachlorodibenzodioxins (Total)	10	pg/Filter	0.211	28.8	6.0768	1.65E+00		0				0
RE39-11-2834	Tetrachlorodibenzofuran[2,3,7,8-]	2.4	pg/Filter	0.153	39.6	6.0588	3.96E-01						
RE39-11-2845	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2824	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.183	33	6.039	1.66E+00						
RE36-11-2825	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			10.18	9.82E-01						
RE36-11-2826	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2827	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.188	29.4	5.5272	1.81E+00						
RE36-11-2828	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.186	37.8	7.0308	1.42E+00						
RE36-11-2829	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.19	22.2	4.218	2.37E+00						

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2830	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.178	45	8.01	1.25E+00						
RE36-11-2831	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.167	28.2	4.7094	2.12E+00						
RE36-11-2832	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.189	44.4	8.3916	1.19E+00						
RE36-11-2833	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-2844	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4185	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.178	36	6.408	1.56E+00						
RE36-11-4186	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.194	40.8	7.9152	1.26E+00						
RE39-11-2835	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.193	27.6	5.3268	1.88E+00						
RE39-11-2836	Tetrachlorodibenzofuran[2,3,7,8-]	1.8	pg/Filter	0.192	19.2	3.6864	4.88E-01						
RE39-11-2837	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.197	31.2	6.1464	1.63E+00						
RE39-11-2838	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.189	25.2	4.7628	2.10E+00						
RE39-11-2839	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.198	30.6	6.0588	1.65E+00						
RE39-11-2840	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.191	24	4.584	2.18E+00						
RE39-11-2841	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.198	27	5.346	1.87E+00						
RE39-11-2842	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4191	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.196	33	6.468	1.55E+00						
RE36-11-4193	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.168	36	6.048	1.65E+00						
RE36-11-4194	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4187	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.198	23.4	4.6332	2.16E+00						
RE36-11-4188	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.189	38.4	7.2576	1.38E+00						
RE36-11-4195	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter			0							
RE36-11-4196	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.197	101.4	19.9758	5.01E-01						
RE36-11-4198	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.169	111	18.759	5.33E-01						
RE39-11-2843	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.198	36.6	7.2468	1.38E+00						
RE39-11-4518	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.197	34.8	6.8556	1.46E+00						
RE39-11-4519	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.202	30.6	6.1812	1.62E+00						
RE39-11-4520	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.189	31.8	6.0102	1.66E+00						
RE39-11-4521	Tetrachlorodibenzofuran[2,3,7,8-]	2.1	pg/Filter			0							
RE39-11-4522	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.186	25.8	4.7988	2.08E+00						
RE39-11-4523	Tetrachlorodibenzofuran[2,3,7,8-]	10	pg/Filter	0.211	28.8	6.0768	1.65E+00		0				0
RE39-11-2834	Tetrachlorodibenzofurans (Totals)	2.4	pg/Filter	0.153	39.6	6.0588	3.96E-01						
RE39-11-2845	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-2824	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.183	33	6.039	1.66E+00						
RE36-11-2825	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			10.18	9.82E-01						
RE36-11-2826	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-2827	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.188	29.4	5.5272	1.81E+00						
RE36-11-2828	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.186	37.8	7.0308	1.42E+00						
RE36-11-2829	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.19	22.2	4.218	2.37E+00						
RE36-11-2830	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.178	45	8.01	1.25E+00						
RE36-11-2831	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.167	28.2	4.7094	2.12E+00						
RE36-11-2832	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.189	44.4	8.3916	1.19E+00						
RE36-11-2833	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2844	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-4185	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.178	36	6.408	1.56E+00						
RE36-11-4186	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.194	40.8	7.9152	1.26E+00						
RE39-11-2835	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.193	27.6	5.3268	1.88E+00						
RE39-11-2836	Tetrachlorodibenzofurans (Totals)	49	pg/Filter	0.192	19.2	3.6864	1.33E+01	detect		1.50E-03		1.50E+06	
RE39-11-2837	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.197	31.2	6.1464	1.63E+00						
RE39-11-2838	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.189	25.2	4.7628	2.10E+00						
RE39-11-2839	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.198	30.6	6.0588	1.65E+00						
RE39-11-2840	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.191	24	4.584	2.18E+00						
RE39-11-2841	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.198	27	5.346	1.87E+00						
RE39-11-2842	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-4191	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.196	33	6.468	1.55E+00						
RE36-11-4193	Tetrachlorodibenzofurans (Totals)	11	pg/Filter	0.168	36	6.048	1.82E+00						
RE36-11-4194	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-4187	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.198	23.4	4.6332	2.16E+00						
RE36-11-4188	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.189	38.4	7.2576	1.38E+00						
RE36-11-4195	Tetrachlorodibenzofurans (Totals)	10	pg/Filter			0							
RE36-11-4196	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.197	101.4	19.9758	5.01E-01						
RE36-11-4198	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.169	111	18.759	5.33E-01						
RE39-11-2843	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.198	36.6	7.2468	1.38E+00						
RE39-11-4518	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.197	34.8	6.8556	1.46E+00						
RE39-11-4519	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.202	30.6	6.1812	1.62E+00						
RE39-11-4520	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.189	31.8	6.0102	1.66E+00						
RE39-11-4521	Tetrachlorodibenzofurans (Totals)	2.1	pg/Filter			0							
RE39-11-4522	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.186	25.8	4.7988	2.08E+00						
RE39-11-4523	Tetrachlorodibenzofurans (Totals)	10	pg/Filter	0.211	28.8	6.0768	1.65E+00		1				0
RE39-11-2936	Aluminum	230	ug/FILTER	1.11851544	36	40.26656	5.71E+00	detect		none specified			
RE39-11-2945	Aluminum	41	ug/FILTER			0		detect		none specified			
RE36-11-2914	Aluminum	34	ug/FILTER	1.104357017	30	33.13071	1.03E+00	detect		none specified			
RE36-11-2915	Aluminum	41	ug/FILTER	1.132673864	54	61.16439	6.70E-01	detect		none specified			
RE36-11-2916	Aluminum	39	ug/FILTER	1.132673864	30	33.98022	1.15E+00	detect		none specified			
RE36-11-2917	Aluminum	32	ug/FILTER	1.132673864	36	40.77626	7.85E-01	detect		none specified			
RE36-11-2918	Aluminum	65	ug/FILTER	1.104357017	18	19.87843	3.27E+00	detect		none specified			
RE36-11-2919	Aluminum	68	ug/FILTER	1.132673864	42	47.5723	1.43E+00	detect		none specified			
RE36-11-2920	Aluminum	100	ug/FILTER	1.132673864	24	27.18417	3.68E+00	detect		none specified			
RE36-11-2921	Aluminum	89	ug/FILTER	1.132673864	42	47.5723	1.87E+00	detect		none specified			
RE36-11-2922	Aluminum	54	ug/FILTER	1.104357017	36	39.75685	1.36E+00	detect		none specified			
RE36-11-2923	Aluminum	46	ug/FILTER	1.104357017	36	39.75685	1.16E+00	detect		none specified			
RE39-11-2935	Aluminum	47	ug/FILTER	1.132673864	30	33.98022	1.38E+00	detect		none specified			
RE39-11-2937	Aluminum	38	ug/FILTER	1.132673864	18	20.38813	1.86E+00	detect		none specified			
RE39-11-2938	Aluminum	190	ug/FILTER	1.132673864	30	33.98022	5.59E+00	detect		none specified			
RE39-11-2939	Aluminum	110	ug/FILTER	1.104357017	24	26.50457	4.15E+00	detect		none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2940	Aluminum	300	ug/FILTER	1.104357017	30	33.13071	9.06E+00	detect		none specified			
RE39-11-2941	Aluminum	62	ug/FILTER	1.132673864	24	27.18417	2.28E+00	detect		none specified			
RE39-11-2942	Aluminum	250	ug/FILTER	1.132673864	24	27.18417	9.20E+00	detect		none specified			
RE36-11-4184	Aluminum	42	ug/FILTER	1.132673864	30	33.98022	1.24E+00	detect		none specified			
RE36-11-4189	Aluminum	49	ug/FILTER	1.132673864	30	33.98022	1.44E+00	detect		none specified			
RE36-11-4190	Aluminum	81	ug/FILTER			0		detect		none specified			
RE36-11-2934	Aluminum	32	ug/FILTER	1.132673864	42	47.5723	6.73E-01	detect		none specified			
RE36-11-4192	Aluminum	36	ug/FILTER	1.132673864	96	108.7367	3.31E-01	detect		none specified			
RE36-11-4197	Aluminum	74	ug/FILTER	1.061881747	108	114.6832	6.45E-01	detect		none specified			
RE36-11-4503	Aluminum	57	ug/FILTER	1.132673864	30	33.98022	1.68E+00	detect		none specified			
RE39-11-2943	Aluminum	45	ug/FILTER	1.132673864	30	33.98022	1.32E+00	detect		none specified			
RE39-11-2944	Aluminum	200	ug/FILTER	1.132673864	36	40.77626	4.90E+00	detect		none specified			
RE39-11-4524	Aluminum	46	ug/FILTER	1.104357017	30	33.13071	1.39E+00	detect		none specified			
RE39-11-4525	Aluminum	28	ug/FILTER	1.104357017	30	33.13071	8.45E-01	detect		none specified			
RE39-11-4526	Aluminum	5.5	ug/FILTER			0				none specified			
RE39-11-4527	Aluminum	9.7	ug/FILTER	1.132673864	24	27.18417	3.57E-01			none specified			
RE39-11-4528	Aluminum	38	ug/FILTER	1.132673864	24	27.18417	1.40E+00	detect	31	none specified			0
RE39-11-2936	Antimony	0.16	ug/FILTER	1.11851544	36	40.26656	3.97E-03	detect		1.5		1.50E+03	
RE39-11-2945	Antimony	0.024	ug/FILTER			0				1.5		1.50E+03	
RE36-11-2914	Antimony	0.08	ug/FILTER	1.104357017	30	33.13071	2.41E-03	detect		1.5		1.50E+03	
RE36-11-2915	Antimony	0.076	ug/FILTER	1.132673864	54	61.16439	1.24E-03	detect		1.5		1.50E+03	
RE36-11-2916	Antimony	0.044	ug/FILTER	1.132673864	30	33.98022	1.29E-03			1.5		1.50E+03	
RE36-11-2917	Antimony	0.042	ug/FILTER	1.132673864	36	40.77626	1.03E-03			1.5		1.50E+03	
RE36-11-2918	Antimony	0.038	ug/FILTER	1.104357017	18	19.87843	1.91E-03			1.5		1.50E+03	
RE36-11-2919	Antimony	0.028	ug/FILTER	1.132673864	42	47.5723	5.89E-04			1.5		1.50E+03	
RE36-11-2920	Antimony	0.044	ug/FILTER	1.132673864	24	27.18417	1.62E-03			1.5		1.50E+03	
RE36-11-2921	Antimony	0.046	ug/FILTER	1.132673864	42	47.5723	9.67E-04			1.5		1.50E+03	
RE36-11-2922	Antimony	0.06	ug/FILTER	1.104357017	36	39.75685	1.51E-03			1.5		1.50E+03	
RE36-11-2923	Antimony	0.06	ug/FILTER	1.104357017	36	39.75685	1.51E-03			1.5		1.50E+03	
RE39-11-2935	Antimony	0.034	ug/FILTER	1.132673864	30	33.98022	1.00E-03			1.5		1.50E+03	
RE39-11-2937	Antimony	0.05	ug/FILTER	1.132673864	18	20.38813	2.45E-03			1.5		1.50E+03	
RE39-11-2938	Antimony	0.14	ug/FILTER	1.132673864	30	33.98022	4.12E-03	detect		1.5		1.50E+03	
RE39-11-2939	Antimony	0.046	ug/FILTER	1.104357017	24	26.50457	1.74E-03			1.5		1.50E+03	
RE39-11-2940	Antimony	0.32	ug/FILTER	1.104357017	30	33.13071	9.66E-03	detect		1.5		1.50E+03	
RE39-11-2941	Antimony	0.06	ug/FILTER	1.132673864	24	27.18417	2.21E-03			1.5		1.50E+03	
RE39-11-2942	Antimony	0.16	ug/FILTER	1.132673864	24	27.18417	5.89E-03	detect		1.5		1.50E+03	
RE36-11-4184	Antimony	0.026	ug/FILTER	1.132673864	30	33.98022	7.65E-04			1.5		1.50E+03	
RE36-11-4189	Antimony	0.038	ug/FILTER	1.132673864	30	33.98022	1.12E-03			1.5		1.50E+03	
RE36-11-4190	Antimony	0.044	ug/FILTER			0				1.5		1.50E+03	
RE36-11-2934	Antimony	0.06	ug/FILTER	1.132673864	42	47.5723	1.26E-03			1.5		1.50E+03	
RE36-11-4192	Antimony	0.06	ug/FILTER	1.132673864	96	108.7367	5.52E-04			1.5		1.50E+03	
RE36-11-4197	Antimony	0.036	ug/FILTER	1.061881747	108	114.6832	3.14E-04			1.5		1.50E+03	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4503	Antimony	0.06	ug/FILTER	1.132673864	30	33.98022	1.77E-03			1.5		1.50E+03	
RE39-11-2943	Antimony	0.048	ug/FILTER	1.132673864	30	33.98022	1.41E-03			1.5		1.50E+03	
RE39-11-2944	Antimony	0.07	ug/FILTER	1.132673864	36	40.77626	1.72E-03	detect		1.5		1.50E+03	
RE39-11-4524	Antimony	0.036	ug/FILTER	1.104357017	30	33.13071	1.09E-03			1.5		1.50E+03	
RE39-11-4525	Antimony	0.06	ug/FILTER	1.104357017	30	33.13071	1.81E-03			1.5		1.50E+03	
RE39-11-4526	Antimony	0.06	ug/FILTER			0				1.5		1.50E+03	
RE39-11-4527	Antimony	0.06	ug/FILTER	1.132673864	24	27.18417	2.21E-03			1.5		1.50E+03	
RE39-11-4528	Antimony	0.032	ug/FILTER	1.132673864	24	27.18417	1.18E-03		7	1.5		1.50E+03	0
RE39-11-2936	Arsenic	0.052	ug/FILTER	1.11851544	36	40.26656	1.29E-03			1.90E-04		1.90E-01	
RE39-11-2945	Arsenic	0.4	ug/FILTER			0				1.90E-04		1.90E-01	
RE36-11-2914	Arsenic	0.052	ug/FILTER	1.104357017	30	33.13071	1.57E-03			1.90E-04		1.90E-01	
RE36-11-2915	Arsenic	0.034	ug/FILTER	1.132673864	54	61.16439	5.56E-04			1.90E-04		1.90E-01	
RE36-11-2916	Arsenic	0.042	ug/FILTER	1.132673864	30	33.98022	1.24E-03			1.90E-04		1.90E-01	
RE36-11-2917	Arsenic	0.4	ug/FILTER	1.132673864	36	40.77626	9.81E-03			1.90E-04		1.90E-01	
RE36-11-2918	Arsenic	0.044	ug/FILTER	1.104357017	18	19.87843	2.21E-03			1.90E-04		1.90E-01	
RE36-11-2919	Arsenic	0.4	ug/FILTER	1.132673864	42	47.5723	8.41E-03			1.90E-04		1.90E-01	
RE36-11-2920	Arsenic	0.4	ug/FILTER	1.132673864	24	27.18417	1.47E-02			1.90E-04		1.90E-01	
RE36-11-2921	Arsenic	0.4	ug/FILTER	1.132673864	42	47.5723	8.41E-03			1.90E-04		1.90E-01	
RE36-11-2922	Arsenic	0.4	ug/FILTER	1.104357017	36	39.75685	1.01E-02			1.90E-04		1.90E-01	
RE36-11-2923	Arsenic	0.4	ug/FILTER	1.104357017	36	39.75685	1.01E-02			1.90E-04		1.90E-01	
RE39-11-2935	Arsenic	0.4	ug/FILTER	1.132673864	30	33.98022	1.18E-02			1.90E-04		1.90E-01	
RE39-11-2937	Arsenic	0.4	ug/FILTER	1.132673864	18	20.38813	1.96E-02			1.90E-04		1.90E-01	
RE39-11-2938	Arsenic	0.068	ug/FILTER	1.132673864	30	33.98022	2.00E-03			1.90E-04		1.90E-01	
RE39-11-2939	Arsenic	0.048	ug/FILTER	1.104357017	24	26.50457	1.81E-03			1.90E-04		1.90E-01	
RE39-11-2940	Arsenic	0.11	ug/FILTER	1.104357017	30	33.13071	3.32E-03			1.90E-04		1.90E-01	
RE39-11-2941	Arsenic	0.4	ug/FILTER	1.132673864	24	27.18417	1.47E-02			1.90E-04		1.90E-01	
RE39-11-2942	Arsenic	0.14	ug/FILTER	1.132673864	24	27.18417	5.15E-03			1.90E-04		1.90E-01	
RE36-11-4184	Arsenic	0.4	ug/FILTER	1.132673864	30	33.98022	1.18E-02			1.90E-04		1.90E-01	
RE36-11-4189	Arsenic	0.4	ug/FILTER	1.132673864	30	33.98022	1.18E-02			1.90E-04		1.90E-01	
RE36-11-4190	Arsenic	0.4	ug/FILTER			0				1.90E-04		1.90E-01	
RE36-11-2934	Arsenic	0.4	ug/FILTER	1.132673864	42	47.5723	8.41E-03			1.90E-04		1.90E-01	
RE36-11-4192	Arsenic	0.4	ug/FILTER	1.132673864	96	108.7367	3.68E-03			1.90E-04		1.90E-01	
RE36-11-4197	Arsenic	0.4	ug/FILTER	1.061881747	108	114.6832	3.49E-03			1.90E-04		1.90E-01	
RE36-11-4503	Arsenic	0.4	ug/FILTER	1.132673864	30	33.98022	1.18E-02			1.90E-04		1.90E-01	
RE39-11-2943	Arsenic	0.4	ug/FILTER	1.132673864	30	33.98022	1.18E-02			1.90E-04		1.90E-01	
RE39-11-2944	Arsenic	0.068	ug/FILTER	1.132673864	36	40.77626	1.67E-03			1.90E-04		1.90E-01	
RE39-11-4524	Arsenic	0.4	ug/FILTER	1.104357017	30	33.13071	1.21E-02			1.90E-04		1.90E-01	
RE39-11-4525	Arsenic	0.4	ug/FILTER	1.104357017	30	33.13071	1.21E-02			1.90E-04		1.90E-01	
RE39-11-4526	Arsenic	0.4	ug/FILTER			0				1.90E-04		1.90E-01	
RE39-11-4527	Arsenic	0.4	ug/FILTER	1.132673864	24	27.18417	1.47E-02			1.90E-04		1.90E-01	
RE39-11-4528	Arsenic	0.4	ug/FILTER	1.132673864	24	27.18417	1.47E-02		0	1.90E-04		1.90E-01	0
RE39-11-2936	Barium	3.8	ug/FILTER	1.11851544	36	40.26656	9.44E-02	detect		1.50E+00		1.50E+03	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2945	Barium	1.8	ug/FILTER			0		detect		1.50E+00		1.50E+03	
RE36-11-2914	Barium	0.97	ug/FILTER	1.104357017	30	33.13071	2.93E-02	detect		1.50E+00		1.50E+03	
RE36-11-2915	Barium	0.79	ug/FILTER	1.132673864	54	61.16439	1.29E-02	detect		1.50E+00		1.50E+03	
RE36-11-2916	Barium	0.95	ug/FILTER	1.132673864	30	33.98022	2.80E-02	detect		1.50E+00		1.50E+03	
RE36-11-2917	Barium	0.54	ug/FILTER	1.132673864	36	40.77626	1.32E-02	detect		1.50E+00		1.50E+03	
RE36-11-2918	Barium	1.1	ug/FILTER	1.104357017	18	19.87843	5.53E-02	detect		1.50E+00		1.50E+03	
RE36-11-2919	Barium	0.74	ug/FILTER	1.132673864	42	47.5723	1.56E-02	detect		1.50E+00		1.50E+03	
RE36-11-2920	Barium	0.69	ug/FILTER	1.132673864	24	27.18417	2.54E-02	detect		1.50E+00		1.50E+03	
RE36-11-2921	Barium	0.79	ug/FILTER	1.132673864	42	47.5723	1.66E-02	detect		1.50E+00		1.50E+03	
RE36-11-2922	Barium	0.47	ug/FILTER	1.104357017	36	39.75685	1.18E-02	detect		1.50E+00		1.50E+03	
RE36-11-2923	Barium	1.2	ug/FILTER	1.104357017	36	39.75685	3.02E-02	detect		1.50E+00		1.50E+03	
RE39-11-2935	Barium	1.8	ug/FILTER	1.132673864	30	33.98022	5.30E-02	detect		1.50E+00		1.50E+03	
RE39-11-2937	Barium	0.88	ug/FILTER	1.132673864	18	20.38813	4.32E-02	detect		1.50E+00		1.50E+03	
RE39-11-2938	Barium	3.8	ug/FILTER	1.132673864	30	33.98022	1.12E-01	detect		1.50E+00		1.50E+03	
RE39-11-2939	Barium	1.1	ug/FILTER	1.104357017	24	26.50457	4.15E-02	detect		1.50E+00		1.50E+03	
RE39-11-2940	Barium	7	ug/FILTER	1.104357017	30	33.13071	2.11E-01	detect		1.50E+00		1.50E+03	
RE39-11-2941	Barium	0.74	ug/FILTER	1.132673864	24	27.18417	2.72E-02	detect		1.50E+00		1.50E+03	
RE39-11-2942	Barium	5.6	ug/FILTER	1.132673864	24	27.18417	2.06E-01	detect		1.50E+00		1.50E+03	
RE36-11-4184	Barium	0.48	ug/FILTER	1.132673864	30	33.98022	1.41E-02	detect		1.50E+00		1.50E+03	
RE36-11-4189	Barium	0.98	ug/FILTER	1.132673864	30	33.98022	2.88E-02	detect		1.50E+00		1.50E+03	
RE36-11-4190	Barium	0.45	ug/FILTER			0		detect		1.50E+00		1.50E+03	
RE36-11-2934	Barium	0.89	ug/FILTER	1.132673864	42	47.5723	1.87E-02	detect		1.50E+00		1.50E+03	
RE36-11-4192	Barium	0.49	ug/FILTER	1.132673864	96	108.7367	4.51E-03	detect		1.50E+00		1.50E+03	
RE36-11-4197	Barium	0.74	ug/FILTER	1.061881747	108	114.6832	6.45E-03	detect		1.50E+00		1.50E+03	
RE36-11-4503	Barium	0.56	ug/FILTER	1.132673864	30	33.98022	1.65E-02	detect		1.50E+00		1.50E+03	
RE39-11-2943	Barium	1	ug/FILTER	1.132673864	30	33.98022	2.94E-02	detect		1.50E+00		1.50E+03	
RE39-11-2944	Barium	2.9	ug/FILTER	1.132673864	36	40.77626	7.11E-02	detect		1.50E+00		1.50E+03	
RE39-11-4524	Barium	0.64	ug/FILTER	1.104357017	30	33.13071	1.93E-02	detect		1.50E+00		1.50E+03	
RE39-11-4525	Barium	0.28	ug/FILTER	1.104357017	30	33.13071	8.45E-03	detect		1.50E+00		1.50E+03	
RE39-11-4526	Barium	0.094	ug/FILTER			0				1.50E+00		1.50E+03	
RE39-11-4527	Barium	0.28	ug/FILTER	1.132673864	24	27.18417	1.03E-02	detect		1.50E+00		1.50E+03	
RE39-11-4528	Barium	0.65	ug/FILTER	1.132673864	24	27.18417	2.39E-02	detect	32	1.50E+00		1.50E+03	0
RE39-11-2936	Beryllium	0.1	ug/FILTER	1.11851544	36	40.26656	2.48E-03			5.00E-03		5.00E+00	
RE39-11-2945	Beryllium	0.1	ug/FILTER			0				5.00E-03		5.00E+00	
RE36-11-2914	Beryllium	0.1	ug/FILTER	1.104357017	30	33.13071	3.02E-03			5.00E-03		5.00E+00	
RE36-11-2915	Beryllium	0.1	ug/FILTER	1.132673864	54	61.16439	1.63E-03			5.00E-03		5.00E+00	
RE36-11-2916	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE36-11-2917	Beryllium	0.1	ug/FILTER	1.132673864	36	40.77626	2.45E-03			5.00E-03		5.00E+00	
RE36-11-2918	Beryllium	0.1	ug/FILTER	1.104357017	18	19.87843	5.03E-03			5.00E-03		5.00E+00	
RE36-11-2919	Beryllium	0.1	ug/FILTER	1.132673864	42	47.5723	2.10E-03			5.00E-03		5.00E+00	
RE36-11-2920	Beryllium	0.1	ug/FILTER	1.132673864	24	27.18417	3.68E-03			5.00E-03		5.00E+00	
RE36-11-2921	Beryllium	0.1	ug/FILTER	1.132673864	42	47.5723	2.10E-03			5.00E-03		5.00E+00	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2922	Beryllium	0.1	ug/FILTER	1.104357017	36	39.75685	2.52E-03			5.00E-03		5.00E+00	
RE36-11-2923	Beryllium	0.1	ug/FILTER	1.104357017	36	39.75685	2.52E-03			5.00E-03		5.00E+00	
RE39-11-2935	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE39-11-2937	Beryllium	0.1	ug/FILTER	1.132673864	18	20.38813	4.90E-03			5.00E-03		5.00E+00	
RE39-11-2938	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE39-11-2939	Beryllium	0.1	ug/FILTER	1.104357017	24	26.50457	3.77E-03			5.00E-03		5.00E+00	
RE39-11-2940	Beryllium	0.1	ug/FILTER	1.104357017	30	33.13071	3.02E-03			5.00E-03		5.00E+00	
RE39-11-2941	Beryllium	0.1	ug/FILTER	1.132673864	24	27.18417	3.68E-03			5.00E-03		5.00E+00	
RE39-11-2942	Beryllium	0.1	ug/FILTER	1.132673864	24	27.18417	3.68E-03			5.00E-03		5.00E+00	
RE36-11-4184	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE36-11-4189	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE36-11-4190	Beryllium	0.1	ug/FILTER			0				5.00E-03		5.00E+00	
RE36-11-2934	Beryllium	0.1	ug/FILTER	1.132673864	42	47.5723	2.10E-03			5.00E-03		5.00E+00	
RE36-11-4192	Beryllium	0.1	ug/FILTER	1.132673864	96	108.7367	9.20E-04			5.00E-03		5.00E+00	
RE36-11-4197	Beryllium	0.1	ug/FILTER	1.061881747	108	114.6832	8.72E-04			5.00E-03		5.00E+00	
RE36-11-4503	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE39-11-2943	Beryllium	0.1	ug/FILTER	1.132673864	30	33.98022	2.94E-03			5.00E-03		5.00E+00	
RE39-11-2944	Beryllium	0.1	ug/FILTER	1.132673864	36	40.77626	2.45E-03			5.00E-03		5.00E+00	
RE39-11-4524	Beryllium	0.1	ug/FILTER	1.104357017	30	33.13071	3.02E-03			5.00E-03		5.00E+00	
RE39-11-4525	Beryllium	0.1	ug/FILTER	1.104357017	30	33.13071	3.02E-03			5.00E-03		5.00E+00	
RE39-11-4526	Beryllium	0.1	ug/FILTER			0				5.00E-03		5.00E+00	
RE39-11-4527	Beryllium	0.1	ug/FILTER	1.132673864	24	27.18417	3.68E-03			5.00E-03		5.00E+00	
RE39-11-4528	Beryllium	0.1	ug/FILTER	1.132673864	24	27.18417	3.68E-03		0	5.00E-03		5.00E+00	0
RE39-11-2936	Cadmium	0.37	ug/FILTER	1.11851544	36	40.26656	9.19E-03	detect		3.00E-02		3.00E+01	
RE39-11-2945	Cadmium	1.2	ug/FILTER			0		detect		3.00E-02		3.00E+01	
RE36-11-2914	Cadmium	0.15	ug/FILTER	1.104357017	30	33.13071	4.53E-03	detect		3.00E-02		3.00E+01	
RE36-11-2915	Cadmium	0.26	ug/FILTER	1.132673864	54	61.16439	4.25E-03	detect		3.00E-02		3.00E+01	
RE36-11-2916	Cadmium	1.3	ug/FILTER	1.132673864	30	33.98022	3.83E-02	detect		3.00E-02		3.00E+01	
RE36-11-2917	Cadmium	0.12	ug/FILTER	1.132673864	36	40.77626	2.94E-03	detect		3.00E-02		3.00E+01	
RE36-11-2918	Cadmium	0.64	ug/FILTER	1.104357017	18	19.87843	3.22E-02	detect		3.00E-02		3.00E+01	
RE36-11-2919	Cadmium	17	ug/FILTER	1.132673864	42	47.5723	3.57E-01	detect		3.00E-02		3.00E+01	
RE36-11-2920	Cadmium	2.3	ug/FILTER	1.132673864	24	27.18417	8.46E-02	detect		3.00E-02		3.00E+01	
RE36-11-2921	Cadmium	0.49	ug/FILTER	1.132673864	42	47.5723	1.03E-02	detect		3.00E-02		3.00E+01	
RE36-11-2922	Cadmium	0.46	ug/FILTER	1.104357017	36	39.75685	1.16E-02	detect		3.00E-02		3.00E+01	
RE36-11-2923	Cadmium	1.1	ug/FILTER	1.104357017	36	39.75685	2.77E-02	detect		3.00E-02		3.00E+01	
RE39-11-2935	Cadmium	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02	detect		3.00E-02		3.00E+01	
RE39-11-2937	Cadmium	0.72	ug/FILTER	1.132673864	18	20.38813	3.53E-02	detect		3.00E-02		3.00E+01	
RE39-11-2938	Cadmium	2.3	ug/FILTER	1.132673864	30	33.98022	6.77E-02	detect		3.00E-02		3.00E+01	
RE39-11-2939	Cadmium	0.72	ug/FILTER	1.104357017	24	26.50457	2.72E-02	detect		3.00E-02		3.00E+01	
RE39-11-2940	Cadmium	4.1	ug/FILTER	1.104357017	30	33.13071	1.24E-01	detect		3.00E-02		3.00E+01	
RE39-11-2941	Cadmium	0.97	ug/FILTER	1.132673864	24	27.18417	3.57E-02	detect		3.00E-02		3.00E+01	
RE39-11-2942	Cadmium	7.1	ug/FILTER	1.132673864	24	27.18417	2.61E-01	detect		3.00E-02		3.00E+01	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4184	Cadmium	0.66	ug/FILTER	1.132673864	30	33.98022	1.94E-02	detect		3.00E-02		3.00E+01	
RE36-11-4189	Cadmium	3	ug/FILTER	1.132673864	30	33.98022	8.83E-02	detect		3.00E-02		3.00E+01	
RE36-11-4190	Cadmium	0.98	ug/FILTER			0		detect		3.00E-02		3.00E+01	
RE36-11-2934	Cadmium	2.2	ug/FILTER	1.132673864	42	47.5723	4.62E-02	detect		3.00E-02		3.00E+01	
RE36-11-4192	Cadmium	8.9	ug/FILTER	1.132673864	96	108.7367	8.18E-02	detect		3.00E-02		3.00E+01	
RE36-11-4197	Cadmium	2.5	ug/FILTER	1.061881747	108	114.6832	2.18E-02	detect		3.00E-02		3.00E+01	
RE36-11-4503	Cadmium	1	ug/FILTER	1.132673864	30	33.98022	2.94E-02	detect		3.00E-02		3.00E+01	
RE39-11-2943	Cadmium	3.3	ug/FILTER	1.132673864	30	33.98022	9.71E-02	detect		3.00E-02		3.00E+01	
RE39-11-2944	Cadmium	0.19	ug/FILTER	1.132673864	36	40.77626	4.66E-03	detect		3.00E-02		3.00E+01	
RE39-11-4524	Cadmium	1.4	ug/FILTER	1.104357017	30	33.13071	4.23E-02	detect		3.00E-02		3.00E+01	
RE39-11-4525	Cadmium	0.46	ug/FILTER	1.104357017	30	33.13071	1.39E-02	detect		3.00E-02		3.00E+01	
RE39-11-4526	Cadmium	2	ug/FILTER			0		detect		3.00E-02		3.00E+01	
RE39-11-4527	Cadmium	0.36	ug/FILTER	1.132673864	24	27.18417	1.32E-02	detect		3.00E-02		3.00E+01	
RE39-11-4528	Cadmium	0.12	ug/FILTER	1.132673864	24	27.18417	4.41E-03	detect	33	3.00E-02		3.00E+01	0
RE39-11-2936	Calcium	230	ug/FILTER	1.11851544	36	40.26656	5.71E+00	detect		none specified			
RE39-11-2945	Calcium	110	ug/FILTER			0				none specified			
RE36-11-2914	Calcium	110	ug/FILTER	1.104357017	30	33.13071	3.32E+00			none specified			
RE36-11-2915	Calcium	94	ug/FILTER	1.132673864	54	61.16439	1.54E+00			none specified			
RE36-11-2916	Calcium	98	ug/FILTER	1.132673864	30	33.98022	2.88E+00			none specified			
RE36-11-2917	Calcium	71	ug/FILTER	1.132673864	36	40.77626	1.74E+00			none specified			
RE36-11-2918	Calcium	160	ug/FILTER	1.104357017	18	19.87843	8.05E+00			none specified			
RE36-11-2919	Calcium	84	ug/FILTER	1.132673864	42	47.5723	1.77E+00			none specified			
RE36-11-2920	Calcium	65	ug/FILTER	1.132673864	24	27.18417	2.39E+00			none specified			
RE36-11-2921	Calcium	60	ug/FILTER	1.132673864	42	47.5723	1.26E+00			none specified			
RE36-11-2922	Calcium	130	ug/FILTER	1.104357017	36	39.75685	3.27E+00			none specified			
RE36-11-2923	Calcium	140	ug/FILTER	1.104357017	36	39.75685	3.52E+00			none specified			
RE39-11-2935	Calcium	70	ug/FILTER	1.132673864	30	33.98022	2.06E+00			none specified			
RE39-11-2937	Calcium	140	ug/FILTER	1.132673864	18	20.38813	6.87E+00			none specified			
RE39-11-2938	Calcium	230	ug/FILTER	1.132673864	30	33.98022	6.77E+00	detect		none specified			
RE39-11-2939	Calcium	120	ug/FILTER	1.104357017	24	26.50457	4.53E+00			none specified			
RE39-11-2940	Calcium	450	ug/FILTER	1.104357017	30	33.13071	1.36E+01	detect		none specified			
RE39-11-2941	Calcium	86	ug/FILTER	1.132673864	24	27.18417	3.16E+00			none specified			
RE39-11-2942	Calcium	340	ug/FILTER	1.132673864	24	27.18417	1.25E+01	detect		none specified			
RE36-11-4184	Calcium	84	ug/FILTER	1.132673864	30	33.98022	2.47E+00			none specified			
RE36-11-4189	Calcium	100	ug/FILTER	1.132673864	30	33.98022	2.94E+00			none specified			
RE36-11-4190	Calcium	91	ug/FILTER			0				none specified			
RE36-11-2934	Calcium	71	ug/FILTER	1.132673864	42	47.5723	1.49E+00			none specified			
RE36-11-4192	Calcium	60	ug/FILTER	1.132673864	96	108.7367	5.52E-01			none specified			
RE36-11-4197	Calcium	71	ug/FILTER	1.061881747	108	114.6832	6.19E-01			none specified			
RE36-11-4503	Calcium	84	ug/FILTER	1.132673864	30	33.98022	2.47E+00			none specified			
RE39-11-2943	Calcium	110	ug/FILTER	1.132673864	30	33.98022	3.24E+00			none specified			
RE39-11-2944	Calcium	280	ug/FILTER	1.132673864	36	40.77626	6.87E+00	detect		none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-4524	Calcium	130	ug/FILTER	1.104357017	30	33.13071	3.92E+00			none specified			
RE39-11-4525	Calcium	41	ug/FILTER	1.104357017	30	33.13071	1.24E+00			none specified			
RE39-11-4526	Calcium	47	ug/FILTER			0				none specified			
RE39-11-4527	Calcium	53	ug/FILTER	1.132673864	24	27.18417	1.95E+00			none specified			
RE39-11-4528	Calcium	200	ug/FILTER	1.132673864	24	27.18417	7.36E+00		5	none specified			0
RE39-11-2936	Chromium	4.2	ug/FILTER	1.11851544	36	40.26656	1.04E-01	detect		1.5		1500	
RE39-11-2945	Chromium	2.1	ug/FILTER			0		detect		1.5		1500	
RE36-11-2914	Chromium	2.8	ug/FILTER	1.104357017	30	33.13071	8.45E-02	detect		1.5		1500	
RE36-11-2915	Chromium	0.81	ug/FILTER	1.132673864	54	61.16439	1.32E-02			1.5		1500	
RE36-11-2916	Chromium	0.78	ug/FILTER	1.132673864	30	33.98022	2.30E-02			1.5		1500	
RE36-11-2917	Chromium	0.5	ug/FILTER	1.132673864	36	40.77626	1.23E-02			1.5		1500	
RE36-11-2918	Chromium	2.1	ug/FILTER	1.104357017	18	19.87843	1.06E-01	detect		1.5		1500	
RE36-11-2919	Chromium	0.83	ug/FILTER	1.132673864	42	47.5723	1.74E-02			1.5		1500	
RE36-11-2920	Chromium	5	ug/FILTER	1.132673864	24	27.18417	1.84E-01	detect		1.5		1500	
RE36-11-2921	Chromium	7.9	ug/FILTER	1.132673864	42	47.5723	1.66E-01	detect		1.5		1500	
RE36-11-2922	Chromium	2.5	ug/FILTER	1.104357017	36	39.75685	6.29E-02	detect		1.5		1500	
RE36-11-2923	Chromium	1	ug/FILTER	1.104357017	36	39.75685	2.52E-02			1.5		1500	
RE39-11-2935	Chromium	0.67	ug/FILTER	1.132673864	30	33.98022	1.97E-02			1.5		1500	
RE39-11-2937	Chromium	1.1	ug/FILTER	1.132673864	18	20.38813	5.40E-02			1.5		1500	
RE39-11-2938	Chromium	2.4	ug/FILTER	1.132673864	30	33.98022	7.06E-02	detect		1.5		1500	
RE39-11-2939	Chromium	1.2	ug/FILTER	1.104357017	24	26.50457	4.53E-02			1.5		1500	
RE39-11-2940	Chromium	2.4	ug/FILTER	1.104357017	30	33.13071	7.24E-02	detect		1.5		1500	
RE39-11-2941	Chromium	0.67	ug/FILTER	1.132673864	24	27.18417	2.46E-02			1.5		1500	
RE39-11-2942	Chromium	2.3	ug/FILTER	1.132673864	24	27.18417	8.46E-02	detect		1.5		1500	
RE36-11-4184	Chromium	1.3	ug/FILTER	1.132673864	30	33.98022	3.83E-02			1.5		1500	
RE36-11-4189	Chromium	1	ug/FILTER	1.132673864	30	33.98022	2.94E-02			1.5		1500	
RE36-11-4190	Chromium	2.8	ug/FILTER			0		detect		1.5		1500	
RE36-11-2934	Chromium	1.2	ug/FILTER	1.132673864	42	47.5723	2.52E-02			1.5		1500	
RE36-11-4192	Chromium	1	ug/FILTER	1.132673864	96	108.7367	9.20E-03			1.5		1500	
RE36-11-4197	Chromium	0.96	ug/FILTER	1.061881747	108	114.6832	8.37E-03			1.5		1500	
RE36-11-4503	Chromium	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02			1.5		1500	
RE39-11-2943	Chromium	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02			1.5		1500	
RE39-11-2944	Chromium	1.1	ug/FILTER	1.132673864	36	40.77626	2.70E-02			1.5		1500	
RE39-11-4524	Chromium	0.74	ug/FILTER	1.104357017	30	33.13071	2.23E-02			1.5		1500	
RE39-11-4525	Chromium	0.46	ug/FILTER	1.104357017	30	33.13071	1.39E-02			1.5		1500	
RE39-11-4526	Chromium	0.23	ug/FILTER			0				1.5		1500	
RE39-11-4527	Chromium	0.25	ug/FILTER	1.132673864	24	27.18417	9.20E-03			1.5		1500	
RE39-11-4528	Chromium	0.83	ug/FILTER	1.132673864	24	27.18417	3.05E-02		11	1.5		1500	0
RE39-11-2936	Cobalt	0.15	ug/FILTER	1.11851544	36	40.26656	3.73E-03			none specified			
RE39-11-2945	Cobalt	0.058	ug/FILTER			0				none specified			
RE36-11-2914	Cobalt	0.034	ug/FILTER	1.104357017	30	33.13071	1.03E-03			none specified			
RE36-11-2915	Cobalt	0.2	ug/FILTER	1.132673864	54	61.16439	3.27E-03			none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2916	Cobalt	0.04	ug/FILTER	1.132673864	30	33.98022	1.18E-03			none specified			
RE36-11-2917	Cobalt	0.032	ug/FILTER	1.132673864	36	40.77626	7.85E-04			none specified			
RE36-11-2918	Cobalt	0.066	ug/FILTER	1.104357017	18	19.87843	3.32E-03			none specified			
RE36-11-2919	Cobalt	0.026	ug/FILTER	1.132673864	42	47.5723	5.47E-04			none specified			
RE36-11-2920	Cobalt	0.15	ug/FILTER	1.132673864	24	27.18417	5.52E-03			none specified			
RE36-11-2921	Cobalt	0.17	ug/FILTER	1.132673864	42	47.5723	3.57E-03			none specified			
RE36-11-2922	Cobalt	0.072	ug/FILTER	1.104357017	36	39.75685	1.81E-03			none specified			
RE36-11-2923	Cobalt	0.038	ug/FILTER	1.104357017	36	39.75685	9.56E-04			none specified			
RE39-11-2935	Cobalt	0.036	ug/FILTER	1.132673864	30	33.98022	1.06E-03			none specified			
RE39-11-2937	Cobalt	0.028	ug/FILTER	1.132673864	18	20.38813	1.37E-03			none specified			
RE39-11-2938	Cobalt	0.12	ug/FILTER	1.132673864	30	33.98022	3.53E-03			none specified			
RE39-11-2939	Cobalt	0.054	ug/FILTER	1.104357017	24	26.50457	2.04E-03			none specified			
RE39-11-2940	Cobalt	0.16	ug/FILTER	1.104357017	30	33.13071	4.83E-03			none specified			
RE39-11-2941	Cobalt	0.054	ug/FILTER	1.132673864	24	27.18417	1.99E-03			none specified			
RE39-11-2942	Cobalt	0.28	ug/FILTER	1.132673864	24	27.18417	1.03E-02	detect		none specified			
RE36-11-4184	Cobalt	0.024	ug/FILTER	1.132673864	30	33.98022	7.06E-04			none specified			
RE36-11-4189	Cobalt	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			none specified			
RE36-11-4190	Cobalt	0.07	ug/FILTER			0				none specified			
RE36-11-2934	Cobalt	0.03	ug/FILTER	1.132673864	42	47.5723	6.31E-04			none specified			
RE36-11-4192	Cobalt	0.028	ug/FILTER	1.132673864	96	108.7367	2.58E-04			none specified			
RE36-11-4197	Cobalt	0.02	ug/FILTER	1.061881747	108	114.6832	1.74E-04			none specified			
RE36-11-4503	Cobalt	0.078	ug/FILTER	1.132673864	30	33.98022	2.30E-03			none specified			
RE39-11-2943	Cobalt	0.03	ug/FILTER	1.132673864	30	33.98022	8.83E-04			none specified			
RE39-11-2944	Cobalt	0.096	ug/FILTER	1.132673864	36	40.77626	2.35E-03			none specified			
RE39-11-4524	Cobalt	0.022	ug/FILTER	1.104357017	30	33.13071	6.64E-04			none specified			
RE39-11-4525	Cobalt	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			none specified			
RE39-11-4526	Cobalt	0.2	ug/FILTER			0				none specified			
RE39-11-4527	Cobalt	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			none specified			
RE39-11-4528	Cobalt	0.026	ug/FILTER	1.132673864	24	27.18417	9.56E-04		1	none specified			0
RE39-11-2936	Copper	22	ug/FILTER	1.11851544	36	40.26656	5.46E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2945	Copper	4.3	ug/FILTER			0		detect		none specified	1.00E+02	1.00E+02	
RE36-11-2914	Copper	8.5	ug/FILTER	1.104357017	30	33.13071	2.57E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2915	Copper	8.8	ug/FILTER	1.132673864	54	61.16439	1.44E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2916	Copper	9.4	ug/FILTER	1.132673864	30	33.98022	2.77E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2917	Copper	10	ug/FILTER	1.132673864	36	40.77626	2.45E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2918	Copper	7.7	ug/FILTER	1.104357017	18	19.87843	3.87E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2919	Copper	6.2	ug/FILTER	1.132673864	42	47.5723	1.30E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2920	Copper	3.6	ug/FILTER	1.132673864	24	27.18417	1.32E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2921	Copper	6.4	ug/FILTER	1.132673864	42	47.5723	1.35E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2922	Copper	3.6	ug/FILTER	1.104357017	36	39.75685	9.06E-02	detect		none specified	1.00E+02	1.00E+02	
RE36-11-2923	Copper	3.5	ug/FILTER	1.104357017	36	39.75685	8.80E-02	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2935	Copper	6.2	ug/FILTER	1.132673864	30	33.98022	1.82E-01	detect		none specified	1.00E+02	1.00E+02	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2937	Copper	9.4	ug/FILTER	1.132673864	18	20.38813	4.61E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2938	Copper	24	ug/FILTER	1.132673864	30	33.98022	7.06E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2939	Copper	18	ug/FILTER	1.104357017	24	26.50457	6.79E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2940	Copper	46	ug/FILTER	1.104357017	30	33.13071	1.39E+00	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2941	Copper	7.7	ug/FILTER	1.132673864	24	27.18417	2.83E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2942	Copper	28	ug/FILTER	1.132673864	24	27.18417	1.03E+00	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4184	Copper	6.1	ug/FILTER	1.132673864	30	33.98022	1.80E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4189	Copper	3.9	ug/FILTER	1.132673864	30	33.98022	1.15E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4190	Copper	2.5	ug/FILTER			0		detect		none specified	1.00E+02	1.00E+02	
RE36-11-2934	Copper	6	ug/FILTER	1.132673864	42	47.5723	1.26E-01	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4192	Copper	4	ug/FILTER	1.132673864	96	108.7367	3.68E-02	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4197	Copper	5.3	ug/FILTER	1.061881747	108	114.6832	4.62E-02	detect		none specified	1.00E+02	1.00E+02	
RE36-11-4503	Copper	10	ug/FILTER	1.132673864	30	33.98022	2.94E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2943	Copper	12	ug/FILTER	1.132673864	30	33.98022	3.53E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-2944	Copper	40	ug/FILTER	1.132673864	36	40.77626	9.81E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-4524	Copper	8.9	ug/FILTER	1.104357017	30	33.13071	2.69E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-4525	Copper	3.4	ug/FILTER	1.104357017	30	33.13071	1.03E-01	detect		none specified	1.00E+02	1.00E+02	
RE39-11-4526	Copper	0.39	ug/FILTER			0				none specified	1.00E+02	1.00E+02	
RE39-11-4527	Copper	2.3	ug/FILTER	1.132673864	24	27.18417	8.46E-02	detect		none specified	1.00E+02	1.00E+02	
RE39-11-4528	Copper	12	ug/FILTER	1.132673864	24	27.18417	4.41E-01	detect	32	none specified	1.00E+02	1.00E+02	0
RE39-11-2936	Iron	270	ug/FILTER	1.11851544	36	40.26656	6.71E+00	detect		none specified			
RE39-11-2945	Iron	44	ug/FILTER			0		detect		none specified			
RE36-11-2914	Iron	99	ug/FILTER	1.104357017	30	33.13071	2.99E+00	detect		none specified			
RE36-11-2915	Iron	89	ug/FILTER	1.132673864	54	61.16439	1.46E+00	detect		none specified			
RE36-11-2916	Iron	67	ug/FILTER	1.132673864	30	33.98022	1.97E+00	detect		none specified			
RE36-11-2917	Iron	74	ug/FILTER	1.132673864	36	40.77626	1.81E+00	detect		none specified			
RE36-11-2918	Iron	74	ug/FILTER	1.104357017	18	19.87843	3.72E+00	detect		none specified			
RE36-11-2919	Iron	57	ug/FILTER	1.132673864	42	47.5723	1.20E+00	detect		none specified			
RE36-11-2920	Iron	77	ug/FILTER	1.132673864	24	27.18417	2.83E+00	detect		none specified			
RE36-11-2921	Iron	110	ug/FILTER	1.132673864	42	47.5723	2.31E+00	detect		none specified			
RE36-11-2922	Iron	36	ug/FILTER	1.104357017	36	39.75685	9.06E-01	detect		none specified			
RE36-11-2923	Iron	50	ug/FILTER	1.104357017	36	39.75685	1.26E+00	detect		none specified			
RE39-11-2935	Iron	56	ug/FILTER	1.132673864	30	33.98022	1.65E+00	detect		none specified			
RE39-11-2937	Iron	51	ug/FILTER	1.132673864	18	20.38813	2.50E+00	detect		none specified			
RE39-11-2938	Iron	190	ug/FILTER	1.132673864	30	33.98022	5.59E+00	detect		none specified			
RE39-11-2939	Iron	90	ug/FILTER	1.104357017	24	26.50457	3.40E+00	detect		none specified			
RE39-11-2940	Iron	390	ug/FILTER	1.104357017	30	33.13071	1.18E+01	detect		none specified			
RE39-11-2941	Iron	73	ug/FILTER	1.132673864	24	27.18417	2.69E+00	detect		none specified			
RE39-11-2942	Iron	340	ug/FILTER	1.132673864	24	27.18417	1.25E+01	detect		none specified			
RE36-11-4184	Iron	41	ug/FILTER	1.132673864	30	33.98022	1.21E+00	detect		none specified			
RE36-11-4189	Iron	43	ug/FILTER	1.132673864	30	33.98022	1.27E+00	detect		none specified			
RE36-11-4190	Iron	75	ug/FILTER			0		detect		none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2934	Iron	43	ug/FILTER	1.132673864	42	47.5723	9.04E-01	detect		none specified			
RE36-11-4192	Iron	30	ug/FILTER	1.132673864	96	108.7367	2.76E-01	detect		none specified			
RE36-11-4197	Iron	48	ug/FILTER	1.061881747	108	114.6832	4.19E-01	detect		none specified			
RE36-11-4503	Iron	61	ug/FILTER	1.132673864	30	33.98022	1.80E+00	detect		none specified			
RE39-11-2943	Iron	61	ug/FILTER	1.132673864	30	33.98022	1.80E+00	detect		none specified			
RE39-11-2944	Iron	180	ug/FILTER	1.132673864	36	40.77626	4.41E+00	detect		none specified			
RE39-11-4524	Iron	55	ug/FILTER	1.104357017	30	33.13071	1.66E+00	detect		none specified			
RE39-11-4525	Iron	19	ug/FILTER	1.104357017	30	33.13071	5.73E-01			none specified			
RE39-11-4526	Iron	5.9	ug/FILTER			0				none specified			
RE39-11-4527	Iron	14	ug/FILTER	1.132673864	24	27.18417	5.15E-01			none specified			
RE39-11-4528	Iron	55	ug/FILTER	1.132673864	24	27.18417	2.02E+00	detect	30	none specified			0
RE39-11-2936	Lead	3.9	ug/FILTER	1.11851544	36	40.26656	9.69E-02	detect		0.15		150	
RE39-11-2945	Lead	0.49	ug/FILTER			0		detect		0.15		150	
RE36-11-2914	Lead	1.4	ug/FILTER	1.104357017	30	33.13071	4.23E-02	detect		0.15		150	
RE36-11-2915	Lead	3.5	ug/FILTER	1.132673864	54	61.16439	5.72E-02	detect		0.15		150	
RE36-11-2916	Lead	12	ug/FILTER	1.132673864	30	33.98022	3.53E-01	detect		0.15		150	
RE36-11-2917	Lead	2.3	ug/FILTER	1.132673864	36	40.77626	5.64E-02	detect		0.15		150	
RE36-11-2918	Lead	6.3	ug/FILTER	1.104357017	18	19.87843	3.17E-01	detect		0.15		150	
RE36-11-2919	Lead	26	ug/FILTER	1.132673864	42	47.5723	5.47E-01	detect		0.15		150	
RE36-11-2920	Lead	18	ug/FILTER	1.132673864	24	27.18417	6.62E-01	detect		0.15		150	
RE36-11-2921	Lead	1.9	ug/FILTER	1.132673864	42	47.5723	3.99E-02	detect		0.15		150	
RE36-11-2922	Lead	8.2	ug/FILTER	1.104357017	36	39.75685	2.06E-01	detect		0.15		150	
RE36-11-2923	Lead	5.9	ug/FILTER	1.104357017	36	39.75685	1.48E-01	detect		0.15		150	
RE39-11-2935	Lead	14	ug/FILTER	1.132673864	30	33.98022	4.12E-01	detect		0.15		150	
RE39-11-2937	Lead	1.8	ug/FILTER	1.132673864	18	20.38813	8.83E-02	detect		0.15		150	
RE39-11-2938	Lead	15	ug/FILTER	1.132673864	30	33.98022	4.41E-01	detect		0.15		150	
RE39-11-2939	Lead	6.9	ug/FILTER	1.104357017	24	26.50457	2.60E-01	detect		0.15		150	
RE39-11-2940	Lead	22	ug/FILTER	1.104357017	30	33.13071	6.64E-01	detect		0.15		150	
RE39-11-2941	Lead	22	ug/FILTER	1.132673864	24	27.18417	8.09E-01	detect		0.15		150	
RE39-11-2942	Lead	63	ug/FILTER	1.132673864	24	27.18417	2.32E+00	detect		0.15		150	
RE36-11-4184	Lead	13	ug/FILTER	1.132673864	30	33.98022	3.83E-01	detect		0.15		150	
RE36-11-4189	Lead	13	ug/FILTER	1.132673864	30	33.98022	3.83E-01	detect		0.15		150	
RE36-11-4190	Lead	8.3	ug/FILTER			0		detect		0.15		150	
RE36-11-2934	Lead	17	ug/FILTER	1.132673864	42	47.5723	3.57E-01	detect		0.15		150	
RE36-11-4192	Lead	120	ug/FILTER	1.132673864	96	108.7367	1.10E+00	detect		0.15		150	
RE36-11-4197	Lead	41	ug/FILTER	1.061881747	108	114.6832	3.58E-01	detect		0.15		150	
RE36-11-4503	Lead	2.1	ug/FILTER	1.132673864	30	33.98022	6.18E-02	detect		0.15		150	
RE39-11-2943	Lead	19	ug/FILTER	1.132673864	30	33.98022	5.59E-01	detect		0.15		150	
RE39-11-2944	Lead	4.5	ug/FILTER	1.132673864	36	40.77626	1.10E-01	detect		0.15		150	
RE39-11-4524	Lead	28	ug/FILTER	1.104357017	30	33.13071	8.45E-01	detect		0.15		150	
RE39-11-4525	Lead	3.7	ug/FILTER	1.104357017	30	33.13071	1.12E-01	detect		0.15		150	
RE39-11-4526	Lead	32	ug/FILTER			0		detect		0.15		150	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug $/m^3$)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-4527	Lead	2	ug/FILTER	1.132673864	24	27.18417	7.36E-02	detect		0.15		150	
RE39-11-4528	Lead	1.5	ug/FILTER	1.132673864	24	27.18417	5.52E-02	detect	33	0.15		150	0
RE39-11-2936	Magnesium	36	ug/FILTER	1.11851544	36	40.26656	8.94E-01	detect		none specified			
RE39-11-2945	Magnesium	6.8	ug/FILTER			0				none specified			
RE36-11-2914	Magnesium	12	ug/FILTER	1.104357017	30	33.13071	3.62E-01			none specified			
RE36-11-2915	Magnesium	6.7	ug/FILTER	1.132673864	54	61.16439	1.10E-01			none specified			
RE36-11-2916	Magnesium	9.8	ug/FILTER	1.132673864	30	33.98022	2.88E-01			none specified			
RE36-11-2917	Magnesium	10	ug/FILTER	1.132673864	36	40.77626	2.45E-01			none specified			
RE36-11-2918	Magnesium	15	ug/FILTER	1.104357017	18	19.87843	7.55E-01			none specified			
RE36-11-2919	Magnesium	8.2	ug/FILTER	1.132673864	42	47.5723	1.72E-01			none specified			
RE36-11-2920	Magnesium	6.5	ug/FILTER	1.132673864	24	27.18417	2.39E-01			none specified			
RE36-11-2921	Magnesium	11	ug/FILTER	1.132673864	42	47.5723	2.31E-01			none specified			
RE36-11-2922	Magnesium	6.1	ug/FILTER	1.104357017	36	39.75685	1.53E-01			none specified			
RE36-11-2923	Magnesium	7.2	ug/FILTER	1.104357017	36	39.75685	1.81E-01			none specified			
RE39-11-2935	Magnesium	12	ug/FILTER	1.132673864	30	33.98022	3.53E-01			none specified			
RE39-11-2937	Magnesium	5.8	ug/FILTER	1.132673864	18	20.38813	2.84E-01			none specified			
RE39-11-2938	Magnesium	36	ug/FILTER	1.132673864	30	33.98022	1.06E+00	detect		none specified			
RE39-11-2939	Magnesium	21	ug/FILTER	1.104357017	24	26.50457	7.92E-01	detect		none specified			
RE39-11-2940	Magnesium	53	ug/FILTER	1.104357017	30	33.13071	1.60E+00	detect		none specified			
RE39-11-2941	Magnesium	11	ug/FILTER	1.132673864	24	27.18417	4.05E-01			none specified			
RE39-11-2942	Magnesium	46	ug/FILTER	1.132673864	24	27.18417	1.69E+00	detect		none specified			
RE36-11-4184	Magnesium	8.9	ug/FILTER	1.132673864	30	33.98022	2.62E-01			none specified			
RE36-11-4189	Magnesium	6.7	ug/FILTER	1.132673864	30	33.98022	1.97E-01			none specified			
RE36-11-4190	Magnesium	4.6	ug/FILTER			0				none specified			
RE36-11-2934	Magnesium	7.4	ug/FILTER	1.132673864	42	47.5723	1.56E-01			none specified			
RE36-11-4192	Magnesium	20	ug/FILTER	1.132673864	96	108.7367	1.84E-01			none specified			
RE36-11-4197	Magnesium	7.6	ug/FILTER	1.061881747	108	114.6832	6.63E-02			none specified			
RE36-11-4503	Magnesium	13	ug/FILTER	1.132673864	30	33.98022	3.83E-01			none specified			
RE39-11-2943	Magnesium	8	ug/FILTER	1.132673864	30	33.98022	2.35E-01			none specified			
RE39-11-2944	Magnesium	30	ug/FILTER	1.132673864	36	40.77626	7.36E-01	detect		none specified			
RE39-11-4524	Magnesium	8.1	ug/FILTER	1.104357017	30	33.13071	2.44E-01			none specified			
RE39-11-4525	Magnesium	20	ug/FILTER	1.104357017	30	33.13071	6.04E-01			none specified			
RE39-11-4526	Magnesium	20	ug/FILTER			0				none specified			
RE39-11-4527	Magnesium	20	ug/FILTER	1.132673864	24	27.18417	7.36E-01			none specified			
RE39-11-4528	Magnesium	11	ug/FILTER	1.132673864	24	27.18417	4.05E-01		6	none specified			0
RE39-11-2936	Manganese	5.5	ug/FILTER	1.11851544	36	40.26656	1.37E-01	detect		none specified			
RE39-11-2945	Manganese	0.95	ug/FILTER			0		detect		none specified			
RE36-11-2914	Manganese	1.3	ug/FILTER	1.104357017	30	33.13071	3.92E-02	detect		none specified			
RE36-11-2915	Manganese	1.1	ug/FILTER	1.132673864	54	61.16439	1.80E-02	detect		none specified			
RE36-11-2916	Manganese	1.3	ug/FILTER	1.132673864	30	33.98022	3.83E-02	detect		none specified			
RE36-11-2917	Manganese	1	ug/FILTER	1.132673864	36	40.77626	2.45E-02	detect		none specified			
RE36-11-2918	Manganese	1.9	ug/FILTER	1.104357017	18	19.87843	9.56E-02	detect		none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2919	Manganese	0.73	ug/FILTER	1.132673864	42	47.5723	1.53E-02	detect		none specified			
RE36-11-2920	Manganese	1	ug/FILTER	1.132673864	24	27.18417	3.68E-02	detect		none specified			
RE36-11-2921	Manganese	1.6	ug/FILTER	1.132673864	42	47.5723	3.36E-02	detect		none specified			
RE36-11-2922	Manganese	0.77	ug/FILTER	1.104357017	36	39.75685	1.94E-02	detect		none specified			
RE36-11-2923	Manganese	1.2	ug/FILTER	1.104357017	36	39.75685	3.02E-02	detect		none specified			
RE39-11-2935	Manganese	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02	detect		none specified			
RE39-11-2937	Manganese	0.9	ug/FILTER	1.132673864	18	20.38813	4.41E-02	detect		none specified			
RE39-11-2938	Manganese	4.7	ug/FILTER	1.132673864	30	33.98022	1.38E-01	detect		none specified			
RE39-11-2939	Manganese	2.6	ug/FILTER	1.104357017	24	26.50457	9.81E-02	detect		none specified			
RE39-11-2940	Manganese	11	ug/FILTER	1.104357017	30	33.13071	3.32E-01	detect		none specified			
RE39-11-2941	Manganese	1.6	ug/FILTER	1.132673864	24	27.18417	5.89E-02	detect		none specified			
RE39-11-2942	Manganese	6.7	ug/FILTER	1.132673864	24	27.18417	2.46E-01	detect		none specified			
RE36-11-4184	Manganese	1.5	ug/FILTER	1.132673864	30	33.98022	4.41E-02	detect		none specified			
RE36-11-4189	Manganese	1.6	ug/FILTER	1.132673864	30	33.98022	4.71E-02	detect		none specified			
RE36-11-4190	Manganese	1	ug/FILTER			0		detect		none specified			
RE36-11-2934	Manganese	0.81	ug/FILTER	1.132673864	42	47.5723	1.70E-02	detect		none specified			
RE36-11-4192	Manganese	0.51	ug/FILTER	1.132673864	96	108.7367	4.69E-03	detect		none specified			
RE36-11-4197	Manganese	0.93	ug/FILTER	1.061881747	108	114.6832	8.11E-03	detect		none specified			
RE36-11-4503	Manganese	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02	detect		none specified			
RE39-11-2943	Manganese	1	ug/FILTER	1.132673864	30	33.98022	2.94E-02	detect		none specified			
RE39-11-2944	Manganese	3.8	ug/FILTER	1.132673864	36	40.77626	9.32E-02	detect		none specified			
RE39-11-4524	Manganese	1.2	ug/FILTER	1.104357017	30	33.13071	3.62E-02	detect		none specified			
RE39-11-4525	Manganese	0.3	ug/FILTER	1.104357017	30	33.13071	9.06E-03			none specified			
RE39-11-4526	Manganese	0.084	ug/FILTER			0				none specified			
RE39-11-4527	Manganese	0.21	ug/FILTER	1.132673864	24	27.18417	7.73E-03			none specified			
RE39-11-4528	Manganese	1.1	ug/FILTER	1.132673864	24	27.18417	4.05E-02	detect	30	none specified			0
RE39-11-2936	Nickel	8.6	ug/FILTER	1.11851544	36	40.26656	2.14E-01	detect		6.00E-03		6.00E+00	
RE39-11-2945	Nickel	1.3	ug/FILTER			0		detect		6.00E-03		6.00E+00	
RE36-11-2914	Nickel	4.9	ug/FILTER	1.104357017	30	33.13071	1.48E-01	detect		6.00E-03		6.00E+00	
RE36-11-2915	Nickel	0.16	ug/FILTER	1.132673864	54	61.16439	2.62E-03			6.00E-03		6.00E+00	
RE36-11-2916	Nickel	1.9	ug/FILTER	1.132673864	30	33.98022	5.59E-02	detect		6.00E-03		6.00E+00	
RE36-11-2917	Nickel	2	ug/FILTER	1.132673864	36	40.77626	4.90E-02	detect		6.00E-03		6.00E+00	
RE36-11-2918	Nickel	1.7	ug/FILTER	1.104357017	18	19.87843	8.55E-02	detect		6.00E-03		6.00E+00	
RE36-11-2919	Nickel	3.6	ug/FILTER	1.132673864	42	47.5723	7.57E-02	detect		6.00E-03		6.00E+00	
RE36-11-2920	Nickel	8.5	ug/FILTER	1.132673864	24	27.18417	3.13E-01	detect		6.00E-03		6.00E+00	
RE36-11-2921	Nickel	7	ug/FILTER	1.132673864	42	47.5723	1.47E-01	detect		6.00E-03		6.00E+00	
RE36-11-2922	Nickel	1	ug/FILTER	1.104357017	36	39.75685	2.52E-02			6.00E-03		6.00E+00	
RE36-11-2923	Nickel	0.58	ug/FILTER	1.104357017	36	39.75685	1.46E-02			6.00E-03		6.00E+00	
RE39-11-2935	Nickel	0.33	ug/FILTER	1.132673864	30	33.98022	9.71E-03			6.00E-03		6.00E+00	
RE39-11-2937	Nickel	0.8	ug/FILTER	1.132673864	18	20.38813	3.92E-02			6.00E-03		6.00E+00	
RE39-11-2938	Nickel	6	ug/FILTER	1.132673864	30	33.98022	1.77E-01	detect		6.00E-03		6.00E+00	
RE39-11-2939	Nickel	0.83	ug/FILTER	1.104357017	24	26.50457	3.13E-02			6.00E-03		6.00E+00	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2940	Nickel	9.3	ug/FILTER	1.104357017	30	33.13071	2.81E-01	detect		6.00E-03		6.00E+00	
RE39-11-2941	Nickel	0.86	ug/FILTER	1.132673864	24	27.18417	3.16E-02			6.00E-03		6.00E+00	
RE39-11-2942	Nickel	13	ug/FILTER	1.132673864	24	27.18417	4.78E-01	detect		6.00E-03		6.00E+00	
RE36-11-4184	Nickel	1.1	ug/FILTER	1.132673864	30	33.98022	3.24E-02	detect		6.00E-03		6.00E+00	
RE36-11-4189	Nickel	0.71	ug/FILTER	1.132673864	30	33.98022	2.09E-02			6.00E-03		6.00E+00	
RE36-11-4190	Nickel	1.9	ug/FILTER			0		detect		6.00E-03		6.00E+00	
RE36-11-2934	Nickel	0.82	ug/FILTER	1.132673864	42	47.5723	1.72E-02			6.00E-03		6.00E+00	
RE36-11-4192	Nickel	0.39	ug/FILTER	1.132673864	96	108.7367	3.59E-03			6.00E-03		6.00E+00	
RE36-11-4197	Nickel	0.91	ug/FILTER	1.061881747	108	114.6832	7.93E-03			6.00E-03		6.00E+00	
RE36-11-4503	Nickel	0.46	ug/FILTER	1.132673864	30	33.98022	1.35E-02			6.00E-03		6.00E+00	
RE39-11-2943	Nickel	4.7	ug/FILTER	1.132673864	30	33.98022	1.38E-01	detect		6.00E-03		6.00E+00	
RE39-11-2944	Nickel	8.6	ug/FILTER	1.132673864	36	40.77626	2.11E-01	detect		6.00E-03		6.00E+00	
RE39-11-4524	Nickel	1.4	ug/FILTER	1.104357017	30	33.13071	4.23E-02	detect		6.00E-03		6.00E+00	
RE39-11-4525	Nickel	1.2	ug/FILTER	1.104357017	30	33.13071	3.62E-02	detect		6.00E-03		6.00E+00	
RE39-11-4526	Nickel	1	ug/FILTER			0				6.00E-03		6.00E+00	
RE39-11-4527	Nickel	0.5	ug/FILTER	1.132673864	24	27.18417	1.84E-02			6.00E-03		6.00E+00	
RE39-11-4528	Nickel	2.4	ug/FILTER	1.132673864	24	27.18417	8.83E-02	detect	19	6.00E-03		6.00E+00	0
RE39-11-2936	Potassium	42	ug/FILTER	1.11851544	36	40.26656	1.04E+00			none specified			
RE39-11-2945	Potassium	200	ug/FILTER			0				none specified			
RE36-11-2914	Potassium	47	ug/FILTER	1.104357017	30	33.13071	1.42E+00			none specified			
RE36-11-2915	Potassium	81	ug/FILTER	1.132673864	54	61.16439	1.32E+00			none specified			
RE36-11-2916	Potassium	76	ug/FILTER	1.132673864	30	33.98022	2.24E+00			none specified			
RE36-11-2917	Potassium	24	ug/FILTER	1.132673864	36	40.77626	5.89E-01			none specified			
RE36-11-2918	Potassium	200	ug/FILTER	1.104357017	18	19.87843	1.01E+01			none specified			
RE36-11-2919	Potassium	200	ug/FILTER	1.132673864	42	47.5723	4.20E+00			none specified			
RE36-11-2920	Potassium	24	ug/FILTER	1.132673864	24	27.18417	8.83E-01			none specified			
RE36-11-2921	Potassium	200	ug/FILTER	1.132673864	42	47.5723	4.20E+00			none specified			
RE36-11-2922	Potassium	200	ug/FILTER	1.104357017	36	39.75685	5.03E+00			none specified			
RE36-11-2923	Potassium	200	ug/FILTER	1.104357017	36	39.75685	5.03E+00			none specified			
RE39-11-2935	Potassium	200	ug/FILTER	1.132673864	30	33.98022	5.89E+00			none specified			
RE39-11-2937	Potassium	35	ug/FILTER	1.132673864	18	20.38813	1.72E+00			none specified			
RE39-11-2938	Potassium	81	ug/FILTER	1.132673864	30	33.98022	2.38E+00			none specified			
RE39-11-2939	Potassium	24	ug/FILTER	1.104357017	24	26.50457	9.06E-01			none specified			
RE39-11-2940	Potassium	130	ug/FILTER	1.104357017	30	33.13071	3.92E+00			none specified			
RE39-11-2941	Potassium	32	ug/FILTER	1.132673864	24	27.18417	1.18E+00			none specified			
RE39-11-2942	Potassium	93	ug/FILTER	1.132673864	24	27.18417	3.42E+00			none specified			
RE36-11-4184	Potassium	200	ug/FILTER	1.132673864	30	33.98022	5.89E+00			none specified			
RE36-11-4189	Potassium	200	ug/FILTER	1.132673864	30	33.98022	5.89E+00			none specified			
RE36-11-4190	Potassium	200	ug/FILTER			0				none specified			
RE36-11-2934	Potassium	200	ug/FILTER	1.132673864	42	47.5723	4.20E+00			none specified			
RE36-11-4192	Potassium	200	ug/FILTER	1.132673864	96	108.7367	1.84E+00			none specified			
RE36-11-4197	Potassium	200	ug/FILTER	1.061881747	108	114.6832	1.74E+00			none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4503	Potassium	23	ug/FILTER	1.132673864	30	33.98022	6.77E-01			none specified			
RE39-11-2943	Potassium	17	ug/FILTER	1.132673864	30	33.98022	5.00E-01			none specified			
RE39-11-2944	Potassium	62	ug/FILTER	1.132673864	36	40.77626	1.52E+00			none specified			
RE39-11-4524	Potassium	21	ug/FILTER	1.104357017	30	33.13071	6.34E-01			none specified			
RE39-11-4525	Potassium	16	ug/FILTER	1.104357017	30	33.13071	4.83E-01			none specified			
RE39-11-4526	Potassium	16	ug/FILTER			0				none specified			
RE39-11-4527	Potassium	17	ug/FILTER	1.132673864	24	27.18417	6.25E-01			none specified			
RE39-11-4528	Potassium	19	ug/FILTER	1.132673864	24	27.18417	6.99E-01		0	none specified			0
RE39-11-2936	Selenium	0.2	ug/FILTER	1.11851544	36	40.26656	4.97E-03			1.47E+00		1.47E+03	
RE39-11-2945	Selenium	0.2	ug/FILTER			0				1.47E+00		1.47E+03	
RE36-11-2914	Selenium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			1.47E+00		1.47E+03	
RE36-11-2915	Selenium	0.2	ug/FILTER	1.132673864	54	61.16439	3.27E-03			1.47E+00		1.47E+03	
RE36-11-2916	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE36-11-2917	Selenium	0.2	ug/FILTER	1.132673864	36	40.77626	4.90E-03			1.47E+00		1.47E+03	
RE36-11-2918	Selenium	0.2	ug/FILTER	1.104357017	18	19.87843	1.01E-02			1.47E+00		1.47E+03	
RE36-11-2919	Selenium	0.2	ug/FILTER	1.132673864	42	47.5723	4.20E-03			1.47E+00		1.47E+03	
RE36-11-2920	Selenium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			1.47E+00		1.47E+03	
RE36-11-2921	Selenium	0.2	ug/FILTER	1.132673864	42	47.5723	4.20E-03			1.47E+00		1.47E+03	
RE36-11-2922	Selenium	0.072	ug/FILTER	1.104357017	36	39.75685	1.81E-03			1.47E+00		1.47E+03	
RE36-11-2923	Selenium	0.2	ug/FILTER	1.104357017	36	39.75685	5.03E-03			1.47E+00		1.47E+03	
RE39-11-2935	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE39-11-2937	Selenium	0.2	ug/FILTER	1.132673864	18	20.38813	9.81E-03			1.47E+00		1.47E+03	
RE39-11-2938	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE39-11-2939	Selenium	0.2	ug/FILTER	1.104357017	24	26.50457	7.55E-03			1.47E+00		1.47E+03	
RE39-11-2940	Selenium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			1.47E+00		1.47E+03	
RE39-11-2941	Selenium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			1.47E+00		1.47E+03	
RE39-11-2942	Selenium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			1.47E+00		1.47E+03	
RE36-11-4184	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE36-11-4189	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE36-11-4190	Selenium	0.2	ug/FILTER			0				1.47E+00		1.47E+03	
RE36-11-2934	Selenium	0.2	ug/FILTER	1.132673864	42	47.5723	4.20E-03			1.47E+00		1.47E+03	
RE36-11-4192	Selenium	0.2	ug/FILTER	1.132673864	96	108.7367	1.84E-03			1.47E+00		1.47E+03	
RE36-11-4197	Selenium	0.2	ug/FILTER	1.061881747	108	114.6832	1.74E-03			1.47E+00		1.47E+03	
RE36-11-4503	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE39-11-2943	Selenium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			1.47E+00		1.47E+03	
RE39-11-2944	Selenium	0.2	ug/FILTER	1.132673864	36	40.77626	4.90E-03			1.47E+00		1.47E+03	
RE39-11-4524	Selenium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			1.47E+00		1.47E+03	
RE39-11-4525	Selenium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			1.47E+00		1.47E+03	
RE39-11-4526	Selenium	0.2	ug/FILTER			0				1.47E+00		1.47E+03	
RE39-11-4527	Selenium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			1.47E+00		1.47E+03	
RE39-11-4528	Selenium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03		0	1.47E+00		1.47E+03	0
RE39-11-2936	Silver	0.19	ug/FILTER	1.11851544	36	40.26656	4.72E-03	detect		0.3		300	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-2945	Silver	0.15	ug/FILTER			0		detect		0.3		300	
RE36-11-2914	Silver	0.038	ug/FILTER	1.104357017	30	33.13071	1.15E-03	detect		0.3		300	
RE36-11-2915	Silver	0.03	ug/FILTER	1.132673864	54	61.16439	4.90E-04	detect		0.3		300	
RE36-11-2916	Silver	0.05	ug/FILTER	1.132673864	30	33.98022	1.47E-03	detect		0.3		300	
RE36-11-2917	Silver	0.016	ug/FILTER	1.132673864	36	40.77626	3.92E-04			0.3		300	
RE36-11-2918	Silver	0.088	ug/FILTER	1.104357017	18	19.87843	4.43E-03	detect		0.3		300	
RE36-11-2919	Silver	0.06	ug/FILTER	1.132673864	42	47.5723	1.26E-03	detect		0.3		300	
RE36-11-2920	Silver	0.22	ug/FILTER	1.132673864	24	27.18417	8.09E-03	detect		0.3		300	
RE36-11-2921	Silver	0.34	ug/FILTER	1.132673864	42	47.5723	7.15E-03	detect		0.3		300	
RE36-11-2922	Silver	0.064	ug/FILTER	1.104357017	36	39.75685	1.61E-03	detect		0.3		300	
RE36-11-2923	Silver	0.032	ug/FILTER	1.104357017	36	39.75685	8.05E-04	detect		0.3		300	
RE39-11-2935	Silver	0.038	ug/FILTER	1.132673864	30	33.98022	1.12E-03	detect		0.3		300	
RE39-11-2937	Silver	0.026	ug/FILTER	1.132673864	18	20.38813	1.28E-03	detect		0.3		300	
RE39-11-2938	Silver	0.092	ug/FILTER	1.132673864	30	33.98022	2.71E-03	detect		0.3		300	
RE39-11-2939	Silver	0.076	ug/FILTER	1.104357017	24	26.50457	2.87E-03	detect		0.3		300	
RE39-11-2940	Silver	0.13	ug/FILTER	1.104357017	30	33.13071	3.92E-03	detect		0.3		300	
RE39-11-2941	Silver	0.094	ug/FILTER	1.132673864	24	27.18417	3.46E-03	detect		0.3		300	
RE39-11-2942	Silver	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03	detect		0.3		300	
RE36-11-4184	Silver	0.048	ug/FILTER	1.132673864	30	33.98022	1.41E-03	detect		0.3		300	
RE36-11-4189	Silver	0.074	ug/FILTER	1.132673864	30	33.98022	2.18E-03	detect		0.3		300	
RE36-11-4190	Silver	0.15	ug/FILTER			0		detect		0.3		300	
RE36-11-2934	Silver	0.026	ug/FILTER	1.132673864	42	47.5723	5.47E-04	detect		0.3		300	
RE36-11-4192	Silver	0.072	ug/FILTER	1.132673864	96	108.7367	6.62E-04	detect		0.3		300	
RE36-11-4197	Silver	0.068	ug/FILTER	1.061881747	108	114.6832	5.93E-04	detect		0.3		300	
RE36-11-4503	Silver	0.074	ug/FILTER	1.132673864	30	33.98022	2.18E-03	detect		0.3		300	
RE39-11-2943	Silver	0.05	ug/FILTER	1.132673864	30	33.98022	1.47E-03	detect		0.3		300	
RE39-11-2944	Silver	0.04	ug/FILTER	1.132673864	36	40.77626	9.81E-04	detect		0.3		300	
RE39-11-4524	Silver	0.028	ug/FILTER	1.104357017	30	33.13071	8.45E-04	detect		0.3		300	
RE39-11-4525	Silver	0.01	ug/FILTER	1.104357017	30	33.13071	3.02E-04			0.3		300	
RE39-11-4526	Silver	0.01	ug/FILTER			0				0.3		300	
RE39-11-4527	Silver	0.02	ug/FILTER	1.132673864	24	27.18417	7.36E-04			0.3		300	
RE39-11-4528	Silver	0.014	ug/FILTER	1.132673864	24	27.18417	5.15E-04		28	0.3		300	0
RE39-11-2936	Sodium	62	ug/FILTER	1.11851544	36	40.26656	1.54E+00			none specified			
RE39-11-2945	Sodium	47	ug/FILTER			0				none specified			
RE36-11-2914	Sodium	70	ug/FILTER	1.104357017	30	33.13071	2.11E+00			none specified			
RE36-11-2915	Sodium	280	ug/FILTER	1.132673864	54	61.16439	4.58E+00	detect		none specified			
RE36-11-2916	Sodium	120	ug/FILTER	1.132673864	30	33.98022	3.53E+00			none specified			
RE36-11-2917	Sodium	48	ug/FILTER	1.132673864	36	40.77626	1.18E+00			none specified			
RE36-11-2918	Sodium	32	ug/FILTER	1.104357017	18	19.87843	1.61E+00			none specified			
RE36-11-2919	Sodium	51	ug/FILTER	1.132673864	42	47.5723	1.07E+00			none specified			
RE36-11-2920	Sodium	92	ug/FILTER	1.132673864	24	27.18417	3.38E+00			none specified			
RE36-11-2921	Sodium	31	ug/FILTER	1.132673864	42	47.5723	6.52E-01			none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-2922	Sodium	22	ug/FILTER	1.104357017	36	39.75685	5.53E-01			none specified			
RE36-11-2923	Sodium	20	ug/FILTER	1.104357017	36	39.75685	5.03E-01			none specified			
RE39-11-2935	Sodium	34	ug/FILTER	1.132673864	30	33.98022	1.00E+00			none specified			
RE39-11-2937	Sodium	22	ug/FILTER	1.132673864	18	20.38813	1.08E+00			none specified			
RE39-11-2938	Sodium	70	ug/FILTER	1.132673864	30	33.98022	2.06E+00			none specified			
RE39-11-2939	Sodium	37	ug/FILTER	1.104357017	24	26.50457	1.40E+00			none specified			
RE39-11-2940	Sodium	170	ug/FILTER	1.104357017	30	33.13071	5.13E+00			none specified			
RE39-11-2941	Sodium	32	ug/FILTER	1.132673864	24	27.18417	1.18E+00			none specified			
RE39-11-2942	Sodium	110	ug/FILTER	1.132673864	24	27.18417	4.05E+00			none specified			
RE36-11-4184	Sodium	51	ug/FILTER	1.132673864	30	33.98022	1.50E+00			none specified			
RE36-11-4189	Sodium	38	ug/FILTER	1.132673864	30	33.98022	1.12E+00			none specified			
RE36-11-4190	Sodium	33	ug/FILTER			0				none specified			
RE36-11-2934	Sodium	200	ug/FILTER	1.132673864	42	47.5723	4.20E+00			none specified			
RE36-11-4192	Sodium	43	ug/FILTER	1.132673864	96	108.7367	3.95E-01			none specified			
RE36-11-4197	Sodium	30	ug/FILTER	1.061881747	108	114.6832	2.62E-01			none specified			
RE36-11-4503	Sodium	30	ug/FILTER	1.132673864	30	33.98022	8.83E-01			none specified			
RE39-11-2943	Sodium	200	ug/FILTER	1.132673864	30	33.98022	5.89E+00			none specified			
RE39-11-2944	Sodium	230	ug/FILTER	1.132673864	36	40.77626	5.64E+00	detect		none specified			
RE39-11-4524	Sodium	200	ug/FILTER	1.104357017	30	33.13071	6.04E+00			none specified			
RE39-11-4525	Sodium	200	ug/FILTER	1.104357017	30	33.13071	6.04E+00			none specified			
RE39-11-4526	Sodium	200	ug/FILTER			0				none specified			
RE39-11-4527	Sodium	200	ug/FILTER	1.132673864	24	27.18417	7.36E+00			none specified			
RE39-11-4528	Sodium	200	ug/FILTER	1.132673864	24	27.18417	7.36E+00		2	none specified			0
RE39-11-2936	Thallium	0.02	ug/FILTER	1.11851544	36	40.26656	4.97E-04			0.3		300	
RE39-11-2945	Thallium	0.006	ug/FILTER			0				0.3		300	
RE36-11-2914	Thallium	0.01	ug/FILTER	1.104357017	30	33.13071	3.02E-04			0.3		300	
RE36-11-2915	Thallium	0.04	ug/FILTER	1.132673864	54	61.16439	6.54E-04			0.3		300	
RE36-11-2916	Thallium	0.006	ug/FILTER	1.132673864	30	33.98022	1.77E-04			0.3		300	
RE36-11-2917	Thallium	0.04	ug/FILTER	1.132673864	36	40.77626	9.81E-04			0.3		300	
RE36-11-2918	Thallium	0.006	ug/FILTER	1.104357017	18	19.87843	3.02E-04			0.3		300	
RE36-11-2919	Thallium	0.01	ug/FILTER	1.132673864	42	47.5723	2.10E-04			0.3		300	
RE36-11-2920	Thallium	0.04	ug/FILTER	1.132673864	24	27.18417	1.47E-03			0.3		300	
RE36-11-2921	Thallium	0.04	ug/FILTER	1.132673864	42	47.5723	8.41E-04			0.3		300	
RE36-11-2922	Thallium	0.008	ug/FILTER	1.104357017	36	39.75685	2.01E-04			0.3		300	
RE36-11-2923	Thallium	0.008	ug/FILTER	1.104357017	36	39.75685	2.01E-04			0.3		300	
RE39-11-2935	Thallium	0.004	ug/FILTER	1.132673864	30	33.98022	1.18E-04			0.3		300	
RE39-11-2937	Thallium	0.016	ug/FILTER	1.132673864	18	20.38813	7.85E-04			0.3		300	
RE39-11-2938	Thallium	0.008	ug/FILTER	1.132673864	30	33.98022	2.35E-04			0.3		300	
RE39-11-2939	Thallium	0.006	ug/FILTER	1.104357017	24	26.50457	2.26E-04			0.3		300	
RE39-11-2940	Thallium	0.008	ug/FILTER	1.104357017	30	33.13071	2.41E-04			0.3		300	
RE39-11-2941	Thallium	0.056	ug/FILTER	1.132673864	24	27.18417	2.06E-03	detect		0.3		300	
RE39-11-2942	Thallium	0.012	ug/FILTER	1.132673864	24	27.18417	4.41E-04			0.3		300	

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE36-11-4184	Thallium	0.046	ug/FILTER	1.132673864	30	33.98022	1.35E-03	detect		0.3		300	
RE36-11-4189	Thallium	0.01	ug/FILTER	1.132673864	30	33.98022	2.94E-04			0.3		300	
RE36-11-4190	Thallium	0.04	ug/FILTER			0				0.3		300	
RE36-11-2934	Thallium	0.026	ug/FILTER	1.132673864	42	47.5723	5.47E-04			0.3		300	
RE36-11-4192	Thallium	0.01	ug/FILTER	1.132673864	96	108.7367	9.20E-05			0.3		300	
RE36-11-4197	Thallium	0.006	ug/FILTER	1.061881747	108	114.6832	5.23E-05			0.3		300	
RE36-11-4503	Thallium	0.04	ug/FILTER	1.132673864	30	33.98022	1.18E-03			0.3		300	
RE39-11-2943	Thallium	0.04	ug/FILTER	1.132673864	30	33.98022	1.18E-03			0.3		300	
RE39-11-2944	Thallium	0.04	ug/FILTER	1.132673864	36	40.77626	9.81E-04			0.3		300	
RE39-11-4524	Thallium	0.01	ug/FILTER	1.104357017	30	33.13071	3.02E-04			0.3		300	
RE39-11-4525	Thallium	0.04	ug/FILTER	1.104357017	30	33.13071	1.21E-03			0.3		300	
RE39-11-4526	Thallium	0.008	ug/FILTER			0				0.3		300	
RE39-11-4527	Thallium	0.04	ug/FILTER	1.132673864	24	27.18417	1.47E-03			0.3		300	
RE39-11-4528	Thallium	0.014	ug/FILTER	1.132673864	24	27.18417	5.15E-04		2	0.3		300	0
RE39-11-2936	Vanadium	0.15	ug/FILTER	1.11851544	36	40.26656	3.73E-03			none specified			
RE39-11-2945	Vanadium	0.2	ug/FILTER			0				none specified			
RE36-11-2914	Vanadium	0.082	ug/FILTER	1.104357017	30	33.13071	2.48E-03			none specified			
RE36-11-2915	Vanadium	0.092	ug/FILTER	1.132673864	54	61.16439	1.50E-03			none specified			
RE36-11-2916	Vanadium	0.06	ug/FILTER	1.132673864	30	33.98022	1.77E-03			none specified			
RE36-11-2917	Vanadium	0.058	ug/FILTER	1.132673864	36	40.77626	1.42E-03			none specified			
RE36-11-2918	Vanadium	0.14	ug/FILTER	1.104357017	18	19.87843	7.04E-03			none specified			
RE36-11-2919	Vanadium	0.052	ug/FILTER	1.132673864	42	47.5723	1.09E-03			none specified			
RE36-11-2920	Vanadium	0.17	ug/FILTER	1.132673864	24	27.18417	6.25E-03			none specified			
RE36-11-2921	Vanadium	0.15	ug/FILTER	1.132673864	42	47.5723	3.15E-03			none specified			
RE36-11-2922	Vanadium	0.11	ug/FILTER	1.104357017	36	39.75685	2.77E-03			none specified			
RE36-11-2923	Vanadium	0.12	ug/FILTER	1.104357017	36	39.75685	3.02E-03			none specified			
RE39-11-2935	Vanadium	0.22	ug/FILTER	1.132673864	30	33.98022	6.47E-03	detect		none specified			
RE39-11-2937	Vanadium	0.2	ug/FILTER	1.132673864	18	20.38813	9.81E-03			none specified			
RE39-11-2938	Vanadium	0.38	ug/FILTER	1.132673864	30	33.98022	1.12E-02	detect		none specified			
RE39-11-2939	Vanadium	0.27	ug/FILTER	1.104357017	24	26.50457	1.02E-02	detect		none specified			
RE39-11-2940	Vanadium	0.58	ug/FILTER	1.104357017	30	33.13071	1.75E-02	detect		none specified			
RE39-11-2941	Vanadium	0.26	ug/FILTER	1.132673864	24	27.18417	9.56E-03	detect		none specified			
RE39-11-2942	Vanadium	0.5	ug/FILTER	1.132673864	24	27.18417	1.84E-02	detect		none specified			
RE36-11-4184	Vanadium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			none specified			
RE36-11-4189	Vanadium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			none specified			
RE36-11-4190	Vanadium	0.2	ug/FILTER			0				none specified			
RE36-11-2934	Vanadium	0.084	ug/FILTER	1.132673864	42	47.5723	1.77E-03			none specified			
RE36-11-4192	Vanadium	0.11	ug/FILTER	1.132673864	96	108.7367	1.01E-03			none specified			
RE36-11-4197	Vanadium	0.12	ug/FILTER	1.061881747	108	114.6832	1.05E-03			none specified			
RE36-11-4503	Vanadium	0.13	ug/FILTER	1.132673864	30	33.98022	3.83E-03			none specified			
RE39-11-2943	Vanadium	0.2	ug/FILTER	1.132673864	30	33.98022	5.89E-03			none specified			
RE39-11-2944	Vanadium	0.076	ug/FILTER	1.132673864	36	40.77626	1.86E-03			none specified			

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug $/m^3$)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte
RE39-11-4524	Vanadium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			none specified			
RE39-11-4525	Vanadium	0.2	ug/FILTER	1.104357017	30	33.13071	6.04E-03			none specified			
RE39-11-4526	Vanadium	0.2	ug/FILTER			0				none specified			
RE39-11-4527	Vanadium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03			none specified			
RE39-11-4528	Vanadium	0.2	ug/FILTER	1.132673864	24	27.18417	7.36E-03		6	none specified			0
RE39-11-2936	Zinc	33	ug/FILTER	1.11851544	36	40.26656	8.20E-01	detect		3.00E+01		3.00E+04	
RE39-11-2945	Zinc	11	ug/FILTER			0		detect		3.00E+01		3.00E+04	
RE36-11-2914	Zinc	20	ug/FILTER	1.104357017	30	33.13071	6.04E-01	detect		3.00E+01		3.00E+04	
RE36-11-2915	Zinc	21	ug/FILTER	1.132673864	54	61.16439	3.43E-01	detect		3.00E+01		3.00E+04	
RE36-11-2916	Zinc	14	ug/FILTER	1.132673864	30	33.98022	4.12E-01	detect		3.00E+01		3.00E+04	
RE36-11-2917	Zinc	15	ug/FILTER	1.132673864	36	40.77626	3.68E-01	detect		3.00E+01		3.00E+04	
RE36-11-2918	Zinc	12	ug/FILTER	1.104357017	18	19.87843	6.04E-01	detect		3.00E+01		3.00E+04	
RE36-11-2919	Zinc	18	ug/FILTER	1.132673864	42	47.5723	3.78E-01	detect		3.00E+01		3.00E+04	
RE36-11-2920	Zinc	10	ug/FILTER	1.132673864	24	27.18417	3.68E-01	detect		3.00E+01		3.00E+04	
RE36-11-2921	Zinc	15	ug/FILTER	1.132673864	42	47.5723	3.15E-01	detect		3.00E+01		3.00E+04	
RE36-11-2922	Zinc	11	ug/FILTER	1.104357017	36	39.75685	2.77E-01	detect		3.00E+01		3.00E+04	
RE36-11-2923	Zinc	11	ug/FILTER	1.104357017	36	39.75685	2.77E-01	detect		3.00E+01		3.00E+04	
RE39-11-2935	Zinc	15	ug/FILTER	1.132673864	30	33.98022	4.41E-01	detect		3.00E+01		3.00E+04	
RE39-11-2937	Zinc	20	ug/FILTER	1.132673864	18	20.38813	9.81E-01	detect		3.00E+01		3.00E+04	
RE39-11-2938	Zinc	40	ug/FILTER	1.132673864	30	33.98022	1.18E+00	detect		3.00E+01		3.00E+04	
RE39-11-2939	Zinc	16	ug/FILTER	1.104357017	24	26.50457	6.04E-01	detect		3.00E+01		3.00E+04	
RE39-11-2940	Zinc	46	ug/FILTER	1.104357017	30	33.13071	1.39E+00	detect		3.00E+01		3.00E+04	
RE39-11-2941	Zinc	14	ug/FILTER	1.132673864	24	27.18417	5.15E-01	detect		3.00E+01		3.00E+04	
RE39-11-2942	Zinc	35	ug/FILTER	1.132673864	24	27.18417	1.29E+00	detect		3.00E+01		3.00E+04	
RE36-11-4184	Zinc	19	ug/FILTER	1.132673864	30	33.98022	5.59E-01	detect		3.00E+01		3.00E+04	
RE36-11-4189	Zinc	11	ug/FILTER	1.132673864	30	33.98022	3.24E-01	detect		3.00E+01		3.00E+04	
RE36-11-4190	Zinc	12	ug/FILTER			0		detect		3.00E+01		3.00E+04	
RE36-11-2934	Zinc	9.8	ug/FILTER	1.132673864	42	47.5723	2.06E-01	detect		3.00E+01		3.00E+04	
RE36-11-4192	Zinc	12	ug/FILTER	1.132673864	96	108.7367	1.10E-01	detect		3.00E+01		3.00E+04	
RE36-11-4197	Zinc	15	ug/FILTER	1.061881747	108	114.6832	1.31E-01	detect		3.00E+01		3.00E+04	
RE36-11-4503	Zinc	22	ug/FILTER	1.132673864	30	33.98022	6.47E-01	detect		3.00E+01		3.00E+04	
RE39-11-2943	Zinc	18	ug/FILTER	1.132673864	30	33.98022	5.30E-01	detect		3.00E+01		3.00E+04	
RE39-11-2944	Zinc	42	ug/FILTER	1.132673864	36	40.77626	1.03E+00	detect		3.00E+01		3.00E+04	
RE39-11-4524	Zinc	17	ug/FILTER	1.104357017	30	33.13071	5.13E-01	detect		3.00E+01		3.00E+04	
RE39-11-4525	Zinc	6.4	ug/FILTER	1.104357017	30	33.13071	1.93E-01	detect		3.00E+01		3.00E+04	
RE39-11-4526	Zinc	2.1	ug/FILTER			0				3.00E+01		3.00E+04	
RE39-11-4527	Zinc	3.6	ug/FILTER	1.132673864	24	27.18417	1.32E-01			3.00E+01		3.00E+04	
RE39-11-4528	Zinc	17	ug/FILTER	1.132673864	24	27.18417	6.25E-01	detect	31	3.00E+01		3.00E+04	0

Sample Name	Analyte Description	Std Result	Std Result Unit	Flow rate (m^3/min)	Flow time (min)	Flow vol (m^3)	Conc. In Air (pg or ug /m^3)	Detection	# of Detects per Analyte	Acute Inhalation Exposure Conc. (mg/m^3)	CA Acute RELs (mg/m^3)	Conversion of screening level to ug/m^3	# of Exceeds per Analyte

ug = micrograms
m^3/min = cubic meters per minute
min = minute
pg or ug /m^3 = picograms or micrograms per cubic meter
mg/m^3 = milligrams per cubic meter
ug/m^3 = microgams per cubic meter
CA Acute RELs = California Acute Reference Exposure Levels
Note: Blank samples have a flow volume of 0 m^3
Screening levels taken from:
EPA, 2005. "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities," Office of Solid Waste and Emergency Response, EPA530-R-05-006, September 2005. EPA, 2010, "Environmental Protection Agency Region 6 Regional Screening Levels," November November 2010.
and
Office of Environmental Health Hazard Assessment (OEHHA), 1999. Air Toxics Hot Spots Program Risk Assessment Guidelines Part I The Determination of Acute Reference Exposure Levels for Airborne Toxicants. California Environmental Protection Agency, Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment. March 1999.

16. Hathcock, C.D., April 2014. *Avian Monitoring at the TA 36 Minie Site, TA-39 Point 6 Site, and TA 16 Burn Ground*. LA-UR-13-27825.
(Hathcock & Fair 2013)

LA-UR-13-27825

Title: Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds

Author(s): Hathcock, Charles D.

Intended for: Report
Environmental Programs

Issued: 2014-04-02 (rev.2)

LA-UR-13-27825
*Approved for public release;
distribution is unlimited.*

Title: **Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds**

Author(s): Charles D. Hathcock and Jeanne M. Fair
Environmental Protection Division

Intended for: RCRA Permitting Team and External

Table of Contents

Executive Summary

Los Alamos National Security, LLC (LANS) biologists in the Environmental Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year monitoring program for migratory birds in Fiscal Year (FY) 2013 to monitor avifauna at two open detonation sites and one open burn site at LANL. The objectives of this on-going study are to monitor patterns and trends of bird abundance and diversity over time at these sites. LANS biologists completed the first year of this effort in 2013.

Three surveys were completed at each of the study sites at the Technical Area (TA)-36 Minie Site, the TA-39 Point 6, and the TA-16 Burn Grounds between May and July 2013. A total of 590 birds representing 55 species were recorded. Of the 55 species detected at the three study sites, 54 are protected under the Migratory Bird Treaty Act (MBTA).

Results indicate that the avian abundance and diversity at the three study sites were comparable to or greater than that of the control sites. Continued monitoring will produce trends over time in avian abundance and diversity that can be compared to local, regional, and national data.

Introduction

As part of the Resource Conservation and Recovery Act (RCRA) permitting process for two open detonation sites, the TA-36 Minie Site and TA-39 Point 6, and one open burn site, the TA-16 Burn Grounds, at LANL, an avian monitoring program was started in 2013. The goal was to monitor avian use of the habitat surrounding the open detonation and open burning sites and compare their use to other locations at LANL in the same habitat type. Comparisons were made to control sites which have been surveyed since 2011 (Hathcock et al. 2011; Hathcock and Keller 2012).

LANS biologists used standard point count methodology to record avian density and diversity along transects in the three study sites during the summer of 2013. Summer surveys provide information about what migratory birds are breeding at the sites. These surveys are most valuable when they are conducted over multiple years, as they provide trend data, which can be compared with regional and national changes in bird populations, changes in the natural environment at LANL, and LANL operations.

Methods

Field Methods

Point count surveys along a transect were chosen as the most rigorous method to monitor patterns of bird abundance and richness, and population trends, in habitats found at two open detonation sites and one open burning site at LANL. This method is already used around LANL at other locations for long-term monitoring. The surveys were conducted along transects in the forested, undeveloped land surrounding the study sites (Figures 1 – 3). The habitat types around the sites are pinyon-juniper woodland (PJ) for the sites at TA-36 and -39 and mixed conifer forest (MC) for the site at TA-16. These habitat descriptions are based on the 1/4 hectare physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The three study sites were compared to control sites at LANL. The control sites (Figure 4) are monitored annually in ongoing surveys conducted at LANL since 2011 as described in Hathcock and Keller (2012). The PJ study sites at TA-36 and -39 are similar to the PJ control sites at TA-70 and -71 in elevation, vegetation, proximity to developed areas, and in being situated on the mesa top. The MC study site at the TA-16 Burn Grounds is similar in elevation, and overstory vegetation, but is dissimilar in that the study site is located on a mesa top and the control sites are located in the bottom of a canyon. Being the bottom of a canyon, there are some differences in understory vegetation with a greater understory present in the control sites.

Transects are approximately 2.0 to 2.5 km in length and allow for nine survey points spaced approximately 250 m apart. These survey routes and points may change over time due to construction activities or access constraints. The time frame for breeding bird surveys is May 1st – August 15. Ideally the breeding bird surveys should take place in the 2nd week of May, June, and July. This protocol requires a total of three surveys per study site and surveys should be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys.

- Each survey consists of nine points along the transect, ~ 250 m apart
- At each point of the survey the surveyor will look and listen for 5 minutes, noting any birds encountered. The distance for observations is considered as an “unlimited-distance circular plot”; however, noting the distance to each bird out to 100 meters should be done. Care is needed to ensure that individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, any birds encountered that have not otherwise been counted from a previous point or future point should also be noted. It should not be the intent for the surveyor to dawdle between points looking for additional birds.
- Surveys should not be conducted during rain events or wind greater than 25 kph.
- Any bird(s) encountered will be recorded on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- The “NOTES” section should be used for indicating any potentially important aspects of the survey that may affect the data. Examples include: excess noise from nearby equipment and vehicles or aircraft that make it hard to hear the birds. Also, noting other wildlife or evidence of wildlife that could be used for further reference should be recorded.

Statistical Methods

Summary statistics are compiled to look at trends in avian abundance and diversity between the three study sites and the control sites. To compare relative abundances between years and with control sites, the “birds per hour” was calculated for each site. This was calculated by taking the total number of birds per habitat type and dividing by the total number of minutes surveyed. Then this number is multiplied by 60 to get the number of birds per hour.

The Shannon’s diversity index (H) (Shannon 1948) was used to examine species diversity by location and habitat type. This diversity index is a popular measure in ecology that is used to describe the species richness in a community. The Shannon’s H can range from 0.0 to 4.6, where larger values represent increasing diversity. H is calculated using the following formula:

$H = -1 (p_i (\ln (p_i))$

Where p_i is a percentage value of a specific species in the total population and ln is the natural log.

Another useful measure is the Shannon's equitability estimate (E_H) (Shannon 1948) which is a measure of evenness in the population. This measures the evenness with which individuals are divided among the taxa present. This measure ranges from 0 to 1 where one represents a completely even community in which all species' abundances are equal. The Shannon's E_H is calculated using the following formula:

$E_H = H/\ln S$

Where S is species count, ln is the natural log, and *H* is the Shannon's diversity index.

To compare indices, a bootstrapping technique is used where two samples, A and B, are pooled. Then 1,000 random pairs of samples (Ai and Bi) are taken from this pool, with the same numbers of individuals as in the original two samples. For each replicate pair, the diversity indices div(Ai) and div(Bi) are computed. The number of times |div(Ai)-div(Bi)| exceeds or equals |div(A)-div(B)| indicates the probability that the observed difference could have occurred by random sampling from one parent population as estimated by the pooled sample. A small probability value less than 0.05 indicates a significant difference in the diversity index between the two samples. The diversity indices and the bootstrap comparisons between indices were completed using the PAST statistical software (Hammer et al. 2001).

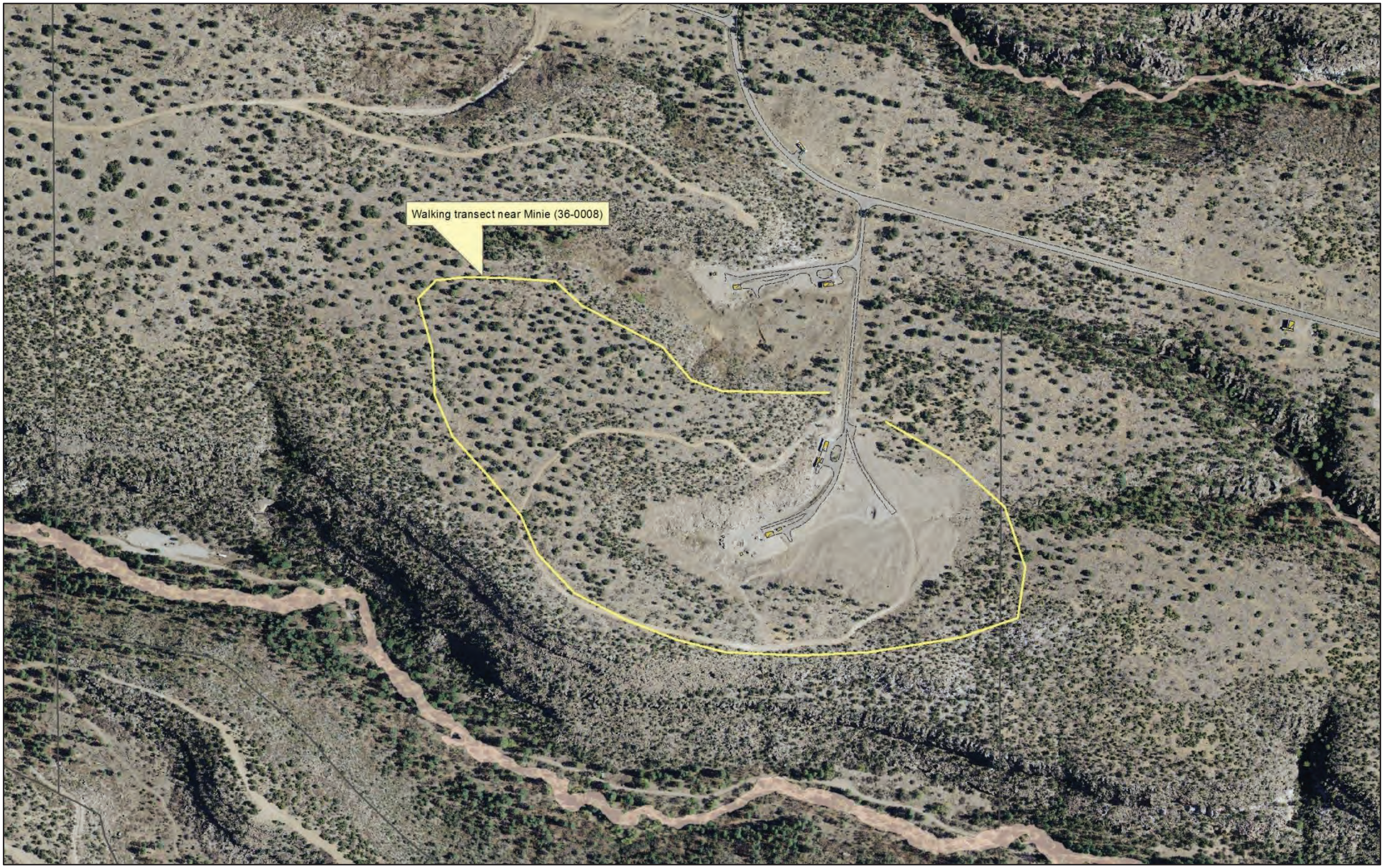


Figure 1. Field Working Map for the Transect Around the TA-36 Minie Site.

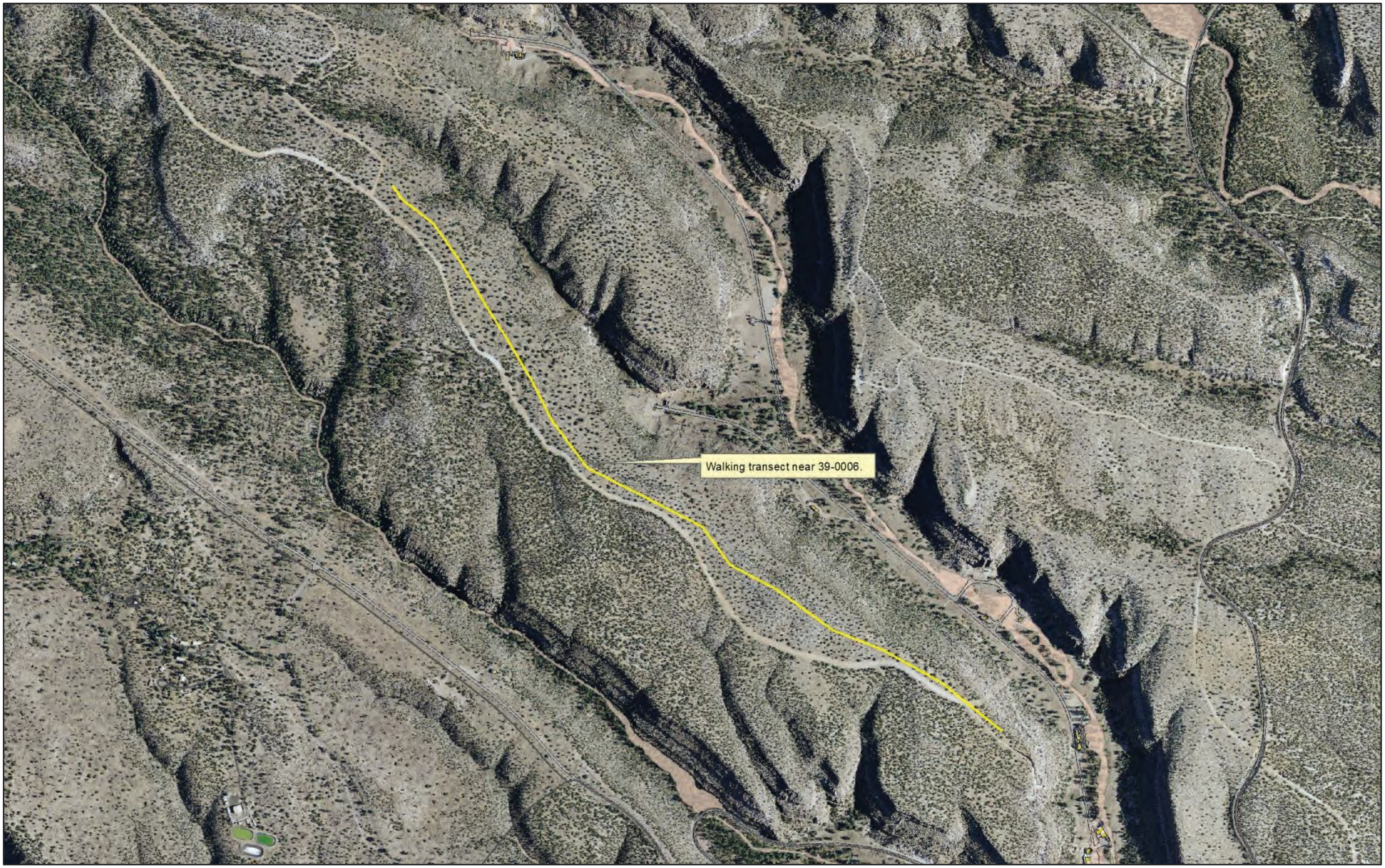


Figure 2. Field Working Map for the Transect Around the TA-39 Point 6.

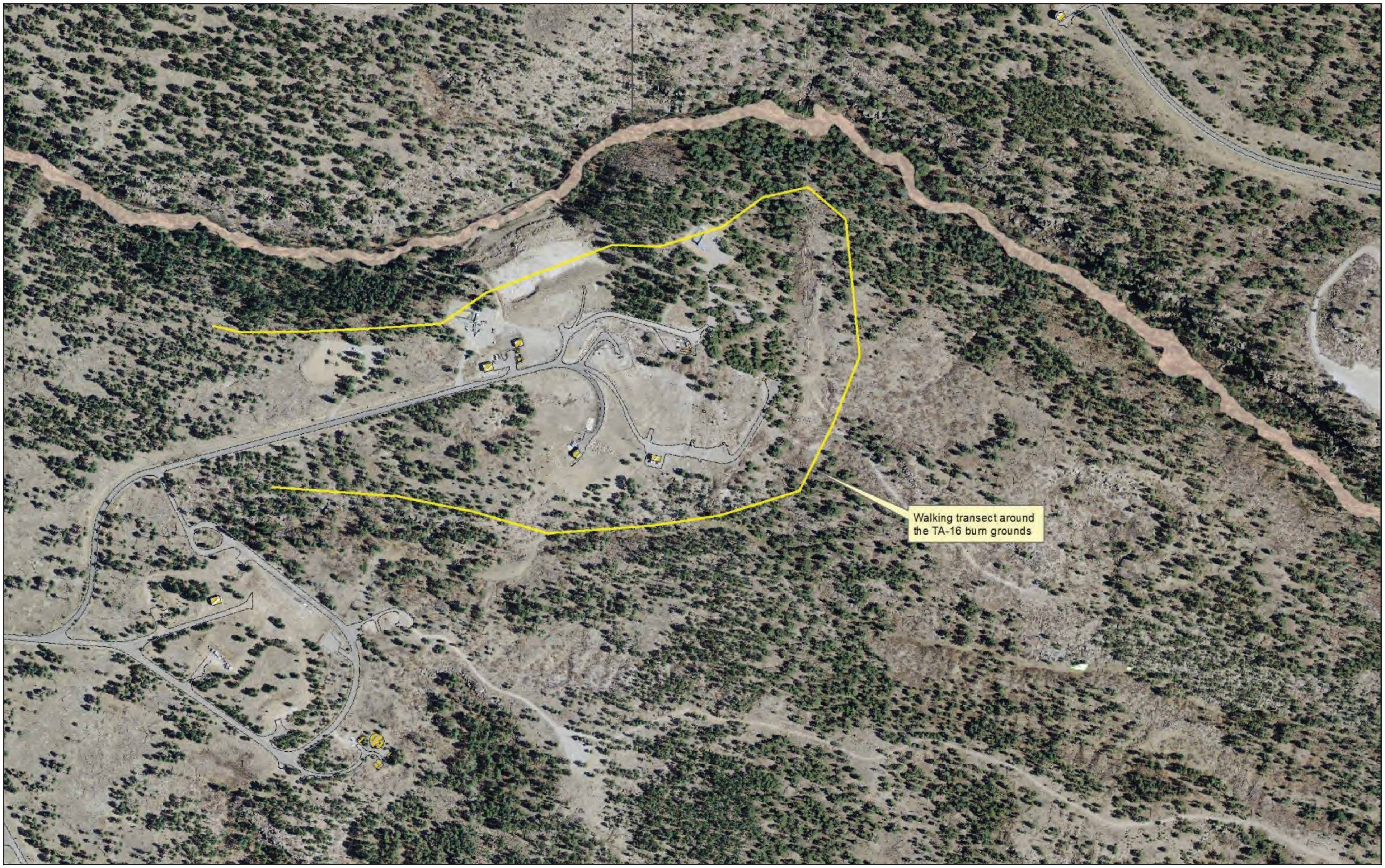


Figure3. Field Working Map for the Transect Around the TA-16 Burn Grounds.

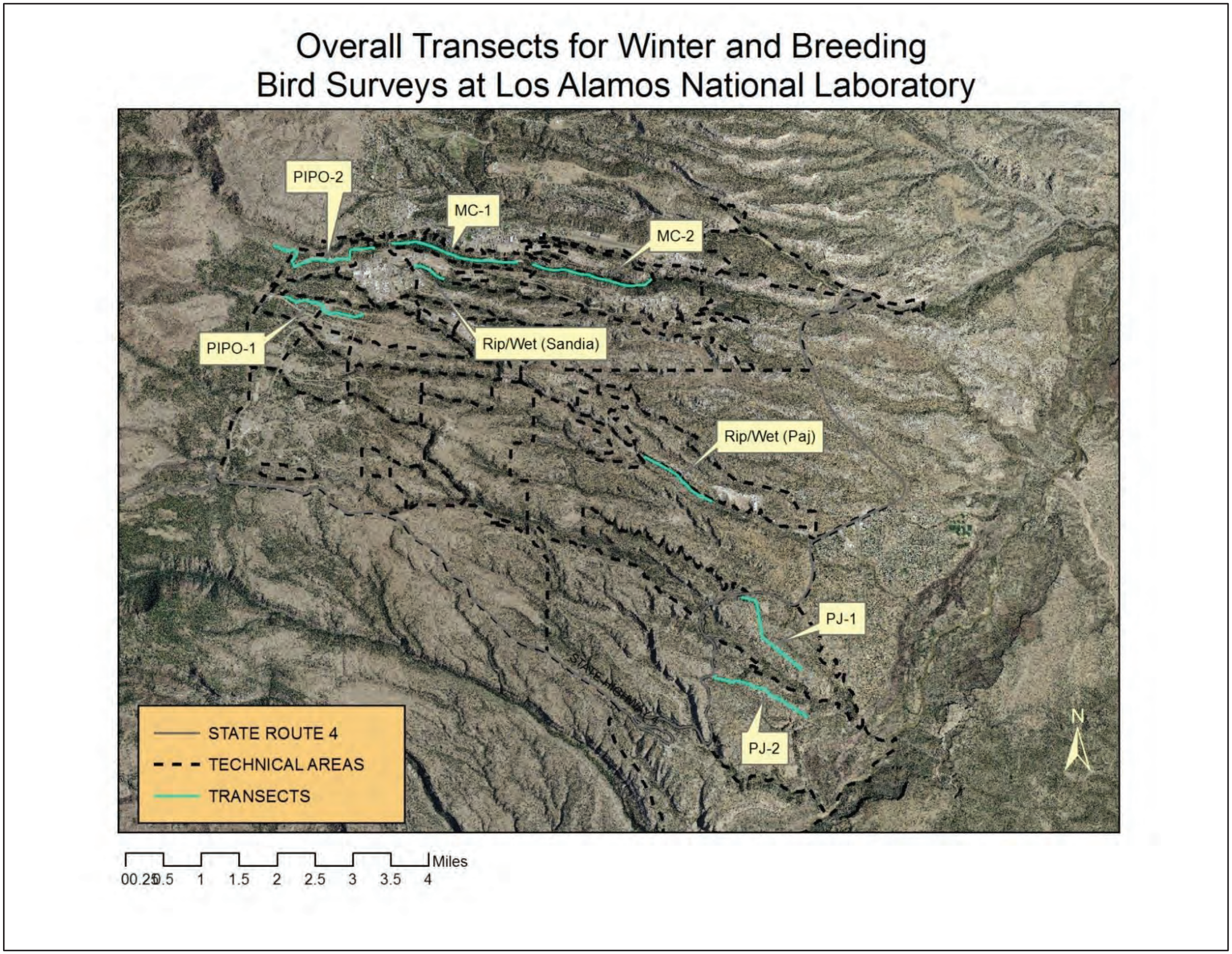


Figure 4. Control Transects from Ongoing Avian Monitoring Around LANL (Hathcock and Keller 2012). MC: Mixed Conifer Forest, PIPO: Ponderosa Pine Forest, PJ: Pinyon-Juniper Woodland, Rip/Wet: Riparian / Wetland.

Results and Discussion

Three surveys were completed at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds between May and July 2013. A total of 590 birds representing 55 species were recorded. The ten most common species at these three sites were the House Finch, Spotted Towhee, Western Bluebird, Mourning Dove, Ash-throated Flycatcher, Pine Siskin, Western Wood-Pewee, Juniper Titmouse, Gray Flycatcher, and Plumbeous Vireo. A full account of the 2013 data is detailed in Table 1.

Table 1. Birds Recorded at the Three Study Sites in 2013.

Species Name	TA-36 Minie Site (PJ Habitat)	TA-16 Burn Grounds (MC Habitat)	TA-39 Point 6 (PJ Habitat)
Acorn Woodpecker		5	
American Kestrel			1
American Robin	1	7	1
Ash-throated Flycatcher	11	3	19
Audubon's Warbler		6	
Bewick's Wren	4		3
Black-chinned Hummingbird		1	3
Black-headed Grosbeak	1		
Black-throated Gray Warbler			5
Blue-gray Gnatcatcher	3		2
Broad-tailed Hummingbird	2	5	3
Brown Creeper		1	
Brown-headed Cowbird	1	4	
Bushtit			2
Canyon Towhee	2	1	1
Chipping Sparrow	3	1	6
Common Nighthawk	6		5
Common Raven	2	5	1
Cooper's Hawk		1	
Cordilleran Flycatcher		5	
Dark-eyed Junco		6	
Eurasian Collared-Dove	3		
Evening Grosbeak	3	5	
Grace's Warbler		6	
Gray Flycatcher	12		10
Great Horned Owl			1
Green-tailed Towhee	3		1
Hairy Woodpecker		1	

Hammond's Flycatcher		8	
House Finch	16	16	21
House Wren		1	
Juniper Titmouse	12		11
Lesser Goldfinch	2	3	4
Mountain Chickadee	5	5	
Mourning Dove	17	4	13
Pine Siskin	10	12	6
Plumbeous Vireo	10	11	1
Pygmy Nuthatch		11	
Red-shafted Flicker	3	3	3
Rock Wren	3	1	7
Say's Phoebe	2	1	2
Spotted Towhee	17	11	12
Steller's Jay		3	
Townsend's Solitaire	1		
Turkey Vulture		1	
Violet-green Swallow			6
Virginia's Warbler		17	
Warbling Vireo		2	
Western Bluebird	15	20	5
Western Kingbird	6		7
Western Scrub-Jay	5	1	8
Western Tanager		2	
Western Wood-Pewee	10	15	
White-breasted Nuthatch	1	9	
White-winged Dove	1		7
Grand Total	**193**	**220**	**177**

The bird surveys were analyzed to determine the “birds per hour”, which is a measure of relative abundance, for each of the three study sites as well as the control sites of the comparable habitat type (Figure 5). The birds per hour were similar between the three study sites and the associated control sites. The TA-16 Burn Grounds site was slightly lower in bird per hour than the MC control sites, but not significantly lower ($t_{3,1}$=3.506, p = 0.07). Error bars were calculated for the control sites since multiple years of data were available. The birds per hour for the TA-16 Burn Grounds was within 2 standard deviations of the mean of the MC control sites (Figure 5). The TA-36 Minie Site and TA-39 Point 6 were very similar to the PJ control sites ($t_{3,1}$=0.717, p = 0.54 and $t_{3,1}$=1.274, p = 0.33).

As described in the next section, the diversity and evenness of the avian community at the TA-16 Burn Grounds were not significantly different than the MC control sites. One possible reason for the lower birds per hour measurement, albeit not significantly lower, at the TA-16 Burn Grounds was related to the control sites that were used. Selecting a control site is one of the fundamental issues when designing an ecological study. In this study the control sites are based on previous and ongoing work at LANL, and the two control sites for the MC habitat are located along the bottom of Los Alamos Canyon. The birds per hour can be slightly different when MC on a mesa-top, such as the TA-16 Burn Grounds, is compared with similar habitat in the bottom of a canyon. There are also species of birds, such as the Common Raven, that are seen in high numbers in Los Alamos Canyon due to close proximity to the townsite.

The 2013 results indicate that the relative abundance of the bird communities at the three study sites were not significantly different than the control sites.

The Shannon’s diversity indices are detailed in Table 2. The TA-16 Burn Grounds showed the largest diversity of bird species, which was expected since it is primarily MC habitat. A bootstrapping technique using 1,000 permutations was used to compare the diversity indices.

Compared to the control sites, the diversity and evenness of the TA-16 Burn Grounds were not significantly different than both the 2013 data (p=0.53 and 0.57) and the pooled data from 2011-2013 (p=0.11 and 0.17).

Compared to the control sites, the diversity of the TA-36 Minie Site was not significantly different than the 2013 data (p=0.38) and the pooled data (p=0.66). However, the evenness of the TA-36 Minie Site was significantly larger than the control sites for both the 2013 data as well as the pooled data (p=0.001 and 0.003).

Compared to the control sites, the diversity at TA-39 Point 6 was significantly larger than the 2013 data (p=0.03) and larger than the pooled data, but not significantly (p=0.13). The evenness of the TA-39 Point 6 was significantly larger than the control sites for both the 2013 data as well as the pooled data (p=0.003 and 0.017).

These results indicate that the bird diversity and evenness of the avian communities at the study sites are comparable to or greater than the control sites, with some being significantly greater. This indicates a healthy avian population at the study sites.

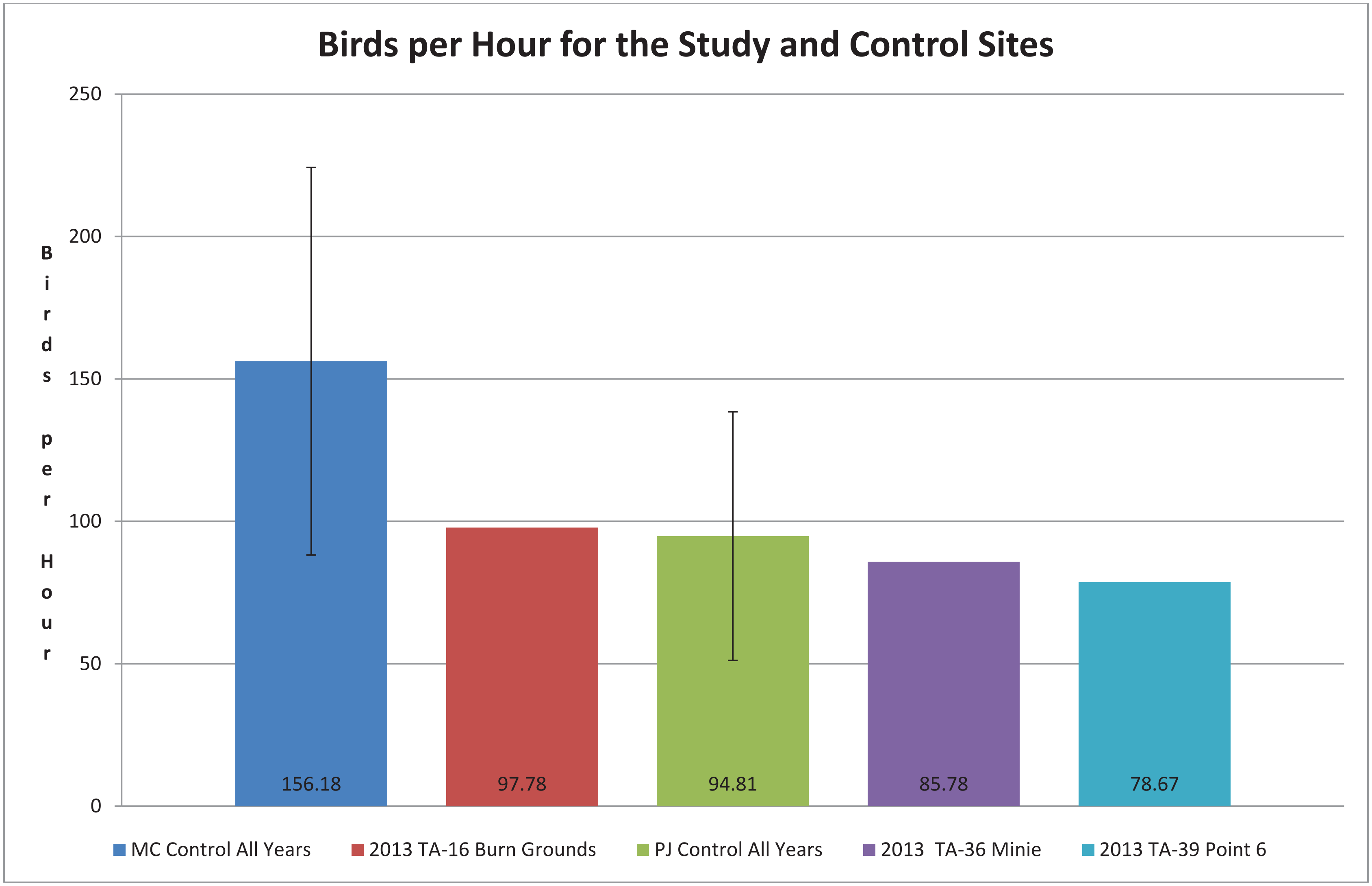


Figure 5. Birds per Hour for the Study and Control Sites. Error Bars are +/- 2 Standard Deviations. MC: Mixed Conifer Forest, PJ: Pinyon-Juniper Woodland.

Table 2. Shannon Values for the Study Sites and Control Sites; Statistically Significant Results are Bolded. MC: Mixed Conifer Forest, PJ: Pinyon-Juniper Woodland.

Transect Name	Diversity Index (H)	2013 PJ Control Sites Diversity Index (H)	All Years PJ Control Sites Diversity Index (H)	2013 MC Control Sites Diversity Index (H)	All Years MC Control Sites Diversity Index (H)
TA-36 Minie Site (PJ)	2.942	2.832	2.878		
TA-39 Point 6 (PJ)	3.09	**2.832 (p=0.03)**	2.878		
TA-16 Burn Grounds (MC)	3.304			3.383	3.501

Transect Name	Equitability Index (EH)	2013 PJ Control Sites Equitability Index (EH)	All Years PJ Control Sites Equitability Index (EH)	2013 MC Control Sites Equitability Index (EH)	All Years MC Control Sites Equitability Index (EH)
TA-36 Minie Site (PJ)	0.729	**0.5143 (p=0.001)**	**0.4805 (p=0.003)**		
TA-39 Point 6 (PJ)	0.709	**0.5143 (p=0.003)**	**0.4805 (p=0.017)**		
TA-16 Burn Grounds (MC)	0.6983			0.6269	0.6269

In addition to supporting federally protected species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for understanding migratory bird conservation. Of the 55 species detected at the three study sites, 54 are protected under the MBTA. Additionally, two of the species detected at the three study sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those two species are the Juniper Titmouse and Grace’s Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980. Another conservation tool used in migratory bird management is the Birder’s Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three study sites are on the top 100 list. These two species are the Virginia’s Warbler and Grace’s Warbler.

Avian Nestbox Network

In 1997, an avian nestbox monitoring network was established on LANL, Los Alamos County land, and U.S. Forest Service land to investigate the health and condition of cavity-nesting bird populations on the Pajarito Plateau. The purpose of this study was to evaluate the magnitude and sources of ecological risks from contaminants and other environmental stressors for cavity-nesting birds at LANL. The main objective was to evaluate the ecological and physiological costs of exposure to various contaminants at LANL and their potential impact on population processes. In 2011, nestboxes were added to the TA-36 Minie Site and TA-39 Point 6 to investigate any potential impacts to cavity-nesting birds (Figures 6 and 7).

On Sept 17th 2012, the Environmental Protection Division received notification from the Waste Facilities Operations Facility Operations Director of potential fire suppression/tree removal activities near archaeological sites near the TA-36 Minie firing site. Nestboxes were removed from trees as part of the fuels mitigation activities. These nestboxes were replaced for the 2013 breeding season and monitoring resumed at TA-36 Minie Site for the summer breeding season. However, the habitat was significantly impacted in the area around TA-36 Minie Site by the removal of trees.

Due to the drought and the lower elevation of the nestboxes at TA-39 Point 6, no birds nested in the nestboxes in 2013. However, TA-36 Minie Site had two nests in the nestboxes in 2013. There was one Mountain Bluebird nest that hatched four eggs and one Western Bluebird nest that presumably hatched and fledged nestlings. Due to the extreme drought conditions in 2013, field work was under fire restrictions and nestboxes were not checked until July 1st, thus all baseline monitoring measurements were not collected. Due to the small sample size, no statistical comparisons can be made at this time to the over 500 nestboxes located throughout LANL and the Pajarito Plateau. However, due to the dry summer of 2013, most locations in the avian nestbox network had a decrease in hatching and fledgling success. For example, the percent of eggs hatched in 2013 was 68.12% compared to all previous years hatching success of 77-95%. Fledgling success was 67.55%, which in our study is highly dependent on elevation of the location. However, there are not noticeable differences in the four nests total that have hatched in the last two years at the TA-36 Minie Site, with a 100% hatch and fledge rate.

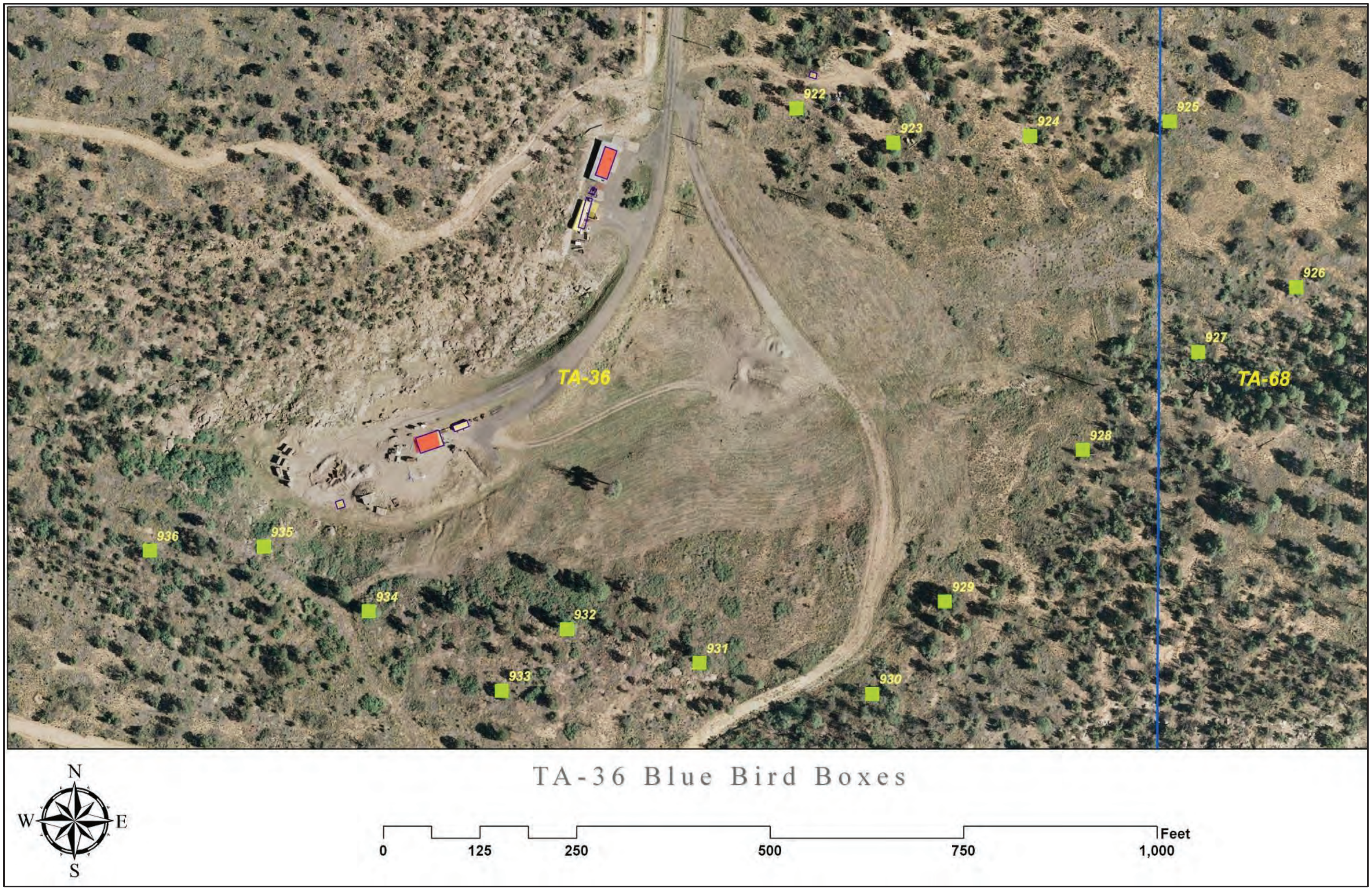


Figure 6. Avian Nestboxes Located at TA-36 Minie Site.

Figure 7. Avian Nestboxes Located at TA-39 Point 6.

Management Recommendations

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL's avifauna at the three study sites, contribute to meeting the Department of Energy's commitments under the MBTA, and allow LANL to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

We'd like to thank Leslie Hansen, David Keller, Hallie Mahowald, and Luciana Vigil-Holterman for comments on earlier versions of this report and Anne Jacobs, Maria Musgrave, Audrey Smith, and Kari Schoenberg for field help during this project.

Literature Cited

Hammer, Ø., Harper, D.A.T., and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, NM.

Hathcock, C.D. and D.C. Keller. 2012. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2012. LA-UR-12-25120. Los Alamos National Laboratory, Los Alamos, NM.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, NM.

Shannon C.E. 1948. A Mathematical Theory of Communication. Bell Syst. Tech. J. 27:379-423.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Wells, J.V. 2007. Birder's Conservation Handbook: 100 North American Birds At Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

17. Hathcock, C.D., October 2014. *Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-14-28161. OSTI Identifier 1160102. (Hathcock 2014)

Title: Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Author(s): Hathcock, Charles Dean

Intended for: Report
Environmental Programs

Issued: 2014-10-20

October 2014

Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Table of Contents

Executive Summary

Los Alamos National Security, LLC (LANS) biologists in the Environmental Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year monitoring program for migratory birds in 2013 to monitor avifauna at two open detonation sites and one open burn site at LANL. The objectives of this on-going study are to monitor patterns and trends of bird abundance and diversity over time at these sites. LANS biologists completed the second year of this effort in 2014.

Three surveys were completed at each of the study sites at the Technical Area (TA) 36 Minie Site, the TA-39 Point 6, and the TA-16 Burn Ground between May and July 2014. A total of 588 birds representing 54 species were recorded. Of the 54 species detected at the three study sites, all but one is protected under the Migratory Bird Treaty Act (MBTA).

Results from 2014 indicate that the avian abundance and diversity at the three study sites were comparable to or significantly greater than that of the control sites. Continued monitoring will produce trends over time in avian abundance and diversity that can be compared to local, regional, and national data.

Introduction

As part of the Resource Conservation and Recovery Act permitting process at LANL for two open detonation sites, the TA-36 Minie Site and TA-39 Point 6, and one open burn site, the TA-16 Burn Ground, an avian monitoring program was started in 2013 (Hathcock and Fair 2013). The goal was to monitor avian use of the habitat surrounding the open detonation and open burning sites and compare their use to other locations at LANL in the same habitat type. Comparisons were made to control sites which have been surveyed since 2011 (Hathcock et al. 2011; Hathcock and Keller 2012).

LANS biologists used standard point count methodology to record avian density and diversity along transects in the three study sites and associated control sites during the summer of 2014. Summer surveys provide information about what migratory birds are breeding at the sites. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with regional and national trends in bird populations. They also can be correlated to changes in the natural environment at LANL.

Methods

Field Methods

Point count surveys along a transect were chosen as the most rigorous method to monitor patterns of bird abundance and richness in habitats found at two open detonation sites and one open burning site at LANL. This method is already used at other LANL locations for long-term monitoring. The surveys were conducted along transects in the forested, undeveloped land surrounding the study sites (Figures 1–3). The habitat types around the sites are pinyon-juniper woodland (PJ) for the sites at TA-36 and TA-39 and mixed conifer forest (MC) for the site at TA-16. These habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The three study sites were compared to control sites at LANL. The control sites (Figure 4) are monitored annually in ongoing surveys that have been conducted at LANL since 2011 as described in Hathcock and Keller (2012). The PJ study sites at TA-36 and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, proximity to developed areas, and in being situated on the mesa top. The MC study site at the TA-16 Burn Ground is similar in elevation and overstory vegetation to the MC control sites, but is dissimilar in that the study site is located on a mesa top and the control sites are located in the bottom of a canyon in TA-43, TA-2, and TA-21. Being the bottom of a canyon, there are some differences in understory vegetation with a greater understory present at the control sites.

Transects are approximately 2.0 to 2.5 km in length and allow for nine survey points spaced approximately 250 m apart. These survey routes and points may change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys is May 1st through August 15. Ideally the breeding bird surveys should take place the second week of May, June, and July. This protocol requires a total of three surveys per study site and surveys should be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys.

- Each survey consists of nine points along the transect, ~ 250 m apart
- At each point of the survey the surveyor will look and listen for 5 minutes, noting any birds encountered. The distance for observations is considered as an “unlimited-distance circular plot”; however, noting the distance to each bird out to 100 m should be done. Care is needed to ensure that individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, any birds encountered that have not otherwise been counted from a previous point or future point should also be noted. The surveyor’s main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Surveys should not be conducted during rain events or wind greater than 25 kph.
- All birds encountered will be recorded on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- The “NOTES” section should be used for indicating any potentially important aspects of the survey that may affect the data. Examples include: excess noise from nearby equipment and

vehicles or aircraft that make it hard to hear the birds. Also, noting other wildlife or evidence of wildlife that could be used for further reference should be recorded.

Statistical Methods

The data were summarized to look at trends in avian abundance and diversity for the three study sites and the control sites. To compare relative abundances between years and sites, the "birds per hour" was calculated for each site. This was calculated by taking the total number of birds detected per survey and dividing by the total number of minutes surveyed. The result is multiplied by 60 to get the number of birds per hour.

The means of the study sites and control sites were compared using the Mann-Whitney U non-parametric two sample test. The data were not normally distributed thus the non-parametric test was used. Probability levels at 0.05 or less were considered significant.

The Shannon's diversity index (*H*) (Shannon 1948) was used to examine avian community diversity by location and habitat type. This diversity index is a popular measure in ecology. The Shannon's *H* can range from 0.0 to 4.6, where larger values represent increasing diversity. *H* is calculated using the following formula:

$H = -1 (p_i (\ln (p_i))$

Where p_i is a percentage value of a specific species in the total population and ln is the natural log.

Another useful measure is the Shannon's equitability estimate (E_H) (Shannon 1948) which is a measure of evenness in the population. This measures the evenness with which individuals are divided among the taxa present. This measure ranges from 0 to 1 where one represents a completely even community in which all species' abundances are equal. The Shannon's E_H is calculated using the following formula:

$E_H = H/\ln S$

Where S is species count, ln is the natural log, and *H* is the Shannon's diversity index.

To compare indices, a bootstrapping technique was used and probability levels at 0.05 or less were considered significant. A general description of the technique is where two samples, A and B, are pooled. Then 1,000 random pairs of samples (Ai and Bi) are taken from this pool, with the same numbers of individuals as in the original two samples. For each replicate pair, the diversity indices div(Ai) and div(Bi) are computed. The number of times |div(Ai)-div(Bi)| exceeds or equals |div(A)-div(B)| indicates the probability that the observed difference could have occurred by random sampling from one parent population as estimated by the pooled sample. A small probability value less than 0.05 indicates a significant difference in the diversity index between the two samples. The diversity indices and the bootstrap comparisons between indices were computed using the PAST statistical software (Hammer et al. 2001).

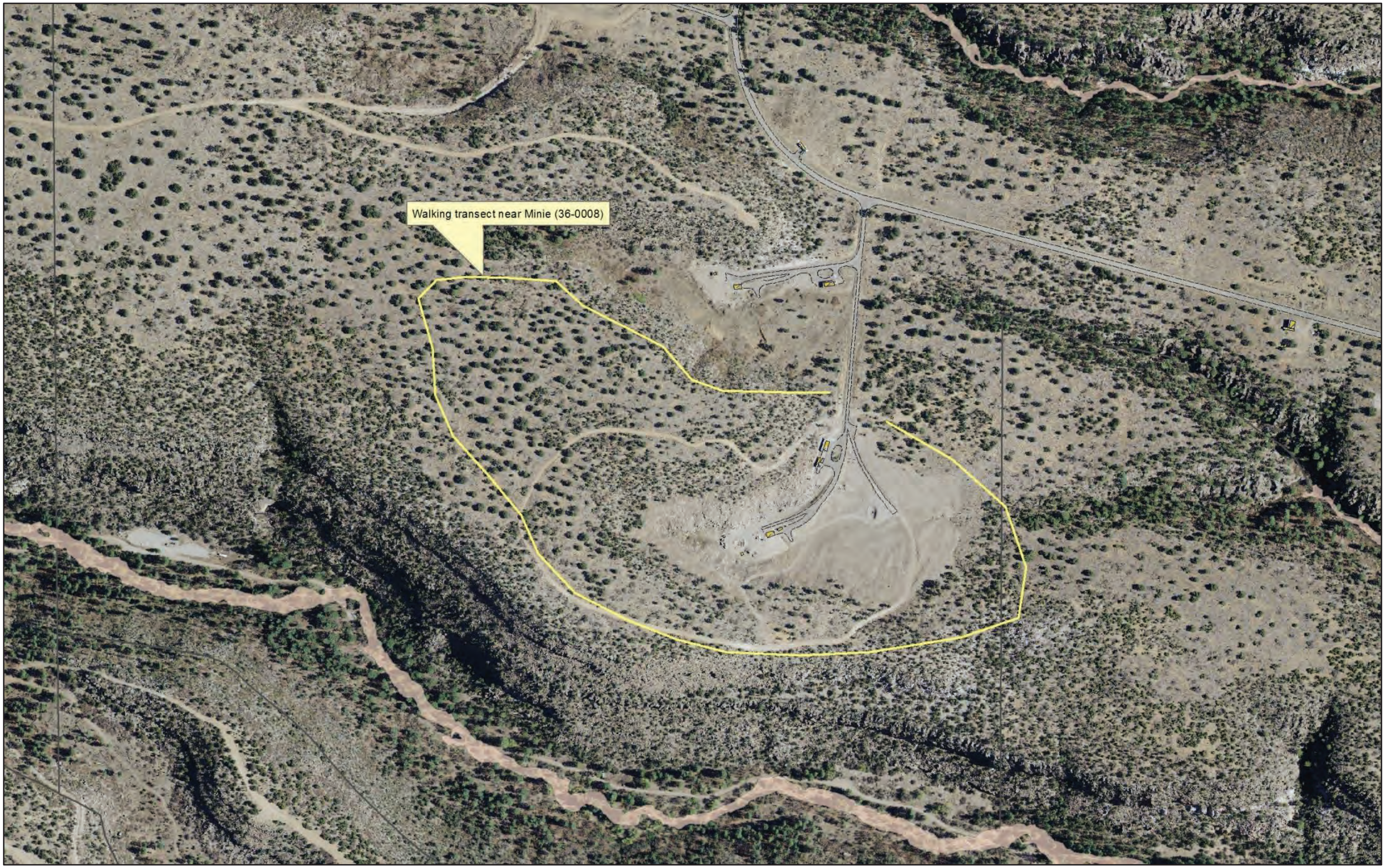


Figure 1. Field working map for the transect around the TA-36 Minie Site.

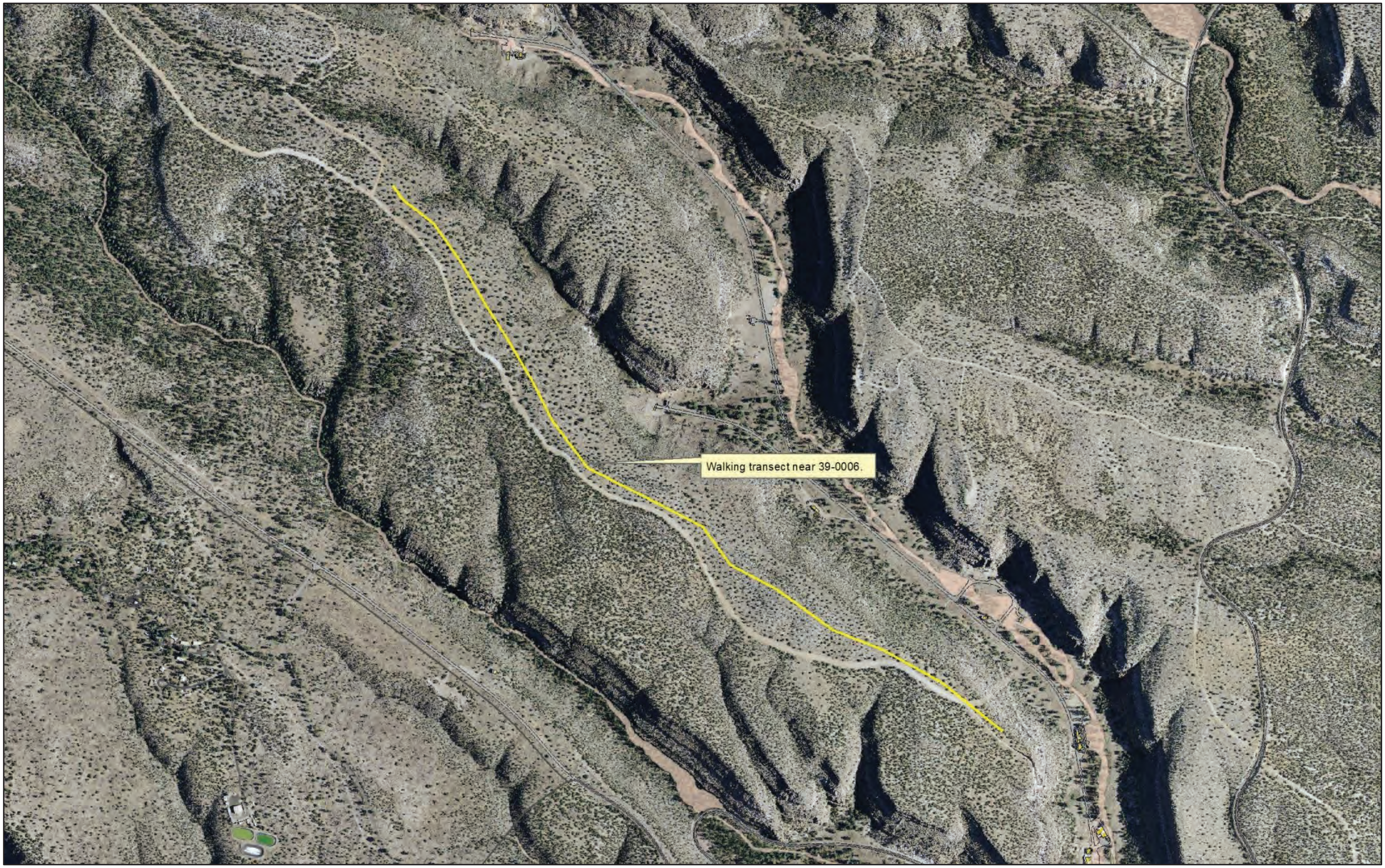


Figure 2. Field working map for the transect around the TA-39 Point 6.

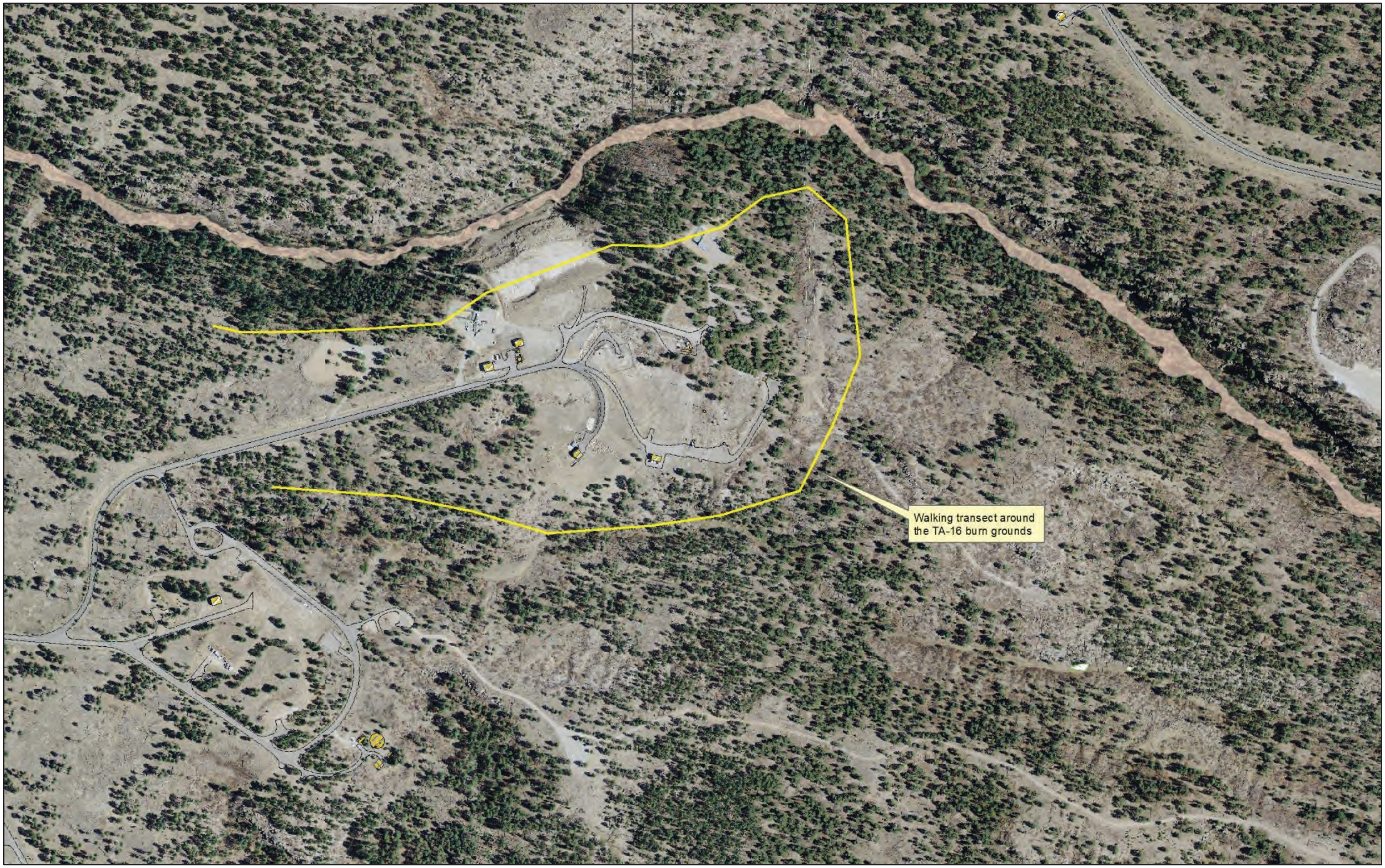


Figure3. Field working map for the transect around the TA-16 Burn Ground.

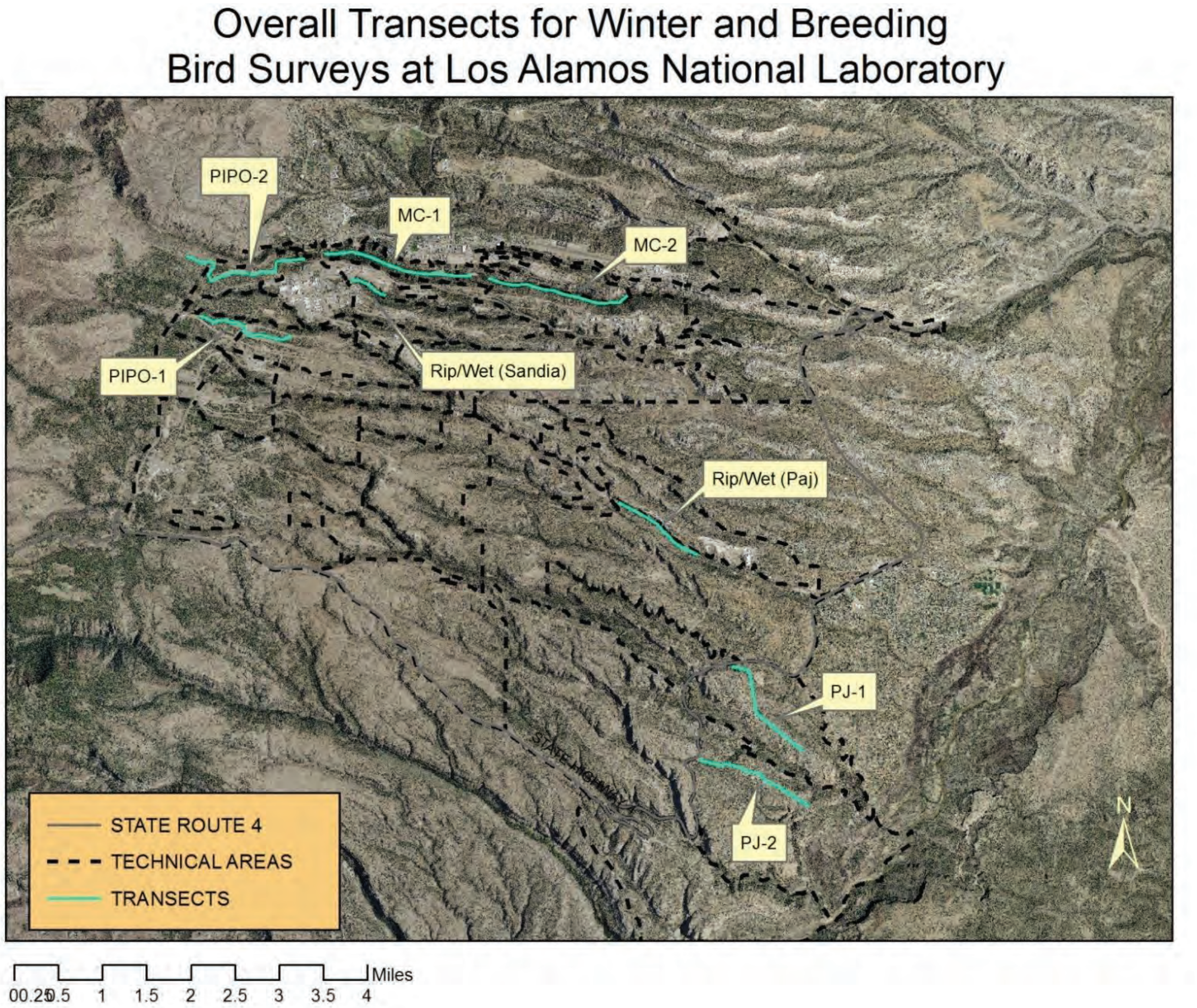


Figure 4. Control transects from ongoing avian monitoring around LANL (Hathcock and Keller 2012).
MC: Mixed Conifer Forest, PIPO: Ponderosa Pine Forest, PJ: Pinyon-Juniper Woodland, Rip/Wet: Riparian / Wetland.

Results and Discussion

Three surveys were completed at each of the three study sites and the associated control sites between May and July 2014. A total of 588 birds representing 54 species were recorded at the three study sites. A full account of the 2013–2014 data is detailed in Table 1.

The bird surveys were analyzed to determine the birds per hour, which is a measure of relative abundance, for each of the three study sites as well as the control sites of the comparable habitat type (Figure 5). The mean birds per hour at the TA-16 Burn Ground site was slightly lower than the MC control sites, but not significantly lower (Mann-Whitney U: $Z = -1.0371$, $p = 0.30$). The TA-36 Minie Site and TA-39 Point 6 birds per hour means were slightly higher that the PJ control sites, but not significantly higher (Mann-Whitney U: $Z = 0.7913$, $p = 0.43$ and $Z = 1.0787$, $p = 0.28$). The mean values with error bars corresponding to +/- 1 standard deviation for both years are represented in Figure 5. The 2014 results indicate that the relative abundance of the bird communities at the three study sites was not significantly different than the control sites.

In the first year of the study, the mean birds per hour at the TA-16 Burn Ground was significantly lower than the MC Control sites (Mann-Whitney U: $Z = -2.2132$, $p = .026$), but the difference lessened and was no longer significant in 2014. The mean birds per hour at the TA-16 Burn Ground were similar between years, but the control site numbers dropped in 2014.

The Shannon's diversity indices are detailed in Table 2. The TA-16 Burn Ground showed the largest diversity of bird species, which was expected since it is primarily MC habitat, which is known to be more diverse than PJ from past studies (Hathcock and Keller 2012).

Compared to the MC control sites, the diversity and evenness of the TA-16 Burn Ground were not significantly different ($p=0.24$ and 0.26).

Compared to the PJ control sites, the diversity of the TA-36 Minie Site was not significantly different ($p=0.15$); however, the evenness of the TA-36 Minie Site was significantly larger than the PJ control sites ($p=0.024$).

Compared to the PJ control sites, the diversity at TA-39 Point 6 was not significantly different ($p=0.38$); however, the evenness of the TA-39 Point 6 was significantly larger than the PJ control sites ($p=0.12$).

These results indicate that the bird diversity and evenness of the avian communities at the study sites are comparable to or greater than the control sites, with some being significantly greater. This suggests a healthy avian population at the study sites.

Table 1. Birds Recorded at the Three Study Sites in 2013–2014

Species	2013	2014	2013	2014	2013	2014
	TA-36	TA-36	TA-39	TA-39	TA-16	TA-16
	Pinyon-Juniper Woodland		Pinyon-Juniper Woodland		Mixed Conifer Forest	
Acorn Woodpecker					5	
American Kestrel			1			
American Robin	1	1	1	1	7	
Ash-throated Flycatcher	11	5	19	11	3	5
Audubon's Warbler		2			6	5
Bewick's Wren	4	8	3	10		
Black-chinned Hummingbird		1	3	2	1	
Black-headed Grosbeak	1	3		2		
Black-throated Gray Warbler			5	6		
Blue-gray Gnatcatcher	3	14	2			6
Broad-tailed Hummingbird	2	1	3	1	5	11
Brown Creeper					1	
Brown-headed Cowbird	1				4	1
Bushtit		2	2	14		
Canyon Towhee	2		1	1	1	
Chipping Sparrow	3	16	6	6	1	5
Clark's Nutcracker						4
Common Nighthawk	6		5	1		
Common Raven	2	5	1		5	6
Cooper's Hawk					1	
Cordilleran Flycatcher					5	10
Dark-eyed Junco					6	2
Downy Woodpecker						1
Eurasian Collared-Dove	3					
Evening Grosbeak	3				5	
Grace's Warbler					6	4
Great Horned Owl		3	1			
Green-tailed Towhee	3	1	1			
Hairy Woodpecker					1	1
Hammond's Flycatcher					8	9
Hermit Thrush						4
House Finch	16	17	21	4	16	2

	2013	2014	2013	2014	2013	2014
	TA-36	TA-36	TA-39	TA-39	TA-16	TA-16
Species	Pinyon-Juniper Woodland		Pinyon-Juniper Woodland		Mixed Conifer Forest	
House Wren					1	1
Juniper Titmouse	12		11	13		
Lesser Goldfinch	2	6	4	12	3	
Mountain Bluebird		2		4		
Mountain Chickadee	5	2			5	8
Mourning Dove	17	17	13	22	4	
Northern Mockingbird				1		
Pine Siskin	10	2	6		12	4
Plumbeous Vireo	10	10	1		11	16
Pygmy Nuthatch					11	13
Red Crossbill				2		2
Red-shafted Flicker	3	1	3	2	3	4
Rock Wren	3	3	7	10	1	2
Say's Phoebe	2	1	2	1	1	
Spotted Towhee	17	8	12	6	11	18
Steller's Jay					3	2
Townsend's Solitaire	1					
Turkey Vulture					1	
Violet-green Swallow		5	6	4		2
Virginia's Warbler					17	11
Warbling Vireo					2	9
Western Bluebird	15	11	5	19	20	20
Western Kingbird	6	13	7	6		
Western Scrub-Jay	5	1	8	10	1	
Western Tanager		2		2	2	3
Western Wood-Pewee	10	8		4	15	10
White-breasted Nuthatch	1	4			9	8
White-throated Swift				1		
White-winged Dove	1	5	7	5		
Grand Total	193	186	177	193	220	209

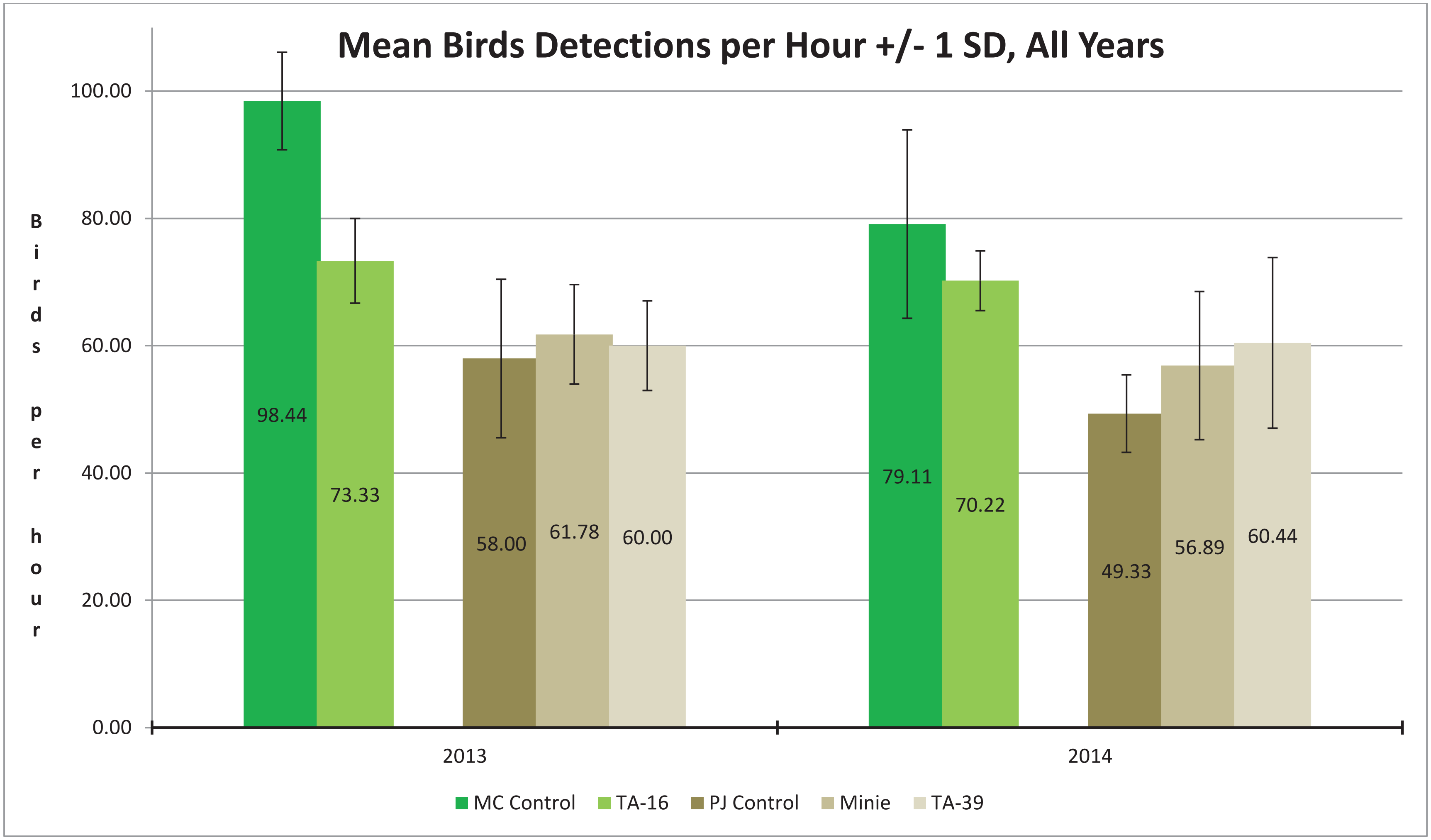


Figure 5. Birds per hour for the study and control sites. Error bars are +/- 1 standard deviation. MC: Mixed Conifer Forest, PJ: Pinyon-Juniper Woodland.

Table 2. Shannon Values for the Study Sites and Control Sites; Statistically Significant Results are Bolded.

Transect Name	Diversity Index (H)	2014 PJ Control Sites Diversity Index (H)	2014 MC Control Sites Diversity Index (H)
TA-36 Minie Site (PJ)	3.141	2.99	
TA-39 Point 6 (PJ)	3.073	2.99	
TA-16 Burn Ground (MC)	3.207		3.327
Transect Name	Equitability Index (EH)	2014 PJ Control Sites Equitability Index (EH)	2014 MC Control Sites Equitability Index (EH)
TA-36 Minie Site (PJ)	**0.7009 (p=0.024)**	0.5525	
TA-39 Point 6 (PJ)	**0.6967 (p=0.012)**	0.5525	
TA-16 Burn Ground (MC)	0.679		0.7487

MC: Mixed Conifer Forest, PJ: Pinyon-Juniper Woodland.

In addition to supporting federally protected species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 54 species detected at the three study sites, all but one are protected under the MBTA. Additionally, three of the species detected at the three study sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those three species are the Pinyon Jay, Juniper Titmouse, and Grace's Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980. Another conservation tool used in migratory bird management is the Birder's Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Three species detected at the three study sites are on the top 100 list. These three species are the Pinyon Jay, Virginia's Warbler, and Grace's Warbler.

Avian Nestbox Network

In 1997, an avian nestbox monitoring network was established on LANL, County of Los Alamos land, and U.S. Forest Service land to investigate the health and condition of cavity-nesting bird populations on the Pajarito Plateau. The purpose of this study was to evaluate the magnitude and sources of ecological risks from past LANL releases and other environmental stressors for cavity-nesting birds. The main objective was to evaluate the ecological and physiological costs of exposure to various constituents at LANL and their potential impact on population processes. In 2011, nestboxes were added to the TA-36 Minie Site and TA-39 Point 6 to investigate any potential impacts to cavity-nesting birds (Figures 6 and 7). Only data from the target species are reported herein, Western and Mountain Bluebirds and the Ash-throated Flycatcher.

During the 2014 nesting season, 15 nestboxes at TA-36 and 12 nestboxes at TA-39 were actively monitored. At TA-36, 10 nests were found and 4 of the nests fledged young successfully. This was an occupancy rate of 66% with a 40% success rate. Two of the nests were inhabited by Mountain Bluebirds and the other eight nests were inhabited by Western Bluebirds.

At TA-39, two nests were found and one of the nests fledged young successfully. This was an occupancy rate of 16%. One nest was inhabited by a Western Bluebird and the other was inhabited by an Ash-throated Flycatcher. Nearby nestboxes in lower Ancho Canyon also had low occupancy rates.

The overall avian nestbox network had 627 nestboxes in 2014 that were actively monitored. There were 126 active nests found and 87 of those nests fledged young successfully. This was an overall occupancy rate of 20% with a 69% success rate.

The occupancy and success rates at TA-36 were similar to the results in the overall network. More years of data are needed to begin to look at the results in a more robust manner.

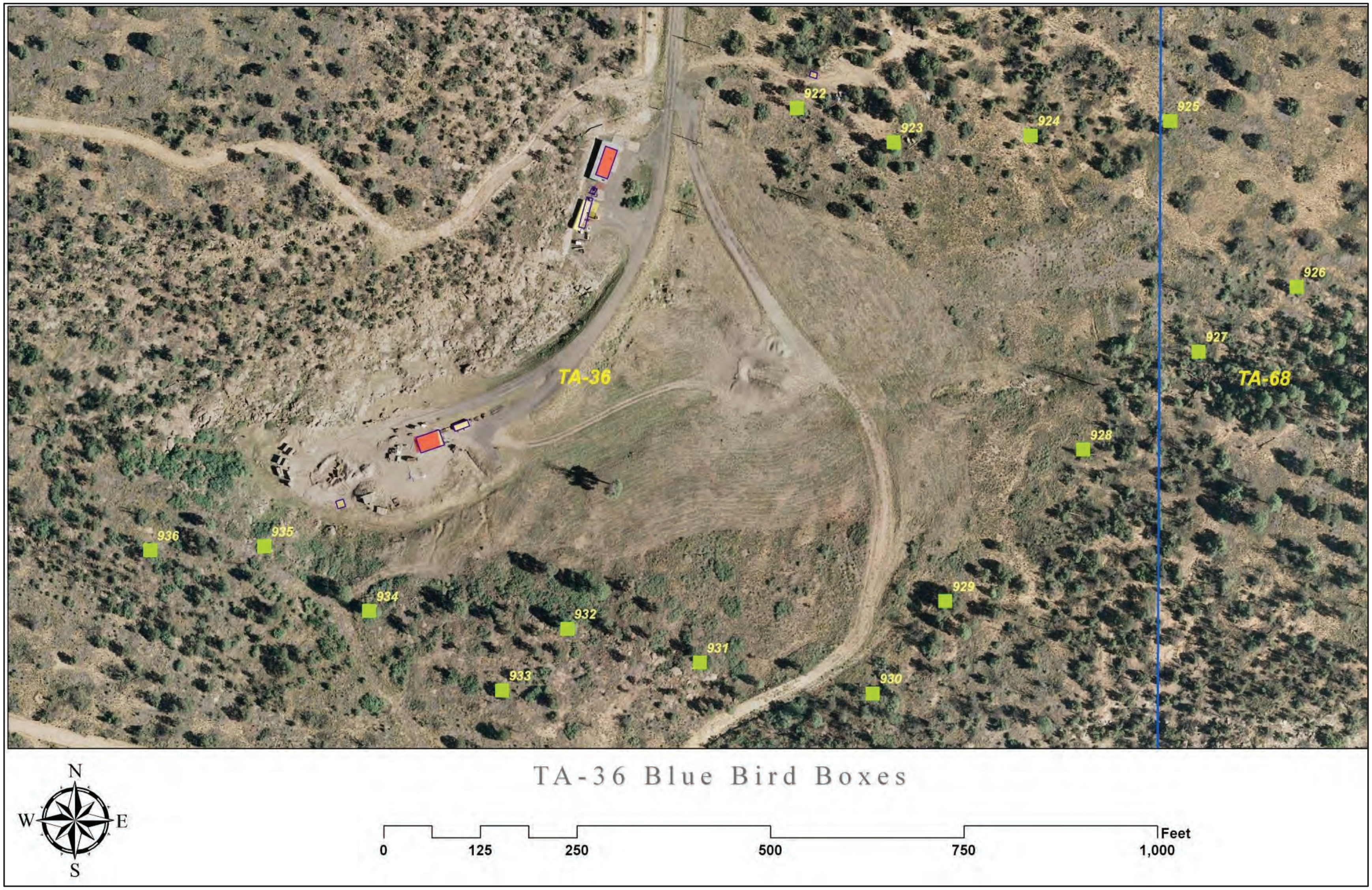


Figure 6. Avian nestboxes located at TA-36 Minie Site.

Figure 7. Avian nestboxes located at TA-39 Point 6.

Management Recommendations

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL's avifauna at the three study sites, contribute to meeting the Department of Energy's commitments under the MBTA, and allow LANS to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

I thank Leslie Hansen, Luciana Vigil-Holterman, and Marjorie Wright for comments on earlier versions of this report and David Keller, Kelsee Hurshman, Kelly Hutchins, Maria Musgrave, Emily Phillips, and Audrey Smith for field help and data entry support during this project.

Literature Cited

Hammer, Ø., D.A.T. Harper, and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., and D.C. Keller. 2012. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2012. LA-UR-12-25120. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. LA-UR-13-27825. Los Alamos National Laboratory, Los Alamos, New Mexico.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, New Mexico.

Shannon C.E. 1948. A Mathematical Theory of Communication. Bell Syst. Tech. J. 27:379–423.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Wells, J.V. 2007. Birder's Conservation Handbook: 100 North American Birds At Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

18. Hathcock, C.D., October 2015. *Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-15-28296. (Hathcock 2015)

LA-UR-15-28296

Title: Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Author(s): Hathcock, Charles Dean

Intended for: Report
Environmental Programs

Issued: 2015-10-23 (Draft)

LA-UR-15-xxxxx

October 2015

Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Charles D. Hathcock,
Environmental Stewardship Services, Los Alamos National Laboratory

Prepared for: U.S. Department of Energy, National Nuclear Security Administration,
Los Alamos Field Office

*An Affirmative Action/Equal Opportunity Employe*r

Contents

Tables

Figures

Executive Summary

Los Alamos National Security, LLC (LANS) biologists in the Environmental Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna at two open detonation sites and one open burn site at LANL. Results from these efforts are compared among years and to avifauna monitoring conducted at other areas across LANL. The objectives of this study are to determine whether LANL firing site operations impact bird abundance or diversity. LANS biologists completed the third year of this effort in 2015.

Three avian point count surveys were completed at each of the study sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground between May and July 2015. A total of 881 birds representing 55 species were recorded at the study sites. All of the 55 species detected at the three study sites are protected under the Migratory Bird Treaty Act (MBTA). Three avian point count surveys were also completed at each of the control sites between May and July 2015.

The data were analyzed to determine abundance using an estimate of birds detected per hour, and to calculate the species diversity. The number of birds detected in three different feeding guilds were compared to examine functional community differences among areas.

Results from 2015 monitoring indicate a general increase in bird abundance across LANL. This is likely indicative of effects from greater precipitation in the winter of 2014 into the spring and early summer of 2015. Precipitation drives habitat suitability which can potentially drive animal populations using the addition resources. The link between moisture and habitat quality for a migratory bird indicates that the availability of high-quality habitats is dynamic due to variation in precipitation among seasons and years (Smith et al. 2010). There were no significant differences in bird abundance when comparing the three study sites to their respective controls. The species diversity indices at Minie site and TA-39 were not significantly different than their controls in 2015. The TA-16 burn ground bird diversity was significantly lower ($p < 0.01$) than its mixed conifer (MC) control, with 12 fewer species present. Also, there were no significant differences in the mean number of birds per feeding guild when comparing the three study sites to their respective controls in 2015.

In addition to avian point counts, nestboxes were monitored around all three study sites. These data are compared to the avian nestbox monitoring network, which was established in 1997 to investigate the occupancy rates and reproductive success of cavity-nesting bird populations. In 2015 there was an overall occupancy rate of 40% with a 66% success rate for the avian nestbox network at LANL. The percent occupancy and nest success were higher at both Minie site and TA-16, suggesting that the firing site operations are not negatively affecting nest success. Further study is needed at TA-39 because only one of 12 nestboxes at TA-39 was occupied. There may be an issue with nestbox placement at TA-39 and this issue will be investigated further in 2016. Continued monitoring will produce data that can be compared to local, regional, and national trends over time.

Introduction

As part of the Resource Conservation and Recovery Act permitting process at LANL for two open detonation sites (TA-36 Minie site and TA-39 point 6), and one open burn site, (TA-16 burn ground), an avian monitoring program was started at these locations in 2013 (Hathcock and Fair 2013). The goal is to compare avian abundance, diversity, and productivity at these sites to other locations at LANL of the same habitat type. Comparisons are made to control sites that have been surveyed since 2011 (Hathcock et al. 2011).

LANS biologists used standard point count methodology to record avian abundance and diversity along transects at the three study sites and associated control sites during the summer of 2015. Summer surveys provide information about what birds are breeding at the sites. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with regional and national trends in bird populations. They also can be correlated to changes in the natural environment at LANL.

In addition to avian point counts, nestboxes are monitored around all three study sites to investigate any potential impacts to occupancy rates and productivity of cavity-nesting birds. These data are compared to the LANL avian nestbox monitoring network, which was established in 1997.

Methods

Field Methods for Point Count Surveys

The point count surveys were conducted along single transects in the forested, undeveloped land surrounding the study sites (Figures 1–3). The habitat types around the sites are pinyon-juniper (PJ) for the sites at TA-36 and TA-39 and MC at TA-16. These habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The three study sites were compared to control sites at LANL of the same habitat type. The control sites (Figure 4) are monitored annually in ongoing surveys that have been conducted at LANL since 2010 as described in Hathcock et al. (2011). Each habitat type control contains two replicate transects that are monitored in the same way as the study sites with the same number of points and during the same time periods. In each survey month, all study site and control site transects are randomized and surveyed following the random order.

The PJ study sites at TA-36 and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, proximity to developed areas, and in being situated on the mesa top. The MC study site at the TA-16 burn ground is similar in elevation and overstory vegetation to the MC control sites, but is dissimilar in that the study site is located on a mesa top and the control sites are located in the bottom of a canyon in TA-43, TA-2, and TA-21. Being the bottom of a canyon, there are some differences in understory vegetation with a greater understory present at the control sites.

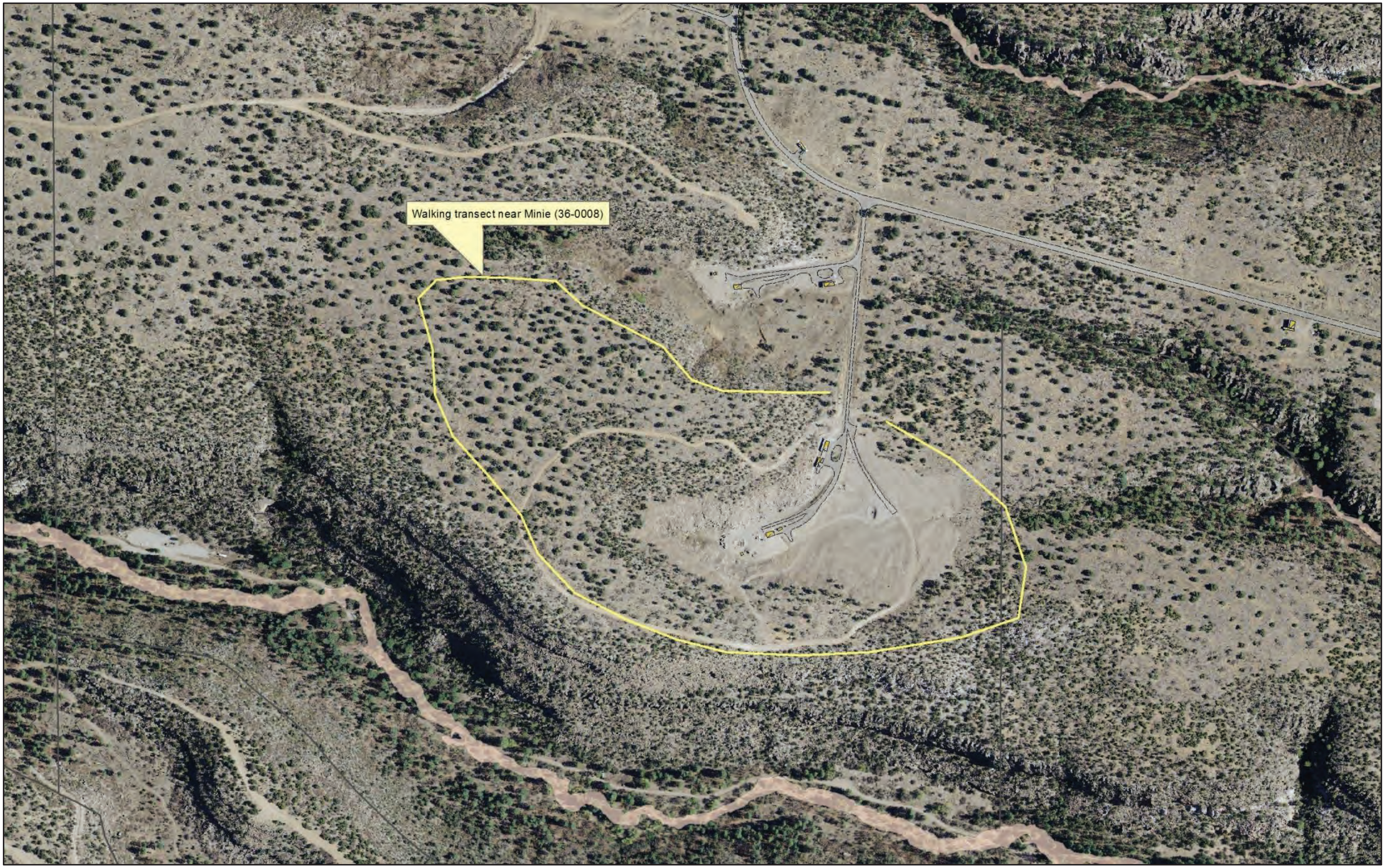


Figure 1. Field working map for the breeding bird survey transect around the TA-36 Minie site.

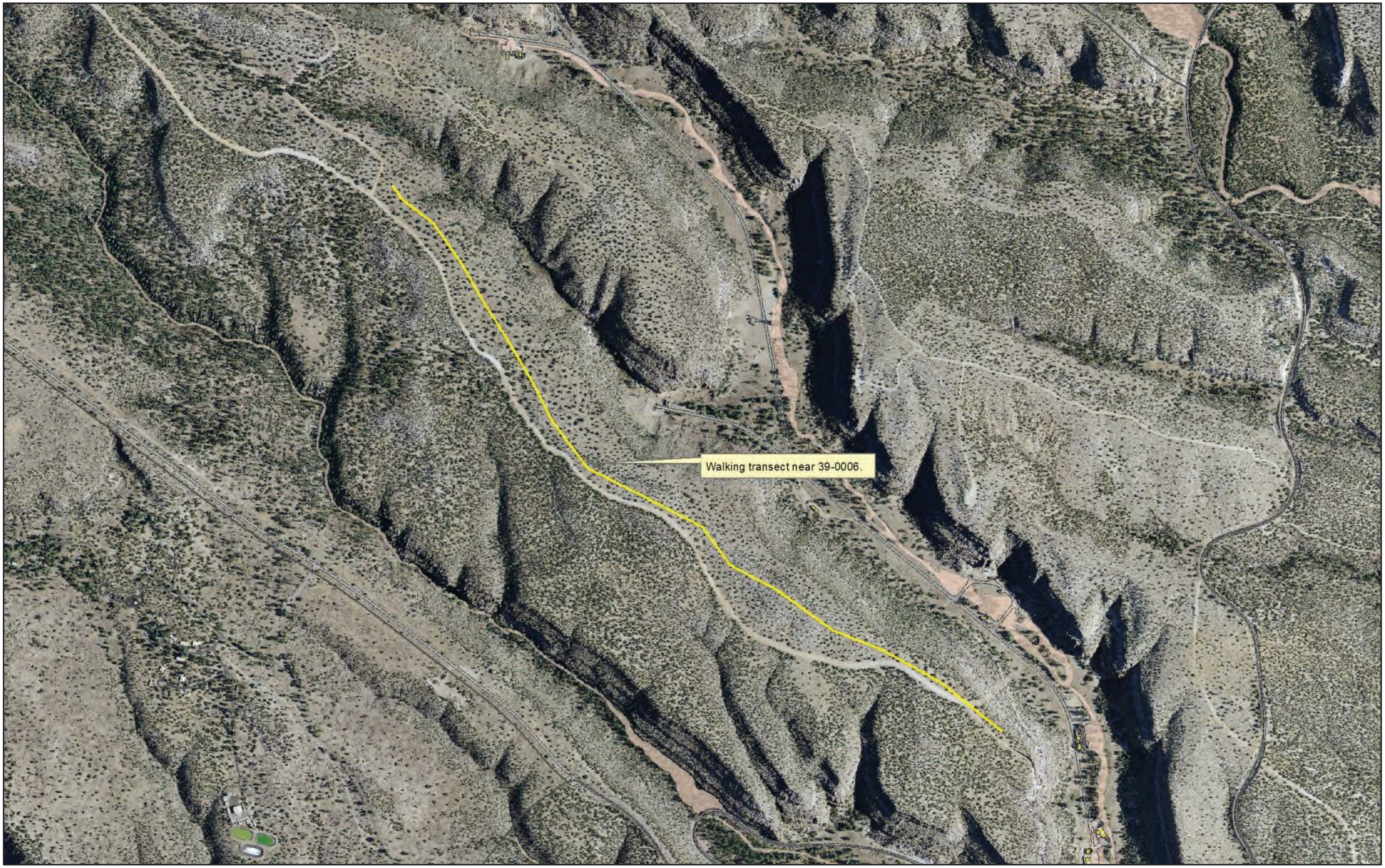


Figure 2. Field working map for the breeding bird survey transect around the TA-39 point 6.

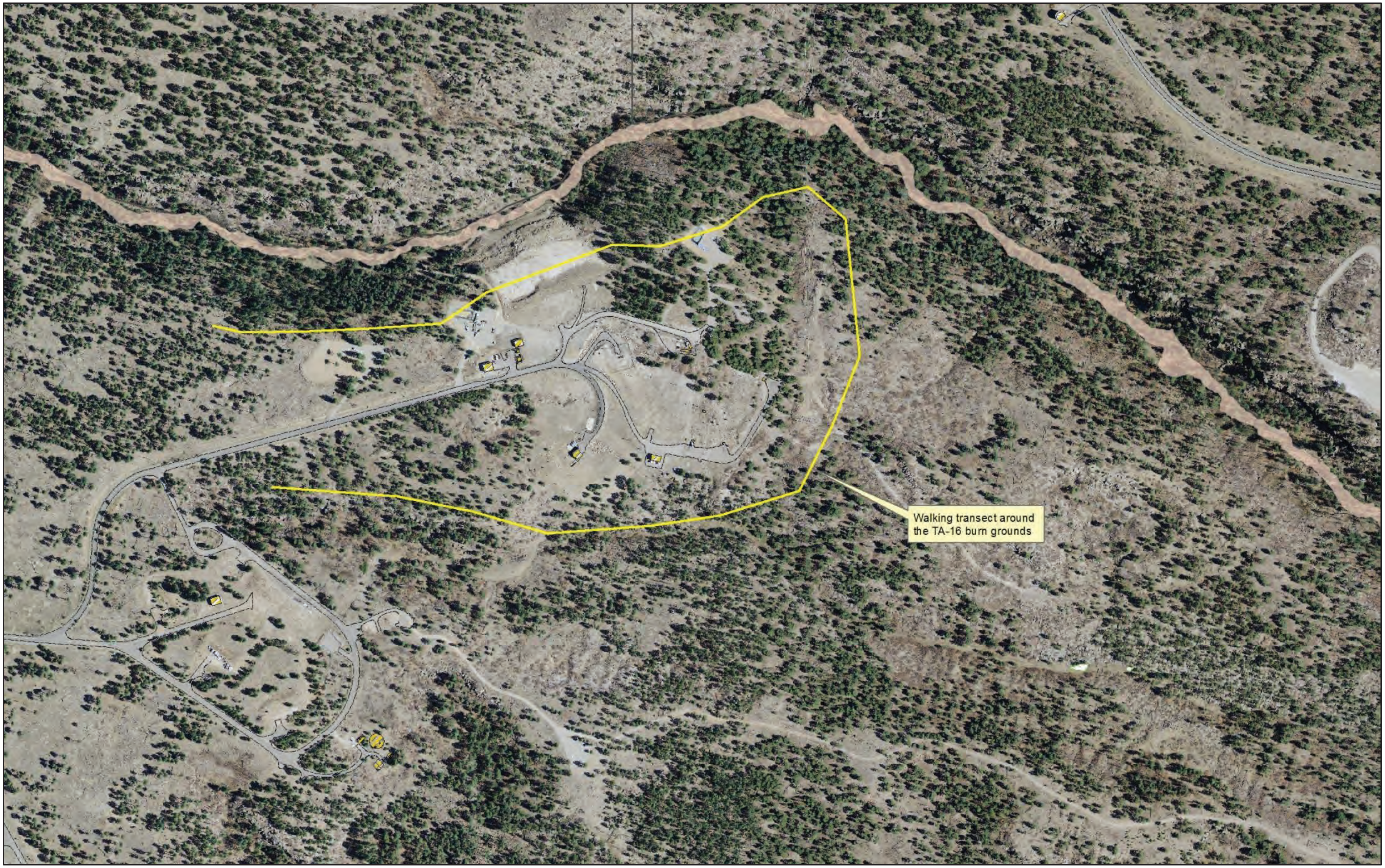


Figure 3. Field working map for the breeding bird survey transect around the TA-16 burn ground.

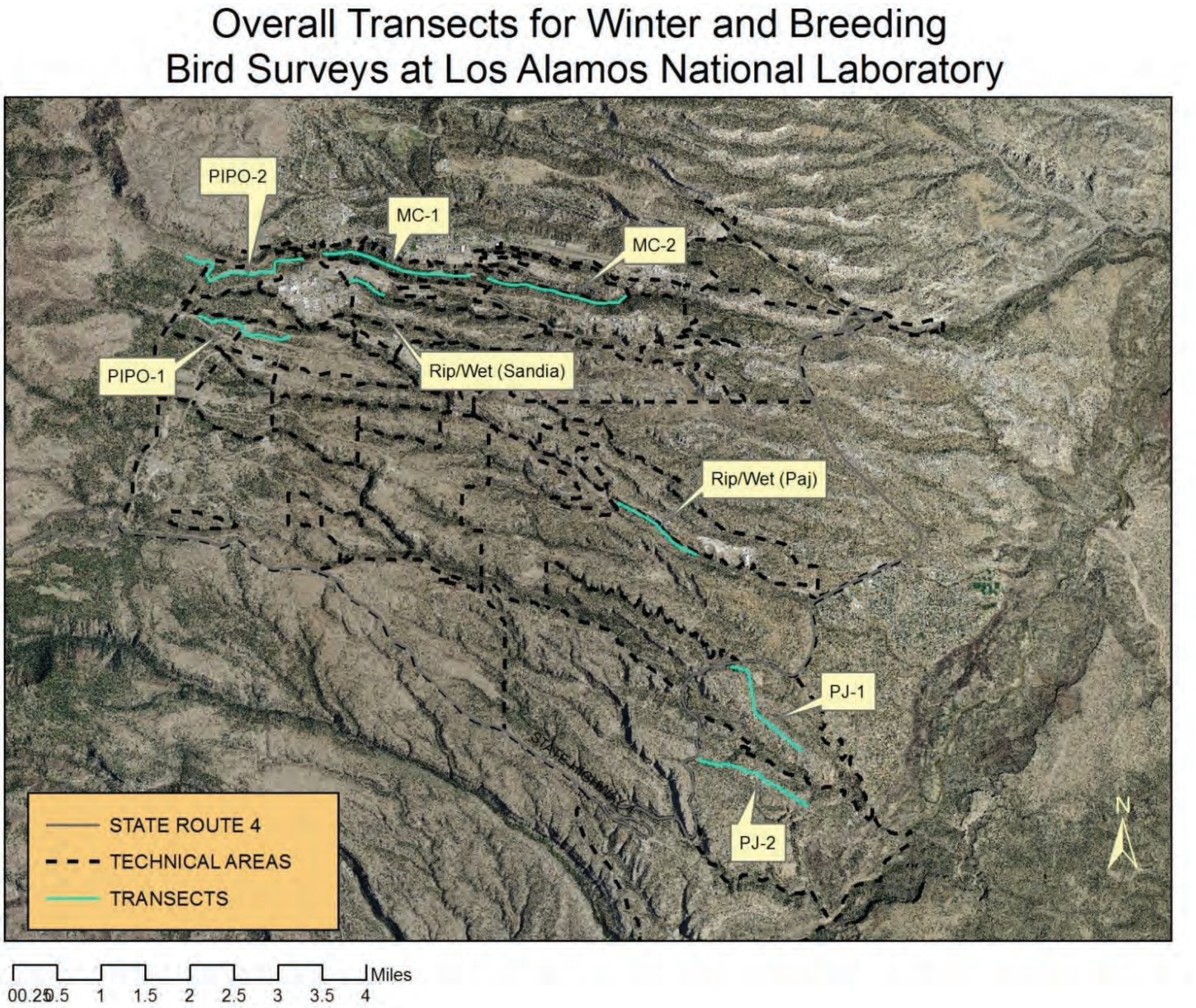


Figure 4. Control transects from ongoing avian monitoring around LANL.
MC: Mixed Conifer Forest, PIPO: Ponderosa Pine Forest, PJ: Pinyon-Juniper Woodland, Rip/Wet: Riparian / Wetland.

Transects are approximately 2.0 to 2.5 km in length and allow for nine survey points spaced approximately 250 m apart. These survey routes and points may change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys is May 1 through August 15. Ideally the breeding bird surveys should take place the second week of May, June, and July. This protocol requires a total of three surveys per study site and surveys should be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along the transect spaced approximately 250 m apart.
- The surveyor will look and listen for 5 minutes, noting any birds encountered at each point. The distance for observations is considered as an "unlimited-distance circular plot"; however, the distance to each bird out to 100 m should be noted. Care is needed to ensure that individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, any birds encountered that have not otherwise been counted from a previous point or future point should also be noted. The surveyor's main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Surveys should not be conducted during rain events or wind greater than 15 mph.
- All birds encountered will be recorded on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- The "NOTES" section should be used for indicating any potentially important aspects of the survey that may affect the data. Examples include: excess noise from nearby equipment and vehicles or aircraft that make it hard to hear the birds. Also, noting other wildlife or evidence of wildlife that could be used for further reference should be recorded.

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to the TA-36 Minie site and TA-39 point 6 (Figures 5 and 6) and in 2015 nestboxes were added to the TA-16 burn ground (Figure 7). Data from the three study sites are compared to the overall avian nestbox network at LANL that was established in 1997.

Nestboxes are monitored every 1 to 2 weeks for active nests. When an active nest is found it is monitored more closely to determine whether the nest fails or successfully fledges young.

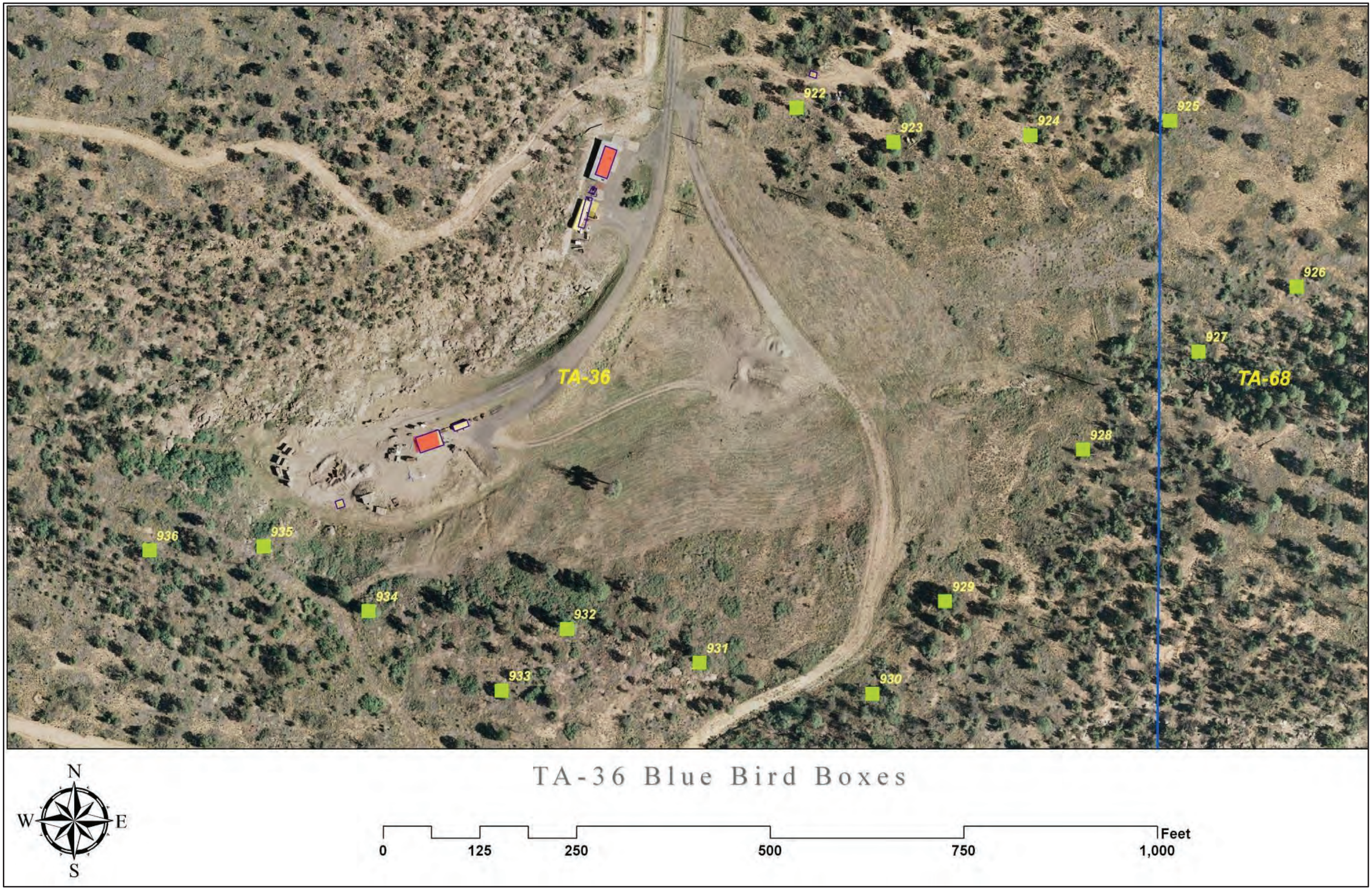


Figure 5. Avian nestboxes located at TA-36 Minie site.

Figure 6. Avian nestboxes located at TA-39 point 6.

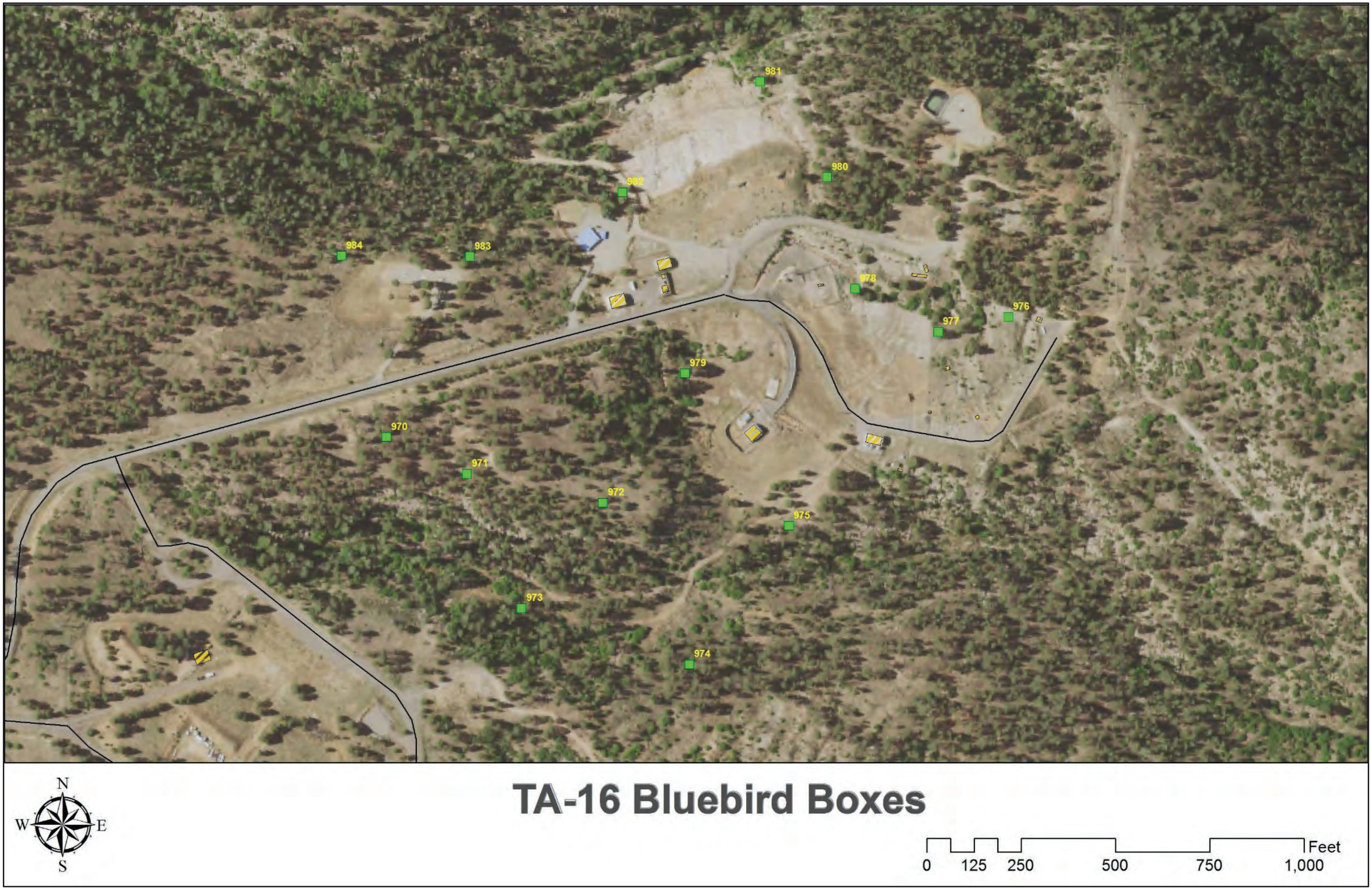


Figure 7. Avian nestboxes located at the TA-16 burn ground.

Statistical Methods

The data were summarized to look at trends in avian abundance and diversity for the three study sites and the control sites. To compare relative abundances between years and sites, the birds per hour (BPH) was calculated for each site by taking the total number of birds detected per survey and dividing by the total number of minutes surveyed. The result is multiplied by 60 to get the BPH. The BPH of the study sites and control sites were compared using the Mann-Whitney U non-parametric two sample test because the data were not normally distributed. Probability values of 0.05 or less were considered significant.

The Shannon's diversity index (*H*) (Shannon 1948) was used to examine avian diversity for the study and control sites. The Shannon's *H* can range from 0.0 to 4.6, where larger values represent increasing diversity. *H* is calculated using the following formula:

$$H = -1 (p_i (\ln (p_i))$$

Where p_i is a percentage value of a specific species in the total population and ln is the natural log.

To compare indices, a Shannon *t* test was used. As described in Magurran (1988), the variance of *H* is determined, which then allows the determination of the *t* value and degrees of freedom. Probability values of 0.05 or less indicated a significant difference in *H* between the two samples. The diversity indices and Shannon's *t* test were computed using PAST version 3.08 statistical software (Hammer et al. 2001).

Birds were categorized into feeding guilds based on the work of De Graaf et al. (1985). For food type, they did not necessarily include all foods taken by each species, only the major food items (20% of diet during a given period).

- Carnivore: vertebrates
- Crustaceovore: crustaceans
- Frugivore: fruits
- Granivore: nuts
- Herbivore: plants (leaves, stems, roots)
- Insectivore: insects
- Moltuscovore: mollusks
- Omnivore: a variety of foods including both animal and plant foods (the less common food group makes up 10% of diet)
- Piscivore: fish
- Vermivore: sandworms, earthworms, etc.

The guilds were customized to account for some bird species being split since the publication. Other changes were made to make it more suited to this study. All woodpeckers were changed from frugivores to omnivores; vermivores (American Robins in this study) were changed to omnivores; hummingbirds were changed from omnivores to nectarivores; Cassin's and House finches were changed from frugivores to granivores. Nectarivores and carnivores were dropped from the analysis due to low samples sizes, leaving granivores, insectivores, and omnivores for this report. The mean number of birds and standard deviation were calculated for each feeding guild. The means of the study sites and control sites were compared using the Mann-Whitney U non-parametric two sample test because the data were not normally distributed. Probability values of 0.05 or less were considered significant. All significant values in tables are bolded and shaded gray.

The control sites have been operated since 2011. The full datatset for the control sites was summarized for the point count surveys (2011–2015) and the Shannon's diversity index (Appendix 2).

Occupancy rate and nest success rate of the nestboxes at the three study sites and in the overall network were calculated. For any single site or overall, the number of active nestboxes divided by the total number of nestboxes is the occupancy rate. Similarly, the number of nestboxes that successfully fledged young divided by the number of active nestboxes is the nest success rate.

Results and Discussion

Three surveys were completed at each of the three study sites and the associated control sites between May and July 2015. A total of 881 birds representing 55 species were recorded at the three study sites. A full account of the 2013–2014 data is detailed in Appendix 1.

The mean BPH abundance values with error bars corresponding to +/- 1 standard deviation for each site by year are represented in Figure 8. The BPH was compared between study sites and their control site for each year using the Mann-Whitney U non-parametric two sample test (Table 1). These results indicate that in 2014 and 2015 the relative abundance of the bird communities at each of the study sites was similar to its respective control site. There was one significant difference in 2013 between the MC control site and the TA-16 burn ground ($p = 0.02$). This has been explained in earlier reports as being related to access restrictions in the first year of the study for this site.

Table 1. Comparisons of BPH between study sites and control sites among years.

Years	MC Control to TA-16	PJ Control to TA-39	PJ Control to Minie Site
2013	**Z = -2.2039 (p = 0.02)**	Z = -0.1313 (p = 0.89)	Z = 0.3889 (p = 0.69)
2014	Z = -1.6852 (p = 0.09)	Z = -0.3889 (p = 0.69)	Z = 1.1818 (p = 0.23)
2015	Z = 0.1291 (p = 0.89)	Z = -0.1296 (p = 0.89)	Z = 0.3939 (p = 0.69)

Note: statistically significant results are shaded.

Additionally, the mean BPH was compared between years for each site using the Mann-Whitney U non-parametric two sample test (Table 2). These results suggest that the relative abundance of bird communities at all three study sites remained similar over the years. The PJ control site does indicate that 2015 was significantly greater that the first two years of this study (p = 0.008 and p = 0.004). However, as noted in Figure 8, all sites had higher BPH values in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in BPH are attributed to the increased precipitation. Links between moisture and habitat quality for a migratory bird have been documented (Smith et al. 2010) and may be a causal factor. The data suggest that LANL operations are not negatively affecting the bird abundances at the three study sites.

Table 2. Comparisons of mean BPH between years and among sites.

Sites	2013 to 2014	2013 to 2015	2014 to 2015
MC Control	Z = 1.3659 (p = 0.17)	Z = -0.4010 (p = 0.68)	Z = -1.2855 (p = 0.19)
TA-16	Z = 0.8729 (p = 0.38)	Z = -1.7457 (p = 0.08)	Z = -1.7457 (p = 0.08)
PJ Control	Z = 0.6439 (p = 0.51)	**Z = -2.6514 (p = 0.008)**	**Z = -2.8121 (p = 0.004)**
TA-39	Z = 0.4364 (p = 0.66)	Z = -1.7457 (p = 0.08)	Z = -0.4364 (p = 0.66)
Minie Site	Z = 0.2214 (p = 1.0)	Z = -1.7457 (p = 0.08)	Z = -1.7457 (p = 0.08)

Note: statistically significant results are shaded.

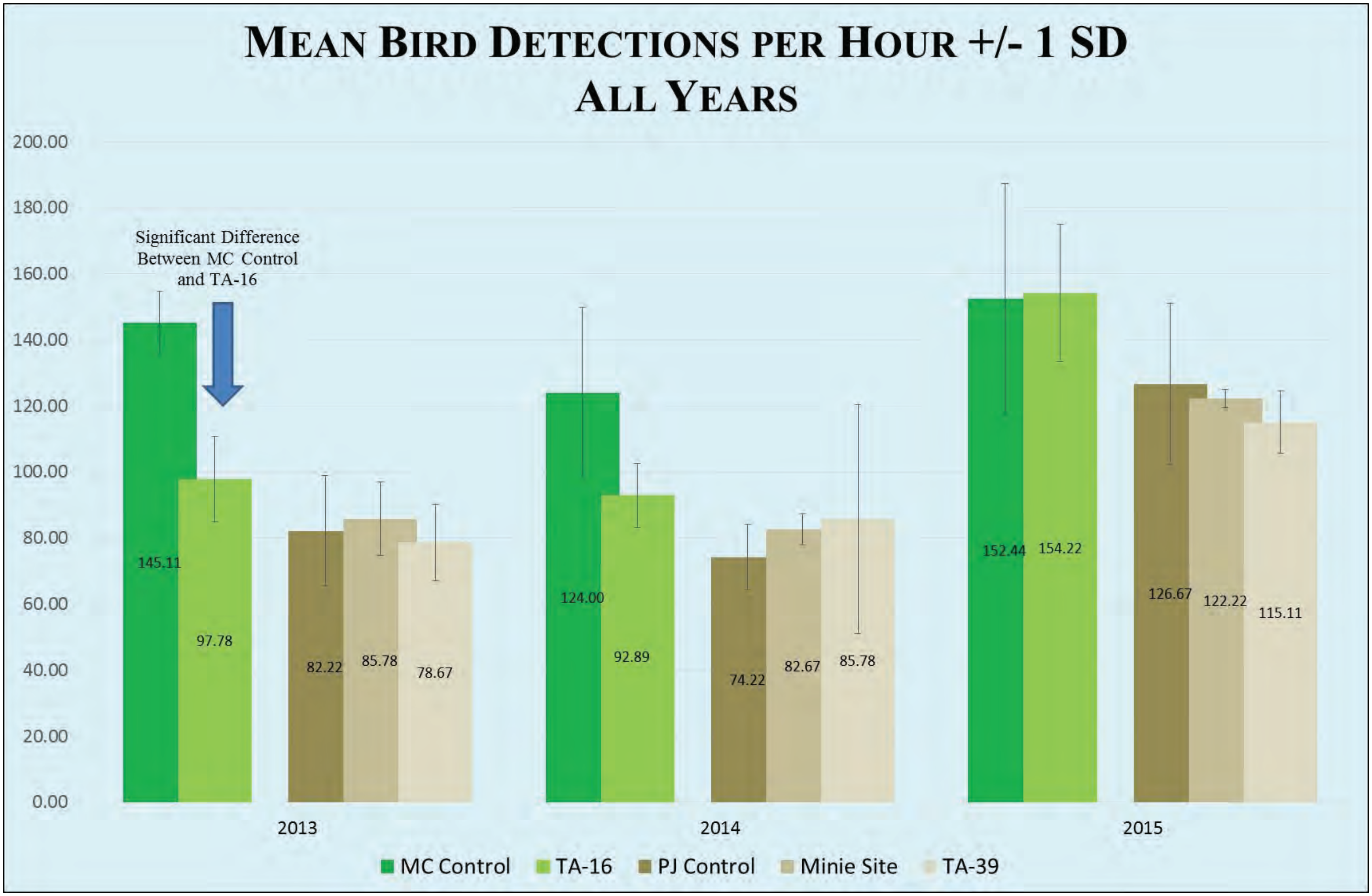


Figure 8. **Birds per hour for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

The species diversity was determined using the Shannon's diversity index for each of the three study sites as well as the control sites of the comparable habitat type. The Shannon's diversity values for each site by year are represented in Figure 9. The bird diversity was compared between study sites and their control site for each year using the Shannon *t* test (Table 3).

Table 3. Shannon values for the study sites and control sites.

Years	MC Control to TA-16	PJ Control to Minie Site	PJ Control to TA-39
2013	t = 1.4194, df = 376 (p = 0.15)	**t = 2.9717, df = 510 (p < 0.01)**	**t = -2.3053, df 466 (p = 0.02)**
2014	t = 1.9235, df 412 (p = 0.06)	t = 1.8716, df = 455 (p = 0.06)	t = -1.0396, df = 477 (p = 0.29)
2015	**t = 4.4626, df = 653 (p < 0.01)**	t = 0.52699, df = 663 (p = 0.59)	t = 0.21662, df = 482 (p = 0.82)

Note: statistically significant results are shaded.

These results indicate that in 2013 the bird diversities in the PJ control sites were significantly less than Minie site ($p < 0.01$) and TA-39 ($p = 0.02$) trending toward similarity in following years. The results also indicate that in 2015 the bird diversity at the TA-16 burn ground was significantly lower ($p < 0.01$) than the MC control. This is contrary to the previously reported BPH data for the TA-16 burn grounds (Figure 5). The lower diversity value is due to 12 fewer species being present at the TA-16 burn grounds compared to the MC controls. Hathcock and Fair (2013) discussed this issue and attributed it to the fact that the MC control sites were in a canyon bottom closer to the townsite compared to the TA-16 burn grounds being on a mesa top.

This lower diversity value warranted further analysis. The Shannon's diversity values were determined for the ponderosa pine control sites. These control sites have not been used in this study because when this study began in 2013, the TA-16 burn ground was considered to be a MC habitat. This habitat does contain some components of a ponderosa pine forest. The Shannon's diversity value in 2015 for the ponderosa pine control was 3.161 which is a better fit to the data than the MC control. The Shannon t test was used to compare the 2015 diversity values from the TA-16 burn ground and the ponderosa pine control. These two sites were not significantly different ($t = 1.2603$, $df = 689$, $p = 0.20$). This is more speculative at this point and will be examined more extensively in the future. A significant difference in one year is not a trend. The data suggest that LANL operations are not negatively affecting bird diversity at the Minie site and TA-39, and more study is needed at the TA-16 burn ground.

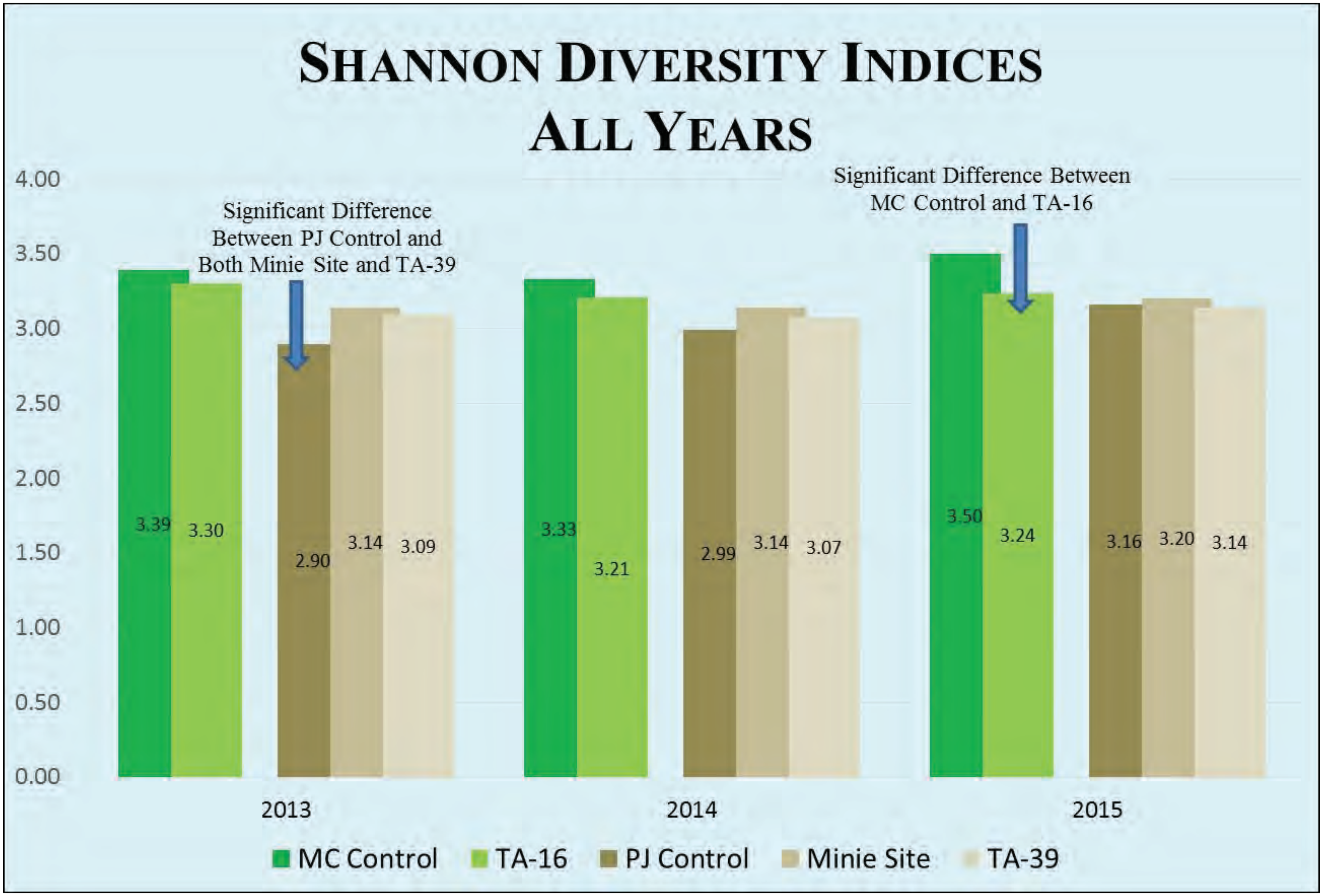


Figure 9. **Shannon's diversity indices for the study and control sites.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat.

A new analysis was conducted in 2015 for this study. Bird species were categorized into feeding guilds based on the work of De Graaf et al. (1985). Only granivores, insectivores, and omnivores are presented in this report. The mean number of birds for these three feeding guilds with error bars corresponding to +/- 1 standard deviation for each site by year are represented in Figures 10–12. Insectivores have consistently been the largest feeding guild, followed by the omnivores and the granivores.

The mean number of birds were compared between years and among feeding guilds by study site using the Mann-Whitney U non-parametric two sample test (Table 4). These results indicate that there were no significant differences in feeding guilds between years for all three study sites. The control sites were analyzed similarly (Table 5) and trends very generally indicate that the mean numbers dropped slightly from 2013 to 2014 and then were highest in 2015. This fits well with the precipitation discussion earlier with the BPH differences.

A final analysis was performed to test for significant differences between study sites and their control site by feeding guild for each year using the Mann-Whitney U non-parametric two sample test (Table 6). There was one significant difference between the MC control site and the TA-16 burn ground ($p = 0.01$) with regard to omnivores. As discussed earlier, access limitations in 2013 may have affected the number of birds recorded. The significant differences disappeared in subsequent years. There were also significantly greater numbers of insectivores at Minie site compared to its control in 2013 and 2014.

Feeding guilds are also useful to monitor for habitat changes. From Figure 10 it is apparent that granivores are more prevalent in PJ habitats compared to MC. The opposite is seen in Figure 11 as insectivores are much higher in MC habitat than PJ. The omnivores are more evenly distributed among both habitats (Figure 12) which is indicative of their generalist nature, although the MC habitat does still have higher numbers of these birds.

During the 2015 nesting season, 15 nestboxes each at Minie site and TA-16, and 12 nestboxes at TA-39 were actively monitored. The overall avian nestbox network without the three study sites contained 653 nestboxes in 2015. Of those, 263 contained active nests and 174 of those nests fledged young successfully. This was an overall occupancy rate of 40% with a 66% success rate.

At Minie site, 14 nests were found and 9 of the nests fledged young successfully. Only 10 nestboxes were used, but 4 of those nestboxes had a second clutch. This was an occupancy rate of 66% with a 64% success rate.

At TA-39, only one nest was found and it successfully fledged young. This was an occupancy rate of 8%. These nestboxes at TA-39 will be relocated in 2016. The firing site at TA-39 is in a small narrow canyon and the nestboxes will be moved a little further out to a more open area to increase nesting attractiveness. The number of nestboxes in 2016 will also increase to 15 to be consistent.

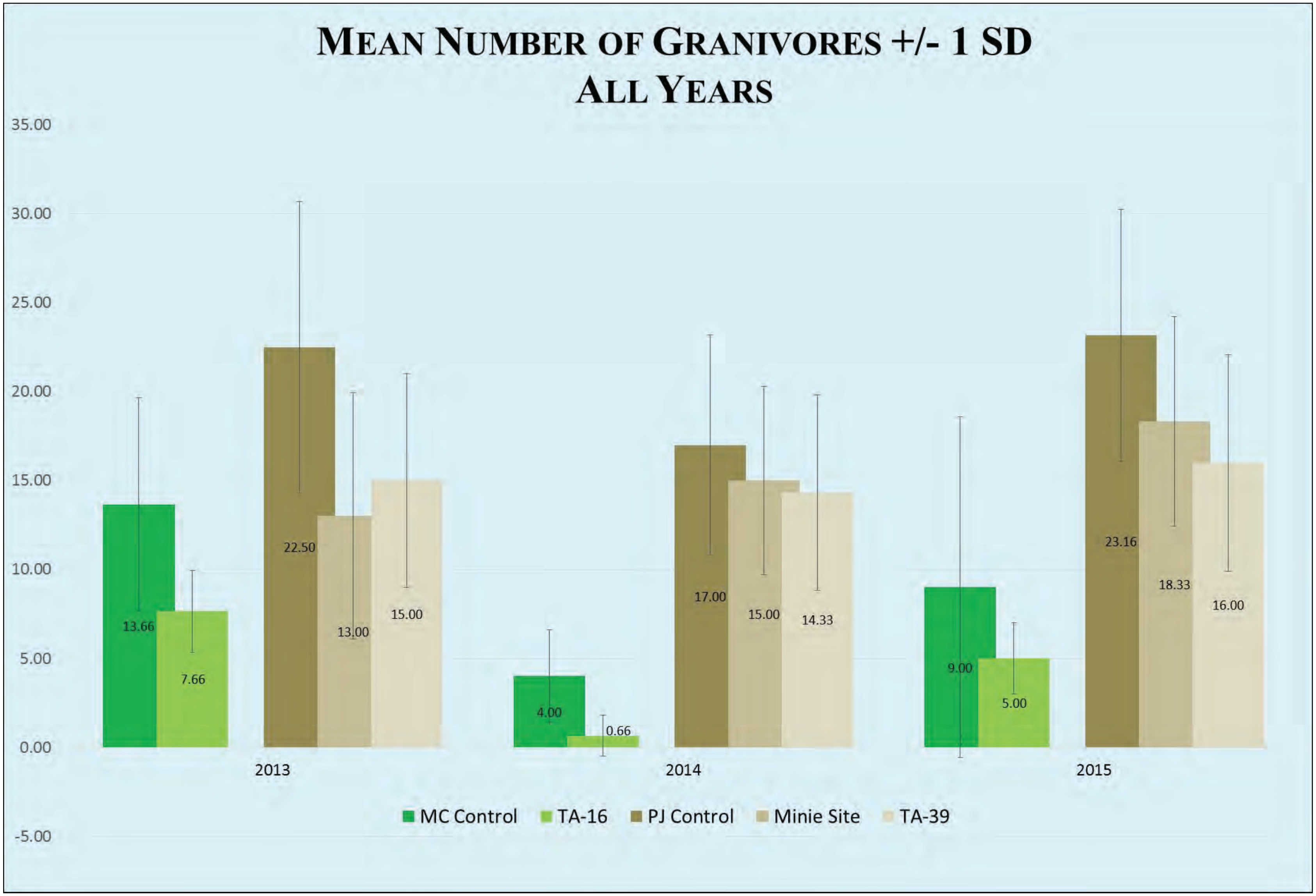


Figure 10. **Mean number of granivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

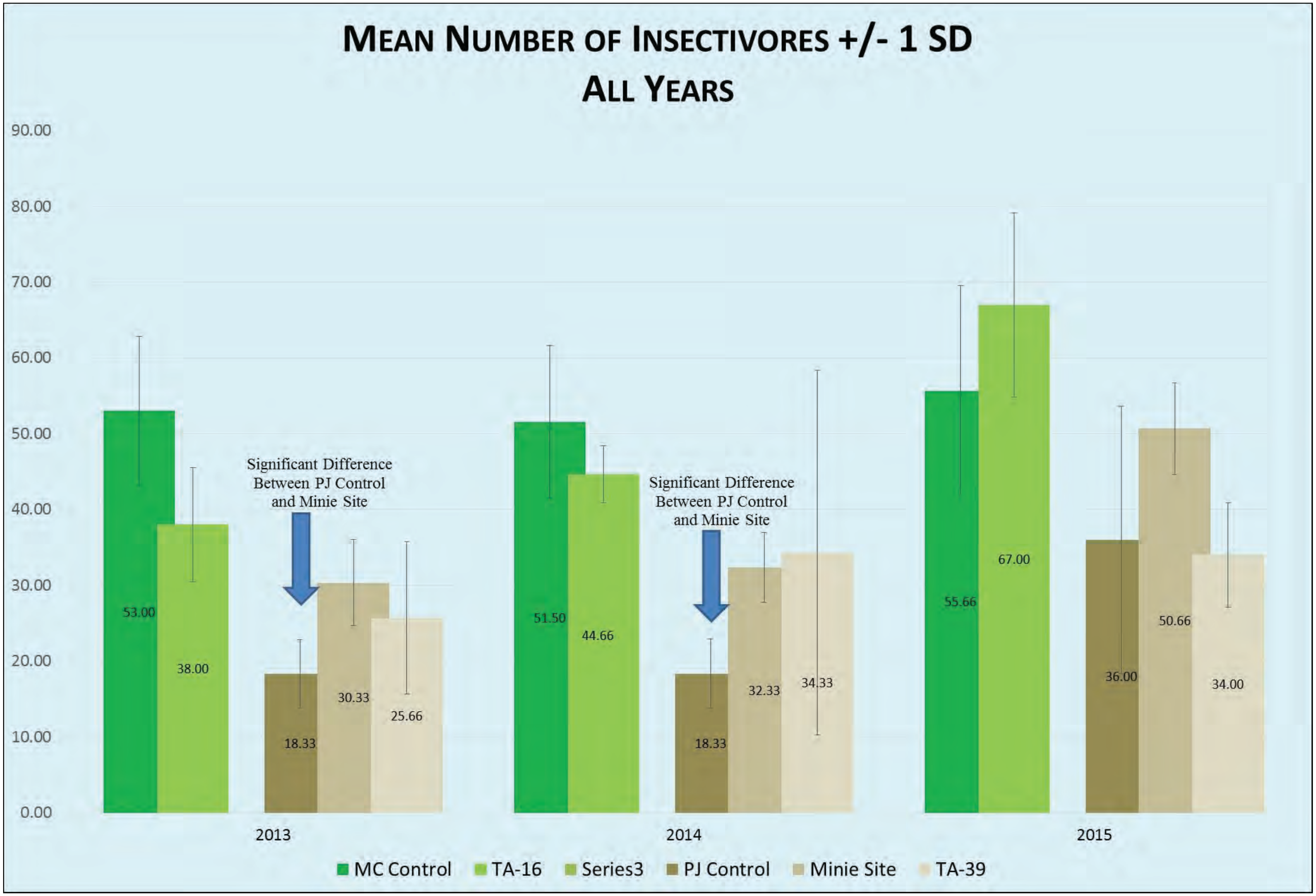


Figure 11. **Mean number of insectivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

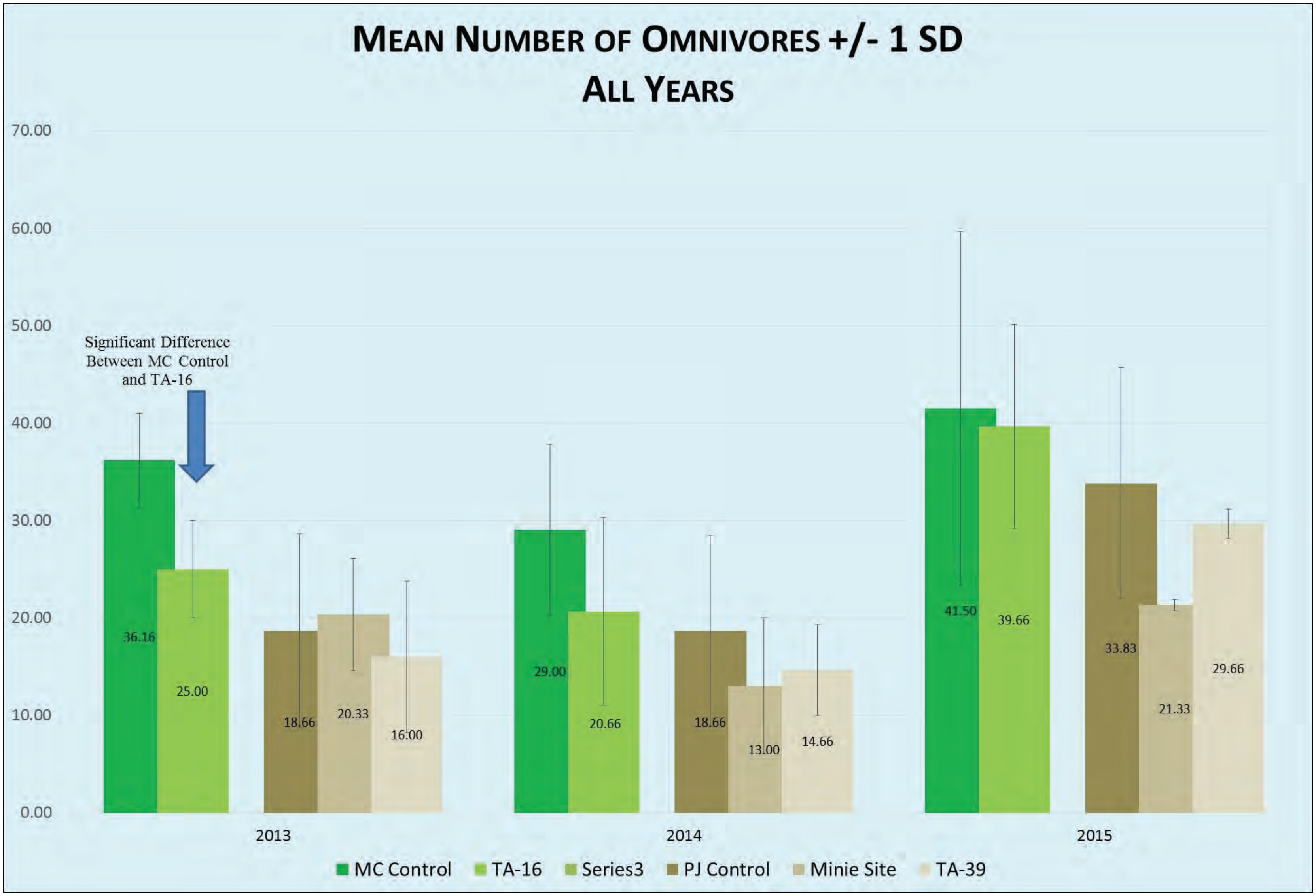


Figure 12. **Mean number of omnivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

Table 4. Comparing the mean number of birds between years among feeding guilds for each study site.

	TA-16			TA-39			Minie Site		
Feeding Guild	**2013 to 2014**	**2013 to 2015**	**2014 to 2015**	**2013 to 2014**	**2013 to 2015**	**2014 to 2015**	**2013 to 2014**	**2013 to 2015**	**2014 to 2015**
Granivore	Z = 1.7979 (p = 0.07)	Z = 1.1237 (p = 0.26)	Z = -1.7712 (p = 0.07)	Z = 0.0000 (p = 1.0)	Z = 0.2214 (p = 1.0)	Z = -0.8729 (p = 0.38)	Z = -0.4637 (p = 0.64)	Z = 0.0000 (p = 1.0)	Z = 0.0000 (p = 1.0)
Insectivore	Z = -0.8729 (p = 0.38)	Z = -1.7457 (p = 0.08)	Z = -1.7457 (p = 0.08)	Z = 0.0000 (p = 1.0)	Z = -0.8856 (p = 0.37)	Z = -0.4428 (p = 0.65)	Z = -0.4637 (p = 0.64)	Z = -1.7457 (p = 0.08)	Z = -1.7712 (p = 0.07)
Omnivore	Z = 0.4364 (p = 0.66)	Z = -1.3093 (p = 0.19)	Z = -1.3093 (p = 0.19)	Z = 0.2214 (p = 1.0)	Z = -1.7457 (p = 0.08)	Z = -1.7457 (p = 0.08)	Z = 0.8856 (p = 0.37)	Z = -0.4495 (p = 0.65)	Z = -1.7712 (p = 0.07)

Table 5. Comparing the mean number of birds between years among feeding guilds for each control site.

	MC Control			PJ Control		
Feeding Guild	**2013 to 2014**	**2013 to 2015**	**2014 to 2015**	**2013 to 2014**	**2013 to 2015**	**2014 to 2015**
Granivore	**Z = 2.3550 (p = 0.01)**	Z = 0.8901 (p == 0.37)	Z = -0.8077 (p = 0.41)	Z = 0.8854 (p = 0.37)	Z = -0.1607 (p = 0.87)	Z = -1.3659 (p = 0.17)
Insectivore	Z = 0.2410 (p = 0.80)	Z = -0.5624 (p = 0.57)	Z = -1.4812 (p = 0.63)	Z = 0.1633 (p = 0.87)	**Z = -2.6608 (p < 0.01)**	**Z = -2.5711 (p = 0.01)**
Omnivore	Z = 1.4462 (p = 0.14)	Z = 0.0000 (p = 1.0)	Z = -1.2010 (p = 0.22)	Z = -1.1610 (p = 0.87)	**Z = -2.0051 (p = 0.04)**	**Z = -2.0890 (p = 0.03)**

Note: statistically significant results are shaded.

Table 6. Comparing the mean number of birds between study sites and their control by feeding guilds for each year.

	2013			2014			2015		
Site Comparisons	**Granivore**	**Insectivore**	**Omnivore**	**Granivore**	**Insectivore**	**Omnivore**	**Granivore**	**Insectivore**	**Omnivore**
MC Control and TA-16	Z = -1.1921 (p = 0.23)	Z = -1.6783 (p = 0.09)	**Z = -2.2039 (p = 0.02)**	Z = -1.8226 (p = 0.06)	Z = -0.9113 (p = 0.36)	Z = -0.9037 (p = 0.36)	Z = -0.5208 (p = 0.60)	Z = 0.7778 (p = 0.43)	Z = 0.1291 (p = 0.89)
PJ Control and Minie Site	Z = -1.1717 (p = 0.24)	**Z = 1.9696 (p = 0.04)**	Z = 0.3956 (p = 0.69)	Z = -0.2593 (p = 0.79)	**Z = 2.2132 (p = 0.02)**	Z = -0.7811 (p = 0.43)	Z = -1.0371 (p = 0.29)	Z = 1.4201 (p = 0.15)	Z = -1.4260 (p = 0.15)
PJ Control and TA-39	Z = -1.1668 (p = 0.24)	Z = 0.9191 (p = 0.35)	Z = -0.3939 (p = 0.69)	Z = -0.5186 (p = 0.60)	Z = 1.0415 (p = 0.29)	Z = -0.6482 (p = 0.51)	Z = -1.1619 (p = 0.24)	Z = 0.0000 (p = 1.0)	Z = -0.5186 (p = 0.60)

Note: statistically significant results are shaded.

At TA-16, 11 nests were found and 10 of the nests fledged young successfully. This was an occupancy rate of 73% with a 90% success rate.

The occupancy and success rates at Minie site and TA-16 were greater than the results in the overall network. The nestboxes at TA-39 have a placement problem that will be addressed in 2016. More years of data are needed to begin to look at the results in a more robust manner.

The nestbox data suggest that LANL operations at these sites are not negatively affecting nest success at two of the study sites, and more work is needed for TA-39.

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 55 species detected at the three study sites, all are protected under the MBTA. Additionally, three of the species detected at the three study sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those three species are the Peregrine Falcon, Juniper Titmouse, and Grace’s Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901). Another conservation tool used in migratory bird management is the Birder’s Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three study sites are on the top 100 list. They are the Virginia’s Warbler and Grace’s Warbler.

Management Recommendations

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL’s avifauna at the three study sites, contribute to meeting the Department of Energy’s commitments under the MBTA and associated memorandums of understanding, and allow LANS to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Many thanks to the following for technical and field support work in 2015: David Bruggeman, Tatiana Espinoza, Marlena Greene, Leslie Hansen, Teresa Hiteman, Luciana Vigil-Holterman, Kelly Hutchins, David Keller, Maria Musgrave, Emily Phillips, Audrey Smith, Brent Thompson, and Marjorie Wright; and former staff and interns that helped in previous years.

Literature Cited

De Graaf, R.M., N.G. Tilghman, and S.H. Anderson. 1985. Foraging Guilds of North America. Environmental Management 9(6):493-536.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. LA-UR-13-27825. Los Alamos National Laboratory, Los Alamos, New Mexico.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, New Mexico.

Magurran, A. 1988. Ecological Diversity and Its Measurement. Princeton University Press. Poole, R.W. 1974. An introduction to quantitative ecology. McGraw-Hill, New York.

Shannon C.E. 1948. A Mathematical Theory of Communication. Bell Syst. Tech. J. 27:379–423.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874-2882.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine. September 2015. “Weather Machine Climatological Monthly Summary,” http://weather.lanl.gov/climo_monthly_summary.asp

Wells, J.V. 2007. Birder’s Conservation Handbook: 100 North American Birds at Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

Appendix 1. All birds recorded at the three study sites from 2013–2015.

Species	2013	2014	2015	2013	2014	2015	2013	2014	2015
	TA-36			TA-39			TA-16		
	Pinyon-Juniper Woodland			Pinyon-Juniper Woodland			Mixed Conifer Forest		
Acorn Woodpecker							5		3
American Kestrel				1					
American Robin	1	1	2	1	1		7		9
Ash-throated Flycatcher	11	5	14	19	11	29	3	5	6
Audubon's Warbler		2					6	5	1
Bewick's Wren	4	8	9	3	10	15			
Black-chinned Hummingbird		1	1	3	2		1		1
Black-headed Grosbeak	1	3			2	4			1
Black-throated Gray Warbler			1	5	6	4			
Blue-gray Gnatcatcher	3	14	16	2		7		6	2
Broad-tailed Hummingbird	2	1	3	3	1	2	5	11	11
Brown Creeper							1		
Brown-headed Cowbird	1					2	4	1	
Bushtit		2		2	14				
Canada Goose						16			
Canyon Towhee	2		5	1	1	2	1		
Canyon Wren						2			2
Cassin's Kingbird	6	13	13	7	6	2			
Chipping Sparrow	3	16	17	6	6	5	1	5	3
Clark's Nutcracker								4	
Common Nighthawk	6		5	5	1	3			1

Species	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**
	TA-36			TA-39			TA-16		
	Pinyon-Juniper Woodland			Pinyon-Juniper Woodland			Mixed Conifer Forest		
Common Raven	2	5	1	1		2	5	6	2
Cooper's Hawk							1		
Cordilleran Flycatcher							5	10	6
Dark-eyed Junco							6	2	4
Downy Woodpecker								1	
Dusky Flycatcher						1			
Eurasian Collared-Dove	3								
Evening Grosbeak	3		4			8	5		29
Grace's Warbler							6	4	4
Gray Flycatcher	12	6	5	10	10	11			
Great-horned Owl		3		1					
Green-tailed Towhee	3	1		1					
Hairy Woodpecker			2			5	1	1	
Hammond's Flycatcher							8	9	12
Hepatic Tanager						1			
Hermit Thrush								4	6
House Finch	16	17	26	21	4	23	16	2	5
House Wren							1	1	
Juniper Titmouse	12		7	11	13	18			
Lesser Goldfinch	2	6	7	4	12	9	3		8
Mountain Bluebird		2	20		4				4
Mountain Chickadee	5	2	1				5	8	9
Mourning Dove	17	17	13	13	22	10	4		1
Northern Mockingbird					1				
Peregrine Falcon						1			

Species	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**
	TA-36			TA-39			TA-16		
	Pinyon-Juniper Woodland			Pinyon-Juniper Woodland			Mixed Conifer Forest		
Pine Siskin	10	2		6		3	12	4	5
Plumbeous Vireo	10	10	7	1		1	11	16	15
Pygmy Nuthatch						2	11	13	26
Red Crossbill					2			2	9
Red-shafted Flicker	3	1	3	3	2	4	3	4	11
Red-tailed Hawk						1			
Rock Wren	3	3	4	7	10	4	1	2	2
Say's Phoebe	2	1	2	2	1		1		1
Scaled Quail			1						
Spotted Towhee	17	8	19	12	6	33	11	18	16
Steller's Jay							3	2	5
Townsend's Solitaire	1								
Turkey Vulture							1		
Violet-green Swallow		5	7	6	4	1		2	19
Virginia's Warbler						1	17	11	21
Warbling Vireo							2	9	7
Western Bluebird	15	11	18	5	19	12	20	20	49
Western Scrub-Jay	5	1	3	8	10	4	1		
Western Tanager		2	3		2	1	2	3	7
Western Wood-Pewee	10	8	18		4	2	15	10	16
White-breasted Nuthatch	1	4	9			2	9	8	7
White-throated Swift					1				
White-winged Dove	1	5	9	7	5	6			1
Grand Total	**193**	**186**	**275**	**177**	**193**	**259**	**220**	**209**	**347**

Appendix 2. The full datatset for the control sites for point count surveys (2011–2015) including the Shannon’s diversity index.

Breeding bird survey results from 2011 to 2015 for all control sites. Replicate control sites were not added until 2012.

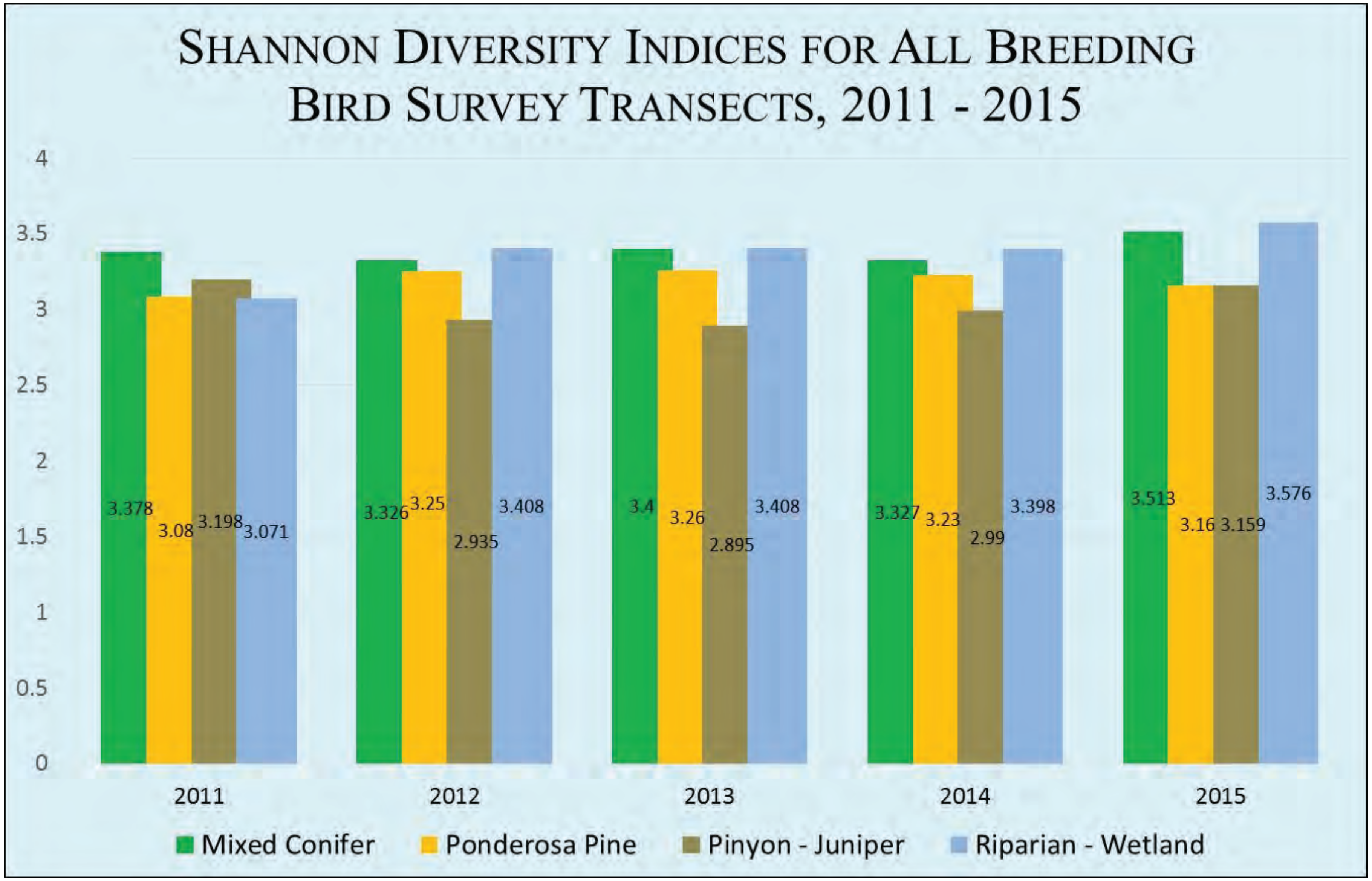
	Summer 2011				Summer 2012				Summer 2013				Summer 2014				Summer 2015			
Species	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**
Acorn Woodpecker	10				11	2		5	7	3		7	9			2	13	1		2
American Crow	3		1																	
American Kestrel		1						1										1	1	
American Robin	18	3	6	22	20	10	15	29	21	4	5	23	11	7	3	22	29	13	3	34
Ash-throated Flycatcher	5	7	29	9	18	8	52	8	13	1	33	10	17	6	30	10	10	1	50	4
Audubon's Warbler	1	5			7	26	1	2		6			4	21	1		6	47		2
Bewick's Wren	1		2				12	4			19	1			18	1	1		35	4
Black-chinned Hummingbird	1	1	2	3	1		1		3	5	4	9	4		2	10	2	3	5	3
Black-headed Grosbeak	7	2		4	1		1		9	2	6		4	1			9	2	5	3
Black-throated Gray Warbler															1				5	
Blue Grosbeak				4				1								1				1
Blue-gray Gnatcatcher			4	2			6	2	2		6	5			6	3		1	12	1
Broad-tailed Hummingbird	16	13	9	1	14	15	2	11	25	27	5	26	25	22	6	8	37	38	2	19
Brown Creeper					3	1							3			1	6			
Brown-headed Cowbird	5	1	9	4	10	5	3	7	12	7	2	9	3	2		4	5	3		24
Bullock's Oriole				1								2				2			2	1

Species	Summer 2011				Summer 2012				Summer 2013				Summer 2014				Summer 2015			
	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland
Bushtit	1	3	1	20			2		10			2			6	2			18	11
Canada Goose								6												16
Canyon Towhee	2		4	2	1		4	3	2		9				8	4		1	10	4
Canyon Wren	8				12				12				6		2	2	23		4	4
Cassin's Finch								1		2										
Cassin's Kingbird		3	4			5				13	3			3	8	8		2	24	6
Cedar Waxwing																	5			
Chipping Sparrow	4	11	14	3	7	17	8	6	1	20	1	3	1	15	5	7	18	52	30	15
Clark's Nutcracker						1														
Common Nighthawk			1								11	1			5			5	6	1
Common Raven	16	8	7	1	28	15	4	6	24	13	4	6	20	23	4	17	29	21	12	24
Cooper's Hawk						1				1			1	1			1			
Cordilleran Flycatcher	3				9				7	1		3	9	4		3	6	2		
Dark-eyed Junco	6	8	1		3	13		2	2	7		5		1		1	4	13	1	2
Downy Woodpecker	3			2																
Dusky Flycatcher	1																2	4		1
Eurasian Collared-Dove						2		3		3		3		3		1		2		3
European Starling								18												
Evening Grosbeak	47	81	10	43	4	3		6	8	28	4	21		10		2	2	26	49	7
Flammulated Owl						2	1	1												
Grace's Warbler						3		1	12	11		1	9	8		2	5	10		

	Summer 2011				**Summer 2012**				**Summer 2013**				**Summer 2014**				**Summer 2015**			
Species	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**	**Mixed Conifer**	**Ponderosa Pine**	**Pinyon - Juniper**	**Riparian - Wetland**
Gray Flycatcher		1	17			1	6	1			14				7				8	1
Great-tailed Grackle			19																	
Green-tailed Towhee	2		7	1		3	7	1			5	4		2						
Hairy Woodpecker	3	3	1	2	5	2	4	6	2				5	3	3	1	2	2	2	2
Hammond's Flycatcher	3	2			21	6			19	9			15	2			16	4		1
Hepatic Tanager				1					1											
Hermit Thrush		1			5	2		1		3			3	5			9	7		
House Finch	3	21	25	13	30	38	43	33	12	39	89	34	2	37	47	28	2	35	59	25
House Wren		2		1	1	3		11	1			20	2			12	3	3		10
Indigo Bunting								1												
Juniper Titmouse			13	8			21	5			20	1			12		1		16	
Lazuli Bunting								2												
Lesser Goldfinch	16	5	13	28	19	22	11	31	35	14	19	28	7	9	14	16	21	17	42	25
Lincoln's Sparrow					1											1				1
MacGillivray's Warbler	2	4		1	1							2	2						1	1
Marsh Wren																				1
Mountain Bluebird															3				1	
Mountain Chickadee	11	3		2	20	7		1	31	10		6	21	4		6	11	5		7
Mourning Dove	3	4	16	6	28	7	38	30	35	4	25	10	15	3	36	16	27	4	30	12
Northern Mockingbird			1				1				1	2			1					
Northern Saw-whet Owl	1																			

Species	Summer 2011				Summer 2012				Summer 2013				Summer 2014				Summer 2015			
	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland
Orange-crowned Warbler									1									3		3
Pine Siskin	13	7		5	1	5			12	27	8	5	15	28		11	40	47	6	6
Pinyon Jay							1								41					
Plumbeous Vireo	9	21	2	3	31	27	1	6	38	23		9	17	22	1	8	18	25	3	10
Pygmy Nuthatch	4	10			57	70		9	47	33		15	59	54		26	26	105		21
Red Crossbill		7				15	2			5				8			3	21		
Red-breasted Nuthatch	2	1				2														
Red-shafted Flicker	2	12	1	4	7	10	4	4	12	1	2	9	9	3	1	9	9	15	3	14
Red-tailed Hawk					1			7	2		2	5	4			2	1		1	3
Red-winged Blackbird								13				29				49				57
Rock Wren		2		1		3	5	3	1		6	3	8	1	8	9	4		5	9
Ruby-crowned Kinglet	4	2		1													4			
Rufous Hummingbird								2												
Say's Phoebe		1	3	1		1		7	2		1	3		2	1	4	3			
Song Sparrow	1				1			17	1			16				11				15
Sora																				6
Spotted Towhee	20	4	13	33	39	23	42	27	44	20	29	31	36	16	23	27	50	29	46	33
Steller's Jay	1	3			7	3		1	9	6		3	7	6		1	6	10		2
Summer Tanager			1																	
Townsend's Solitaire		1	1					1						2			2	1		1
Turkey Vulture					25	1	1		4	12		1	17	3	2		8		4	1

	Summer 2011				Summer 2012				Summer 2013				Summer 2014				Summer 2015			
Species	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland	Mixed Conifer	Ponderosa Pine	Pinyon - Juniper	Riparian - Wetland
Unknown Hummingbird					11	6	1	8	2		2									
Violet-green Swallow	23	10	6	6	54	51	7	47	38	28	8	52	52	21		38	43	43	3	52
Virginia Rail								1				7								10
Virginia's Warbler	18	11		16	26	13	5	13	38	30	1	15	15	19	1	8	20	22	1	7
Warbling Vireo	16				15				18			2	28	5		5	28	3	1	2
Western Bluebird	6	26	11	2	3	35	17	8	1	44	3	2	11	43	9	11	5	91	26	11
Western Scrub-Jay	1	1	14	5		1	28	11	1		16	8			11	2			20	7
Western Tanager	7		1	1	2	3	1		15	9	2	1	4	3	1	2	10	3		5
Western Wood-Pewee	8	19	8	19	49	49	11	49	38	36	3	18	33	38	2	31	50	41	4	53
White-breasted Nuthatch	4	9		1	25	16		4	15	3		8	17	5		5	11	19	4	10
White-crowned Sparrow	1															1				
White-throated Swift					36	6			7	4			28	5			32		2	8
White-winged Dove			3	1			1	1			2	1		1	5	2	4		8	15
Williamson's Sapsucker		2						2												
Willow Flycatcher				1																
Wilson's Warbler	1																4			2
Yellow Warbler				1					1							1				1
Yellow-breasted Chat				1																1
Wilson's Warbler	1																4			2
Yellow Warbler				1					1							1				1
Yellow-breasted Chat				1																1



Shannon's diversity indices during the breeding season from 2011 to 2015 for all control sites. Replicate control sites were not added until 2012.

19. Hathcock, C.D., B.E. Thompson, and J. T. Berryhill, April 2017. *2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-17-20359. OSTI Identifier 1340948. (Hathcock *et al*. 2017)

LA-UR-17-20359

Title: 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Author(s): Hathcock, Charles Dean
Thompson, Brent E.
Berryhill, Jesse Tobias

Intended for: Report
Environmental Programs

Issued: 2017-04-12 (rev.3)

LA-UR-17-20359

Minor Revision April 2017

2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Charles D. Hathcock, Brent E. Thompson, and Jesse T. Berryhill.
Environmental Stewardship Services, Los Alamos National Laboratory

An Affirmative Action/Equal Opportunity Employer

Contents

Tables

Figures

Executive Summary

Los Alamos National Security, LLC (LANS) biologists in the Environmental Compliance and Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna at two open detonation sites and one open burn site on LANL property. Monitoring results from these efforts are compared among years and with avifauna monitoring conducted at other areas across LANL. The objectives of this study are to determine whether LANL firing site operations impact bird abundance or diversity. LANS biologists completed the fourth year of this effort in 2016. The overall results from 2016 continue to indicate that operations are not *negatively* affecting bird populations. Data suggest that community structure may be changing at some sites and this trend will continue to be monitored.

Three avian point count surveys were completed at each of the study sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground (hereafter referred to as Minie site, TA-39, and TA-16) between May and July 2016. A total of 730 birds representing 54 species were recorded at the study sites. Three avian point count surveys were also completed at each of the control sites between May and July 2016.

The data were analyzed to determine abundance using an estimate of birds detected per hour, and to calculate the species diversity. The number of birds detected in three different feeding guilds were compared to examine functional community differences among areas.

Results from 2016 monitoring indicate a slight decrease from 2015 in bird abundances in pinyon-juniper (PJ) habitat and a small increase in bird abundances in mixed conifer (MC) habitat across LANL. The decrease is likely indicative of effects from below-average precipitation in the winter of 2015 into the spring and early summer of 2016. Precipitation drives habitat suitability, which can potentially drive animal populations using the resources. The link between moisture and habitat quality for a migratory bird indicates that the availability of high-quality habitats is dynamic due to variation in precipitation among seasons and years (Smith et al. 2010). Mixed conifer habitat is wetter than PJ, which may account for the small increase in bird abundance in the MC habitat. This increase in bird abundance was significantly higher ($p = 0.03$) in the MC control habitat compared with TA-16. There were no significant differences in bird abundance for the other two sites when comparing their respective controls.

The species diversity indices at Minie site were significantly less ($p = 0.01$) than its PJ control, with fourteen fewer species present. The TA-16 bird diversity was also significantly less ($p < 0.01$) than its MC control, with seven fewer species present. The fluctuations in bird abundances are not alarming and the differences between the study sites and control sites are not biologically significant. The 2016 results at the three study sites are still higher than the first two years of the study. The significant drop in species diversity at Minie site may be indicative of a change in community structure. Due to increased fuels reduction, including more tree removals, the habitat availability is changing. The site is becoming more grassland-like than PJ. There are currently no control sites for grasslands at LANL and this may be needed in the future.

In addition to avian point counts, nestboxes were monitored around all three study sites. These data are compared with the overall avian nestbox monitoring network. This network was established in 1997 to investigate the occupancy rates and reproductive success of cavity-nesting bird populations at LANL. The total number of boxes in the network in 2016 was 416, with another 42 placed around the three study sites. In 2016 there was an overall occupancy rate of 47% with a 65% success rate for the avian nestbox network at LANL. The percent occupancy and nest success at both Minie site and TA-16 were similar to the overall rate, suggesting that the firing site operations are not negatively affecting nest success. Further study is needed at TA-39 to ascertain if the 2016 re-deployment of some nestboxes within the more open habitat east of point 6 continues to lead to increased occupancy. An additional three boxes are needed at TA-39 to maintain even numbers at all three sites.

Introduction

As part of the Resource Conservation and Recovery Act permitting process at LANL for two open detonation sites (TA-36 Minie site and TA-39 point 6), and one open burn site, (TA-16 burn ground), an avian monitoring program was started at these locations in 2013 (Hathcock and Fair 2013). The goal is to compare avian abundance, diversity, and productivity at these sites with other locations at LANL of the same habitat type. Comparisons are made with control sites that have been surveyed since 2011 (Hathcock et al. 2011).

LANS biologists used standard point count methodology to record avian abundance and diversity along transects at the three study sites and associated control sites during the summer of 2016. Summer surveys provide information about what birds are breeding at the sites. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. They also can be correlated to changes in the natural environment at LANL.

In addition to avian point counts, nestboxes are monitored around all three study sites to investigate any potential impacts to occupancy rates and productivity of cavity-nesting birds. These data are compared with the overall LANL avian nestbox monitoring network established in 1997.

Methods

Field Methods for Point Count Surveys

The point count surveys are conducted along single transects in the forested, undeveloped land surrounding the study sites (Figures 1–3). The habitat types around the sites are PJ for the sites at TA-36 and TA-39 and MC at TA-16. These habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The three study sites were compared with control sites at LANL of the same habitat type. The control sites (Figure 4) are monitored annually in ongoing surveys that have been conducted at LANL since

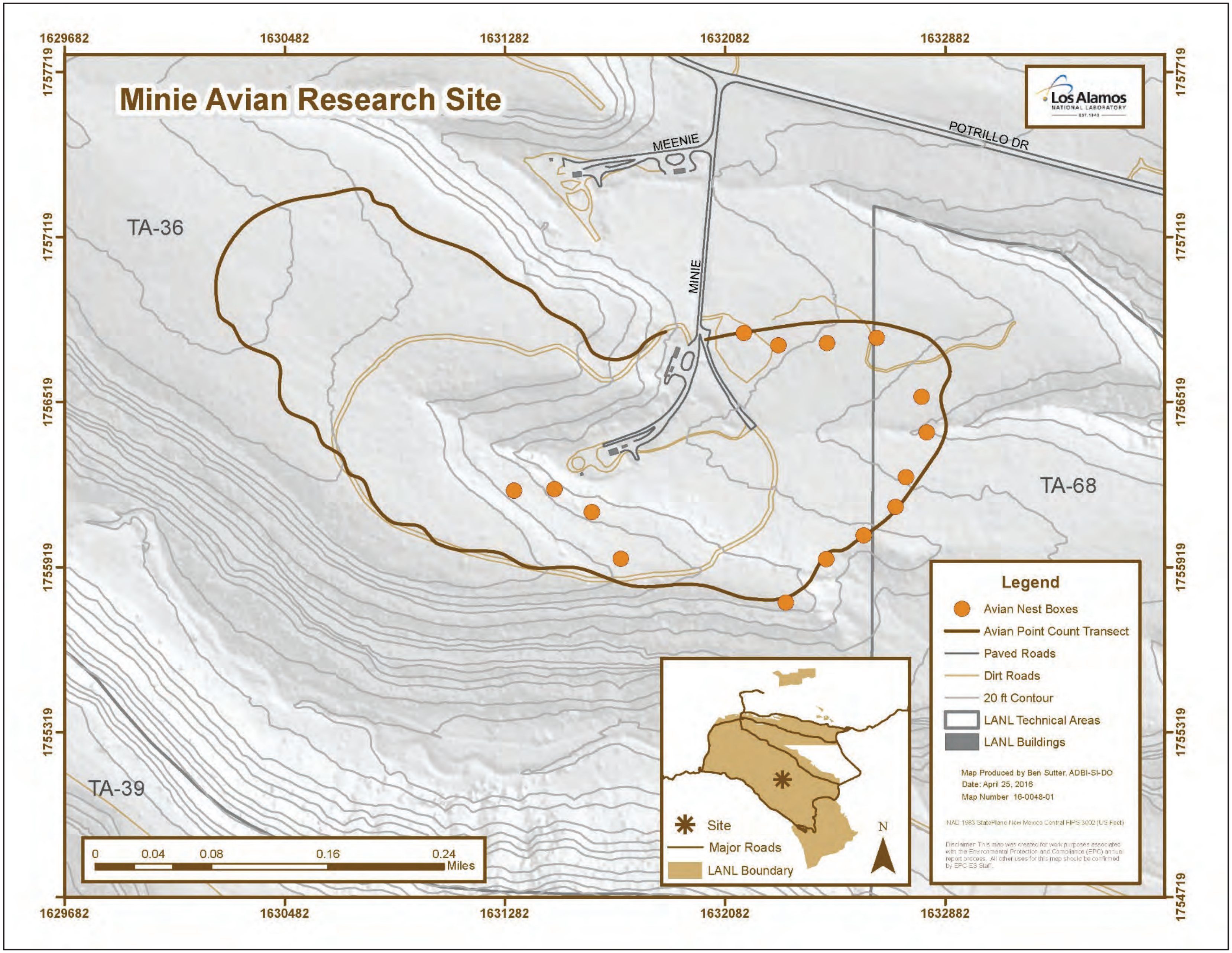
2011 as described in Hathcock et al. (2011). Each habitat type control contains two replicate transects that are monitored in the same way as the study sites with the same number of points and during the same time periods. In each survey month, all study site and control site transects are randomized and surveyed following the random order.

The PJ study sites at Minie site and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, proximity to developed areas, and in being situated on the mesa top. The MC study site at TA-16 is similar in elevation and overstory vegetation to the MC control sites, but is dissimilar in that the study site is located on a mesa top and the control sites are located in the bottom of a canyon in TA-43, TA-2, and TA-21. Being the bottom of a canyon, there are some differences in understory vegetation with a greater understory present at the control sites.

Transects are approximately 2.0 to 2.5 km in length and allow for nine survey points spaced approximately 250 m apart. These survey routes and points may change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys is May 1 through August 15. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol requires a total of three surveys per study site and surveys should be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along the transect spaced approximately 250 m apart.
- The surveyor will look and listen for 5 minutes, noting any birds encountered at each point. The distance for observations is considered as an “unlimited-distance circular plot”; however, the distance to each bird out to 100 m should be noted. Care is needed to ensure that individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, note any birds encountered that have not otherwise been counted from a previous point or future point. The surveyor’s main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Do not conduct surveys during rain events or winds greater than 15 mph.
- Record all birds encountered on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- Use the “NOTES” section to indicate any potentially important aspects of the survey that may affect the data. Examples include excess noise from nearby equipment and vehicles or aircraft that make it hard to hear the birds. Also, noting other wildlife or evidence of wildlife that could be used for further reference should be recorded.



Map Produced by Ben Sutter, ADBI-SI-DO
Date: April 25, 2016
Map Number 16-0048-01

NAD 1983 StatePlane New Mexico Central FIPS 3002 (US Feet)

Disclaimer: This map was created for work purposes associated with the Environmental Protection and Compliance (EPC) annual report process. All other uses for this map should be confirmed by EPC-ES Staff.

Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie site.

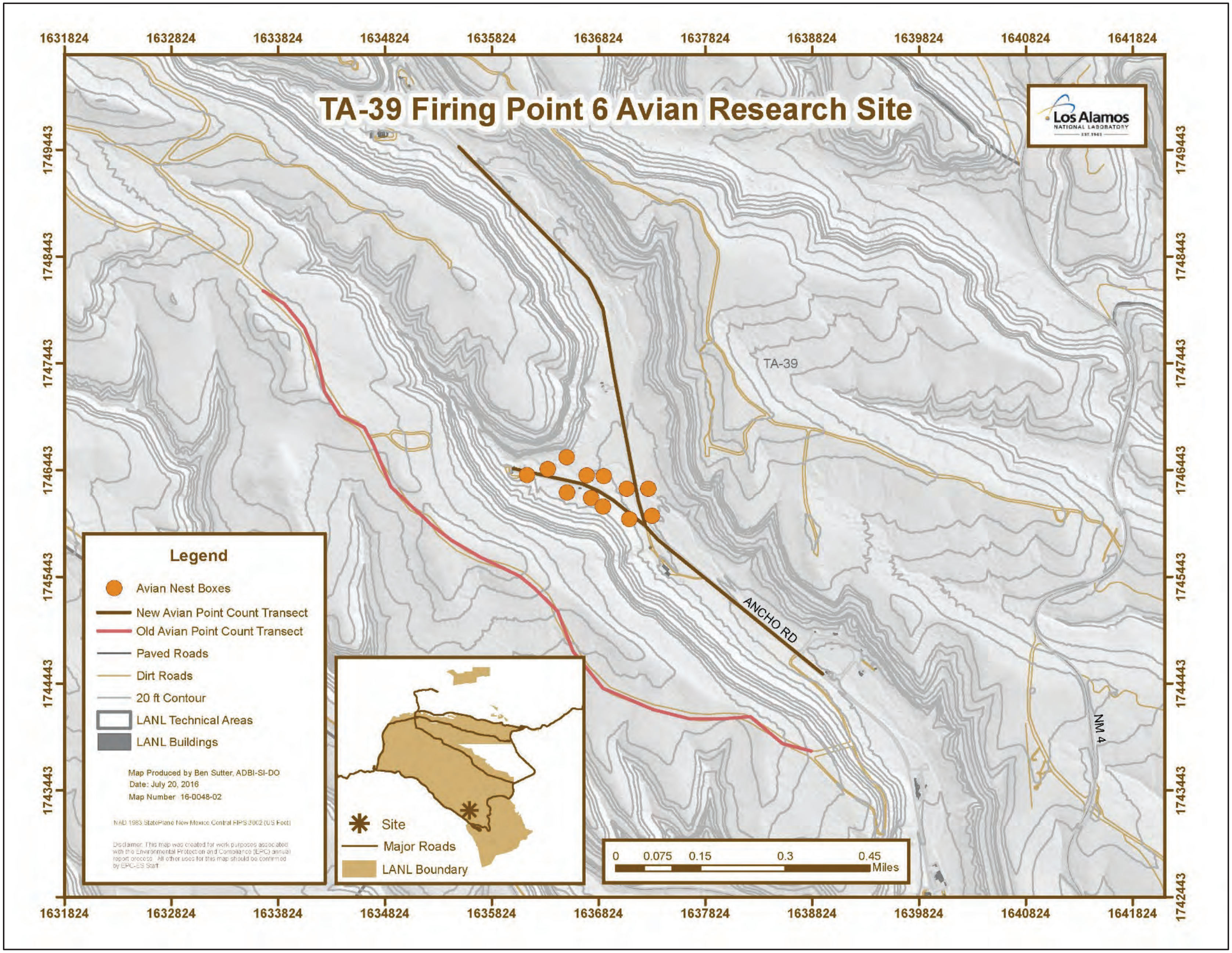


Figure 2. **Breeding bird survey transect and nestbox locations around TA-39 point 6.**

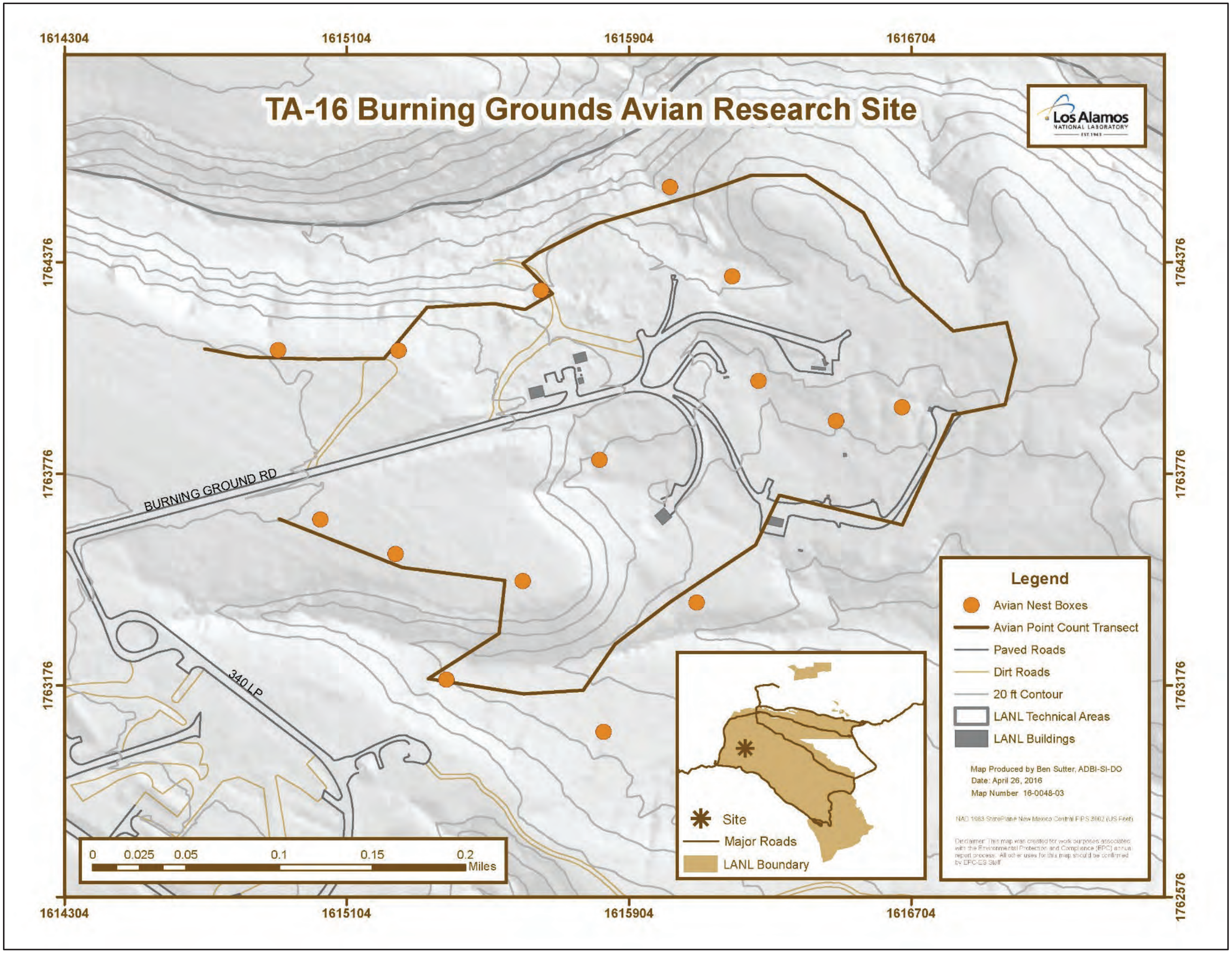


Figure 3. **Breeding bird survey transect and nestbox locations around the TA-16 burn ground.**

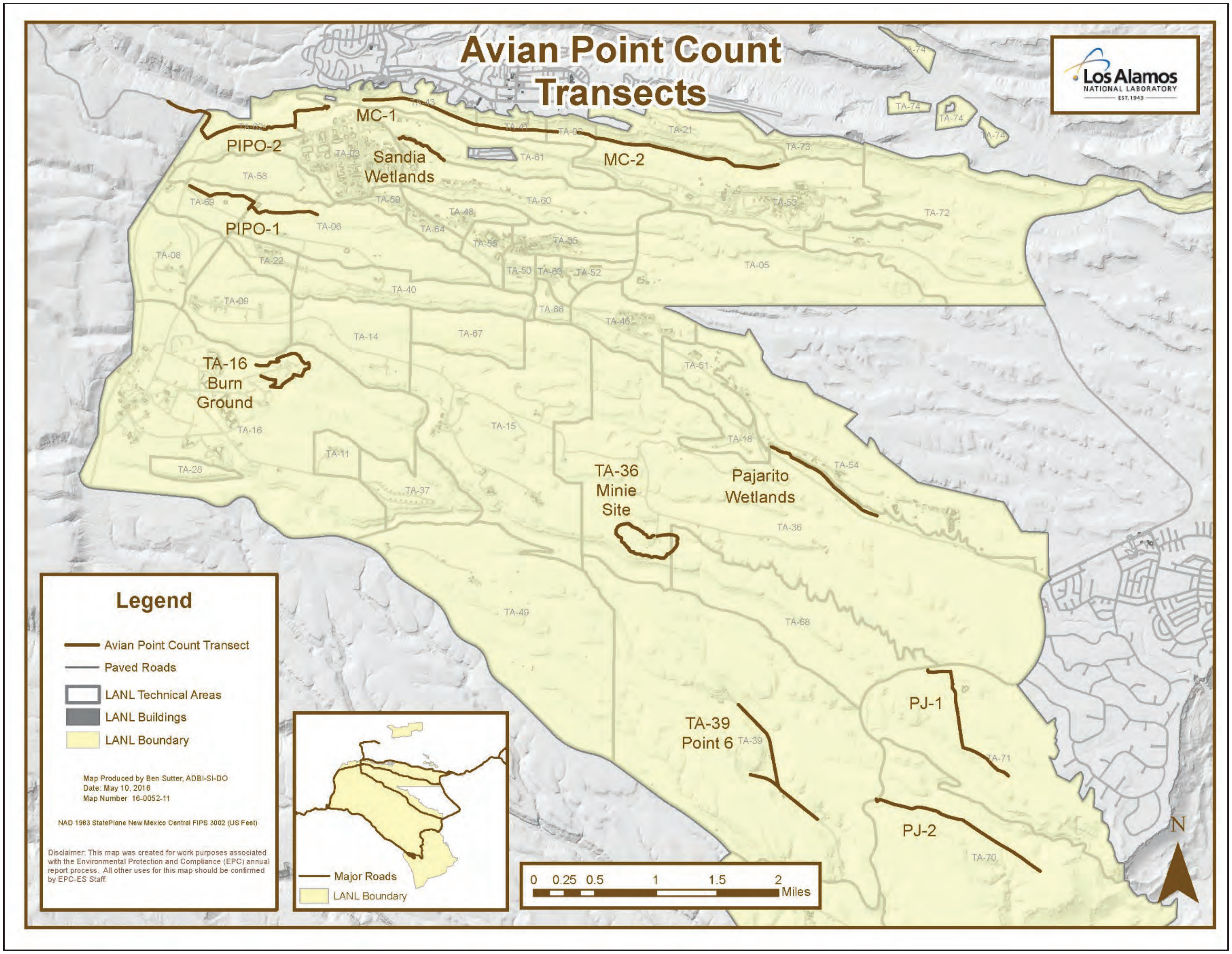


Figure 4. **All avian point count transects around LANL.**

MC: Mixed Conifer Forest, PIPO: Ponderosa Pine Forest, PJ: Pinyon-Juniper Woodland.

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to Minie site and TA-39 (Figures 1 and 2) and in 2015 nestboxes were added to TA-16 (Figure 3). Data from the three study sites are compared with the overall avian nestbox network at LANL that was established in 1997.

Nestboxes are monitored every 1 to 2 weeks for active nests. When an active nest is found, it is monitored more closely to determine whether the nest fails or successfully fledges young.

Statistical Methods

The data were summarized to look at trends in avian abundance and diversity for the three study sites and the control sites. To compare relative abundances between years and sites, the birds per hour (BPH) was calculated for each site by taking the total number of birds detected per survey and dividing by the total number of minutes surveyed. The result is multiplied by 60 to get the BPH. The BPH of the study sites and control sites were compared using the Mann-Whitney U non-parametric two-sample test because the data were not normally distributed. Probability values of 0.05 or less were considered significant.

The Shannon's diversity index (H) (Shannon 1948) was used to examine avian diversity for the study and control sites. The Shannon's H can range from 0.0 to 4.6, where larger values represent increasing diversity. H is calculated using the following formula:

$$H = -1 (p_i (\ln (p_i))$$

Where p_i is a percentage value of a specific species in the total population and ln is the natural log.

To compare indices, a Shannon t test was used. As described in Magurran (1988), the variance of H is determined, which then allows the determination of the t value and degrees of freedom. Probability values of 0.05 or less indicated a significant difference in H between the two samples. The diversity indices and Shannon's t test were computed using PAST version 3.08 statistical software (Hammer et al. 2001).

Birds were categorized into feeding guilds based on the work of De Graaf et al. (1985). For food type, they did not necessarily include all foods taken by each species, only the major food items (20% of diet during a given period).

- Carnivore: vertebrates
- Crustaceovore: crustaceans
- Frugivore: fruits
- Granivore: nuts
- Herbivore: plants (leaves, stems, roots)

- Insectivore: insects
- Moltuscovore: mollusks
- Omnivore: a variety of foods including both animal and plant foods (the less common food group makes up 10% of diet)
- Piscivore: fish
- Vermivore: sandworms, earthworms, etc.

The guilds were customized to account for some bird species being split since the publication. Other changes were made to make it more suited to this study. All woodpeckers were changed from frugivores to omnivores; vermivores (American Robins in this study) were changed to omnivores; hummingbirds were changed from omnivores to nectarivores; Cassin's and House finches were changed from frugivores to granivores. Nectarivores and carnivores were dropped from the analysis due to low samples sizes, leaving granivores, insectivores, and omnivores for this report. The mean number of birds and standard deviation were calculated for each feeding guild. The means of the study sites and control sites were compared using the Mann-Whitney U non-parametric two-sample test because the data were not normally distributed. Probability values of 0.05 or less were considered significant. All significant values in tables are bolded and shaded gray.

Occupancy rate and nest success rate of the nestboxes at the three study sites and in the overall network were calculated. For any single site or overall, the number of active nestboxes divided by the total number of nestboxes is the occupancy rate. Similarly, the number of nestboxes that successfully fledged young divided by the number of active nestboxes is the nest success rate.

Results and Discussion

Three surveys were completed at each of the three study sites and the associated control sites between May and July 2016. A total of 730 birds representing 54 species were recorded at the three study sites. A full account of the 2013–2016 data is detailed in Appendix 1.

The mean BPH abundance values with error bars corresponding to +/- 1 standard deviation for each site by year are represented in Figure 5. The BPH was compared between study sites and their control site for each year using the Mann-Whitney U non-parametric two sample test (Table 1). These results indicate that in 2016 the relative abundance of the bird communities at Minie Site and TA-39 was similar to its respective control site. The MC control site was significantly ($p = 0.03$) higher than TA-16.

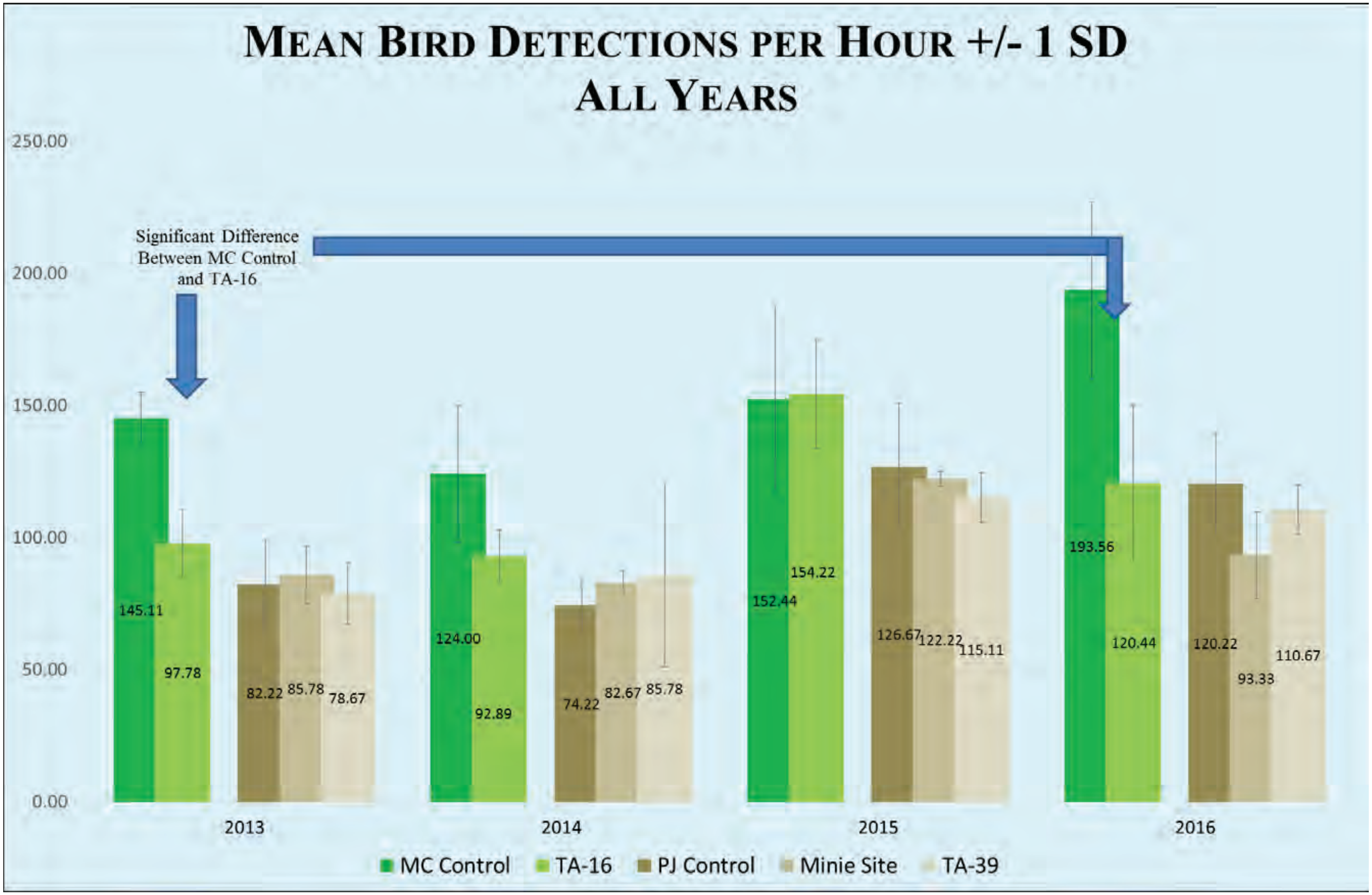


Figure 5. Birds per hour for the study and control sites. Error bars are +/- 1 standard deviation.
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

Table 1. Comparisons of BPH between study sites and control sites among years.

Years	MC Control to TA-16	PJ Control to TA-39	PJ Control to Minie Site
2013	**Z = -2.203 (p = 0.03)**	Z = -0.1313 (p = 0.89)	Z = 0.3889 (p = 0.69)
2014	Z = -1.6853 (p = 0.09)	Z = -0.3889 (p = 0.69)	Z = 1.1818 (p = 0.23)
2015	Z = 0.1291 (p = 0.89)	Z = -0.1296 (p = 0.89)	Z = 0.3939 (p = 0.69)
2016	**Z = -2.194 (p = 0.03)**	Z = -0.6482 (p = 0.52)	Z = -1.1668 (p = 0.24)

Note: statistically significant results are shaded.

Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in BPH in 2015 were attributed to the increased precipitation. Links between moisture and habitat quality for a migratory bird have been documented (Smith et al. 2010) and may be a causal factor. The winter of 2015 and into early 2016 was drier. The fluctuations in bird abundances are not alarming and the differences between the study sites and control sites are not *biologically* significant. The 2016 results at the three study sites are still higher than the first two years of the study. The data suggest that LANL operations are not negatively affecting the bird abundances at the three study sites.

The species diversity was determined using the Shannon's diversity index for each of the three study sites as well as the comparable habitat type control sites. The Shannon's diversity values for each site by year are represented in Figure 6. The bird diversity was compared between study sites and their control site for each year using the *t* test (Table 2).

Table 2. Shannon values for the study sites and control sites.

Years	MC Control and TA-16	PJ Control and Minie Site	PJ Control and TA-39
2013	t = 1.4194, df = 376, p = 0.15	**t = 2.9717, df = 510, p < 0.01**	**t = 2.3053, df 466, p = 0.02**
2014	t = 1.9235, df 412, p = 0.06	t = 1.8716, df = 455, p = 0.06	t = 1.0396, df = 477, p = 0.29
2015	**t = 4.4626, df = 653, p < 0.01**	t = 0.52699, df = 663, p = 0.59	t = -0.2166, df = 482, p = 0.82
2016	**t = -2.6496, df 501, p < 0.01**	**t = 2.5304, df = 489, p = 0.01**	t = -1.587, df = 515, p = 0.11

Note: statistically significant results are shaded.

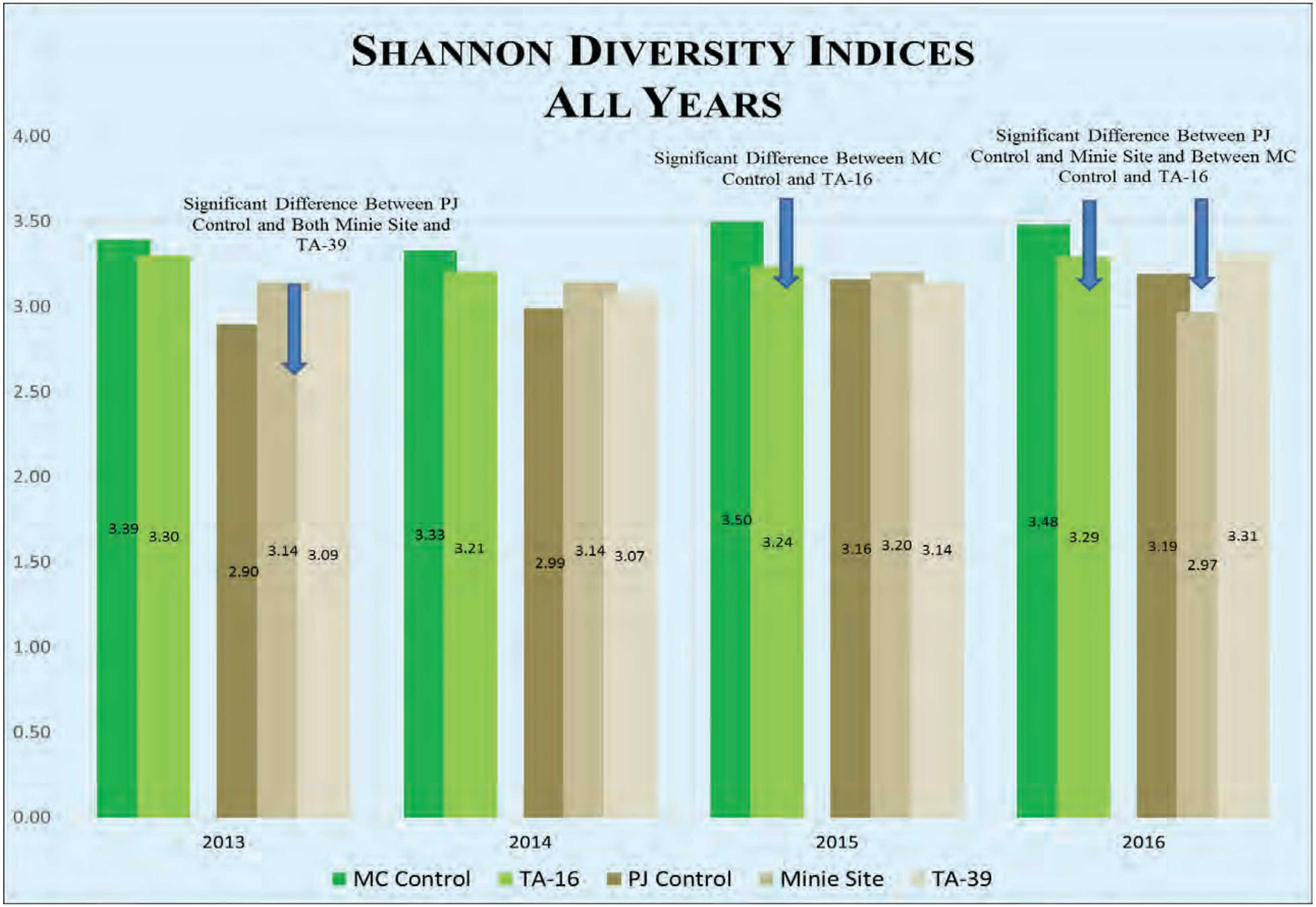


Figure 6. **Shannon's diversity indices for the study and control sites.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat.

The 2013 results indicated that the bird diversities in the PJ control sites were significantly less than Minie site ($p < 0.01$) and TA-39 ($p = 0.02$) trending toward similarity in following years. The results also indicate that in 2015 the bird diversity at TA-16 was significantly lower ($p < 0.01$) than the MC control. Hathcock and Fair (2013) discussed this issue and attributed it to the circumstance that the MC control sites were located in a canyon bottom closer to the townsite compared with TA-16 located on a mesa top.

In 2016, the species diversity indices at Minie site were significantly less ($p = 0.01$) than its PJ control, with 14 fewer species present. The TA-16 bird diversity was also significantly less ($p < 0.01$) than its MC control, with seven fewer species present. The significant drop in species diversity at Minie site may be indicative of a change in community structure. Due to increased fuels reduction, including more tree removals, the habitat availability is changing. The site is becoming more grassland-like than PJ. There are currently no control sites for grasslands at LANL but additional control sites may be needed in the future. The 2016 data also show that species diversity was again significantly less at TA-16 than the MC control sites. This trend will continue to be monitored and new research may be warranted to investigate changes in habitat structure and quality.

A new analysis was started in 2015 for this study. Bird species were categorized into feeding guilds based on the work of De Graaf et al. (1985). Only granivores, insectivores, and omnivores are presented in this report. The mean number of birds for these three feeding guilds with error bars corresponding to +/- 1 standard deviation for each site by year are represented in Figures 7–9. Insectivores have consistently been the largest feeding guild, followed by the omnivores and the granivores.

The mean number of birds in 2016 were compared between years and among feeding guilds by study site using the Mann-Whitney U non-parametric two-sample test (Table 3). These results indicate that omnivores increased in the MC control and were significantly higher ($p = 0.03$) than at TA-16. Additionally, the overall number of granivores increased in the PJ control and were significantly higher ($p = 0.03$) than at Mine site. The control sites were analyzed similarly and trends very generally indicate that the mean numbers dropped slightly from 2013 to 2014, increased dramatically in 2015 and then decreased slightly in 2016. This fits well with the precipitation discussion earlier with the BPH differences.

Feeding guilds are also useful to monitor for habitat changes. From Figure 7 it is apparent that granivores are more prevalent in PJ habitats compared with MC. The opposite is seen in Figure 8 as insectivores are much higher in MC habitat than PJ. The omnivores are more evenly distributed among both habitats (Figure 9), which is indicative of their generalist nature, although the MC habitat does still have higher numbers of these birds.

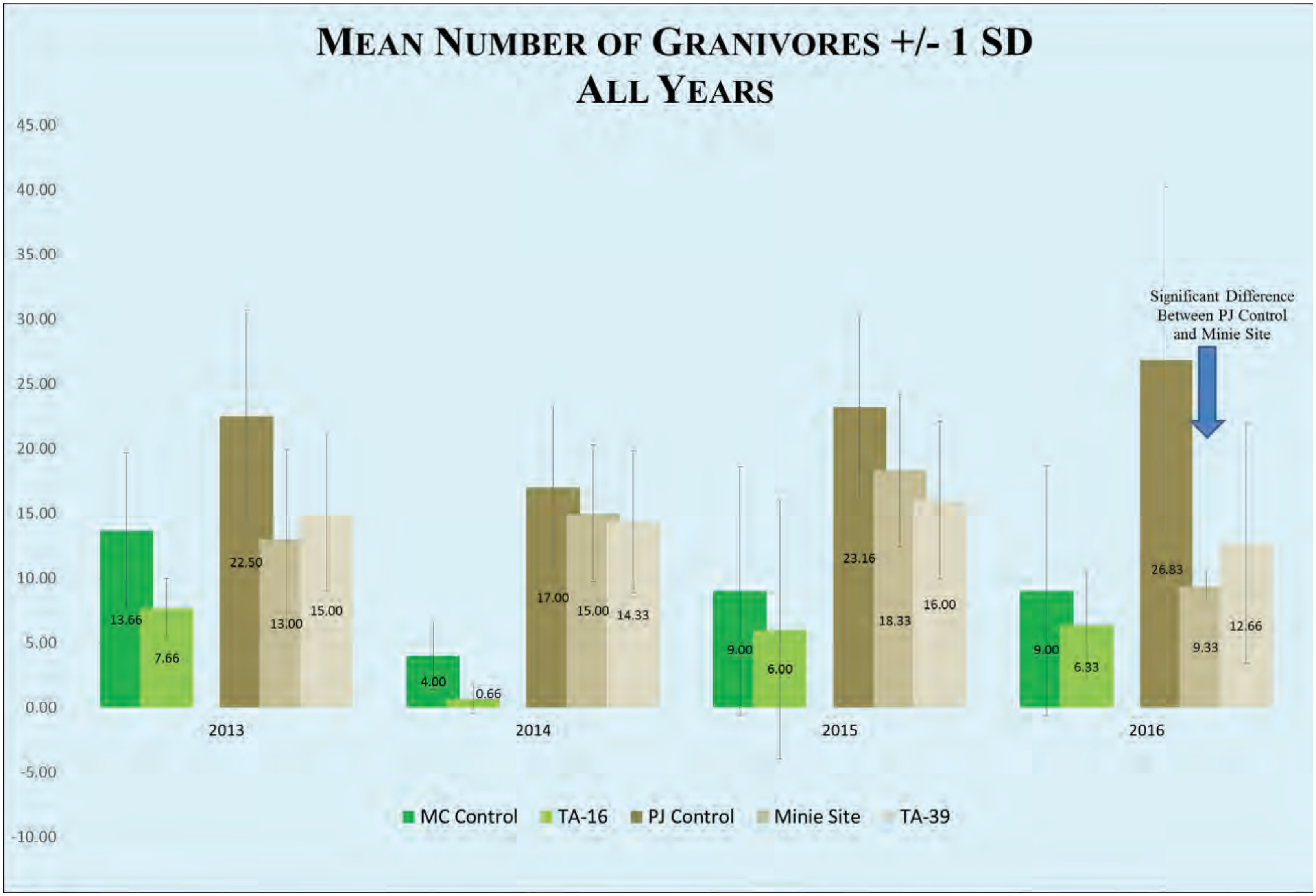


Figure 7. **Mean number of granivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

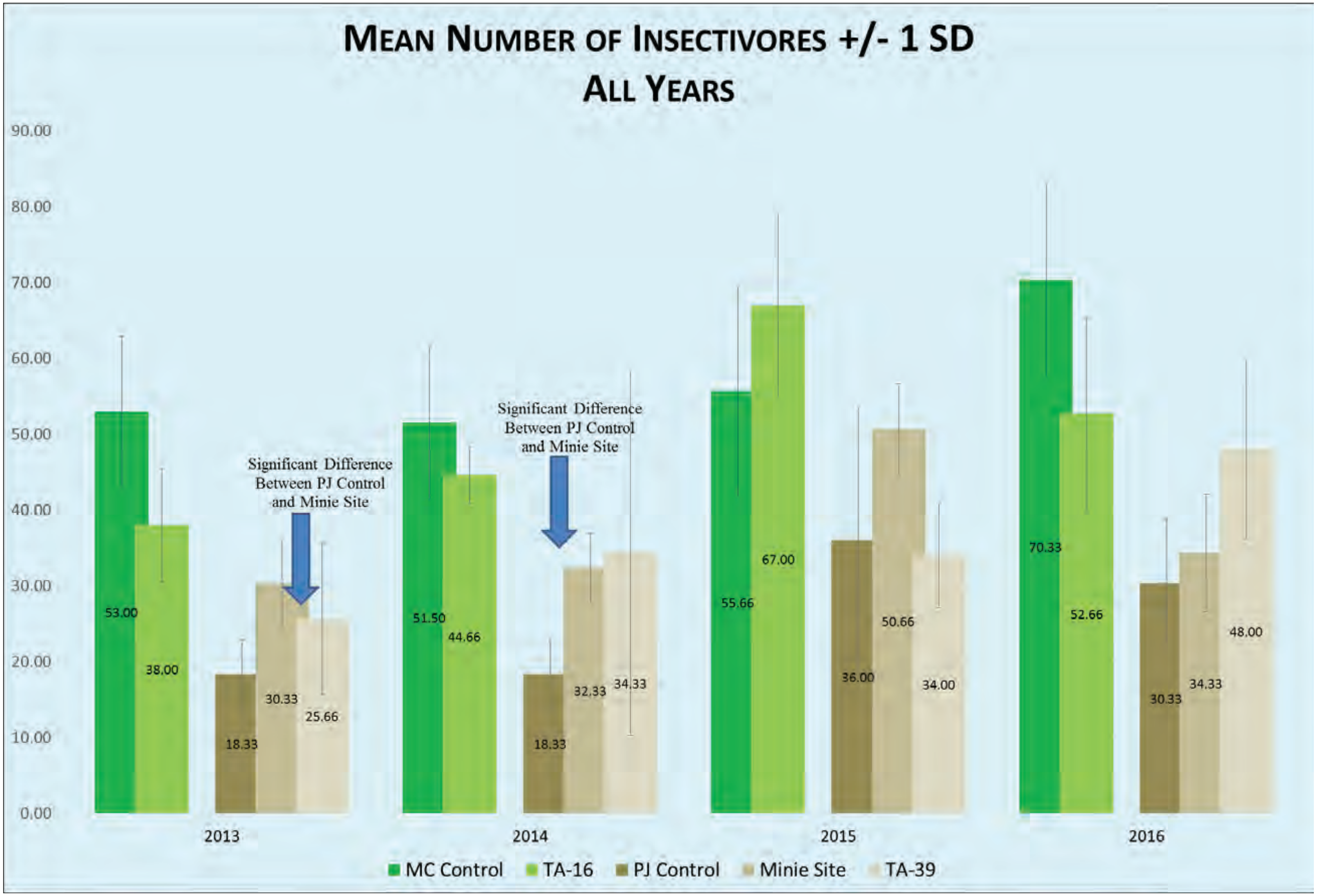


Figure 8. **Mean number of insectivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

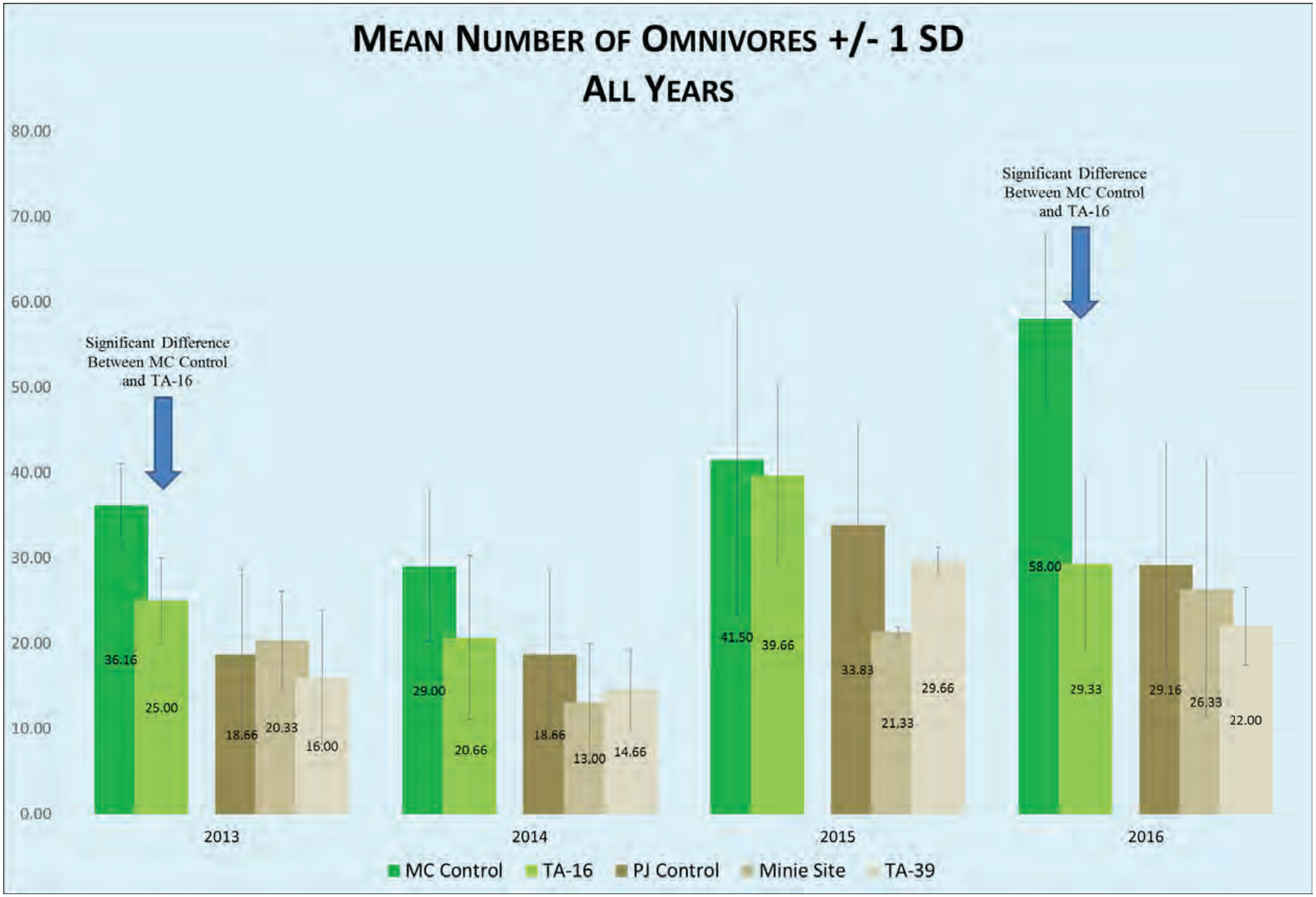


Figure 9. **Mean number of omnivores for the study and control sites. Error bars are +/- 1 standard deviation.**
MC Control: Mixed conifer habitat, PJ control: Pinyon-juniper habitat

Table 3. Comparing the mean number of birds between study sites and their control by feeding guilds for each year.

	2013			**2014**		
Site Comparisons	**Granivore**	**Insectivore**	**Omnivore**	**Granivore**	**Insectivore**	**Omnivore**
MC Control and TA-16	Z = -1.1921 (p = 0.23)	Z = -1.6783 (p = 0.09)	**Z = -2.2039 (p = 0.03)**	Z = -1.8226 (p = 0.07)	Z = -0.9113 (p = 0.36)	Z = -0.9037 (p = 0.36)
PJ Control and Minie Site	Z = -1.1717 (p = 0.24)	**Z = 1.9696 (p = 0.05)**	Z = 0.3956 (p = 0.69)	Z = -0.2593 (p = 0.79)	**Z = 2.2132 (p = 0.03)**	Z = -0.7811 (p = 0.43)
PJ Control and TA-39	Z = -1.1668 (p = 0.24)	Z = 0.9191 (p = 0.35)	Z = -0.3939 (p = 0.69)	Z = -0.5186 (p = 0.60)	Z = 1.0415 (p = 0.29)	Z = -0.6482 (p = 0.51)

Note: statistically significant results are shaded.

(Continued)	**2015**			**2016**		
Site Comparisons	**Granivore**	**Insectivore**	**Omnivore**	**Granivore**	**Insectivore**	**Omnivore**
MC Control and TA-16	Z = -0.5208 (p = 0.60)	Z = 0.7778 (p = 0.43)	Z = 0.1291 (p = 0.89)	Z = 0.0000 (p = 1.00)	Z = -1.6783 (p = 0.09)	**Z = -2.1947 (p = 0.03)**
PJ Control and Minie Site	Z = -1.0371 (p = 0.29)	Z = 1.4201 (p = 0.15)	Z = -1.4260 (p = 0.15)	**Z = -2.2039 (p = 0.03)**	Z = 0.3873 (p = 0.69)	Z = -0.2593 (p = 0.79)
PJ Control and TA-39	Z = -1.1619 (p = 0.24)	Z = 0.0000 (p = 1.0)	Z = -0.5186 (p = 0.60)	Z = -1.2964 (p = 0.19)	Z = 1.6783 (p = 0.09)	Z = -0.2593 (p = 0.79)

Note: statistically significant results are shaded.

During the 2016 nesting season, fifteen nestboxes each at Minie site and TA-16 and twelve nestboxes at TA-39 were actively monitored. The overall avian nestbox network without the three study sites contained 416 nestboxes in 2016. Of those, 188 contained active nests and 130 of those nests fledged young successfully. This was an overall occupancy rate of 45% with a 69% success rate.

At Minie site, thirteen nests were found and three of the nests fledged young successfully. Only eleven nestboxes were occupied, but two of those nestboxes had a second clutch. This was an occupancy rate of 73% with a 23% success rate.

At TA-39, seven nests were found. This was an occupancy rate of 58% with a 57% success rate. These nestboxes at TA-39 were relocated in 2016, and their occupancy increased seven-fold. The firing site at TA-39 is in a small narrow canyon and the nestboxes were moved a little further out to a more open area to increase nesting attractiveness. The number of nestboxes in 2016 will also increase to 15 to be consistent.

At TA-16, eleven nests were found and seven of the nests fledged young successfully. This was an occupancy rate of 73% with a 63% success rate.

The occupancy rates at Minie site and TA-16 were greater than the results in the overall network. Yet, the nest success rates of these sites dropped well below the average of the rest of the network. This was largely due to an increase in predation. The redeployment of nestboxes within TA-39 also led to higher occupancy and nest success over previous years' placement. However, more years of data are needed to begin to look at the results in a more robust manner.

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 54 species detected at the three study sites, all are protected under the Migratory Bird Treaty Act. Additionally, two of the species detected at the three study sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those two species are the Juniper Titmouse and Grace's Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901). Another conservation tool used in migratory bird management is the Birder's Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three study sites are on the top 100 list. They are the Virginia's Warbler and Grace's Warbler.

Management Recommendations

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL's avifauna at the three study sites, contribute to meeting the Department of Energy's commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and allow LANS to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Many thanks to the following for technical and field support work in 2016: Tatiana Espinoza, Marlena Greene, Teresa Hiteman, Luciana Vigil-Holterman, David Keller, Rich Mirenda, Maria Musgrave, Emily Phillips, Aaron Skinner, and Jordan Herman; and former staff and interns that helped in previous years.

Literature Cited

De Graaf, R.M., N.G. Tilghman, and S.H. Anderson. 1985. Foraging Guilds of North America. Environmental Management 9(6):493–536.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. LA-UR-13-27825. Los Alamos National Laboratory, Los Alamos, New Mexico.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, New Mexico.

Magurran, A. 1988. Ecological Diversity and Its Measurement. Princeton University Press.

Shannon C.E. 1948. A Mathematical Theory of Communication. Bell Syst. Tech. J. 27:379–423.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874–2882.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine. September 2015. “Weather Machine Climatological Monthly Summary,” http://weather.lanl.gov/climo_monthly_summary.asp.

Wells, J.V. 2007. Birder’s Conservation Handbook: 100 North American Birds at Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

Appendix 1. All birds recorded at the three study sites from 2013–2016.

	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Species	TA-36				TA-39				TA-16			
	Pinyon-Juniper Woodland				Pinyon-Juniper Woodland				Mixed Conifer Forest			
Acorn Woodpecker									5		3	2
American Kestrel				1	1			2				
American Robin	1	1	2		1	1		2	7		9	4
Ash-throated Flycatcher	11	5	14	13	19	11	29	12	3	5	6	2
Audubon's Warbler		2						2	6	5	1	6
Bewick's Wren	4	8	9	9	3	10	15	9				
Black-chinned Hummingbird		1	1		3	2			1		1	
Black-headed Grosbeak	1	3				2	4	1			1	2
Black-throated Gray Warbler			1		5	6	4					
Blue-gray Gnatcatcher	3	14	16	8	2		7	5		6	2	1
Broad-tailed Hummingbird	2	1	3		3	1	2		5	11	11	5
Brown Creeper									1			
Brown-headed Cowbird	1						2		4	1		
Bushtit		2		2	2	14						
Canada Goose							16					
Canyon Towhee	2		5	3	1	1	2	10	1			1
Canyon Wren							2	3			2	
Cassin's Kingbird	6	13	13	5	7	6	2	21				1
Chipping Sparrow	3	16	17	29	6	6	5	8	1	5	3	10
Clark's Nutcracker										4		1
Common Nighthawk	6		5	2	5	1	3	2			1	2
Common Raven	2	5	1		1		2	1	5	6	2	2
Cooper's Hawk									1			1

	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Species	TA-36				TA-39				TA-16			
	Pinyon-Juniper Woodland				Pinyon-Juniper Woodland				Mixed Conifer Forest			
Cordilleran Flycatcher									5	10	6	3
Dark-eyed Junco									6	2	4	
Downy Woodpecker				1				1		1		1
Dusky Flycatcher				1			1					
Eurasian Collared-Dove	3											
Evening Grosbeak	3		4				8		5		29	
Grace's Warbler									6	4	4	8
Gray Flycatcher	12	6	5	7	10	10	11	10				
Great Horned Owl		3			1							
Green-tailed Towhee	3	1			1							
Hairy Woodpecker			2	1			5	3	1	1		1
Hammond's Flycatcher									8	9	12	5
Hepatic Tanager							1	2				1
Hermit Thrush										4	6	1
House Finch	16	17	26	17	21	4	23	9	16	2	5	5
House Wren									1	1		2
Juniper Titmouse	12		7	6	11	13	18	6				
Lesser Goldfinch	2	6	7	4	4	12	9	10	3		8	9
MacGillivray's Warbler												1
Mountain Bluebird		2	20	10		4					4	4
Mountain Chickadee	5	2	1	2				1	5	8	9	6
Mourning Dove	17	17	13	5	13	22	10	3	4		1	3
Northern Flicker								3				
Northern Mockingbird						1						
Peregrine Falcon							1					

	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
Species	TA-36				TA-39				TA-16			
	Pinyon-Juniper Woodland				Pinyon-Juniper Woodland				Mixed Conifer Forest			
Pine Siskin	10	2		5	6		3	3	12	4	5	
Plumbeous Vireo	10	10	7	3	1		1	6	11	16	15	14
Pygmy Nuthatch				2			2	4	11	13	26	29
Red Crossbill						2				2	9	13
Red-shafted Flicker	3	1	3	2	3	2	4	5	3	4	11	11
Red-tailed Hawk							1	1				
Rock Wren	3	3	4		7	10	4	12	1	2	2	6
Say's Phoebe	2	1	2		2	1		5	1		1	3
Scaled Quail			1									
Spotted Towhee	17	8	19	27	12	6	33	16	11	18	16	14
Steller's Jay									3	2	5	6
Townsend's Solitaire	1											
Turkey Vulture									1			
Violet-green Swallow		5	7	1	6	4	1	9		2	19	2
Virginia's Warbler							1	2	17	11	21	13
Warbling Vireo									2	9	7	6
Western Bluebird	15	11	18	17	5	19	12	21	20	20	49	37
Western Scrub-Jay	5	1	3	4	8	10	4	8	1			
Western Tanager		2	3			2	1	1	2	3	7	2
Western Wood-Pewee	10	8	18	11		4	2	10	15	10	16	14
White-breasted Nuthatch	1	4	9	10			2	4	9	8	7	9
White-throated Swift						1						
White-winged Dove	1	5	9	2	7	5	6	16			1	2
Grand Total	**193**	**186**	**275**	**210**	**177**	**193**	**259**	**249**	**220**	**209**	**347**	**271**

20. Hathcock, C.D., A.W. Bartlow, and B.E. Thompson, April 2018. *2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-18-22897. OSTI Identifier 1435543. (Hathcock *et al*. 2018)

LA-UR-18-22897

Title: 2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory

Author(s): Hathcock, Charles Dean
Bartlow, Andrew William
Thompson, Brent E.

Intended for: Environmental Regulatory Document

Issued: 2018-04-30 (rev.1)

LA-UR-18-22897

March 2018

2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Charles D. Hathcock[1], Andrew W. Bartlow[2], and Brent E. Thompson[1]

[1] Environmental Protection and Compliance Division, Environmental Stewardship, Los Alamos National Laboratory

[2] Biosecurity and Public Health, Los Alamos National Laboratory

An Affirmative Action/Equal Opportunity Employer

Contents

Figures

Tables

Executive Summary

Los Alamos National Security, LLC (LANS) biologists in the Environmental Compliance and Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. Monitoring results from these efforts were compared among years to monitor trends. The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Additionally, nesting success of secondary-cavity nesting birds was examined using nestboxes. LANS biologists completed the fifth year of this effort in 2017. The overall results from 2017 continue to indicate that operations are not negatively affecting bird populations; however, we are seeing some species turnover through time and that will continue to be monitored.

Three bird point count surveys were completed at each of the treatment sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground between May and July 2017. A total of 785 birds representing 59 species were recorded at the treatment sites. Three bird point count surveys were also completed at each of the control sites between May and July 2017. Occupancy and nest success data from nestboxes at treatment sites were compared with the overall avian nestbox monitoring network.

Species richness and diversity at the treatment sites were not statistically different than their associated controls. Avian abundance showed more variability but treatment and controls were trending together year to year. Species composition seems to indicate some species turnover in the habitat types but very little difference between treatment and control sites.

This page intentionally left blank.

Introduction

An annual avian monitoring program was started in 2013 as part of the Resource Conservation and Recovery Act permitting process at Los Alamos National Laboratory (LANL) for two open detonation sites, Technical Area (TA) 36 Minie site and TA-39 point 6, and one open burn site, TA-16 burn ground (hereafter referred to as Minie, TA-39, and TA-16, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017). The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Comparisons were made with control sites of similar habitat that have been surveyed since 2011 (Hathcock et al. 2011).

Los Alamos National Security, LLC (LANS) biologists used standard point count methodology to record avian abundance and diversity along transects at the three treatment sites and associated control sites during the summer of 2017. Summer surveys provide information about what birds were breeding at each site. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental change at LANL.

In addition to avian point counts, nestboxes were monitored around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success data were compared with the overall avian nestbox monitoring network, which was established in 1997.

Changes to the analysis methodologies were implemented this year. TA-16 is now being compared with a different set of controls, switching from a mixed conifer control to a ponderosa control. This change is retroactive for this report and all previous years were reanalyzed. The larger analysis of feeding guilds was dropped because of low sample sizes and difficulty in assigning guilds, they are still mentioned in a more general sense. Also, more robust statistics are used to analyze the datasets. In this report, the year 2017 is first analyzed separately, and then all years are analyzed to examine trends over time.

Methods

Field Methods for Point Count Surveys

The point count surveys were conducted along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon-juniper woodland (PJ) for Minie and TA-39 and a ponderosa pine forest (PIPO) at TA-16. These habitat descriptions were based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (Figure 4) were monitored annually in ongoing surveys that have been conducted at LANL since 2011 as described in Hathcock et al. (2011). Each habitat type control contained two replicate transects that were monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects were randomized and surveyed according to the random order.

The treatment sites at Minie and TA-39 were similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was more natural.

Transects were approximately 2.0 to 2.5 km in length and allowed for nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys was May 1 through August 15. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site and surveys must be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor will look and listen for 5 minutes, noting any birds encountered at each point. The distance for observations is considered as an “unlimited-distance circular plot”; however, the distance to each bird out to 100 m should be noted. Care is needed to ensure that individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, note any species encountered that have not otherwise been counted from a previous point or future point. The surveyor’s main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Do not conduct surveys during rain events or winds greater than 24 kph.
- Record all birds encountered on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- Use the “NOTES” section to indicate any potentially important aspects of the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Other wildlife or evidence of wildlife that could be used for other projects should be recorded.

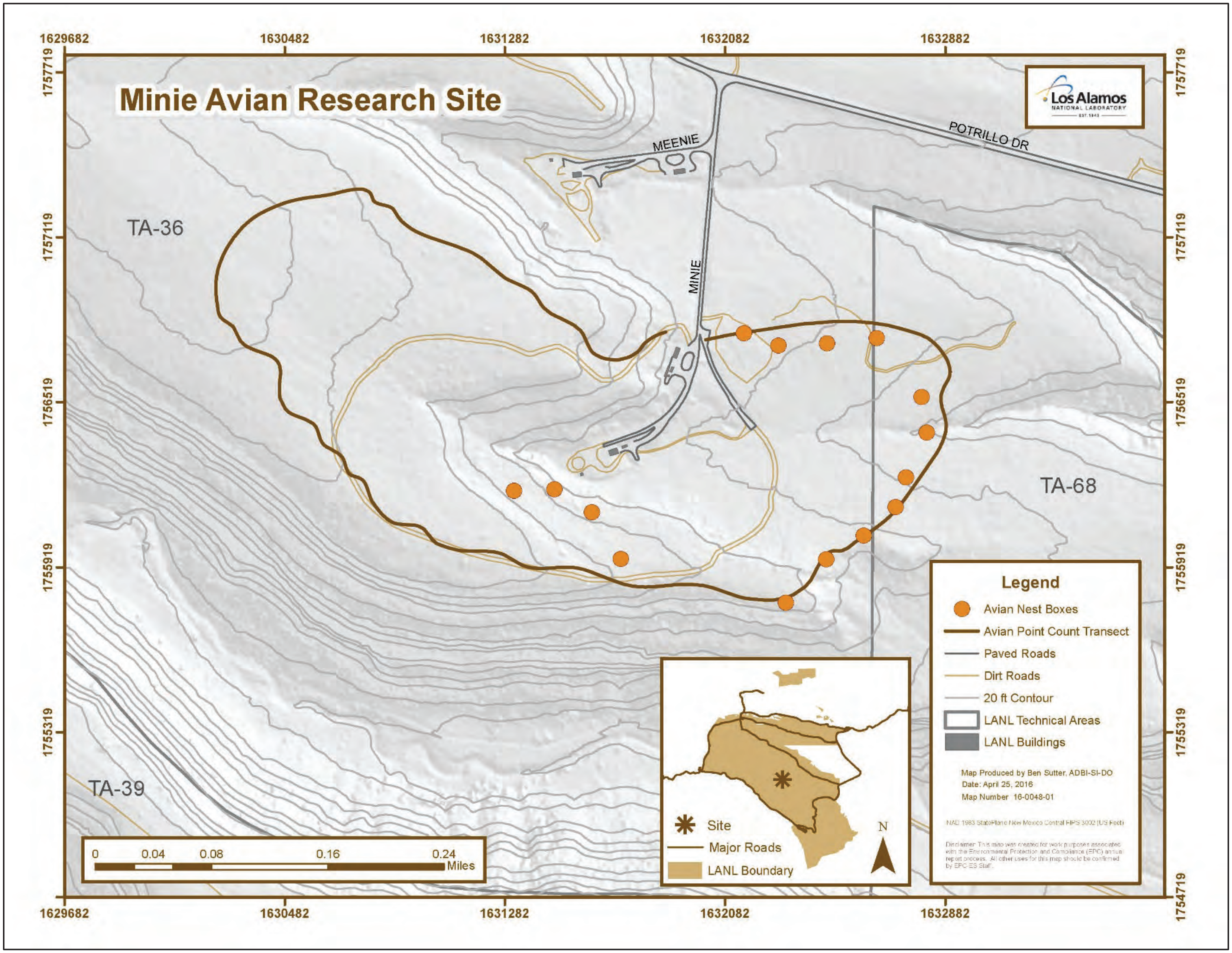


Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie site

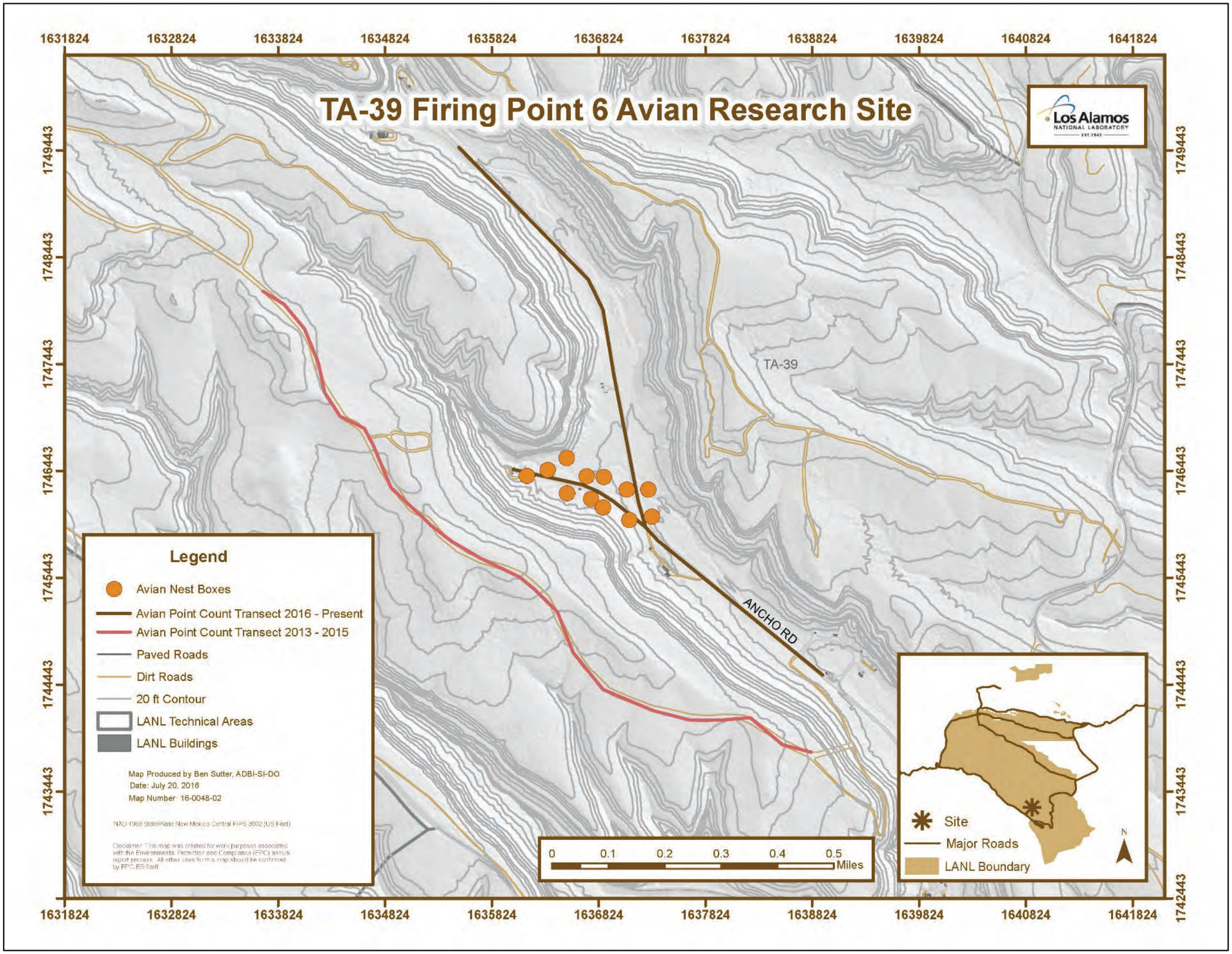


Figure 2. **Breeding bird survey transect and nestbox locations around TA-39 point 6**

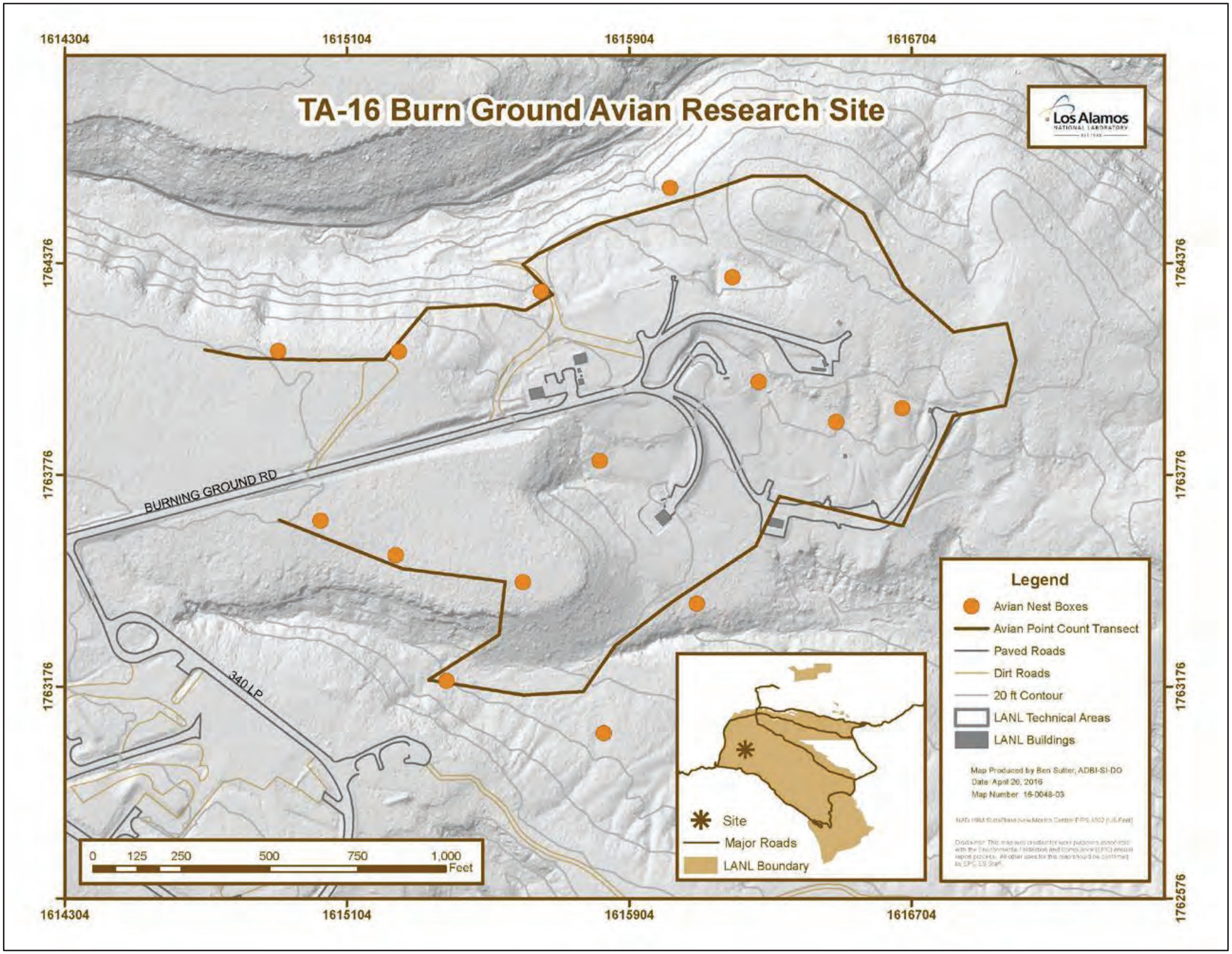
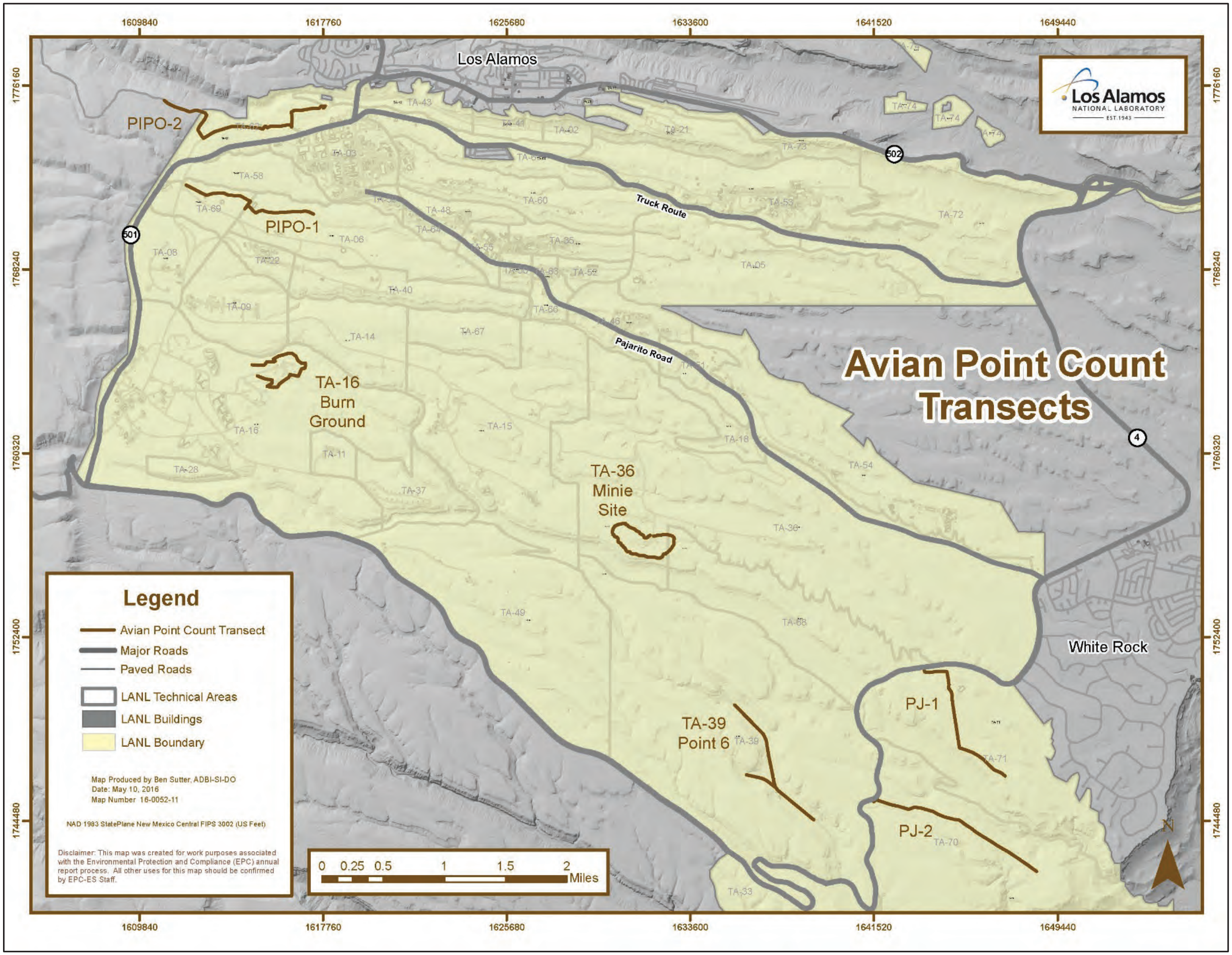


Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 burn ground



Map Produced by Ben Sutter, ADBI-SI-DO
Date: May 10, 2016
Map Number 16-0052-11

NAD 1983 StatePlane New Mexico Central FIPS 3002 (US Feet)

Disclaimer: This map was created for work purposes associated with the Environmental Protection and Compliance (EPC) annual report process. All other uses for this map should be confirmed by EPC-ES Staff.

Figure 4. **All avian point count transects around LANL**

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to Minie and TA-39 (Figures 1 and 2). In 2015, nestboxes were added to TA-16 (Figure 3). Nestboxes were monitored every 1 to 2 weeks for active nests. When an active nest was found, it was monitored more frequently to determine whether the nest failed or successfully fledged young. Nestlings were also banded and the sex determined after the age of 10 days.

Statistical Methods for Point Counts

The data were summarized to compare species richness, diversity, abundance, and composition between sites and among years using the statistical software R (version 3.4.1; R Core Team 2017). Species richness and diversity were computed using the R-package ‘iNEXT’ (Hsieh et al. 2016; Chao et al. 2014) and plotted with bootstrap confidence intervals around the mean for rarefied/extrapolated samples, facilitating the comparisons of richness and diversity. The estimated asymptote along with a confidence interval was also provided. The Simpson’s diversity index was calculated using the following formula: $D = 1 – (\sum n(n-1) / N(N-1))$, where n = the total number of organisms of a particular species and N = the total number of organisms of all species. The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0 represents no diversity. Species diversity was also computed using the statistical software PAST (Hammer et al. 2001) and a t-test was used to test for differences between treatment and control sites each year. Comparisons of Simpson diversity in two samples is described by Hutcheson (1970) and is an alternative to the permutation test. To examine species abundance, we used the number of individual birds among sites and across years and looked for trends. To examine species composition, non-metric multidimensional scaling (NMDS) was used to determine dissimilarity among sites. To compare species composition between treatments and years, an analysis of similarity (ANOSIM) was conducted using 1000 permutations. These analyses were completed using the community ecology package ‘vegan’ (Oksanen et al. 2017) in R.

Statistical Methods for Nestboxes

Occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network were calculated. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. Annually, data from the three treatment sites were compared with the overall avian nestbox network at LANL that was established in 1997.

Results and Discussion

Year 2017

Three surveys were completed at each of the three treatment sites and the associated control sites between May and July 2017. A total of 785 birds representing 59 species were recorded at the three treatment sites. A full account of the 2013–2017 data is detailed in Appendix 1.

Species richness is the number of different species represented in an ecological community and is simply a count of species. In this case, each treatment site and control are individual communities. Species diversity is a measure that takes into account the species richness and the overall abundance to compare evenness across a community. Here we used the Simpson's diversity index which measures the probability that two individuals randomly selected from a sample will belong to different species. The abundance is the total number recorded of a given species. Table 1 details the species richness, diversity, and abundance for 2017 for each site and its associated controls.

Table 1. The species richness, diversity, and abundance recorded at each site in 2017

2017	*Minie Site*	*TA-39*	*PJ Control 1*	*PJ Control 2*	*TA-16*	*PIPO Control 1*	*PIPO Control 2*
Richness	35	34	37	39	41	46	44
Diversity	0.9429	0.9486	0.9211	0.9462	0.9429	0.931	0.9462
Abundance	222	261	240	300	302	447	449

Species rarefaction and extrapolation from 2017 show no differences between treatment and control sites for species richness. There were overlapping 95% confidence intervals for species richness (Figures 5A–7A) for all three treatments and their controls. Simpson's diversity (Figures 5B–7B) was not as clear with 95% confidence intervals being further apart. To further analyze species diversity, we compared treatments to control sites using t-tests and confirmed that there was not a significant difference (Minie/Control t-test: $t = 0.1504$, $p = 0.88$; TA-39/Control t-test: $t = 1.2234$, $p = 0.22$; TA-16/Control t-test: $t = -0.6903$, $p = 0.49$) when comparing treatment to combined control sites. The two control transects for PJ were not as similar in diversity as expected ($t = -2.5322$, $p = 0.01$). For the PJ habitat type, control 1 is a walking transect and control 2 is a driving transect and the act of driving between points may be causing more species to be seen.

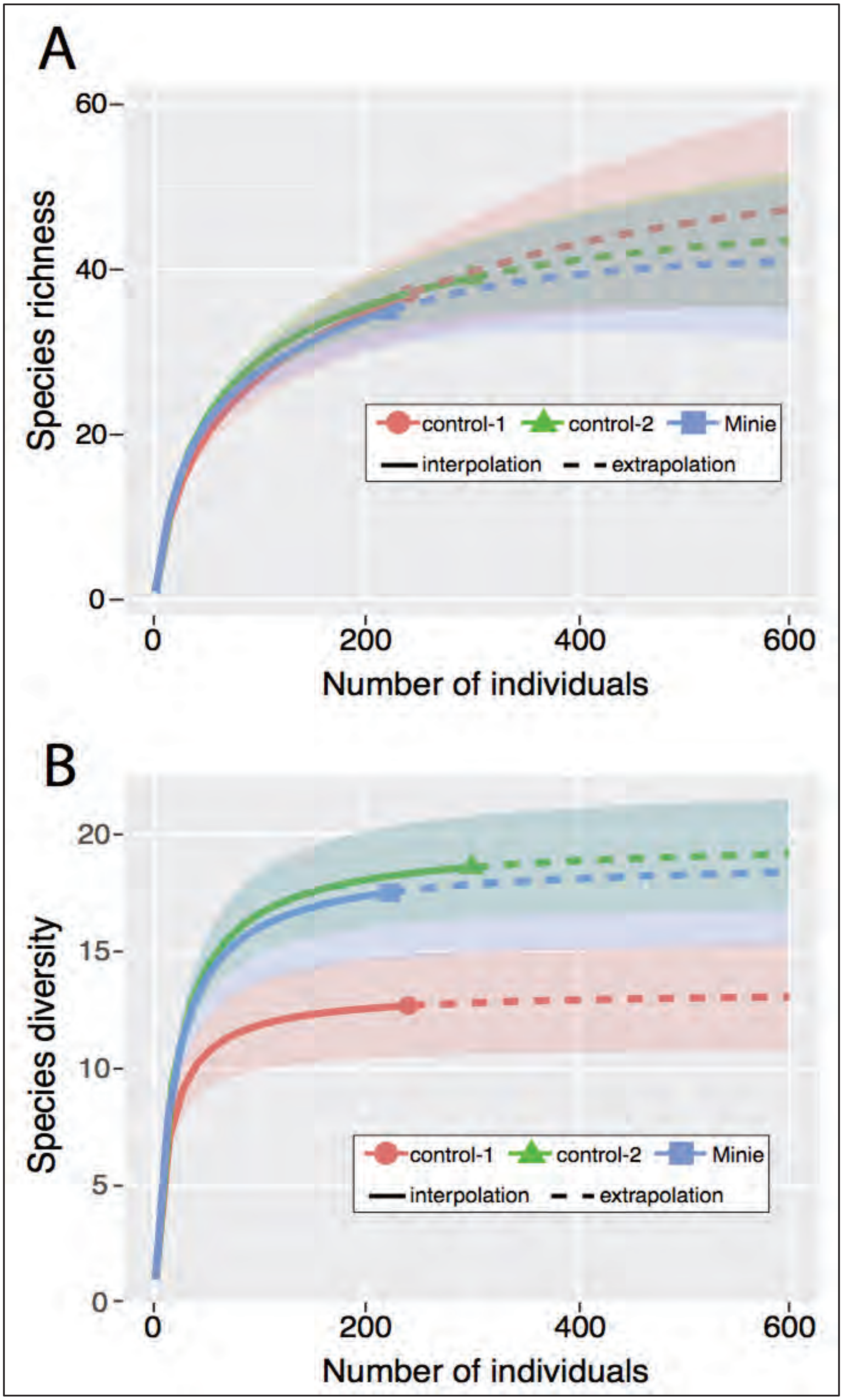


Figure 5. **Species rarefaction and extrapolation for species richness and diversity comparing Minie with the PJ controls**

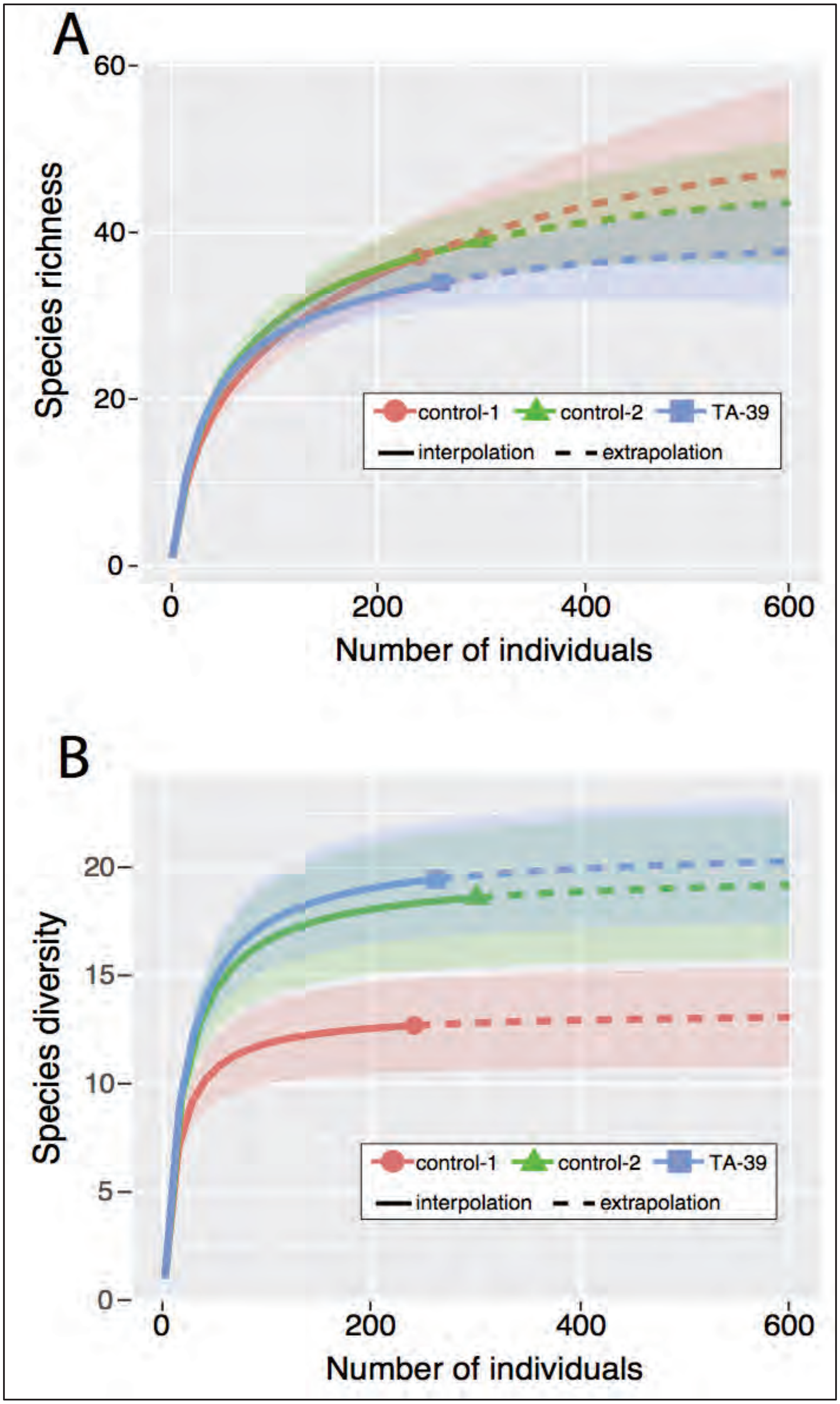


Figure 6. **Species rarefaction and extrapolation for species richness and diversity comparing TA-39 with the PJ controls**

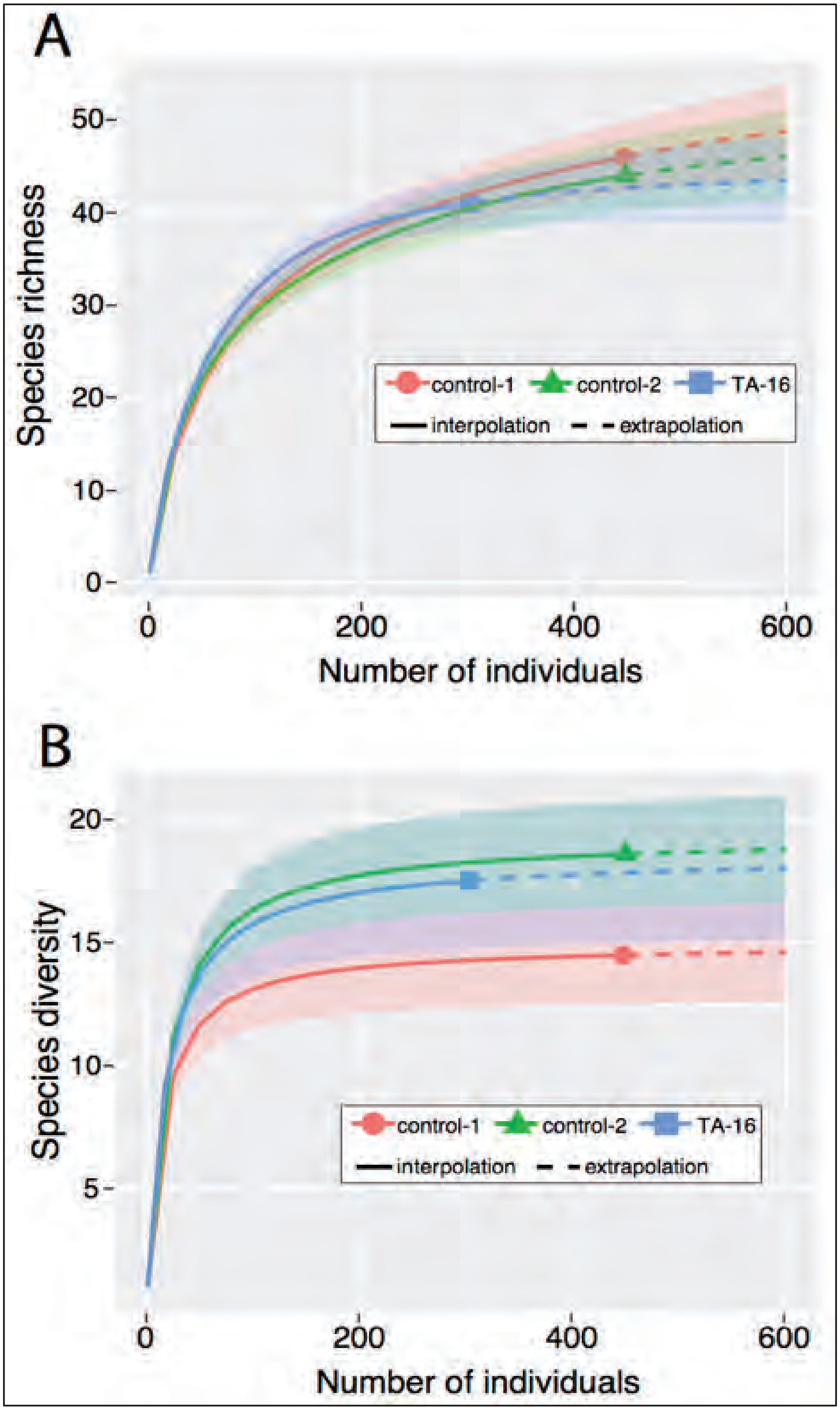


Figure 7. **Species rarefaction and extrapolation for species richness and diversity comparing TA-16 with the PIPO controls**

Multivariate analysis with ordination was used to explore the data further to look for patterns that may be explained by a multitude of other environmental factors not assessed directly. We used NMDS with three dimensions (Gardener 2014) in which a measure of 'stress' (mismatch between the rank order of distances in the data, and the rank order of distances in the ordination) was calculated. The samples were moved slightly in a direction that decreases the stress until stress appeared to reach a minimum. The final configuration of points is represented in Figure 8. Here, the species surrounding each site means that these species were important in separating the sites. The different species composition between the left and right and the upper and lower part of the graph (dotted lines = the reference lines) correlate with the associated habitat types. This graphically shows how the data for the PJ control sites were not as similar as the PIPO control sites in terms of species composition, which were on either side of the y-axis. This also shows what species were driving the patterns. The transect in TA-39 was in a canyon bottom whereas the PJ control transects were on mesa tops. The species driving the location of TA-39 was the White-winged Dove (WWDO), which is not as prevalent at both of the PJ control transects. Additionally, the Pinyon Jay (PIJA) and the Black-throated Gray Warbler (BTYW) were found mostly in PJ sites, while the Acorn Woodpecker (ACWO) and Hammond's Flycatcher (HAFL) were mainly found in ponderosa habitats. Based on their known habitat preferences, these data were consistent. The treatment sites were not significantly different from control sites (ANOSIM: R = 0.0, P = 0.4).

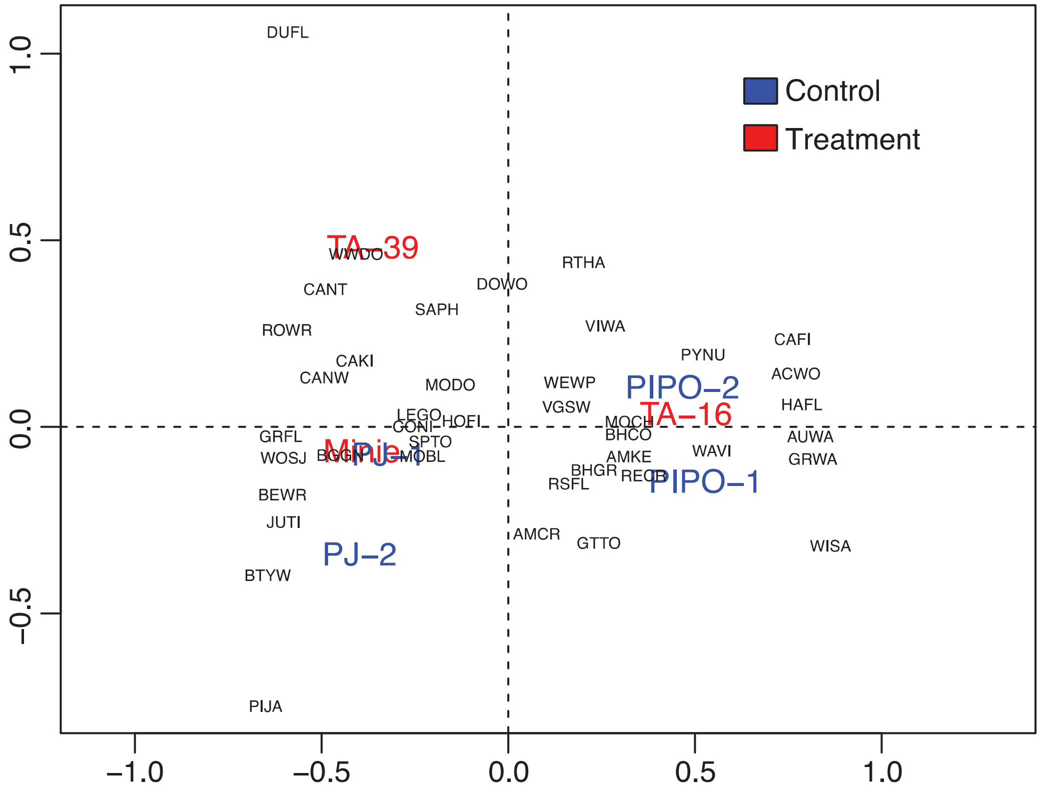


Figure 8. **Non-metric multidimensional scaling of bird species and sites in 2017**

Trends Over Time

Table 2 outlines the species richness over time at the treatment and individual control sites. The three treatment sites were maintaining a steady species richness over time with almost all indicating a slight increase in the number of species in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in richness, diversity, and abundance in 2015 were most likely attributed to the increased precipitation. Links between moisture and habitat quality for a migratory birds have been documented (Smith et al. 2010) and may be a causal factor. In addition, the winter of 2015 and into early 2016 was drier. The fluctuations in bird abundances are not alarming, and the differences between the treatment sites and control sites are not biologically significant.

Table 2. Changes in species richness over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*
Minie	33	33	34	30	35
TA-39	31	31	39	38	34
PJ Control 1	29	30	33	36	37
PJ Control 2	30	29	37	33	39
TA-16	33	33	40	44	41
PIPO Control 1	34	34	30	41	41
PIPO Control 2	33	36	43	43	44

Tables 3–5 compare the species diversity over time between the treatment site and the combined control. The two control sites were combined to analyze diversity because we were interested in the relative abundances among species and not the actual numbers. There have been some significant differences at times over the course of the study. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Figures 9 and 10 graphically represent the data fluctuations over time. Even though we see significant differences, the bird diversity at all sites is greater than 0.90, which compared with other systems, is very high.

Figures 11 and 12 graphically represent bird abundances over time. The overall abundance of birds is trending the same for all treatment sites compared with the controls. At TA-16, the overall abundance is lower, but the percent abundance is similar year to year when compared with the control sites.

Table 3. Changes in species diversity over time comparing Minie Site with the PJ controls*

	2013	*2014*	*2015*	*2016*	*2017*
Minie	0.9464	0.9463	0.9502	0.9315	0.9429
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419
t-test	t = 3.9572 df = 501.3 p = <0.01	t = 2.5469 df = 510.42 p = 0.01	t = 1.5902 df = 644.91 p = 0.11	t = 0.4385 df = 499.33 p = 0.66	t = 0.1504 df = 448.66 p = 0.88

* Darker shading indicates a significant difference.

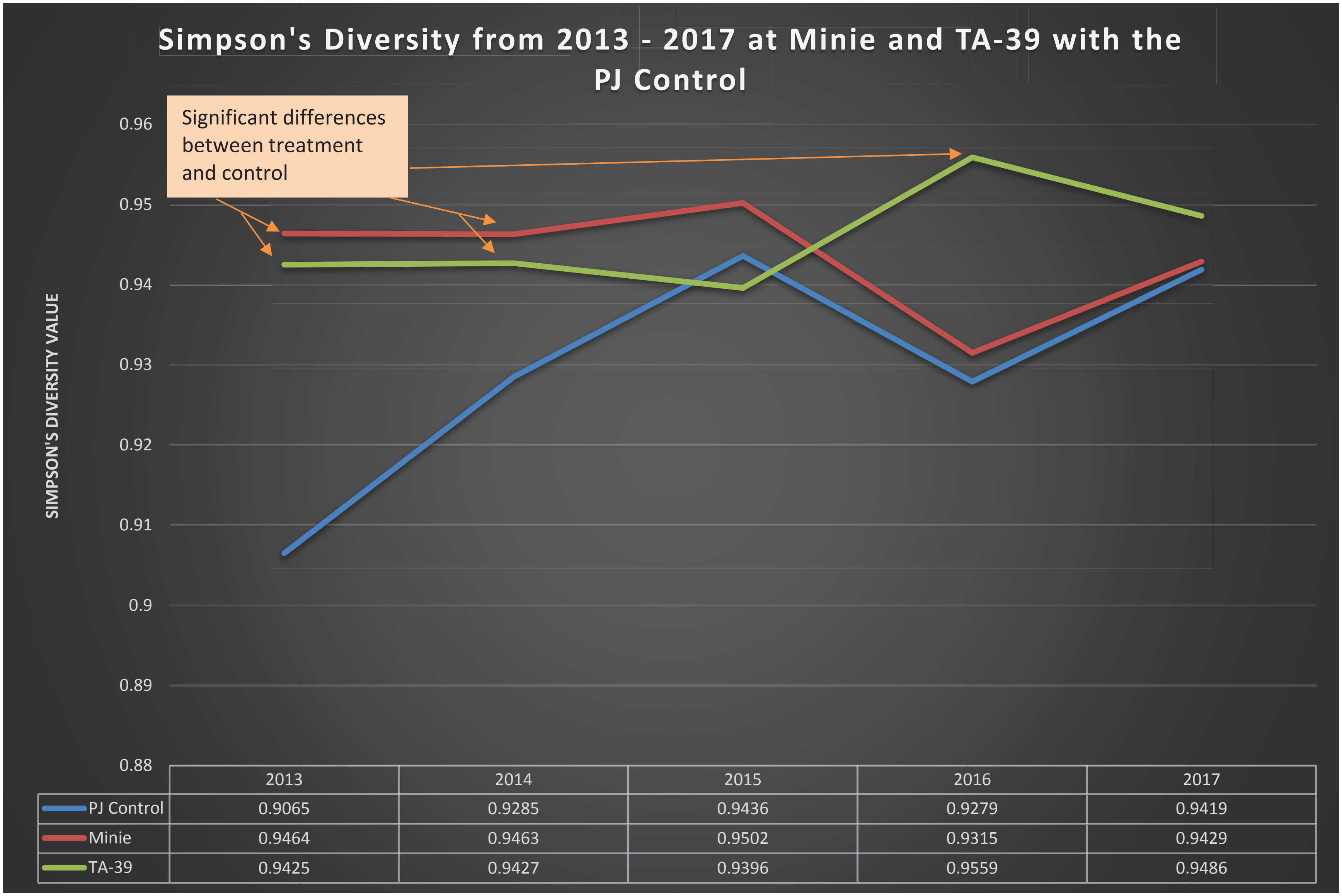
Table 4. Changes in species diversity over time comparing TA-39 with the PJ controls*

	2013	*2014*	*2015*	*2016*	*2017*
TA-39	0.9425	0.9427	0.9396	0.9559	0.9486
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419
t-test	t = 3.3636 df = 538 p <0.01	t = 1.9703 df = 509.25 p = 0.05	t = -0.6751 df = 401.58 p = 0.50	t = 4.5611 df = 783.86 p <0.01	t = 1.2234 df = 705.5 p = 0.22

* Darker shading indicates a significant difference.

Table 5. Changes in species diversity over time comparing TA-16 with the PIPO controls

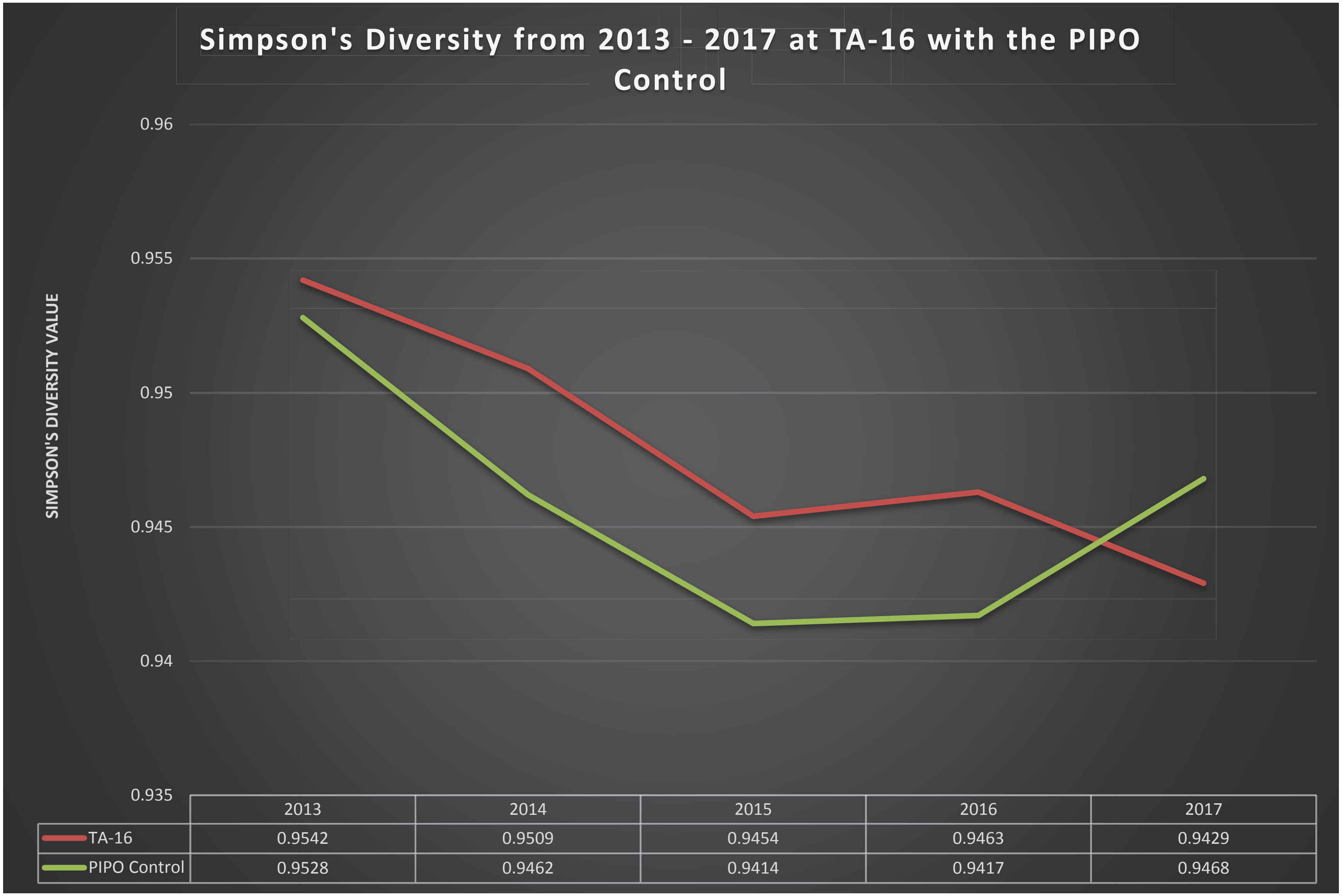
	2013	*2014*	*2015*	*2016*	*2017*
TA-16	0.9542	0.9509	0.9454	0.9463	0.9429
PIPO Control	0.9528	0.9462	0.9414	0.9417	0.9468
t-test	t = 0.3323 df = 378.91 p = 0.73	t = 0.9236 df = 472.24 p = 0.35	t = 0.748 df = 633.26 p = 0.45	t = 0.7438 df = 475.6 p = 0.45	t = -0.6903 df = 444.95 p = 0.49


Simpson's Diversity from 2013 - 2017 at Minie and TA-39 with the PJ Control

Significant differences between treatment and control

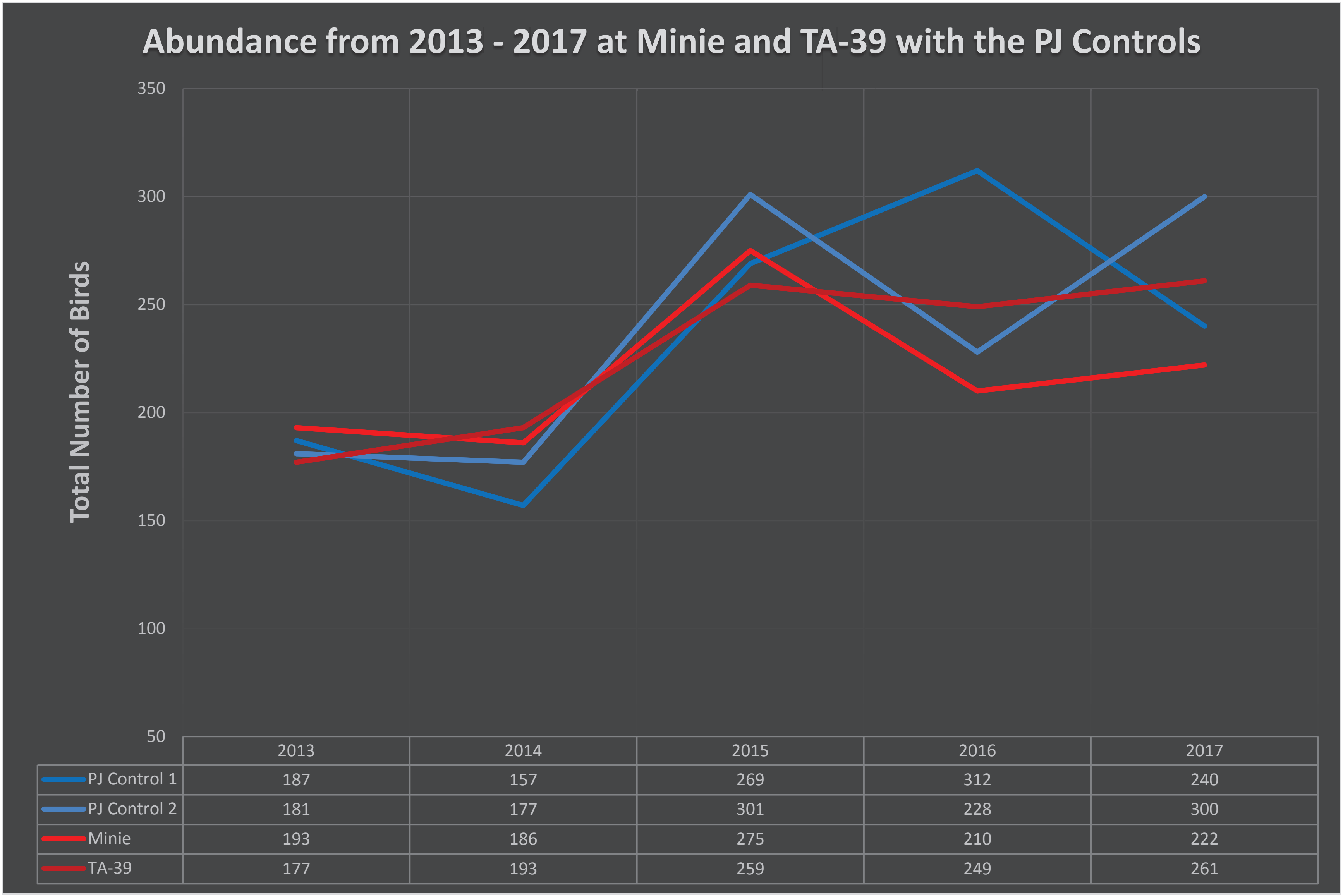
	2013	2014	2015	2016	2017
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419
Minie	0.9464	0.9463	0.9502	0.9315	0.9429
TA-39	0.9425	0.9427	0.9396	0.9559	0.9486

Figure 9. **Changes in species diversity over time comparing Minie and TA-39 with the PJ controls**



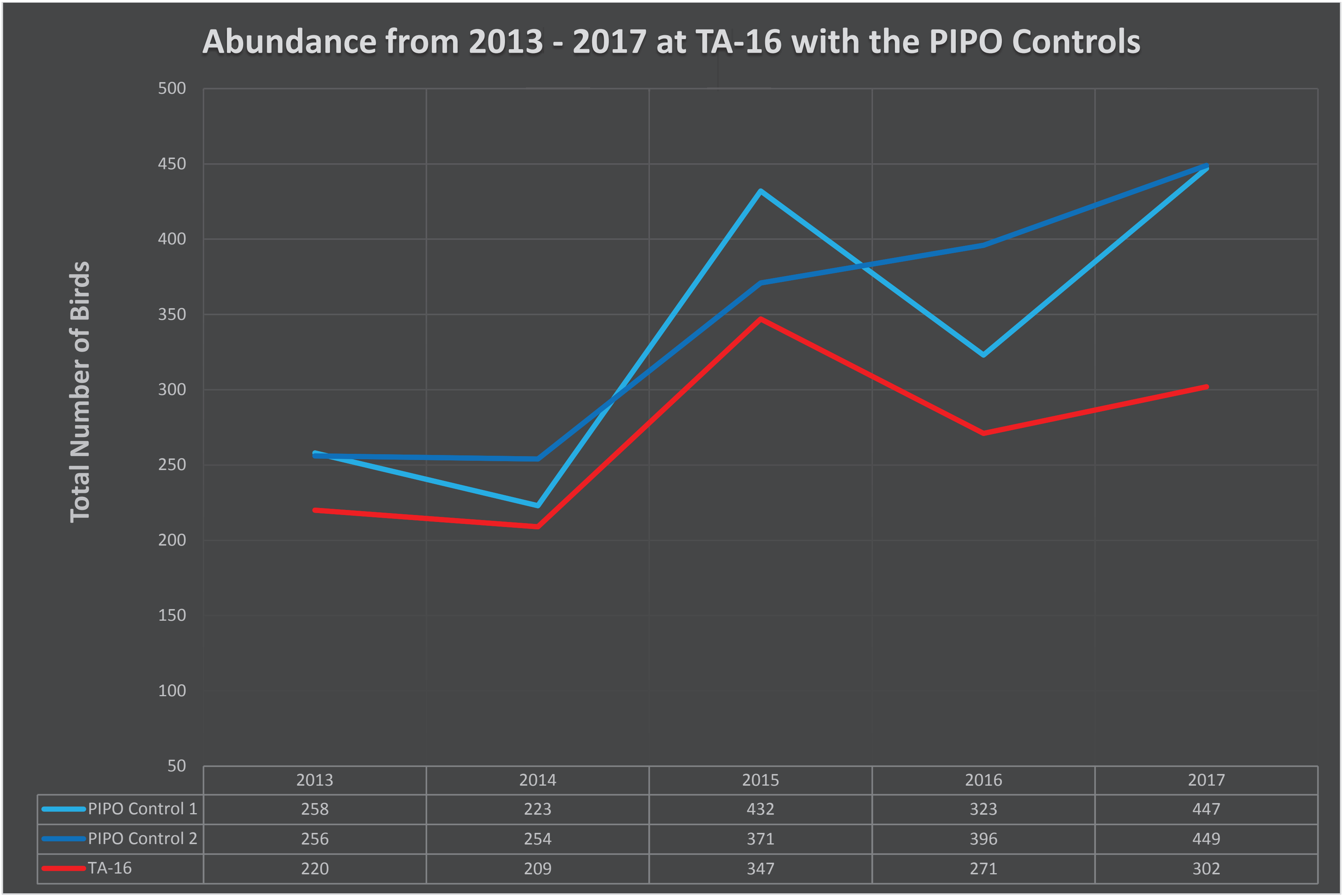
	2013	2014	2015	2016	2017
🟥 TA-16	0.9542	0.9509	0.9454	0.9463	0.9429
🟩 PIPO Control	0.9528	0.9462	0.9414	0.9417	0.9468

Figure 10. Changes in species diversity over time comparing TA-16 with the PIPO controls



	2013	2014	2015	2016	2017
PJ Control 1	187	157	269	312	240
PJ Control 2	181	177	301	228	300
Minie	193	186	275	210	222
TA-39	177	193	259	249	261

Figure 11. Changes in abundance over time comparing Minie and TA-39 with the PJ controls



	2013	2014	2015	2016	2017
PIPO Control 1	258	223	432	323	447
PIPO Control 2	256	254	371	396	449
TA-16	220	209	347	271	302

Figure 12. Changes in abundance over time comparing TA-16 with the PIPO controls

Species composition was analyzed over time according to whether sites were controls or treatments for PJ sites and ponderosa sites separately (Figures 13 and 14). Figure 13 shows the species composition for PJ sites for each year. The difference in species composition was significant between treatment sites and control sites for PJ habitats (ANOSIM: R = 0.35, P = 0.05; Figure 13). The species closest to each site were the species most important in separating those sites from the rest.

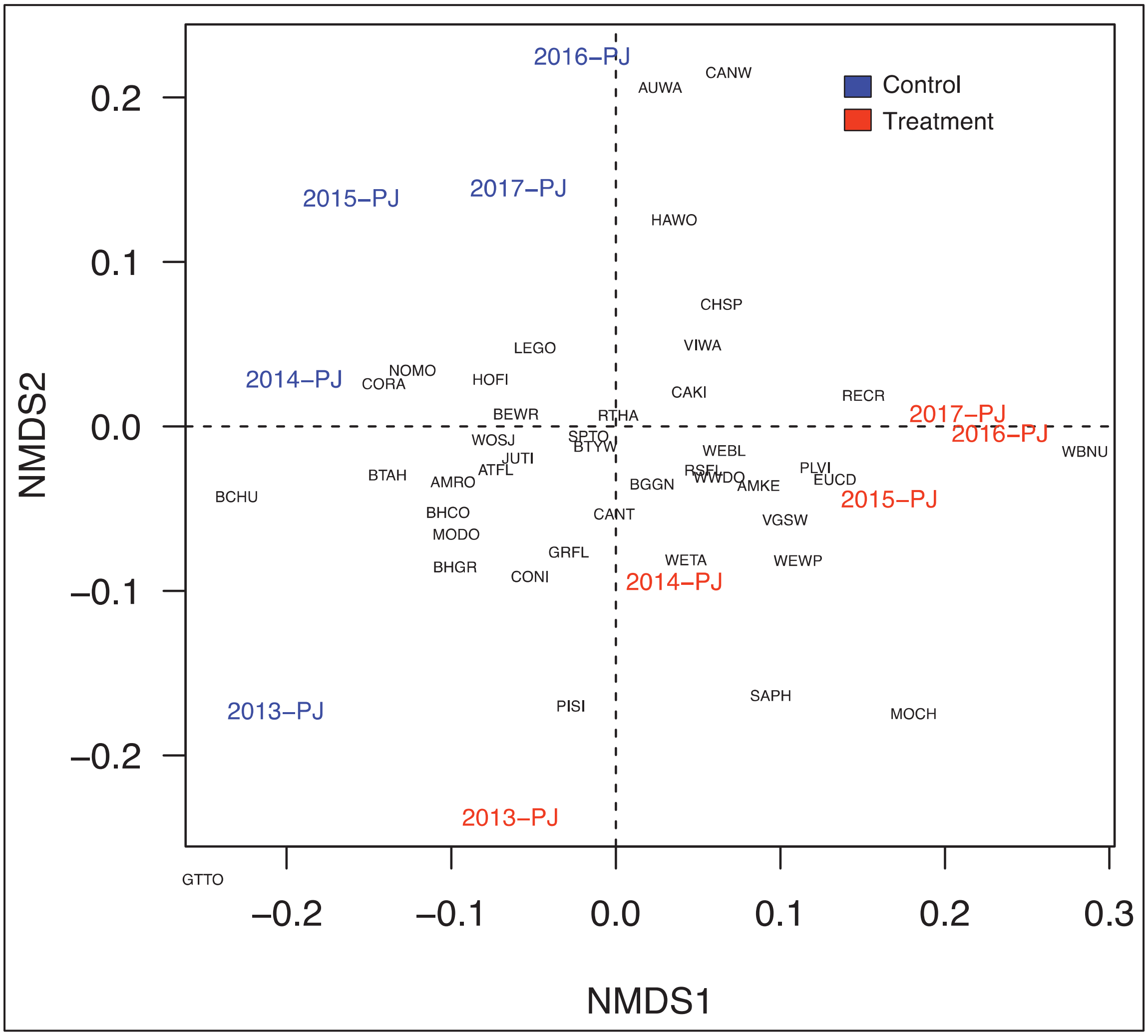


Figure 13. Non-metric multidimensional scaling of bird species from 2013 to 2017 by treatment for PJ sites

Species composition over time for ponderosa sites is shown in Figure 14. The difference in species composition was significant between treatment sites and control sites for ponderosa habitats (ANOSIM: R = 0.85, P = 0.007; Figure 14). Collectively, Figures 13 and 14 suggest that the control sites have different species composition than treatment sites over the course of the study.

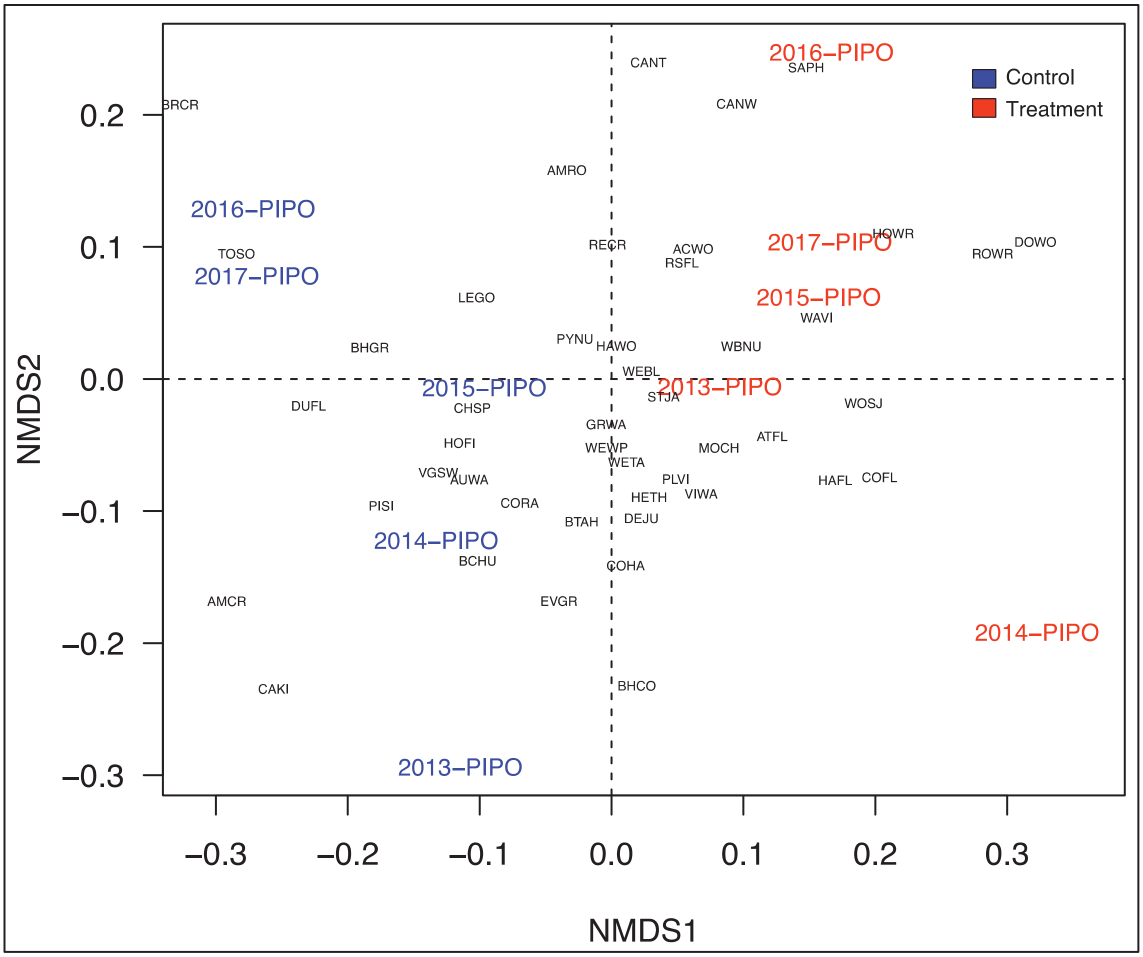


Figure 14. Non-metric multidimensional scaling of bird species from 2013 to 2017 by treatment for ponderosa sites

Figures 13 and 14 also show patterns over the five years. To examine these patterns further, we compared early years (2013 and 2014) and later years (2016 and 2017), excluding 2015. We tested for differences in similarity between the two time points for each of the habitat types, disregarding treatment for these tests. Species composition significantly differed between time points for PJ habitats (ANOSIM: R = 0.73, P = 0.029). This significance indicates that species composition has changed over the last five years. Species composition was similar between both time points for ponderosa sites (ANOSIM: R = 0.0, P = 0.44).

Rather than plot these results, we determined the top ten most abundant species for each habitat type for the early and late years (Tables 6 and 7). In PJ habitat, two of the top ten from early years, Mourning Dove and Gray Flycatcher, are absent in the late years. They were replaced by the Chipping Sparrow and Cassin's Kingbird. Additionally, bird abundances went up in later years. Although species turnover is happening, the top ten for both early and late years are equally represented by granivores and insectivores and the replacements were of the same feeding guild. In ponderosa habitat, only one of the top ten from early years, the Virginia's

Warbler, is absent in late years. It was replaced by the Chipping Sparrow. Again, the granivores and insectivores are well represented in the top ten list for early and late years.

Table 6. The top ten bird species in abundance in PJ habitat for early (2013 and 2014) and late (2016 and 2017) years

PJ Habitat Early		PJ Habitat Late	
Species	Number seen	**Species**	Number seen
House Finch	194	House Finch	247
Mourning Dove	130	Spotted Towhee	175
Ash-throated Flycatcher	109	Chipping Sparrow	143
Spotted Towhee	95	Ash-throated Flycatcher	107
Juniper Titmouse	68	Lesser Goldfinch	102
Western Bluebird	62	Juniper Titmouse	93
Bewick's Wren	62	Western Bluebird	93
Gray Flycatcher	59	Bewick's Wren	89
Lesser Goldfinch	57	Cassin's Kingbird	78
Woodhouse's Scrub-Jay	51	Woodhouse's Scrub-Jay	76

Table 7. The top ten bird species in abundance in ponderosa habitat for early (2013 and 2014) and late (2016 and 2017) years

Ponderosa Habitat Early		Ponderosa Habitat Late	
Species	Number seen	**Species**	Number seen
Western Bluebird	127	Pygmy Nuthatch	269
Pygmy Nuthatch	111	Western Bluebird	234
Western Wood-Pewee	99	House Finch	157
House Finch	94	Pine Siskin	145
Virginia's Warbler	77	Western Wood-Pewee	132
Plumbeous Vireo	72	Chipping Sparrow	128
Pine Siskin	71	Spotted Towhee	115
Spotted Towhee	65	Violet-green Swallow	91
Broad-tailed Hummingbird	65	Plumbeous Vireo	86
Violet-green Swallow	51	Broad-tailed Hummingbird	77

Species in a community align themselves in ways similar to those described by MacArthur and Wilson (1967) in *The Theory of Island Biogeography*. It hypothesized how distance and area could combine to regulate the balance between immigration and extinction in an island population. Immigration is the appearance of a new species in a community, while extinction is the disappearance of a species from a community. This relationship is known as species turnover. This concept of species turnover is what is driving the changes in composition over time. More study is needed to better understand these patterns and to determine the mechanism for species turnover in these areas. For example, are the changes in species composition normal fluctuations that occur every few years or are we actually seeing permanent loss and gain of species? This and similar questions can be answered by continuing to monitor these sites and to analyze bird community data in other areas on the Pajarito Plateau.

Nestboxes

During the 2017 nesting season, 15 nestboxes at each of the treatment sites were actively monitored. The overall avian nestbox network without the three treatment sites contained 475 nestboxes in 2017. Of those, 226 contained active nests and 129 of those nests fledged young successfully. This was an overall occupancy rate of 48% with a 57% success rate.

At Minie, seven nests were found and two of the nests fledged young successfully. This was an occupancy rate of 46% with a 29% success rate.

At TA-39, three nests were found and none were successful. This was an occupancy rate of 20% with a 0% success rate. These are lower than the overall avian nestbox network; however, when compared with nestboxes within the greater Ancho Canyon area, the numbers are similar.

At TA-16, 17 nests were found and 13 of the nests fledged young successfully. Some of the nestboxes had double clutches, which is why the number of nests is higher than the number of nestboxes. This was an occupancy rate of 100% with a 76% success rate.

The occupancy rates at Minie and TA-16 were similar and greater than the results in the overall network. Yet, the nest success rates at Minie dropped well below the average of the rest of the network. This was largely due to an increase in predation of nests in this area.

In 2017, nonviable eggs and tissue samples from nestlings that died before fledging were submitted to an analytical lab for chemical analysis. Gaukler (2017) explained that eggs collected from all locations contained significantly higher concentrations of copper when compared with background concentrations from samples on nearby public lands. Macronutrients magnesium, potassium, and sodium were also higher compared with background eggs. Eggs collected from TA-16 also contained significantly higher concentrations of barium, mercury, and selenium. Nestlings collected from Minie, TA-39, and TA-16 contained detectable concentrations of some dioxin and furan congeners and also exceeded regional statistical reference levels (RSRLs). Polychlorinated biphenyls were detected in nestlings, although all concentrations were below RSRLs. Lastly, 2,3,7,8-tetrachlorodibenzodioxin toxic equivalents were calculated. Although there were significant differences, most chemical concentrations were below RSRLs, lowest observable adverse effect levels, and biota dose screening levels and were therefore not of ecological concern. As these data were preliminary, more samples are needed to make a robust assessment, including additional background samples.

Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 59 species detected at the three treatment sites, all are protected under the Migratory Bird Treaty Act. Additionally, two of the species detected at the three treatment sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those two species are the Juniper Titmouse and Grace's Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901). Another conservation tool used in migratory bird management is the Birder's Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three treatment sites are on the top 100 list. They are the Virginia's Warbler and Grace's Warbler.

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL's avifauna at the three treatment sites, contribute to meeting the Department of Energy's commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and allow LANS to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Thanks to the following individuals for technical and field support work in 2017: Jesse Berryhill, Tatiana Espinoza, Teresa Hiteman, Luciana Vigil-Holterman, David Keller, Maria Musgrave, Emily Phillips, Maricela Salazar, and Aaron Skinner; and former staff and interns that helped in previous years.

Literature Cited

Chao, A., N.J. Gotelli, T.C. Hsieh, E.L. Sander, K.H. Ma, R.K. Colwell, and A.M. Ellison 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs* 84:45–67.

Gardener, M. 2014. Community Ecology: Analytical Methods Using R and Excel. Pelagic Publishing. Exeter, United Kingdom. 556 pp.

Gaukler, S. 2017. Chemical Concentrations in Passerine Eggs and Nestlings Collected near the Dual-Axis Radiographic Hydrodynamic Test Facility and Technical Areas 36, 39, and 16 at Los Alamos National Laboratory. LA-UR-17-31033. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. LA-UR-13-27825. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-14-28161. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-15-28296. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-17-20359. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hsieh, T.C., K.H. Ma, and A. Chao 2016. iNEXT: iNterpolation and EXTrapolation for species diversity. R package version 2.0.12 URL: http://chao.stat.nthu.edu.tw/blog/software-download/.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology* 29:151–154.

MacArthur, R.H. and E.O. Wilson 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, N.J. 215pp.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, New Mexico.

Oksanen, J., F.G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H. Stevens, E. Szoecs and H. Wagner 2017. vegan: Community Ecology Package. R package version 2.4-4. https://CRAN.R-project.org/package=vegan.

R Core Team 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. *Ecology* 91(10):2874–2882.

U.S. Fish and Wildlife Service (USFWS) 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine 2015. Weather Machine Climatological Monthly Summary, September 2015, http://weather.lanl.gov/climo_monthly_summary.asp.

Wells, J.V. 2007. Birder’s Conservation Handbook: 100 North American Birds at Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

This page intentionally left blank.

Appendix 1. All birds recorded at the three treatment sites from 2013–2017

	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Species	TA-36 Minie Site					TA-39 Point 6					TA-16 Burn Grounds				
	Pinyon-Juniper Woodland					Pinyon-Juniper Woodland					Ponderosa Pine Forest				
Acorn Woodpecker											5		3	2	3
American Crow															1
American Kestrel				1		1			2						
American Robin	1	1	2		2	1	1		2		7		9	4	4
Ash-throated Flycatcher	11	5	14	13	13	19	11	29	12	8	3	5	6	2	3
Audubon's Warbler		2							2		6	5	1	6	
Bewick's Wren	4	8	9	9	14	3	10	15	9	2					
Black-chinned Hummingbird		1	1			3	2				1		1		1
Black-headed Grosbeak	1	3					2	4	1				1	2	
Black-throated Gray Warbler			1		2	5	6	4							
Blue-gray Gnatcatcher	3	14	16	8	10	2		7	5	4		6	2	1	3
Broad-tailed Hummingbird	2	1	3		1	3	1	2		3	5	11	11	5	7
Brown Creeper											1				
Brown-headed Cowbird	1							2			4	1			4
Bushtit		2		2		2	14			1					
Canada Goose								16							
Canyon Towhee	2		5	3	6	1	1	2	10	13	1			1	
Canyon Wren					1			2	3	8			2		
Cassin's Kingbird	6	13	13	5	2	7	6	2	21	21				1	
Chipping Sparrow	3	16	17	29	6	6	6	5	8	15	1	5	3	10	5
Clark's Nutcracker												4		1	

	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Species	TA-36 Minie Site					TA-39 Point 6					TA-16 Burn Grounds				
	Pinyon-Juniper Woodland					Pinyon-Juniper Woodland					Ponderosa Pine Forest				
Common Nighthawk	6		5	2	4	5	1	3	2	7			1	2	2
Common Raven	2	5	1		1	1		2	1		5	6	2	2	5
Cooper's Hawk					1						1			1	
Cordilleran Flycatcher											5	10	6	3	3
Dark-eyed Junco											6	2	4		5
Downy Woodpecker				1					1	2		1		1	1
Dusky Flycatcher				1				1		1					
Eurasian Collared-Dove	3									4					
Evening Grosbeak	3		4					8			5		29		
Grace's Warbler											6	4	4	8	5
Gray Flycatcher	12	6	5	7	3	10	10	11	10	5					
Great Horned Owl		3				1									
Green-tailed Towhee	3	1				1									
Hairy Woodpecker			2	1				5	3		1	1		1	1
Hammond's Flycatcher											8	9	12	5	7
Hepatic Tanager								1	2	1				1	
Hermit Thrush												4	6	1	2
House Finch	16	17	26	17	12	21	4	23	9	30	16	2	5	5	12
House Wren											1	1		2	2
Juniper Titmouse	12		7	6	9	11	13	18	6	1					
Lesser Goldfinch	2	6	7	4	9	4	12	9	10	14	3		8	9	4
MacGillivray's Warbler														1	3
Mountain Bluebird		2	20	10	11		4						4	4	4
Mountain Chickadee	5	2	1	2					1	1	5	8	9	6	8
Mourning Dove	17	17	13	5	8	13	22	10	3	15	4		1	3	17

	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Species	TA-36 Minie Site					TA-39 Point 6					TA-16 Burn Grounds				
	Pinyon-Juniper Woodland					Pinyon-Juniper Woodland					Ponderosa Pine Forest				
Northern Mockingbird					2		1								
Peregrine Falcon								1							
Pine Siskin	10	2		5	1	6		3	3		12	4	5		4
Plumbeous Vireo	10	10	7	3	9	1		1	6	6	11	16	15	14	11
Pygmy Nuthatch				2				2	4	12	11	13	26	29	41
Red Crossbill					1		2					2	9	13	9
Red-shafted Flicker	3	1	3	2	5	3	2	4	8		3	4	11	11	5
Red-tailed Hawk								1	1	1					
Rock Wren	3	3	4		2	7	10	4	12	14	1	2	2	6	
Say's Phoebe	2	1	2		2	2	1		5	2	1		1	3	3
Scaled Quail			1												
Spotted Towhee	17	8	19	27	32	12	6	33	16	12	11	18	16	14	21
Steller's Jay											3	2	5	6	3
Townsend's Solitaire	1														1
Turkey Vulture					1						1				
Violet-green Swallow		5	7	1	3	6	4	1	9	6		2	19	2	2
Virginia's Warbler					1			1	2	4	17	11	21	13	7
Warbling Vireo											2	9	7	6	5
Western Bluebird	15	11	18	17	16	5	19	12	21	13	20	20	49	37	32
Western Tanager		2	3		1		2	1	1	2	2	3	7	2	4
Western Wood-Pewee	10	8	18	11	10		4	2	10	8	15	10	16	14	22
White-breasted Nuthatch	1	4	9	10	13			2	4	4	9	8	7	9	20
White-throated Swift							1								
White-winged Dove	1	5	9	2		7	5	6	16	15			1	2	
Woodhouse's Scrub-Jay	5	1	3	4	8	8	10	4	8	6	1				

21. Hathcock, C.D., *et al*., May 2019. *2018 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory*. LA-UR-19-24156. OSTI Identifier 1514915. (Hathcock *et al*. 2019)

LA-UR-19-24156

Title:	2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory
Author(s):	Hathcock, Charles Dean Bartlow, Andrew William Sanchez, Audrey Anna Stanek, Jenna Thompson, Brent E.
Intended for:	Environmental Regulatory Document
Issued:	2019-05-20 (rev.1)

LA-UR-19-24156

May 2019

2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Charles D. Hathcock[1], Andrew W. Bartlow[2], Audrey, A. Sanchez[1], Jenna Stanek[1], and Brent E. Thompson[1]

[1] Environmental Protection and Compliance Division, Environmental Stewardship, Los Alamos National Laboratory

[2] Biosecurity and Public Health, Los Alamos National Laboratory

Contents

Figures

Tables

Executive Summary

Los Alamos National Laboratory biologists in the Environmental Compliance and Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. Monitoring results from these efforts were compared among years to monitor trends. The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Additionally, nesting success of secondary-cavity nesting birds was examined using nestboxes. LANL biologists completed the sixth year of this effort in 2018. The overall results from 2018 continue to indicate that operations are not negatively affecting bird populations; however, we are seeing some species turnover through time and that will continue to be monitored.

Three bird point count surveys were completed at each of the treatment sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground between May and July 2018. A total of 842 birds representing 58 species were recorded at the three treatment sites. Three bird point count surveys were also completed at each of the control sites between May and July 2018. Occupancy and nest success data from nestboxes at treatment sites were compared with the overall avian nestbox monitoring network.

Species richness at the treatment sites was not statistically different from their associated controls; however, species diversity was. In all three cases, the diversity was higher at the treatment sites than at the control sites. Avian abundance showed more variability but treatment and controls were trending together year to year. Species composition seems to indicate some species turnover in the habitat types but very little difference between treatment and control sites.

This page intentionally left blank.

Introduction

An annual avian monitoring program was started in 2013 as part of the Resource Conservation and Recovery Act permitting process at Los Alamos National Laboratory (LANL) for two open detonation sites, Technical Area (TA) 36 Minie site and TA-39 point 6, and one open burn site, TA-16 burn ground (hereafter referred to as Minie, TA-39, and TA-16, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014 & 2015; Hathcock et al. 2017 & 2018). The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Comparisons were made with control sites of similar habitat that have been surveyed since 2011 (Hathcock et al. 2011).

Biologists at LANL used standard point count methodology to record avian abundance and diversity along transects at the three treatment sites and associated control sites during the summer of 2018. Summer surveys provide information about what birds were breeding at each site. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental change at LANL.

In addition to avian point counts, nestboxes were monitored around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success data were compared with the overall avian nestbox monitoring network, which was established in 1997.

Methods

Field Methods for Point Count Surveys

The point count surveys were conducted along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon-juniper woodland (PJ) for Minie and TA-39 and a ponderosa pine forest (PIPO) at TA-16. These habitat descriptions were based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (Figure 4) were monitored annually in ongoing surveys that have been conducted at LANL since 2011 as described in Hathcock et al. (2011). Each habitat type control contained two replicate transects that were monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects were randomized and surveyed according to the random order.

The treatment sites at Minie and TA-39 were similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was more natural.

Transects were approximately 2.0 to 2.5 km in length and allowed for nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys was May 1 through August 15. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site and surveys must be conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor will look and listen for 5 minutes, noting any birds encountered at each point. The distance for observations is considered as an “unlimited-distance circular plot”; however, the distance to each bird out to 100 m should be noted. Ensure individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, note any species encountered that have not otherwise been counted from a previous point or future point. The surveyor’s main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Do not conduct surveys during rain events or winds greater than 24 kph.
- Record all birds encountered on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- Use the “NOTES” section to indicate any potentially important aspects of the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Other wildlife or evidence of wildlife that could be used for other projects should be recorded.

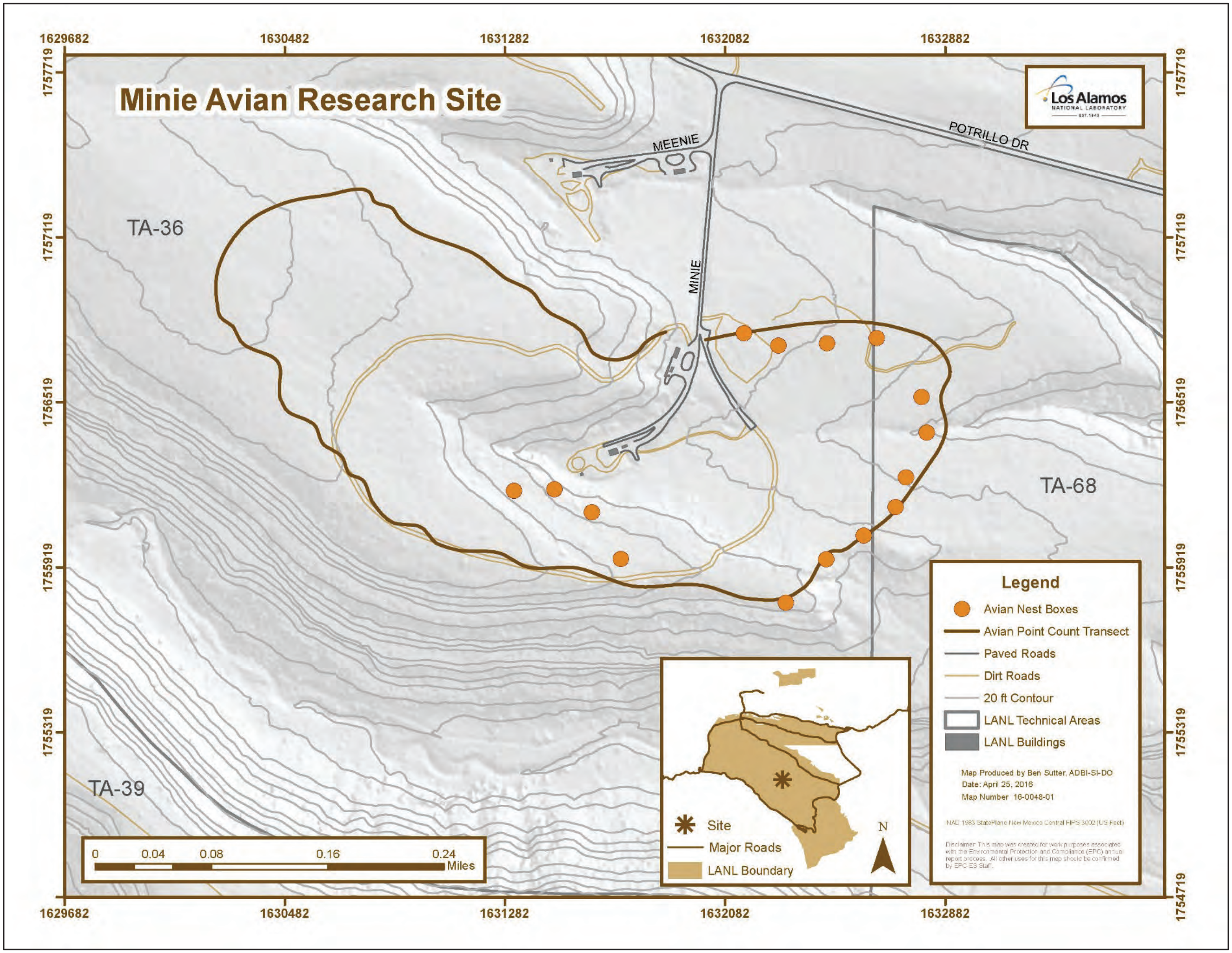


Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie site

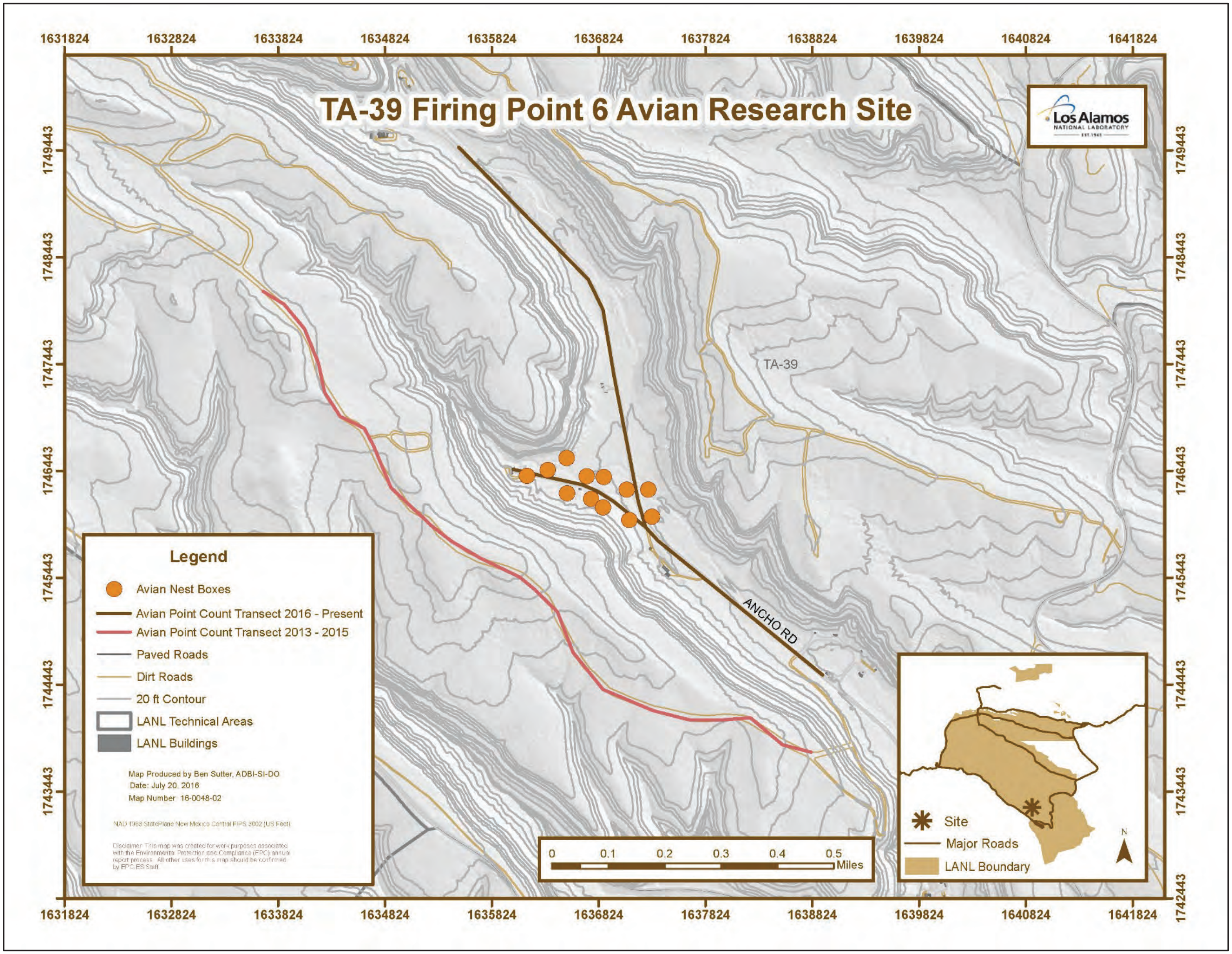


Figure 2. Breeding bird survey transect and nestbox locations around TA-39 point 6

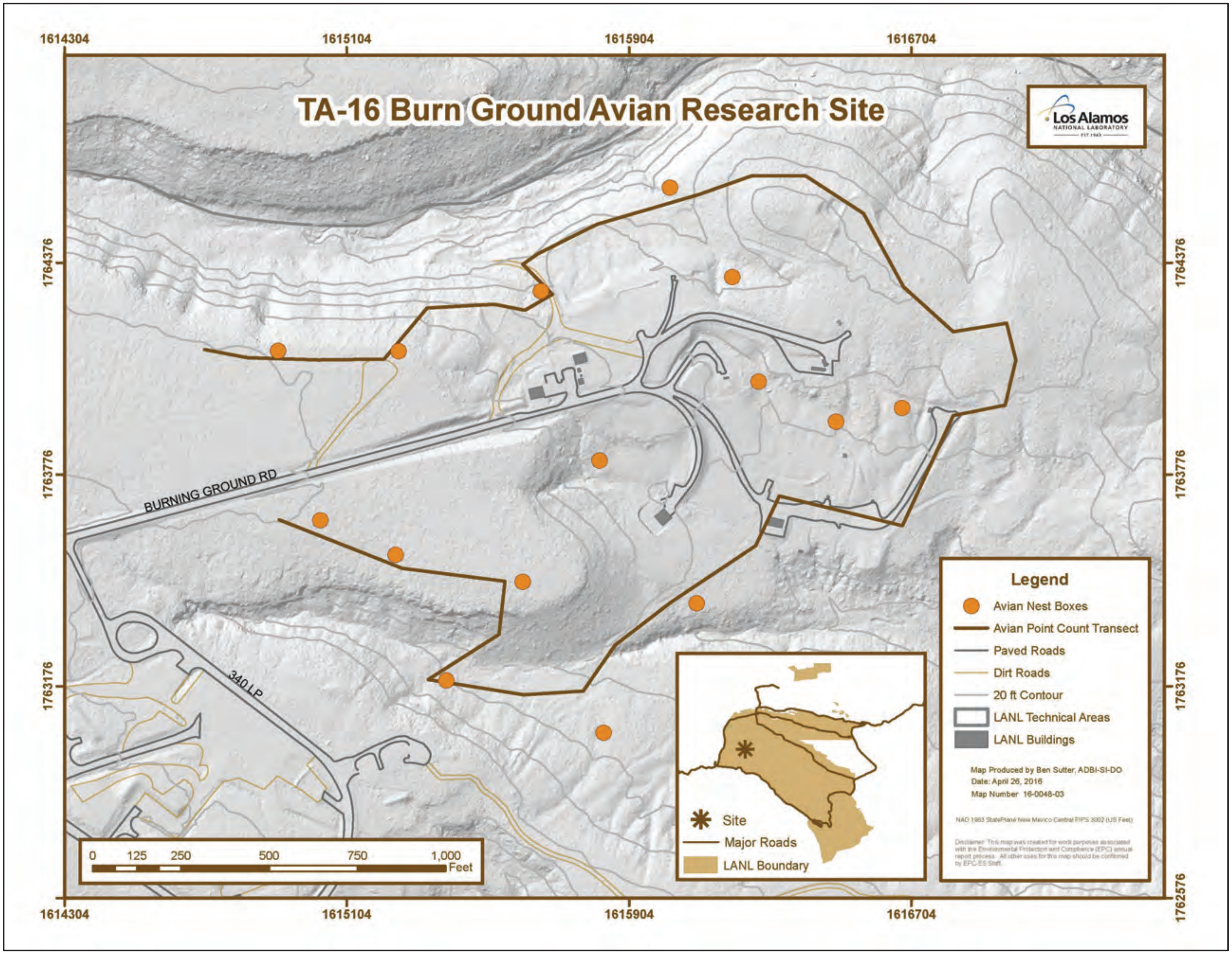
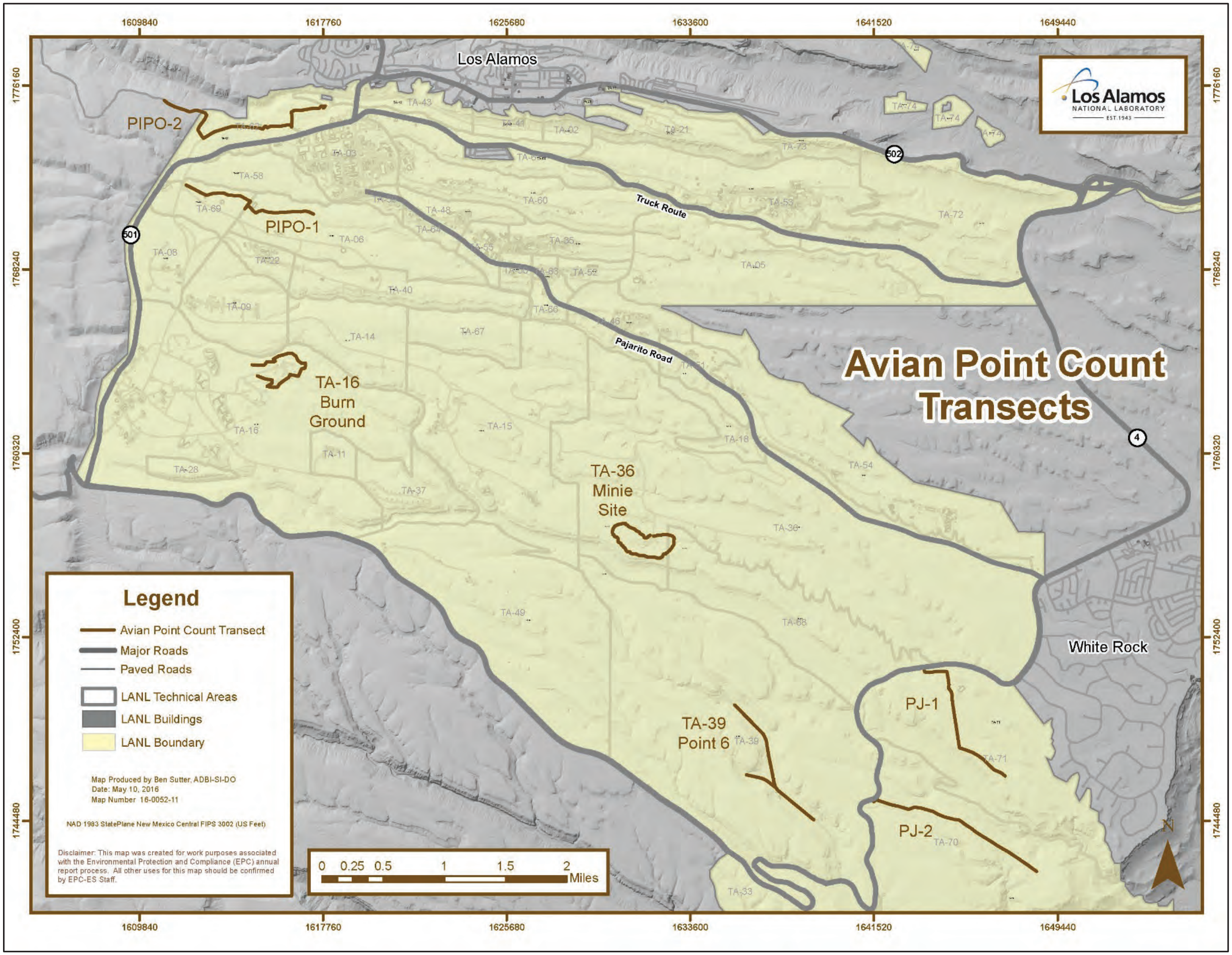


Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 burn ground



Map Produced by Ben Sutter, ADBI-SI-DO
Date: May 10, 2016
Map Number 16-0052-11

NAD 1983 StatePlane New Mexico Central FIPS 3002 (US Feet)

Disclaimer: This map was created for work purposes associated with the Environmental Protection and Compliance (EPC) annual report process. All other uses for this map should be confirmed by EPC-ES Staff.

Figure 4. All avian point count transects around LANL

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to Minie and TA-39 (Figures 1 and 2). In 2015, nestboxes were added to TA-16 (Figure 3). Nestboxes were monitored every 1 to 2 weeks for active nests. When an active nest was found, it was monitored more frequently to determine whether the nest failed or successfully fledged young. Nestlings were also banded and the sex determined after the age of 10 days.

Statistical Methods for Point Counts

The data were summarized to compare species richness, diversity, abundance, and composition between sites and among years using the statistical software R (version 3.4.1; R Core Team 2017). Species richness and diversity were computed using the R-package 'iNEXT' (Hsieh et al. 2016; Chao et al. 2014) and plotted with bootstrap confidence intervals around the mean for rarefied/extrapolated samples, facilitating the comparisons of richness and diversity. The estimated asymptote along with a confidence interval were also provided. The Simpson's diversity index was calculated using the following formula: $D = 1 – (\sum n(n-1) / N(N-1))$, where n = the total number of organisms of a particular species and N = the total number of organisms of all species. The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0 represents no diversity. Species diversity was also computed using the statistical software PAST (Hammer et al. 2001) and a t-test was used to test for differences between treatment and control sites each year. Comparisons of Simpson diversity in two samples are described by Hutcheson (1970) and is an alternative to the permutation test. To examine species composition, non-metric multidimensional scaling (NMDS) was used to determine dissimilarity among sites. To compare species composition between treatments and years, an analysis of similarity (ANOSIM) was conducted using 1000 permutations. These analyses were completed using the community ecology R-package 'vegan' (Oksanen et al. 2017).

Statistical Methods for Nestboxes

Occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network were calculated. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. Annually, data from the three treatment sites were compared with the overall avian nestbox network at LANL that was established in 1997.

In 2019 a nest survival model (Dinsmore et al. 2002) in Program MARK was generated to estimate nest survival (S) for Western Bluebirds during a 22-year period (1997-2018). The nesting period spanned 21 April to 16 August (118 days) across all years of the study. Data for each nest were subdivided into the incubation and nestling periods and formatted as groups for analyses in Program MARK (Dinsmore and Dinsmore 2007). There was also an interest in survival estimates for the three treatment sites. Because there were not enough data to fit models specific to each site, a simple constant survival model was used, by nest stage. These estimates are presented for planning purposes only and are not meant to be directly comparable to estimates generated from the entire dataset (Unpublished data 2019).

Results and Discussion

Year 2018

Three surveys were completed at each of the three treatment sites and the associated control sites between May and July 2018. A total of 842 birds representing 58 species were recorded at the three treatment sites. A full account of the 2013–2018 data is detailed in Appendix 1.

Species richness is the number of different species represented in an ecological community and is simply a count of species. In this case, each treatment site and control are individual communities. Species diversity is a measure that takes into account the species richness and the overall abundance to compare evenness across a community. Here we used the Simpson's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species. The abundance is the total number recorded of a given species. Table 1 details the species richness, diversity, and abundance for 2018 for each treatment site.

Table 1. The species richness, diversity, and abundance recorded at each site in 2018

2018	*Minie Site*	*TA-39*	*TA-16*
Richness	35	39	43
Diversity	0.9494	0.9405	0.9541
Abundance	242	315	285

To further analyze species richness and diversity, species rarefaction and extrapolation plots were developed with the control sites being combined. Species rarefaction and extrapolation from 2018 show no differences between treatment and control sites for species richness. There were overlapping 95% confidence intervals for species richness (Figures 5A–6A) for all three treatments and their controls. Simpson's diversity (Figures 5B–6B) was significantly different since the 95% confidence intervals did not overlap. In these cases, the treatment sites were higher in diversity than the controls.

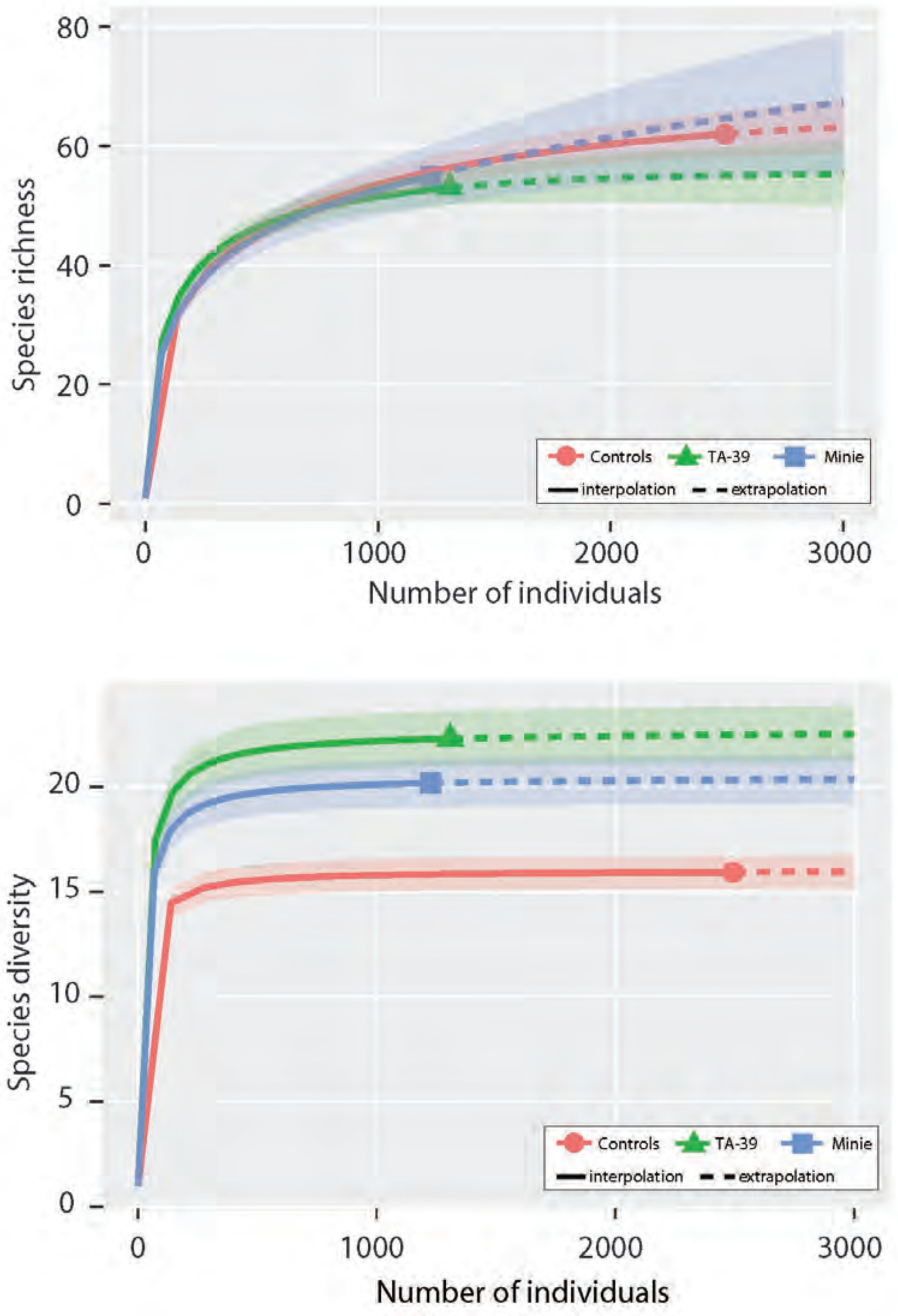


Figure 5. Species rarefaction and extrapolation for species richness and diversity comparing Minie and TA-39 with the PJ controls

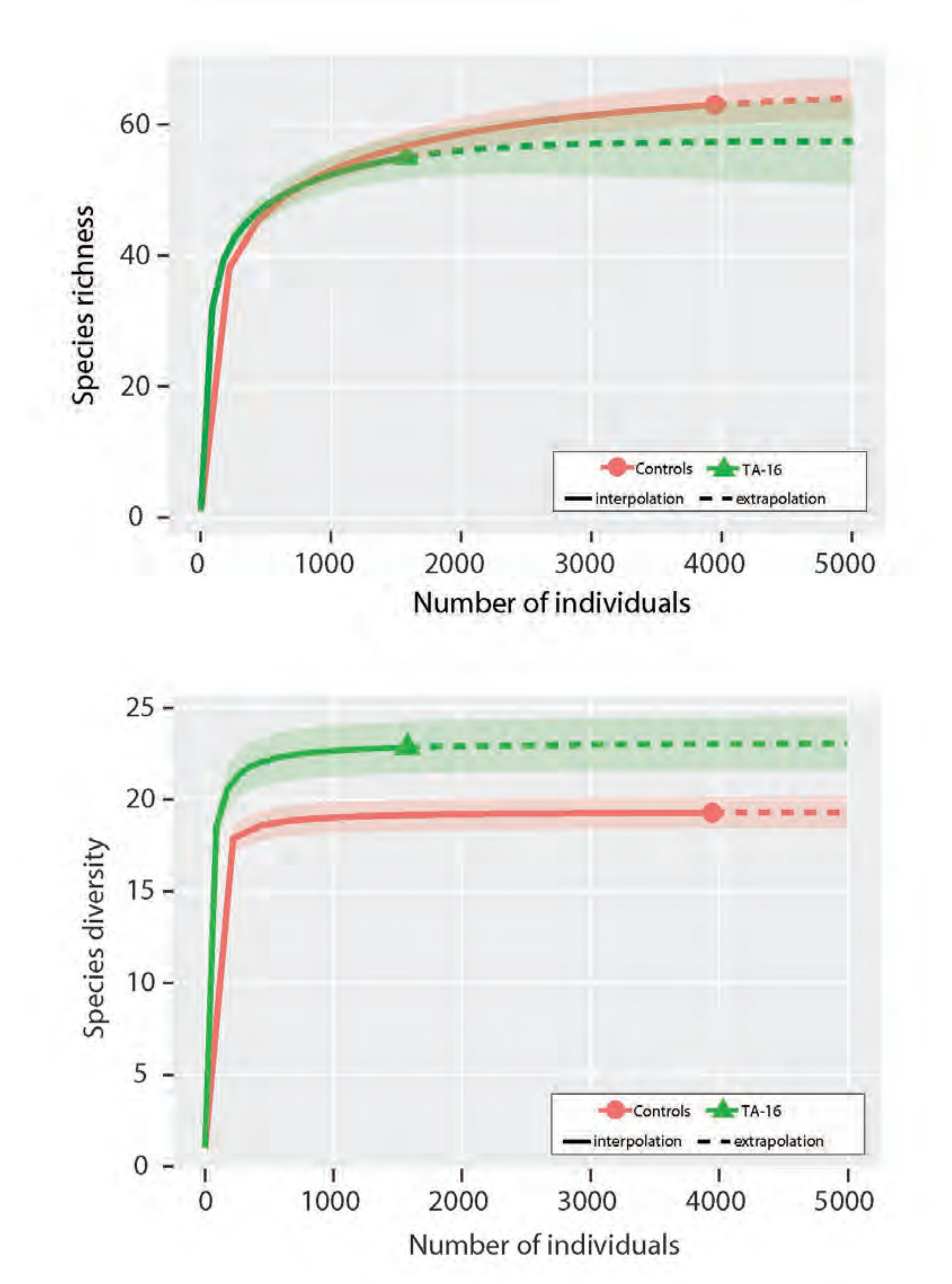


Figure 6. Species rarefaction and extrapolation for species richness and diversity comparing TA-16 with the PIPO controls

Multivariate analysis with ordination was used to explore the data further to look for patterns that may be explained by a multitude of other environmental factors not assessed directly. We used non-metric multidimensional scaling (NMDS) (Gardener 2014). NMDS is a method used to collapse data from multiple dimensions–such as several communities in different sites–into just a few dimensions. A measure of ‘stress’ (mismatch between the rank order of distances in the actual data, and the rank order of distances in the ordination) is calculated according to the number of dimensions (k). Lower stress values (typically < 0.1) mean greater conformity of the ordinated distances to the actual multivariate distances. Using this method, the samples are moved slightly in a direction that decreases the stress until stress reaches a minimum. More dimensions can be added when high stress is produced from too few dimensions. The final configuration of points for 2018 is represented in Figure 7 where the treatments and controls are plotted (k = 3, stress = 0.002). The different species composition between the left and right and the upper and lower part of the graph (dotted lines = the reference lines) correlate with the associated habitat types. Here, the PJ sites are grouped on the left and PIPO sites on the right. In the plot it is clear that the PJ-2 control transect is slightly different that the other control and the two treatments. The species that seem to be driving the PJ-2 control are the Black-throated Gray Warbler, American Kestrel, Black-chinned Hummingbird, and Juniper Titmouse. There must be some subtle habitat differences between the two controls for PJ. The PIPO controls and treatment site are more closely aligned with one another. In 2018, even with some variation, the treatments were not statistically different than the controls overall (ANOSIM: R = -0.15, P = 0.67) and the two habitat types were different as one would expect (ANOSIM: R = 0.96, P = 0.037).

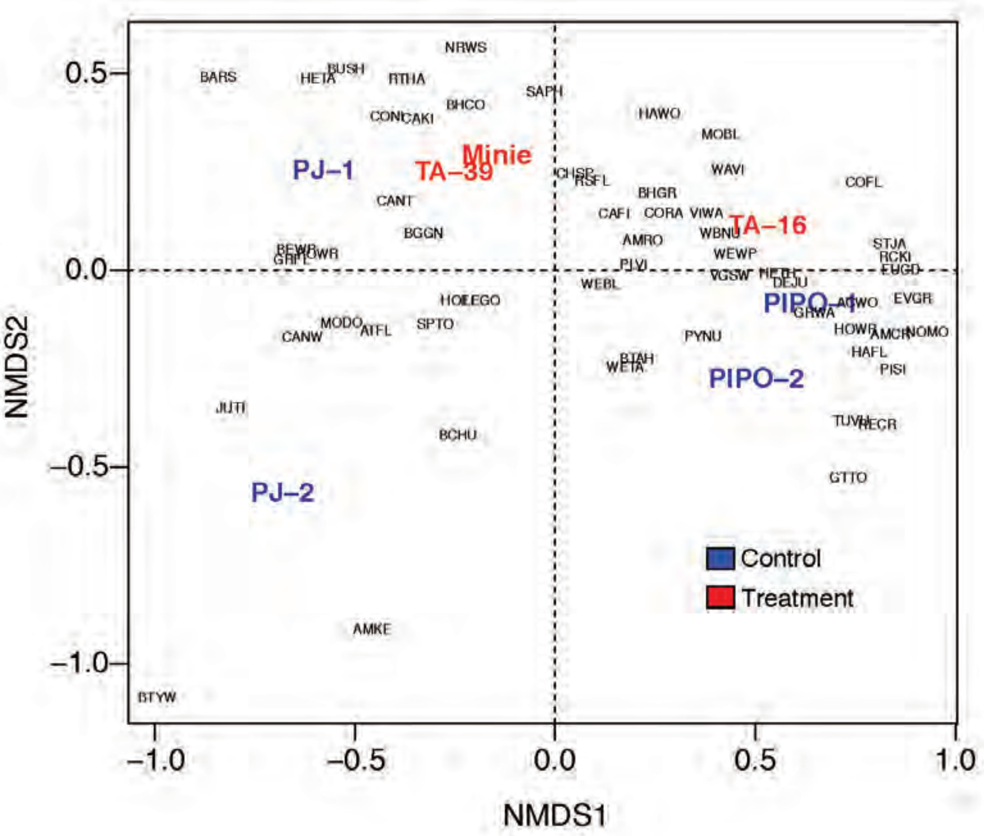


Figure 7. Non-metric multidimensional scaling of bird species and sites in 2018

Trends Over Time

Table 2 outlines the species richness over time at the treatment and individual control sites. The three treatment sites were maintaining a steady species richness over time with almost all indicating a slight increase in the number of species in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in richness, diversity, and abundance in 2015 were most likely attributed to the increased precipitation. Links between moisture and habitat quality for a migratory birds have been documented (Smith et al. 2010) and may be a causal factor. In addition, the winter of 2015 and into early 2016 was drier. The fluctuations in bird abundances are not alarming, and the differences between the treatment sites and control sites are not biologically significant. The winter moisture for the winter of 2018-2019 was at or slightly above normal (personal communication B. Parmenter) so it will be interesting to see what the effects will be to bird numbers in 2019.

Table 2. Changes in species richness over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
Minie	33	33	34	30	35	35
TA-39	31	31	39	38	34	39
PJ Control 1	29	30	33	36	37	30
PJ Control 2	30	29	37	33	39	23
TA-16	33	33	40	44	41	43
PIPO Control 1	34	34	30	41	41	37
PIPO Control 2	33	36	43	43	44	40

Tables 3–5 compare the species diversity over time between the treatment site and the combined control. The two control sites were combined to analyze diversity because we were interested in the relative abundances among species and not the actual numbers. There have been some significant differences at times over the course of the study. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Even though we see significant differences, the bird diversity at all sites is greater than 0.90, which compared with ecological systems in general, is very high.

The overall abundance of birds is trending the same for all treatment sites compared with the controls. At TA-16, the overall abundance is lower, but the percent abundance is similar year to year when compared with the control sites. Darker shading indicates a significant difference.

Table 3. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
Minie	0.9464	0.9463	0.9502	0.9315	0.9429	0.9494
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419	0.9255
t-test	t = 3.9572 df = 501.3 p = <0.01	t = 2.5469 df = 510.42 p = 0.01	t = 1.5902 df = 644.91 p = 0.11	t = 0.4385 df = 499.33 p = 0.66	t = 0.1504 df = 448.66 p = 0.88	t = 3.577 df = 644.09 p < 0.01

Table 4. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
TA-39	0.9425	0.9427	0.9396	0.9559	0.9486	0.9405
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419	0.9255
t-test	t = 3.3636 df = 538 p <0.01	t = 1.9703 df = 509.25 p = 0.05	t = -0.6751 df = 401.58 p = 0.50	t = 4.5611 df = 783.86 p <0.01	t = 1.2234 df = 705.5 p = 0.22	t = 2.085 df = 717.79 p = 0.03

Table 5. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
TA-16	0.9542	0.9509	0.9454	0.9463	0.9429	0.9541
PIPO Control	0.9528	0.9462	0.9414	0.9417	0.9468	0.9431
t-test	t = 0.3323 df = 378.91 p = 0.73	t = 0.9236 df = 472.24 p = 0.35	t = 0.748 df = 633.26 p = 0.45	t = 0.7438 df = 475.6 p = 0.45	t = -0.6903 df = 444.95 p = 0.49	t = 2.52 df = 570.39 p = 0.01

Species composition was analyzed over time according to whether sites were controls or treatments for PJ sites and ponderosa sites separately (Figures 8 and 9 respectively). Figure 8 shows the species composition for PJ sites for each year (k = 4, stress = 0.09). Four dimensions were used to decrease the stress and get a better representation of the data. As expected, the difference in species composition was significant between treatment sites and control sites for PJ habitats (ANOSIM: R = 0.64, P = 0.001). In the figure, the species closest to each site were the species most important in separating those sites from the rest. An early versus late analysis was done where the years 2013 – 2015 were compared to 2016 – 2018. The differences in species composition was not significantly different (ANOSIM: R = 0.108, P = 0.11).

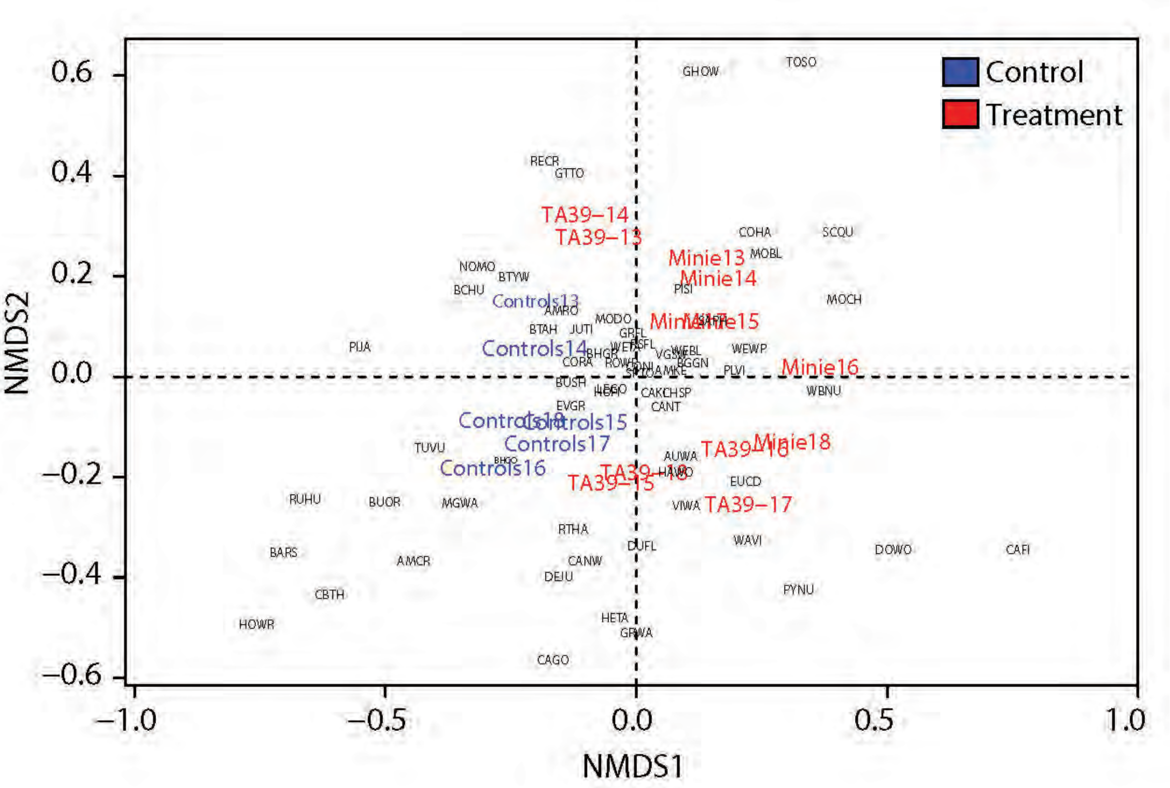


Figure 8. Non-metric multidimensional scaling of bird species from 2013 to 2018 by treatment for PJ sites

Species composition over time for ponderosa sites are shown in Figure 9 (k = 3, stress = 0.06). As expected, the difference in species composition was significant between treatment sites and control sites for ponderosa habitats (ANOSIM: R = 0.88, P = 0.003). The species closest to each site were the species most important in separating those sites from the rest. An early versus late analysis was done where the years 2013 – 2015 were compared to 2016 – 2018. The differences in species composition was not significantly different (ANOSIM: R = -0.026, P = 0.46).

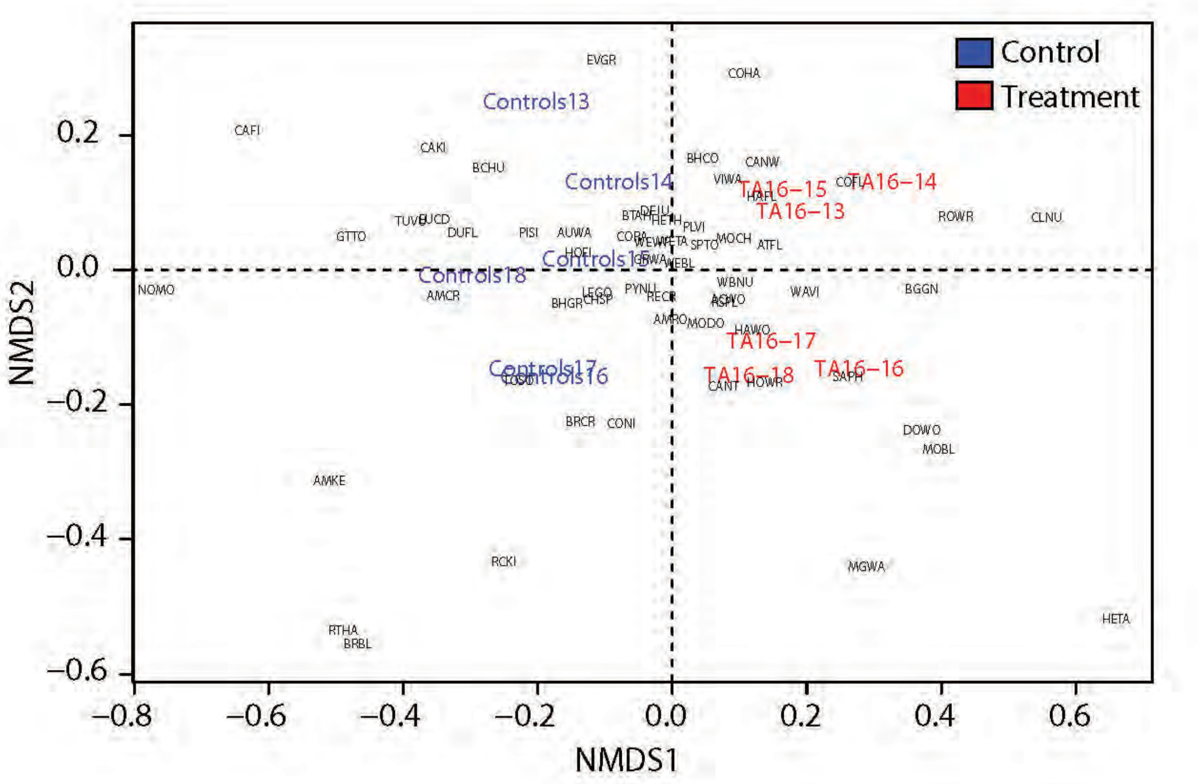


Figure 9. Non-metric multidimensional scaling of bird species from 2013 to 2018 by treatment for ponderosa sites

Collectively, Figures 8 and 9 suggest that the control sites have slightly different species composition than treatment sites over the course of the study.

Species in a community align themselves in ways similar to those described by MacArthur and Wilson (1967) in *The Theory of Island Biogeography*, which hypothesized how distance and area could combine to regulate the balance between immigration and extinction in an island population. Immigration is the appearance of a new species in a community, while extinction is the disappearance of a species from a community. This relationship is known as species turnover. The concept of species turnover is what drives the changes in composition over time.

More study is needed to better understand these patterns and to determine the mechanism for species turnover in these areas. The subtle changes in composition over time may be normal fluctuations, but if the gap widens then it may be indicative of a larger process at work. This and similar questions can be answered by continuing to monitor these sites and to analyze bird community data in other areas on the Pajarito Plateau.

Nestboxes

During the 2018 season, the overall avian nestbox network was managed at lower levels than previously. The treatment sites were maintained at previous years' effort, but site-specific constraints from increased fire restrictions in 2018 limited the overall network management.

During the 2018 nesting season, 15 nestboxes each at Minie, Burn Grounds, and TA-39 were actively monitored. The overall avian nestbox network, without the three treatment sites, only contained 177 nestboxes in 2018. Of those, 94 contained active nests and 46 of those nests fledged young successfully. This was an overall occupancy rate of 53% with a 49% success rate.

Tables 6 and 7 compare the occupancy and success rates for each treatment site and the overall nestbox network since 2015.

Table 6. Comparison of occupancy for the treatment sites and the overall nestbox network over time.

	2015	*2016*	*2017*	*2018*
Overall Network	40%	45%	48%	53%
Minie	66%	73%	46%	20%
TA-39	8%	58%	20%	33%
TA-16	-	73%	100%	53%

Table 7. Comparison of success for the treatment sites and the overall nestbox network over time.

	2015	*2016*	*2017*	*2018*
Overall Network	66%	69%	57%	49%
Minie	64%	23%	29%	33%
TA-39	100%	57%	0%	40%
TA-16	-	63%	76%	63%

In 2018 there were three successful nests that fledged young at Minie, five at TA-39, and eight at TA-16. The occupancy rate at Minie is lower and stands out in comparison to previous years.

Precipitation was low, possibly contributing to reduced nesting attempts and lower box occupancy rates. Success rates at the three treatment sites were not very different in comparison to the overall network and did not display decrease over time.

In 2018, nonviable eggs collected from nestboxes at Minie, TA-16, and TA-39 were submitted to an analytical lab for chemical analyses. Eggs collected from two of the firing sites (Minie and TA-39) contained higher concentrations of copper when compared with background concentrations from samples on nearby public lands. The source of elevated copper found in two western bluebird egg samples collected near the firing sites could be from some high-explosives testing; copper has historically been detected above soil screening levels at Technical Area 39 (Juarez and Vigil-holterman 2011). Yet, copper soil levels at Minie, near the firing site were below the regional statistical reference level (RSRL) in 2018. However, it has been suggested that birds are relatively resistant to copper toxicity when compared with other taxa (Eisler 1998). Although magnesium, potassium, and sodium concentrations were higher compared with background egg concentrations, these elements are macronutrients which are required by living organisms in large quantities. Eggs collected from TA-16 contained higher concentrations of antimony, mercury, and selenium and exceeded regional RSRLs, but were all below the known lowest observable adverse effects levels (LOAELs). Eggs collected from TA-39 contained higher concentrations of mercury and selenium compared to the RSRLs, but were below the LOAEL. Most chemical concentrations that were detected at all of the sites were below RSRLs and all were below the LOAELs. These data suggest that egg element concentrations observed here are not of ecological concern. As these data are preliminary, more samples are needed to make a robust assessment, including additional background samples.

Nest survival estimates for the three treatment sites for the incubation and nestling periods of the Western Bluebird are in figures 10 and 11. Nest survival is comprised of two phases for this analysis, the incubation phase and the nestling phase. Due to low sample sizes for this type of analysis, confidence intervals are large and these results should be considered only for possible pattern analyses. During incubation, survival at Burn Grounds and TA-39 Point 6 did not differ from all other sites while survival at Minie Site was lower than that at all other sites pooled (Figure 10). During the nestling period survival at the three sites did not differ from that at all other sites pooled together (Figure 11).

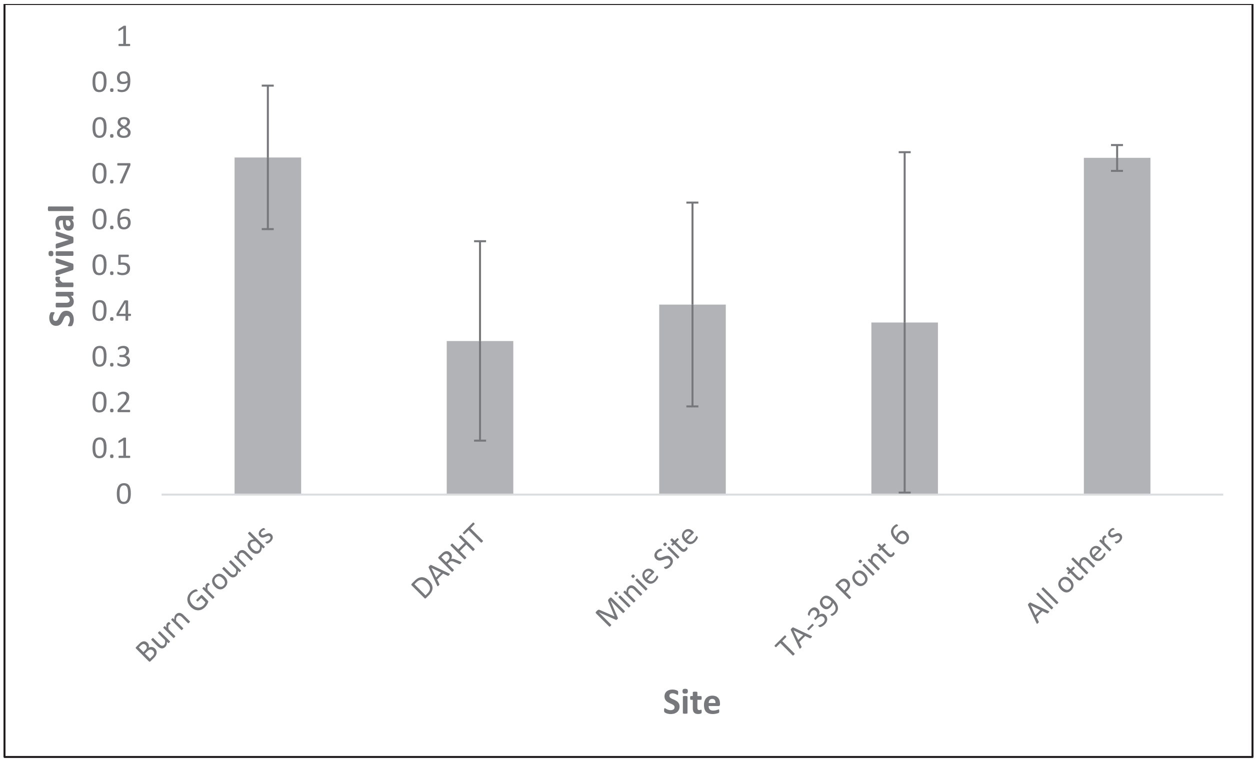


Figure 10. Estimated probability of surviving the 14-day incubation period for Western Bluebird nests at selected sites. Estimates (±95% CI) were generated using a constant survival model with no covariates.

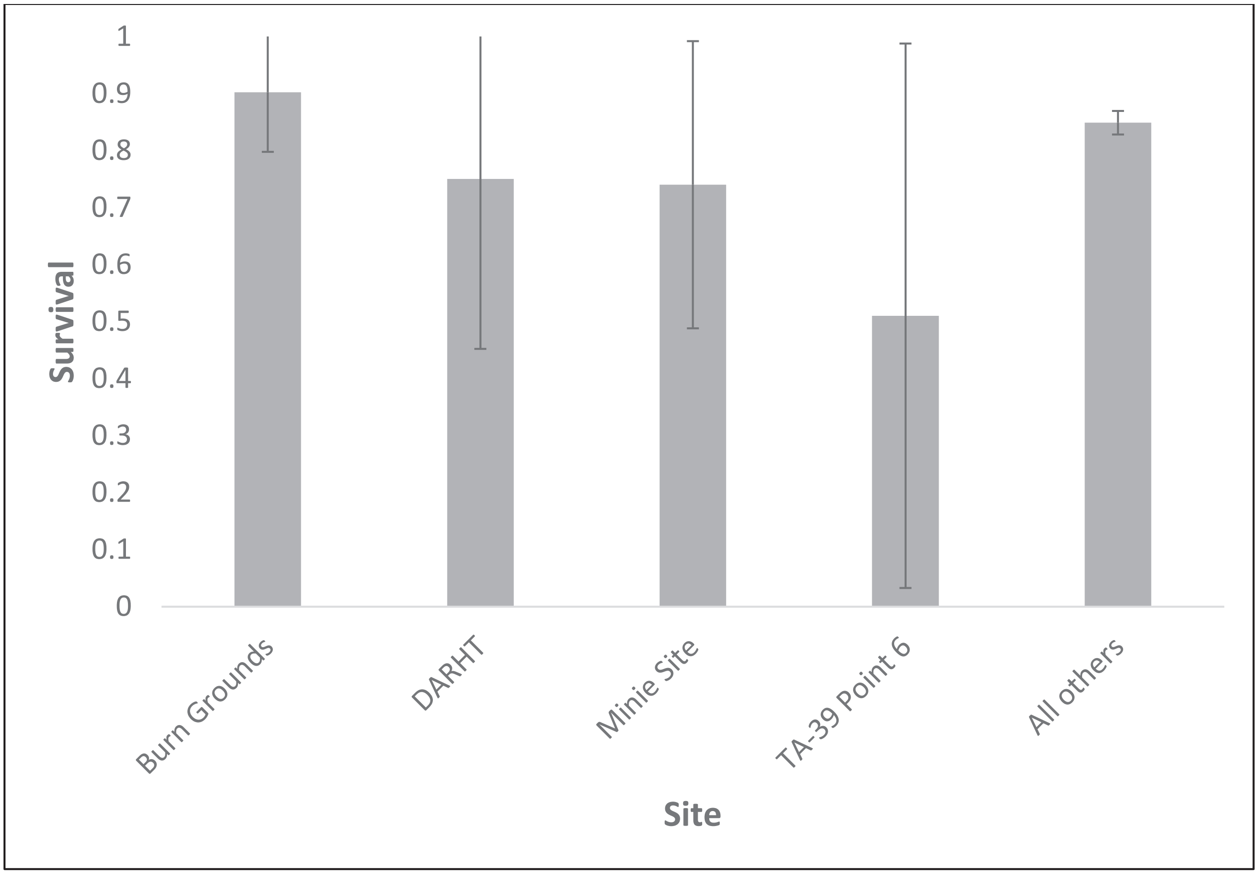


Figure 11. Estimated probability of surviving the 18-day nestling period for Western Bluebird nests at selected sites. Estimates (±95% CI) were generated using a constant survival model with no covariates.

Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 59 species detected at the three treatment sites, all are protected under the Migratory Bird Treaty Act. Additionally, two of the species detected at the three treatment sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those two species are the Juniper Titmouse and Grace's Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901). Another conservation tool used in migratory bird management is the Birder's Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three treatment sites are on the top 100 list. They are the Virginia's Warbler and Grace's Warbler.

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL’s avifauna at the three treatment sites, contribute to meeting the Department of Energy’s commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and allow LANL to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Thanks to the following individuals for data analyses, technical, and field support work in 2018: Jesse Berryhill, Steven Dinsmore, Luciana Vigil-Holterman, Maria Musgrave, Maricela Salazar, and former staff and interns that helped in previous years.

Literature Cited

Chao, A., N.J. Gotelli, T.C. Hsieh, E.L. Sander, K.H. Ma, R.K. Colwell, and A.M. Ellison 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs* 84:45–67.

Dinsmore, S.J., G.C. White, and F.L. Knopf. 2002. Advanced techniques for modeling avian nest survival. *Ecology* 83:3476-3488.

Dinsmore, S.J., and J.J. Dinsmore. 2007. Modeling avian nest survival in Program MARK. *Studies in Avian Biology* 34:73-83.

Eisler, R. 1998. Copper hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Geological Survey, Biological Resources Division, Biological Science Report.

Gardener, M. 2014. *Community Ecology: Analytical Methods Using R and Excel.* Pelagic Publishing. Exeter, United Kingdom. 556 pp.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 9pp.

Hathcock, C.D., K. Zemlick, and B. Norris 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. LA-UR-11-05054. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. LA-UR-13-27825. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-14-28161. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-15-28296. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. LA-UR-17-20359. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16

Burn Ground at Los Alamos National Laboratory. LA-UR-18-22897. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hsieh, T.C., K.H. Ma, and A. Chao 2016. iNEXT: iNterpolation and EXTrapolation for species diversity. R package version 2.0.12 URL: http://chao.stat.nthu.edu.tw/blog/software-download/.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology* 29:151–154.

Juarez, C.L., and L.R. Vigil-holterman. 2011. Soil Sampling Results Summary Report for the Open Detonation Units at Technical Area (TA) 36-08 and TA-39-6. LA-UR-11-03156. Los Alamos National Laboratory, Los Alamos, New Mexico.

MacArthur, R.H. and E.O. Wilson 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, N.J. 215pp.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville 2003. Land cover classification map for the Eastern Jemez Region. LA-14029. Los Alamos National Laboratory, Los Alamos, New Mexico.

Oksanen, J., F.G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H. Stevens, E. Szoecs and H. Wagner 2017. vegan: Community Ecology Package. R package version 2.4-4. https://CRAN.R-project.org/package=vegan.

R Core Team 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. *Ecology* 91(10):2874–2882.

U.S. Fish and Wildlife Service (USFWS) 2008. *Birds of Conservation Concern 2008.* United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine 2015. Weather Machine Climatological Monthly Summary, September 2015, http://weather.lanl.gov/climo_monthly_summary.asp.

Wells, J.V. 2007. *Birder's Conservation Handbook: 100 North American Birds at Risk.* Princeton University Press. Princeton, New Jersey. 452 pp.

Appendix 1. All birds recorded at the three treatment sites from 2013–2018

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Acorn Woodpecker													5		3	2	3	5
American Crow																	1	1
American Kestrel				1			1			2								
American Robin	1	1	2		2		1	1		2		4	7		9	4	4	6
Ash-throated Flycatcher	11	5	14	13	13	10	19	11	29	12	8	8	3	5	6	2	3	8
Audubon's Warbler		2				5				2			6	5	1	6		1
Bewick's Wren	4	8	9	9	14	14	3	10	15	9	2	8						
Black-chinned Hummingbird		1	1				3	2				1	1		1		1	
Black-headed Grosbeak	1	3				1		2	4	1		3			1	2		2
Black-throated Gray Warbler			1		2		5	6	4									
Blue-gray Gnatcatcher	3	14	16	8	10	9	2		7	5	4	2		6	2	1	3	6
Broad-tailed Hummingbird	2	1	3		1		3	1	2		3	1	5	11	11	5	7	10
Brown Creeper													1					
Brown-headed Cowbird	1								2			3	4	1			4	2
Bushtit		2		2		11	2	14			1	12						
Canada Goose									16									
Canyon Towhee	2		5	3	6	2	1	1	2	10	13	19	1			1		1
Canyon Wren					1				2	3	8	6			2			
Cassin's Finch						4												
Cassin's Kingbird	6	13	13	5	2	5	7	6	2	21	21	32				1		

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Chipping Sparrow	3	16	17	29	6	22	6	6	5	8	15	25	1	5	3	10	5	21
Clark's Nutcracker														4		1		
Common Nighthawk	6		5	2	4	4	5	1	3	2	7	5			1	2	2	
Common Raven	2	5	1		1	2	1		2	1		1	5	6	2	2	5	5
Cooper's Hawk					1								1			1		
Cordilleran Flycatcher													5	10	6	3	3	1
Dark-eyed Junco												1	6	2	4		5	2
Downy Woodpecker				1						1	2			1		1	1	1
Dusky Flycatcher				1					1		1							
Eurasian Collared-Dove	3										4							1
Evening Grosbeak	3		4						8				5		29			1
Grace's Warbler												2	6	4	4	8	5	8
Gray Flycatcher	12	6	5	7	3	6	10	10	11	10	5	8						
Great Horned Owl		3					1											
Green-tailed Towhee	3	1					1											
Hairy Woodpecker			2	1		1			5	3			1	1		1	1	2
Hammond's Flycatcher													8	9	12	5	7	5
Hepatic Tanager									1	2	1	2				1		
Hermit Thrush						1								4	6	1	2	2
House Finch	16	17	26	17	12	18	21	4	23	9	30	44	16	2	5	5	12	7
House Wren													1	1		2	2	6
Juniper Titmouse	12		7	6	9	3	11	13	18	6	1							
Lesser Goldfinch	2	6	7	4	9	12	4	12	9	10	14	19	3		8	9	4	8
MacGillivray's Warbler																1	3	

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Mountain Bluebird		2	20	10	11	1		4							4	4	4	7
Mountain Chickadee	5	2	1	2						1	1		5	8	9	6	8	9
Mourning Dove	17	17	13	5	8	8	13	22	10	3	15	11	4		1	3	17	3
Northern Mockingbird					2			1										
Peregrine Falcon									1									
Pine Siskin	10	2		5	1		6		3	3			12	4	5		4	2
Plumbeous Vireo	10	10	7	3	9	9	1		1	6	6	5	11	16	15	14	11	18
Pygmy Nuthatch				2		2			2	4	12	9	11	13	26	29	41	20
Red Crossbill					1			2						2	9	13	9	
Red-shafted Flicker	3	1	3	2	5	2	3	2	4	8		3	3	4	11	11	5	5
Red-tailed Hawk									1	1	1	1						
Rock Wren	3	3	4		2	10	7	10	4	12	14	14	1	2	2	6		
Ruby-crowned Kinglet																		2
Say's Phoebe	2	1	2		2	5	2	1		5	2	4	1		1	3	3	4
Scaled Quail			1															
Spotted Towhee	17	8	19	27	32	24	12	6	33	16	12	16	11	18	16	14	21	22
Steller's Jay													3	2	5	6	3	4
Townsend's Solitaire	1																1	
Turkey Vulture					1								1					1
Violet-green Swallow		5	7	1	3	2	6	4	1	9	6	6		2	19	2	2	4
Virginia's Warbler					1	3			1	2	4		17	11	21	13	7	5
Warbling Vireo						2							2	9	7	6	5	4
Western Bluebird	15	11	18	17	16	19	5	19	12	21	13	6	20	20	49	37	32	27
Western Tanager		2	3		1			2	1	1	2	2	2	3	7	2	4	6

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Western Wood-Pewee	10	8	18	11	10	7		4	2	10	8	11	15	10	16	14	22	20
White-breasted Nuthatch	1	4	9	10	13	5			2	4	4	2	9	8	7	9	20	10
White-throated Swift								1										
White-winged Dove	1	5	9	2		3	7	5	6	16	15	15			1	2		
Woodhouse's Scrub-Jay	5	1	3	4	8	7	8	10	4	8	6	4	1					
Northern Rough-winged Swallow						3												

22. Hites, D.A., 2011. *Dioxins: An Overview and History*. Envt’l Science & Tech, Vol. 45, No. 1.

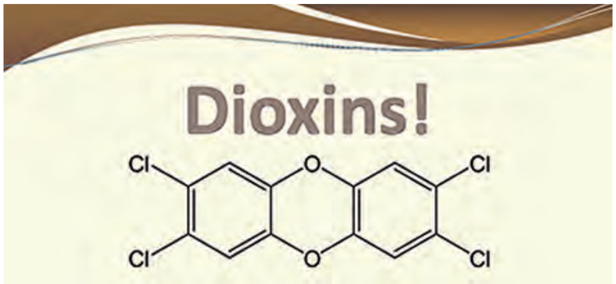
(Hites 2011)

Environmental Science & Technology
Feature

Environ. Sci. Technol. **2011**, *45*, 16–20

Dioxins: An Overview and History[†]

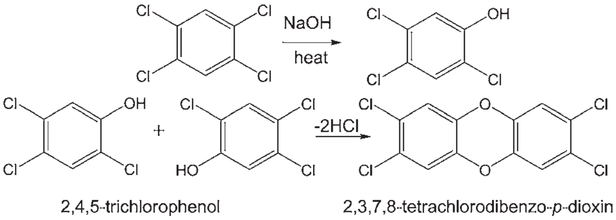
RONALD A. HITES*
School of Public and Environmental Affairs, Indiana University, Bloomington, Indiana



RONALD A. HITES

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and their cousins, the polychlorinated dibenzofurans (PCDFs), are well-known environmental contaminants. Depending on where on the rings the chlorine atoms are attached, one can have 210 chemically different PCDD/Fs, each of which is called a “congener”. Collectively the 210 compounds are often called “dioxins”—note the plural—even though the majority of them are actually dibenzofurans. PCDD/Fs have received considerable public and scientific attention because of the acute toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2378-TCDD), which has one of the lowest known LD_{50} (lethal dose to 50% of the population) values. It takes only 0.6 μg/kg of body weight to kill male guinea pigs (*1*). Thus, 2378-TCDD is frequently highlighted, at least in the popular press, as “the most toxic man-made chemical”. The polychlorinated dibenzofurans are only slightly less toxic; for example, the LD_{50} of 2378-TCDF is about 6 μg/kg for male guinea pigs (*2*). Other dioxin and furan congeners are also toxic, and many of these compounds have both acute and chronic effects. Incidentally, the toxicity of dioxins varies dramatically from species to species; for example, 2378-TCDD is about 500 times less toxic to rabbits than it is to guinea pigs (*1*).

Unlike the polychlorinated biphenyls (PCBs), PCDD/Fs were never produced intentionally as marketable products. In fact, dioxins were unwanted byproducts of industrial and combustion processes. For example, dioxins were present in chlorinated phenols and in related compounds as accidental contaminants. The most classic example was the presence of 2378-TCDD in 2,4,5-trichlorophenol (also known as Dowicide 2), which was produced by the reaction of 1,2,4,5-tetrachlorobenzene with sodium hydroxide (NaOH). Dimerization of the resulting phenol produced small amounts of 2378-TCDD, which contaminated the chlorinated phenol product. Although dioxins were present at low levels in some commercial products, their widespread use resulted in the release of PCDD/Fs into the environment at levels that have sometimes required remediation.



This feature article will summarize some of the history concerning dioxins in the environment over the last 50 years and end with a commentary on the U.S. Environmental Protection Agency’s (EPA’s) approach to these problems.

Chick Edema Disease (*3*). In 1957, a mysterious disease was killing millions of young chickens in the eastern and midwestern U.S. The symptoms were excessive fluid in the heart sac and abdominal cavity, and the cause was traced to the fatty acids that had been added to the chicken’s feed. Considerable efforts over several years lead to the isolation of one of the toxic materials and to its identification by X-ray crystallography; it was 1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin.

The source of this dioxin in the fatty acid material was traced to the tanning industry. Hides, after they are removed from the animal, have a layer of fat that must be removed. Until the midtwentieth century, the first step in the tanning process was to apply large amounts of salt (NaCl) to the hides as a preservative, but in the last 50–60 years, this approach was supplanted by the use of “modern” preservatives, such as chlorinated phenols, which we now know to have been contaminated with PCDD/Fs. As the fat was stripped from the hide, the chlorinated phenols and their impurities, both being relatively lipophilic, ended up in this so-called “fleshing grease”. This material was saponified to produce fatty acids, which were purified by high temperature distillation. Both of these steps tended to dimerize the chlorinated phenols and to concentrate the resulting dioxin impurities in the fatty acid product, which was then used as a supplement in chicken feed. In fact, analysis of three contaminated fatty acid products showed the presence of 2,3,4,6-tetrachlorophenol (also known as Dowicide 6), which could dimerize by way of a Smiles rearrangement to form 1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin. Analysis of toxic fleshing grease samples also showed the presence of several other dioxins. Both 1,2,3,7,8,9- and 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin are about 10% as toxic as 2378-TCDD (*2*), clearly contraindicating the use of chlorinated phenols in a material destined for food use or production.

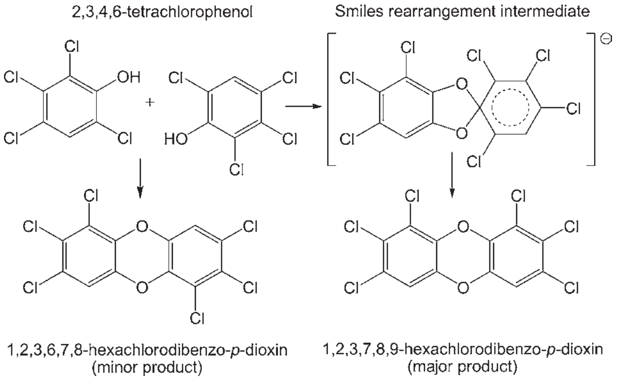
Although an understanding of the chemical etiology of chick edema disease largely eliminated the problem in chickens by the early 1970s, the problem reappeared in the mid-1980s (*4*). This more recent problem was traced to pentachlorophenol (also known as Dowicide 7), which had

---

[†] This manuscript is part of the Environmental Policy: Past, Present, and Future Special Issue.

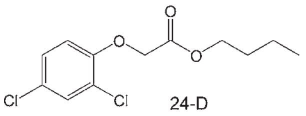
* E-mail: hitesr@indiana.edu.

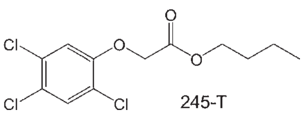
10.1021/es1013664



contaminated wood shavings used as bedding for chickens. In this case, the hepta- and octachlorinated dioxin and dibenzofuran congeners were relatively abundant, amounting to about 20 ppm in the wood shavings, but 1,2,3,6,7,8- and 1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxins were also present in the chickens and wood shavings.

Agent Orange (*5*). During the war in Vietnam, the U.S. military used a herbicide dubbed Agent Orange as a defoliant. Spraying by airplanes and helicopters occurred in South Vietnam from 1965 to 1971. The intent was to kill food crops being used by the North Vietnamese and the Viet Cong and to kill foliage around U.S. military base perimeters (thus improving the defensibility of these bases). Agent Orange was a mixture of roughly equal amounts of the *n*-butyl esters of 24-D and 245-T, the latter of which was made from 2,4,5-trichlorophenol. As a result of the use of this starting material, 245-T and thus Agent Orange were contaminated with small amounts of 2378-TCDD. While it is now almost impossible to know what the concentrations of 2378-TCDD in Agent Orange were, the current estimate is an average of about 3 ppm. Given that a total of about 4.5×10^7 L of Agent Orange were sprayed, it follows that on the order of 150 kg of 2378-TCDD could have been added to the environment of southern Vietnam.


24-D


245-T

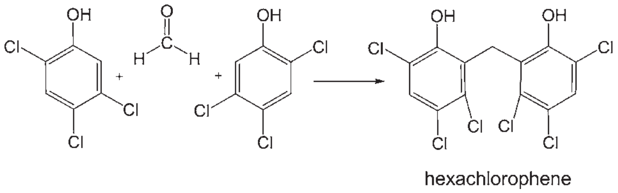
Often the scientific issues associated with Agent Orange have paled in comparison to the political issues, which have focused on U.S. Vietnam veterans and the Vietnamese people. Both groups have argued that health problems they have had since the 1970s have been caused by the dioxin impurities in Agent Orange.

In the case of the U.S. veterans, a large epidemiological study was organized starting in 1979. The idea was to associate Agent Orange exposure information with health effects as determined by medical examinations. This study soon focused on those veterans of the U.S. Air Force who had participated in the spraying program—the so-called Ranch Hands—who had presumably been exposed to Agent Orange. About 1000 such veterans and an equal number of veterans who had not been involved in the spraying operation were enrolled in this study, and their health status was assessed every 5 years. Early results found few statistically significant differences in the health outcomes of these two groups.

Later, exposure assessment was based on the measured tissue or blood concentrations of 2378-TCDD, and health differences between the exposed and unexposed populations began to emerge. This epidemiological study was terminated in 2006 over the protests of the scientific community, but all of the specimens, medical records, and data have been archived by the Institute of Medicine. The total cost of this 27-year project was about $140,000,000. The most recent assessment of the Ranch Hand and other data by the Institute of Medicine (*6*) indicates that there is "sufficient evidence of an association" between herbicide exposure and incidence of soft-tissue sarcoma, non-Hodgkin's lymphoma, Hodgkin's disease, chronic lymphocytic leukemia, and chloracne. Vietnam veterans can now be compensated if they have one of these health problems; for a 50% disability, this compensation is on the order of $800/month.

Agent Orange may also have had effects on the Vietnamese people and environment, but there are no plans to do an epidemiological study as was done with the U.S. veterans. Instead, efforts have focused on preventing further exposures by cleaning up "hot spots", where Agent Orange may have been spilled or dumped during U.S. operations in Vietnam. One estimate is that about 10^4 m^2 (1 ha) of soil will need to be remediated. This is about the size of two U.S. football fields, so this remediation should be feasible. It is interesting to note that some Vietnamese have sued the U.S. manufacturers of Agent Orange for health damages in a U.S. court; the case was dismissed in 2005, but the decision has been appealed (*5*).

Times Beach and Missouri (*7, 8*). In the 1960s and early 1970s, the Northeastern Pharmaceutical and Chemical Company (NEPACCO) operated a plant in Verona, MO, making hexachlorophene from 2,4,5-trichlorophenol and formaldehyde. Hexachlorophene's production rate soon reached 450 t (1 million pounds) per year. Unfortunately, 2378-TCDD was an impurity in the 2,4,5-trichlorophenol starting material used in this process; thus, the hexachlorophene product needed to be purified before sale. The waste from this cleanup process, with its relatively high load of 2378-TCDD, was stored in a holding tank on the NEPACCO property in Verona. Because of its neurotoxicity, the U.S. Food and Drug Administration restricted the use of hexachlorophene in 1971.



At about that time, Russell Bliss was contracted to "recycle" the chemical waste oil (also called still bottoms) from the NEPACCO holding tank in Verona. Bliss ran a small business in which he picked up waste oil from garages, airports, and military bases, and took it back to one of four 91,000 L (24,000 U.S. gal) holding tanks at his facility. He made his money by paying a small fee for picking up the oil and collecting a larger fee when selling it to petroleum reprocessors and by spraying the oil for dust control on dirt roads or in horse-riding arenas. The oil he usually dealt with was almost exclusively used crankcase oil from cars and trucks. Apparently no one realized that the oil he picked up from the NEPACCO facility was chemical waste oil as opposed to petroleum based oil, and as a result, about 70,000 L of this chemical waste oil with its dioxin impurities was mixed in with other oil in one or more of his holding tanks. NEPACCO claims Bliss was warned that this waste was hazardous, but he and his drivers insisted they were not. The 2378-TCDD concentration in this waste oil was about 300 ppm.

On May 26, 1971, Bliss took some oil from his holding tank and sprayed it at the Shenandoah Stables indoor horse-riding arena for dust control. The next day horses became ill; in the end, 75 horses had died or had to be euthanized. Within a week, small birds were found dead in the arena. Within two weeks, the same oil had been sprayed at the

Bubbling Springs arena and at the Timberline Stables arena, both of which soon had similar problems. Soil from these three arenas was removed within a few weeks, but the animal health problems persisted. At the Bubbling Springs site, 25–30 truckloads of dirt were removed and taken to several private building sites, thus spreading the contaminated soil to other parts of Missouri. Samples from the horse arenas were eventually analyzed by the U.S. Centers for Disease Control (CDC), who identified 2,4,5-trichlorophenol, hexachlorophene, and 2378-TCDD. By 1974, the CDC had traced the source of the contamination to the NEPACCO facility, which by this time was owned by another company named Syntex Agribusiness Inc. Several thousand gallons of chemical waste were still present at this facility, and this oily waste still contained about 8 kg of 2378-TCDD.

Between 1972 and 1976, Bliss also had been paid to spray oil for dust control on the unpaved streets of Times Beach, MO, and on other unpaved streets throughout the state of Missouri. Once it became clear that Missouri had a dioxin problem, and once typical bureaucratic in-fighting had cleared, the state government and the EPA began cooperating in 1982 to fully determine the spatial extent of the problem and to implement cleanup plans. In due course, the EPA published a list of 38 dioxin contaminated sites in Missouri, including Times Beach. By the end of 1982, the Missouri Department of Health recommended that the entire town of Times Beach be evacuated, and it was. By February of 1983, the EPA announced that $33,000,000 would be spent to buy all the homes and businesses in Times Beach. In April 1986, the aldermen voted to dis-incorporate and everyone left Times Beach. This site was eventually remediated and removed from the Superfund list in 2001 (*9*).

In addition to the soil cleanup, the $\sim$8 kg of 2378-TCDD in the former NEPACCO holding tank (now owned by Syntex) had to be remediated. Syntex first protected the tank from storms and vandals by building a concrete dike around tank and fencing the area. Incineration in Minnesota was considered, but groups in Iowa threatened to call out the National Guard to block transport of this material through their state. Instead, a waste-management company developed a technique for breaking down 2378-TCDD by direct ultraviolet photolysis. The process was tested successfully in 1979; the waste began to be treated in May 1980; it ran full time for 13 weeks; and by August 1980, all the waste had been treated with 99% destruction of 2378-TCDD.

Seveso, Italy (*10*). In the mid-1970s, a Swiss company, Roche Group, operated a small chemical production plant, known as Industrie Chimiche Meda Società Anonima (ICMESA), in the northern Italian town of Meda. Among other products, this plant made 2,4,5-trichlorophenol by the reaction of 1,2,4,5-tetrachlorobenzene with NaOH. On Saturday, July 10, 1976 at about noon, the vessel in which this reaction was being carried out overheated, and its pressure increased. This caused the rupture disk in a safety valve to burst, and the contents of the vessel were released to the atmosphere and transported south by the wind. Most of the contamination landed in the town of Seveso.

On Sunday, July 11, ICMESA managers informed local authorities of the escape of a chemical cloud and that it might contain "toxic substances". These plant managers requested that local authorities warn the residents, and they sent soil samples to Roche in Switzerland for analysis. By the next day, nearby residents were warned not to eat vegetables from their gardens. Within a few days, more than 1000 chickens and rabbits had died, and Roche informed the ICMESA plant manager that the soil samples contained traces of 2378-TCDD. The next day, the mayors of Seveso and Meda declared the area south of the ICMESA plant to be contaminated, and warning signs and fences were erected.

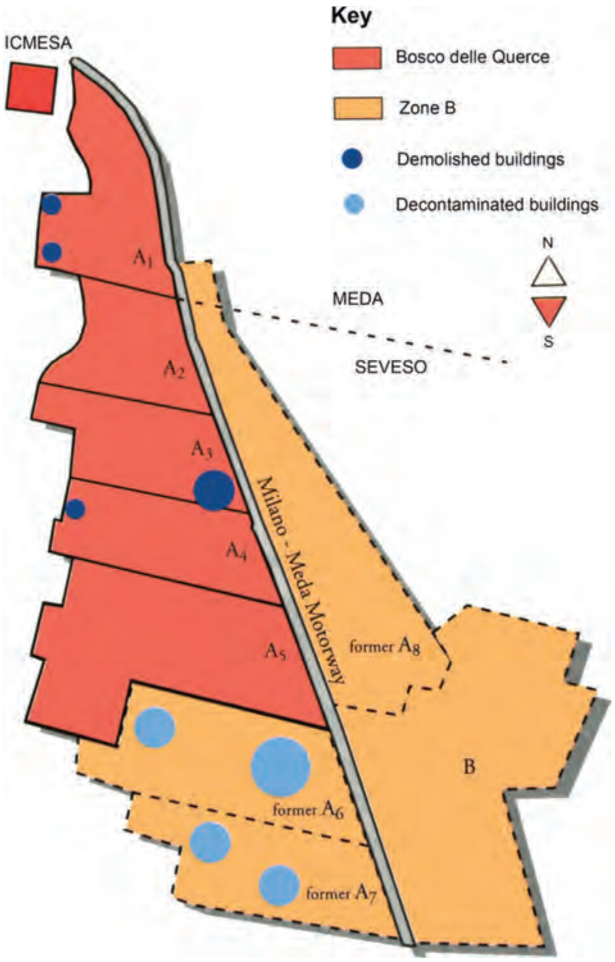


FIGURE 1. Map of the dioxin contaminated zones in Seveso, Italy. Zone A (red) was the most contaminated with soil levels of 2378-TCDD of $>50\ \mu g/m^2$) and Zone B (yellow) was less contaminated with soil levels of 2378-TCDD of $5-50\ \mu g/m^2$. This map is reprinted from ref *11* with permission.

By July 16, several children had been hospitalized due to skin reactions. The mayor of Seveso informed a national newspaper about this chemical disaster, and on July 19, the first articles about it appeared in the national press and on television. At about this time, the government sealed the building where the accident occurred, and the mayor of Meda ordered that all other ICMESA buildings be sealed as well. On July 20, Roche notified the Italian authorities that 2378-TCDD had been found in the soil samples. This information caused a sensation in northern Italy, and the next day the ICMESA Technical Director and the ICMESA Director of Production were arrested. Roche provided a preliminary map of concentrations as a function of location on July 23 and suggested closing the area closest to the plant and evacuating the people living there.

On July 24, two weeks after the accident, various governmental officials, provincial and national scientists, and industrial representatives met. One result of this meeting was to set up a team of Italian scientific institutions to establish sampling and analytical protocols. This team also recommended the evacuation of people living closest to the ICMESA plant. On July 26, 230 people were evacuated, and by the end of July, more than a thousand 2378-TCDD measurements of soil and vegetation had been made. These data led to the geographical definition of the most contaminated area, named Zone A (1). This zone covered an area of 87 ha, and about 730 people were evacuated from this area. Estimates of the total amount of 2378-TCDD in Zone A soil are imprecise, but more than 2 kg is the best guess.

By August, following further soil measurements, Zone B was defined (Figure 1). It is interesting to note that the dividing line between Zones A and B is the Milano-Meda Motorway. About 4600 people lived in Zone B. These people were not evacuated, but they were asked to follow some restrictions. They could not eat produce grown in Zone B, and their children were sent to schools outside of the area. In addition, many businesses in Zone B were closed for several years. Decontamination of both zones began in August 1976, and an agreement was reached between the Regional Government and Roche for removal and disposal of chemicals from the plant. Roche covered the costs.

By 1977, decontamination of Zone A had been completed. The entire top 40 cm of soil was removed, and the contaminated ICMESA plant and several contaminated houses were demolished. All of this waste was buried in two new 300,000 m^3 hazardous waste facilities built near the accident site. Decontamination of zone B started next. In this case, the contaminated surface layer of soil was simply mixed with deeper uncontaminated soil by repeated plowing of the fields. By 1987, Zone A had been converted to a park known as the Bosco delle Querce (Oak Woods).

Epidemiological monitoring programs were established to follow possible metabolic modifications, spontaneous abortions, malformations, tumors, and deaths among the exposed population. Health monitoring of the workers at the ICMESA plant and on the decontamination projects was also established. An International Steering Committee was formed to assess toxicological and epidemiological data and findings of the monitoring program. In 1984, this Steering Committee reported that there were no human effects other than ~200 cases of chloracne. Nevertheless, longer term epidemiological studies have continued. One of the most interesting such studies is the "where the boys aren't" effect reported by Mocarelli et al. (*12*). They observed that the sex ratio in the children of fathers who had high levels (>118 ppt) of 2378-TCDD in their blood in 1976 was significantly skewed toward female children. This is an example of a subtle biological effect that did not become apparent until over 20 years after exposure.

Although the human health effects continue to be studied, it is important to note that the people who lived in Seveso also suffered significant economic effects. For example, within Europe, the term "made in Seveso" became pejorative—who would want to buy a product that had been so closely associated with a famous toxic substance? As a result of this public antipathy, many people in Seveso lost their jobs. Seveso's property values became depressed—who would want to buy housing or land there? These economic effects were as real as health effects and deserved equal attention, and a reimbursement plan was established to cover these individual and social costs.

Combustion Sources of Dioxins (*13*). All of the incidents described above were ultimately the result of dioxin impurities in commercial chemical products, especially chlorinated phenols, but in 1977 Olie et al. noticed that dioxins were present in fly ash from an industrial heating facility (*14*). In 2000, Bumb et al. in a famous paper titled "Trace chemistries of fire: A source of chlorinated dioxins", showed that dioxins were present in particles from the combustion of most types of organic material, including the combustion of municipal and chemical waste (*15*). This was an important discovery. No longer could the simple presence of dioxins in a sample be blamed on the chemical industry. Indeed, it was suggested that "dioxins have been with us since the advent of fire" (*16*).

It seemed that this "advent of fire" idea was subject to experimental verification, and my laboratory began work on this issue (*13*). We started by developing the following operational hypothesis: Chlorinated dioxins and furans are formed during combustion and are emitted into the atmosphere. Depending on the ambient temperature, some of these compounds are adsorbed to particles and some are in the vapor phase. In either case, these compounds travel through the atmosphere for some unknown distances and are deposited by various routes. Particles with their load of adsorbed compounds settle out of the air, and precipitation scavenges both particle-bound and vapor-phase compounds.

We tested this hypothesis by measuring dioxins and furans in the ambient environment. Our first step was to look at historical aspects. What was the history of chlorinated dioxin and furan concentrations in the atmosphere? Were these compounds really present in the environment since the "advent of fire"? Since it was not possible to retroactively sample the atmosphere, we resorted to an indirect strategy by sampling lake sediment. This technique is based on the rapid transport of material deposited on the top of a lake to its bottom and on the regular accumulation of sediment at the bottom of the lake. Thus, the sediment preserves a record of atmospheric deposition. Experimentally, we obtained cylinders of sediment (called "cores") from the bottom of several lakes, sliced them into 0.5−1 cm layers, and analyzed each layer for the tetrachloro- through octachlorodibenzo-*p*-dioxins and dibenzofurans by gas chromatographic mass spectrometry. Using radio-isotopic methods, we determined when a particular layer of sediment was last in contact (through the water column) with the atmosphere.

We analyzed many sediment cores from the Great Lakes and from a few alpine lakes in Europe, but the site that we consider the most significant is Siskiwit Lake on Isle Royale (*13*). This island is in northern Lake Superior; it is an infrequently visited U.S. national park; it lacks roads and other development; it is a wilderness area and a Biosphere Reserve. Siskiwit Lake is the largest lake on Isle Royale, and its water level is about 17 m higher than that of Lake Superior. Clearly, the only way for dioxins and furans to get into this lake is through deposition from the atmosphere.

Our measured concentrations of dioxins and furans in this sediment core were dominated by octachlorodibenzo-*p*-dioxin, and 2378-TCDD was a minor component. The heptachlorinated dioxins and furans were the second most abundant set of congeners. These relatively high levels of the octa- and heptachlorinated congeners are different from what had been observed in soil samples from Missouri and Seveso, which were dominated by 2378-TCDD. In terms of absolute levels, we found that the concentrations of the dioxins and furans were not much higher than the limit of detection in sediment layers corresponding to deposition dates prior to about 1935. At this time, the concentrations began to increase and maximized in about 1970, after which they decreased to about two-thirds of their maximum levels. From these data, we concluded that atmospheric dioxin and furan levels increased slowly starting in about 1935 and have decreased considerably since about 1970.

What happened in about 1935 that led to the emission of dioxins? Clearly it was not the "advent of fire." We suggest that it was a change in the chemical industry that took place at about this time. Before World War II (1939−1945), the chemical industry was commodity based, selling large amounts of inorganic products. During WWII, organic products were introduced; for example, plastics became an important part of the chemical industry. Some of these products were organochlorine based, and in fact, some of them were chlorinated phenols. As waste materials containing these chemicals were burned, dioxins and furans were produced and released into the atmosphere. These compounds deposited to the water and ended up in lake sediments. Incidentally, coal combustion could not account for the historical record that we observed. Coal combustion was almost constant between 1910 and 1980; there was no major shift either in amount burned or in combustion technology around 1935.

We observed the 1970 maximum in almost all of the sediment cores we analyzed for dioxins. This suggests that

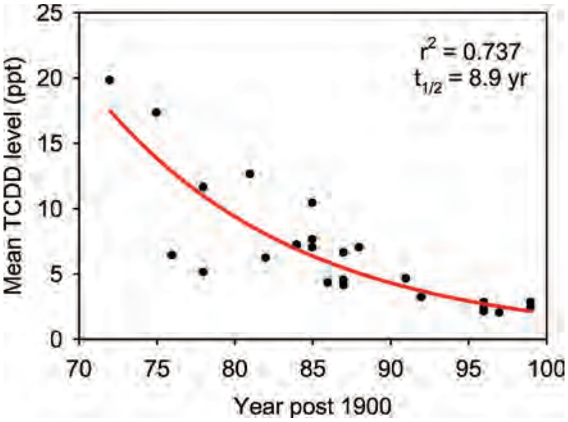


FIGURE 2. Concentrations of TCDD (parts per trillion lipid) in human tissue and serum as a function of when the samples were taken. Each point is the mean of, on average, ~50 samples; plotted from ref *19*.

emission control devices, which were beginning to be widely installed at about this time, were effective in removing dioxins and furans as well as more conventional air pollutants. Subsequent work in my laboratory on another set of cores from Siskiwit Lake has confirmed these results and shown that dioxin levels in surficial sediment have decreased to about one-half of their maximum levels (*17*). This suggests that emissions of dioxins have decreased even more between the time of our first study (cores taken in 1983) and our second study (cores taken in 1998).

Dioxin Reassessment. By the mid-1980s, it was apparent that dioxins from both chlorinated phenols and from combustion were a potential public health issue, and the EPA sprang into action. In 1994, a massive report, called the "Dioxin Reassessment" was generated and reviewed by the EPA's Science Advisory Board (*18*). This report included detailed reviews of the scientific literature and presented a comprehensive assessment of dioxin exposure and human health effects. This report more or less languished in the files of the EPA (although parts have been published in the peer-reviewed literature) for 15 years, but an official draft version of this report has been released recently.

As a result of this delay, few regulations limiting dioxin emissions have been issued in the U.S. Nevertheless, things have changed. The continued reduction in particle emissions from large combustion systems, the elimination of chemical waste burning, and the abandonment of the chlorinated phenol business by large sectors of the chemical industry have meant that lower amounts of dioxins are entering the environment over time. This almost incidental reduction of dioxin emissions has had an effect. For example, Figure 2 shows the average lipid adjusted TCDD levels in people from the U.S., Canada, Germany, and France as a function of time, starting in 1972. The reduction in TCDD shown by this meta-analysis is substantial, decreasing by about a factor of 7 over a 25-year period. One might call these reductions "inadvertent regulation", which is a good thing.

Because of the acute toxicity of dioxins, the environmental problems outlined in this article have received a fair amount of public attention and have contributed to the public's demand for an environment free of toxicants. In a sense, dioxins have been a catalyst for environmental policy makers: Dioxins themselves have not been extensively regulated, but they have led to the regulation of other chemicals.

Ronald Hites is a Distinguished Professor at Indiana University in the School of Public and Environmental Affairs. His research focuses on the behavior of toxic organic compounds in the environment. He has published six books and almost 400 scientific papers and supervised over 70 postdoctoral associates and graduate students. He is a Fellow of the ACS, the winner of the 1993 Founders Award from the Society of Environmental Toxicology and Chemistry, the winner of the 1991 ACS Award for Creative Advances in Environmental Science and Technology, and an Associate Editor of Environmental Science & Technology.

Acknowledgments

I thank Marie Sweeney, Paolo Mocarelli, Jurgen Exner, and Al Franzblau for helpful comments.

Literature Cited

(1) Schwetz, B. A.; Norris, J. M.; Sparschu, G. L.; Rowe, V. K.; Gehring, P. J.; Emerson, J. L.; Gerbig, C. G. Toxicology of chlorinated dibenzo-*p*-dioxins. *Adv. Chem.* **1973**, *120*, 55–69.

(2) Van den Berg, M.; Birnbaum, L. S.; Denison, M.; De Vito, M.; Farland, W.; Feeley, M.; Fiedler, H.; Hakansson, H.; Hanberg, A.; Haws, L.; Rose, M.; Safe, S.; Schrenk, D.; Tohyama, C.; Tritscher, A.; Tuomisto, J.; Tysklind, M.; Walker, N.; Peterson, R. E. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol. Sci.* **2006**, *93*, 223–241.

(3) Firestone, D. Etiology of chick edema disease. *Environ. Health Perspect.* **1973**, *5*, 59–66.

(4) Ryan, J. J.; Lizotte, R.; Sakuma, T.; Mori, B. Chlorinated dibenzo-*p*-dioxins, chlorinated dibenzofurans and pentachlorophenol in Canadian chicken and pork samples. *J. Agric. Food Chem.* **1985**, *33*, 1021–1026.

(5) Stone, R. Agent Orange's bitter harvest. *Science* **2007**, *315*, 176–179.

(6) Institute of Medicine. *Veterans and Agent Orange*; The National Academy Press: Washington, DC, 2009; p 7.

(7) Carter, C. D.; Kimbrough, R. D.; Liddle, J. A.; Cline, R. E.; Zack, M. M.; Barthel, W. F. Tetrachlorodibenzodioxin: An accidental poisoning episode in horse arenas. *Science* **1975**, *188*, 738–740.

(8) Powell, R. L. Dioxin in Missouri: 1971−1983. *Bull. Environ. Contam. Toxicol.* **1984**, *33*, 648–654.

(9) U.S. Environmental Protection Agency. National oil and hazardous substances pollution control contingency plan: National priorities list. *Fed. Regist.* **2001**, *66*, 48969.

(10) Mocarelli, P. Seveso: A teaching story. *Chemosphere* **2001**, *43*, 391–402.

(11) Ramondetta, M., Repossi, A., Eds. *Seveso: 20 Years After*; Fondazione Lombardia per l'Ambiente: Milan, Italy, 1998; pp 17−32.

(12) Mocarelli, P.; Gerthoux, P. M.; Ferrari, E.; Patterson, D. G.; Kieszak, S. M.; Brambilla, P.; Vincoli, N.; Signorini, S.; Tramacere, P.; Carreri, V.; Sampson, E. J.; Turner, W. E.; Needham, L. L. Paternal concentrations of dioxin and sex ratio of offspring. *Lancet* **2000**, *355*, 1858–1863.

(13) Hites, R. A. Environmental behavior of chlorinated dioxins and furans. *Acc. Chem. Res.* **1990**, *23*, 194–201.

(14) Olie, K.; Vermeulen, P. L.; Hutzinger, O. Chlorodibenzo-*p*-dioxins and chlorodibenzofurans are trace components of fly ash and flue gas of some municipal incinerators in the Netherlands. *Chemosphere* **1977**, *6*, 455–459.

(15) Bumb, R. R.; Crummett, W. B.; Cutie, S. S.; Gledhill, J. R.; Hummel, R. H.; Kagel, R. O.; Lamparski, L. L.; Luoma, E. V.; Miller, D. L.; Nestrick, T. J.; Shadoff, L. A.; Stehl, R. H.; Woods, J. S. Trace chemistries of fire: A source of chlorinated dioxins. *Science* **1980**, *210*, 385–389.

(16) Rawls, R. L. Dow finds support, doubt for dioxin ideas. *Chem. Eng. News* **1979**, (Feb 12), 23–29.

(17) Baker, J. I.; Hites, R. A. Siskiwit Lake revisited: Time trends of polychlorinated dibenzo-*p*-dioxin and dibenzofuran deposition at Isle Royale, Michigan. *Environ. Sci. Technol.* **2000**, *34*, 2887–2891.

(18) U.S. Environmental Protection Agency. *Health Assessment Document for 2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD) and Related Compounds*; Washington, DC, 1994; Vol. I, EPA/600/BP-92/001a (NTIS PB94205465); Vol. II, EPA/600/BP-92/001b (NTIS PB94205473); Vol. III, EPA/600/BP-92/001c (NTIS PB94205481).

(19) Aylward, L. L.; Hays, S. M. Temporal trends in human TCDD body burden: Decreases over three decades and implications for exposure levels. *J. Exposure Anal. Environ. Epidemiol.* **2002**, *12*, 319–328.

ES1013664

23. Huang, H., and A. Buekens, 1995. *On the Mechanisms of Dioxin Formation in Combustion Processes*. Chemosphere, Vol. 31, No. 9. (Huang *et al*. 1995)

Pergamon

0045-6535(95)00287-1

Chemosphere, Vol. 31, No. 9, pp. 4099–4117, 1995
Copyright © 1995 Elsevier Science Ltd
Printed in Great Britain. All rights reserved
0045-6535/95 $9.50+0.00

ON THE MECHANISMS OF DIOXIN FORMATION IN COMBUSTION PROCESSES

H.Huang[+] and A.Buekens[*]

Department of Chemical Engineering and Industrial Chemistry
Free University of Brussels, Pleinlaan 2, 1050 Brussels, Belgium

(Received in Germany 31 July 1995; accepted 4 September 1995)

Abstract

The experimental observations on dioxin formation from various combustion sources, from detailed incinerator measurements and from laboratory simulation studies including *de novo* synthesis and precursor formation pathways are discussed in this paper. The *de novo* synthesis seems to be the dominant mechanism of dioxin formation in actual combustion systems. As *de novo* synthesis experiments indicate that carbon morphology of certain degenerated graphitic structure is essential for dioxin formation, the morphologies of the particulate emissions from actual combustion sources are examined and it appears that soot particles formed in gas phase combustion reactions consisting of degenerated graphitic structures are the plausible source for *de novo* synthesis of dioxins. With this understanding dioxin formation in combustion systems is described as a two-stage process: (1) the formation of the graphitic structure of soot particles in the combustion zone; and (2) the conversion of the graphitic structure of soot particles to aromatic compounds including PCDD/Fs in the postcombustion zone. New explanations are given for some seemingly unrelated experimental observations including the high dioxin emissions from municipal waste incineration, the low dioxin emissions from coal combustion, the similar dioxin "fingerprint" from all combustion sources and the discrepancy between the dioxin formation rates observed in laboratory experiments and incinerator measurements.

1. Introduction

Dioxins are a group of chlorinated polynuclear aromatic compounds. They are emitted in trace quantities from combustion sources, especially the incineration of municipal wastes. Because some isomers of dioxins are highly toxic and may have carcinogenic and mutagenic effects, the control of dioxin emissions from combustion sources has received great attention and the mechanisms of dioxin formation have been studied extensively. It is now believed that dioxins

---

[*] *Correspondence concerning this paper should be addressed to Prof. A.Buekens.*

[+] *On leave from Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, P.O.Box 1254, Guangzhou 510070, China.*

are formed in the low-temperature postcombustion zone of incinerators through some heterogeneous catalytic reactions occurring in the flue gas - fly ash environment. The detailed chemical reactions are however not well understood. Recent reviews on the formation mechanisms and models of dioxins are given by Altwicker et al.[1-3] and Luijk[4]. In an effort to incorporate the kinetics of dioxin formation into an incinerator mathematical model for process simulation and optimization purposes, the findings of the formation mechanisms of dioxins have been studied in our department. The results especially those concerning the connection of laboratory findings to incinerator observations are presented in this paper.

2. The Experimental Evidence of Dioxin Formation

2.1 Dioxin Emissions from Various Combustion Sources

Some data of dioxin emissions from various combustion sources are shown in Table 1. Several observations can be made:

(1) Dioxins have been detected in a variety of combustion sources. The prediction from the "trace chemistry of fire" hypothesis that "emissions of PCDDs and PCDFs are general phenomena related to all combustion processes"[20,21] has been verified to a large extent.

(2) Municipal solid waste incineration has very high dioxin emissions while coal combustion generates the lowest dioxin emissions. This fact has been recognized in many previous studies.[22-23]

(3) Dioxins emitted from these combustion processes have similar "fingerprints". Here we refer to dioxin "fingerprints" as the furan/dioxin ratio, the homologue profile and isomer pattern collectively. The typical dioxin "fingerprints" from combustion sources are: furan/dioxin ratio (w/w) is larger than 1, the weight distribution of the homologues increases with increasing degree of chlorination for PCDDs, but shows a maximum at P_5CDF or H_6CDF for PCDFs, and the isomer pattern contains almost every isomer.[24,25] Dioxins from other sources, e.g. pulp bleaching and chloralkali electrolysis have different dioxin "fingerprints".[25] Because of the similar dioxin "fingerprint" from all combustion processes, especially the similar furan/dioxin ratio, it is very likely that the mechanisms of dioxin formation in all these combustion processes are similar or at least their controlling steps are similar.

2.2 Incinerator Measurements

Comprehensive measurements of dioxin emissions from incineration plants have been conducted for a number of years. The data from a recent German report are shown in Tables 2 to 4. Several observations can be made:

(1) Dioxins already present in MSW are destroyed in the combustion zone of incinerators as shown in Table 2, but dioxins are regenerated in the postcombustion zone as indicated in Table 3; overall dioxins are formed in the incineration process as shown in Table 4. This phenomenon of dioxin regeneration in the low-temperature postcombustion zone has been known since 1980s and confirmed by a large number of studies.

(2) Table 4 shows that the important streams of dioxin emissions from incinerators are ESP ash, filter cake and stack gas accounting for about 56.7%, 22.7% and 11.8% of the total TE output respectively.

Table 1. Dioxin emissions from various combustion sources[a,b]

Combustion sources	Dioxins in flue gas (ng-TE/Nm^3)	Dioxins in fly ash (ng-TE/g)	Ref.
Municipal waste incineration	0.2-63	1-28	[5]
Hazardous waste incineration	0.1-0.5	n.a.	[6]
Wood combustion: Natural wood Waste wood	 0.02-1.8 2.7-14	 n.a. 0.08-8	 [7-11]
Coal combustion	n.d.	n.d.-10	[12-14]
Plastics pyrolysis	detected	detected	[15,16]
Oil combustion: Oil furnace Leaded gasoline in vehicle Leadfree gasoline in vehicle	 0.03-0.3 10-60 (pg/L-oil) 3.5 (pg/L-oil)	 n.a.	 [17] [18]
Gas combustion	0.07-100	n.a.	[19]

[a]TE is referred to I-TEQ. [b]n.a.=not available, n.d.=not detected.

Table 2. Balancing of dioxin flows in the combustion zone of incinerators (mean values of 11 incineration plants, adapted from [5])

Input/output	Dioxin concentration	Mass/volume flow per tonne waste	Dioxin flow (µg-TE/tonne-waste)
Input: municipal waste	 0.09 ng-TE/g		 90
Output: bottom ash slag water raw gas total	 0.03 ng-TE/g 9 ng-TE/L 1.4 ng-TE/Nm^3	 300 kg 350 L 5000 Nm^3	 9 3.2 7 19.2
Balance			-70.8

Table 3. Balancing of dioxin flows in the postcombustion zone of incinerators (mean values of 11 incineration plants, adapted from [5])

Input/output	Dioxin concentration	Mass/volume flow per tonne waste	Dioxin flow (µg-TE/tonne-waste)
Input:			
raw gas	1.4 ng-TE/Nm^3	5000 Nm^3	7
Output:			
boiler ash	0.2 ng-TE/g	7 kg	1.4
ESP ash	4 ng-TE/g	30 kg	120
scrubber water	7 ng-TE/L	750 L	5
filter cake	6 ng-TE/g	8 kg	48
stack gas	5 ng-TE/Nm^3	5000 Nm^3	25
total			199.4
Balance			192.4

Table 4. Balancing of dioxin flows in incinerators (mean values of 11 incineration plants, adapted from [5])

Input/output	Dioxin concentration	Mass/volume flow per tonne waste	Dioxin flow (µg-TE/tonne-waste)	Percent of total output (%)
Input:				
municipal waste	0.09 ng-TE/g		90	
Output:				
bottom ash	0.03 ng-TE/g	300 kg	9	4.3
slag water	9 ng-TE/L	350 L	3.2	1.5
boiler ash	0.2 ng-TE/g	7 kg	1.4	0.7
ESP ash	4 ng-TE/g	30 kg	120	56.7
scrubber water	7 ng-TE/L	750 L	5	2.4
filter cake	6 ng-TE/g	8 kg	48	22.7
stack gas	5 ng-TE/Nm^3	5000 Nm^3	25	11.8
total			211.6	
Balance			121.6	

(3) Table 4 also shows that the dioxin concentration of solid discharges from incinerators is in the increasing order of bottom ash < boiler ash < ESP ash < filter cake < fly dust (for the dioxin concentration of 5 ng-TE/Nm^3 and dust loading of 0.02 g/Nm^3 in stack gas,[5] the corresponding dioxin concentration in fly dust is about 25 ng-TE/g assuming that only 10% of the PCDD/Fs in stack gas are present in particulate phase considering the possible desorption of gaseous PCDD/Fs in the upstream system), therefore it appears that the finer the particles, the higher are the dioxin concentrations.

(4) The effects of flue gas O_2, HCl and SO_2 levels on dioxins: An optimum O_2 level with minimum dioxin formation can be found for some incinerators;[26,27] the relationship between chlorine and dioxin formation seems still unclear as conflicting results are reported;[28-30] SO_2 has been suggested to be able to suppress dioxin formation,[31] but laboratory and field testings seem inconclusive.[32,33]

2.3 Laboratory Study

Laboratory experiments simulating incinerator postfurnace conditions to study the mechanisms of dioxin formation have been carried out by Stieglitz et al.[35-44], Dickson et al.[34] and others[45-53]. Two formation pathways relevant to incinerator conditions have been identified: the *de novo* synthesis and precursor formation. In precursor formation pathway dioxins are formed from gas phase precursors such as chlorobenzenes and chlorophenols; in *de novo* synthesis the carbon source of dioxin formation is the carbon present in solid phase material. The two pathways of dioxin formation have been shown to operate simultaneously and independently.[34] In Tables 5 and 6 these experiments are summarized for *de novo* synthesis and precursor formation pathway respectively. In all experiments solid phase material was placed inside a fixed bed reactor and gas phase material was passed through it. Gas phase PCDD/Fs produced are captured downstream and analyzed together with solid phase PCDD/Fs. The various units reporting PCDD/F formation in the original literature have all been converted into μg/g·min based on the weight of solid phase material and solid phase residence time in Tables 5 and 6 to allow for a quantitative comparison.

From Table 5 it can be seen that the total PCDD/F formation rate and furan/dioxin ratio in *de novo* synthesis experiments from different laboratories are in reasonable agreement considering the differences in testing material and analytical procedure. Other observations such as the dependence of dioxin formation on temperature and oxygen given in the various reports are in good agreement. Therefore, the *de novo* synthesis experiments can be regarded to have an acceptable reproducibility. Additional observations about the influencing factors in *de novo* synthesis of dioxins are summarized as follows:

(1) Gas phase material: O_2 is essential for *de novo* synthesis,[44] the total PCDD/F formation rate is about 0.5 order with respect to O_2 concentration;[46,48] the presence of HCl, SO_2, CO and H_2 have little influence,[38,39,47,48] H_2O may affect the homologue profile.[38,44]

(2) Solid phase material: Carbon of certain degenerated graphitic structure, chlorine and metallic catalyst are essential for *de novo* synthesis;[44] Cu^{2+} is a strong catalyst,[44] Fe^{3+} is another possible catalyst;[38] the total PCDD/F formation rate is about first order with respect to carbon concentration and 1.5 order to Cu^{2+},[44] but is independent of the solid surface area[40].

Table 5. *De Novo* Synthesis of PCDD/Fs

Author	Gas phase material	Solid phase material	Temperature[a] (°C)	Solid phase residence time (min)	Total PCDD/F formation rate[b] (µg/g·min)	Furan/dioxin ratio
Luijk et al. [45]	Air, H_2O and HCl	Active carbon and $CuCl_2$	300	60	0.017	0.03-5
Milligan and Altwicker [49]	O_2 (10%) and N_2	Fly ash	..	30	0.034	4.2
Stieglitz et al. [36]	Air	Fly ash	..	120	0.059	1.6
Dickson et al. [34]	^{13}C-P_5CP and air	Mixture of silica gel, charcoal and $CuCl_2$	..	10-60	0.107 (^{12}C-PCDDs)	n.a.
Addink et al. [47]	O_2 (10%), N_2 and HCl (4%)	Mixture of fly ash and carbon	373	60	0.128	5
Hagenmaier et al. [50]	Air	Fly ash	300	120	0.014	2
Stieglitz and Vogg [44]	Air and H_2O	Mixture of Mg-Al-silicate, charcoal, KCl and $CuCl_2$	..	..	0.054	3.3

[a] Temperatures at which maximum PCDD/F formations were observed. [b] Total PCDD/F formation rate based on weight of solid phase material (g) and solid phase residence time (min).

Table 6. Precursor Formation of PCDD/Fs

Author	Gas phase material	Solid phase material	Temperature[a] (°C)	Solid phase residence time (min)	Total PCDD/F formation rate[b] (μg/g·min)	Furan/dioxin ratio
Luijk et al. [45]	2,4,6-T_3CP, air and $H_2O^{c,e}$	Active carbon	300	30	50.1	0.0002
Altwicker and Milligan [51]	2,3,4,6-T_4CP, O_2 and $N_2^{d,e}$	Fly ash	325	2-15	1.6	0.01-0.001
Naikwadi et al. [52]	^{13}C-P_5CP and air[f]	..	300	60	0.09 (^{13}C-PCDDs)	n.a.
Gullett et al. [53]	Chlorophenol mixture, N_2 and O_2^{e}	CuO	400	30	0.83 (PCDDs)	..
Dickson et al. [34]	^{13}C-P_5CP and air[f]	Mixture of silica gel, charcoal and $CuCl_2$	300	10-60	2.89 (^{13}C-PCDDs)	..

[a,b] See table 5. [c] Precursor concentration: 4.1×10^6 μg/Nm^3. [d] Precursor concentration: 3.75×10^5 μg/Nm^3. [e] The gas was passed through chlorophenol solution reservoir. [f] Chlorophenol solution was placed on top of the solid phase material.

(3) Temperature: Maximum dioxin formation occurs at about 300°C, little dioxins can be observed below 250°C and above 400°C.[34-50]

(4) Reaction time: In most of the experiments gas phase residence time is not important, solid phase residence time is the relevant time scale; in the course of the reaction from 5 to 30 minutes of solid phase residence time, the PCDD/F formation rate remains constant shown in one experiment.[49]

(5) Product distribution: The typical combustion "fingerprint" of dioxins is produced, the molar ratio of organochlorocompound products is approximately PCDD : PCDF : PCBz : PCPh : PCNP : PCB = 1 : 1.6 : 75 : 6 : 0.6 : 0.3;[36,41] the phase distribution of PCDD/Fs is about 0.7%, 37% and 94% in the gas phase at 250, 300 and 350°C respectively.[48]

In the experiments of precursor formation pathway shown in Table 6 the total PCDD/F formation rates vary more significantly probably due to the different precursor concentrations adopted. Metallic catalyst such as Cu^{2+} is no longer essential for dioxin formation.[34,53] The furan/dioxin ratio is much smaller than 1. Other observations are similar to *de novo* synthesis experiments.

3. Analyzing the Experimental Evidence

3.1 *De Novo* Synthesis vs. Precursor Formation

Under laboratory conditions dioxin formation through precursor pathway is faster than *de novo* synthesis comparing Tables 5 and 6. However, the precursor concentration in these experiments is several orders of magnitude higher than those in actual incinerator postfurnace conditions (3.75×10^5 and 4.1×10^6 μg/Nm^3 in two laboratory experiments[51,45] comparing to incinerator boiler and stack measurements of about 10 μg/Nm^3 in the Environment Canada study[54,55]). The question arises which PCDD/F formation rate is actually inferred from the laboratory experiments for precursor formation pathway.

From a reaction stoichiometry assuming that two precursor molecules are coupled to form a dioxin structure, or $P + P \rightarrow D$, the reaction rate is expected to be second order with respect to the precursor concentration, or $r = k \cdot P^n$, ($n = 2$), where r is the reaction rate, k is the kinetic constant and n is the reaction order. But for heterogeneous reactions the kinetics do not necessarily follow the "law of mass action". A heterogeneous reaction model for dioxin formation from precursor pathway has been proposed by Shaub and Tsang and some calculation results based on this model with modified kinetic data have been presented by Kolluri and Altwicker:[56] For a reaction time of 3 seconds, when the precursor concentration is 0.327 μg/Nm^3, the dioxins formed amount to 4.5 ng/Nm^3; when the precursor concentration is increased to 3.27 μg/Nm^3, the dioxins formed are 200 ng/Nm^3. From these data we can estimate a reaction order of $n = \ln(r_1/r_2)/\ln(P_1/P_2) = \ln(200/4.5)/\ln(3.27/0.327) = 1.6$. Also, from the first two experiments listed in Table 6, assuming that the PCDD/F formation rate is primarily influenced by the precursor concentration in these experiments, the reaction order is $n = \ln(50.1/1.6)/\ln(4.1\times10^6/3.75\times10^5) = 1.4$. In an experiment of PCDD formation from T_4CPh for three different gas phase T_4CPh concentration of 150, 350 and 700 ng/ml,[51] a first-order dependence of PCDD formation on T_4CPh concentration can be seen from the data. Based on these theoretical and experimental evidence we estimate that it is at least first order for the PCDD/F formation rate with respect to the precursor concentration although we note that for a wide range of precursor concentration the reaction order may not be constant. Thus we calculate approximately that $r_{actual}/r_{experimental} = (P_{actual}/P_{experimental})^n = (10/3.75X10^5)^1 = 2.67X10^{-5}$. This implies that the experimental PCDD/F formation rates in Table 6 should be reduced by 5 orders of magnitude when compared with incinerator postfurnace conditions and the actual PCDD/F formation rate from precursor pathway would range from $9X10^{-7}$ to $5X10^{-4}$ µg/g-min.

Comparing *de novo* synthesis with precursor formation we draw the following points:

(1) The rate of dioxin formation in *de novo* synthesis ranges from 0.014 to 0.128 µg/g-min in Table 5 and in precursor formation is from $9X10^{-7}$ to $5X10^{-4}$ µg/g-min as discussed above. so *de novo* synthesis is likely to be several orders of magnitude faster than precursor formation in actual combustion systems.

(2) *De novo* synthesis can produce the correct combustion "fingerprint" of dioxins, i.e. furan/dioxin ratio > 1 and the typical homologue profile, which agree with actual incinerator findings. But in precursor formation little furans are produced and the furan/dioxin ratio is much smaller than 1.

(3) Not only the dioxin "fingerprint", but also the distribution of other organochlorocompounds from *de novo* synthesis resembles quite well the actual incinerator data which typically show a decreasing order of PCBz > PCPh > PCDF > PCDD > PCNP > PCB.[41]

(4) In most measurements PCBz and PCPh together with PCDD/F are found to increase when the flue gas passes the postcombustion region of incinerators, but the ratio PCDD / PCDF / PCBz / PCPh remains approximately constant, e.g. when measured at the inlet, middle passes and outlet of a waste heat boiler.[57] This indicates that PCDD, PCDF, PCBz and PCPh are formed in parallel reactions, not in serial reactions.

The above evidence suggests that *de novo* synthesis is the dominant mechanism of dioxin formation in actual combustion processes.

Certainly from basic chemistry the precursor formation pathway is much easier than *de novo* synthesis. However, in actual combustion systems dioxin formation from precursors is limited by the low precursor concentration (about 10 µg/Nm^3 in municipal waste incinerators), on the other hand, the starting material for *de novo* synthesis, i.e. O_2 (about 10% of the flue gas) and carbon in fly ash (the carbon concentration of fly ash is about 5%, and the ash loading of raw gas is about 1 g/Nm^3) is relatively abundant.

3.2 Laboratory Study vs. Incinerator Measurement

Another question arising when comparing laboratory study with incinerator measurement is whether the experimental PCDD/F formation rate from *de novo* synthesis is able to explain quantitatively the observed PCDD/F emission level of incinerators. We analyze this question by an order of magnitude estimation as follows: From Table 5 we choose Milligan and Altwicker's data because in this experiment true fly ash was used and the O_2 concentration was 10% which resembles incinerator postfurnace conditions, thus assume the total PCDD/F formation rate as 34 ng/g min and neglect the influence of other factors; from Table 4 we have the dioxin concentration of fly ashes (to estimate ng-total PCDD/Fs from ng-TE, multiply by 50, see [24]); then assuming 50% of the dioxins generated in *de novo* synthesis are present in solid phase we calculate the required reaction time to reach the measured dioxin level as shown below:

	Dioxin concentration, ng/g	Required reaction time, min
Boiler ash	10	0.6
ESP ash	200	11.8
Filter cake	300	17.6
Fly dust	1250	73.5

It appears that the experimental PCDD/F formation rate is sufficient to explain the dioxin level of collected particles in APCDs, but is not sufficient for uncollected particles or fly dust in stack emissions. This analysis agrees with the discussions by Altwicker et al.[1-3,49] We note that in the above analysis the possible adsorption of gaseous PCDD/Fs from the flue gas has been neglected and that all ashes tested in *de novo* synthesis experiments shown in Table 5 are in fact ESP ash, so the PCDD/F formation rate obtained may only be applicable to ESP ash.

3.3 The Relationship Between Carbon Morphology and Dioxin Formation

The influence of carbon morphology on dioxin formation was firstly recognized by Stieglitz et al.[42,44] In their *de novo* synthesis experiments when active charcoal, sugar coal (from pyrolysis of glucose) or soot (from a domestic oil burner) were tested, dioxins were formed, but when graphite was tested, little dioxins were found. They suggested that carbon of certain degenerated graphitic structure is the primary source for *de novo* synthesis of dioxins. Similar experimental work by Milligan and Altwicker also reveals a relationship between carbon morphology and dioxin formation.[49,58] From this evidence and the discussions in section 2.3 it seems that a condition for *de novo* synthesis of dioxins to occur is the presence of carbon of certain degenerated graphitic structure together with oxygen and minute quantities of chlorine and metal ion at 250-400°C (MSWI fly ash contains organic chlorine ca. 500 µg/g and copper 500-1500 µg/g.[36,54]) In most combustion processes oxygen and minute quantities of chlorine and metal ion are present, a crucial factor of dioxin formation is therefore likely to be the carbon morphology. To relate this laboratory finding to practical combustion systems the carbon morphology of the particulate emissions from different combustion sources thus appears to be important. Morphological descriptions of the numerous crystalline and amorphous forms of carbon have been given in some handbooks.[59,60] In what follows we examine in detail the carbon morphology of the particulate emissions from gas, liquid and solid combustion and the possible connections to dioxin formation.

In gas combustion the particulate emissions consist of soot particles formed in homogeneous combustion reactions[61-63] (see also the biennial Symp. Combust.) Soot formation can be observed in flames of almost all organic gases and vapours including methane, ethane, propane, ethylene, acetylene, benzene and alcohols. The yellowish luminosity of flames is due to soot formation as soot at combustion temperature radiates strongly in the yellow region of the electromagnetic spectrum. Soot formation in gas phase reactions is believed to proceed via three steps: nucleation, surface condensation and particle growth, and coagulation. Soot particles have diameters in the submicrometer range and are usually clustered together in chains and thus appear as a carbon filament in electron micrographs. The elemental composition of soot is 97-99% by weight carbon and 1-3% hydrogen, so sometimes soot is also termed as carbon particles or black carbon. The carbon in soot particles is basically crystalline with a graphitic structure in which the graphitic sheets are stacked turbostratically. Soot from all combustion sources has similar graphitic structures irrespective of the type of flame, the nature of the fuel being burned and other combustion conditions although the extent of sooting does vary considerably with these factors. Generally the sooting tendency of fuels is in the decreasing order of aromatics > alkynes > alkenes > alkanes, and a diffusion flame produces more soot than a premixed flame for the same fuel. The half-life for soot burnout is about $7X10^{-3}$ seconds, thus soot burnout is usually diffusion-controlled. The emissions of soot particles from a gas burning system depend on soot formation and burnout, but in most cases due to incomplete mixing and combustion, some soot particles will leave the combustion zone and deposit on the chimney as chimney black or discharge with the exhaust as black smoke.

Dioxins have been detected in exhausts from gas combustion in the presence of HCl including methane, propane and ethylene flames.[19] Because (1) dioxins are not thermodynamically stable at combustion temperature; (2) the homogeneous mechanism is unlikely to explain dioxin formation; and (3) in the postcombustion zone of a gas burning system the degenerated graphitic structure of soot particles combined with O_2, trace quantities of chlorine and metal ion will suffice to create a condition for *de novo* synthesis of dioxins, therefore it is very likely that dioxins are formed via a *de novo* synthesis mechanism occurring on the soot particles and that dioxin formation is related to the sooting tendency of the flame. This assumption is in agreement with the experimental observation by De Fre and Rymen that dioxin formation in a yellow, slightly sooting ethylene flame is much higher than in a blue, carbon-lean ethylene flame.[19]

In liquid fuel combustion the fuel undergoes combined vaporization/pyrolysis followed by gas phase combustion reactions, the particulate emissions consist of soot particles formed in the process and mineral matter or ash present in the fuel (and coke from liquid phase cracking for heavy oils).[64] The proportion of soot and ash particles depends on the fuel type and combustion conditions. For spray combustion in an internal combustion engine "soot is always produced and the flame zone always exhibits a yellow luminosity".[64] Soot from a domestic oil burner has been shown to be active in *de novo* synthesis experiments,[42,44] so that dioxin formation through a *de novo* synthesis mechanism occurring on soot particles in actual combustion system of liquid fuels can be expected to occur. This explains the findings that dioxins are emitted from gasoline fueled cars and a waste oil furnace.[17,18]

In solid fuel combustion the fuel undergoes pyrolysis at first and decomposes into volatiles and char, then the former are burned in gas phase and the later in solid phase, the particulate emissions consist of soot particles formed in gas phase reactions and ash with residual carbon formed in solid phase combustion. The proportion of soot and ash particles depends on the volatiles and ash content of the fuel and combustion conditions. The higher the volatile content, the higher is the sooting tendency.

Coal usually burns with low to non-sooting flames depending on the coal ranks.[65,66] Assuming that dioxin formation is related to the sooting tendency as discussed above we list the volatile content[67], the sooting tendency[65] and the available dioxin emission data from coal combustion[12,14] according to the type of coal as below (the type of coal tested in [14] is found in [68]):

Coal type	Volatiles, %	Sooting	Dioxins in ash, ng-TE/g
Bituminous	18-45	Yes	1-10 (3 samples)
Subbituminous	15-20	No	n.d. (1 sample)
Anthracite	8-15	No	0.04 (1 sample)

These very limited data do not reject the assumption. Probably, in a sooting flame the soot particles serve as a source for *de novo* synthesis of dioxins because of their degenerated graphitic structures, whereas in a non-sooting flame the particulate emissions are mainly mineral matter or ash particles originated from the fragmentation and entrainment of char as well as the vaporization and condensation of mineral matter,[69,70] the residual carbon in ash is in an activated state,[71] but most of the carbon is likely to be bonded to metal or oxygen or in aliphatic hydrocarbons and does not have the degenerated graphitic structure as a source for *de novo* synthesis of dioxins. This gives another possible explanation for the low dioxin emissions from coal combustion.

Wood combustion and plastics combustion have slightly to medium sooting flames.[66,72,73] PVC and PS fires are the most sooting flames.[72,73] Dioxin emissions from these combustion sources have been reported.[7-11,15,16]

In municipal waste combustion luminous yellowish sooting flames are dominant[74] mainly due to the high volatile content, the particulate emissions consist essentially of soot and ash particles[75]. Usually we refer to the particulate emissions as fly ash and there is no need to distinguish between soot and ash particles. But in fact soot and ash particles have different origins, morphologies and compositions. Soot is from gas phase combustion reactions and roughly spherical with a diameter ranging from 0.005 to 0.25 μm and has a very high carbon content.[61-63] Ash is from the high-temperature transformation of incombustible matter present in the fuel and has a particle size ranging from about 1 to 100 μm and a high mineral matter content.[69,70] An electron micrograph of MSWI fly ash shows that there are some "carbon fibers" with a high carbon content among other large ash particles.[35] These "carbon fibers" resemble well the electron microscopic view of soot particles strung together in chains as shown in another electron micrograph for soot particles from a gas flame[61], so these "carbon fibers" are probably soot particles. In actual combustion systems most of the soot particles are too small to be captured by APCDs and will be emitted with stack gas, in other words, most of the uncollected particles in stack emissions are soot particles. This accounts for the observation in section 3.2 that the fine particulates in stack emissions have a very high dioxin concentration noticing the assumption that *de novo* synthesis of dioxins occurs on soot particles.

In the above discussions beginning with an observation originated from *de novo* synthesis experiments that some degenerated graphitic structure is necessary for *de novo* synthesis of dioxins to occur, an examination of the morphology of the particulate emissions from actual combustion processes directs us to believe that the small soot particles from gas phase combustion have a very high graphitization degree and are thus a primary source for *de novo* synthesis of dioxins, whereas the large ash particles from solid phase combustion have a low graphitization degree and are thus not an important source for *de novo* synthesis of dioxins. With this assumption many experimental observations can be explained.

3.4 The Nature of *De Novo* Synthesis of Dioxins

The *de novo* synthesis of dioxins occurs essentially by a process of the oxidative degradation of the degenerated graphitic structures; the major oxidation products are CO and CO_2; the by-products are a variety of organic compounds including PCDD, PCDF, PCBz, PCPh, PCNP and PCB.[36,42,44]

Probably, for amorphous carbon the oxidation products are only CO and CO_2. For graphite, because the graphitic sheets are stacked orderly and strengthened by bonds of the van der Waals type between them,[59] at the low reaction temperatures considered the oxidative attack occurs only on the periphery sites of the graphitic sheets, but not on their surfaces.[67,76,77] This peripheral attack opens the hexagonal carbon rings of the graphitic sheets,[77] so that the oxidation products are also CO and CO_2. For carbon with degenerated graphitic structures including activated carbon, charcoal, carbon black and soot, because the graphitic sheets are stacked disorderly and disorientedly and surface imperfections such as vacancies and dislocations are present, not only the periphery but also the surface of the graphitic sheets can be attacked especially when metallic catalysts are present.[67,76,77] In the basal plane attack some of the hexagonal carbon rings of the graphitic sheets may not be opened and hence serve as a source for the formation of aromatic compound classes including PCDD/Fs. This explains why the carbon morphology is important for dioxin formation.

The similar dioxin "fingerprint" from all combustion sources may originate from the similar graphitic structure of soot particles from all combustion sources. Hydrogen atoms are present in soot particles and distributed between the graphite layers,[62] chlorine atoms may also be present and take the form as organic chlorines. The role of metallic catalysts in *de novo* synthesis is probably to facilitate the oxidative attack on the surface of the graphitic layers which causes a drastic increase of the carbon gasification rate at low temperatures[67] and lead to the transformation of graphitic structures into organic compounds.

4. A Scheme of Dioxin Formation in Combustion Processes

Following the above discussions it is possible to describe dioxin formation in combustion systems as a two-stage process: (1) carbon formation: carbon particles consisting of degenerated graphitic structures are formed in the combustion zone; (2) carbon oxidation: the unburnt carbon particles continue to be oxidized in the low-temperature postcombustion zone and PCDD/Fs are formed as by-products of the oxidative degradation of the graphitic structure of the carbon particles. Many steps and chemical reactions are involved in each of the two stages. For carbon formation there are at least three steps: nucleation, particle growth and agglomeration; for carbon oxidation four steps: oxidant adsorption, formation of complex intermediate with metal ion catalysts, interaction with graphitic carbon structure and products desorption. The chemical reactions involved are extremely complex and heterogeneous. The details need to be further elucidated in more experimental and theoretical studies.

5. Use of the Theory to Explain the Experimental Observations

Based on the above two sections new explanations of the observations in section 2 are given. We note that these explanations are preliminary.

For section 2.1: (1) Dioxin formation in the combustion of all organic fuels can be described using the above general scheme of dioxin formation. For example, in a forest fire carbon particles are present in the dense black smoke and will undergo low-temperature oxidation in the open air and hence may generate dioxins in the process. (2) The very high dioxin formation in municipal waste incineration is due to the highly sooting flame, high metal content and unsteady-state combustion of municipal wastes. In MSWI the feed is extremely heterogeneous and non-uniform, so unsteady-state operation occurs often. This may set free more unburnt carbon particles to the postcombustion zone and increase significantly the *de novo* synthesis of dioxins. The low dioxin formation in coal combustion is mainly due to its low to non-sooting flames. (3) Soot from all combustion processes has similar graphitic structure.[63] The oxidative degradation of the similar graphitic structure should give similar product distribution including the similar dioxin "fingerprint" from all combustion sources.

For section 2.2: (1) At combustion temperature dioxins are not thermodynamically stable and decomposition is favoured over formation. (2) Dioxin formation occurs on particulate matter and desorption is not favoured at low temperatures, so that most of the dioxins found are in particulate phase. (3) "The finer the particles, the higher are the dioxin concentrations" is due to that the finer particulate matter contains a higher proportion of soot particles and *de novo* synthesis of dioxins occurs on the small soot particles. (4) Flue gas O_2 level can affect both carbon burnout in the combustion zone and *de novo* synthesis in the postcombustion zone; at a low O_2 level more unburnt carbon particles are present so dioxin formation is increased; at a high O_2 level, however, the *de novo* synthesis of dioxins can also be increased because of the higher oxidant concentration in flue gas; depending on the structure and operating conditions of incinerators sometimes an optimum flue gas O_2 level with minimum dioxin formation can be reached when these competing effects are balanced. Gas phase chlorine is not involved in *de novo* synthesis of dioxins as shown in laboratory experiments,[38] on the other hand, the amount of chlorine in municipal waste is about six orders of magnitude in excess of the chlorine present in dioxins emitted from incinerators,[78] therefore the controlling factor in dioxin formation may not be the chlorine supply but rather the formation of the biaryl structure of dioxins. Chlorine is however a well-known flame inhibitor, its presence in municipal waste may increase carbon formation in flames and hence the dioxin formation to some extent. SO_2 addition reduces dioxin emissions in some cases. However, because gas phase chlorine is not involved in *de novo* synthesis, its action may not be by reducing gas phase Cl_2 through the Deacon reaction but by masking the catalytic dust surface due to sulphatization of SO_3 which is in equilibrium with SO_2.[79]

Most of the discussions in this paper are inferential. Experimental work to further clarify these points would include: comparison of dioxin formation in *de novo* synthesis experiments with and without gas phase precursors in the concentration range of 10-100 $\mu g/Nm^3$ at both a short and a long time scale, as well as with MSWI boiler ash, ESP ash and filter cake as solid phase material respectively; characterization of the morphology and chemical state of carbon in MSWI and coal fly ashes; laboratory study of dioxin formation in gas combustion with sooting and non-sooting flames; laboratory and field studies of dioxin emissions from coal combustion for different ranks of coal; field study of the effects of optimal waste charge to incinerators on dioxin emissions.

In actual combustion systems whether they are gas, liquid or solid combustion sooting flames can be recognized from the bright yellow coloration of the flame and the dark black coloration of the ash and smoke. Technical measures that can maintain stable operation of incinerators, reduce carbon formation in the combustion zone, enhance carbon burnout in the freeboard and inhibit low-temperature carbon oxidation in the postcombustion zone are expected to reduce dioxin emissions.

Literature Cited

1. Altwicker E.R. (1993), Dioxin/furans in incinerators: laboratory and modelling studies and technical issues remaining, 3rd Int. Conf. on Municipal Waste Combust., Mar.30 - Apr.2, 1993, Williamsburg, US.

2. Altwicker E.R. (1991), Some laboratory experimental designs for obtaining dynamic property data on dioxins, *Sci. Total. Environ.*, 104, 47-72

3. Altwicker E.R., J.S.Schonberg, R.K.N.V.Konduri, M.S.Milligan (1990), Polychlorinated dioxin/furan formation in incinerators, *Hazard. Waste. Hazard. Mater.*, 7, 73-87

4. Luijk R. (1993), Formation of polyhalogenated dibenzo-p-dioxins and dibenzofurans during thermal degradation processes, Ph.D. Dissertation, University of Amsterdam, May 1993, Appendix, On the *de novo* synthesis

5. Johnke B., E.Stelzner (1992), Results of the German dioxin measurement programme at MSW incinerators, *Waste. Manage. Res.*, 10, 345-55

6. Schoner P. (1992), Investigation on the reduction of the PCDD and PCDF emissions at hazardous waste incineration plant, *Chemosphere*, 25, 1421-7

7. Schatowitz B., G.Brandt, F.Gafner, E.Schlumpf, R.Buhler, P.Hasler, T.Nussbaumer (1993), Dioxin emissions from wood combustion, *Organohalogen Compd.*, 11, 301-10

8. Kolenda J., H.Gass, M.Wilken, J.Jager, B.Zeschmar-Lahl (1993), Determination and reduction of PCDD/F emissions from wood burning facilities, *ibid.*, 11, 401-4

9. Vikelsoe J., H.Madsen, K.Hansen (1993), Emission of dioxins from Danish wood-stoves, *ibid.*, 11, 405-8

10. Dumler-Gradl R., H.Thoma, O.Vierle (1993), PCDD/F concentrations in chimney soot and ash from wood combustions in house-heating systems, *ibid.*, 11, 397-400

11. Thoma H. (1988), PCDD/F concentrations in chimney soot from house-heating systems, *Chemosphere*, 17, 1369-79

12. Harrad S.J., A.R.Fernandes, C.S.Creaser (1991), Domestic coal combustion as a source of PCDDs and PCDFs in the British environment, *ibid.*, 23, 255-61

13. Junk G.A., J.J.Richard (1981), Dioxins not detected in effluents from coal/refuse combustion, *ibid.*, 10, 1237-41

14. Kimble B.J., M.L.Gross (1980), Tetrachlorodibenzo-p-dioxin quantitation in stack-collected coal fly ash, *Sci.*, 207, 59-61

15. Dudhuis A.B.J., P.J.J.Tromp, K.Olie, J.A.Moulijn (1990), Formation of PCDDs and PCDFs during low-temperature pyrolysis of PVC in an inert and oxidative atmosphere, *Organohalogen Compd.*, 3, 303-6

16. Christmann W., D.Kasiske, K.D.Kloppel, H.Partscht, W.Rotard (1988), Combustion of polyvinylchloride - an important source for the formation of PCDD/PCDF, *Chemosphere*, 19, 387-92

17. Taucher J.A., D.J.Hannah, N.J.L.Green, L.J.Porter, Z.Czochanska (1992), PCDD, PCDF and PCB emissions from a waste oil furnace, *ibid.*, 25, 1429-33

18. Marklund S., R.Andersson, M.Tysklind, C.Rappe, K.Egeback, E.Bjorkman, V.Grigoriadis (1990), Emissions of PCDDs and PCDFs in gasoline and diesel fueled cars, *ibid.*, 20, 553-61

19. De Fre K., T.Rymen (1989), PCDD and PCDF formation from hydrocarbon combustion in the presence of hydrogen chloride, *ibid.*, 19, 331-6

20. Bumb R.R., W.B.Crumment, S.S.Cutie, J.R.Gledhill, R.H.Hummel, R.O.Kagel, L.L.Lamparski, E.V.Luoma, D.L.Miller, T.J.Nestrick, L.A.Shadoff, R.H.Stehl, J.S.Woods (1980), Trace chemistries of fire: a source of chlorinated dioxins, *Sci.*, 210, 385-90

21. Crumment W.B., D.I.Townsend (1984), The trace chemistries of fire hypothesis: review and update, *Chemosphere*, 13, 777-88

22. Department of the Environment (1989), Dioxins in the Environment, Pollution Paper No. 27, June 1989, London

23. Fiedler H. (1993), Formation and sources of PCDD/PCDF, *Organohalogen Compd.*, 11, 221-8

24. Pitea D., M.Lasagni, L.Bonati, U.Cosentino (1993), Estimation of the toxicity equivalents of PCDD/PCDF mixtures from combustion sources when specific congener information is lacking: preliminary results, *Chemosphere*, 26, 1419-27

25. Rappe C. (1992), Sources of PCDDs and PCDFs: Introduction, reactions, levels, patterns, profiles and trends, *ibid.*, 25, 41-4

26. Hasselriis F. (1987), Optimization of combustion conditions to minimize dioxin emissions, *Waste Manage. Res.*, 5, 311-26

27. Huang H. (1994), A multivariate analysis of dioxin emissions from municipal solid waste incineration, Thesis, The University of Brussels, June 1994

28. Mark F.E. (1994), Energy recovery through co-combustion of mixed plastics waste and municipal solid waste, Association of Plastics Manufacturers in Europe, Report, June 1994, Brussels

29. Frankenhaeuer M., H.Manninen, I.Kojo, J.Ruuskanen, T.Vartiainen, R.Veaterinen, J.Virkki (1992), Organic emissions from co-combustion of mixed plastics with coal in a bubbling fluidized-bed boiler, *Chemosphere*, 27, 309-16

30. Lenoir D., A.Kaune, O.Hutzinger, G.Mutzenich, K.Horch (1991), Influence of operating parameters and fuel type on PCDD/F emission from a fluidized bed incinerator, *ibid.*, 23, 1491-500

31. Griffin R.D. (1986), A new theory of dioxin formation in municipal solid waste combustion, *ibid.*, 15, 1987-90

32. Gullett B.K., K.R.Bruce, L.O.Beach (1992), Effect of sulfur dioxide on the formation mechanism of polychlorinated dibenzodioxin and dibenzofuran in municipal waste combustion, *Environ. Sci. Technol.*, 26, 1938-43

33. Lindbauer R.L., F.Wurst, Th.Prey (1993), PCDD/F emission control by sulfur addition - new results with high-S lignite, SO_2 and SO_3, *Organohalogen Compd.*, 12, 35-8

34. Dickson L.C., D.Lenoir, O.Hutzinger (1992), Quantitative comparison of *de novo* and precursor formation of polychlorinated dibenzo-p-dioxins and furans under simulated municipal solid waste incinerator postcombustion conditions, *Environ. Sci. Technol.*, 26, 1822-8

35. Stieglitz L., M.Eichberger, H.Bautz, W.Roth, J.Romer, D.Schild (1994), Investigation of chloride transfer and oxidation as processes in the *de novo* synthesis of PCDD/PCDF on fly ash, *Organohalogen Compd.*, 20, 391-6

36. Stieglitz L., M.Eichberger, J.Schleihauf, G.Zwick, R.Will (1993), The oxidative degradation of carbon and its role in the *de novo* synthesis of organohalogen compounds in fly ash, *Chemosphere*, 27, 343-50

37. Schwarz G., L.Stieglitz (1992), Formation of organohalogen compounds in fly ash by metal-catalysed oxidation of residual-carbon, *ibid.*, 25, 277-82

38. Stieglitz L., H.Vogg, G.Zwick, J.Beck, H.Bautz (1991), On formation conditions of organohalogen compounds from particulate carbon of fly ash, *ibid.*, 23, 1255-64

39. Stieglitz L., H.Vogg, H.Bautz, J.Beck, G.Zwick (1990), The effects of sulfur dioxide on *de novo* synthesis of PCDD/PCDF on fly ash, *Organohalogen Compd.*, 3, 175-7

40. Stieglitz L., G.Zwick, J.Beck, H.Bautz, W.Roth (1990), The role of particulate carbon in the *de novo* synthesis of polychlorinated dibenzodioxins and furans in fly ash, *Chemosphere*, 20, 1953-8

41. Stieglitz L., G.Zwick, J.Beck, H.Bautz, W.Roth (1989), Carbonaceous particles in fly ash - a source for the *de novo* synthesis of organochlorocompounds, *ibid.*, 19, 283-90

42. Stieglitz L., G.Zwick, J.Beck, W.Roth, H.Vogg (1989), On the *de novo* synthesis of PCDD/PCDF on fly ash of municipal waste incineration, *ibid.*, 18, 1219-26

43. Stieglitz L., H.Vogg (1987), On formation conditions of PCDD/PCDF in fly ash from municipal waste incineration, *ibid.*, 16, 1917-22

44. Stieglitz L., H.Vogg (1987), New aspects of PCDD/PCDF formation in incineration processes, Int. Workshop on Municipal Waste Incineration, 1-2 Oct. 1987, Montreal

45. Luijk R., D.M.Akkermam, P.Slot, K.Olie, F.Kapteijn (1994), Mechanisms of formation of polychlorinated dibenzo-p-dioxins and dibenzofurans in the catalytic combustion of carbon, *Environ. Sci. Technol.*, 28, 312-21

46. Addink R., K.Olie (1993), The influence of oxygen concentration on PCDD/PCDF formation during *de novo* synthesis on fly ash, *Organohalogen Compd.*, 11, 355-8

47. Addink R., W.C.M.Bakker, K.Olie (1992), Influence of H_2O and HCl on the formation of polychlorinated dibenzo-p-dioxins/dibenzofurans in a carbon/fly ash mixture, Short Papers, Dioxin'92, Aug. 1992, Tampere, Finland

48. Altwicker E.R., Y.Xun, M.S.Milligan (1994), Dioxin formation over fly ash: oxygen dependence, temperature dependence and phase distribution, *Organohalogen Compd.*, 20, 381-4

49. Milligan M.S., E.Altwicker (1993), The relationship between *de novo* synthesis of polychlorinated dibenzo-p-dioxins and dibenzofurans and low-temperature carbon gasification in fly ash, *Environ. Sci. Technol.*, 27, 1595-601

50. Hagenmaier H., M.Kraft, H.Brunner, R.Haag (1987), Catalytic effects of fly ash from waste incineration facilities on the formation and decomposition of polychlorinated dibenzo-p-dioxins and dibenzofurans, *ibid.*, 21, 1080-4

51. Altwicker E., M.S.Milligan (1993), Dioxin formation from tetrachlorophenol over fly ash under breakthrough conditions, *Organohalogen Compd.*, 11, 269-72

52. Naikwadi K.P., I.D.Albrecht, F.W.Karasek (1993), Mechanism of formation of PCDD/PCDF in industrial waste incineration and a method for prevention of their formation, *Chemosphere*, 27, 335-42

53. Gullett B.K., K.R.Bruce, L.O.Beach, A.M.Dragon (1992), Mechanistic steps in the production of PCDD and PCDF during waste combustion, *ibid.*, 25, 1387-92

54. Environment Canada (1988), National Incinerator Testing and Evaluation Programme: Environmental Characterization of Mass Burning Incinerator Technology at Quebec City, Report EPS 3/UP/5, June 1988

55. Environment Canada (1985), National Incinerator Testing and Evaluation Programme: Two-stage Combustion, Report EPS 3/UP/1, Sept. 1985

56. Kolluri R., E. Altwicker (1992), A model to analyze formation of dioxins in the high temperature regions of municipal solid waste incinerators, *J. Air Waste Manage. Assoc.*, 42, 1577-82

57. Yoshida H., R.Ishikawa, Y.Mizoguchi (1994), The behaviour of dioxins in fluidized bed incineration facilities, *Organohalogen Compd.*, 20, 407-12

58. Milligan M.S., E.R.Altwicker (1991), Low temperature carbon gasification from MSW fly ash - implications to *de novo* synthesis of PCDD/F, Short Papers, Dioxin'91, Sept. 1991, NC, US., Cited in [49]

59. Long J.C., R.W.Soffel, E.L.Piper, H.F.Folk, R.M.Bushong, R.H.Wentorf,Jr. (1980), Carbon, in Encyclopedia of Chemical Technology, Wiley, New York, Vol.4, p.556-697

60. Vohler O., H.Von Kienle, M.Voll, P.Kleinschmit (1986), Carbon, in Ullmann's Encyclopedia of Industrial Chemistry, VCH, Weinhein, 1986, Vol.A5, p.95-160

61. Gaydon A.G., H.G.Wolfhard (1979), Flames, Chapman & Hall, London, Ch.8 Solid Carbon in Flames

62. Barnard J.A., J.N.Bradley (1985), Flame and Combustion, Chapman & Hall, London, 7.3 Carbon Formation

63. Glassman I. (1977), Combustion, Academic Press, New York, 8.D Particulate Formation

64. Williams A. (1976), Combustion of Sprays of Liquid Fuels, Elek Sci., London, p.101-7

65. Morrison C.F. (1986), Understanding Pulverized Coal Combustion, IEA Coal Res., London, p.19

66. Howard J.B. (1990), Carbon addition and oxidation reactions in heterogeneous combustion and soot formation, 23rd Symp. Combust., The Combust. Inst., Pittsburg, p.1107-27

67. Elliott M.A. (1981), The Chemistry of Coal Utilization, 2rd Suppl.Ed. Wiley, New York, p.22,1175-6 and 1260-4

68. Ondov J.M., R.C.Ragaini, A.H.Biermann (1979), Elemental emissions from a coal-fired power plant, *Environ. Sci. Technol.*, 13, 598-607

69. Couch G. (1994), Understanding Slagging and Fouling in Pulverized Coal Combustion, IEA Coal Res., London, Ch.3 Ash Formation

70. Wall T.F. (1992), Mineral matter transformation and ash deposition in pulverized coal combustion, 24th Symp. Combust., The Combust. Inst., Pittsburg, p.1119-26

71. Smith I.M. (1990), Management of Atmospheric Fluidized Bed Combustion Residues, IEA Coal Res., London, Ch.3 Chemical and Physical Characteristics

72. Cullis C.F., M.M.Hirschler (1981), The Combustion of Organic Polymers, Clarendon Press, Oxford, p.211

73. Wheatley L., Y.A.Levendis, P.Vouros (1993), Exploratory study on the combustion and PAH emissions of selected waste plastics, *Environ. Sci. Technol.*, 27, 2885-95

74. Boscak V. (1993), Transformation of carbon in refuse incineration, *Waste. Manage. Res.*, 11, 493-505

75. Pavoni J.L., J.E.Heer,Jr., D.S.Hagerty (1975), Handbook of Solid Waste Disposal, Von Nostrad, London, p.110

76. Thomas J.M., W.J.Thomas (1967), Introduction to Heterogeneous Catalysis, Academic Press, London, p.441-4

77. Anderson J.R. (1975), Structure of Metallic Catalysts, Academic Press, London, p.81-7

78. Buekens A., H.Huang (1994), Literature Survey Regarding the Formation Mechanisms and Models of Dioxins, Report CHIS-2-VUB, Nov. 1994, Brussels

79. Lindbauer R.L., F.Wurst, Th.Prey (1994), PCDD/F emission control for MSWI by SO_3 addition, *Organohalogen Compd.*, 19, 355-9

24. Kulkarni, P.S., *et al*., July 2008. *Dioxins sources and current remediation technologies*--*A review*. Environment International, Vol. 34, Issue 1, Pages 139-153. (Kulkarni *et al*. 2008)

Available online at www.sciencedirect.com

ScienceDirect

Environment International 34 (2008) 139–153

ENVIRONMENT INTERNATIONAL

www.elsevier.com/locate/envint

Review article

Dioxins sources and current remediation technologies — A review

Prashant S. Kulkarni [a,b,*], João G. Crespo [b], Carlos A.M. Afonso [a]

[a] *CQFM, Departamento de Engenharia Química e Biológica, Instituto Superior Técnico, 1049-001 Lisboa, Portugal*
[b] *REQUIMTE, Departamento de Química, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal*

Received 12 April 2007; accepted 20 July 2007

Abstract

Dioxins are highly toxic and ubiquitous compounds that are unintentional by-products of several chemical processes on earth. According to the earth pollutant terminology, they are next to the nuclear catastrophes. It is because of their concerns over adverse health effects, a number of countries have introduced stringent emission standards. The present review focuses on entire sources of dioxins present in the environment. They are broadly classified into four major categories such as, incineration, combustion, industrial and reservoir sources. State-of-the-art remediation technologies available for reducing dioxins formation and emission from the important sources such as, flue gas, fly ash and soil were described in detail. Further, in order to get a comprehensive perception about the dioxins subject, topics such as, dioxins transfer in the environment, their mode of action, toxicity equivalence factor, exposure and health risk assessment were highlighted in brief in the introduction. A future prospects based on the findings of the review was discussed at the end.

Keywords: Dioxins; Toxicity; Health hazard; Sources; Fly ash; Flue gas; Soil; Remediation technologies

---

Contents

---

[*] Corresponding author. CQFM, Departamento de Engenharia Química e Biológica, Instituto Superior Técnico, 1049-001 Lisboa, Portugal. Tel.: +351 218419756; fax: +351 218464455.
E-mail address: ps_kulkarni@rediffmail.com (P.S. Kulkarni).

doi:10.1016/j.envint.2007.07.009

1. Introduction

Dioxins are a class of structurally and chemically related polyhalogenated aromatic hydrocarbons that mainly includes polychlorinated dibenzo-*p*-dioxins (PCDDs or dioxins), dibenzofurans (PCDFs or furans) and the 'dioxin-like' biphenyls (PCBs). They constitute a group of persistent environmental chemicals and usually occur as a mixture of congeners. Their presence in the incinerator fly ash samples was firstly reported by Dutch and Swiss scientists in the year 1977 and 1978, respectively (Buser et al., 1978; Olie et al., 1977). However, dioxins had come to public attention in the year 1982 when an explosion at ICMESA factory in Seveso, Italy, deposited these chemicals over an area of 2.8 km^2 (Wilson, 1982).

Only 7 of the 75 possible PCDD congeners, and 10 of the 135 possible PCDF congeners, those with chlorine substitution in the 2,3,7,8 positions, have dioxin-like toxicity. Likewise, there are 209 possible PCB congeners, only 12 of which have dioxin-like toxicity (USEPA, 1994a,b). These dioxin-like PCB congeners have four or more chlorine atoms and are sometimes referred to as coplanar PCBs, since their rings can rotate into the same plane. Physical and chemical properties of each congener vary according to the degree and position of chlorine substitution. Fig. 1 and Table S-1 depict the basic structural formula of PCDDs, PCDFs, and PCBs together with the numbering convention at the positions on benzene rings where chlorine or other halogen atoms can be substituted.

1.1. Mode of transfer to the environment

The largest release of these chemicals today is open burning of household waste, municipal waste, medical waste, landfill fires, and agricultural and forest fires (Dyke et al., 1997). Dioxin and furan compounds exhibit little potential for significant leaching or volatilization once sorbed to particulate matter. The available evidence indicates that PCDDs and PCDFs, particularly the tetra- and higher chlorinated congeners, are extremely stable compounds under most environmental conditions. The only environmentally significant transformation process for these congeners is believed to be photodegradation of non-sorbed species in the gaseous phase, at the soil–air or water–air interface (Tysklind et al., 1993).

PCDDs/PCDFs entering the atmosphere are removed either by photodegradation or by deposition. Burial in-place, resuspension back into the air, or erosion of soil to water bodies appears to be the predominant fate of PCDDs/PCDFs sorbed to soil. The ultimate environmental sink of PCDDs/PCDFs is believed to be aquatic sediments. Levels of PCDDs/PCDFs in fish and invertebrates have been found to be higher than those in the water column, suggesting bioaccumulation (Atkinson, 1991). Conversely, a little information exists on the environmental transport and fate of the 12 coplanar PCBs (Sakai et al., 2001).

1.2. Mode of action

The general population exposure to dioxins chemicals occurs as an exposure to a mixture of different congeners (Masuda et al., 1998). Clearly, however, many of the effects are mediated through an interaction with the aryl hydrocarbon receptor (AhR). Dioxins induces a broad spectrum of biological responses, including induction of gene expression for cytochrome P450, CYP1A1, and CYP1A2, disruption of normal hormone signaling pathways, reproductive and developmental defects. Briefly, it indicates that the inappropriate modulation of gene expression represents the initial steps in a series of biochemical, cellular and tissue changes that result in the toxicity observed (Mandal, 2005). The variation in toxicity amount the dioxins and furans and the effect at the AhR is 10,000 fold, with TCDD being the most potent. Fig. 2, depicts a schematic model of the action of dioxin in cell.

1.3. Toxicity equivalency factor (TEF)

The toxicity of dioxins are expressed as toxic equivalent quantities (TEQs) where the most toxic congener TCDD is rated as 1.0 and the less toxic congeners as fractions of this. The toxicity of dioxins is mediated through the aryl hydrocarbon receptor; a toxic equivalency factor (TEF) is used, assuming that the effects are additive and act via a common mechanism to cause toxicity (Boening, 1998; Kerkvliet, 2002). The TEF system was initiated for dioxins and furans in 1998 by NATO/CCMS scheme, adopted internationally and termed International-TEFs (I-TEFs). Many of the other PCDDs and PCDFs and certain PCBs are less potent than TCDD but vary considerably in their respective concentrations. Each congener can be assigned a potency value relative to TCDD [TEF]. When a TEF is multiplied by the congener concentration level, a toxic equivalency (TEQ) value is obtained. In the early 1990s, WHO added TEFs for PCBs. The coplanar-polychlorinated biphenyls have less potency, but their concentrations are often much higher than concentrations of TCDD (Kang et al., 1997; Patterson et al., 1994), so their relative contribution to the total TEQ is potentially sizable. The 7 dioxin congeners, 10 furan congeners (all chlorinated in at least the 2,3,7,8 position) and the 12 PCBs which exhibit 'dioxin-like activity' were rated with

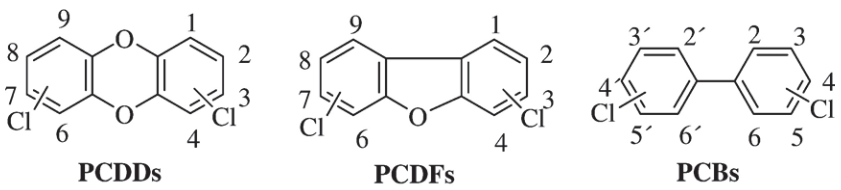


Fig. 1. Chemical structures of a) PCDD b) PCDF, and c) PCBs.

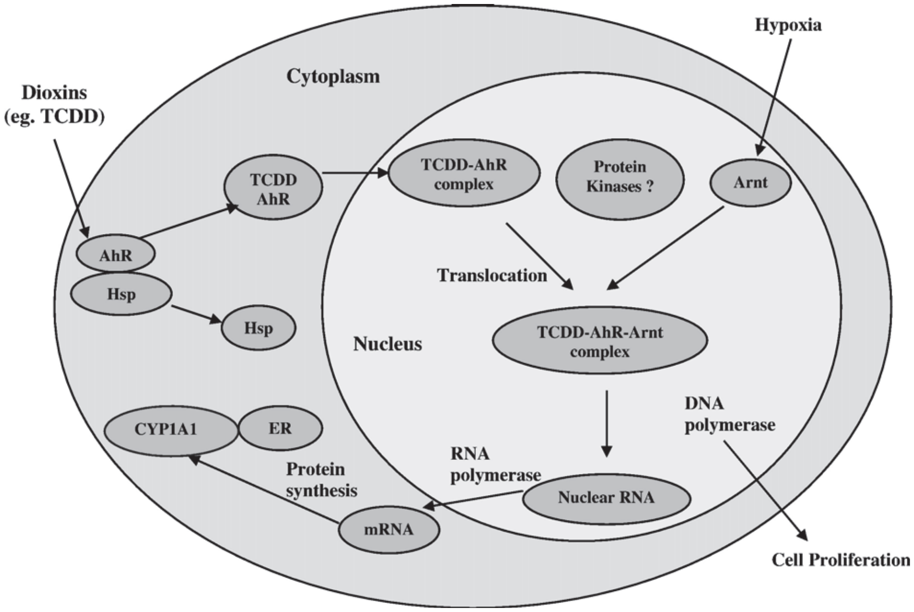


Fig. 2. A schematic model of the action of dioxins in cell (adapted from Mandal, 2005).

TEFs (Giesy and Kannan, 1998) (seeTable S-2). Thus, the toxic contribution of the PCDDs and PCDFs and certain PCBs can then be compared. In 1998 and 2005 the WHO expert meeting derived consensus TEFs for both human and wildlife risk assessment (Van den Berg et al., 1998, 2006).

1.4. Exposure and health risk assessment

People are exposed primarily through foods that are contaminated with PCDDs and PCDFs as a result of the accumulation of these substances in the food chain and in high-fat foods, such as, dairy products, eggs, animal fats, and some fish. Further, the exposure also includes industrial accidents (Baccarelli et al., 2002) and several miscellaneous exposures (Yoshimura, 2003). The approximate estimation of human exposure pathways is shown in Fig. 3.

Several adverse health effects have been associated with dioxins, including soft tissue, sarcomas, lymphomas, skin lesions (chloracne), stomach cancer, biochemical liver-test abnormalities, elevated blood lipids, fatal injury, immune system and neurological effects (Mitrou et al., 2001). Moreover, carcinogenic, genetic, reproductive, and developmental effects have been observed in many animal studies although species differ dramatically in sensitivity to these chemicals (Cole et al., 2003; Huff et al., 1994). TCDD has the LD_{50} (lethal dose) of 0.04 mg/kg for rats. However, other dioxin isomers have LD_{50} values up to 100 mg/kg for rats (Kao et al., 2001).

A number of countries and organizations have studied various approaches to the health risk assessment of dioxins with regard to dioxin as carcinogenic promoters and have defined tolerable daily intake (TDI) based on No Observed Adverse Effect Level (NOEAL) derived from animal studies (EuropeanCommission, 1994; Steenland and Deddens, 2003). In assessing the risk of 2,3,7,8-TCDD the USEPA came up with a virtual safe dose of 6 fg/kg body weight per day. The two most recent health risk assessments, carried out by the Health Council of the Netherlands in 1996 and WHO in 1998, are based on developmental effects initiated during gestation and/or lactation. The international risk assessments of dioxins are summarized inTable S-3. These doses are based on the carcinogenicity of 2,3,7,8-TCDD and provides protection from toxic effects as well. The reactions of the various member states of the European Union to these risk evaluations have put an emission limit of 0.1 ng/m^3 I-TEQ primarily waste incineration plants and tolerable daily intake of 1–4 pg I-TEQ/day/kg body.

Apart from the toxicity of dioxins and its presence in the environment, many scientists have shown the compound to be highly resistant to biodegradation. This resistance may be due to its very low water solubility and high octanol–water partition coefficients (Orazio et al., 1992). Thus, public health risk from environmental exposure to dioxins from contaminated sites can be significant. As a result, a clean-up of environmental dioxins contamination is an area requiring more attention.

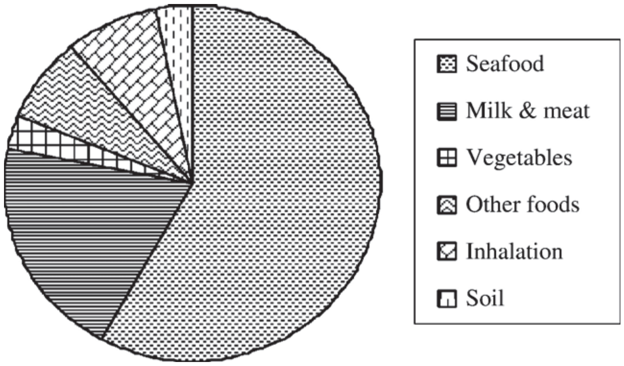


Fig. 3. Exposure of human beings to dioxins (adapted from Kishimoto et al., 2001).

2. Dioxins sources

Earlier human tissue samples show very low levels of dioxins than found today (Ligon et al., 1989). Studies of the sediments near industrial areas of the United States have shown that dioxins were very low until about 1920 (Alcock and Jones, 1996; Czuczwa et al., 1984). These studies show increases in dioxins concentrations from 1920s and continuing until about 1970. Some decline in concentrations has been observed this time. These findings can be explained by the corresponding trends of chlorophenol production (Czuczwa and Hites, 1984).

Therefore, it appears that the presence of dioxin-like compounds in environment occurs principally as a result of anthropogenic sources. These compounds are released to the environment in a variety of ways and in varying quantities depending upon the source. This ubiquitous nature of dioxins compounds suggests that multiple sources exist and that long range transport can occur. The major identified sources of environmental release have been grouped into four major categories as shown in Fig. 4.

2.1. Incineration sources

It is the largest source of dioxins release in the environment. Dioxins can be generated and released to the environment from following incineration processes.

2.1.1. Municipal solid waste incinerators

Dioxins are predominantly produced by municipal solid waste incineration processes. Several researchers have described their mechanism of formation. Overall, it is observed that the emission of dioxins and furans into the environment can be explained mainly by two principal surface catalytic processes: i) formation from precursors and ii) formation by de novo synthesis (Altwicker, 1996). An informative review on the formation and mechanism of dioxins from municipal solid waste incineration was presented (Tuppurainen et al., 1998). It was observed that several past studies demonstrated the presence of significant quantities of dioxins and dioxin precursors in municipal solid waste around 50 ng I-TEQ/kg (Abad et al., 2002).

2.1.2. Hospital waste incinerators

Hospital waste include human organs, bandages, blood tubes, test tubes, needles, syringes, tissue cell culture, and other plastic materials. Incineration has been the most widely used treatment of hospital waste in every country. However, these incinerators do not rely on advanced technologies, are high in number, burn high chlorine content waste and hence are important source of dioxin emissions (Stanmore and Clunies-Ross, 2000).

2.1.3. Hazardous waste incinerator

The harmful products of chemical processes produced from industries are called hazardous waste. Depending on the waste type, hazardous waste can be explosive, oxidizing, highly flammable, corrosive, infectious, mutagenic, irritant, toxic, or carcinogenic. A practice of separate incineration for hazardous waste has also started several years ago. Hazardous organic compounds such as chlorinated phenols can be incinerated under this method (Karademir et al., 2003).

2.1.4. Sewage sludge incinerator

Wastewater treatment generates a solid residue with high organic and toxic metal contents called sewage sludge. The

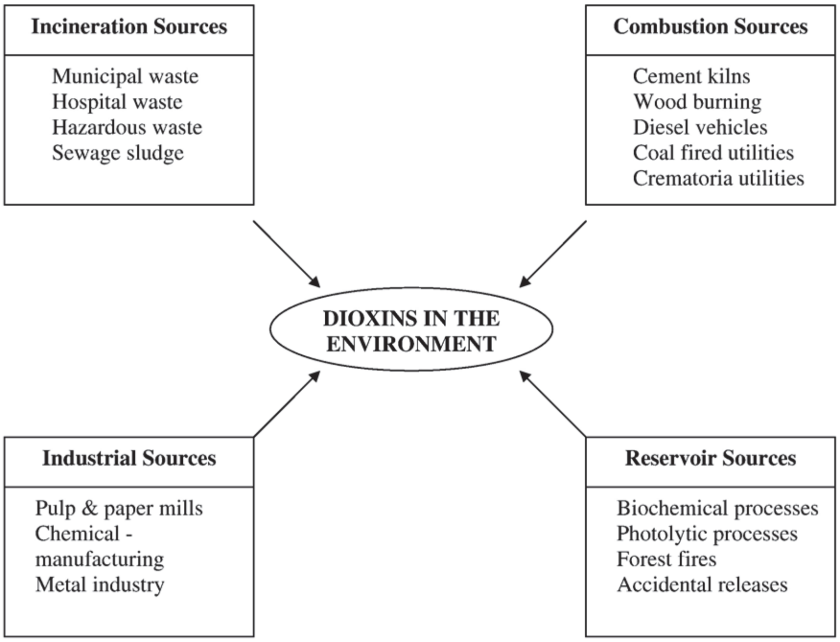


Fig. 4. Dioxins release in the environment.

limitations facing land filling and recycling and the planned ban on sea disposal has led to the use of incineration processes for the disposal of sewage sludge. A few studies were reported on the sewage sludge incineration (Fullana et al., 2004).

2.2. Combustion sources

2.2.1. Cement kilns

The switch to burning hazardous waste as fuels for cement kilns has created problem for individuals and organizations. About 16% of the facilities burn hazardous waste as an auxiliary fuel; limited data suggests that PCDD/PCDF levels in clinker dust and stack emissions of these kilns may be significantly higher than the kilns which do not burn hazardous waste (Abad et al., 2004; Eduljee, 1999).

2.2.2. Wood burning

A number of studies have found dioxins in the emissions and ash/soot from wood fires in non industrial situations (Stanmore, 2004). According to the European Emission Inventory, wood combustion is at present one of the most important air emission sources for dioxins (Quass et al., 2000). In an appealing review paper it is reported that the dioxins emission from wood burning is about 945 g I-TEQ/year (Lavric et al., 2004).

2.2.3. Diesel vehicles

A very scant literature available on emission of dioxin from diesel vehicles. Researchers from Sweden and Norway have studied dioxin emission from diesel vehicles (Marklund et al., 1990; Oehme et al., 1991). As these studies depend on the fuel used in a particular country more studies are required in order to reach a conclusive estimation.

2.2.4. Crematoria

Crematoria procedures can be a ready source of organic material and chlorine, and hence are possible source of dioxins emission (Alcock et al., 1999). Inventory estimates rate this source as 0.3% of European output (Landesrumweltanmt, 1997) and 0.24% of US output (USEPA, 1998).

2.2.5. Coal-fired utilities

Although emission of dioxins compared to the wood burning is very less, they are numerous, large in size and their high stacks indicate that they could impact very large areas (Chen, 2004; Harrad et al., 1991). Considering the large scale usage the importance of these facilities is very much unknown.

2.3. Industrial sources

2.3.1. Pulp and paper mills

The manufacture of bleached pulp and paper has in the past resulted in dioxin releases to water, land and paper products. These compounds can be formed through the chlorination of naturally occurring phenolic compounds such as those present in wood pulp (Rappe et al., 1987). It is reported that the waste generated from a pulp mill of China produces dioxins concentration of 300 pg/l I-TEQ (Zheng et al., 2001).

2.3.2. Metals industry

The metallurgical processes such as high temperature steel production, smelting operations, and scrap metal recovery furnaces are found to be typical sources of dioxins (Anderson and Fisher, 2002). Processes in the primary metals industry, such as sintering of iron ore, have also been identified as potential sources (Cieplik et al., 2003; Wang et al., 2003). In several countries the annual release of dioxins is estimated to be 500–4000 g I-TEQ (Anderson and Fisher, 2002).

2.3.3. Chemical manufacturing

PCDDs and PCDFs can be formed as by-products from the manufacture of chlorinated compounds such as chlorinated phenols, PCBs, phenoxy herbicides, chlorinated benzenes, chlorinated aliphatic compounds, chlorinated catalysts and halogenated diphenyl ethers (Oberg et al., 1992, 1993; Sidhu and Edwards, 2002). Although the manufacture of many chlorinated phenolic intermediates and products, as well as PCBs, was terminated in the late 1970s in the United States, production continued around the world until 1990, and continued, limited use and disposal of these compounds can result in release of dioxins into the environment.

2.4. Reservoir sources

The persistent and hydrophobic nature of these compounds causes them to accumulate in soils, sediments, landfill sites, vegetation and organic matter. They have potential for redistribution and circulation of dioxins in the environment. The dioxin compounds in the “reservoirs” can be redistributed and circulated in the environment by dust or sediment resuspension and transport (Kjeller and Rappe, 1995; Rotard et al., 1994).

The major reservoir sources include:

2.4.1. Biological processes

The action of microorganisms on chlorinated phenolic compounds results in the formation of dioxins under certain environmental conditions (Siewers and Schacht, 1994).

2.4.2. Photochemical processes

Dioxins like OCDD (1,2,3,4,5,6, 7,8,9-octachlorodibenzodioxin), HPCD (1,2,3,4,5,6,7,8-heptachlorodibenzodioxin) formation occurs by photolytic radical reactions of pentachlorophenol (Baker and Hites, 2000; Tysklind et al., 1993).

2.4.3. Accidental sources

The incidents of dioxins release at Seveso, Italy and Yusho Japan can be considered as an accidental release of dioxins into atmosphere. Further, forest fires and volcanoes also come under this category (Clement and Tashiro, 1991; Ruokojarvi et al., 2000).

2.4.4. Miscellaneous sources

Miscellaneous sources includes formation of dioxins in FBC (Fluidized Bed Combustion) boilers, thermal oxygen cutting of scrap metal at demolition sites, power generation, PVC in house fires, Kraft liquor boilers, laboratory waste, drum and barrel reclaimers, tire combustors, carbon reactivation furnaces and scrap electric wire recovery facilities, etc. (Anthony et al., 2001; Carroll, 1996; Menzel et al., 1998).

3. Techniques of dioxin remediation, reduction and prevention

It was observed that dioxins enter into the environment mainly from the flue gas originated from incineration and combustion processes, formation of fly ash (originated from incineration and combustion processes) and dioxins contaminated soil occurred due to industrial and reservoir sources. Therefore, it was decided to highlight a comprehensive state-of-the-art study on the remediation, reduction and prevention of these components which are threatening the environment.

3.1. Treatment of flue gases

Incineration and combustion processes releases large amount of flue gases which are one of the bulk sources of dioxin emissions in the environment. The formation of dioxins in the flue gases of the incinerator system occurs by precursors and de novo synthesis at temperature of 300–500 °C. A schematic diagram of a typical incinerator system is shown in Fig. 5. The composition of dioxins in the flue gases varies from 1–500 ng I-TEQ/m^3. Therefore, it is important to treat the flue gas to reduce its concentration to an acceptable limit (0.1 ng I-TEQ/Nm^3) before entering into the environment.

Following methods were adopted for the reduction in emission of dioxins.

3.1.1. Particulate matter collection

It is possible to eliminate particle bound dioxins with a dust collector. At temperatures below 200 °C the collection of particle bound dioxins overcomes the de novo synthesis. The removal of particle-bound dioxins from the waste gas coming from an iron ore sintering plant with a cloth filter yielded a reduction of the dioxins up to 73% (Ergebnisse, 1996). Dioxin removal efficiencies of the electrostatic precipitator IZAYDAS Incinerator (Turkey) were examined in a trial burn. It was showed that removal efficiencies of greater than 90% for all congeners and homologues of dioxins (Karademir et al., 2003).

A fabric filters and electrostatic precipitators (ESP) have more efficiency in the removal of particle bound dioxins and are currently used as dust collectors during the incineration processes. Electrostatic precipitator having strong electrical field is generally used for the collection of particulate matter or dust. A product consisting of particulate matter or dust and hydrated lime, settles to the bottom of the reactor vessel. It was observed that with the use of the combined system, dioxins removal rates of 90–92% can be achieved (Kim et al., 2000). However, there are technical difficulties of removing the dust from the waste gas of incinerators at high temperatures. Some heavy metal salts because of their relatively high vapor pressure could not be removed from the waste gas in sufficient amounts.

3.1.2. Scrubbers or spray absorber and electrostatic precipitators

Scrubbers followed by electrostatic precipitators have been in use for many years in waste incinerator for reduction of dioxin emissions. The absorbent (lime slurry) is atomized in the spray tower. The gas is first absorbed by the liquid phase and then by the solid phase. The lime slurry mixes with the combustion gases within the reactor. The neutralizing capacity of the lime reduces the percentage of acid gas constituents (e.g. HCl and SO_2 gas) in the reactor. It was also observed that the addition of coke made from bituminous coal in a quantity of up to 500 mg/m^3 a much higher dioxin collection efficiency of approx. 90% can be achieved (Maier-Schwinning and Herden, 1996).

3.1.3. Sorbent or flow injection process

The flow injection process is generally based on the injection of finely grained coke stemming from anthracite or bituminous coal mixed with limestone, lime or inert material into the waste gas flow with a temperature of approx. 120 °C. So the material is suspended in the flow homogeneously and subsequently settles in a layer on the surface of the cloth filter. The inert material which is added in an amount of more than 80% serves to take up the heat that is developed by the exothermic reactions involved in the adsorption process. It also helps to prevent ignition of the coke (Cudahy and Helsel, 2000).

The use of naturally and synthetically occurring zeolites is also found to be a good alternative (Abad et al., 2003). Flow injection processes are being used in Europe and USA in a number of waste incineration plants for the collection of dioxins, HCl, HF and SO_2. Due to the necessary high amounts of inert material, the residual matters left from the process are

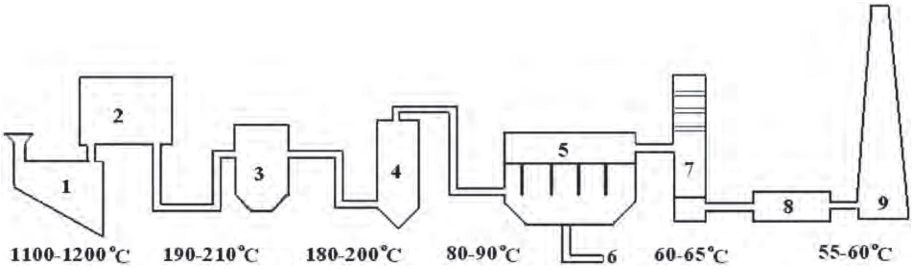


Fig. 5. A schematic diagram of the incinerator system: 1) bunker waste, 2) boiler, 3) electrostatic precipitator, 4) spray absorber or dry sorbent injection, 5) bag filter or fabric filter, 6) fly ash for treatment, 7) wet scrubber, 8) AC (Activated Carbon) unit, and 9) Chimney.

considerable. With this process dioxins removal efficiency of 99% can be achieved.

3.1.4. Fluidized-bed process with adsorbent recycling

From the process engineering point of view the fluidized-bed process lies between the flow injection process and the fixed-bed as well as moving-bed adsorbent process. The advantage of the fluidized-bed process lies in the high residence times of the adsorbent and in better utilization of sorbent because of the more favorable mass transfer conditions and longer solids retention times in the system.

In this process, the flue gas passes through the grate from the bottom and forms a fluid bed of coke stemming from bituminous coal and inert material with a temperature of about 100 to 120 °C. A limestone or lime can be used as inert material and the amount of coke can be higher than in the flow injection process. The adsorbent is separated from the flue gas in a dust collector and re-circulated to the fluidized bed. Usually the adsorbent can be recycled many times, so that, it is possible to collect other acid components such as HCl, HF and SO_2. The advantages of the fluidized-bed process, lies in the high residence times of the adsorbent and in better utilization of sorbent because of the more favorable mass and heat transfer conditions and longer solids retention time in the system (Liljelind et al., 2001; Shiomitsu et al., 2002).

3.1.5. Fixed-bed or moving-bed processes

This process uses the same adsorbent as that of the fluidized-bed process. But, the coke moves slowly from top to bottom while the waste gas flows in opposite direction. The activated coke takes up contaminants during its entire residence time in the reactor, which may be several 1000 operating hours. The time period during which an effective exchange of matter takes place is in fixed-bed or moving-bed processes about 10 times longer than in flow injection or fluidized-bed processes (Fell and Tuczek, 1998). The difference between fixed-bed and moving-bed process is in the former the bed of activated coke of cross-flow adsorbers is not moved during the time adsorption takes place and the spent coke is withdrawn and replaced by new coke. In moving-bed reactors the coke bed travels continuously. A very high dioxins separation efficiency of more than 99% can be achieved with the moving-bed process (Karademir et al., 2004).

Fixed bed process used for the waste gas cleaning has some problems like blocking due to moisture absorption and corrosion. Therefore in current flue gas cleaning plants, the fixed-bed process has been largely replaced by the turbulent-contact method applied in the moving-bed process with continuously exchanged adsorbent.

3.1.6. Catalytic decomposition of dioxins

A method of selective catalytic reduction for the NO*x* gases can be also applied for the dioxins remediation. The present evidence shows that the catalysts used in selective reduction of the NO*x* in the flue gas suppressed the formation of dioxins by 85% (Goemans et al., 2004). It proves that a single, effectively designed catalyst can be used in the removal of the oxides of nitrogen and dioxins (Liljelind et al., 2001). The catalysts are mostly composed of the oxides of Ti, V and W. Additionally, oxides of Pt and Au supported on silica-boria-alumina are found to be effective for the destruction of dioxins at 200 °C (Everaert and Baeyens, 2004).

To avoid blockage of the catalyst with coarse fly ash particles and ammonium sulfate the catalyst for the destruction of dioxins is usually applied after the cleaning stages. The advantage of selective catalytic reduction (SCR) over the other methods is the elimination of complicated disposal problems of residual matter. On the contrary, the catalyst lacks the capacity of removing as wide spectrum of contaminants as activated coke (Andersson et al., 1998).

3.1.7. Electron irradiation processes

It is a new process for destruction of dioxins compounds in the flue gas. The method has following features: i) no possibility of secondary pollution because of the direct decomposition of dioxins which is different from the recovery method using a filter, ii) no need for temperature control, and iii) very simple process resulting in easy installation to existent incinerators.

Recently, Hirota and Kojima studied the decomposition behavior of dioxin and furan isomers under electron-beam irradiation in incinerator gases at a temperature of 473 K. They noticed a significant decomposition for all PCDD isomers, which resulted from oxidation reactions with OH radicals yielded by electron-beam irradiation (Hirota and Kojima, 2005). With this process dioxins can be reduced up to 99%. It involves gas-phase degradation of dioxin molecules by OH radicals formed under the action of ionizing radiation on gas macro components (Gerasimov, 2001). The benefits of this process are decomposition products are only organic acids and low energy consumption.

All the aforementioned processes with their dioxins reducing measures are presented inTable S-4.

3.2. Treatment of fly ash

The incineration processes of hospital, hazardous, sewage sludge and municipal solid waste produces thick solid residues or cake called fly ash. It contains dioxins and heavy metals. These pollutants are extremely harmful to soil, marine and fresh water ecosystems, especially when they bioaccumulate through earthy and aquatic food webs. The dioxins concentration in fly ash varies from 100–5000 ng/kg. In many countries, the environmental protection legislation classifies municipal solid waste incineration fly ash as hazardous material and further treatment is required before they are released in to the atmosphere or disposed of in landfills.

Following methods were practiced for the destruction of dioxins in fly ash; however, many of them are limited only to the laboratory stage.

3.2.1. Thermal treatment

Thermal treatment is a process by which heat is applied to the waste in order to sanitize it. The primary function of thermal treatment is to convert the waste to a stable and usable end product and reduce the amount that requires final disposal in landfills (Cheung et al., 2007; Lundin and Marklund, 2007). It is observed that dioxins present in fly ash can be decomposed by thermal treatment under suitable conditions. The work of Vogg and Stieglitz revealed that in an inert atmosphere, thermal treatment of dioxins at 300 °C for 2 h resulted in 90% decomposition of dioxins (Vogg and Stieglitz, 1986). Further in an oxidative atmosphere, thermal treatment at 600 °C for 2 h resulted in 95% decomposition of dioxins, but at lower temperatures dioxins are formed.

It is reported in a review that more than 95% destruction of dioxins can be obtained using thermal treatment equipments such as electrical, oven, coke-bed melting furnace, rotary kiln with electric heater, sintering in LPG burning furnace, plasma melting furnace, etc (Buekens and Huang, 1998).

3.2.2. Non-thermal plasma

The application of non-thermal plasma technology on toxic substance process has been widely studied (Nifuku et al., 1997; Obata and Fujihira, 1998). This process has several advantages over the conventional control devices. It performs effectively and economically at very low concentrations under ambient temperature condition and low maintenance. It doesn't require auxiliary fuel and eliminates disposal problems and sensitivity to poisoning by sulfur or halogen containing compounds. Researchers are paying attention on this new technology for application to environmental protection.

Zhou et al. (2003) applied non-thermal nanosecond plasma to destroy dioxins contained fly ash. They found that a positive pulse discharge provides a higher destruction effect on the compounds contained than does a negative one. They reported that different isomer compounds show different toxic removal effects and the higher the toxicity of the compounds is, the higher is the destruction efficiency. Among all of the congener contained in the fly ash, the isomer 2 3,7,8-TCDD which has the highest toxicity shows the highest destruction efficiency up to 81%.

3.2.3. UV irradiation (photolytic)

A photocatatlytic degradation of dioxins using semiconductors films such as TiO_2, ZnO, CdS, and Fe_2O_3 under UV or solar light is a highly promising method, as it operates at ambient temperature and pressure with low energy photons. This process use light to generate conduction band (CB) electrons and valence band (VB) holes (e^- and h^+) which are able to initiate redox chemical reactions on semiconductors. TiO_2 has been predominantly used as a semiconductor photocatalyst. The VB holes of TiO_2 are powerful oxidants that initiate the degradation reactions of a wide variety of organic compounds (Kim et al., 2006). It was reported that a complete degradation of 2-chlorordibenzo-*p*-dioxin and 2,7-dichlorodibenzo-*p*-dioxin was observed after 2 and 90 h, respectively, in UV illuminated aqueous suspension with no significant intermediates detection. The products obtained after the completion of process were CO_2 and HCl (Pelizzetti et al., 1988).

Choi et al. in their work of photocatalytic degradation of highly chlorinated dioxin compounds found that degradation rates of dioxins decreased with the number of chlorine and increases with the intensity of light and the TiO_2 coating weight (Choi et al., 2000). The photolysis products from 2,3,7,8-TCDD do not bind to either the Ah receptor or the estrogen receptor in vitro (Konstantinov et al., 2000).

3.2.4. Chemical reaction

A chemical reagent method involves use of a reagent and medium for the decomposition of polychlorinated aromatic compounds. In the past years, research was mainly focused on the removal and destruction of dioxins and incineration was favored over the other methods. Nevertheless, the interest in the recovery of reusable materials (e.g., PCBs are present mostly in transformer oils) and the necessity to treat contaminated products with low concentration of PCBs have renewed the interest in the dechlorination methods. The dehalogenation methods mostly involve use of low-valent metal such as alkali metal in alcohol, Mg and Zn/acidic or basic solution (Krishnamurthy and Brown, 1980).

Mitoma et al. have studied detoxification of highly toxic polychlorinated aromatic compounds using metallic calcium in ethanol (Mitoma et al., 2004). They found that metallic calcium can be kept stable under atmospheric conditions for a long period as compared to metallic sodium since the surface is coated with $CaCO_3$, which is formed in contact with air. Moreover, ethanol, which is one of the safe solvents for humans, acts not only as a solvent but also as an accelerator due to its ability to remove the carbonated coating. This decomposition method for dioxins is therefore one of the most environment friendly and economic detoxification methods with respect to the energy and safety of the reagents. Concentration for each isomer of PCDDs, PCDFs and PCBs was reduced in 98–100% conversions by treatment in ethanol at room temperature. The TEQ for the total residues of isomers was reduced from 22000 to 210 pg-TEQ at room temperature.

3.2.5. Hydrothermal treatment

As a large amount of fly ashes are generated annually, there is a continuing interest in establishing ways in which they may be used. It is well known that fly ashes demonstrate satisfactory performance when intermixed with Portland cements. However, fly ashes contain toxic dioxins compounds. Therefore, identification of further means to facilitate the use of fly ashes and avoid the need to dispose then as hazardous wastes is rather desirable. Fly ashes reacted with suitable additives have been reported to produce new types of cementitious materials (Derojas et al., 1993; Jing et al., 2007).

A hydrothermal treatment is a physico-chemical process based on the T/RH/t relation (temperature, relative humidity, time). Fly ashes were put into water or a solution and subject to hydrothermal treatment at high pressure and temperature. An effective solution for dioxins decomposition was found to be NaOH containing methanol; fly ashes containing 1100 ng/g total dioxins subjected to hydrothermal treatment using this solution at 300 °C for 20 min were found to have only 0.45 ng/g total dioxins. It was suggested that the process is superior to purely thermal treatment at the same temperature and the regenerated fly ashes can be used in the cement industries (Ma and Brown, 1997).

3.2.6. Supercritical water oxidation (SCWO)

A waste treatment process using supercritical water, which exists as a phase above the critical temperature (647.3 K) and critical pressure (22.12 MPa) has proved to be a novel way for an effective dioxin remediation. Sako et al. applied the process for the decomposition of dioxins in fly ashes with oxidizer such as air, pure oxygen gas and hydrogen peroxide (Sako et al., 1997). They performed a reaction under the conditions of temperature 673 K, pressure 30 MPa and time 30 min. They observed the importance of behavior of a strong oxidizer and found that the decomposition yield of dioxins is 99.7% with the use of supercritical water and hydrogen peroxide. They have also successfully examined the process for dechlorination of PCBs from transformer oil (Sako et al., 1999).

Recently, the same group studied a hybrid process for the destruction of dioxins in fly ashes (Sako et al., 2004). They performed extraction of dioxins from fly ashes using supercritical fluid (CO_2) and concentration by adsorption, and destruction by SCWO. In the extraction–adsorption process, dioxins contained in fly ashes can be transferred and concentrated to the adsorbent (activated carbon). Then, the adsorbent containing dioxins is completely destructed by SCWO.

The dioxins destruction efficiencies from fly ash and current remediation technologies are presented in Table S-5.

3.3. Remediation of soil and sediment

Environmental problems created by forest fires, oil tanker accidents and oil spillage from cars and trucks, leaky containers, industrial accidents and poorly disposed of wastes are much more common cause for concern. The reservoir processes outlined in Section 2.4 mainly contributes to the contamination of soil. Numerous tons of soil and sediment in the world were contaminated with dioxins that need an appropriate remediation method. The most common soil contaminants are petroleum-based, ex. diesel fuel, gasoline polyaromatic hydrocarbons (PAH), etc. Many PAHs are known carcinogens and others are suspected problem chemicals which tend to spread through soil by diffusion and convection.

Soil remediations involve two distinct classes: *in-situ*, or on-site, and *ex-situ*, or off-site. On-site cleanups are often preferred because they are cheaper. On the other hand, *ex-situ* remediation has the added bonus of taking the bulk of contaminants off-site before they can spread further. In addition, *in-situ* situations are limited because only the topside of the soil is accessible. These environmental limitations force *in-situ* remediation to fall into three categories: washing, venting and bioremediation. Off-site facilities have the luxury of more complete control over the cleaning chemical processes.

Following on- and off-site methods can be used for the remediation of soil.

3.3.1. Radiolytic degradation

Ionizing radiation in the form of high-energy electron beams and gamma rays is a potential non-thermal destruction technique. Theoretical and some empirical assessments suggest that these high-energy sources may be well suited to transforming dioxin to innocuous products. Gamma radiolysis has been shown to be effective in the degradation of PCDD and PCBs in organic solvents and in the disinfection of wastewaters (Farooq et al., 1993; Nickelsen et al., 1992; Zhao et al., 2007).

Using a cobalt-60 gamma ray source, Hllarides et al. extensively studied dioxin destruction on artificially contaminated soil (Gray and Hilarides, 1995; Hilarides et al., 1994). A standard soil (EPASSM-91) was artificially contaminated with 2,3,7,8-TCDD to 100 ppb, and in the presence of 25% water and 2% surfactant (RA-40) and at a high irradiation dose (800 kGy), greater than 92% TCDD destruction was achieved, resulting in a final TCDD concentration of less than 7 ppb. The results of these experiments demonstrate that radiolytic destruction of TCDD bound to soil using gamma radiation can be achieved. The role of surfactant was very useful and was thought to mobilize TCDD molecule to a more favorable location in the soil, thereby modifying target size and density to make the direct effects of radiolysis more effective. The study of by-products and theoretical target theory calculations indicate that TCDD destruction proceeds through reductive dechlorination.

Recently, Mucka et al. found that addition of promoters to the toxicants increases the percentage of destruction under electron beam radiation. They observed a positive influence of active carbon and Cu_2O oxide on dechlorination of PCBs in alkaline 2-propanol solution using radiolytic degradation method (Mucka et al., 2000).

3.3.2. Base catalyzed dechlorination

The base-catalyzed decomposition (BCD) process is a chemical dehalogenation process (Chen et al., 1997). It involves the addition of an alkali or alkaline earth metal carbonate, bicarbonate or hydroxide to the contaminated medium. BCD is initiated in a medium temperature thermal desorber (MTTD) at temperatures ranging from 315–426 °C. Alkali is added to the contaminated medium in proportions ranging from 1 to about 20% by weight. A hydrogen donor compound is added to the mixture to provide hydrogen ions for reaction, if these ions are not already present in the contaminated material. The BCD process then chemically detoxifies the chlorinated organic contaminants by removing chlorine from the contaminants and replacing it with hydrogen.

Pittman Jr. and Jinabo He, have studied dechlorination of chlorinated hydrocarbons and pesticides. They used Na/NH_3 to de-halogenate polychlorinated compounds from the soils and sludges. Several soils, purposely contaminated with 1,1,1-trichloroethane, 1-chlorooctane and tetrachloroethylene, were remediated by slurring the soils in NH_3 followed by addition of sodium. The consumption of sodium per mole of chlorine removed was examined as a function of both the hazardous substrate's concentration in the soil and the amount of water present. The Na consumption per Cl removed increases as the amount of water increases and as the substrate concentration in soil decreases. PCB and dioxin-contaminated oils were remediated with Na/NH_3 as were PCB-contaminated soils and sludges from contaminated sites. Ca/NH_3 treatments also successfully remediated PCB-contaminated clay, sandy and organic soils but laboratory studies demonstrated that Ca was less efficient than Na when substantial amounts of water were present (Pittman and He, 2002).

3.3.3. Subcritical water treatment

Water which is held in liquid state above 100 °C by applying a pressure is called subcritical water. It has properties similar to the organic solvents and can act as a benign medium. It has been used to extract PCBs and other organic pollutants from soil and sediment (Weber et al., 2002). Hashimoto and co-workers examined the process of subcritical water extraction for removing dioxins from contaminated soil (Hashimoto et al., 2004). They observed 99.4% extraction of dioxins at a temperature of 350 °C within 30 min; however, it took a much longer time at lower temperatures. In one of the experiment, by the addition of OCDDs to the soil they found that dechlorination is a major reaction pathway.

A use of zero-valent (ZVI) iron in reductive dechlorination of PCDDs and remediation of contaminated soils with subcritical water as reaction medium and extractive solvent was studied by Kluyev and co-workers (Kluyev et al., 2002). They observed by using iron powder as a matrix higher chlorinated congeners were practically completely reduced to less than tetra-substituted homologues. Zero-valent iron has become accepted as one of the most effective means of environmental remediation. It is inexpensive, easy to handle and effective in treating a wide range of chlorinated compounds or heavy metals. It has been widely applied *in-situ, ex-situ* or as part of a controlled treatment process in wastewater, drinking water soil amendment stabilization and mine tailing applications.

3.3.4. Thermal desorption

Thermal desorption is a separation process frequently used to remediate many Superfund sites (Depercin, 1995). It is an *ex-situ* remediation technology that uses heat to physically separate petroleum hydrocarbons from excavated soils. Thermal desorbers are designed to heat soils to temperatures sufficient to cause constituents to volatilize and desorb (physically separate) from the soil.

Although they are not designed to decompose organic constituents, thermal desorbers can, depending upon the specific organics present and the temperature of the desorber system, cause some of the constituents to completely or partially decompose. The vaporized hydrocarbons are generally treated in a secondary treatment unit (e.g., an afterburner, catalytic oxidation chamber, condenser, or carbon adsorption unit) prior to discharge to the atmosphere. Afterburners and oxidizers destroy the organic constituents. Condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal. Kasai et al. (2000) and Harjanto et al. (2002), have proposed a thermal remediation process based on a zone combustion method for the remediation of soils contaminated by dioxins. The process uses stable combustion of coke particles in the packed bed to soils. They removed 98.9% of dioxins from the soil in a laboratory scale experiment. They also observed increase in the removal efficiency with the pre-treatment of soil such as drying, pre-granulation and addition of limestone.

3.3.5. In-situ photolysis

In this method dioxins can undergo photolysis by sunlight under proper conditions. It is cost effective and less destructive to the site. An organic solvent mixture is added to the contaminated soil and time is then allowed for dioxin solubilization, transport and photodegradation. For this purpose, the surface of the soil is sprayed with the low-toxicity organic solvent and allowed to photodegrade under the sunlight. Several researchers have used this approach, finding that dioxins on the soil surface rapidly decomposed after being sprayed with various organics such as isooctane, hexane, cyclohexane, etc. (Balmer et al., 2000; Goncalves et al., 2006). Dougherty et al. (1993), found that solar-induced photolytic reactions can be a principal mechanism for the transformation of these chemicals to less toxic degradation products. Convective upward movement of the dioxins as the volatile solvents evaporated was the major transport mechanism in these studies. The effectiveness of this process depends on a balance between two rate controlling factors: convective transport to the surface and sunlight availability for photodegradation.

The *in-situ* vitrification is another developing process for on-site soil decontamination which means to make glass out of something. It involves the use of electricity to melt the waste and surrounding soil in place, then cooling it to form glass. The pollutants that cannot be destroyed by the heat are encapsulated within the glass, so they cannot leach into the surrounding soil or groundwater.

3.3.6. Solvent and liquefied gas extraction

Solvent extraction is a physico-chemical means of separating organic contaminants from soil and sediment, thereby concentrating and reducing the volume of contaminants that needs to be destroyed. This is an *ex-situ* process and requires the contaminated site soil to be excavated and mixed with the solvent. Eventually, it produces relatively clean soil and sediment that can be returned to the site (Silva et al., 2005).

Liquefied gas solvent extraction (LG-SX) technology uses liquefied gas solvents to extract organics from soil. Gases, when liquefied under pressure, have unique physical properties that enhance their use as solvents. The low viscosities, densities, and surface tensions of these gases result in significantly higher rates of extraction compared to conventional liquid solvents. Due to their high volatility, gases are also easily recovered from the suspended solids matrix, minimizing solvent losses. Liquefied carbon dioxide and propane solvent is typically used to treat soils and sediments (Saldana et al., 2005).

Contaminated solids, slurries, or wastewaters are fed into the extraction system along with solvent. Typically, more than 99% of the organics are extracted from the feed. After the solvent and organics are separated from the treated feed, the solvent and organic mixture passes to the solvent recovery system. Once in the solvent recovery system, the solvent is vaporized and recycled as fresh solvent. The organics are drawn off and either reused or disposed of. Treated feed is discharged from the extraction system as slurry. The slurry is filtered and dewatered. The reclaimed water is recycled to the extraction system and the filter cake is sent to disposal or reused.

The U.S. Environmental Protection Agency's (EPA) evaluated a pilot scale solvent extraction process that uses liquefied propane to extract organic contaminants from soil and sediments. Approximately 1000 pounds of soil, with an average polychlorinated biphenyl (PCB) concentration of 260 mg/kg, was obtained from a remote Superfund site. Results showed that PCB removal efficiencies varied between 91.4 and 99.4%, with the propane-extracted soils retaining low concentrations of PCBs (19.0–1.8 mg/kg). Overall extraction efficiency was found to be dependant upon the number of extraction cycles used (Meckes et al., 1997).

3.3.7. Steam distillation

A distillation in which vaporization of the volatile constituents of a liquid mixture takes place at a lower temperature (than the boiling points of the either of the pure liquids) by the introduction of steam directly into the charge; steam used in this manner is known as open steam. It is an ideal way to separate volatile compounds from nonvolatile contaminants in high yield. Steam distillation is effective with microwave energy to treat contaminated soil and sediments. Microwaves are electromagnetic radiation with a wavelength ranging from 1 mm to 1 m in free space with a frequency between 300 GHz to 300 MHz, respectively. In the microwave process, heat is internally generated within the material, rather than originating from external sources. The heating is very fast as the material is heated by energy conversion rather than by energy transfer, as, in contrast, occurs in conventional techniques. Microwave radiation penetrates the sample and heats water throughout the matrix. The developing steam caused volatile and semi-volatile organic pollutants to be removed from the soil without decomposition. The temperature necessary for microwave induced steam distillation was less than 100 °C. Microwave treatments can be adjusted to individual waste streams: depending on the soil, the contaminants and their concentrations, remediation treatment can be conducted in several steps until the desired clean-up level is reached. All contaminants could be removed to non-detectable or trace levels (Windgasse and Dauerman, 1992).

Steam distillation was found to be effective for the removal of 2,7-dichlorodibenzo-*p*-dioxin (DCDD) from DCDD-applied soil. The DCDD concentration (250 μg/50 g soil) in the original soil decreased to less than 5% after steam distillation for only 20 min. The results suggest that steam distillation could be a new remedial method for soils contaminated with dioxins (Mino and Moriyama, 2001).

3.3.8. Mechanochemical (MC)

In this technology the mechanical energy is transferred from the milling bodies to the solid system through shear stresses or compression, depending on the device used. A significant part of the milling energy is converted into heat and a minor part is used to induce breaks, stretches and compression at micro and macroscopic level or for performing a reaction. MC degradation can be easily performed using *ball mills* that are readily available in different sizes (treatment of materials up to several tons is possible) and constructions. The pollutants are eliminated directly inside a contaminated material, regardless of complex structure and strong nature of the pollutant. This method has a high potential to dispose of organic wastes at any desired locations with flexible operation due to its use of a portable facility composed of a mill and a washing tank with a filter. Although this method needs a dechlorinating reagent such as CaO in the grinding operation, it does not require any heating operation. To support use of the MC dechlorination method, it would be useful to have a correlation between the dechlorination rate of organic waste and the grinding (MC) conditions to determine the optimum condition in a scaled-up MC reactor (Mio et al., 2002; Napola et al., 2006).

In a laboratory experiment, it was shown that polyhalogenated pollutants such as polychlorinated biphenyls (PCBs) or pentachlorophenol (PCP) to their parent hydrocarbons in high yields, i.e., biphenyl and phenol, respectively by applying magnesium, aluminum or sodium metal plus a low acidic hydrogen source (Birke et al., 2004). For instance, PCBs in contaminated soils, filter dusts, transformer oils, or as pure substances are dechlorinated to harmless chloride and their parent hydrocarbon biphenyl (over 90%). The method offers several economic and ecological benefits: ball milling requires a low energy input only. Because of the strikingly benign reaction conditions, toxic compounds can be converted to defined and usable products. No harmful emissions to the environment have to be expected. This opened up the development of novel, innovative *ex-situ* dioxins remediation and decontamination processes.

3.3.9. Biodegradation process

Bioremediation is a treatment process which uses microorganisms such as fungi and bacteria to degrade hazardous substances into nontoxic substances (Ballerstedt et al., 1997; Mori and Kondo, 2002). The microorganisms break down the organic contaminants into harmless products- mainly carbon dioxide and water. Once the contaminants are degraded, the microbial population is reduced because they have used their entire food source. The extent of biodegradation is highly dependent on the toxicity and initial concentrations of the contaminants, their biodegradability, the properties of the contaminated soil and the type of microorganism selected. There are mainly two types of microorganisms: indigenous and exogenous. The former are those microorganisms that are found already living at a given site. To stimulate the growth of these indigenous microorganisms, the proper soil temperature, oxygen, and nutrient content may need to be provided. If the biological activity needed to degrade a particular contaminant is not present in the soil at the site, microorganisms from other locations, whose effectiveness has been tested, can be added to the contaminated soil. These are called exogenous microorganisms.

Bioremediation can take place under aerobic and anaerobic conditions. With sufficient oxygen, microorganisms will convert many organic contaminants to carbon dioxide and water. Anaerobic conditions support biological activity in which no oxygen is present so the microorganisms break down chemical compounds in the soil to release the energy they need. A key difference between aerobic (oxidative) and anaerobic breakdown is the former predominantly used for lower chlorinated congeners and the later for high chlorinated congeners (hydrodechlorination).

Sometimes, during aerobic and anaerobic processes of breaking down the original contaminants, intermediate products that are less, equally, or more toxic than the original contaminants are created. Kao and Wu (2000) have invented an *ex-situ* method in which a chemical pre-treatment (partial oxidation) in combination with bioremediation was developed to efficiently remediate TCDD-contaminated soils. In a slurry reactor, they used Fenton's Reagent as an oxidizing agent to transform TCDD to compounds more amenable for biodegradation. They observed up to 99% TCDD was transformed after the chemical pre-treatment process. The slurry reactor was then converted to a bioreactor for the biodegradation experiment. They concluded that the two-stage partial oxidation followed by biodegradation system has the potential to be developed to remediate TCDD-contaminated soils on-site.

On this topic, an appealing review titled "Degradation of dioxin like compounds by microorganisms" was presented (Wittich, 1998).

Table S-6 depicts the technologies used for soil decontamination along with their efficiency.

4. Future prospects and conclusions

Dioxins compounds are environmentally and biologically stable and, as a result, human exposure is chronic and wide spread. An exposure to such type of chemicals can damage the immune system, leading to increased susceptibility and it can disrupt the functions of several hormones. Major routes of dioxins entering into the atmosphere are incineration and combustion sources and therefore, more attention is required for the enhanced understanding of the precursor and de novo mechanisms of dioxins formation. The interaction between chlorine and precursors must be well understood. Further, it is important to identify the conditions under which chlorine, carbon and oxygen can become limiting reactants in the incineration and combustion chamber. The relationship between the rate of carbon consumption and the rate of production of dioxins should be clarified.

Over the past several years, there has been a shift in the major sources of dioxins, in large part due to the stringent regulations and focused voluntary efforts. Production of pesticides used to be associated with relatively high levels of contamination with dioxins. Many of these products have been banned. Bleaching of paper and pulp products using free chlorine in Kraft mills led to the production of dioxins. But the use of alternative processes reduced dioxin formation. Therefore, the chemical industries are taking proper measures to avoid the generation of dioxins. Although incineration process of municipal solid waste once used to be the major source, its contribution to the current emission inventories is now decreasing. However, medical waste incineration is still a major source of dioxins. Polyvinyl chloride (PVC) plastic, as the dominant source of organically bound chlorine in the medical waste stream, is the main cause of dioxin formation by the incineration of medical wastes. Therefore, health professionals have a responsibility to work to reduce dioxin exposure from medical sources. Health care institutions should implement policies to reduce the use of PVC plastics as much as possible, thus achieving major reductions in medically related dioxin formation.

Emissions of these toxic contaminants are believed to have reduced in some industrial countries and there are suggestive data indicating that background levels in human blood and milk in Germany, the Netherlands, and United States have declined, recently. The other important sources of dioxin family compounds today involve combustion processes and reservoir sources. Uncontrolled burning and collection of small sources are the significant sources of new dioxins emissions today. Attempts should be made in order to tap these sources.

The atmospheric transport of dioxins from the source to the site is a complex process and different sources introduce intricate mixtures of dioxins into the environment; no single congener can be used to attribute the occurrence of dioxins in a sample to specific source. Therefore, improved knowledge of the transport mechanisms is required. In this view, there is a strong need for the development of fast and accurate analytical tools. The development of continuous emission monitor (CEM) technology could be an answer for this.

In order to avoid the formation of dioxins in the flue gas it is important to manipulate properly the process parameters such as temperature, residence time and turbulence of the combustion chamber and the post combustion flue gas treatment facilities, etc. A number of technologies are available for removing or destroying dioxins from gases. Waste incineration plants commonly use bag house filters (fabric filters) equipped with activated carbon injection, or fixed bed carbon filters in order to fulfill the emission limits for dioxin. SCR-catalysts (selective catalytic reduction) for NOx reduction combined with an oxidation catalyst are also known to be an effective method to destroy dioxins. Among other recent developments are the installation of systems of catalytic destruction of dioxins and use of better filter materials. The company *Caldo Environmental Engineering* commercializes ceramic filters that can be used at high temperatures and that allow a continuous removal of particles from air or other gases (Calado(UK)). These materials are very resistant in extreme conditions of temperature (>450 °C) and/or of chemical corrosion. In the year 2000, W. L. Gore and Associates proposed a system of destruction of dioxins through the use of catalytic filters REMEDIA D/F. These filters consist of membranes of expanded (PTFE), containing the catalytic system (Gore(USA)). In this process, the membrane captures the fine particles in the surface of the filter, the dioxins and furans pass through the membrane and react instantaneously with the catalyst giving as products CO_2, H_2O and HCL.

The treatment of fly ash and soil for the destruction of dioxins is a broader area of investigation. The currently practiced *ex-situ* thermal treatment methods are energy demanding and hence, alternative techniques are required to save the consumption of energy. The use of photolytic techniques for *in-situ* destruction of dioxins seems to be very economical but their effectiveness largely depends on the sunlight availability for photodegradation. The application of supercritical water for the remediation of dioxins presenting in the fly ash and soil finds to be a promising one, however, more studies are required in order to make the process realistic. Solvent and liquefied gas extraction, steam distillation and mechanochemical are upcoming technologies and may have the potential to eliminate dioxins efficiently from the contaminated soils. Nevertheless, a single pilot scale study is reported (USEPA) on the use of liquefied gas for the removal of PCBs from soil and the present information on removal high molecular weight, toxic, dioxin compounds are very limited. Amongst all the methods described biodegradation is the cheapest method for the destruction of dioxins; however efficient hybrid organisms have to be constructed in the laboratory for the maximum destruction of these compounds. Since biodegradation is a slow process, due to the low bioavailability of dioxins, their rates can be increased by the use of bio-emulsifiers and chemical pre-treatment of the soil.

In our opinion, the use of super critical water, liquefied gas and biodegradation (along with the chemical pre-treatment) have a higher potential and reinforcing the need for more research for the development of sustainable methods of treatment.

Acknowledgements

The authors acknowledge Fundação Para a Ciência e a Tecnologia and FEDER (ref. SFRH/BPD/14848/2003) for the financial support.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.envint.2007.07.009.

References

Abad E, Adrados MA, Caixach J, Rivera J. Dioxin abatement strategies and mass balance at a municipal waste management plant. Environ Sci Technol 2002;36:92–9.

Abad E, Caixach J, Rivera J. Improvements in dioxin abatement strategies at a municipal waste management plant in Barcelona. Chemosphere 2003;50: 1175–82.

Abad E, Martinez K, Caixach J, Rivera J. Polychlorinated dibenzo-*p*-dioxin/ polychlorinated dibenzofuran releases into the atmosphere from the use of secondary fuels in cement kilns during clinker formation. Environ Sci Technol 2004;38:4734–8.

Alcock RE, Jones KC. Dioxins in the environment: a review of trend data. Environ Sci Technol 1996;30:3133–43.

Alcock RE, Gemmill R, Jones KC. Improvements to the UK PCDD/F and PCB atmospheric emission inventory following an emissions measurement programme. Chemosphere 1999;38:759–70.

Altwicker ER. Relative rates of formation of polychlorinated dioxins and furans from precursor and de novo reactions. Chemosphere 1996;33:1897–904.

Anderson DR, Fisher R. Sources of dioxins in the United Kingdom: the steel industry and other sources. Chemosphere 2002;46:371–81.

Andersson P, Rappe C, Maaskant O, Unsworth JF, Marklund S. Low temperature catalytic destruction of PCDD/F in flue gas from waste incineration. Organohalog Compd 1998;36:109–12.

Anthony EJ, Jia L, Granatstein DL. Dioxin and furan formation in FBC boilers. Environ Sci Technol 2001;35:3002–7.

Atkinson R. Atmospheric lifetimes of dibenzo-*para*-dioxins and dibenzofurans. Sci Total Environ 1991;104:17–33.

Baccarelli A, Mocareli P, Patterson DG, Bonzini M, Pesatori AC, Caporaso N, et al. Immunologic effects of dioxin: new results from Seveso and comparison with other studies. Environ Health Perspect 2002;110:1169–73.

Baker JI, Hites RA. Is combustion the major source of polychlorinated dibenzo-*p*-dioxins and dibenzofurans to the environment? A mass balance investigation. Environ Sci Technol 2000;34:2879–86.

Ballerstedt H, Kraus A, Lechner U. Reductive dechlorination of 1,2,3,4-tetrachlorodibenzo-*p*-dioxin and its products by anaerobic mixed cultures from Saale river sediment. Environ Sci Technol 1997;31:1749–53.

Balmer ME, Goss KU, Schwarzenbach RP. Photolytic transformation of organic pollutants on soil surfaces — an experimental approach. Environ Sci Technol 2000;34:1240–5.

Birke V, Mattik J, Runne D. Mechanochemical reductive dehalogenation of hazardous polyhalogenated contaminants. J Mater Sci 2004;39:5111–6.

Boening DW. Toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin to several ecological receptor groups: a short review. Ecotoxicol Environ Saf 1998;39:155–63.

Buekens A, Huang H. Comparative evaluation of techniques for controlling the formation and emission of chlorinated dioxins/furans in municipal waste incineration. J Hazard Mater 1998;62:1–33.

Buser HR, Bosshardt HP, Rappe C, Lindahl R. Identification of polychlorinated dibenzofuran isomers in fly-ash and Pcb pyrolyses. Chemosphere 1978;7: 419–29.

Calado(UK), Calado Environmental Engineering (UK), 1995. http://www.caldo.com/ceramic.html.

Carroll WFJ. Is PVC in house fires the great unknown source of dioxin? Fire Mater 1996;20:161–6.

Chen CM. The emission inventory of PCDD/PCDF in Taiwan. Chemosphere 2004;54:1413–20.

Chen ASC, Gavaskar AR, Alleman BC, Massa A, Timberlake D, Drescher EH. Treating contaminated sediment with a two-stage base-catalyzed decomposition (BCD) process: bench-scale evaluation. J Hazard Mater 1997;56: 287–306.

Cheung WH, C. Lee VKC, McKay G. Minimizing dioxin emissions from integrated MSW thermal treatment. Environ Sci Technol 2007;41:2001–7.

Choi W, Hong SJ, Chang YS, Cho Y. Photocatalytic degradation of polychlorinated dibenzo-*p*-dioxins on TiO_2 film under UV or solar light irradiation. Environ Sci Technol 2000;34:4810–5.

Cieplik MK, Carbonell JP, Munoz C, Baker C, Kruger S, Liljelind P, et al. On dioxin formation in iron ore sintering. Environ Sci Technol 2003;37:3323–31.

Clement RE, Tashiro C. Forest fires as a source of PCDD and PCDF. Presented at: Dioxin ’91, 11th International Symposium on Chlorinated Dioxins and Related Compounds; RTP, NC. September 23–27 1991.

Cole P, Trichopoulos D, Pastides H, Starr T, Mandel JS. Dioxin and cancer: a critical review. Regul Toxicol Pharmacol 2003;38:378–88.

Cudahy JJ, Helsel RW. Removal of products of incomplete combustion with carbon. Waste Manage 2000;20:339–45.

Czuczwa JM, Hites RA. Environmental fate of combustion-generated polychlorinated dioxins and furans. Environ Sci Technol 1984;18:444–50.

Czuczwa JM, McVeety BD, Hites RA. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans in sediments from Siskiwit Lake, Isle-Royale. Science 1984;226:568–9.

Depercin PR. Application of thermal-desorption technologies to hazardous-waste sites. J Hazard Mater 1995;40:203–9.

Derojas MIS, Luxan MP, Frias M, Garcia N. The influence of different additions on portland-cement hydration heat. Cem Concr Res 1993;23:46–54.

Dougherty EJ, McPeters AL, Overcash MR, Carbonell RG. Theoretical-analysis of a method for in situ decontamination of soil containing 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. Environ Sci Technol 1993;27: 505–15.

Dyke P, Coleman P, James R. Dioxins in ambient air, bonfire night 1994. Chemosphere 1997;34:1191–201.

Eduljee G. Waste disposal in cement kilns: a review of dioxin formation and control. Environ Waste Manag 1999;2:45–54.

Ergebnisse. Ergebnisse von Dioxin-Emissionsmessungen an Industrieanlagen in NRW; Dioxinmeßprogramm Nordrhein-Westfalen. In: Landesumweltamt Nordrhein-Westfalen, editor. Materialien 1996, vol. 30. 1996. 102ps Essen.

EuropeanCommission. PCDD/PCDF emission limits from municipal waste incineration plants. J Eur Comm 1994;34:1365–85.

Everaert K, Baeyens J. Catalytic combustion of volatile organic compounds. J Hazard Mater 2004;109:113–39.

Farooq S, Kurucz CN, Waite TD, Cooper WJ. Disinfection of wastewaters: high-energy electron vs gamma irradiation. Water Res 1993;27:1177–84.

Fell HJ, Tuczek M. Removal of dioxins and furans from flue gases by non-flammable adsorbents in a fixed bed. Chemosphere 1998;37:2327–34.

Fullana A, Conesa JA, Font R, Sidhu S. Formation and destruction of chlorinated pollutants during sewage sludge incineration. Environ Sci Technol 2004;38:2953–8.

Gerasimov GY. Degradation of dioxins in electron-beam gas cleaning of sulphur and nitrogen dioxides. Radiat Chem 2001;35:427–31.

Giesy JP, Kannan K. Dioxin-like and non-dioxin-like toxic effects of polychlorinated biphenyls (PCBs): implications for risk assessment. Crit Rev Toxicol 1998;28:511–69.

Goemans M, Clarysse P, Joannes J, De Clercq P, Lenaerts S, Matthys K, et al. Catalytic NO*x* reduction with simultaneous dioxin and furan oxidation. Chemosphere 2004;54:1357–65.

Goncalves C, Dimou A, Sakkas V, Alpendurada MF, Albanis TA. Photolytic degradation of quinalphos in natural waters and on soil matrices under simulated solar irradiation. Chemosphere 2006;64:1375–82.

Gore(USA) Gore, WL, and Associates (USA), 2000. http://www.gore.com/remedia.

Gray KA, Hilarides RJ. Radiolytic treatment of dioxin contaminated soils. Radiat Phys Chem 1995;46:1081–4.

Harjanto S, Kasai E, Terui T, Nakamura T. Behavior of dioxin during thermal remediation in the zone combustion process. Chemosphere 2002;47: 687–93.

Harrad SJ, Fernandes AR, Creaser CS, Cox EA. Domestic coal combustion as a source of PCDDs and PCDFs in the British environment. Chemosphere 1991;23:255–61.

Hashimoto S, Watanabe K, Nose K, Morita M. Remediation of soil contaminated with dioxins by subcritical water extraction. Chemosphere 2004;54:89–96.

Hilarides RJ, Gray KA, Guzzetta J, Cortellucci N, Sommer C. Radiolytic degradation of 2,3,7,8-TCDD in artificially contaminated soils. Environ Sci Technol 1994;28:2249–58.

Hirota K, Kojima T. Decomposition behavior of PCDD/F isomers in incinerator gases under electron-beam irradiation. Bull Chem Soc Jpn. 2005;78:1685–90.

Huff J, Lucier G, Tritscher A. Carcinogenicity of Tcdd — experimental, mechanistic, and epidemiologic evidence. Annu Rev Pharmacol Toxicol 1994;34: 343–72.

Jing ZZ, Matsuoka N, Jin FM, Hashida T, Yamasaki N. Municipal incineration bottom ash treatment using hydrothermal solidification. Waste Management 2007;27:287–93.

Kang DH, Tepper A, Patterson DG. Coplanar PCBs and the relative contribution of coplanar PCBs, PCDDs, and PCDFs to the total 2,3,7,8-TCDD toxicity equivalents in human serum. Chemosphere 1997;35:503–11.

Kao CM, Wu MJ. Enhanced TCDD degradation by Fenton's reagent preoxidation. J Hazard Mater 2000;74:197–211.

Kao CM, Chen SC, Liu JK, Wu MJ. Evaluation of TCDD biodegradability under different redox conditions. Chemosphere 2001;44:1447–54.

Karademir A, Bakoglu M, Ayberk S. PCDD/F removal efficiencies of electrostatic precipitator and wet scrubbers in izaydas hazardous waste incinerator. Fresenius Environ Bull 2003;12:1228–32.

Karademir A, Bakoglu M, Taspinar F, Ayberk S. Removal of PCDD/Fs from flue gas by a fixed-bed activated carbon filter in a hazardous waste incinerator. Environ Sci Technol 2004;38:1201–7.

Kasai E, Harjanto S, Terui T, Nakamura T, Waseda Y. Thermal remediation of PCDD/Fs contaminated soil by zone combustion process. Chemosphere 2000;41:857–64.

Kerkvliet NI. Recent advances in understanding the mechanisms of TCDD immunotoxicity. Int J Immunopharmacol 2002;2:277–91.

Kim HH, Yamamoto I, Takashima K, Katsura S, Mizuno A. Incinerator flue gas cleaning using wet-type electrostatic precipitator. J Chem Eng Jpn 2000;33: 669–74.

Kim SH, Kwak SY, Suzuki T. Photocatalytic degradation of flexible PVC/TiO2 nanohybrid as an eco-friendly alternative to the current waste landfill and dioxin-emitting incineration of post-use PVC. Polymer 2006;47:3005–16.

Kishimoto A, Oka T, Yoshida K, Nakanishi J. Cost effectiveness of reducing dioxin emissions from municipal solid waste incinerators in Japan. Environ Sci Technol 2001;35:2861–6.

Kjeller LO, Rappe C. Time trends in levels, patterns, and profiles for polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and biphenyls in a sediment core from the Baltic Proper. Environ Sci Technol 1995;29:346–55.

Kluyev N, Cheleptchikov A, Brodsky E, Soyfer V, Zhilnikov V. Reductive dechlorination of polychlorinated dibenzo-*p*-dioxins by zerovalent iron in subcritical water. Chemosphere 2002;46:1293–6.

Konstantinov AD, Johnston AM, Cox BJ, Petrulis JR, Orzechowski MT, Bunce NJ, et al. Photolytic method for destruction of dioxins in liquid laboratory waste and identification of the photoproducts from 2.3.7,8-TCDD. Environ Sci Technol 2000;34:143–8.

Krishnamurthy S, Brown HC. Selective reductions. 27. Reaction of alkyl halides with representative complex metal hydrides and metal hydrides. Comparison of various hydride reducing agents. J Org Chem 1980;45: 849–56.

Landesrumweltanmt NRW. Identification of relevant industrial sources of dioxins and furans in Europe 1997; LUA Materialien 43, North Rhine-Westphalia State Environment Agency on behalf of the European Commission, DG XI; 1997.

Lavric ED, Konnov AA, De Ruyck J. Dioxin levels in wood combustion — a review. Biomass Bioenergy 2004;26:115–45.

Ligon WV, Dorn SB, May RJ, Allison MJ. Chlorodibenzofuran and chlorodibenzo-*para*-dioxin levels in Chilean mummies dated to about 2800 years before the present. Environ Sci Technol 1989;23:1286–90.

Liljelind P, Unsworth J, Maaskant O, Marklund S. Removal of dioxins and related aromatic hydrocarbons from flue gas streams by adsorption and catalytic destruction. Chemosphere 2001;42:615–23.

Lundin L, Marklund S. Thermal degradation of PCDD/F, PCB and HCB in municipal solid waste ash. Chemosphere 2007;67:474–81.

Ma WP, Brown PW. Hydrothermal reactions of fly ash with Ca(OH)2 and CaSO4.2H2O. Cem Concr Res 1997;27:1237–48.

Maier-Schwinning, G., Herden, H. Minderungstechniken zur Abgasreinigung von PCDD/PCDF. 1996, VDI-Berichte Nr. 1298, 191–229. 1996.

Mandal PK. Dioxin: a review of its environmental effects and its aryl hydrocarbon receptor biology. J Comp Physiol B Biochem Syst Environ Physiol 2005;175: 221–30.

Marklund S, Andersson R, Tysklind M, Rappe C, Egeback KE, Bjorkman E, et al. Emissions of PCDDs and PCDFs in gasoline and diesel fueled cars. Chemosphere 1990;20:553–61.

Masuda Y, Schecter A, Papke O. Concentrations of PCBs, PCDFs and PCDDs in the blood of Yusho patients and their toxic equivalent contribution. Chemosphere 1998;37:1773–80.

Meckes MC, Tillman J, Drees L, Saylor E. Removal of PCBs from a contaminated soil using CF-systems(R) solvent extraction process. J Air Waste Manage Assoc 1997;47:1119–24.

Menzel HM, Bolm-Audorff U, Turcer E, Bienfait HG, Albracht G, Walter D, et al. Occupational exposure to dioxins by thermal oxygen cutting, welding, and soldering of metals. Environ Health Perspect 1998;106:715–22.

Mino Y, Moriyama Y. Possible remediation of dioxin-polluted soil by steam distillation. Chem Pharm Bull 2001;49:1050–1.

Mio H, Saeki S, Kano J, Saito F. Estimation of mechanochemical dechlorination rate of poly(vinyl chloride). Environ Sci Technol 2002;36:1344–8.

Mitoma Y, Uda T, Egashira N, Simion C, Tashiro H, Tashiro M, et al. Approach to highly efficient dechlorination of PCDDs, PCDFs, and coplanar PCBs using metallic calcium in ethanol under atmospheric pressure at room temperature. Environ Sci Technol 2004;38:1216–20.

Mitrou PI, Dimitriadis G, Raptis SA. Review article-toxic effects of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin and related compounds. Eur J Int Med 2001;12: 406–11.

Mori T, Kondo R. Oxidation of chlorinated dibenzo-*p*-dioxin and dibenzofuran by white-rot fungus, *Phlebia lindtneri*. FEMS Microbiol Lett 2002;216: 223–7.

Mucka V, Silber R, Pospisil M, Camra M, Bartonicek B. Radiolytic dechlorination of PCBs in presence of active carbon, solid oxides, bentonite and zeolite. Radiat Phys Chem 2000;59:399–404.

Napola A, Pizzigallo MDR, Di Leo P, Spagnuolo M, Ruggiero P. Mechanochemical approach to remove phenanthrene from a contaminated soil. Chemosphere 2006;65:1583–90.

Nickelsen MG, Cooper WJ, Kurucz CN, Waite TD. Removal of benzene and selected alkyl-substituted benzenes from aqueous solution utilizing continuous high-energy electron irradiation. Environ Sci Technol 1992;26: 144–52.

Nifuku M, Horvath M, Bodnar J, Zhang GY, Tanaka T, Kiss E, et al. A study on the decomposition of volatile organic compounds by pulse corona. J Electrost 1997;40:687–92.

Obata S, Fujihira H. Dioxin and NO*x* control using pilot-scale pulsed corona plasma technology. Combust Sci Technol 1998;133:3–11.

Oberg LG, Anderson R, Rappe C. De novo formation of hepta- and octachlorodibenzo-*p*-dioxins from pentachlorophenol in municipal sewage sludge. Organohalog Compd 1992;9:351–4.

Oberg LG, Wagman N, Anderson R, Rappe C. De novo formation of PCDD/Fs in compost and sewage sludge — a status report. Organohalog Compd 1993;11:297–302.

Oehme M, Larssen S, Brevik EM. Emission factors of PCDD and PCDF for road vehicles obtained by tunnel experiment. Chemosphere 1991;23:1699–708.

Olie K, Vermeulen PL, Hutzinger D. Chlorobenzo-*p*-dioxins and chlorodibenzofurans are trace components of fly ash and flue gas of some municipal incinerators in the Netherlands. Chemosphere 1977;6:455–9.

Orazio CE, Kapila S, Puri RK, Yanders AF. Persistence of chlorinated dioxins and furans in the soil environment. Chemosphere 1992;25:1469–74.

Patterson DG, Todd GD, Turner WE, Maggio V, Alexander LR, Needham LL. Levels of non-*ortho*-substituted (coplanar), mono-*ortho*-substituted and di-*ortho*-substituted polychlorinated-biphenyls, dibenzo-*p*-dioxins, and dibenzofurans in human serum and adipose-tissue. Environ Health Perspect 1994;102:195–204.

Pelizzetti E, Borgarello M, Minero C, Pramauro E, Borgarello E, Serpone N. Photocatalytic degradation of polychlorinated dioxins and polychlorinated biphenyls in aqueous suspensions of semiconductors irradiated with simulated solar light. Chemosphere 1988;17:499–510.

Pittman CU, He JB. Dechlorination of PCBs, CAHs, herbicides and pesticides neat and in soils at 25°C using Na/NH3. J Hazard Mater 2002;92:51–62.

Quass U, Fermann MW, Broker G. Steps towards a European dioxin emission inventory. Chemosphere 2000;40:1125–9.

Rappe C, Andersson R, Bergovist PA, Brohede C, Hansson M, Kjeller LO, et al. Overview on environmental fate of chlorinated dioxins and dibenzofurans-sources, levels and isomeric pattern in various matrices. Chemosphere 1987;16:1603–18.

Rotard W, Christmann W, Knoth W. Background levels of PCDD/F in soils of Germany. Chemosphere 1994;29:2193–200.

Ruokojarvi P, Aatamila M, Ruuskanen J. Toxic chlorinated and polyaromatic hydrocarbons in simulated house fires. Chemosphere 2000;41:825–8.

Sakai SI, Hayakawa K, Takatsuki H, Kawakami I. Dioxin-like PCBs released from waste incineration and their deposition flux. Environ Sci Technol 2001;35:3601–7.

Sako T, Sugeta T, Otake K, Sato M, Tsugumi M, Hiaki T, et al. Decomposition of dioxins in fly ash with supercritical water oxidation. J Chem Eng Jpn 1997;30:744–7.

Sako T, Sugeta T, Otake K, Kamizawa C, Okano M, Negishi A, et al. Dechlorination of PCBs with supercritical water hydrolysis. J Chem Eng Jpn 1999;32:830–2.

Sako T, Kawasaki S, Noguchi H, Kimura T, Sato H. Destruction of dioxins and PCBs in solid wastes by supercritical fluid treatment. Organohalog Compd 2004;66:1187–93.

Saldana MDA, Nagpal V, Guigard SE. Remediation of contaminated soils using supercritical fluid extraction: a review (1994–2004). Environ Technol 2005;26:1013–32.

Shiomitsu T, Hirayama A, Iwasaki T, Akashi T, Fujisawa Y. Volatilization and decomposition of dioxin from fly ash with agitating fluidized bed heating chamber. NKK Tech Rev 2002;86:25–9.

Sidhu S, Edwards P. Role of phenoxy radicals in PCDD/F formation. Int J Chem Kinet 2002;34:531–41.

Siewers S, Schacht U. Untersuchungen zur dioxinne-bildung beim compostierungprozess-unter realen bedingungen. Organohalog Compd 1994;18: 180–5.

Silva A, Delerue-Matos C, Fiuza A. Use of solvent extraction to remediate soils contaminated with hydrocarbons. J Hazard Mater 2005;124:224–9.

Stanmore BR. The formation of dioxins in combustion systems. Combust Flame 2004;136:398–427.

Stanmore BR, Clunies-Ross C. An empirical model for the de novo formation of PCDD/F in medical waste incinerators. Environ Sci Technol 2000;34:4538–44.

Steenland K, Deddens J. Dioxin: exposure-response analyses and risk assessment. Ind Health 2003;41:175–80.

Tuppurainen K, Halonen I, Ruokojarvi P, Tarhanen J, Ruuskanen J. Formation of PCDDs and PCDFs in municipal waste incineration and its inhibition mechanisms: a review. Chemosphere 1998;36:1493–511.

Tysklind M, Fangmark I, Marklund S, Lindskog A, Thaning L, Rappe C. Atmospheric transport and transformation of polychlorinated dibenzo-*p*-dioxins and dibenzofurans. Environ Sci Technol 1993;27: 2190–7.

USEPA. Health assessment document for 2, 3, 7, 8-tertachlorodibenzo-*p*-dioxin (TCDD) and related compounds. EPA/600/Bp-92/001c estimating exposure to dioxin-like compounds, epa/600/6-88/005cb. Washington, DC: Office of research and development; 1994a.

USEPA. Combustion emission technical resource document (CETRED), Report No. EPA 530-R-94-014. Washington, DC: Office of Solid Waste Emergency Response; 1994b.

USEPA. The inventory of sources of dioxins in the United States. EPA/600/P-98/002Aa; 1998.

Van den Berg M, Birnbaum L, Bosveld ATC, Brunstorm B, Cook P, Feeley M, et al. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Health Perspect 1998;106:775–92.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, et al. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxins-like compounds. Toxicol Sci 2006;93:223–41.

Vogg H, Stieglitz L. Thermal-behavior of Pcdd/Pcdf in fly-ash from municipal incinerators. Chemosphere 1986;15:1373–8.

Wang LC, Lee WJ, Tsai PJ, Lee WS, Chang-Chien GP. Emissions of polychlorinated dibenzo-*p*-dioxins and dibenzofurans from stack flue gases of sinter plants. Chemosphere 2003;50:1123–9.

Weber R, Yoshida S, Miwa K. PCB destruction in subcritical and supercritical water —evaluation of PCDF formation and initial steps of degradation mechanisms. Environ Sci Technol 2002;36:1839–44.

Wilson DC. Lessons from Seveso. Chem Br 1982;18:499–504.

Windgasse G, Dauerman L. Microwave treatment of hazardous wastes — removal of volatile and semivolatile organic contaminants from soil. J Microw Power Electromagn Energy 1992;27:23–32.

Wittich RM. Degradation of dioxin-like compounds by microorganisms. Appl Microbiol Biotechnol 1998;49:489–99.

Yoshimura T. Yusho in Japan. Ind. Health 2003;41:139–48.

Zhao CL, Hirota K, Taguchi M, Takigami M, Kojima T. Radiolytic degradation of octachlorodibenzo-*p*-dioxin and octachlorodibenzofuran in organic solvents and treatment of dioxin-containing liquid wastes. Radiat Phys Chem 2007;76:37–45.

Zheng MH, Bao ZC, Zhang B, Xu XB. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans in paper making from a pulp mill in China. Chemosphere 2001;44:1335–7.

Zhou YX, Yan P, Cheng ZX, Nifuku M, Liang XD, Guan ZC. Application of non-thermal plasmas on toxic removal of dioxin-contained fly ash. Powder Technol 2003;135:345–53.

25. LANL (Los Alamos National Laboratory), June 2020c. Supplement 4-3 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Screening Level Air Modeling Analysis and Risk Evaluation for Open Detonation Operations*. LA-UR-20-24479. (LANL 2020c)

Supplement 4-3

Screening Level Air Modeling Analysis and Risk Evaluation for Open Detonation Operations

Screening Level Air Modeling Analysis and Risk Evaluation for Open Detonation Operations

for

Los Alamos National Laboratory

Operated by:
Triad National Security, LLC
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
Owned by:
U.S. Department of Energy
National Nuclear Security Administration
Office of Los Alamos Site Operations
Los Alamos, New Mexico 87544

Contents

List of Tables

List of Figures

List of Attachments

List of Acronyms

AIEC	acute inhalation exposure concentrations
CCS	Chemical Compliance Systems, Inc.
DOE	U.S. Department of Energy
EF	emission factor
EPA	U.S. Environmental Protection Agency
ESL	ecological screening level
GLC	ground level concentration
LANL	Los Alamos National Laboratory
NAAQS	National Ambient Air Quality Standards
NMAAQS	New Mexico Ambient Air Quality Standards
NMED	New Mexico Environment Department
OBODM	Open Burn Open Detonation Model
OD	open air detonation
REL	Reference Exposure Levels
RSL	Regional Screening Level
SL	Screening Level
SR	State Road
SSL	Soil Screening Levels
TA	Technical Area

1.0 Introduction

This report describes the air modeling analysis and risk evaluation for open detonation (OD) operations conducted at Technical Area (TA) 36 and TA-39 located at Los Alamos National Laboratory (LANL). The purpose of this air modeling exercise is to develop reasonable estimates of air quality impacts from OD treatment operations at these units.

LANL is located in Los Alamos County in north-central New Mexico. It is approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. The facility and the associated residential and commercial areas of Los Alamos County are situated on the Pajarito Plateau. The facility is owned and co-operated by the U.S. Department of Energy (DOE) and Triad National Security, LLC. The location of LANL and the OD units addressed in this report is shown in Figure 1-1.

1.1 Description of the OD Units and Operations

TA-36 is located in the east-central portion of LANL and is spread over several mesa tops between a branch of Pajarito Canyon to the north and Water Canyon to the south. Mesa-top elevations at TA-36 range from approximately 6,380 to 7,120 feet above mean sea level. TA-36 contains an OD unit, several firing sites, and supporting offices where research is conducted with various types of explosives. The OD unit at TA-36 is located in the southern portion of TA-36 near Building TA-36-8 and is shown in Figure 1-2. The TA-36-8 OD unit consists of an irregularly shaped, sand- and grass-covered area that measures approximately 500 feet east to west and 300 feet north to south. The western portion is relatively flat; the eastern portion is concave to minimize fragment dispersion. The TA-36-8 OD unit may be used to treat solid and liquid hazardous explosive waste.

The TA-36-8 OD unit has a maximum treatment capacity of 2,000 pounds of explosive waste per detonation. Due to preparation time and monitoring requirements at this unit, only one detonation is performed per hour. The unit is used primarily for nontreatment-related experimental test detonations and may occasionally be used for treatment of hazardous explosive waste. Following waste placement at the unit, detonation operations are conducted from Building TA-36-8, the control building.

TA-39 is located in the southern portion of LANL and includes much of the mesa between Water Canyon to the north and Ancho Canyon to the south. Mesa-top elevations at TA-39 range from approximately 6,500 to 7,000 feet above mean sea level. The area was established in 1959 for testing of explosive materials and has been used continuously for that purpose. The OD unit at TA-39 consists of a relatively flat, sand-covered area that measures approximately 40 feet by 40 feet in a canyon bottom. Steep canyon walls rise to heights of 100 feet or more in the immediate vicinity of the OD unit, roughly forming a semicircle around the unit. Additionally, the area has recently been reconfigured to have a retaining wall in front of the canyon wall. The canyon and retaining walls serve to attenuate the force of the detonations. The OD unit at TA-39 is associated with Building TA-39-6 as shown in Figure 1-3. Building TA-39-6 is a reinforced concrete structure extending partially beneath the detonation area. The TA-39-6 OD unit may be used to treat solid and liquid hazardous explosive waste.

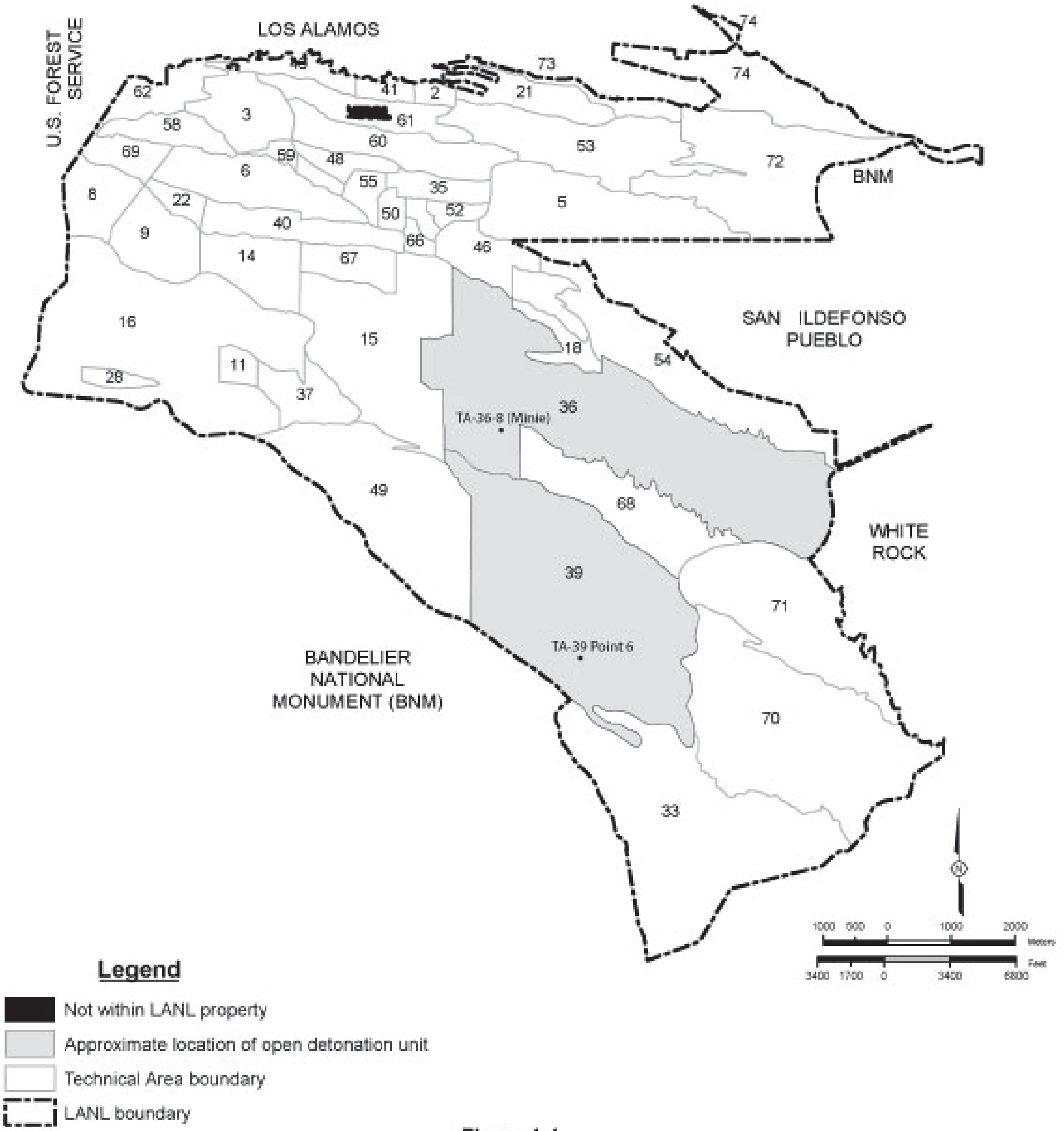


Figure 1-1

Location Map of Open Detonation Units at Los Alamos National Laboratory

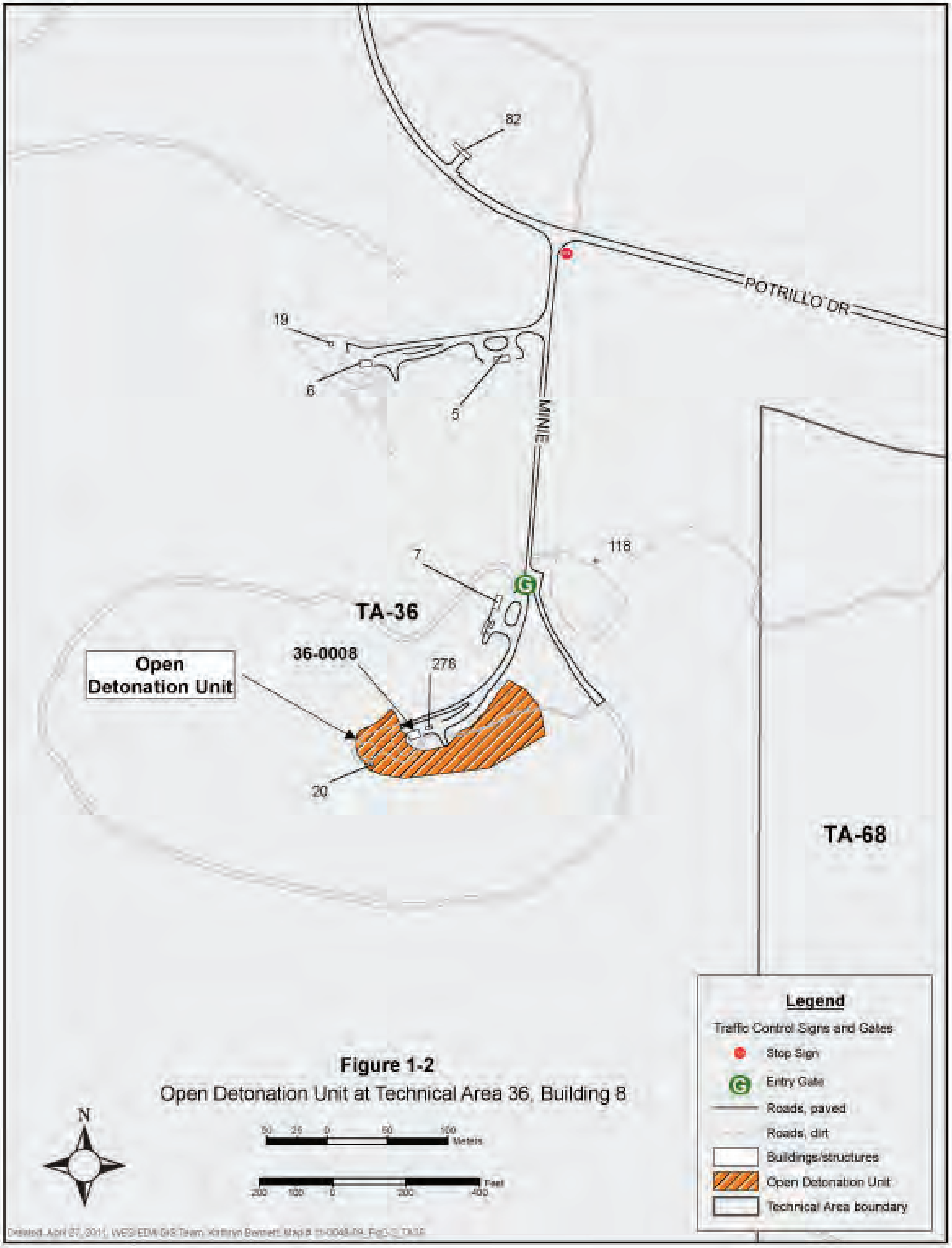


Figure 1-2
Open Detonation Unit at Technical Area 36, Building 8

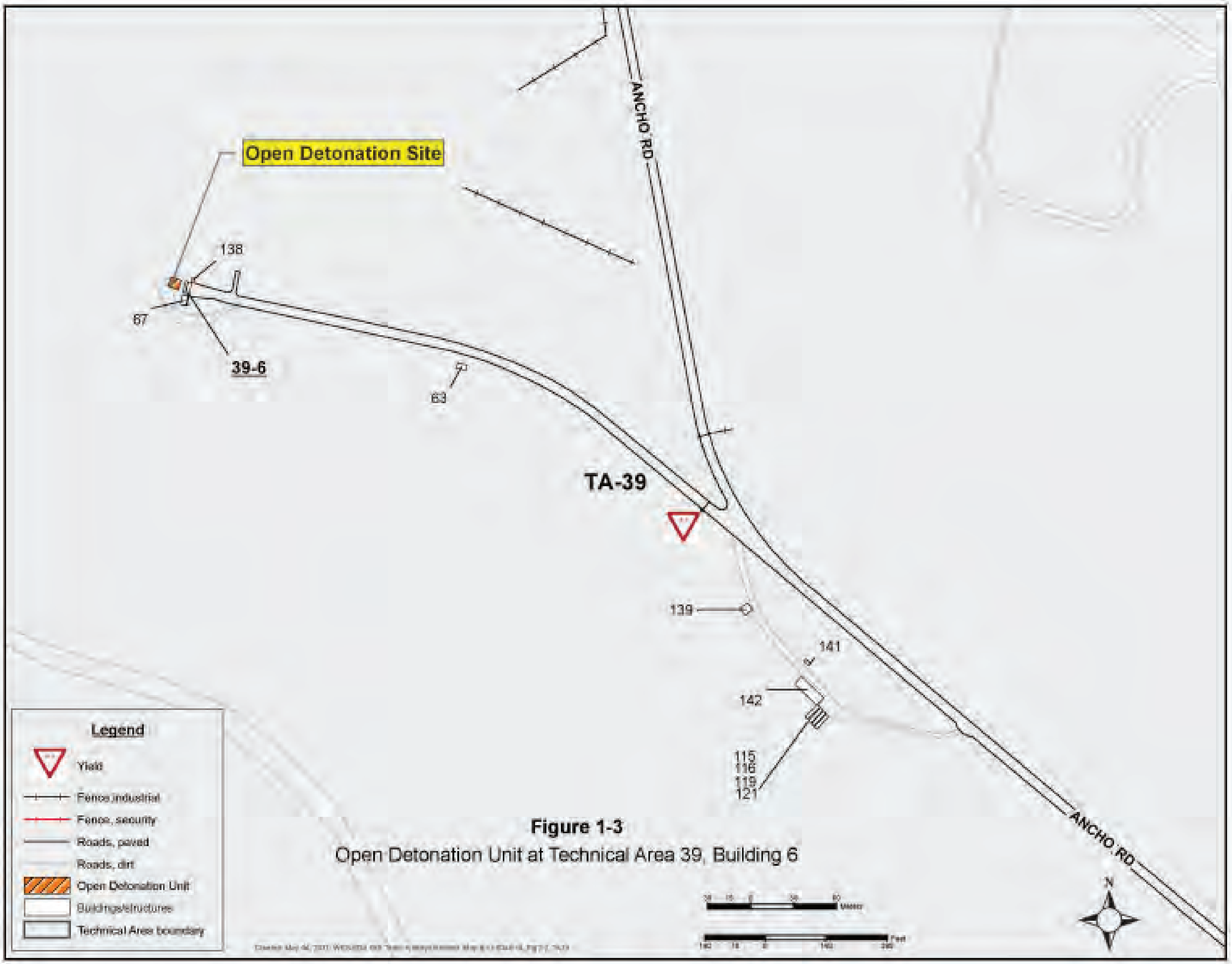


Figure 1-3
Open Detonation Unit at Technical Area 39, Building 6

The TA-39-6 OD unit has a maximum waste treatment capacity of 250 pounds of explosive waste per detonation. Up to four detonations may be performed per hour. The unit is used primarily for nontreatment-related experimental test detonations and may occasionally be used for treatment of hazardous explosive waste. Following waste placement at the unit, detonation operations are conducted from Building TA-39-6 (the control building).

1.2 Waste Treated Through Open Detonation

OD operations are necessary for hazardous waste treatment to remove the characteristic of reactivity. Treatment by OD renders hazardous waste nonreactive and any infrequent residue amenable to handling and dispositioning. Nontreatment-related experimental test detonations (i.e., shots) are also currently performed at these locations.

Solid and liquid hazardous explosive waste may be treated (i.e., open detonated) at the unit. Waste streams treated through OD include the following:

- Excess explosives varying from large pieces of explosives, small amounts of standard explosives, and developmental explosives;
- Detonators, initiators, and mild detonating fuses that may be in metal or plastic casings and may contain lead-based primaries or be in a lead sheath;
- Shaped charges and test assemblies with metal or plastic liners, sheaths, or holders;
- Projectiles and munitions that may be larger than 50 caliber or smaller caliber ammunition that is damaged;
- Pressing molds that are contaminated with explosives;
- Explosives-contaminated waste generated in laboratories, make-up rooms, and at the firing site; and
- Black powder or gun powder.

The listing above breaks up the two basic categories of explosives that may be managed at the OD treatment units. One category consists of explosives-contaminated waste and another category consists of explosive waste. Most of the waste treated at the OD units is explosive waste.

Explosives-contaminated waste includes make-up room (also called preparation room) wastes, laboratory wastes, contaminated molds, firing site debris, and decommissioning and demolition waste. Make-up room waste and laboratory waste consist of explosives-contaminated waste, such as paper towels, swabs, and similar materials that contain no tangible pieces of explosives but are used in the preparation of shots in the make-up building or as part of research and development processes. Firing site debris that consists of wood scraps, cardboard, burlap, Plexiglas®/Lexan®, plastic, glass, styrofoam, electrical cables, and metallic foils used for pin switches or metals such as target plates is not generally explosives contaminated; however, occasionally potentially explosives-contaminated firing site debris can be generated. If the debris is explosives-contaminated and not rendered safe immediately, it is stored in the satellite accumulation area within the make-up building and treated as soon as possible. Decommissioning and demolition waste can come as buildings are upgraded or removed from service. These wastes may be metal or glass piping that is not amenable to steam cleaning or open burning. Firing site debris could also include corrective action wastes or wastes generated as a result of investigation or remediation in the future. Other explosives-contaminated waste includes molds and other materials used in manufacturing high explosives parts that may become contaminated and cannot be steam cleaned.

Explosive waste includes identifiable excess explosives that are safe to handle. It includes explosives assemblies and explosives, identifiable booster charge scrap, and any other process or cleanup wastes that are believed to be potentially reactive. Waste containers for explosives-contaminated waste and explosive waste generally consist of plastic bags or paper-lined cardboard boxes. These wastes make up most of the waste treated through OD at LANL. Up to 90% of the wastes treated within a year are excess explosives. Munitions, detonators, projectiles, and initiators make up an estimated annual quantity of approximately 2% of waste treated through OD.

2.0 Air Dispersion Modeling

Air dispersion modeling was conducted to estimate the ground level concentrations (GLC) that occur downwind following an OD event. The GLC is required to compare potential air quality impacts of OD operations with health-based screening levels for air and soil. Dispersion modeling is a standard technique accepted by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) to estimate downwind concentrations.

2.1 Model Selection

The NMED specified this analysis should be conducted using the Open Burn and Open Detonation Model (OBODM). The U.S. EPA has approved the use of OBODM for modeling open burning/open detonation operations. Previously, NMED used OBODM to model air emissions from LANL's TA-16 Burn Ground during the Resource Conservation and Recovery Act permit application process.

Models such as OBODM are used for predicting downwind concentrations assume dispersion follows a uniform Gaussian distribution within the plume. In reality, atmospheric dispersion is far more complex and dependent on unique source and terrain features than a model is capable of considering. Nevertheless, dispersion models are a long accepted tool to assess source impacts for regulatory purposes.

Considering numerous studies over time, the U.S. EPA states in Title 40 of the Code of Federal Regulations 51, *Appendix W – Guideline on Air Quality Models* that models are reasonably reliable for estimating the magnitude of the highest concentrations occurring within an area. Errors in the highest estimated concentrations of plus or minus 10 to 40 percent are found to be typical. However, estimates of concentrations that occur at a specific time and location are less reliable. Models are also more reliable in estimating longer time-averaged concentrations, such as annual averages, than for estimating short-term concentrations at specific locations.

OBODM is intended for use in evaluating the potential air quality impacts of the open-air burning and detonation of obsolete munitions and solid propellants at U.S. Department of Defense and DOE installations (Bjorklund, et al., 1998a). OBODM predicts the downwind transport of pollutants using cloud rise and dispersion model algorithms from existing dispersion models. A complete description of the plume rise and dispersion algorithms used in OBODM is found in Volume II of the user's manual (Bjorklund, et al., 1998b). The OBODM allows for a simplistic representation of local meteorology and includes a screening-level complex terrain algorithm. All OBODM source and receptor locations are defined relative to a rectangular or a polar coordinate system in which north (0 degrees) is the positive Y-axis and east (90 degrees) is the positive X-axis. All vertical (z) coordinates are heights above ground level except when the OBODM complex terrain screening mode is used, in which case the z coordinates are terrain heights above mean sea level.

2.2 Methodology Steps

OBODM runs were conducted to determine the maximum GLC for acute and chronic exposures. Emission factors (EFs) for specific contaminants generated by OD operations were then applied to model results to obtain concentrations for comparison to ambient air quality standards and health screening levels. The methodology was comprised of the following steps:

1. For each detonation site, a source strength model input file was prepared for short-term GLCs using the maximum hourly waste quantity for each site. The input file contained the maximum waste quantity for each hour from 8 AM to 5 PM for each day of the year.
2. Using a one-year continuous hourly on-site meteorological data set, OBODM was run for each site using the hourly source strength file for the short-term 1-, 3-, 8-, and 24-hour averaging periods.
3. The hourly model results were used to create a source strength input file for estimating annual or chronic GLCs. In a descending order, maximum hourly waste quantities were assigned to the hours of the year with the highest predicted GLC from the hourly model runs. This was done until the sum of the hourly values equaled the maximum annual waste quantity.
4. OBODM was run for each site using the annual source strength file and the same one-year on-site meteorological data set for the annual averaging period.
5. In each model run, the contaminant emission rate was set at 1 gram per second (1 g/sec). Thus, the maximum GLC predicted was for a contaminant emission rate of 1 g/sec. The maximum GLC over the 1-g/sec emission rate, referenced as the X/Q value, has units of µg/m^3 per 1 g/sec.
6. EFs together with maximum waste quantities were used to calculate the emission rate in g/sec for each specific pollutant or contaminant projected to occur from a detonation.
7. Contaminant-specific GLCs for all averaging periods were calculated by multiplying the model result X/Q value (µg/m^3 divided by g/sec) times each chemical-specific emission rate (g/sec).
8. The calculated GLCs were compared to ambient air quality standards and health risk screening levels.

2.3 Model Input Values

The input values used in the model runs are summarized in Table 2-1. The fuel heat content specified is representative of the range of wastes treated. The fuel quantities are maximum hourly and annual values. Note that for the TA-39-6 site, the hourly waste quantity for one detonation was used. Since it is possible to have four detonations per hour at this site, model results were then scaled upwards by a factor of four. Selection of the instantaneous emission type in model setup resulted in the model calculated fuel burn rate of 2.5 seconds. The fuel burn rates were calculated from the hourly fuel quantity divided by the fuel burn time. The release height was not specified. Instead, the model option using OBODM to calculate this value was selected.

Table 2-1
Model Input Values

Parameter	TA-36-8	TA-39-6
Fuel Heat Content, cal/g	1,000	1,000
Hourly Fuel Quantity, lbs	2,000	250
Annual Fuel Quantity, lbs	15,000	15,000
Fuel Burn Time, sec	2.5	2.5
Fuel Burn Rate, lb/s	800	100
Fuel Burn Rate, g/sec	362,874	45,359
Contaminant Emission Rate, g/sec	1	1

2.4 Meteorological Data

LANL maintains a network of on-site meteorological stations that is adequate to predict maximum downwind concentrations from open detonation operations when using a full year of meteorological data. The centrally located TA-6 station is the official meteorological station for LANL and data from it are reported to the National Weather Service. The station consists of a 92-meter tower that is instrumented for wind and temperature at four levels. A one-year continuous hourly record from this station was used in the model input. This data set has been approved for use by NMED and was used by NMED in the modeling and health screening for the TA-16 Burn Ground. Elevations of the open detonation sites are 6,895 feet for TA-36-8 and 6,422 feet for TA-39-6 and the elevation of the TA-6 Meteorological Station is 7,424 feet. The use of an official meteorological station consistently lessens uncertainty and increases the ability to compare current, previous, and future modeling.

Figure 2-1 illustrates daytime and nighttime wind rose diagrams for the meteorological stations at LANL. The TA-6 tower and associated near-surface instrumentation are located on the Pajarito Plateau in an east-west meadow on Two-mile Mesa. The TA-6 meteorological station is sited on a mesa top and is surrounded by sparse vegetation that is similar to each of the open detonation sites. The fetch within a few hundred meters of the tower is over short grasses and widely scattered low shrubs. The roughness length, based on turbulence, varies from 0.4 m to 0.8 m depending on wind direction.

Open detonations are restricted to daytime only; however, both day and night are included on Figure 2-1. Comparing the wind rose for the TA-6 and TA-49 stations that are included on Figure 2-1, winds are predominantly from the south-southwest for each station. Overall, the two wind roses are quite similar in all respects for each of the 16 wind directions which are plotted. There is no meteorological data measured or collected at the detonation sites themselves. Although the TA-49 meteorological station is physically closer to the two open detonation sites than the TA-6 tower, meteorological data from the TA-6 station was used as input, as it is the official station for LANL. The stations are sited on mesa tops at similar elevations, both surrounded by similar sparse vegetation, and elevations for the stations are similar.

Table 2-2 below contrasts the physical location of the relationship of the two closest towers to the two OD sites.

Table 2-2

Comparison of LANL Meteorological Stations at TA-6 and TA-49

Parameter	TA-6 Station	TA-49 Station
Elevation, feet	7,424	7,045
Surrounding Vegetation	Short grasses/scattered shrubs	Short grasses/scattered shrubs
Distance to TA-36-8, miles	3.2	1.5
Distance to TA-39-6, miles	5.2	2.1

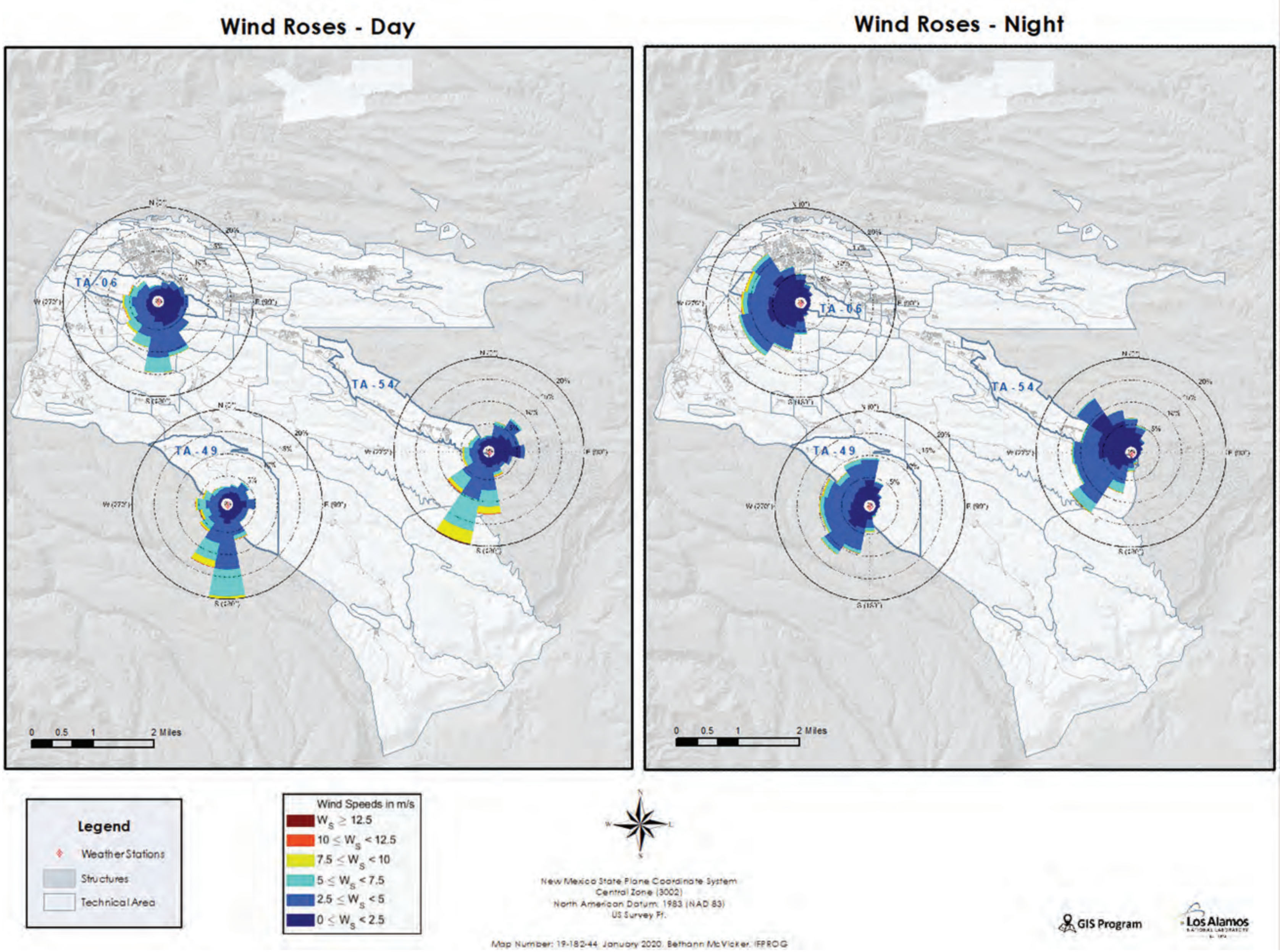


Figure 2-1
Annual Wind Rose Diagrams for Meteorological Stations at Los Alamos National Laboratory

2.5 Receptors

Receptors with terrain elevations were established to ensure the maximum downwind concentrations were captured in the model runs. A Cartesian receptor grid was set up for each detonation site with the site being the center point of a 1,000- by 1,000-meter grid with 100-meter spacing between receptors. Public receptors included nearby roadways, recreation areas, schools, hospitals, and tribal land. A list of public receptors is shown in Table 2-2.

Figure 2-2 shows the LANL property boundary, roadways, and the receptors used in the analysis. LANL property is shaded darker than the surrounding land in the figure. The two sites and associated receptor grids are indicated in the black grid squares with TA-36 north of the TA-39 site. Public receptors are indicated in yellow.

Table 2-2

Public Receptors

Receptor	X-Coordinate[1] (meters)	Y-Coordinate[1] (meters)	Elevation[2] (feet)
Bandelier Entrance at State Road (SR) 4	384789.7	3962060.7	2031.2
Bandelier Visitor Center	385202.9	3960086.4	1845.1
Midpoint 2 OD Sites	385071.3	3964015.1	2058.1
TA-36-8 Proximity	384473.6	3965417.7	2117.9
San Ildefonso West of SR 4	388891.3	3967279.6	2006.7
White Rock Overlook Park	393146.0	3965274.7	1911.6
Piñon Elementary School, White Rock	390207.5	3964769.6	1981.0
Royal Crest Trailer Park	382432.8	3970723.1	2228.0
Los Alamos Medical Center	381001.8	3971679.6	2226.7
West Jemez Road	377585.0	3969284.5	2386.7
Ponderosa Campground	377386.1	3966238.8	2311.2
TA-39 Entrance	386855.8	3961142.4	1916.8
LANL SE Boundary	388723.0	3958724.3	1643.8
SR 4 SE	387161.9	3961999.5	1993.5
SR 4 SE	387131.3	3963223.8	1952.0
SR 4 SE	388019.0	3963805.4	1985.6
Pajarito Rd	388416.9	3965488.9	2003.9
Pajarito Rd	386702.8	3966284.8	2035.8
Pajarito Rd	385417.2	3967692.8	2130.0
Pajarito Rd	383764.3	3968549.8	2180.4
Pajarito Rd	382142.0	3969498.7	2220.6
West Jemez Rd	377367.0	3967907.1	2364.6
West Jemez Rd	378132.2	3970600.7	2406.3
SR 4 SW	383427.6	3962917.7	2105.2
SR 4 SW	382264.4	3964080.9	2156.9
SR 4 SW	380948.2	3965427.7	2208.7
SR 4 SW	379142.3	3966223.5	2260.6

[1] All Universal Transverse Mercator (UTM) coordinates are based on the datum, North American Datum (NAD) 83.

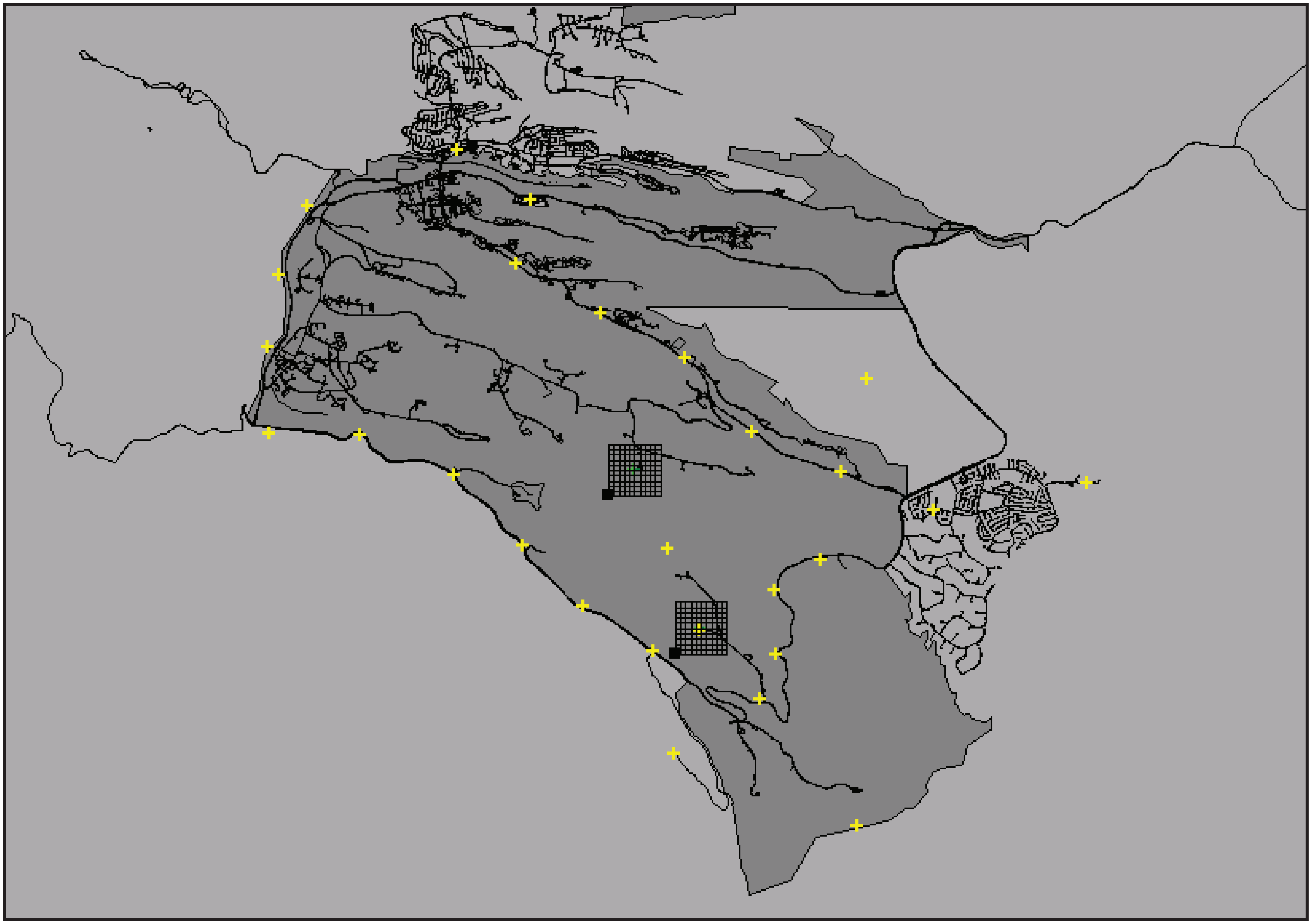


Figure 2-2
Location of Public Receptors and Receptor Grids

2.6 Model Methodology Description

OBODM runs were conducted for each site to determine the maximum 1-, 3-, 8-, and 24-hour and annual air concentrations. The annual air concentration was used to calculate the 10-year soil concentration from pollutant deposition. Details of the technical approach are provided below.

OD operations at TA-36 and TA-39 occur from 8 AM to 5 PM local time in the summer and from 9 AM to 4 PM in the winter. At TA-36-8, up to 2,000 lbs of high explosives waste is treated in each open air surface detonation; and a maximum of 15,000 lbs of waste per year. Due to preparation and radiation monitoring requirements, only one shot per hour is conducted. At TA-39-6, up to 250 lbs of high explosives waste is treated per open air surface detonation—and a maximum of 15,000 lbs of waste per year. Because preparation times are less, four shots may be conducted in an hour.

Typically, only one detonation occurs daily. However, to ensure the maximum hourly concentration was captured; all hours of the year from 8 AM to 5 PM were modeled. This was done by using as input a source strength file with the maximum hourly high explosives waste quantity for each site of 2,000 lbs for TA-36 and 250 lbs for TA-39 for each hour from 8 AM to 5 PM. All other hours were specified as 0 lbs of waste. In the calculations comparing model results to health screening levels, the hourly concentration for TA-39 was scaled upwards by a factor of four to account for the potential of four detonations in one hour for that site.

To ensure the maximum annual air concentration was captured by the analysis, annual source strength files for each site were created based on the results of the hourly model run. Using an annual file with 8,760 hours per year, hourly waste quantities were placed within the file for the hour of the year, which corresponded to the hours that showed the highest concentrations in the hourly model runs. This was done in a descending manner starting with the hour showing the highest concentration and moving down the hourly results until the annual waste quantities of 15,000 lbs/yr were reached.

In all model runs, a 1-g/sec contaminant emission rate was specified. The contaminant for model purposes was non-specific. The model results for this analysis were not dependent on specification of a particular contaminant or pollutant. The model does not consider any reactivity or unique characteristic of a pollutant as it travels downwind for the emission source. Although within OBODM a user can specify the molecular weight for a specific pollutant, the value is only used by the model if results are requested in terms of parts per million, which was not the case in this analysis where results in $\mu g/m^3$ were used.

Plume rise was calculated for each hour of each day by OBODM. The maximum one hour concentration predicted for the TA-39-6 site occurred on March 1 (Day 60) of the annual data set at a time of 0800. The plume rise present for this maximum concentration was 88.7 meters. This maximum impact was projected to occur on LANL property approximately 360 meters from the detonation site and within the canyon surrounding the site.

Overall, four model runs were conducted. Each run was conducted using the appropriate source strength file described above, the one-year hourly meteorological data set from the LANL TA-6 Station, and the receptors described in Section 2.5. Table 2-3 summarizes the four scenarios modeled.

Table 2-3

Four Modeling Scenarios

OD Site	Averaging Time	Waste Quantity	Input/output File Name[1]
TA-36-8	1, 3, 8, and 24 hours[2]	2,000 lbs	ODTA36V.INP ODTA36V.OUT
TA-36-8	Annual	15,000 lbs[3]	ODTA36A1.INP ODTA36A1.OUT
TA-39-6	1, 3, 8, and 24 hours	250 lbs	ODTA39V.INP ODTA39V.OUT
TA-39-6	Annual	15,000 lbs	ODTA39A4.INP ODTA39A4.OUT

[1] OBODM input and output files, the accompanying hourly source strength files, and the model-ready meteorological data file have been provided to the NMED in electronic format for review purposes.

[2] The 1-, 3-, 8-, and 24-hour averaging periods were needed to assess compliance with ambient air quality standards for those averaging times.

[3] The annual source strength file for this site had 8 hours with 2,000 lbs per hour rather than use of a single hour with 1,000 lbs waste to produce a 15,000-lb total. Thus, the maximum concentration is conservative.

2.7 Model Results

The maximum GLCs from each model run are shown in Table 2-4 together with the X and Y coordinates where each maximum occurred. All UTM coordinates used in the analysis are based on the datum North American Datum (NAD) 83. The elevation for each receptor is listed in Table 2-2. All maximum GLCs occurred close to the detonation sites on LANL property at receptors within the 1,000- by 1,000-meter receptor grids centered on the detonation sites. The highest single GLC for the nearby public receptors is also shown. The high public receptor value is one to two orders of magnitude lower than the maximum GLC on LANL property. The values shown represent results using the 1-g/sec contaminant emission rates. Specific concentrations for individual pollutants were calculated using these results. Each of these locations with the predicted maximum GLC is shown on Figures 2-3 and 2-4.

Table 2-4
Maximum Ground Level Concentrations By Location and Averaging Times

OD Site / Averaging Times	Maximum GLC (µg/m³)	X-Coordinate (meters)	Y-Coordinate (meters)	Public Receptor Maximum GLC (µg/m³)	Public Receptor Location
TA-36-8		384428.8	3965530.0		
1-hour	2.37×10^{-1}	384030.0	3965830.0	7.67×10^{-3}	West Jemez Rd
3-hour	8.21×10^{-2}	384230.0	3965730.0	4.26×10^{-3}	Midpoint 2 OD Sites
8-hour	3.30×10^{-2}	384330.0	3965630.0	2.28×10^{-3}	Pajarito Rd
24-hour	1.22×10^{-2}	384330.0	3965630.0	7.87×10^{-4}	Pajarito Rd
Annual	6.16×10^{-5}	384130.0	3965730.0	3.87×10^{-7}	West Jemez Rd
TA-39-6		385714.0	3962501.0		
1-hour	1.54	385414.0	3962701.0	6.53×10^{-2}	Bandelier Entrance SR4
3-hour	6.53×10^{-1}	385714.0	3962701.0	2.81×10^{-2}	Bandelier Entrance SR4
8-hour	5.68×10^{-1}	385714.0	3962701.0	1.93×10^{-2}	Bandelier Entrance SR4
24-hour	1.89×10^{-1}	385714.0	3962701.0	6.42×10^{-3}	Bandelier Entrance SR4
Annual	1.79×10^{-3}	385614.0	3962401.0	4.83×10^{-5}	Bandelier Entrance SR4

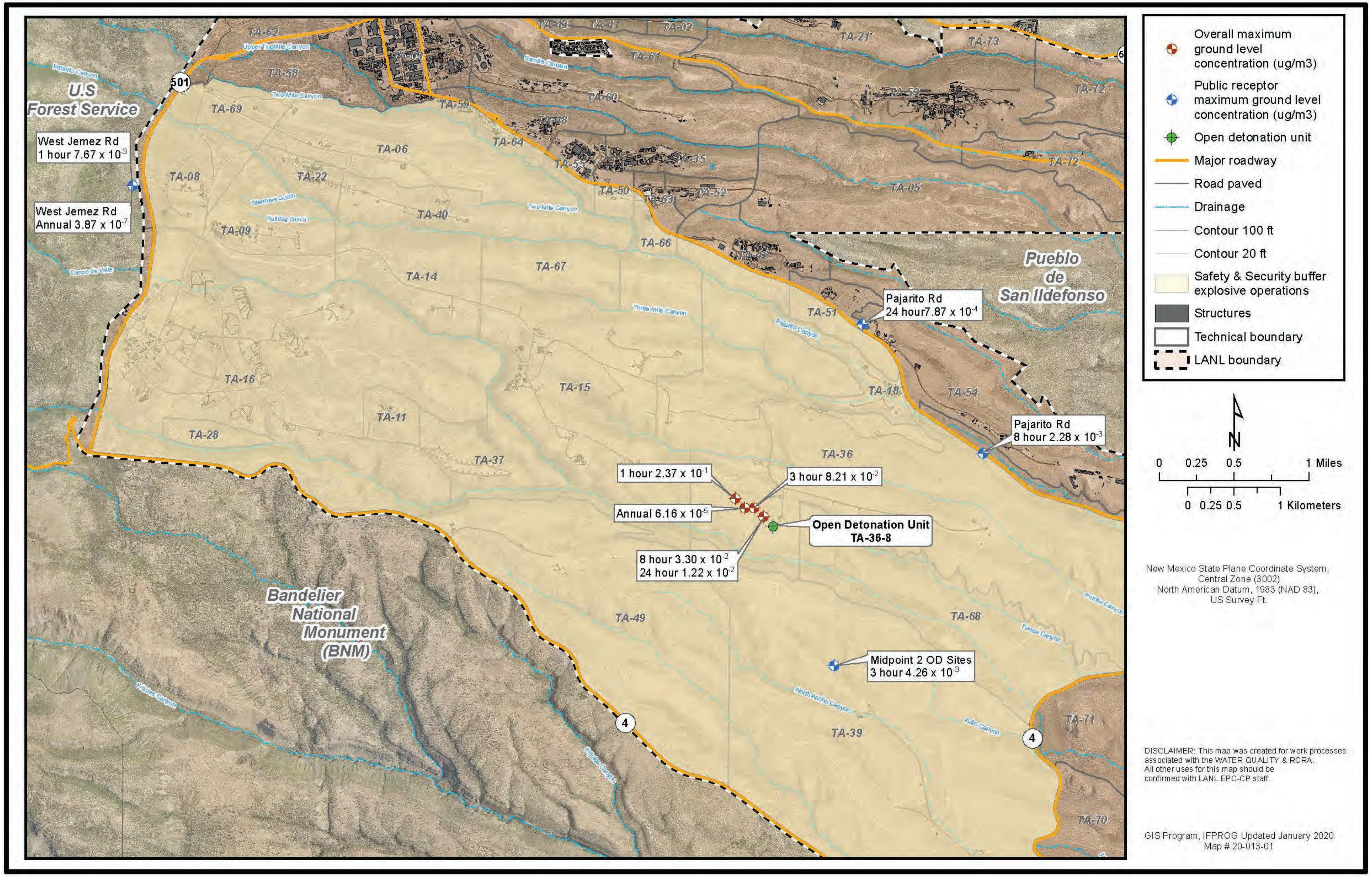


Figure 2-3
Locations of Highest Predicted Ground Level Concentrations from TA-36-8 Open Detonation Unit

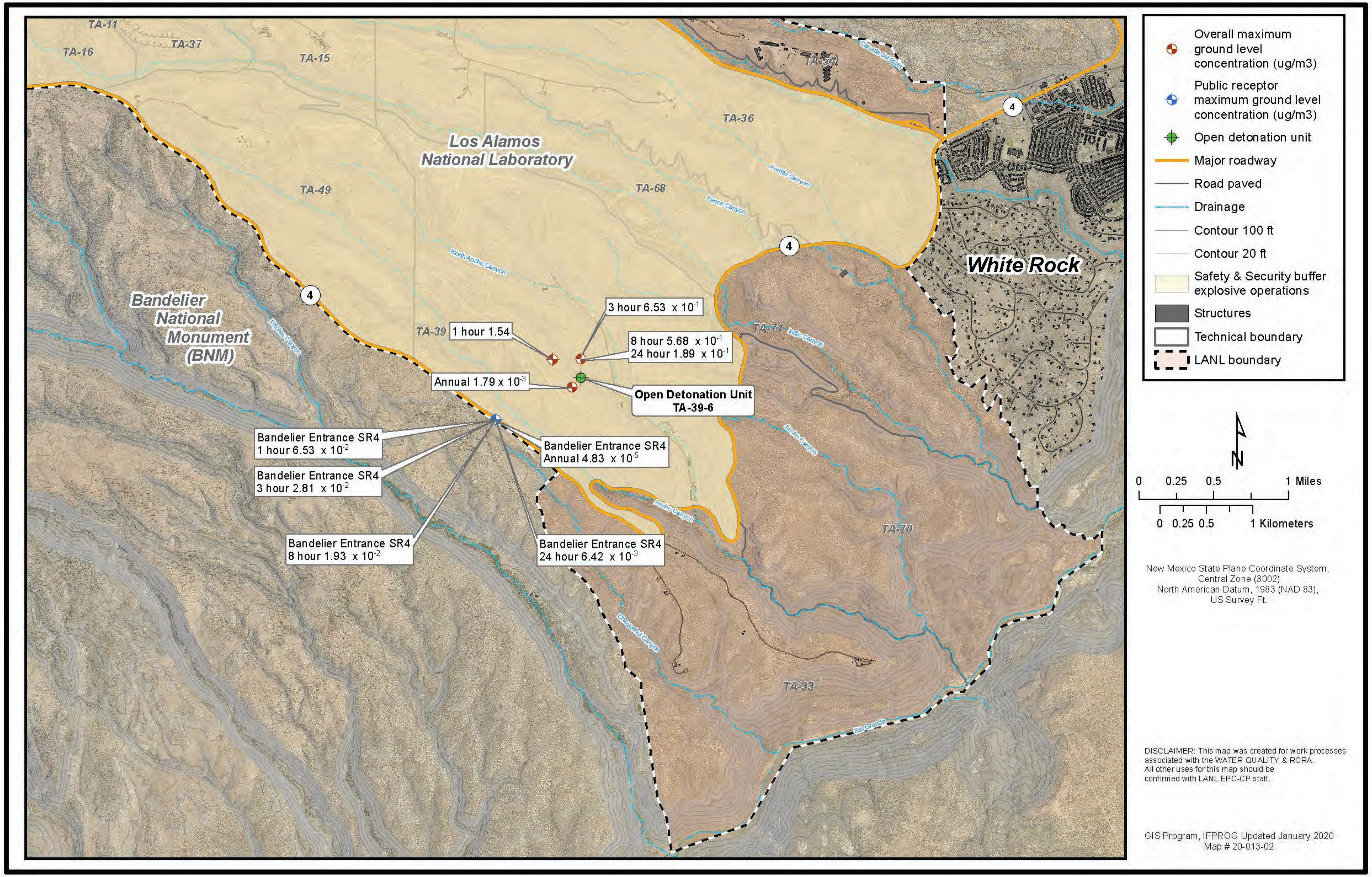


Figure 2-4
Locations of Highest Predicted Ground Level Concentrations from TA-39-6 Open Detonation Unit

3.0 Emission Factors

Waste streams treated through OD are described in Section 1.2 of this document. After review of the operating record, it was determined that wastes treated during calendar year 2006 were varied and represented a data set that encompassed all waste streams and waste stream components expected to be treated at the units throughout the current and future waste treatment uses. For the treatment units, emission factors (EFs) were chosen based on the components within the waste streams treated in 2006 using the draft Chapter 16 for AP-42 (AP-42, 2009). The emission factors provided in AP-42, draft Chapter 16 are a summary of the data publicly available through 1995. Based on the draft Chapter 16, section 16.2.1, the emission factors were obtained from a series of emission characterization studies conducted on an open test range (OTR) and in a 32,900 ft^3, 50-ft diameter hemispherical detonation chamber. These studies were conducted at Dugway Proving Grounds, UT (DPG) between 1989 and 1995.

As stated draft Chapter 16, section 16.1.1, in 1988, the United States Army conducted a highly successful study using a detonation chamber at Sandia National Laboratories (SNL) in Albuquerque, NM. Based on the test results, DOD concluded that the plumes released when energetic materials are destroyed by OB and OD processes do not contain sufficient quantities of toxic or hazardous pollutants to pose a danger to human health or the environment. The study also concluded that the emission factors for the predominant EPs produced in the emissions tests were statistically equivalent to those produced in the DPG open range tests. That is, the EPs did not change substantially even when the quantity of energetic material detonated increased by a factor of 32,000.

In this document, the primary reference for emission factors (EF) is Table 16.2-14, Summary Statistics for the Detonation Data Sets. In this table, many of the units of measure for the Emission Products (EP) are expressed in such forms as lb/lb NEW (Net Explosive Weight), where NEW is the total weight of all explosives substances (i.e., high explosive weight, propellant weight, and pyrotechnic weight). Other listed EFs are provided as lb/lb N, lb/lb C, or lb/lb S, etc. These EFs allow a more reasonable and less conservative estimate of emissions if applied. For most of the modeling assessments to determine the environmental impacts, the amount of NEW, nitrogen, carbon or sulfur were not assessed in the LANL waste materials; however, the lb metal/lb waste was assessed for this application based on the waste assessments presented in Attachment A. The maximum amount of metals was assessed for computing the amount of metal emissions for these constituents. Otherwise, all other calculations were based on the total mass of explosive waste used in the detonation. Applying lb/lb explosive waste for the unit of measure in lieu of the specific EFs where lb/lb NEW, lb/lb N or lb/lb C, etc. are not known, increases the conservativeness of the estimate of environmental impact for the risk assessment, since the total mass of combined waste is greater than any one of the constituents, such as net explosive weight, carbon or nitrogen, etc. To add to the conservativeness of the estimates for environmental impact, LANL applied the maximum EF values listed in Table 16.2-14 rather than the mean value listed in the table.

Research on OD emissions at the Naval Air Warfare Center Weapons Division at China Lake, California, addressed the fate of metals from munitions during OD treatment operations (NAVAIR, 2004). This research showed that metal components of waste (e.g., casings, projectiles, platings, paints, coatings) do not melt or vaporize during OD, but rather fragment. During OD, explosives quickly transform from solid to high-temperature and high-pressure gases, which cause the metal components to fracture. The metal fragments are in contact with the hot gases, but not long enough to cause the metal to melt or vaporize. The metal fragments are accelerated outside of the detonation zone by the initial blast and are not exposed to the afterburning (fireball) phase of the detonation. The majority of metal components end up as fragments, with a minor proportion becoming particulates. In this regard, the emission calculations for metals is an overestimate of particulate by allowing the assumption that the fragment portion is modeled as particulate.

For CDD/CDF emissions, EPA (EPA, 2006) states there are three primary mechanisms for controlled combustion sources. The first mechanism is “pass through”. This mechanism involves CDDs/CDFs contained in the feed passing through the combustor intact and being subsequently released into the environment. For most controlled combustor systems, this is not thought to be a major contributor to CDD/CDF emissions; however, for an uncontrolled open burn condition this may be otherwise.

The second mechanism (EPA, 2006) involves the formation of CDDs/CDFs from the thermal breakdown and molecular rearrangement of aromatic precursors either originating in the feed or forming as a product of incomplete combustion. Gaseous benzene is the most abundant aromatic compound associated with products of incomplete combustion of waste. Benzene reacts with Cl within the combustion gas plasma, causing aromatic H abstraction and the subsequent formation of chlorobenzenes and chlorophenols. Homogeneous gas-phase formation of CDDs/CDFs occurs from these precursor compounds at temperatures >500°C, catalyzed by the presence of copper compounds. In addition, the CDDs/CDFs can form from gas-phase precursors as heterogeneous, catalytic reactions with reactive fly ash surfaces. This reaction has been observed to be catalyzed by the presence of a transition metal sorbed to the fly ash. The most potent catalyst is $CuCl_2$. Relatively low temperatures—in the range of 200 to 450°C—have been identified as a necessary condition for these heterogeneous reactions to occur, with either lower or higher temperatures inhibiting the process.

Because these reactions involve homogeneous gas-phase and heterogeneous solid-phase chemistry, the rate of emissions is less dependent on reactant concentration than on conditions that are favorable to formation, such as temperature, retention time, source and species of chlorine, and the presence of a catalyst.

PCDD/Fs and their precursors actively arise within two temperature windows: between 500 and 800^{o}C “homogeneous” pyrogenic routes proceed in the gas phase and the “heterogeneous” catalytic routes relate to entrained and deposited particles between 200 and 500^{o}C (M. Zhang, et.al. 2017).

The third mechanism (EPA, 2006) for controlled combustion is *de novo* synthesis (from elemental carbon) involving the heterogeneous solid-phase formation of CDDs/CDFs in the post-combustion environment on the surface of fly ash. Such heterogeneous chemistry occurs in two ways: (1) directly from the oxidation of carbon within the fly ash and subsequent reactions with organic and inorganic chlorine, and (2) the oxidative breakdown of macromolecular carbon structures (e.g., graphite) and oxychlorination reactions of aromatic precursors (such as chlorobenzenes and chlorophenols) on fly ash surfaces, leading to CDD/CDF formation. In either case, formation kinetics is most favored at temperatures in the range of 200 to 450°C and is promoted by the catalytic properties of either the fly ash or the presence of a transition metal compound.

EPA (EPA, 2006) states that the second and third mechanisms (for controlled combustion processes) can occur simultaneously, share a number of common reaction pathways, and occur in the same physical environment, and they are controlled by many of the same physical conditions. In well-designed and well-operated combustion systems, the precursor species needed for the second mechanism are reduced; consequently *de novo* synthesis can become the dominant pathway for formation. In systems with incomplete combustion (such as open burning), it is difficult to sort out the relative contribution of these mechanisms to total emissions. The mechanisms, however, can be curtailed if steps are taken to minimize the physical conditions needed to support formation (i.e., time, temperature, and reactive surface).

Additional research conducted by the Navy at China Lake, California, addressed the formation of dioxins during OD treatment operations (NAVAIR, 2005). This research pointed out significant differences between OD of wastes and incineration of wastes. During incineration, dioxins are formed through recombination of combustion gases (e.g., oxygen, chlorine). Very specific conditions are needed to form dioxins, including a temperature range of 250 to 450 degrees Celsius (^{o} C) (482^{o} F to 842^{o} F), and a residence time of seconds to minutes. These conditions are common in incinerators, but not present during OD operations. OD occurs in microseconds and the afterburning phase is complete in seconds. Temperatures during OD operations can range from about 2500° C to 5600° C and the temperatures associated with afterburning are on the order of 1700° C (Boggs, T., et.al., 2004). These higher temperature causes the dioxin precursor molecules to fall apart. Also, OD operations occur at very high pressures on the order of hundreds of kilo bars, while incinerators operate at ambient pressure.

As described in the draft AP-42, Chapter 16 (AP-42, 2009) for detonations, the intramolecular rearrangement is so fast that only a small percentage of the atoms in one molecule have time to react with atoms in adjacent energetic molecules that are decomposing at the exact same time. Because the detonation of explosives does not require air, it can occur in a vacuum, in an inert atmosphere, or even under water. The initial detonation products are free carbon (soot), carbon monoxide, hydrogen, methane, ethane, formaldehyde, nitrogen, carbon dioxide, water vapor, small hydrocarbons and small CxHy fragments. The initial stage of the detonation process is over in less than 10 microseconds and is followed by a 2 to 10 second duration fireball (afterburn). In this second stage of the process, combustible detonation reaction products (e.g., carbon monoxide, methane, ethane, formaldehyde, hydrogen and the CxHy fragments) are spontaneously oxidized (combusted) to CO2 and H2O. Fireball temperatures are on the order of 1,700 to 3,100° F. As the plume expands it entrains additional air which allows further combustion reactions to take place until the plume temperature falls to approximately 1,500° F (815° C) where these reactions stop.

Because of this, dioxins are not formed during OD operations and so dioxins/furans are not considered emissions during OD operations at TA-36 and TA-39 and are not included in the modeling exercise.

For VOC emissions, section 2.1.4.3 of the background document for the draft Chapter 16, the SNL and DPG test results had demonstrated conclusively that the VOCs emitted were almost exclusively the first members of the alkane, alkene, and alkyne classes of hydrocarbons and the first members of the aromatic hydrocarbon class, of which benzene is the most toxic. A key point was that for every energetic material detonated in the SNL study and on the test range at DPG, benzene represented a substantial percentage of the total mass of the aromatic hydrocarbons found, but was only 2.0% of the total mass for all of the non-methane hydrocarbons (TNMHCs).

The emission products and related EFs used in the modeling exercise for OD operations at TA-36 and TA-39 are shown in Table 3-1. These emission factors are based primarily on Table 16.2-14, Summary Statistics for the Detonation Data Sets from the Draft AP-42 Chapter 16. A list of explosives detonated at the units was developed from the operating record and is included in Attachment A (List of all RCRA waste explosives detonated). The chemicals have been placed into categories and there is a single EF for each category. Categories can generally be described to be components of the waste stream itself (e.g. energetics, metals, and fuel) or constituents produced as part of the treatment process (i.e. Emissions Products). The list of emission products (EPs) and EFs in Attachment B were derived from a list of explosives and explosive-contaminated waste detonated at the TA-36-8 OD unit as described in Attachment A.

Subsequent work and OD plume studies have been conducted since 2010 as part of program under the direction of Dr. Clift and the program studies have been conducted by a group led by Dr. Brian Gullett. Dr. Keith Clift is the Demil Capabilities Division Chief for the Demil Directorate at the Joint Munitions Command. Dr. Clift's program has continued OB/OD emissions testing with Dr. Gullet's team for the two-fold purpose: 1) to continue to fill data gaps for OB/OD emissions factors (i.e., covered OD data gaps, etc.), and 2) to increase both the quantity and representativeness of the data by collecting open air/live fire data from actual production OB/OD demil operations. Some of the testing is being done because of the improved sampling methods and/or analytical methods available. This includes the use of drones allowing for much improved latitude to sample emissions within the dynamic OB/OD plume. Presently, interim data processing is being performed. The program is an ongoing effort to enhance and improve the data quality of existing OB/OD emission factors.

Dr. Gullett is the Senior Professional Research Engineer for the Air and Energy Management Division at the National Risk Management Research Laboratory at the Office of Research and Development for the U.S. Environmental Protection Agency in the Research Triangle Park in North Carolina. Dr. Gullett is the lead researcher for the Joint Munitions Command (JMC) demil program for OB/OD studies. Dr. Gullett's team has compiled a database on OB/OD EFs since 2010 for the military's Joint Munitions Command. This database references data that have gone through the EPA's QA review process and are published in public journals or DoD reports. Presently, the published journals and DoD reports available for public review have little or no additional information on (uncovered) open range detonations, such as those being conducted at LANL. Additional studies, including those for uncovered open range detonations are planned for 2020. Once the database is available, the data should be more representative and extensive than that obtained in past measurements.

For this application submittal, the draft Chapter 16 for AP-42 represents the most current publicly available information as prepared for the U.S. Army Defense Ammunition Center, McAlester, OK under Contract Number DACA 87-02-D0028.

Table 3-1

Emission Products and Emission Factors Used in Screening Analysis for OD Operations

Emission Products	CAS RN	Maximum EF[1] for OD	UOM as listed in draft AP-42 Ch. 16	UOM as applied for modeling
PM-10	N/A	1.1E+01	lb/lb NEW	lb/lb Waste[2]
Carbon Monoxide	630-08-0	2.0E-01	lb/lb C	lb/lb Waste[2]
Carbon Dioxide	124-38-9	3.90E+00	lb/lb C	lb/lb Waste[2]
Nitrogen Oxides	N/A	3.2E-01	lb/lb N	lb/lb Waste[2]
Sulfur Dioxide	7446-09-5	1.4E-03	lb/lb NEW	lb/lb Waste[2]
Energetics	N/A	2.0E-06	lb/lb Energetic	lb/lb Waste[2]
Semi-volatile organic compounds (SVOCs) in Energetic	N/A	1.00E-08	lb/ lb SVOC	lb/lb Waste
SVOCs Not in Energetic	N/A	2.0E-06	lb/lb NEW	lb/lb Waste[2]
Benzene	71-43-2	6.0E-04	lb/lb C	lb/lb Waste[2]
TNMHC	N/A	3.4E-02	lb/lb C	lb/lb Waste[2]
Acetylene	74-86-2	1.8E-03	lb/lb C	lb/lb Waste[2]
Ethylene	74-85-1	2.3E-03	lb/lb C	lb/lb Waste[2]
Methylene Chloride	75-09-2	2.4E-03	lb/lb C	lb/lb Waste[2]
Propylene	115-07-1	4.1E-04	lb/lb C	lb/lb Waste[2]
Toluene	108-88-3	1.9E-04	lb/lb C	lb/lb Waste[2]
Naphthalene (as SVOC)	91-20-3	2.0E-06	lb/lb NEW	lb/lb Waste[2]
Metals in Energetic As Particle (or Elemental)	N/A	1.4E-01	lb/lb Metal	lb metal/lb Waste[2,3]
Metals In Energetic As Compound	N/A	7.8E-01	lb/lb Metal	lb metal/lb Waste[2,3]
Metals In Alloys	N/A	2.0E-01	lb/lb Metal	lb metal/lb Waste[2,3]

[1] EF = emission factor. The maximum EF as listed in AP-42 Chapter 16 draft are used in the calculation of the ground level concentration.

[2] Application of the EF to the weight of waste processed in lieu of the initial draft Ch. 16 value is a conservative estimate of emissions.

[3] Based on the data listed in Attachment A, the lb/lb waste calculation is adjusted for the amount of metal per lb of waste using a factor of 0.092 lb metal/lb waste.

4.0 Screening Levels

Air quality impacts were evaluated against EPA National Ambient Air Quality Standards (NAAQS) and New Mexico Ambient Air Quality Standards (NMAAQS) and EPA-recommended toxic air pollutant screening levels for acute and chronic exposures. Deposition impacts were evaluated with NMED and EPA screening levels.

4.1 Ambient Air Quality Standards

EPA has NAAQS for particulate matter (PM_{10} and $PM_{2.5}$), lead, sulfur dioxide, carbon monoxide, nitrogen dioxide, and ozone. NMAAQS are established for sulfur dioxide, carbon monoxide, and nitrogen dioxide. Both the NAAQS and NMAAQS are set for multiple averaging periods ranging from 1 hour to an annual basis for EPA and NMED air permitting purposes. The ambient standards do not apply within the boundary of the permitted facility. This analysis followed this long-standing protocol. The screening analysis did not include the NAAQS for ozone. Dispersion models such as OBODM for OD sources do not simulate photochemical reactions and ozone formation impacts are not considered significant (EPA, 2002).

4.2 Toxic Air Pollutant Screening Levels

EPA's *OBOD Permitting Guidelines* (EPA, 2002) suggest evaluating both short-term (acute) and long-term (chronic and cancer) risk-based impacts, as follows:

Short-term impacts were evaluated using the acute inhalation exposure concentrations (AIEC) from the Human Health Risk Assessment Protocol Companion Database (HHRAP Database) to EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA, 2005). This database includes the acute inhalation sources listed in Section 4.1.4 of the *OBOD Permitting Guidelines* (EPA, 2002). The Non-Cancer Acute Inhalation RELs for Airborne Toxicants were also listed as established in the Air Toxics Hot Spots Program's Guidance Manual for Preparation of Health Risk Assessments (Appendix L) developed by the California Office of Environmental Health Hazard Assessment (OEHHA, February 2015). The available data from the HHRAP Database (AEIC) or the RELs were used for the assessments in Table 5-3 and 5-4. Where both databases provided a value for a given constituent, the lesser and more conservative of the two values was applied. The OEHHA data was also used for the Non-Cancer Chronic Inhalation RELs.

Long-term chronic non-cancer impacts were evaluated using the Regional Screening Levels (RSLs) - Generic Tables (November 2019) (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables). For the EPA RSLs, the Non-Cancer Resident Air RSL Chronic value for THI = 0.1 was listed in the table provided in Attachment B. This value was compared to the CA-OEHHA non-cancer chronic reference exposure level (REL) provided in $\mu g/m^3$. Where the two databases provided a chronic RSL for the same chemical constituent, the lesser and more conservative of the two values was used to compare to the annual impact concentrations, i.e. acrylonitrile.

4.3 Deposition Screening Levels

Screening levels for deposition were compared to an estimated 10-year impact to show a quantitative estimate over the anticipated lifetime of the permit. Deposition of pollutants was compared to the NMED Cancer and Non-Cancer Human Health Residential Soil Screening Levels (SSLs) (NMED, 2019), or the EPA Cancer and Non-Cancer RSLs for Resident Soil (EPA, 2019) where NMED values are not listed. For Attachment B, the lesser screening level for the Cancer (TR=1E-06) and Non-Cancer (HI=0.1) EPA RSLs is listed. The EPA RSL is applied when an NMED value is not available. The estimated 10-year soil concentrations were also compared to the LANL-derived ecological screening levels (ESLs) obtained from the ECORSK Database, Version 2.5 (LANL, 2019).

5.0 Results

Modeled impacts through the use of OBODM in this report assumed the detonation plume travels in a straight line in each given hour. This conservatively calculates the maximum impact at a given receptor by maintaining the target receptor along the plume centerline for the averaging period with the least amount of dispersion. For receptors in complex terrain, this is unlikely to occur with additional dispersion occurring in practicality. In addition, the modeling approach used did not use any option to reduce downwind concentrations through either deposition or depletion of the detonation plume as it moves from the site to a given receptor. In reality, these mechanisms would lower projected impacts.

EXCEL® spreadsheets were used to calculate constituent-specific air and soil concentrations and for comparison to appropriate screening levels (see Attachment C). For each OD site the following calculations and comparisons were made:

- Maximum 1-, 3-, 8-, 24-hour, quarterly (Pb) concentrations and annual average concentrations were calculated and compared to the NAAQS and NMAAQS for public receptors;
- Maximum 1-hour concentrations were calculated and compared to AIEC acute values or CA-OEHHA acute RELs, or the lesser of the two where both values exist;
- Annual average air concentrations were calculated and compared to the lesser of the CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3) and EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3);
- Soil concentrations from deposition were calculated and compared to NMED Human Health Cancer and Non-Cancer Residential Soil SSLs. Where NMED data was not available, EPA RSL screening levels for Residential Soil were applied. Where both Cancer and Non-Cancer values existed, the lesser of the two was listed in the table provided in Attachment A. EPA Carcinogenic SL values are based on a target risk of TR=1E^{-06} and Non-Carcinogenic SL Child values are based on a Target Hazard Index (THI) of 0.1 (mg/kg). The LANL-derived ESLs are also included for review and comparison and in some cases was the only value available for soil concentrations.
- Concentrations for emission products were calculated whether there was a screening level or not. A comparison of the calculated values from model results with the EPA and NMED ambient air quality standards are summarized in Tables 5-1 and 5-2. In cases where there is a NAAQS and NMAAQS for the same pollutant and same averaging period, the more stringent standard is referenced in the tables. Background concentrations for all forms of particulate matter have been added to model results as specified by NMED and the total value is shown in the tables for comparison to standards (NMED, 2019).

The Ambient Air Quality Standard (AAQS) included within Tables 5-1 and 5-2 is the more stringent of the applicable NAAQS or NMAAQS in cases where there is both an EPA NAAQS and a New Mexico NMAAQS. All calculations used in providing results, as well as all NAAQS and NMAAQS, are shown in the spreadsheets included in Attachment C.

This analysis was conducted using the highest maximum model result which occurred at any public receptor. Receptors on LANL property were not used as is the protocol under NMED modeling guidelines when demonstrating compliance with ambient air quality standards for permit purposes (NMED, 2019). In this respect, NMED follows EPA direction in regards to the definition of *ambient air* which defines where the air quality standards are applicable.

As demonstrated in the tables, no AAQS are projected to be exceeded by the model results. All results are conservatively predicted; as presented in Tables 5-1 and 5-2. Tables 5-3a, -3b, -3c , -4a, -4b and -4c compare the calculated values from model results with the acute and chronic air health screening levels and the soil deposition screening and LANL ESL levels. Because OBODM cannot estimate deposition in complex terrain such as present within the LANL site, an alternative approach was needed. Gravitational deposition would be significant only for relatively large particles deposited close the detonation sites. Wet deposition should be insignificant for detonations which occur infrequently and never during precipitation events. Thus, non-gravitational dry deposition should be the major contributor to soil concentrations of contaminants. This type of deposition was conservatively estimated using the calculation provided by the California EPA for air toxics analyses found in the document *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (CA OEHHA, 2015).

There are several levels of conservatism present in the deposition estimates using this approach. First, the annual contaminant air concentration used in the calculation is based on running OBODM using the maximum permitted annual waste detonated placed within the hours of the year predicted to yield maximum concentrations from the hourly air concentration model runs. Second, the single maximum annual air concentration is used which is a non-depleted value, e.g. there is no removal of contaminant mass from the detonation cloud as a function of downwind distance. In the calculation, it is assumed there is no degradation of organic compounds in the soil over time which again results in an over prediction of soil concentrations during the 10 year estimate. The deposition rate or Dep-rate used was the CAL EPA recommended value for an uncontrolled source which is 0.05 meters/second.

Using this procedure, soil concentrations were calculated using the maximum annual air concentrations for each contaminant predicted by OBODM. The calculation is shown below:

$C_s = Dep * X / (K_s * SD * BD * T_t)$

Dep = Deposition on the affected soil area per day (µg/m^2/d)

Dep = GLC * Dep-rate * 86,400

GLC = chemical specific annual ground level concentration from OBODM result and emission factor (µg/m^3)

Dep-rate = 0.05 m/sec (default value for uncontrolled source)

86,400 = Seconds per day conversion factor

$X = [\{e^{-Ks * Tf} - e^{-Ks * To}\} / K_s] + T_t$

e = 2.718

K_s = Soil elimination constant = 6.93 x 10^{-9} (no degradation of contaminant in soil assumed)

T_f = End of evaluation period (d) = 3650

T_o = Beginning of evaluation period (d) = 0

T_t = Total days of exposure period T_f - T_o (d) = 3650 (ten year period)

SD = Soil mixing depth (m) = 0.01 for soil ingestion or dermal pathway (analysis is on Laboratory property)

BD = Soil bulk density (kg/m^3) = 1,333

Table 5-1
Air Quality Standards Results for TA-36-8[1]

Pollutant	Averaging Time	Maximum Concentration ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?
Nitrogen Dioxide					
(As NOX)	1-hour	6.19E-01	188.03	none	No
	24-hour	6.35E-02	none	188.03	No
	Annual	2.67E-08	99.66	94.02	No
Carbon Monoxide					
	1-hour	3.87E-01	40069.6	14997.5	No
	8-hour	1.15E-01	10303.6	9960.1	No
Sulfur Dioxide					
	1-hour	2.71E-03			
Background(10)	1-hour	1.32E+01			
Total	1-hour	1.32E+01	196.40	none	
	3-hour	1.50E-03	1309.30	none	No
	24-hour	2.78E-04	none	261.90	No
	Annual	1.17E-10	none	52.40	No
PM_{10}					
	24-hour	2.18E+00			
Background(7)		2.30E+01			
Total		2.52E+01	150	none	No
$PM_{2.5}$					
	24-hour	2.18E+00			
Background(8)		9.45E+00			
Total		1.16E+01	35	none	No
	Annual	9.18E-07			
Background(9)		4.32E+00			
Total		4.32E+00	12	none	No
Lead	Quarterly	1.42E-02	0.15	none	No

[1] Calculations used are included in Attachment C.

[2] The more stringent of the applicable NAAQS or NMAAQS in cases where both standards exist.

Table 5-2

Air Quality Standards Results for TA-39-6[1]

Pollutant	Averaging Time	Maximum Concentration ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?
Nitrogen Dioxide					
	1-hour	2.63E+00	188.03	none	No
	24-hour	6.47E-02	none	188.03	No
	Annual	3.33E-06	99.66	94.02	No
Carbon Monoxide					
	1-hour	1.65E+00	40069.6	14997.5	No
	8-hour	1.22E-01	10303.6	9960.1	No
Sulfur Dioxide					
	1-hour				
Background(10)	1-hour				
Total	1-hour		196.40	none	
	3-hour	1.24E-03	1309.30	none	No
	24-hour	2.83E-04	none	261.90	No
	Annual	1.46E-08	none	52.40	No
PM$_{10}$					
	24-hour	2.22E+00			No
Background(7)		2.30E+01			
Total		2.52E+01	150.00	none	
PM$_{2.5}$					
	24-hour	2.22E+00			No
Background(8)		9.45E+00			
Total		1.17E+01	35.00	none	
	Annual	1.15E-04			No
Background(9)		4.32E+00			
Total		4.32E+00	12.00	none	
Lead	Quarterly	1.45E-02	0.15	none	No

[1] Calculations used are included in Attachment C.

[2] The more stringent of the applicable NAAQS or NMAAQS in cases where both standards exist.

Table 5-3a

Acute Health Screening Level Results for TA-36-8

Contaminant	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Carbon Monoxide (1)	1.19E+01	-	2.30E+04	No
Nitrogen Oxides (as NO_2 only)	1.91E+01	-	4.70E+02	No
Sulfur Dioxide (1)	8.35E-02	-	6.60E+02	No
Benzene (1)	3.58E-02	1.30E+03	2.70E+01	No
TNMHC (1)	2.03E+00	-	-	-
Acetylene (1)	1.07E-01	-	-	-
Ethylene (1)	1.37E-01	-	-	-
Propylene (1)	2.45E-02	-	-	-
Toluene (1)	1.13E-02	3.70E+04	3.70E+04	No
Naphthalene (2)	1.19E-04	7.50E+04	-	No
Methylene Chloride (1)	1.43E-01	1.40E+04	1.40E+04	No
Aluminum Oxide (3)	4.65E+01	-	-	-
Barium(3)	4.65E+01	1.50E+03	-	No
Cobalt Acetoacetonate (3)	4.65E+01	-	-	-
Copper (3)	4.65E+01	-	1.00E+02	No
Lead (3)	4.65E+01	1.50E+02	-	No
Trioctyl phosphate (3)	4.65E+01	-	-	-
Tungsten Trioxide (3)	4.65E+01	-	-	-
Aluminum (4)	8.35E+00	-	-	-
Titanium (4)	8.35E+00	-	-	-
Tungsten (4)	8.35E+00			
Ammonium perchlorate (2)	1.19E-04	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	1.19E-04	-	-	-
Nitrocellulose (2)	1.19E-04	-	-	-
Nitroguanidine (2)	1.19E-04	-	-	-
Nitromethane (2)	1.19E-04	-	-	-
Pentaerythritol tetranitrate (PETN) (2)	1.19E-04	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	1.19E-04	-	-	-
Tetryl (2)	1.19E-04	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	1.19E-04	1.50E+03	-	No
Acrylonitrile (5)	5.96E-07	2.18E+04	-	No
Bis(2-ethylhexyl)adipate (5)	5.96E-07	-	-	-
tris-2-chloroethyl phosphate (5)	5.96E-07	-	-	-
Dibutylphthalate (5)	5.96E-07	1.50E+04	-	No
Dinitrotoluene (2,4-) (note #5)	5.96E-07	6.00E+02	-	No
Dioctyladipate (5)	5.96E-07	-	-	-
Dioctylphthalate (5)	5.96E-07	1.00E+04	-	No
Diphenylamine (5)	5.96E-07	-	-	-

Notes:

See Attachment C for detailed calculations.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

Table 5-3b

Chronic Health Screening Level Results for TA-36-8

Contaminant	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Carbon Monoxide (1)	2.66E-06	-	-	-
Nitrogen Oxides (as NO_2 only)	4.25E-06	-	-	-
Sulfur Dioxide (1)	1.86E-08	-	-	-
Benzene (1)	7.97E-09	3.00E+00	3.1E+01	No
TNMHC (1)	4.52E-07	-	-	-
Acetylene (1)	2.39E-08	-	-	-
Ethylene (1)	3.05E-08	-	-	-
Propylene (1)	5.44E-09	3.00E+03	3.1E+02	No
Toluene (1)	2.52E-09	3.00E+02	5.2E+02	No
Naphthalene (2)	2.66E-11	9.00E+00	3.1E-01	No
Methylene Chloride (1)	3.19E-08	4.00E+02	6.3E+01	No
Aluminum Oxide (3)	9.53E-07	-	5.20E-01	No
Barium (3)	9.53E-07	-	5.20E-02	No
Cobalt Acetoacetonate (3)	9.53E-07	-	6.30E-04	No
Copper (3)	9.53E-07	-	-	-
Lead (3)	9.53E-07	-	1.5E-01	No
Trioctyl phosphate (3)	9.53E-07	-	-	-
Tungsten Trioxide (3)	9.53E-07	-	-	-
Aluminum (4)	1.71E-07	-	5.20E-01	No
Titanium (4)	1.71E-07	-	-	-
Tungsten (4)	1.71E-07	-	-	-
Ammonium perchlorate (2)	2.66E-11	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	2.66E-11	-	-	-
Nitrocellulose (2)	2.66E-11	-	-	-
Nitroguanidine (2)	2.66E-11	-	-	-
Nitromethane (2)	2.66E-11	-	5.20E-01	No
Pentaerythritol tetranitrate (PETN) (2)	2.66E-11	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	2.66E-11	-	-	-
Tetryl (2)	2.66E-11	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	2.66E-11	-	-	-
Acrylonitrile (5)	1.33E-13	5.00E+00	6.30E+00	No
Bis(2-ethylhexyl)adipate (5)	1.33E-13	-	-	-
tris-2-chloroethyl phosphate (5)	1.33E-13	-	-	-
Dibutylphthalate (5)	1.33E-13	-	-	-
Dinitrotoluene (2,4-) (note #5)	1.33E-13	-	-	-
Dioctyladipate (5)	1.33E-13	-	-	-
Dioctylphthalate (5)	1.33E-13	-	-	-
Diphenylamine (5)	1.33E-13	-	-	-

Notes:

See Attachment C for detailed calculations.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

Table 5-3c

Residential Soil Screening Level and LANL ESL Screening Level Results for TA-36-8

Contaminant	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum LANL ESL mg/kg	Receptor	ESL exceeded?
Carbon Monoxide	1.57E-03	-	-	-	-	-	-	-
Nitrogen Oxides (as NO_2 only)	2.51E-03	-	-	-	-	-	-	-
Sulfur Dioxide	1.10E-05	-	-	-	-	-	-	-
Benzene	4.71E-06	1.14E+02	1.78E+01	1.20E+00	No	2.40E+02	Deer mouse	No
TNMHC	2.67E-04	-	-	-	-	-	-	-
Acetylene	1.41E-05	-	-	-	-	-	-	-
Ethylene	1.81E-05	-	-	-	-	-	-	-
Propylene	3.22E-06	-	-	2.20E+02	No	-	-	-
Toluene	1.49E-06	5.23E+03	-	4.90E+02	No	2.30E+01	Montane shrew	No
Naphthalene	1.57E-08	1.62E+02	4.97E+01	1.22E+02	No	1.00E+00	Plant	No
Methylene Chloride	1.88E-05	4.09E+02	7.66E+02	3.50E+01	No	2.60E+00	Deer mouse	No
Aluminum Oxide	5.64E-04	7.80E+04	-	7.70E+03	No	-	-	-
Barium	5.64E-04	1.56E+04	-	1.50E+03	No	1.10E+02	Plant	No
Cobalt Acetoacetonate	5.64E-04	2.34E+01	1.72E+04	2.30E+00	No	1.30E+01	Plant	No
Copper	5.64E-04	3.13E+03	-	3.10E+02	No	1.40E+01	American robin	No
Lead	5.64E-04	4.00E+02	-	4.00E+02	No	1.10E+01	American robin	No
Trioctyl phosphate	5.64E-04	-	-	1.70E+02	No	-	-	-
Tungsten Trioxide	5.64E-04	-	-	6.30E+00	No	-	-	-
Aluminum	1.01E-04	7.80E+04	-	7.70E+03	No	-	-	-
Titanium	1.01E-04	-	-	-	-	7.70E+01	Montane shrew	No
Tungsten	1.01E-04	-	-	6.30E+00	No	-	-	-
Ammonium perchlorate	1.57E-08	-	-	5.50E+00	No	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX)	1.57E-08	3.85E+03	-	3.90E+02	No	1.60E+01	Earthworm	No
Nitrocellulose	1.57E-08	-	-	1.90E+07	No	-	-	-
Nitroguanidine	1.57E-08	-	-	6.30E+02	No	-	-	-
Nitromethane	1.57E-08	-	-	5.40E+00	No	-	-	-
Pentaerythritol tetranitrate (PETN)	1.57E-08	-	-	1.30E+01	No	1.00E+02	Deer mouse	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.57E-08	3.01E+02	8.31E+01	8.30E+00	No	2.30E+00	American robin	No
Tetryl	1.57E-08	1.56E+02	-	1.60E+01	No	1.50E+00	Deer mouse	No
2,4,6-trinitrotoluene (TNT)	1.57E-08	3.60E+01	2.11E+02	3.60E+00	No	7.50E+00	American robin	No
Acrylonitrile	7.85E-11	-	-	8.10E+01	No	-	-	-
Bis(2-ethylhexyl)adipate	7.85E-11	-	-	4.50E+02	No	-	-	-
tris-2-chloroethyl phosphate	7.85E-11	-	-	2.70E+01	No	-	-	-

Contaminant	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum LANL ESL mg/kg	Receptor	ESL exceeded?
Dibutylphthalate	7.85E-11	6.16E+03	-	6.30E+02	No	1.10E-02	American robin	No
Dinitrotoluene (2,4-)	7.85E-11	1.23E+02	1.71E+01	1.70E+00	No	6.00E+00	Plant	No
Dioctyladipate	7.85E-11	-	-	4.50E+02	No	-	-	-
Dioctylphthalate	7.85E-11	1.23E+03	3.80E+02	3.90E+01	No	9.10E-01	Montane shrew	No
Diphenylamine	7.85E-11	-	-	6.30E+02	No	1.00E+01	Robin insectivore	No

See Attachment C for detailed calculations.

Table 5-4a

Acute Health Screening Level Results for TA-39-6

Contaminant	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Carbon Monoxide (1)	3.88E+01	-	2.30E+04	No
Nitrogen Oxides (as NO_2 only)	6.21E+01	-	4.70E+02	No
Sulfur Dioxide (1)	2.72E-01	-	6.60E+02	No
Benzene (1)	1.16E-01	1.30E+03	2.70E+01	No
TNMHC (1)	6.60E+00	-	-	-
Acetylene (1)	3.49E-01	-	-	-
Ethylene (1)	4.46E-01	-	-	-
Propylene (1)	7.96E-02	-	-	-
Toluene (1)	3.69E-02	3.70E+04	3.70E+04	No
Naphthalene (2)	3.88E-04	7.50E+04	-	No
Methylene Chloride (1)	4.66E-01	1.40E+04	1.40E+04	No
Aluminum Oxide (1a, 3)	1.39E+01	-	-	-
Barium(1a, 3)	1.39E+01	1.50E+03	-	No
Cobalt Acetoacetonate (1a, 3)	1.39E+01	-	-	-
Copper (1a, 3)	1.39E+01	-	1.00E+02	No
Lead (1a, 3)	1.39E+01	1.50E+02	-	No
Trioctyl phosphate (1a, 3)	1.39E+01	-	-	-
Tungsten Trioxide (1a, 3)	1.39E+01	-		
Aluminum (4)	2.50E+00	-	-	-
Titanium (4)	2.50E+00	-	-	-
Tungsten (4)	2.50E+00			
Ammonium perchlorate (2)	3.88E-04	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	3.88E-04	-	-	-
Nitrocellulose (2)	3.88E-04	-	-	-
Nitroguanidine (2)	3.88E-04	-	-	-
Nitromethane (2)	3.88E-04	-	-	-
Pentaerythritol tetranitrate (PETN) (2)	3.88E-04	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	3.88E-04	-	-	-
Tetryl (2)	3.88E-04	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	3.88E-04	1.50E+03	-	No
Acrylonitrile (5)	1.94E-06	2.18E+04	-	No
Bis(2-ethylhexyl)adipate (5)	1.94E-06	-	-	-
tris-2-chloroethyl phosphate (5)	1.94E-06	-	-	-
Dibutylphthalate (5)	1.94E-06	1.50E+04	-	No
Dinitrotoluene (2,4-) (5)	1.94E-06	6.00E+02	-	No
Dioctyladipate (5)	1.94E-06	-	-	-
Dioctylphthalate (5)	1.94E-06	1.00E+04	-	No
Diphenylamine (5)	1.94E-06	-	-	-

Notes:

See Attachment C for detailed calculations.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic.

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

Table 5-4b

Chronic Health Screening Level Results for TA-39-6

Contaminant	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Carbon Monoxide (1)	7.72E-05	-	-	-
Nitrogen Oxides (as NO_2 only)	1.24E-04	-	-	-
Sulfur Dioxide (1)	5.41E-07	-	-	-
Benzene (1)	2.32E-07	3.00E+00	3.10E+01	No
TNMHC (1)	1.31E-05	-	-	-
Acetylene (1)	6.95E-07	-	-	-
Ethylene (1)	8.88E-07	-	-	-
Propylene (1)	1.58E-07	3.00E+03	3.10E+02	No
Toluene (1)	7.34E-08	3.00E+02	5.20E+02	No
Naphthalene (2)	7.72E-10	9.00E+00	3.10E-01	No
Methylene Chloride (1)	9.27E-07	4.00E+02	6.30E+01	No
Aluminum Oxide (3)	2.77E-05	-	5.20E-01	No
Barium (3)	2.77E-05	-	5.20E-02	No
Cobalt Acetoacetonate (3)	2.77E-05	-	6.30E-04	No
Copper (3)	2.77E-05	-	-	-
Lead (3)	2.77E-05	-	1.50E-01	No
Trioctyl phosphate (3)	2.77E-05	-	-	-
Tungsten Trioxide (3)	2.77E-05	-	-	-
Aluminum (4)	4.97E-06	-	5.20E-01	No
Titanium (4)	4.97E-06	-	-	-
Tungsten (4)	4.97E-06	-	1.52E+00	-
Ammonium perchlorate (2)	7.72E-10	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	7.72E-10	-	-	-
Nitrocellulose (2)	7.72E-10	-	-	-
Nitroguanidine (2)	7.72E-10	-	-	-
Nitromethane (2)	7.72E-10	-	5.20E-01	No
Pentaerythritol tetranitrate (PETN) (2)	7.72E-10	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	7.72E-10	-	-	-
Tetryl (2)	7.72E-10	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	7.72E-10	-	-	-
Acrylonitrile (5)	3.86E-12	5.00E+00	6.30E+00	No
Bis(2-ethylhexyl)adipate (5)	3.86E-12	-	-	-
tris-2-chloroethyl phosphate (5)	3.86E-12	-	-	-
Dibutylphthalate (5)	3.86E-12	-	-	-
Dinitrotoluene (2,4-) (note #5)	3.86E-12	-	-	-
Dioctyladipate (5)	3.86E-12	-	-	-
Dioctylphthalate (5)	3.86E-12	-	-	-
Diphenylamine (5)	3.86E-12	-	-	-

Notes:

See Attachment C for detailed calculations.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

Table 5-4c
Residential Soil Screening Level and LANL ESL Screening Level Results for TA-39-6

Contaminant	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs (4) - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum (No Effect) LANL ESL mg/kg	Receptor	ESL exceeded?
Carbon Monoxide	4.57E-02	-	-	-	-	-	-	-
Nitrogen Oxides (as NO_2 only)	7.31E-02	-	-	-	-	-	-	-
Sulfur Dioxide	3.20E-04	-	-	-	-	-	-	-
Benzene	1.37E-04	1.14E+02	1.78E+01	1.20E+00	No	2.40E+02	Deer mouse	No
TNMHC	7.77E-03	-	-	-	-	-	-	-
Acetylene	4.11E-04	-	-	-	-	-	-	-
Ethylene	5.25E-04	-	-	-	-	-	-	-
Propylene	9.36E-05	-	-	2.20E+02	No	-	-	-
Toluene	4.34E-05	5.23E+03	-	4.90E+02	No	2.30E+01	Montane shrew	No
Naphthalene	4.57E-07	1.62E+02	4.97E+01	1.22E+02	No	1.00E+00	Plant	No
Methylene Chloride	5.48E-04	4.09E+02	7.66E+02	3.50E+01	No	2.60E+00	Deer mouse	No
Aluminum Oxide	1.64E-02	7.80E+04	-	7.70E+03	No	-	-	-
Barium	1.64E-02	1.56E+04	-	1.50E+03	No	1.10E+02	Plant	No
Cobalt Acetoacetonate	1.64E-02	2.34E+01	1.72E+04	2.30E+00	No	1.30E+01	Plant	No
Copper	1.64E-02	3.13E+03	-	3.10E+02	No	1.40E+01	American robin	No
Lead	1.64E-02	4.00E+02	-	4.00E+02	No	1.10E+01	American robin	No
Trioctyl phosphate	1.64E-02	-	-	1.70E+02	No	-	-	-
Tungsten Trioxide	1.64E-02	-	-	6.30E+00	No	-	-	-
Aluminum	2.94E-03	7.80E+04	-	7.70E+03	No	-	-	-
Titanium	2.94E-03	-	-	-	-	7.70E+01	Montane shrew	No
Tungsten	2.94E-03	-	-	6.30E+00	No	-	-	-
Ammonium perchlorate	4.57E-07	-	-	5.50E+00	No	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX)	4.57E-07	3.85E+03	-	3.90E+02	No	1.60E+01	Earthworm	No
Nitrocellulose	4.57E-07	-	-	1.90E+07	No	-	-	-
Nitroguanidine	4.57E-07	-	-	6.30E+02	No	-	-	-
Nitromethane	4.57E-07	-	-	5.40E+00	No	-	-	-
Pentaerythritol tetranitrate (PETN)	4.57E-07	-	-	1.30E+01	No	1.00E+02	Deer mouse	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	4.57E-07	3.01E+02	8.31E+01	8.30E+00	No	2.30E+00	American robin	No
Tetryl	4.57E-07	1.56E+02	-	1.60E+01	No	1.50E+00	Deer mouse	No
2,4,6-trinitrotoluene (TNT)	4.57E-07	3.60E+01	2.11E+02	3.60E+00	No	7.50E+00	American robin	No
Acrylonitrile	2.28E-09	-	-	8.10E+01	No	-	-	-
Bis(2-ethylhexyl)adipate	2.28E-09	-	-	4.50E+02	No	-	-	-
tris-2-chloroethyl phosphate	2.28E-09	-	-	2.70E+01	No	-	-	-
Dibutylphthalate	2.28E-09	6.16E+03	-	6.30E+02	No	1.10E-02	American robin	No
Dinitrotoluene (2,4-)	2.28E-09	1.23E+02	1.71E+01	1.70E+00	No	6.00E+00	Plant	No
Dioctyladipate	2.28E-09	-	-	4.50E+02	No	-	-	-
Dioctylphthalate	2.28E-09	1.23E+03	3.80E+02	3.90E+01	No	9.10E-01	Montane shrew	No
Diphenylamine	2.28E-09	-	-	6.30E+02	No	1.00E+01	Robin insectivore	No

See Attachment C for detailed calculations.

5.1 Discussion of Results

Dispersion modeling was used to predict maximum ground-level concentrations of contaminants that occur downwind from detonation sites. Model input parameters were selected that conservatively reflect the characteristics of waste streams treated through OD at the sites. Receptors were used in the modeling to estimate concentrations close to the detonation sites as well as public receptors nearby. The hourly and annual maximum waste quantities to be treated were also used in the model input. Model results indicated the maximum GLCs for each site occur on LANL property within the receptor grids adjacent to the sites. Predicted concentrations at public receptors were far less than impacts within the LANL property boundary. Thus, the maximum impact used in the health screening analysis was the maximum value on LANL property. Impacts at public areas would be much less.

Model results were applied to emission factors for each predicted contaminant and the results compared to air quality standards and recommended health screening levels where they were identified. All calculations are included in Attachment C and summarized in Tables 5-1 through 5-4. The results show predicted impacts for acute and annual air concentrations to be below all health screening levels. Additionally, predicted soil deposition over a 10-year period shows impacts to soil concentrations to be less than residential screening levels and less than the minimum identified ESLs.

The air screening analysis conducted by LANL and detailed within this report was designed to provide a very conservative air dispersion and deposition impact analysis for OD waste treatment operations at LANL. Input parameters were used as conservatively as deemed reasonable, emission products and related constituents were obtained from a third party based on waste treated at LANL (CCS, 2011), emission factors were based on AP-42, draft Chapter 16 and background document, the quantities of waste assessed were the maximum amounts of waste that could possibly be treated at the OD units, and all potential impacts were found to be below identified screening levels. Additionally, routine OD operations are far less than the quantity assessed through this screening analysis. Proposed current and future operations are described within the LANL permit modification request for these units. Due to the factors outlined here, current and future operations at the OD units do not require a more refined risk-based analysis to assess the potential for adverse effects due to migration of waste constituents in the air. Waste treatment operations at the OD units can be conducted and considered protective of human health and the environment.

5.2 Uncertainties Associated With Results

Models such as OBODM used for predicting downwind concentrations assume dispersion follows a uniform Gaussian distribution within the plume. In reality, atmospheric dispersion is far more complex and dependent on unique source and terrain features than a model is capable of considering. Nevertheless, dispersion models are a long accepted tool to assess source impacts for regulatory purposes.

Considering numerous studies over time, the U.S. EPA states in 40 CFR Part 51, *Appendix W – Guideline on Air Quality Models* that models are reasonably reliable for estimating the magnitude of the highest concentrations occurring within an area. Errors in the highest estimated concentrations of +/- 10 to 40 percent are found to be typical. However, estimates of concentrations that occur at a specific time and location are less reliable. Models are also more reliable in estimating longer time-averaged concentrations, such as annual averages, than for estimating short-term concentrations at specific locations.

Modeled impacts through the use of OBODM in this report assumed the detonation plume travels in a straight line in each given hour. This conservatively calculates the maximum impact at a given receptor by maintaining the target receptor along the plume centerline for the averaging period with the least amount of dispersion. For receptors in complex terrain, this is unlikely to occur with additional dispersion occurring as a practicality. In addition, the modeling approach used did not use any option to reduce downwind concentrations through either deposition or depletion of the detonation plume as it moves from the site to a given receptor. In reality, these mechanisms would lower the projected impacts.

References

AP-42, 2009. Draft Chapter 16 "Emission Factors for Demilitarization Processes: Open Burning and Open Air Detonation."

Background Document for AP-42 Chapter 16 – Emissions Factors for Demilitarization Processes: Open Burning and Open Detonation. Report prepared for the U.S. Army Defense Ammunition Center, McAlester, OK by Chemical Compliance Systems, Inc. February 2009.

Bjorklund, J. R., J. F. Bowers, G. C. Dodd, and J. M. White, 1998a. Open Burn/Open Detonation Model (OBODM) User's Guide, Volume I, User's Instructions, DPG Document No. DPG-TR-96-008a, February 1998.

Bjorklund, J. R., J. F. Bowers, G. C. Dodd, and J. M. White, 1998b. Open Burn/Open Detonation Model (OBODM) User's Guide, Volume II, Technical Description. DPG Document No. DPGTR-96-008b, April 1998.

Boggs, T. Atienza Moore, O. Heimdahl, M. Pepe, J. Hibbs, Jr., K. Wells, M. Martyn, D. Wooldridge, R. Gerber, L. Zellmer and B. Abernathy, 2004. Metals Emissions From The Open Detonation Treatment of Energetic Wastes. NAWCWD TP 8528, October 2004, Naval Air Warfare Center Weapons Division, China Lake, California.

CCS, 2011. Chemical Compliance Systems, Inc. (CCS) 2011. *Chemical Compliance Systems, Hazardous Materials.* May 2011. http://www.chemply.com

CA OEHHA, 2015. Air Toxics Hot Spots Program Guidance Manual for the Preparation of Health Risk Assessments, 2015, California Environmental Protection Agency, Air Toxicology and Epidemiology Section, Office of Environmental Health Hazard Assessment, February 2015. https://oehha.ca.gov/air/crnr/notice-adoption-air-toxics-hot-spots-program-guidance-manual-preparation-health-risk-0

CA OEHHA, 2019. Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

EPA, 2002. Draft Final Open Burning Open/Detonation Permitting Guidelines. U.S. Environmental Protection Agency, Region III, EPA contract No. 68-E-99-020, February 2002.

EPA, 2016. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Final. Office of Solid Waste and Emergency Response, EPA520-R-05-006, February 2016. https://archive.epa.gov/epawaste/hazard/tsd/td/web/html/risk.html#hhrad

EPA, 2019. Regional Screening Levels (RSLs) – Generic Tables. U.S. Environmental Protection Agency. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

LANL, 2011. Los Alamos National Laboratory Permit Modification Request for Open Detonation Units at Technical Areas 36 and 39 (TA-36-8 & TA-39-6). LA-UR-11-03642. Los Alamos National Laboratory, Los Alamos, New Mexico, July 2011.

LANL, 2019. ECORSK Database, on CD, LA-UR-12-24548, Los Alamos National Laboratory, Los Alamos, New Mexico, 2019.

NMED, 2019. New Mexico Environment Department (NMED), 2019. *New Mexico Environment Department Risk Assessment Guidance for Site Investigations and Remediation. Volume I Soil Screening Guidance for Human Health Risk Assessments.* February 2019 (Revision 2, 6/19/2019). https://www.env.nm.gov/wp-content/uploads/sites/12/2016/11/Final-NMED-SSG-VOL-I_-Rev.2-6_19_19.pdf

NMED, 2019. Air Dispersion Modeling Guidelines. Revised June 6, 2019. https://www.env.nm.gov/wp-content/uploads/sites/2/2017/01/NM_AirDispersionModelingGuidelines_6June2019.pdf

NAVAIR, 2004. Metals Emissions from the Open Detonation Treatment of Energetic Wastes. NAWCWD TP 8528, Naval Air Warfare Center Weapons Division, China Lake, California, October 2004. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA433712

NAVAIR, 2005. Emissions from the Energetic Component of Energetic Wastes During Treatment by Open Detonation. NAWCWD TP 8603, Naval Air Warfare Center Weapons Division, China Lake, California, June 2005. https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/2799200

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
Excess HE	34760	D003	No	02/21/06	0.03			95% HMX, 5% carbon black		0.03	-						Shot contained classified plastic shapes for sanitization	(1) det; (1) pellet, 122 lbs. ANFO; (4) PBX-9501 cylinders = 17.2 lbs.
Classified explosives	34760	D003	Yes		<1		CHNO detonators			1.00	-							
HE on cellulosics	28345	D003	No		0.33					0.33	-	PETN on filter cartridge						
Excess Baratol	35762	D001, D003, D005, D030	No	03/08/06	21.90	Baratol, 21.9 lbs.				21.90	NA						Barium Content	(1) det; (7) pellets
Excess HE	35763	D003, D030	Yes		289.40	PBX-9501, 15.6 lbs.	CHNO Dets, <1 lb.			289.40	NA				Octol, 2.18 lbs.		Shot contained classified HE shapes	
						PBX-9502, 33.26 lbs.												
						PBX-9404, 0.66 lbs.												
						PBX-9407, 0.01 lbs.												
						PBX-9205, 11.02 lbs.												
						PBXN-9, 33 lbs.												
						Comp B, 52.8 lbs												
						Detasheet, 12.58 lbs												
						RDX, 5 lbs.												
						TNT, 76.91 lbs.												
						CHNO HE, 41.38 lbs.												
						Black Powder, 5.0 lbs.												

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
Excess HE	35763	D003, D030	Yes	03/09/06	429.97	Comp B, 35.11 lbs.	CHNO Dets, <1 lb.			429.97	NA				RDX, 13.0 lbs.			(1) det; (8) pellets; (11) PBX-9501 cylinders = 46.2 lbs.; 103 lbs. PBX-9501 bulk material
						Nitroguanidine, 49.90 lbs.									MDF (PETN), 5.0 lbs.			
						PBX-9205, 26.03 lbs.												
						PBX-9404, 0.66 lbs.												
						PBX-9407, 0.04 lbs.												
						PBX-9501, 238.08 lbs.												
						PBX-9502, 23.76 lbs.												
						TNT, 1.87lbs.												
						X-0533, 35.9 lbs.												
						Primacord (CHNO), 0.62 lbs.												
Excess Baratol	35762	D001, D003, D005, D030	No	05/03/06	34.21	Baratol, 34.21 lbs.				34.21	NA						Barium content	(1) det; (7) pellets
Excess HE	35763	D003, D030	Yes		650.89					650.89	NA						Shot contained classified HE shapes	
						ANFO, 13.56 lbs.	PETN/HMX, 33.16 lbs.											
						CHNO Classified, 11.18 lbs.												
						Comp. B, 82.94 lbs.												
						Comp. C-4, 4.98 lbs.												
						Cyclotol, 30.00 lbs.												
						Detasheet, 0.26 lbs.												

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
						LX-14, 170.61 lbs.												
						Octol, 1.10 lbs.												
						PBX-9404, 192.29 lbs.												
						PBX-9407, 0.24 lbs.												
						PBX-9501, 95.61 lbs.												
						PBX-9502, 10.01 lbs.												
						XTX-8003, 4.89 lbs.												
						XTX-8004, 0.04 lbs.												
M-100, M-105 Electric Matches	37092	D003, D008	No	05/04/06	11.00		(50) M-105 (Lead azide, RDX) (50) M-100 (Lead azide, lead styphnate, HMX)										Lead based primary HE, RDX, HMX. SENSITIVE	(1) det; (6) pellets; 19 lbs. PBX-9501 bulk material; (1) PBX-9501 cylinder = 4.2 lbs.
HE contaminated debris	28345	D003	No	05/11/06	0.01							PETN on filter cartridge						(1) det; (1) pellet; 21 lbs. PBX-9501 bulk material; (1) PBX-9501 cylinder = 4.2 lbs.
HE contaminated debris w/ ethanol	39254	D001, D003	No		2.00							HE contaminated lab debris with trace ethanol (kimwipes, swabs, weigh boats)						
Classified explosives	34760	D003	YES		<2.0		Classified CHNO dets											

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
HE contaminated debris	30373	D003	No		0.53							CHNO contaminated lab debris (kimwipes, swabs, weigh boats)						
Excess HE	37560	D003, D030	No	05/16/06	39.81	AN, 29.93 lbs.	Black powder dets, 0.002 lbs.	Total lab quantity HE in this section = 9.677 lbs.	PLG/UW (RDX/AP/Al), 0.05 lbs.	39.81	NA	Nitroguanidine, 0.11 lbs + 40 lb Fiberboard drum	Developmental propellant HMX/NC/NG/Al/AP, 0.04 lbs.					(2) dets; (1) pellet; 50 lbs. PBX-9501 bulk material; (1) PBX-9501 cylinder = 4.2 lbs.
								Bullseye Powder, 0.29 lbs.	DNAZ/DNPA/EtGDMA, 0.002 lbs.									
								Comp. B, 0.02 lbs.										
								Cyclotol, 0.01 lbs.										
								DAAF, 0.02 lbs.										
								HMX, 4.602 lbs.										
								IMR Smokeless Powder, 0.084 lbs.										
								PETN, 0.123 lbs.										
								RDX, 0.032 lbs.										
								TATB, 0.12 lbs.										
								Tetryl, 0.02 lbs.										
								Tetrytol, 0.292 lbs.										
								TNT, 0.002 lbs.										
								Semtex 10, 0.070 lbs.										
								Semtex 1A, 0.13 lbs.										
								LX-04, 0.01 lbs.										
								LX-07, 0.007 lbs.										

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
								LX-14, 0.01 lbs.										
								LX-16, 0.001 lbs.										
								PBX-9404, 0.011 lbs.										
								PBX-9407, 0.113 lbs.										
								PBX-9501, 2.25 lbs.										
								PBX-9502, 0.616 lbs.										
								X-0298, 0.066 lbs.										
								X-0319, 0.015 lbs.										
								X-0407, 0.055 lbs.										
								X-0557, 0.075 lbs.										
								X-0564, 0.012 lbs.										
								X-0565, 0.011 lbs.										
								X-0567, 0.002 lbs.										
								X-0569, 0.062										
								XTX-8003, 0.037 lbs.										
								XTX-8004, 0.509 lbs.										
Excess HE	37845	D003	No		0.21			Total lab quantity HE in this section = 0.21 lbs. .		0.21	NA							
								HMX, 0.002 lbs.										
								PBX-9501, 0.137 lbs.										
								PBX-9502, 0.07 lbs.										
Excess HE	37560	D003, D030	No		0.04			Total lab quantity HE in this section = 0.04 lbs. .		0.04	NA							

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
								Explosive D, 0.012 lbs.										
								BP, 0.011 lbs.										
								PETN, 0.002 lbs.										
								TNT, 0.011 lbs.										
PBX-9501 on brass bar	37446	D003	No		0.55					0.55	NA					PBX-9501, PBX-9502 bonded to brass		
HE (PETN) on cellulosics	28345	D003, D030	No	06/14/06	0.10					0.10	NA	PETN on filter cartridge						(1) det; (1) pellet; 25 lbs. ANFO; (1) PBX-9501 cylinder = 4.2#
Classified explosives	34760	D003, D030	Yes		<2.0		CHNO Dets, 1.03 lbs.			2.00	NA							
Type 6S Primaries	34760	D003	No		2.22		HMX Primaries, 2.00 lbs.											
Lead-based Primaries	37092	D003, D008	No		1.00		Lead Primaries, 1.00 lbs.										Lead styphnate, lead azide	
HE Contaminated Debris	30373	D003, D030	No		0.61							CHNO contaminated lab debris (kimwipes, swabs, weigh boats)						
Excess HE	37560	D003, D030	No	06/27/06	175.36	Total quantity HE in this section = 151.61 lbs.		Total lab quantity HE in this section = 19.45 lbs.		175.36	NA		Gun Propellant (NC/NG/NQ/DNT), 0.52 lb.			PBX-9501 HE from Spigot Gun Targets, Modified Stevens Targets, 3.78 lbs.		(1) det; (4) pellets; 50 lbs. PBX-9501 bulk material; 50lbs. ANFO; 10 ft Primacord; (2) PBX-9501
						ANFO, 1.0 lbs.												
						Comp A, 0.77 lb												
						Comp B		Comp B, 0.07 lb.										
						Comp. C-4, 0.73 lb.												
						Cyclotol, 0.33 lb.		Cyclotol, 0.71 lb.										

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
						DINGU, 0.62		DINGU										cylinders = 8.4 lbs.
						EDC-32		EDC-32, 0.11 lb.										
						EDC-35		EDC-35, 0.22 lb.										
						EDC-37		EDC-37, 5.14 lb.										
						Exp. D, 2.0 lb.		Exp D, 0.06 lb.										
						Octol, 0.55 lb.												
						Pentolite, 1.5 lb.		Pentolite, 0.49										
						PYX		PYX, 0.19 lb.										
						TATB, 15.55lb.		TATB										
						Tetryl		Tetryl, 0.30 lbs.										
						TNT, 2.26 lb.		TNT										
						PBX-9010, 0.56 lbs.		08/31/24										
						PBX-9404		PBX-9404, 0.08 lb.										
						PBX-9501, 89.57 lbs.		PBX-9501, 10.81										
						PBX-9502, 14.37 lbs.		PBX-9502										
						LX-10		LX-10, 0.04 lb.										
						LX-14		LX-14, 0.04 lb.										
						LX-17		LX-17, 0.24 lb.										
						X-0211		X-0211, 0.04 lb.										
						X-0233,		X-0233, 0.01 lb.										
						X-0242, 19.6		X-0242, 0.03 lb.										
						X-0523,		X-0523, 0.02 lb.										
						X-0527,		X-0527, 0.77 lb.										
						X-0533		X-0533, 0.04 lb.										
						X-0534		X-0534, 0.03 lb.										
						X-0544, 2.2 lb.												
						XTX-8003		XTX-8003, 0.01 lb.										

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
?? HE	37560	D003, D030	No	08/02/06	172.99	Total HE this section = 142.93 lbs.		Total Lab Quantity this section = 30.06 lbs.		172.99	NA							(1) det; (1) pellet; (1) PBX-9501 cylinder = 2 lbs.; 45 lbs. PBX-9501 bulk material
						PBX-9501, 129.02 lbs.		PBX-9501, 28.58 lbs.										
						PBX-9502, 11.88 lbs.		PBX-9502, 0.91 lbs.										
						TATB, 0.88 lbs.		TATB, 0.29 lbs.										
						X-0562, 0.50 lbs.		PBX-9407, 0.28 lbs.										
						X-0563, 065 lbs.												
PBX 9501 on brass	37446	D003, D030	No	08/10/06	0.01											5 grams PBX-9501 bonded to brass piece		(3) dets; (1) PBX-9407 pellet; 22 lbs. PBX-9501 hemi; 135 lbs. PBX-9501 bulk material
Excess HE in metal cylinders	37560	D003, D030	No		100.00											(10) PBX 9501 charges, each 6" dia. X 10" tall encased in welded steel cylinders. 10 pounds each.		
Classified explosives	34760	D003	YES	08/28/06	<1.0		CHNO Dets, 0.16 lbs.			1.00	NA							(1) det; (4) pellets; (2) PBX-9501 boosters = 10 lbs.; 1 lb. LX17 booster; 1 lb PBX-
HE contaminated debris	28345	D003	No		0.32							PETN on filter cartridge; CHNO contaminated lab debris (kimwipes, swabs, weigh boats)						

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
HE contaminated debris	39522	D003, D030	No		4.50							CHNO contaminated lab debris (kimwipes, swabs, gloves, adhesives, paper, weigh boats)						9404 booster; (2) PBX-9502 cylinders = 16 lbs.;164 lbs. PBX-9501 bulk material; 5 lbs. TNT
HE contaminated debris	39521	D003, D030	No		4.00							CHNO contaminated lab debris (kimwipes, swabs, gloves, adhesives, paper, weigh boats)						
Excess HE in metal cylinders	37560	D003, D030	No	08/30/06	110.00											(11) PBX 9501 charges, each 6" dia. X 10" tall encased in welded steel cylinders. 10 pounds each.		(1) det; (1) pellet; (1) PBX-9501 hemi = 22 lbs.; 140 lbs. PBX-9501 bulk material
Picric acid, partially wetted	37560	D003, D030	No		1.10	Picric Acid, partially wetted, 1.10 lbs.											EXTREME CAUTION --in jar, wetted Handle as 1.1 D	
Box 4220 TA09 Magazine 0208A	37560	D003, D030	No		1.11			Total Lab Quantity this section = 1.11 lbs.		1.11	NA							
								PBX-9404, 0.12 lbs.										
								PBX-9407, 0.09 lbs.										
								PBX-9501, 0.65 lbs.										
								PBX-9502, 0.22 lbs.										
								TNT, 0.03 lbs.										

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
Damaged HE from compression testing, spigot gun tests, and impact samples. L category	37560	D003, D030	No	08/31/06	4.04					4.04	NA					PBX-9502, 2.31 lbs. PBX-9501, 1.73 lbs.		
Excess HE in metal boxes	37560	D003, D030	No		0.28											Black Powder in metal box, 0.22 lbs.; Mixed DINGU/TNT/TATB in metal box, 0.06 lbs.		(1) det; (3) pellets; (1) PBX-9501 hemi = 22 lbs.; (2) PBX-9501 cylinders = 4 lbs.; 148 lbs. PBX-9502 bulk material; 80 lbs. PBX-9501 bulk material; 52 lbs. Comp B; 46 lbs. X-0557 .
Excess HE and mixed propellants	37560	D003, D030	No		230.92	Total HE this section = 213.68 lbs.		Total Lab Quantity HE this section = 17.24 lbs.		230.92	NA						Propellants and smokeless powders appeared to have been mixed with other materials for experiments	
						M1 Propellant, 28.39 lbs.		M1 Propellant, 1.424 lbs.										
						M8 Propellant, 2.0 lbs.		PBX-9501, 6.727 lbs.										
						PBX-9501, 5.11 lbs.	5.11	PBX-9502, 1.285 lbs.										
						PBX-9502, 24.21 lbs.	24.21	Tetritol, 2.0 lbs.										
						TATB, 40.87 lbs.	40.87	Tritonal, 0.17 lbs.										
						Smokeless Powder, 7.97 lbs.		TATB, 0.22 lbs.										
						X-0407, 62.63 lbs.		X-0407, 1.97 lbs.										
						X-0450, 19.50 lbs.		HMX/RDX/PETN Mixed, 1.35 lbs.										

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
						X-0541, 23.00 lbs.		DAAF, 0.006 lbs.										
								PBXN-110, 0.55 lbs.										
								PBXN-9, 0.06 lbs.										
								Comp B, 0.522 lbs.										
								Semtex, 0.008 lbs.										
								ANFO, 0.68 lbs.										
								EDC-29, 0.06										
								LAX-112, 0.01 lbs.										
								PBX-9404, 0.075 lbs.										
								X-0541, 0.06 lbs.										
								EDC-37, 0.06 lbs.										
Excess HE, lab quantity, and mixed HE samples from TA37 Magazines	39555	D003, D030	No	10/04/06	221.98	Total HE this section = 203.30 lbs.		Total Lab Quantity and HE Samples this section = 18.68 lbs.		221.98	NA						Some of this HE originated in TA16-340, TA16-430, and TA16-460 and was transferred to TA37 magazines when facilities were vacated	(1) det, (5) pellets, 20 feet Primacord
						PBX-9501, 16.5 lbs.		HNS Mixed, 0.25 lbs.										
						PBX-9502, 11.5 lbs.		Tripeon, 0.27 lbs.										
						PBX-9205, 3.0 lbs.		NC/TNT Mixed, 0.06 lbs.										
						LX-07, 3.0 lbs.		NC, 0.06 lbs.										

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
						PBX-9501 Mixed, 20 lbs.		TNT, 0.81 lbs.										
						PBX-9502 Mixed, 16 lbs.		TNT Mixed, 0.61 lbs.										
						TNT Mixed, 5.0 lbs.		1,3,5-Trinitrobenzene / HE Samples, 0.03 lbs.										
						DAAF, 0.8 lbs.		2,4,6-Trinitrobenzoic Acid / HE Samples, 0.23 lbs.										
						XTX-8003 Mixed, 3.5 lbs.		1,3 Dichloro-2,4,6-Trinitrobenzene / HE Samples, 0.17 lbs.										
						XTX-8004, 10 lbs.		2,4,6-Trinitroanisole / HE Samples, 0.22 lbs.										
						9007, 1 lbs.		2,4,6-Trinitroresorcinol / HE Samples, 0.06 lbs.										
						NQ, 11.5 lbs.		Nitroguanidine Mixed , 0.25 lbs.										
						AN, 1.25 lbs.		PBX-9501, 13.3 lbs.										
						9001, 1 lbs.		PBX-9502, 0.2 lbs.										
						PBX-9404, 0.5 lbs.		Comp B Mixed, 0.06 lbs.										
						PBX-9407, 1.0 lbs.		Dipicrylamine Mixed, 0.02 lbs.										
						RDX, 0.5 lbs.		DINGU, 0.01 lbs.										
						TATB, 4.5 lbs.		X-0290, 0.75 lbs.										
						X-0182, 2.0 lbs.		LX-07, 0.17 lbs.										

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
						X-0224, 8.25 lbs.		Nitro Urea/Urea Nitrate, 0.03 lbs.										
						X-0228, 2.5 lbs.		PBX-9407, 0.06 lbs.										
						X-0233, 3.5 lbs.		2,4,6-Trinitrometaxylene Samples, 0.11 lbs.										
						X-0234, 5 lbs.		DATB, 0.25 lbs.										
						X-0242, 3 lbs.		(6) Vials Mixed HE Samples										
						X-0280, 10 lbs.		RDX, 0.2 lbs.										
						X-0282, 2.5 lbs.												
						X-0283, 6.0 lbs.												
						X-0286, 1.5 lbs.												
						X-0298, 22 lbs.												
						X-0301, 1 lbs.												
						X-0303, 1.5 lbs.												
						X-0306, 4.5 lbs.												
						X-0308, 3.25 lbs.												
						X-0312, 1 lbs.												
						X-0406, 1 lbs.												
						X-0409, 0.5 lbs.												
						X-0410, 0.5 lbs.												
						X-0418, 1 lbs.												
						X-0419, 0.5 lbs.												
						X-0430, 0.5 lbs.												
						X-0438, 0.5 lbs.												
						X-0444, 1.5 lbs.												
						X-0463, 3.0 lbs.												
						X-0464, 0.5 lbs.												
						X-0513, 1.0 lbs.												
						X-0515, 1 lbs.												
						X-0516, 1.25 lbs.												
						X-0517, 1 lbs.												
						X-0521, 1 lbs.												
						RX-03-AT, 0.5 lbs.												

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
Excess HE and HE samples	39555	D003, D030	No	10/20/06	6.50	Total HE this section = 4.5 lbs.		Total Lab quantity HE and HE samples this section = 2.0 lbs.		6.50								(1) det; (1) pellet; 83 lbs. PBX-9501 pieces; 135 lbs. PBX-9501 bulk material; 9 lbs. PBX-9502 pieces; 46.5 lbs. TNT
						X-0233, 0.5 lbs.		(28) Misc HE Samples, 2.0 lbs. HE										
						X-0298, 1.5 lbs.												
						X-0407, 0.5 lbs.												
						PBX-9407, 0.5 lbs.												
						PBX-9502, 1 lbs.												
						EDD, 0.5 lbs.												
Excess Barium-based HE	39554	D001, D003, D005, D030	No		52.70	Total HE this section = 52.7 lbs.												
						X-0256, 0.50 lbs.				0.50								
						X-0262, 7.10 lbs.				7.10								
						X-0264, 7.10 lbs.				7.10								
						Baratol, 38 lbs.												
HE-contaminated shot debris B/C 10055613	30373	D003	YES	11/17/06	1.06							Polyamide film, cellulosics, copper, wood, plastics, 5% CHNO dets						(1) det; (1) pellet; 2 lbs. PBX-9501 piece; 45 lbs. PBX-9501 bulk material
HE and ethanol contaminated lab cleaning debris	39254	D001, D003	No		0.66					0.66		HE contaminated lab debris with trace ethanol (kimwipes, swabs, weigh boats)						

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
Classified explosives	34760	D003	YES		<1.0		CHNO dets			1.00	NA							
HE contaminated cellulosics (PETN filter)	28345	D003	No		0.15					0.15	NA	PETN on filter cartridge						
Excess explosives	39693	D003, D030	No	12/06/06	13.53	Total HE this section = 1 lbs.		Total lab quantity HE this section = 0.48 lbs.		0.48	NA					Total HE Assemblies this section = 12.05 lbs.		(1) det; (1) pellet; (1) PBX-9501 disc, 2 lbs.; 172.7 lbs. PBX-9501 bulk material; 102.5 lbs. PBX-9502 bulk material; 10 lbs. Octol; 2.5 lbs. PBX-9407; 24 lbs. TNT; 8 lbs. Comp B; 7 lbs. LX-07
						IMR 4198 Powder (NC / 2,4-DNT), 1.0 lbs.		IMR 4198 Powder (NC/2,4-DNT), 0.33 lbs.		0.33	NA					LX-07/PBX-9502 Assemblies, 12 lbs.		
								TATB, 0.04 lbs.		0.04	NA					DAAF Assemblies, 0.05 lbs.		
								Aluminum powder/HE/oil, 0.06 lbs.										
								Comp C-4, 0.02 lbs.		0.02	NA							
								PBX-9502, 0.03 lbs.		0.03	NA							
HE contaminated debris	39611	D003, D030	No		15.98							Total HE contaminated debris this section = 15.98 lbs.						
												HE contaminated debris with PBX-9501 chips and PBX-9502 pieces, 1.0 lbs.						

2006 RCRA Waste Explosive Descriptions, EPA Waste Codes, and Waste Amounts for TA-36-8 Plus the Calculation of the Metal to Waste Ratio

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
												HE contaminated debris with PBX-9502 pieces, 0.54 lbs.						
												HE contaminated debris (primarily cellulosics) with chunks of PBX-9501, PBX-9502, TATB, and PETN, 5.42 lbs.						
												HE contaminated debris, PETN and C-4, 0.06 lbs.						
												HE contaminated debris and sweepings TATB, LX-07, PBX-9501, PETN , C-4 8.75 lbs.						
												HE contaminated debris TATB, 0.06 lbs.						
												HE contaminated debris, X-0565, 0.06 lbs.						
Excess barium-based HE	39554	D001, D003, D005	No	12/13/06	116.50	Baratol, 56.5 lbs.	56.50											(1) det; (1) pellet; 67 lbs. PBX-

Description	WPF	EPA Waste Code(s)	Classified?	Date Treated	Waste Wt, lbs.	HE	Detonators, initiators	Lab Quantity HE	Developmental CHNO Explosives	Combined HE / Excess Explosives - lbs	Combined HE / Excess Explosives - Metal Content - lbs	HE Contaminated Debris	Propellants	Munitions	Shaped Charges	Other	Comments	Fuel (1) detonator = 0.625 g CHNO HE (1) pellet = 3 g PBX-9407
		, D030																9502 bulk material; 45 lbs. PBX-9501 bulk material; 8 lbs. X-0242; 12 lbs. PBX-9501 pieces
						LX-10, 60 lbs.	60.00			60.00								
		LBS.			**2602.00**					**2,361.7**								

Potential Metal Waste - lbs	**240.25**	
Factor for Metal containing waste	**0.092**	**Lb Metal / Lb Waste**

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

The following table lists the explosive waste detonated at the TA-36 and TA-39 OD units, based on a review of the operating record for these units. For each explosive material, an emission factor is shown with the appropriate emitted compound indicated in units emitted per unit of explosive waste detonated. For the emission products/constituents that have available screening values, the values have been included. Screening values are as identified in Section 4 of this document.

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute ($\mu g/m^3$)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute ($\mu g/m^3$)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)- Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
	Metals - Compounds in Energetics												
Aluminum Oxide 50-nm	Applied elemental data	1344-28-1	7.80E-01	lb/lb Metal	NL*	NL*	NL*	5.20E-01	7.80E+04	NL*	7.70E+03	NC	NL*
B+B113Barium nitrate		10022-31-8	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		
Barium	Applied elemental data	7440-39-3	7.80E-01	lb/lb Metal	1.50E+03	NL*	NL*	5.20E-02	1.56E+04	NL*	1.50E+03	NC	1.10E+02
Bismuth Trioxide		1304-76-3	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Calcium carbonate		471-34-1	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Calcium stearate		1592-23-0	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Cobalt Acetoacetonate	Applied elemental data	21679-46-9	7.80E-01	lb/lb Metal	NL*	NL*	NL*	6.30E-04	2.34E+01	1.72E+04	2.30E+00	NC	1.30E+01
Copper		7440-50-8	7.80E-01	lb/lb Metal	NL*	1.00E+02	NL*	NL*	3.13E+03	NL*	3.10E+02	NC	1.40E+01
KNO3	Potassium Nitrate	7757-79-1	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Lead		7439-92-1	7.80E-01	lb/lb Metal	1.50E+02	NL*	NL*	1.5E-01	4.00E+02	NL*	4.00E+02	G	1.10E+01
ortho-boric acid	Boric acid	10043-35-3	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Talc		14807-96-6	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Trioctyl phosphate	Tris(2-ethylhexyl)phosphate	78-42-2	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	1.70E+02	C	NL*
Tungsten Trioxide	Applied elemental data	1314-35-8	7.80E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	6.30E+00	NC	NL*
	Metals - Elemental in Energetics												
Aluminum, Type IV		7429-90-5	1.40E-01	lb/lb Metal	NL*	NL*	NL*	5.2E-01	7.80E+04	NL*	7.70E+03	NC	NL*
Aluminum, X-81		7429-90-5	1.40E-01	lb/lb Metal	NL*	NL*	NL*	5.2E-01	7.80E+04	NL*	7.70E+03	NC	NL*
Titanium		7440-32-6	1.40E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	NL*		7.70E+01

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)-Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
Tungsten, 112micron		7440-33-7	1.40E-01	lb/lb Metal	NL*	NL*	NL*	NL*	NL*	NL*	6.30E+00	NC	NL*
	Energetic												
AN	Ammonium nitrate	6484-52-2	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
AP	Ammonium perchlorate	7790-98-9	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	5.50E+00	NC	NL*
CL20	hexantrohexaazaisowurtzitane	135285-90-4	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DAAF	Diamino-azoxyfurazaz	78644-89-0	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DAAT	3,3'-azobis (6-amino-1,2,4,5-tetrazine)	303749-95-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DAATOx	3,3'-azobis (6-amino-1,2,4,5-tetrazine) n-oxide	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
DAAzF	3,3' -diamino-4,4'-azofurazan	78644-90-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DATB	Diaminotrinitrobenzene	26616-30-8	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DHT	3,6-dihydrazino-s-tetrazine	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
DINA	Di (nitratoethyl) nitramine	4185-47-1	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DINGU	Dinitroglycouril	55510-04-8	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DiPEHN		not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
DNAN	2,4-Dinitroanisol	119-27-7	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DNAT	Dinitroazotriazole 100%	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
EDNA	Ethylenedinitramine, Halite	505-71-5	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
FOX-7	1,1-diamino-2,2-dinitroethylene	145250-81-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)- Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine	2691-41-0	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	3.85E+03	NL*	3.90E+02	NC	1.60E+01
HNAB	2,2',4,4',6,6'-Hexanitroazobenzene	19159-68-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
HNS	Hexanitrostilbene	20062-22-0	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Hydrogen Peroxide	Pure Compound (above 80%)	7722-84-1	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Isopropylnitrate	IPN	1712-64-7	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
LAX-112	3,6-diamino-s-tetrazine-1,4-dioxide	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
LLM-105	2,6-Diamino-3,5-dinitropyrazine-1-Oxide	194486–77–6	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Methylnitrate	MN	598-58-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Nitrocellulose	NC	9004-70-0	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	1.90E+07	NC	NL*
Nitroguanidine (NQ)	Nitroguanidine, picrite	556-88-7	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	6.30E+02	NC	NL*
Nitromethane	NM	75-52-5	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	5.2E-01	NL*	NL*	5.40E+00	C	NL*
NTO	3-nitro-1,2,4-triazol-5-one	932–64–9	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
PETN	Pentaerythritol tetranitrate	78-11-5	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	1.30E+01	NC	1.00E+02
Picric Acid	2,4,6-trinitro-phenol	88-89-1	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
PYX	2,6-Bis(picrylamino)-3,5-dinitropyridine	38082-89-2	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine	121–82–4	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	3.01E+02	8.31E+01	8.30E+00	C	2.30E+00
TAGDNAT	Bis-Triaminoguanidinium 3,3'-Dintroazotriazole	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
TAGN	Triaminoguanidine Nitrate	4000–16–2	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
TAGN4BIM		not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
TAGzT	triaminoguanidium azotetrazolate	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents		Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (µg/m³)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m³)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)-Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
TATB		1,3,5-triamino-2,4,6-trinitro-benzene	3058–38–6	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Tetranitromethane		TNM	509-14-8	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Tetryl*		2,4,6-Trinitrophenyl-methyl-nitramine	479–45–8	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	1.56E+02	NL*	1.60E+01	NC	1.50E+00
TMETN		Trimethylolethane trinitrate	3032-55-1	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
TNAZ		1,3,3-Trinitroazetidine	97645–24–4	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
TNT		2,4,6-trinitrotoluene	118-96-7	2.0E-06	lb/lb Energetic	1.50E+03	NL*	NL*	NL*	3.60E+01	2.11E+02	3.60E+00	NC	7.50E+00
TriPEON		Tripentaerythritol octanitrate	29908-97-2	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
TZX		Diaminotetrazine dioxide	not found	2.0E-06	lb/lb Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Urea Nitrate			124-47-0	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
	Fuels													
dodecane			112-40-3	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
sugar			57-50-1	2.0E-06	lb/lb Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
	Binder/Plasticizer/Anti-oxidants													
2-bf			not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Acrylonitrile		Acetonitrile	75-05-8	1.00E-08	lb/lb SVOC in Energetic	2.18E+04	NL*	5.00E+00	6.30E+00	NL*	NL*	8.10E+01	NC	NL*
BDNPA		BIS(2,2-DINITROPROPYL) ACETAL	5108-69-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
BDNPF		BIS(2,2-DINITROPROPYL) FORMAL	5917-61-3	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Beeswax			8012-89-3	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Bis(2-ethylhexyl) adipate		DEHA or Di(2-ethylhexyl)adipate	103-23-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	4.50E+02	C	NL*
Blue Dye			not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Butadiene rubber			9003-17-2	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)- Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
Cab-o-sil		112945-52-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Carnuba Wax SP-8		8015-86-9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
CEF	tris-beta-chloroethyl phosphate or tris(2-cloroethyl) phosphate	115-96-8	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	2.70E+01	C	NL*
DBP	Dibutylphthalate	84-74-2	1.00E-08	lb/lb SVOC in Energetic	1.50E+04	NL*	NL*	NL*	6.16E+03	NL*	6.30E+02	NC	1.10E-02
acetylene black	acetylene black	1333-86-4	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
di(2-ethylhexyl) sebacate		122-62-3	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DNEB	Dinitroethylbenzene	26590-17-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
DNT	Dinitrotoluene	121-14-2	1.00E-08	lb/lb SVOC in Energetic	6.00E+02	NL*	NL*	NL*	1.23E+02	1.71E+01	1.70E+00	C	6.00E+00
DOA	Dioctyladipate or Di(2-ethylhexyl)adipate	103-23-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	4.50E+02	C	NL*
DOP	Dioctylphthalate or Ethylhexyl Phthlate, Bis 2 or Bis(2-ethylhexyl)phthalate (di(2-ethylhexyl)phthalate, DEHP)	117-81-7	1.00E-08	lb/lb SVOC in Energetic	1.00E+04	NL*	NL*	NL*	1.23E+03	3.80E+02	3.90E+01	C	2.00E-02
DPA	Diphenylamine	122-39-4	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	6.30E+02	NC	1.00E+01
Dye		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
elastomeric binder		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Epoxy		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Estane 5703	polymeric elastomer	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Exon 461	copolymer of chlorotrifluoroethylene/ tetrafluoroethylene/ vinylidene fluoride	24937-97-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
FEFO	Bis (2-fluoro-2,2-dinitroethyl) formal	17003-79-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
FO	Fuel Oil	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Fomblin YL-VAC 16/6	1-Propene, 1,1,2,3,3,3-hexafluoro-, oxidized, polymd.	69991-67-9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
FPC 461		24937-97-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
GAP	Glycidyl Azide *Polymer*	143178–24–9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)- Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
graphite		7782-42-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Heavy oil (C28-H58)		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
HTPB	Hydroxy-terminated butadiene	69102-90-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Hytemp	Polyacrylate elastomer	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Inert Binder		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
IPDI		4098-71-9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Irganox 1010	Pentaerythritol Tetrakis (3-(3,5-di-tert-butyl-4-hydroxyphenyl) Propionate	6683-19-8	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Isodecyl pelargonate		109-32-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
K-10	DNEB/TNEB	mix	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Kel-F	homopolymer of chlorotrifluoroethylene	9002-83-9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Kel-F 800	Chlorotrifluoroethylene/Vinylidene Fluoride Copolymer	9010-75-7	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Kraton	not specific	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Lecithin, Liquid		8002-43-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Motor Oil		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
NP	not specific	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
NuSil CF6-3500		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Oil		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
OXY-461		24937-97-1	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
PCP-0260		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
PCP-0301		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
perfluoropolyether diol		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (μg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (μg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (μg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (μg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)-Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
Plastic Tubing		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
plasticizer		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Poly (laurylmethacrylate)		25719-52-2	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
polyisobutylene		9003-27-4	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Polystyrene		9003-53-6	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Polyurethane		9009-54-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Resin		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Rubber		9003-31-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Silicone rubber		63394-02-5	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Stearic Acid		57-11-4	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Sylgard 182		mix	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Sylgard 24		mix	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Teflon		9002-84-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
TNEB	Trinitroethylbenzene	13985-60-9	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Viton A		9011-17-0	1.00E-08	lb/lb SVOC in Energetic	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Wax		not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Zeon polymer	Polyacrylate elastomer	not found	1.00E-08	lb/lb SVOC in Energetic	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
	Emission Products												
PM-10	Particulate Matter	none	1.1E+01	lb/lb NEW	NL*		NL*	NL*	NL*	NL*	NL*		NL*
Carbon Monoxide		630-08-0	2.0E-01	lb/lb C	NL*	2.30E+04	NL*	NL*	NL*	NL*	NL*		NL*
Carbon Dioxide		124-38-9	3.9E+00	lb/lb C	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Nitrogen Oxides (as NO_2 only)		multiple	3.2E-01	lb/lb N	NL*	4.70E+02	NL*	NL*	NL*	NL*	NL*		NL*

Emission Products, Emission Factors and Identified Screening Levels for Explosives Waste Detonated at the TA-36 and TA-39 OD Units

Emission Products/Constituents	Other Names, Composition, or Reference/Notes	CAS RN	Maximum Emission Factor - Surface Open Detonation (as fraction)	Unit of Measure based on AP-42, draft Ch. 16	Air Inhalation Emission Concentration (AIEC) - acute (μg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (μg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (μg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (μg/m3)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil - TR=1E-05 (mg/kg)	EPA RSLs(1)- Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	EPA RSLs - Minimum of C-Cancer or NC-NonCancer Listings	LANL Ecological Minimum Soil - No Effect ESL (mg/kg)
Sulfur Dioxide		7446-09-5	1.4E-03	lb/lb NEW	NL*	6.60E+02	NL*	NL*	NL*	NL*	NL*		NL*
Benzene		71-43-2	6.0E-04	lb/lb C	1.30E+03	2.70E+01	3.00E+00	3.1E+00	1.14E+02	1.78E+01	1.20E+00	C	2.40E+01
TNMHC	Total Non-methane hydrocarbons	na	3.4E-02	lb/lb C	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS	no CAS		no CAS
Acetylene		74-86-2	1.8E-03	lb/lb C	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Ethylene		74-85-1	2.3E-03	lb/lb C	NL*	NL*	NL*	NL*	NL*	NL*	NL*		NL*
Propylene		115-07-1	4.1E-04	lb/lb C	NL*	NL*	3.00E+03	3.1E+02	NL*	NL*	2.20E+02	NC	NL*
Toluene		108-88-3	1.9E-04	lb/lb C	3.70E+04	3.70E+04	3.00E+02	5.2E+02	5.23E+03	NL*	4.90E+02	NC	2.30E+01
Naphthalene		91-20-3	2.0E-06	lb/lb C	7.50E+04	NL*	9.00E+00	3.1E-01	1.62E+02	4.97E+01	3.80E+00	C	1.00E+00
Methylene Chloride		75-09-2	2.4E-03	lb/lb C	1.40E+04	1.40E+04	4.00E+02	6.3E+01	4.09E+02	7.66E+02	3.50E+01	NC	2.60E+00

NMED – New Mexico Environment Department; EPA – Environmental Protection Agency; LANL ESL – Los Alamos National Laboratory Ecological Screening Level; CA-OEHHA - California OEHHA Acute and Chronic RELs

c = cancer n = non-cancer μg/m^3 = micrograms per cubic meter mg/kg = milligram per kilogram

(1) Based on EPA Regional Screening Levels - RSLs - Residential Soil (RSL) table where carcinogenic Target Risk (TR) = 1E-06 and Non-cancer Child Hazard Index (HI) - 0.1

NL* - Not Listed in reference tables or database - No information provided based on CAS Number

G - for Lead and Lead Compounds based on User's Guidance

EXCEL Tables Used for Modeling Results Evaluation

TA-36-8 Screening Analysis Worksheet for Ambient Air Quality Standards

Basis	
2000	lb/hr detonation
0.092	lb metal / lb waste (1)
15000	lb/yr detonation
1	g/sec contaminant emission rate
Model Results (X/Q)	
7.67E-03	1-hour maximum value, ug/m^3 per g/sec contaminant
4.26E-03	3-hour maximum value, ug/m^3 per g/sec contaminant
2.28E-03	8-hour maximum value, ug/m^3 per g/sec contaminant
7.87E-04	24-hour maximum value, ug/m^3 per g/sec contaminant
3.87E-07	Annual maximum value, ug/m^3 per g/sec contaminant

Pollutant	Averaging Time	Emisson Factor lb/lb waste	Emission Rate g/sec	Maximum Concentration ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?
Nitrogen Dioxide		3.2E-01					
(As NOX)	1-hour		8.06E+01	6.19E-01	188.03	none	No
	24-hour		8.06E+01	6.35E-02	none	188.03	No
	Annual		6.90E-02	2.67E-08	99.66	94.02	No
Carbon Monoxide		2.0E-01					
	1-hour		5.04E+01	3.87E-01	40069.6	14997.5	No
	8-hour		5.04E+01	1.15E-01	10303.6	9960.1	No
Sulfur Dioxide		1.4E-03					
	1-hour		3.53E-01	2.71E-03			
Background(10)	1-hour			1.32E+01			
Total	1-hour			1.32E+01	196.40	none	
	3-hour		3.53E-01	1.50E-03	1309.30	none	No
	24-hour		3.53E-01	2.78E-04	none	261.90	No
	Annual		3.02E-04	1.17E-10	none	52.40	No
PM_{10}		1.1E+01					
	24-hour		2.77E+03	2.18E+00			
Background(7)				2.30E+01			
Total				2.52E+01	150	none	No
$PM_{2.5}$							
	24-hour	1.1E+01	2.77E+03	2.18E+00			
Background(8)				9.45E+00			
Total				1.16E+01	35	none	No
	Annual	1.1E+01	2.37E+00	9.18E-07			
Background(9)				4.32E+00			
Total				4.32E+00	12	none	No
Lead	Quarterly	7.80E-01	1.81E+01	1.42E-02	0.15	none	No

Notes

1. Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.
2. Both federal and state AAQS values are listed in the New Mexico Air Quality Bureau Air Dispersion Modeling Guidelines dated 2019 JUNE 06.
3. Calculated maximum concentrations for NAAQS and NMAAQS are based on the first high value from OBODM model runs.
4. Calculated lead 3-month arithmetic mean assumes maximum 24-hour concentration occurs every day of the year.
   Lead standard is typically specified as a three -month rolling average or quarterly average.
5. Emission factor for PM_{10} used also for $PM_{2.5}$ which over predicts $PM_{2.5}$ concentrations.
6. Particulate matter background concentrations added as specified from NMED Air Dispersion Modeling Guidelines, March 2019.
7. PM10 24-hr background - 2019 JUNE - North Central - Santa Fe - 23.0 ug/m3 max.

EXCEL Tables Used for Modeling Results Evaluation

8. PM2.5 24-hr background - 2019 JUNE - North Central - Santa Fe - 98 percentile - 9.45 ug/m3
9. PM2.5 Annual background - 2019 JUNE - North Central - Santa Fe - 4.32 ug/m3
10. SO2 1hr-background - 2019 JUNE - Albuquerque Region - 1-hr background - 15.8 ug/m3 and 1-hour background 99th percentile - 13.2 ug/m3

EXCEL Tables Used for Modeling Results Evaluation

TA-39-8 Screening Analysis Worksheet for Air Quality Standards

Basis

250	lb/hr detonation
4	detonations/hr
0.092	lb metal / lb waste (1)
15000	lb/yr detonation
1	g/sec contaminant emission rate

Model Results (X/Q)

6.53E-02	1-hour maximum value, ug/m3 per g/sec contaminant
2.61E-01	1-hour maximum value, ug/m3 per g/sec contaminant for 4 detonations/hr
2.81E-02	3-hour maximum value, ug/m3 per g/sec contaminant
1.93E-02	8-hour maximum value, ug/m3 per g/sec contaminant
6.42E-03	24-hour maximum value, ug/m3 per g/sec contaminant
4.83E-05	Annual maximum value, ug/m3 per g/sec contaminant

Pollutant	Averaging Time	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Concentration ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?
Nitrogen Dioxide		3.2E-01					
	1-hour		1.01E+01	2.63E+00	188.03	none	No
	24-hour		1.01E+01	6.47E-02	none	188.03	No
	Annual		6.90E-02	3.33E-06	99.66	94.02	No
Carbon Monoxide		2.0E-01					
	1-hour		6.30E+00	1.65E+00	40069.6	14997.5	No
	8-hour		6.30E+00	1.22E-01	10303.6	9960.1	No
Sulfur Dioxide		1.4E-03					
	1-hour		4.41E-02				
Background(10)	1-hour		1.32E+01				
Total	1-hour		1.32E+01		196.40	none	
	3-hour		4.41E-02	1.24E-03	1309.30	none	No
	24-hour		4.41E-02	2.83E-04	none	261.90	No
	Annual		3.02E-04	1.46E-08	none	52.40	No
PM$_{10}$		1.1E+01					
	24-hour		3.47E+02	2.22E+00			No
Background(7)				2.30E+01			
Total				2.52E+01	150.00	none	
PM$_{2.5}$							
	24-hour	1.1E+01	3.47E+02	2.22E+00			No
Background(8)				9.45E+00			
Total				1.17E+01	35.00	none	
	Annual	1.1E+01	2.37E+00	1.15E-04			No
Background(9)				4.32E+00			
Total				4.32E+00	12.00	none	
Lead	Quarterly	7.80E-01	2.26E+00	1.45E-02	0.15	none	No

Notes

1. Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.
2. Both federal and state AAQS values are listed in the New Mexico Air Quality Bureau Air Dispersion Modeling Guidelines dated 2019 JUNE 06.
3. Calculated maximum concentrations for NAAQS and NMAAQS are based on the first high value from OBODM model runs.

EXCEL Tables Used for Modeling Results Evaluation

Pollutant	Averaging Time	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Concentration ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?

4. Calculated lead 3-month arithmetic mean assumes maximum 24-hour concentration occurs every day of the year.
   Lead standard is typically specified as a three -month rolling average or quarterly average.
5. Emission factor for PM_{10} used also for $PM_{2.5}$ which over predicts $PM_{2.5}$ concentrations.
6. Particulate matter background concentrations added as specified from NMED Air Dispersion Modeling Guidelines, March 2019.
7. PM10 24-hr background - 2019 JUNE - North Central - Santa Fe - 23.0 ug/m3 max.
8. PM2.5 24-hr background - 2019 JUNE - North Central - Santa Fe - 98 percentile - 9.45 ug/m3
9. PM2.5 Annual background - 2019 JUNE - North Central - Santa Fe - 4.32 ug/m3
10. SO2 1hr-background - 2019 JUNE - Albuquerque Region - 1-hr background - 15.8 ug/m3 and 1-hour background 99th percentile - 13.2 ug/m3

EXCEL Tables Used for Modeling Results Evaluation

TA-36-8 Screening Analysis Worksheet for 1-Hour Air Concentration

Basis	
2000	lb/hr detonation
0.092	Metal Waste fraction for metals emissions (see Explosives List explanation) - lb metal/lb waste
1	g/sec contaminant emission rate
Model Result (X/Q)	
2.37E-01	1-hour maximum value, ug/m3 per g/sec contaminant

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded ?
Carbon Monoxide (1)	2.00E-01	5.04E+01	1.19E+01	-	2.30E+04	No
Nitrogen Oxides (as NO_2 only)	3.20E-01	8.06E+01	1.91E+01	-	4.70E+02	No
Sulfur Dioxide (1)	1.40E-03	3.53E-01	8.35E-02	-	6.60E+02	No
Benzene (1)	6.00E-04	1.51E-01	3.58E-02	1.30E+03	2.70E+01	No
TNMHC (1)	3.40E-02	8.57E+00	2.03E+00	-	-	-
Acetylene (1)	1.80E-03	4.54E-01	1.07E-01	-	-	-
Ethylene (1)	2.30E-03	5.80E-01	1.37E-01	-	-	-
Propylene (1)	4.10E-04	1.03E-01	2.45E-02	-	-	-
Toluene (1)	1.90E-04	4.79E-02	1.13E-02	3.70E+04	3.70E+04	No
Naphthalene (2)	2.00E-06	5.04E-04	1.19E-04	7.50E+04	-	No
Methylene Chloride (1)	2.40E-03	6.05E-01	1.43E-01	1.40E+04	1.40E+04	No
Aluminum Oxide (3)	7.80E-01	1.81E+01	4.28E+00	-	-	-
Barium(3)	7.80E-01	1.81E+01	4.28E+00	1.50E+03	-	No
Cobalt Acetoacetonate (3)	7.80E-01	1.81E+01	4.28E+00	-	-	-
Copper (3)	7.80E-01	1.81E+01	4.28E+00	-	1.00E+02	No
Lead (3)	7.80E-01	1.81E+01	4.28E+00	1.50E+02	-	No
Trioctyl phosphate (3)	7.80E-01	1.81E+01	4.28E+00	-	-	-
Tungsten Trioxide (3)	7.80E-01	1.81E+01	4.28E+00	-	-	-
Aluminum (4)	1.40E-01	3.25E+00	7.68E-01	-	-	-
Titanium (4)	1.40E-01	3.25E+00	7.68E-01	-	-	-
Tungsten (4)	1.40E-01	3.25E+00	7.68E-01			
Ammonium perchlorate (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Nitrocellulose (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Nitroguanidine (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Nitromethane (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Pentaerythritol tetranitrate (PETN) (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
Tetryl (2)	2.00E-06	5.04E-04	1.19E-04	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	2.00E-06	5.04E-04	1.19E-04	1.50E+03	-	No
Acrylonitrile (5)	1.00E-08	2.52E-06	5.96E-07	2.18E+04	-	No
Bis(2-ethylhexyl)adipate (5)	1.00E-08	2.52E-06	5.96E-07	-	-	-
tris-2-chloroethyl phosphate (5)	1.00E-08	2.52E-06	5.96E-07	-	-	-

EXCEL Tables Used for Modeling Results Evaluation

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded ?
Dibutylphthalate (5)	1.00E-08	2.52E-06	5.96E-07	1.50E+04	-	No
Dinitrotoluene (2,4-) (note #5)	1.00E-08	2.52E-06	5.96E-07	6.00E+02	-	No
Dioctyladipate (5)	1.00E-08	2.52E-06	5.96E-07	-	-	-
Dioctylphthalate (5)	1.00E-08	2.52E-06	5.96E-07	1.00E+04	-	No
Diphenylamine (5)	1.00E-08	2.52E-06	5.96E-07	-	-	-

Notes:

(1a) Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

EXCEL Tables Used for Modeling Results Evaluation

TA-36-8 Screening Analysis Worksheet for Annual Air Concentration

Basis

15,000	lb/yr detonation
1	g/sec contaminant emission rate
0.092	lb metal / lb waste (1a)

Model Result (X/Q)

6.16E-05	Annual maximum value, ug/m3 per g/sec contaminant

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Carbon Monoxide (1)	2.00E-01	4.32E-02	2.66E-06	-	-	-
Nitrogen Oxides (as NO_2 only)	3.20E-01	6.90E-02	4.25E-06	-	-	-
Sulfur Dioxide (1)	1.40E-03	3.02E-04	1.86E-08	-	-	-
Benzene (1)	6.00E-04	1.29E-04	7.97E-09	3.00E+00	3.1E+01	No
TNMHC (1)	3.40E-02	7.34E-03	4.52E-07	-	-	-
Acetylene (1)	1.80E-03	3.88E-04	2.39E-08	-	-	-
Ethylene (1)	2.30E-03	4.96E-04	3.05E-08	-	-	-
Propylene (1)	4.10E-04	8.85E-05	5.44E-09	3.00E+03	3.1E+02	No
Toluene (1)	1.90E-04	4.10E-05	2.52E-09	3.00E+02	5.2E+02	No
Naphthalene (2)	2.00E-06	4.32E-07	2.66E-11	9.00E+00	3.1E-01	No
Methylene Chloride (1)	2.40E-03	5.18E-04	3.19E-08	4.00E+02	6.3E+01	No
Aluminum Oxide (3)	7.80E-01	1.55E-02	9.53E-07	-	5.20E-01	No
Barium (3)	7.80E-01	1.55E-02	9.53E-07	-	5.20E-02	No
Cobalt Acetoacetonate (3)	7.80E-01	1.55E-02	9.53E-07	-	6.30E-04	No
Copper (3)	7.80E-01	1.55E-02	9.53E-07	-	-	-
Lead (3)	7.80E-01	1.55E-02	9.53E-07	-	1.5E-01	No
Trioctyl phosphate (3)	7.80E-01	1.55E-02	9.53E-07	-	-	-
Tungsten Trioxide (3)	7.80E-01	1.55E-02	9.53E-07	-	-	-
Aluminum (4)	1.40E-01	2.78E-03	1.71E-07	-	5.20E-01	No
Titanium (4)	1.40E-01	2.78E-03	1.71E-07	-	-	-
Tungsten (4)	1.40E-01	2.78E-03	1.71E-07	-	-	-
Ammonium perchlorate (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Nitrocellulose (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Nitroguanidine (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Nitromethane (2)	2.00E-06	4.32E-07	2.66E-11	-	5.20E-01	No
Pentaerythritol tetranitrate (PETN) (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Tetryl (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	2.00E-06	4.32E-07	2.66E-11	-	-	-
Acrylonitrile (5)	1.00E-08	2.16E-09	1.33E-13	5.00E+00	6.30E+00	No
Bis(2-ethylhexyl)adipate (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-
tris-2-chloroethyl phosphate (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-
Dibutylphthalate (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-

EXCEL Tables Used for Modeling Results Evaluation

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Dinitrotoluene (2,4-) (note #5)	1.00E-08	2.16E-09	1.33E-13	-	-	-
Dioctyladipate (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-
Dioctylphthalate (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-
Diphenylamine (5)	1.00E-08	2.16E-09	1.33E-13	-	-	-

Notes:

(1a) Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

TA-36-8 Screening Analysis Worksheet for Soil Deposition

Basis

15,000 lb/yr detonation

1 g/sec contaminant emission rate

Model Result (X/Q)

6.16E-05 Annual maximum value, ug/m3 per g/sec contaminant

Contaminant	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	$t_{1/2}$ days	K_s	X	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum LANL ESL mg/kg	Receptor	ESL exceeded?
Carbon Monoxide	2.66E-06	1.15E-02	1.00E+08	6.93E-09	4.62E-02	1.57E-03	-	-	-	-	-	-	-
Nitrogen Oxides (as NO_2 only)	4.25E-06	1.84E-02	1.00E+08	6.93E-09	4.62E-02	2.51E-03	-	-	-	-	-	-	-
Sulfur Dioxide	1.86E-08	8.03E-05	1.00E+08	6.93E-09	4.62E-02	1.10E-05	-	-	-	-	-	-	-
Benzene	7.97E-09	3.44E-05	1.00E+08	6.93E-09	4.62E-02	4.71E-06	1.14E+02	1.78E+01	1.20E+00	No	2.40E+02	Deer mouse	No
TNMHC	4.52E-07	1.95E-03	1.00E+08	6.93E-09	4.62E-02	2.67E-04	-	-	-	-	-	-	-
Acetylene	2.39E-08	1.03E-04	1.00E+08	6.93E-09	4.62E-02	1.41E-05	-	-	-	-	-	-	-
Ethylene	3.05E-08	1.32E-04	1.00E+08	6.93E-09	4.62E-02	1.81E-05	-	-	-	-	-	-	-
Propylene	5.44E-09	2.35E-05	1.00E+08	6.93E-09	4.62E-02	3.22E-06	-	-	2.20E+02	No	-	-	-
Toluene	2.52E-09	1.09E-05	1.00E+08	6.93E-09	4.62E-02	1.49E-06	5.23E+03	-	4.90E+02	No	2.30E+01	Montane shrew	No
Naphthalene	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	1.62E+02	4.97E+01	1.22E+02	No	1.00E+00	Plant	No
Methylene Chloride	3.19E-08	1.38E-04	1.00E+08	6.93E-09	4.62E-02	1.88E-05	4.09E+02	7.66E+02	3.50E+01	No	2.60E+00	Deer mouse	No
Aluminum Oxide	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	7.80E+04	-	7.70E+03	No	-	-	-
Barium	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	1.56E+04	-	1.50E+03	No	1.10E+02	Plant	No
Cobalt Acetoacetonate	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	2.34E+01	1.72E+04	2.30E+00	No	1.30E+01	Plant	No
Copper	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	3.13E+03	-	3.10E+02	No	1.40E+01	American robin	No
Lead	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	4.00E+02	-	4.00E+02	No	1.10E+01	American robin	No
Trioctyl phosphate	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	-	-	1.70E+02	No	-	-	-
Tungsten Trioxide	9.53E-07	4.12E-03	1.00E+08	6.93E-09	4.62E-02	5.64E-04	-	-	6.30E+00	No	-	-	-
Aluminum	1.71E-07	7.39E-04	1.00E+08	6.93E-09	4.62E-02	1.01E-04	7.80E+04	-	7.70E+03	No	-	-	-
Titanium	1.71E-07	7.39E-04	1.00E+08	6.93E-09	4.62E-02	1.01E-04	-	-	-	-	7.70E+01	Montane shrew	No
Tungsten	1.71E-07	7.39E-04	1.00E+08	6.93E-09	4.62E-02	1.01E-04	-	-	6.30E+00	No	-	-	-
Ammonium perchlorate	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	-	-	5.50E+00	No	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX)	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	3.85E+03	-	3.90E+02	No	1.60E+01	Earthworm	No
Nitrocellulose	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	-	-	1.90E+07	No	-	-	-
Nitroguanidine	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	-	-	6.30E+02	No	-	-	-
Nitromethane	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	-	-	5.40E+00	No	-	-	-
Pentaerythritol tetranitrate (PETN)	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	-	-	1.30E+01	No	1.00E+02	Deer mouse	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	3.01E+02	8.31E+01	8.30E+00	No	2.30E+00	American robin	No
Tetryl	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	1.56E+02	-	1.60E+01	No	1.50E+00	Deer mouse	No
2,4,6-trinitrotoluene (TNT)	2.66E-11	1.15E-07	1.00E+08	6.93E-09	4.62E-02	1.57E-08	3.60E+01	2.11E+02	3.60E+00	No	7.50E+00	American robin	No
Acrylonitrile	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	-	-	8.10E+01	No	-	-	-
Bis(2-ethylhexyl)adipate	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	-	-	4.50E+02	No	-	-	-
tris-2-chloroethyl phosphate	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	-	-	2.70E+01	No	-	-	-

EXCEL Tables Used for Modeling Results Evaluation

Contaminant	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	$t_{1/2}$ days	K_s	X	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum LANL ESL mg/kg	Receptor	ESL exceeded?
Dibutylphthalate	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	6.16E+03	-	6.30E+02	No	1.10E-02	American robin	No
Dinitrotoluene (2,4-)	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	1.23E+02	1.71E+01	1.70E+00	No	6.00E+00	Plant	No
Dioctyladipate	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	-	-	4.50E+02	No	-	-	-
Dioctylphthalate	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	1.23E+03	3.80E+02	3.90E+01	No	9.10E-01	Montane shrew	No
Diphenylamine	1.33E-13	5.74E-10	1.00E+08	6.93E-09	4.62E-02	7.85E-11	-	-	6.30E+02	No	1.00E+01	Robin insectivore	No

Notes

1 Soil concentrations calculated from annual model result using procedures from *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, CA OEHHA August 2003.

2 No degradation is assumed using half-live of 1.00E+08 which overpredicts for organic compounds.

3 Calculation used described below.

C_s = Dep * X / (K_s * SD * BD * T_t)

Dep = Deposition on the affected soil area per day (ug/m^2/d)

Dep = GLC * Dep-rate * 86,400

GLC = The chemical specific annual ground level concentation from OBODM result and emission factor (ug/m^3)

Dep-rate = 0.05 m/sec (default value for uncontrolled source)

86,400 = Seconds per day conversion factor

X = $[\{e^{-K_s * T_f} - e^{-K_s * T_o}\} / K_s] + T_t$

e = 2.718

K_s = Soil elimination constant

3650 T_f = End of evaluation period (d)

0 T_o = Beginning of evaluation period (d)

3650 T_t = Total days of exposure period T_f - T_o (d)

K_s = 0.693 / $t_{1/2}$

0.693 = Natural log of 2

$t_{1/2}$ = Chemical specific soil half-life (d)

Additional default values

0.01 SD = Soil mixing depth (m) = 0.01 for soil ingestion or dermal pathway (analysis is on Laboratory property)

1,333 BD = Soil bulk density (kg/m^3)

4 As described in the narrative, where there is either a non-cancer or cancer screening level for COPC, the lesser of the two is used for the evaluation. The EPA RSL is only applied when NMED has no value listed for the COPC.

EXCEL Tables Used for Modeling Results Evaluation

TA-39-6 Screening Analysis Worksheet for 1-Hour Air Concentration

Basis

250	lb/hr detonation
4	detonations/hr
0.092	lb metal / lb waste (1a)
1.00E+00	g/sec contaminant emission rate

Model Result (X/Q)

1.54E+00	1-hour maximum value, ug/m3 per g/sec contaminant for 1 detonation
6.16E+00	1-hour maximum value, ug/m3 per g/sec contaminant for 4 detonations/hr

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Carbon Monoxide (1)	2.00E-01	6.30E+00	3.88E+01	-	2.30E+04	No
Nitrogen Oxides (as NO_2 only)	3.20E-01	1.01E+01	6.21E+01	-	4.70E+02	No
Sulfur Dioxide (1)	1.40E-03	4.41E-02	2.72E-01	-	6.60E+02	No
Benzene (1)	6.00E-04	1.89E-02	1.16E-01	1.30E+03	2.70E+01	No
TNMHC (1)	3.40E-02	1.07E+00	6.60E+00	-	-	-
Acetylene (1)	1.80E-03	5.67E-02	3.49E-01	-	-	-
Ethylene (1)	2.30E-03	7.25E-02	4.46E-01	-	-	-
Propylene (1)	4.10E-04	1.29E-02	7.96E-02	-	-	-
Toluene (1)	1.90E-04	5.99E-03	3.69E-02	3.70E+04	3.70E+04	No
Naphthalene (2)	2.00E-06	6.30E-05	3.88E-04	7.50E+04	-	No
Methylene Chloride (1)	2.40E-03	7.56E-02	4.66E-01	1.40E+04	1.40E+04	No
Aluminum Oxide (1a, 3)	7.80E-01	2.26E+00	1.39E+01	-	-	-
Barium(1a, 3)	7.80E-01	2.26E+00	1.39E+01	1.50E+03	-	No
Cobalt Acetoacetonate (1a, 3)	7.80E-01	2.26E+00	1.39E+01	-	-	-
Copper (1a, 3)	7.80E-01	2.26E+00	1.39E+01	-	1.00E+02	No
Lead (1a, 3)	7.80E-01	2.26E+00	1.39E+01	1.50E+02	-	No
Trioctyl phosphate (1a, 3)	7.80E-01	2.26E+00	1.39E+01	-	-	-
Tungsten Trioxide (1a, 3)	7.80E-01	2.26E+00	1.39E+01	-		
Aluminum (4)	1.40E-01	4.06E-01	2.50E+00	-	-	-
Titanium (4)	1.40E-01	4.06E-01	2.50E+00	-	-	-
Tungsten (4)	1.40E-01	4.06E-01	2.50E+00			
Ammonium perchlorate (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Nitrocellulose (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Nitroguanidine (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Nitromethane (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Pentaerythritol tetranitrate (PETN) (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
Tetryl (2)	2.00E-06	6.30E-05	3.88E-04	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	2.00E-06	6.30E-05	3.88E-04	1.50E+03	-	No
Acrylonitrile (5)	1.00E-08	3.15E-07	1.94E-06	2.18E+04	-	No

EXCEL Tables Used for Modeling Results Evaluation

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum 1-Hour Concentration ug/m^3	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Bis(2-ethylhexyl)adipate (5)	1.00E-08	3.15E-07	1.94E-06	-	-	-
tris-2-chloroethyl phosphate (5)	1.00E-08	3.15E-07	1.94E-06	-	-	-
Dibutylphthalate (5)	1.00E-08	3.15E-07	1.94E-06	1.50E+04	-	No
Dinitrotoluene (2,4-) (5)	1.00E-08	3.15E-07	1.94E-06	6.00E+02	-	No
Dioctyladipate (5)	1.00E-08	3.15E-07	1.94E-06	-	-	-
Dioctylphthalate (5)	1.00E-08	3.15E-07	1.94E-06	1.00E+04	-	No
Diphenylamine (5)	1.00E-08	3.15E-07	1.94E-06	-	-	-

Notes:

(1a) Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic.

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

EXCEL Tables Used for Modeling Results Evaluation

TA-39-6 Screening Analysis Worksheet for Annual Air Concentration

Basis

15,000	lb/yr detonation
1	g/sec contaminant emission rate
0.092	lb metal / lb waste (1a)

Model Result (X/Q)

1.79E-03	Annual maximum value, ug/m3 per g/sec contaminant

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Carbon Monoxide (1)	2.00E-01	4.32E-02	7.72E-05	-	-	-
Nitrogen Oxides (as NO_2 only)	3.20E-01	6.90E-02	1.24E-04	-	-	-
Sulfur Dioxide (1)	1.40E-03	3.02E-04	5.41E-07	-	-	-
Benzene (1)	6.00E-04	1.29E-04	2.32E-07	3.00E+00	3.10E+01	No
TNMHC (1)	3.40E-02	7.34E-03	1.31E-05	-	-	-
Acetylene (1)	1.80E-03	3.88E-04	6.95E-07	-	-	-
Ethylene (1)	2.30E-03	4.96E-04	8.88E-07	-	-	-
Propylene (1)	4.10E-04	8.85E-05	1.58E-07	3.00E+03	3.10E+02	No
Toluene (1)	1.90E-04	4.10E-05	7.34E-08	3.00E+02	5.20E+02	No
Naphthalene (2)	2.00E-06	4.32E-07	7.72E-10	9.00E+00	3.10E-01	No
Methylene Chloride (1)	2.40E-03	5.18E-04	9.27E-07	4.00E+02	6.30E+01	No
Aluminum Oxide (3)	7.80E-01	1.55E-02	2.77E-05	-	5.20E-01	No
Barium (3)	7.80E-01	1.55E-02	2.77E-05	-	5.20E-02	No
Cobalt Acetoacetonate (3)	7.80E-01	1.55E-02	2.77E-05	-	6.30E-04	No
Copper (3)	7.80E-01	1.55E-02	2.77E-05	-	-	-
Lead (3)	7.80E-01	1.55E-02	2.77E-05	-	1.50E-01	No
Trioctyl phosphate (3)	7.80E-01	1.55E-02	2.77E-05	-	-	-
Tungsten Trioxide (3)	7.80E-01	1.55E-02	2.77E-05	-	-	-
Aluminum (4)	1.40E-01	2.78E-03	4.97E-06	-	5.20E-01	No
Titanium (4)	1.40E-01	2.78E-03	4.97E-06	-	-	-
Tungsten (4)	1.40E-01	2.78E-03	4.97E-06	-	1.52E+00	-
Ammonium perchlorate (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX) (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Nitrocellulose (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Nitroguanidine (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Nitromethane (2)	2.00E-06	4.32E-07	7.72E-10	-	5.20E-01	No
Pentaerythritol tetranitrate (PETN) (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-

EXCEL Tables Used for Modeling Results Evaluation

Contaminant	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration ug/m^3	CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Tetryl (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
2,4,6-trinitrotoluene (TNT) (2)	2.00E-06	4.32E-07	7.72E-10	-	-	-
Acrylonitrile (5)	1.00E-08	2.16E-09	3.86E-12	5.00E+00	6.30E+00	No
Bis(2-ethylhexyl)adipate (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
tris-2-chloroethyl phosphate (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
Dibutylphthalate (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
Dinitrotoluene (2,4-) (note #5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
Dioctyladipate (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
Dioctylphthalate (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-
Diphenylamine (5)	1.00E-08	2.16E-09	3.86E-12	-	-	-

Notes:

(1a) Based on all waste being treated by OD at TA-36-8, the explosive waste with known metal contamination is less than 9.2%. See Attachment A for the calculation.

(1) Based on Maximum Emission Factors (EF) listed in Table 16.2-14 of the draft Chapter 16 of AP-42.

(2) Based on the Maximum Efs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs Not In Energetic

(3) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Compounds in Energetics.

(4) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for Metals - Elemental in Energetics.

(5) Based on the Maximum EFs listed in Table 16.2-14 of the draft Chapter 16 of AP-42 for SVOCs in Energetics. These are under the header of Binder/Plasticizer/Anti-oxidants in Att. A.

(5 continued) Since no data is listed for this EP, the value for BDL was assigned as explained In Section 2.1.4.4 on Page 22 of the Ch. 16 Background Document.

EXCEL Tables Used for Modeling Results Evaluation

TA-39-6 Screening Analysis Worksheet for Soil Concentration from Deposition

Basis

15,000 lb/yr detonation

1 g/sec contaminant emission rate

Model Result (X/Q)

1.79E-03 Annual maximum value, ug/m3 per g/sec contaminant

Contaminant	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	$t_{1/2}$ days	K_s	X	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs (4) - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum (No Effect) LANL ESL mg/kg	Receptor	ESL exceeded?
Carbon Monoxide	7.72E-05	3.34E-01	1.00E+08	6.93E-09	4.62E-02	4.57E-02	-	-	-	-	-	-	-
Nitrogen Oxides (as NO_2 only)	1.24E-04	5.34E-01	1.00E+08	6.93E-09	4.62E-02	7.31E-02	-	-	-	-	-	-	-
Sulfur Dioxide	5.41E-07	2.34E-03	1.00E+08	6.93E-09	4.62E-02	3.20E-04	-	-	-	-	-	-	-
Benzene	2.32E-07	1.00E-03	1.00E+08	6.93E-09	4.62E-02	1.37E-04	1.14E+02	1.78E+01	1.20E+00	No	2.40E+02	Deer mouse	No
TNMHC	1.31E-05	5.67E-02	1.00E+08	6.93E-09	4.62E-02	7.77E-03	-	-	-	-	-	-	-
Acetylene	6.95E-07	3.00E-03	1.00E+08	6.93E-09	4.62E-02	4.11E-04	-	-	-	-	-	-	-
Ethylene	8.88E-07	3.84E-03	1.00E+08	6.93E-09	4.62E-02	5.25E-04	-	-	-	-	-	-	-
Propylene	1.58E-07	6.84E-04	1.00E+08	6.93E-09	4.62E-02	9.36E-05	-	-	2.20E+02	No	-	-	-
Toluene	7.34E-08	3.17E-04	1.00E+08	6.93E-09	4.62E-02	4.34E-05	5.23E+03	-	4.90E+02	No	2.30E+01	Montane shrew	No
Naphthalene	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	1.62E+02	4.97E+01	1.22E+02	No	1.00E+00	Plant	No
Methylene Chloride	9.27E-07	4.00E-03	1.00E+08	6.93E-09	4.62E-02	5.48E-04	4.09E+02	7.66E+02	3.50E+01	No	2.60E+00	Deer mouse	No
Aluminum Oxide	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	7.80E+04	-	7.70E+03	No	-	-	-
Barium	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	1.56E+04	-	1.50E+03	No	1.10E+02	Plant	No
Cobalt Acetoacetonate	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	2.34E+01	1.72E+04	2.30E+00	No	1.30E+01	Plant	No
Copper	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	3.13E+03	-	3.10E+02	No	1.40E+01	American robin	No
Lead	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	4.00E+02	-	4.00E+02	No	1.10E+01	American robin	No
Trioctyl phosphate	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	-	-	1.70E+02	No	-	-	-
Tungsten Trioxide	2.77E-05	1.20E-01	1.00E+08	6.93E-09	4.62E-02	1.64E-02	-	-	6.30E+00	No	-	-	-
Aluminum	4.97E-06	2.15E-02	1.00E+08	6.93E-09	4.62E-02	2.94E-03	7.80E+04	-	7.70E+03	No	-	-	-
Titanium	4.97E-06	2.15E-02	1.00E+08	6.93E-09	4.62E-02	2.94E-03	-	-	-	-	7.70E+01	Montane shrew	No
Tungsten	4.97E-06	2.15E-02	1.00E+08	6.93E-09	4.62E-02	2.94E-03	-	-	6.30E+00	No	-	-	-
Ammonium perchlorate	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	-	-	5.50E+00	No	-	-	-
Octahydro-1,3,5,7-tertanitro-1,3,5,7-tetrazocine (HMX)	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	3.85E+03	-	3.90E+02	No	1.60E+01	Earthworm	No
Nitrocellulose	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	-	-	1.90E+07	No	-	-	-
Nitroguanidine	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	-	-	6.30E+02	No	-	-	-
Nitromethane	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	-	-	5.40E+00	No	-	-	-
Pentaerythritol tetranitrate (PETN)	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	-	-	1.30E+01	No	1.00E+02	Deer mouse	No
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	3.01E+02	8.31E+01	8.30E+00	No	2.30E+00	American robin	No
Tetryl	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	1.56E+02	-	1.60E+01	No	1.50E+00	Deer mouse	No
2,4,6-trinitrotoluene (TNT)	7.72E-10	3.34E-06	1.00E+08	6.93E-09	4.62E-02	4.57E-07	3.60E+01	2.11E+02	3.60E+00	No	7.50E+00	American robin	No
Acrylonitrile	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	-	-	8.10E+01	No	-	-	-
Bis(2-ethylhexyl)adipate	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	-	-	4.50E+02	No	-	-	-
tris-2-chloroethyl phosphate	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	-	-	2.70E+01	No	-	-	-
Dibutylphthalate	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	6.16E+03	-	6.30E+02	No	1.10E-02	American robin	No
Dinitrotoluene (2,4-)	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	1.23E+02	1.71E+01	1.70E+00	No	6.00E+00	Plant	No
Dioctyladipate	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	-	-	4.50E+02	No	-	-	-
Dioctylphthalate	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	1.23E+03	3.80E+02	3.90E+01	No	9.10E-01	Montane shrew	No
Diphenylamine	3.86E-12	1.67E-08	1.00E+08	6.93E-09	4.62E-02	2.28E-09	-	-	6.30E+02	No	1.00E+01	Robin insectivore	No

Contaminant	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	$t_{1/2}$ days	K_s	X	10 Year Soil Concentration mg/kg	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	EPA RSLs (4) - Resident Soil based on TR=1E-06 or HI =0.1 (mg/kg)	Screening Level Exceeded?	Minimum (No Effect) LANL ESL mg/kg	Receptor	ESL exceeded?

Notes

1 Soil concentrations calculated from annual model result using procedures from *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments,* CA OEHHA August 2003.

2 No degradation is assumed using conservative half-live which over predicts for organic compounds.

3 Calculation used described below.

C_s = Dep * X / (K_s * SD * BD * T_t)

Dep = Deposition on the affected soil area per day (ug/m^2/d)

Dep = GLC * Dep-rate * 86,400

GLC = The chemical specific annual ground level concentration from OBODM result and emission factor (ug/m^3)

Dep-rate = 0.05 m/sec (default value for uncontrolled source)

86,400 = Seconds per day conversion factor

X = $[\{e^{-K_s * T_f} - e^{-K_s * T_o}\} / K_s] + T_t$

e = 2.718

K_s = Soil elimination constant

3650 T_f = End of evaluation period (d)

0 T_o = Beginning of evaluation period (d)

3650 T_t = Total days of exposure period T_f - T_o (d)

K_s = 0.693 / $t_{1/2}$

0.693 = Natural log of 2

$t_{1/2}$ = Chemical specific soil half-life (d)

Additional default values

0.01 SD = Soil mixing depth (m) = 0.01 for soil ingestion or dermal pathway (analysis is on Laboratory property)

1,333 BD = Soil bulk density (kg/m^3)

4 As described in the narrative, where there is either a non-cancer or cancer screening level for COPC, the lesser of the two is used for the evaluation. The EPA RSL is only applied when NMED has no value listed for the COPC.

26. LANL (Los Alamos National Laboratory), June 2020f. Supplement 4-7 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Open Detonation Unit at Technical Area 36 Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. (LANL 2020f)

Supplement 4-7

Open Detonation Unit at Technical Area 36 Human Health and Ecological Risk Screening Assessments

LA-UR-20-24479

OPEN DETONATION UNIT AT TECHNICAL AREA 36
HUMAN HEALTH AND ECOLOGICAL RISK-SCREENING ASSESSMENTS

June 15, 2020

EXECUTIVE SUMMARY

The area around the open detonation (OD) area Technical Area (TA) 36 (the TA-36 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-36 OD Unit is referred to as "the Unit" in the remainder of this risk assessment. Surface soil samples were collected in September 2018 and analyzed for inorganic and organic compounds. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released into the soil at levels that pose an unacceptable risk to human health or the environment.

For the human health risk-screening assessment, residential and industrial exposure scenarios were evaluated by comparing the maximum exposure point concentration for each analyte to the New Mexico Environment Department (NMED) soil screening levels (NMSSLs). The following conclusions are made:

- **Detected inorganics were compared to background values (BVs) and risk-based screening levels (i.e., the NMSSLs).** Eight detected inorganics exceeded background, although three of those were only 1.2 to 2 times higher than background. Only thallium exceeded risk-based screening levels (SLs).
- **Detected organics were compared to risk-based SLs.** There are no individual organic constituents that exceed SLs.
- **Screening Level Hazard Indices (HI) were calculated.** The sum of the screening level cancer risk ratios or the noncancer hazard quotients (HQs) is called a HI. The HIs based on a cancer endpoint for inorganics or organics do not exceed a value of one. This is not equivalent to cancer risk, but is an indicator of how the exposure point concentration (EPC) compares to the conservative screening levels. The noncancer HI for the hypothetical future resident is 3, and the HI for workers is less than 1. A statistically – based estimate of the EPC for thallium was below the screening level and no further evaluation for human health risk analysis was done.
- **The screening evaluation indicates that residents or workers are not at risk due to exposure to soils at the Unit.**

Potential risk to ecological receptors was evaluated by analyzing different lines of evidence that were weighed to draw a conclusion regarding potential for adverse ecological effects. This included:

- **Comparing maximum exposure point concentrations (EPC) to minimum no effect (NE) and low effect (LE) ecological screening levels (ESLs).** There were 10 analytes for which the maximum value exceeded NE ESLs, and eight analytes that exceeded LE ESLs. A total of 13 analytes had HQs greater than 0.3 for comparison of the maximum detected value to the NE ESL.
- **Comparing upper 95th percentile confidence limits (UCL95) as the EPC to minimum NE and LE ESLs.** There were five analytes for which the UCL95 EPC exceeded NE ESLs, and three that also exceeded LE ESLs.
- **Calculating HIs.** The HIs for NE ESL and LE ESL comparisons to the UCL95 as the EPC exceeded 1.
- **Application of site-specific area use factors.** The American robin, plants, and earthworms had HQs above 1 under the area use factor analysis. There were no analytes that exceeded LE ESLs once the areal extent of the Unit was taken into consideration in conjunction with typical home range for ecological receptors. The HIs for plants and earthworms were 6 and 20 respectively for NE ESLs, and 2 for earthworms for LE ESLs. The HIs for robins feeding as omnivores or insectivores for comparison to NE ESLs were 2 and 3, respectively. Plants and earthworms are

not expected to occur in the Unit due to intended use and bare ground, and robins are not expected to feed on a daily basis totally within the Unit due to lack of food and cover, as well as human disturbance due to intended use.

- **Avian and mammalian population information does not indicate that birds or mammals are adversely affected**.
- **The ecological risk assessment concludes that there is likely no risk to ecological receptors at the Unit.**

Table of Contents

ATTACHMENT A. ProUCL Output

ATTACHMENT B. LANL ECORISK DATABASE 4.1

List of Tables

List of Figures

Acronyms and Abbreviations

AUF	Area Use Factor
BMP	Best Management Practice
BV	Background Value
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSEM	Conceptual Site Exposure Model
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESL	Ecological Screening Level
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Cyclotetramethylene-tetranitramine
HQ	Hazard Quotient
HR	Home Range
LANL	Los Alamos National Laboratory
LD50	Lethal Dose for Half of the Population
LE	Low Effect
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
NE	No Effect
NMED	New Mexico Environment Department
NMSSL	New Mexico Soil Screening Levels
NOAEL	No Observed Adverse Effect Level
OD	Open Detonation
PAUF	Population Area Use Factor
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RSL	Regional Screening Level
SD	Standard Deviation
SF	Cancer Slope Factor
SL	Screening Level
TA	Technical Area
TATB	2,4,6-Triamino-1,3,5-trinitrobenzene
TECi	Toxicity Equivalent Concentration for congener ***i***
TEF	Toxicity Equivalency Factor
TEQ	Toxicity Equivalent Quotient
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
UCL95	95% Upper Confidence Limit of The Mean
WHO	World Health Organization

1. INTRODUCTION

The area around the open detonation (OD) area at Technical Area (TA) 36 (the TA-36 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-36 OD Unit is referred to as “the Unit” in the remainder of this risk assessment.

The Unit is a hazardous waste management unit located in the southern portion of LANL (Figure 1-1), near Building 8. The unit was established in 1959 for the testing of explosives materials and has been used for open detonation of high explosives debris potentially contaminated with depleted uranium and other metals. The Unit consists of a relatively flat area that measures approximately 1.44 acres. All waste treatment detonations are conducted above ground with the use of a predetermined amount of explosive to initiate and increase the effectiveness of the treatment. Waste treatment shots are assembled in a manner to ensure complete detonation of the waste with minimized fragmentation dispersal. There are several firing sites and support buildings. The firing pit is bounded on the east, south, and west sides by storm water best management practices (BMPs) consisting of earth berms that have been hydroseeded and mulched.

One surface soil sampling event of the top 2 inches of soil at 15 discrete locations (Figure 1-1) was conducted in and around the Unit on September 19, 2018. Sample collection included soil both in and out of potential run-off areas; however, sample collection did not include rocks, debris, or vegetation. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

The results of the risk assessments are presented in the following sections.

2. HUMAN HEALTH RISK ASSESSMENT

2.1. CONCEPTUAL SITE MODEL

The primary land use is industrial because only authorized Laboratory workers currently have access to the area around the Unit. Laboratory workers are the primary human receptors, and the industrial scenario is the defining scenario for the human health risk-screening assessment (i.e., the scenario on which decisions are based). Because the site is located within the boundaries of an operational facility (i.e., TA-36), the reasonably foreseeable future land use will continue to be industrial. A Hypothetical Future Residential exposure is also assessed and provided for comparison purposes.

The release of contaminants from open detonation operations has potentially occurred for many years. Releases are transported primarily by wind, which rapidly disperses the material in ambient air. Most material is likely deposited close to the source(s), and concentrations are expected to decrease with distance from the source. Exposure to a site worker may occur through various surface soil contact pathways. Potential exposure pathways are:

- Incidental ingestion of surface soil
- Inhalation of fugitive dust or volatiles emanating from surface soil
- Dermal contact with surface soil

2.2. IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2.2.1. Sampling and Data Analysis

Fifteen surface soil samples and one duplicate were collected September 19, 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 to 2 inches below ground surface. The duplicate pair was sample 1 and 1 dup (WST36-18-162834 and WST36-18-162985). Each sample set was analyzed for the following:

- Volatile Organic Compounds (VOCs)
- Semi-Volatile Organic Compounds (SVOCs)
- Total Metals
- Dioxins/Furans
- Perchlorates
- High Explosives

A staged approach was used for the risk assessment. Duplicates were handled consistent with the New Mexico Environment Department (NMED) guidance (NMED 2019) which states that in the initial screening assessment the maximum, and not the average, of the duplicate pair must be used. The approach for the human health (HHRA) risk assessment was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to background values (BVs). Analytes less than BVs were eliminated from further evaluation.
- The screening approach then used the maximum of all detected data, including the duplicate pair, for the initial screening evaluation. The maximum concentration of each analyte was divided by its screening level (SL). For the HHRA, this meant using two SLs based on toxicity endpoints, (i.e., a cancer and noncancer SL were used to obtain a cancer ratio and non-cancer hazard quotient (HQ)).
- All analytes that exceeded the initial SLs were considered to have "failed" the initial screen. These are considered to be contaminants of potential concern (COPCs).
- A refinement of the exposure point concentrations (EPCs) was performed. Duplicates were averaged prior to calculating an upper 95th percent confidence limit on the mean (UCL95). The UCL95 concentrations were compared to SLs, and any analytes above the SLs were evaluated further if necessary.

Figure 1-1 shows the current sampling locations from which data were obtained for use in the risk assessment.

2.2.2. Evaluation of Inorganic Analytes

Inorganic analytes are first compared to BVs established for the site (LANL 1998). No further evaluation is necessary for analytes for which the maximum is less than the BV, and these data are not compared to risk-based SLs. For analytes for which the maximum exceeded the BV but did not exceed risk-based SLs known as the New Mexico Soil Screening Levels (NMSSLs) (NMED 2019), no further evaluation is necessary. If the maximum exceeded the BV and one or more risk-based SLs as indicated by a ratio of the maximum to the SL being > 1, a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the SLs. The toxicity of the various constituents analyzed in this investigation is incorporated into the screening levels.

Where an NMSSL was not available, the USEPA Regional Screening Level (RSL) was used. If an RSL was also not available, a suitable surrogate is proposed if toxicity and physicochemical data are sufficient to allow identifying a suitable surrogate. The following inorganic analytes required surrogates:

- Calcium, sodium, potassium, magnesium – these are macronutrients, so unless concentrations exceed background they are not evaluated for toxicity. SLs for these are lacking.
- Chromium (Cr) – the toxicity values based on NMED CrIII were used since NMED has no SLs specifically for total Cr, and the site is unlikely to have significant CrVI because CrIII is more stable in the environment that CrVI, and CrVI is most often associated with industrial processes (ATSDR 2012).
- Mercury – the toxicity values for NMED mercuric salts was used for the SL as this is the form expected in arid soils
- Lead – the EPA toxicity values of 400 mg/kg for residents and 800 mg/kg for workers were applied for lead.

All reporting limits were adequate for nondetected inorganics as indicated by ratios of the maximum reporting limit to minimum screening level being 1 or less. There were no rejected (R-qualified) inorganic data in the dataset.

2.2.3. Evaluation of Organic Analytes

Twelve soil samples and one duplicate were collected for analysis of organics, but some organic analytes were evaluated by more than one method, resulting in an apparently higher sample count (i.e., 2,4- and 2,6- dinitrotoluene, dichlorobenzenes). The maximum concentration regardless of the method was used as the EPC.

Organic analytes are not compared to background values as a matter of standard practice, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based SLs. Where a SL was not available, a suitable surrogate is proposed. Surrogates were obtained for the following analytes:

- Acenapthylene – there are no NMSSLs or RSLs for this chemical. The NMSSL for naphthalene was used as a surrogate.
- Benzoic Acid – there are no NMSSLs. The EPA RSLs were used to represent noncancer health effects.
- Benzyl Alcohol– there are no NMSSLs. The EPA RSLs were used to represent noncancer health effects.
- Butylbenzylphthalate – there are no NMSSLs and the EPA RSLs were used to represent cancer and noncancer health effects. The RSL was adjusted to a 10^{-5} cancer risk level consistent with NMED practice.
- 2,4,6-triamino-1,3,5- trinitrobenzene (TATB) – there is no NMSSL or RSL for TATB. RSLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.
- 1,2 and 1,4 Xylene [m,p-xylenes] - the toxicity values for m-xylene (1,3-xylene) were used as the basis of the screening levels as it is just slightly more conservative than using values for p-xylene (1,4-xylene).

Reporting limits were adequate for all analytes with the exception of nitrosodimethylamine[N-], for which the reporting limit to residential SL ratio was 4. This analyte was not detected in any of the samples, and all reporting limits were similar and exceeded the screening level. It is subject to photodecomposition, and degrades with heat or biological processes (EPA 2014). Therefore, it is not expected to be stable in the environment and is not expected to occur at the Unit. This chemical is not considered further. There were no rejected (R-qualified) inorganic data in the dataset.

2.3. EXPOSURE POINT CONCENTRATIONS

A phased approach was used to establish the EPCs. First the maximum detected value for each analyte was used as the EPC and was compared to a screening level. Analytes for which the maximum value was less than the lowest screening level are not evaluated further. If the maximum EPC exceeded screening levels, evaluation was continued with the UCL95 used as the EPC for the comparison. If there were too few detected concentrations reported to allow calculation of a UCL95 (i.e., number of detects <6), the median of all the data for the analyte including the detected concentrations and the method detection limits (MDLs) was used. All non-rejected data were used to calculate the UCL95 for the risk-screening assessments, if appropriate.

Guidance from NMED was used to evaluate concentrations with the potential toxicity of the dioxin/furans. This guidance relies on the 2005 World Health Organization (WHO) toxicity equivalency factors (TEF) (Van den berg et al. 2006) approach. The TEFs are multiplied by the measured concentration to obtain a congener-specific product called the toxicity equivalent concentration (TECi), and the product for each (TECi) is summed for each sample location. This sum is referred to as the toxicity equivalent quotient (TEQ). The TEQ is divided by the NMED screening level for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) to obtain a risk ratio.

2.4. SCREENING EVALUATION

The following sections present the human health risk-screening assessments for the Unit. The EPCs are presented in Table 2-1.

The EPC for each detected analyte was divided by the industrial and residential soil SLs to obtain a hazard quotient (HQ), and the hazard index (HI) was calculated by summing the HQs (NMED 2019). The chemical SLs used in the evaluations were obtained from current NMED guidance (NMED 2019) or the most recent EPA regional screening levels (RSLs) (EPA 2019) if an NMED value was not available. The cancer-based EPA RSLs were multiplied by 10 to adjust them to a cancer risk level of $1x10^{-5}$, consistent with the NMSSLs. The NMSSLs for carcinogens are equivalent to a 1×10^{-5} cancer risk, and for noncarcinogens the NMSSLs correlate to a ratio or HQ of 1. The EPC was compared to the carcinogenic and noncarcinogenic SL for residents and industrial workers, and the hazard index (HI) was calculated by summing the HQs (NMED 2019). Any detected organic analytes that exceeded the SLs were considered COPCs. Any inorganic analytes that exceeded both background and the SL were also considered COPCs.

2.4.1. Background Data

The background data used in this evaluation were obtained from LANL "Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico, September 1998. The background data are used in the RCRA corrective action process to distinguish between contaminated and uncontaminated media and have been accepted by NMED. As stated in LANL (1998) on page 4, section 3.1.1,

> Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for inorganic chemical analyses. These samples provide information about the varied soils

and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, 05702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms.

The locations sampled as part of the background study were not impacted by deposition from the historical operation of the OD units or other firing sites. Benchmarks termed BVs were obtained from this document to use in comparison to site data.

2.4.2. **Data Analysis**

Table 2-1 presents summary statistics for the September 2018 surface soil samples. There were 15 samples included in this data set collected in September 2018. However, including data from duplicate pair for grid point 1, and including analysis by different methods for certain analytes, results in an increased apparent sample size above 15 for some analytes (Table 2-1). Maximum concentrations in the soil samples analyzed for inorganics were compared to the established soil BVs (LANL 1998) (Table 2-1).

Inorganics

For detected inorganic analytes, the maximum detected reported result was used as the initial EPC (Table 2-1). Background values for the site are from the 1998 background report (LANL 1998), and soil screening levels are NMSSLs (Table 2-2). The maximum concentration for the following detected inorganics exceeded BVs:

- Chromium
- Copper
- Mercury
- Silver
- Thallium

There were three other detected inorganics that were approximately equivalent or just slightly higher than BVs. These were as follows:

- Cadmium – 1.2 times above background
- Lead – 1.6 times above background
- Zinc – 1.1 times above background

All other inorganics were equal to or lower than BVs. A BV for perchlorate was not available.

Only thallium exceeded the residential NMSSLs (NMED 2019) based on a noncancer toxicity endpoint. Thallium did not exceed the worker NMSSL.

The sum of the screening level risk ratios is termed a Hazard Index (HI), which were calculated for inorganics and organics separately. The cancer-based sum of the screening level HQs for maximum detected soil concentrations of inorganics above background was 5E-06 for residents, and 1E-06 for workers (Table 2-2). This is not a cancer risk estimate in terms of cancer probability, but an indication of how soil concentrations compare to screening levels. The noncancer-based sum of the screening level HQs for maximum detected soil concentrations of inorganics above background was 3 for residents, and 0.2 for workers.

Organics

Numerous organics were detected in the surface soil samples (Table 2-1). These include energetics or explosives (e.g., HMX [cyclotetramethylene-tetranitramine] and TATB). SVOCs including fluoranthene and pyrene were detected. Phthalates (e.g., butylbenzyl- and di-n-butylphthalate) were also detected (Table 2-1), as were some dioxin/furan congeners.

No individual constituents exceeded NMSSLs (NMED 2019). The HI for the evaluation of maximum detected soil concentrations of organics for cancer-based health effects was 0.1 for residents, and 0.02 for workers (Table 2-2). The noncancer-based HI for maximum detected soil concentrations of organics was 0.03 for residents, and 0.002 for workers.

Dioxin/Furans

The dioxin/furans are organics but are evaluated in the analysis differently than other organics. Dioxins/furans were detected in the surface soil samples (Table 2-1). The evaluation of the dioxin/furans is summarized in Table 2-3. The measured detected concentration or the MDL for nondetects is shown for each congener in each sample. The detection status is indicated by a zero for nondetect, and a 1 for a detected value. The TEFs are shown for each congener, and multiplying the TEF by the concentration produces the TECi. Summing the TECi yields the TEQ. Dividing the TEQ for each sample by the residential or industrial SL also shown in Table 2-3 produces a ratio which for all samples was 1 or less. Therefore, the dioxins and furans do not exceed risk-based SLs.

Data Analysis Conclusions

The initial risk analysis for all inorganic and organic analytes was based on comparison of the maximum detected value as the EPC. Thallium is the only individual constituent that exceeded SLs. The noncancer HI exceeded a value of one. Thallium was carried forward for further evaluation with a UCL95 as described in Section 2.4.3.

2.4.3. Additional Data Analysis

The UCL95 for thallium cannot be calculated due to low detection frequency (n=3); and therefore the value used as the EPC was 0.137 mg/kg. This is based on the median of all detected data and the MDLs to reflect an estimate of the concentration throughout the area. The median value was used as the EPC since a UCL95 cannot be reliably calculated. There are no cancer-based toxicity values for thallium. The EPC was therefore compared only to the noncancer NMSSLs for thallium. The HQ for the hypothetical future resident is less than 1, indicating that there is unlikely any excess noncancer hazard for hypothetical future residents potentially exposed to thallium. The worker ratio was even lower at 0.01. The highest concentration (2.22 mg/kg) was at point 12 (WST36-18-162995), and all other concentrations or MDLs were about an order of magnitude lower. The mean of 0.286 mg/kg for thallium would produce an HQ of 0.4 for residential use and an HQ of 0.02 for industrial use. Thallium is not widespread throughout the exposure area, and potential hazard is minimal.

HHRA	EPC (mg/kg)	EPC Type	Residential Noncancer SSL	Residential HQ	Worker Noncancer SSL	HQ
Thallium	0.137	Median all data	7.8E-01	0.2	1.3E+01	0.01

2.5. UNCERTAINTY ANALYSIS

The human health risk assessment has inherent uncertainties associated with data and data evaluation, exposure assessment, and the toxicity values on which the SLs are based. Each or all of these uncertainties may affect the assessment results, biasing the risk assessment results high or low.

2.5.1. Data and Data Analysis

Uncertainties in the data or its analysis may include errors in sampling, laboratory analysis, and data analysis. Data evaluation uncertainties are expected to have little effect on the assessment results because the data have undergone validation to minimize errors, and any errors are not expected to bias the results high or low. The J-flagged (estimated) qualification of detected concentrations of some organic COPCs does not affect the assessment. The data represent deposition from more than 60 years of operation into 2019. Therefore, the data and subsequently the screening assessment results represent current baseline conditions.

The use of a judgemental sampling design biases the risk results high since samples were targeted to locations where contamination was most likely to occur or known to occur from past sampling events.

The use of the maximum or a UCL95 as the COPC EPC for each COPC is also expected to bias risk estimates high, erring towards being conservative. Use of the maximum as the EPC overestimates exposure, as by definition all other concentrations are below this value. Use of the UCL95 may also result in an overestimation of risk since by definition true mean values are nearly always going to be less than this value.

2.5.2. Exposure Assessment

The exposure assessment assumptions bias the risk results high (i.e., overestimate risk). Assumptions for the industrial SLs are that the potentially exposed individual is a Laboratory worker who is outside at the site for 8 hours per day for 225 days per year (NMED 2019), and who spends the entire 8 hours on-site within the contaminated area. Assumptions for the residential SLs are that the potentially exposed individual is a resident who is present 24 hours per day for 350 days per year (NMED 2019) and spends the entire 24 hours on-site within the contaminated area. Because it is unlikely the worker or resident would be within the contaminated area for the entire time, the screening assessments overestimate the exposure. As a result, risks may be overestimated.

Assumptions underlying the exposure parameters, routes of exposure, and intake rates for routes of exposure are consistent with NMED parameters and default values (NMED 2019). In the absence of site-specific data, several upper-bound values for the assumptions may be combined to estimate exposure for any one pathway, and the resulting risk estimate can exceed the 99th percentile. Therefore, uncertainties in the assumptions underlying the exposure pathways may contribute to risk assessments that overestimate the reasonably expected risk levels.

2.5.3. Toxicity Values

The primary uncertainty associated with the screening values is related to the derivation of toxicity values used in their calculation. Toxicity values (slope factors [SFs] and reference doses [RfDs]) were used to derive the risk-based screening values used in the screening evaluation (NMED 2019). Uncertainties were identified in four areas with respect to the toxicity values: (1) extrapolation from animals to humans, (2) variability between individuals in the human population, (3) the derivation of RfDs and SFs, and (4) the chemical form of the COPC.

The SFs and RfDs are often determined by extrapolation from animal data to humans, which may result in uncertainties in toxicity values because differences exist between animals and humans in chemical absorption, metabolism, excretion, and toxic responses. Differences in body weight, surface area, and pharmacokinetic relationships between animals and humans are taken into account to address these uncertainties in the dose-response relationship. However, conservatism is usually incorporated in each of these steps, potentially biasing the estimate high and resulting in the overestimation of potential risk.

For noncarcinogenic effects, the degree of variability in human physical characteristics is important both in determining the risks that can be expected at low exposures and in defining the no observed adverse effect level (NOAEL). The NOAEL uncertainty factor approach incorporates a 10-fold factor to reflect individual variability within the human population that can contribute to uncertainty in the risk assessment. This factor of 10 is generally considered to result in a conservative estimate of risk for noncarcinogenic COPCs.

The RfDs and SFs for different chemicals are derived from experiments conducted by different laboratories that may have different accuracy and precision that could lead to an over- or underestimation of risk. The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. For carcinogens, the weight of evidence classification indicates the likelihood that a contaminant is a human carcinogen.

COPCs may be bound to the environmental matrix and not be available for absorption into the human body following ingestion. However, the exposure scenarios typically default to the assumption that the COPCs are bioavailable. This assumption can lead to an overestimation of the total exposure and overestimate risk.

2.5.4. Additive Approach

For noncarcinogens, the effects of exposure to multiple chemicals are generally unknown and possible interactions could be synergistic or antagonistic, resulting in either an underestimation or overestimation of the potential risk by assuming additivity. Additionally, RfDs used in the risk calculations typically are not based on the same endpoints with respect to severity, effects, or target organs. Therefore, the potential for noncarcinogenic effects may be overestimated by the HI considering individual COPCs act by different mechanisms and on different target organs but are addressed additively. Cancer risks are typically assumed to be additive.

2.6. CONCLUSIONS

Inorganics were compared to BVs and risk-based SLs. Eight inorganics exceeded background to some extent. One inorganic exceeded risk-based SLs. The cancer and noncancer screening level HIs for inorganics for workers were less than 1, and for hypothetical residents the cancer HI was less than 1, and the noncancer HI was 3 due to thallium. Additional evaluation using a statistically based EPC indicated thallium would not exceed the noncancer NMSSL for residential use.

Organics were compared to risk-based SLs. There were numerous organics detected, including some energetics, some SVOCs, and dioxin/furans. However, maximum concentrations of all of the detected analytes were below SLs for all constituents. None of the TEQs for dioxin/furans exceeded the TCDD SL. The Unit does not present an elevated cancer risk or noncancer hazard to human health due to exposure to surficial soils. The following interpretation can be made from the analysis:

- Based on an industrial scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer (0.2) and cancer-based (0.000001) HIs are less than the NMED target level of 1. This means that the sum of the ratios for maximum concentrations divided by SLs correlate to a cancer risk less than $1x10^{-5}$ and a noncancer hazard less than 1.
- For the residential scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer HI (3) exceeds the NMED target level of 1. The cancer HI of 0.000005 is below the NMED target level of 1.
- The median value of 0.137 mg/kg for thallium representing exposure throughout the exposure area produced an HQ of 0.2 for residential use and 0.01 for industrial use. The mean of 0.286 mg/kg for thallium would produce an HQ of 0.4 for residential use and an HQ of 0.02 for industrial use.
- The concentration of each dioxin/furan congener was summed to obtain a TEQ which was compared to the NMED NMSSL for TCDD. The maximum ratio was 0.04 for residential use and 0.0002 for industrial use.
- Summing the maximum dioxin/furan ratio with the other cancer risk HIs provides an HI for residential use of 0.2 and an HI for industrial use of 0.02.
- The maximum lead concentration of 35.2 mg/kg at TA-36 is just slightly above the background value of 22.3 mg/kg, and is much less than the residential SSL (400 mg/kg).
- There are no elevated human health risks for exposure to soils based on this evaluation.

3. ECOLOGICAL RISK ASSESSMENT

3.1. INTRODUCTION

The ecological risk assessment (ERA) for the Unit is presented in the following sections. The ecological risk-screening evaluation identifies chemicals of potential ecological concern (COPECs) and is based on the comparison of EPCs with Ecological Screening Levels (ESLs) in accordance with Laboratory guidance (LANL 2012a) and NMED (2017) guidance.

Site information including ESLs, biological studies, and historical information were reviewed and a site visit was conducted. A preliminary conceptual site exposure model (CSEM) was prepared.

The ESLs obtained from the ECORISK Database, Version 4.1 (LANL 2017; LANL 2019) are presented in Table 3-1. The ESLs are based on toxicity data for laboratory species similar to those expected to occur at the site, and are derived from experimentally determined NOAELs, lowest observed adverse effect levels (LOAELs), or doses determined to be lethal to 50% of the test population (LD50). Information relevant to the calculation of ESLs, including concentration equations, dose equations, bioconcentration factors, transfer factors, and toxicity reference values, are presented in the ECORISK Database, Versions 2.0, 3.1, and 4.1 (LANL 2003; LANL 2012b; LANL 2017).

The screening evaluation is conducted by dividing the EPCs by the ESLs to obtain a HQ calculated for each COPEC and screening receptor. As a generalization, the higher the contaminant levels relative to the ESLs, the higher the potential risk to receptors; conversely, the higher the ESLs relative to the contaminant levels, the lower the potential risk to receptors. The analysis begins with a comparison of the minimum ESL for each COPEC to the EPC. HQs greater than 0.3 are used to identify COPECs requiring additional evaluation (LANL 2012a).

Individual HQs for a receptor are summed to derive a HI. An HI greater than 1 indicates that further assessment may be needed to ensure exposure to multiple COPECs at a site will not lead to potential adverse impacts to a given receptor population. The HQ and HI analysis is a conservative indication of potential adverse effects and is designed to minimize the potential of overlooking possible COPECs at the site.

3.2. PROBLEM FORMULATION AND CONCEPTUAL SITE EXPOSURE MODEL

The Unit is a terrestrial ecosystem. The area is disturbed with little to no vegetation present. Vegetation increases with distance from the OD area and consists of grasses and shrubs. There are likely terrestrial birds and small mammals including deer mice or ground squirrels using the area, although intermittently due to the lack of food or cover. There is not enough vegetation within the 1.44-acre Unit to support large herbivores.

Due to the site history, there is the potential for energetic compounds or their breakdown products to be present in surface soils, where terrestrial animals and plants may contact surface soils and potentially be exposed. This possibility led to the collection of data and ecological risk assessment.

3.2.1. Data Summary

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- VOCs –15 samples and one duplicate
- SVOCs –15 samples and one duplicate
- Total Metals –15 samples and one duplicate
- Dioxins/Furans –15 samples and one duplicate
- High Explosives –15 samples and one duplicate

In addition, two samples were resampled for SVOCs, and some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dinitrobenzenes). Figure 1-1 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment, and habitat in the immediate site vicinity is also shown in Figure 1-1.

3.2.2. Site Visit Summary

A site visit was conducted in March 2019. The area is disturbed by human activity with buildings, roads, and maintained cleared areas to minimize fire danger. The vicinity around the Unit is a terrestrial ecosystem, although within the Unit it is largely bare ground (Figure 1-1). There are likely terrestrial birds and small mammals including deer mice or ground squirrels using the area; however, there is not enough vegetation within the Unit to support birds or mammals or their prey items.

3.2.3. Receptors and Pathways

Exposure pathways are considered complete if all of the following components are present (US EPA, 1989; NMED, 2017):

- A source and mechanism for hazardous waste/constituent release into the environment;
- An environmental transport medium or mechanism;

- A point of contact directly between the receptor and site-related contaminated media, or indirectly via dietary ingestion of prey or forage items contaminated by contact with site related contaminants; and
- An exposure route leading to interaction of the contaminant with target organs within the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site.

A CSEM was developed for the site (Figure 3-1). The primary contaminant source is the testing of explosives and detonation of explosives debris at the site. Any uncombusted material, if present, could remain in soil or be released to air as fugitive dust. Materials in surface soil could be carried by overland flow or percolate into the subsurface with rain, whereas material in air could be transported by wind. Receptors could contact contaminants within the immediate site area, up to the site boundary, or slightly beyond. The use of stormwater BMPs and earthern berms reduces the potential for migration beyond the Unit.

Ingestion of soil, plants, or animals are all potential exposure routes to ecological receptors. Although inhalation is recognized to occur, it is typically considered insignificant relative to ingestion and only quantified for burrowing animals where volatile organics are present in the subsurface. Respirable dust particles are likely ingested rather than inhaled by ecological receptors, and this pathway is considered negligible (EPA 1997; EPA 2003), while non-respirable dust is ingested and accounted for in incidental soil ingestion values for wildlife species (EPA 1993; EPA 2003). Therefore, the exposure pathways considered in the development of the ecological screening levels (ESLs) used in the risk-screening assessment capture the primary exposure for wildlife receptors.

Terrestrial flora (i.e., plants) and fauna (e.g., invertebrates, birds, and mammals) are the general categories of ecological receptors that could be exposed. The primary ecological exposure pathways are based on direct or indirect contact with surface soils. These include root uptake, incidental ingestion of soil, and biotic uptake leading to food-web transport. Exposure of plants and soil invertebrates is not related to dietary pathways but is the result of direct contact with, and uptake from, the surrounding medium. For terrestrial wildlife, most exposure is considered to be through the oral pathway from the diet and incidental soil ingestion (Sample et al. 1998). The dermal contact and inhalation pathways are not typically assessed quantitatively in ecological risk assessments, based on guidance indicating the ingestion route is most important to terrestrial animals (EPA 1997; EPA 2003). Dermal exposure to wildlife is mitigated by the fur or feathers covering the bodies of most vertebrates and the incidental soil consumption during grooming is included in the direct soil ingestion estimates.

3.2.4. Technical Decision Point and Recommendations

Because of the ecological habitat near the Unit boundaries, and because of the potential for exposure, the data were used to perform a quantitative screening level ecological evaluation.

3.3. ECOLOGICAL SCREENING EVALUATION

The summary statistics for the data were presented in Table 2-1. Maximum detected concentrations of each analyte are used as the initial EPC. The EPCs and the screening results for the ecological screening assessment are presented in Table 3-1. Any analytes for which the measured maximum detected value exceeded the minimum SL were considered COPECs and were evaluated further by calculating UCL95s and comparing the UCL95s to the SLs. The initial ESLs were the minimum no effect (NE) and low effect (LE) SLs in the 2019 LANL database for each of the analytes. The approach used to evaluate the data for ecological risk was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to BVs. Analytes less than BVs were eliminated from further evaluation.
- The screening approach then used the maximum of all detected data, including the duplicate pair, for the initial screening evaluation. The maximum concentration of each analyte was divided by its SL. For the ERA, the minimum no effect and low effect ESL was used.
- All analytes that exceeded the initial SLs were considered to have "failed" the initial screen. These are considered to be COPCs.
- A refinement of the EPCs was performed. Duplicates were averaged prior to calculating a UCL95. The UCL95 concentrations were compared to SLs, and any analytes above the SLs would be evaluated further if necessary.

3.3.1. Inorganics

There are five inorganics that exceed site BVs by a factor of 2 or more, and three that are less than a factor of 2 above background. The maximum concentration of each of these was compared to the minimum no effect (NE) ESL, if one was available, to determine if the resulting HQ >0.3. Some of these analytes also exceeded the low effect (LE) ESL to produce an HQ >0.3. The analytes that exceed ecological SLs are as follows (Table 3-1):

- Cadmium– exceeds NE ESLs for ratio > 0.3; 1.2 times higher than BV
- Chromium – exceeds NE ESLs for ratio > 0.3; 2.5 times higher than BV
- Copper – exceeds NE and LE ESLs for ratio > 0.3; 41 times higher than BV
- Lead– exceeds NE and LE ESLs for ratio > 0.3; 1.6 times higher than BV
- Mercury– exceeds NE and LE ESLs for ratio > 0.3; 7.8 times higher than BV
- Silver– exceeds NE ESLs for ratio > 0.3; 2 times higher than BV
- Thallium– exceeds NE and LE ESLs for ratio > 0.3; 3 times higher than BV
- Zinc – exceeds NE ESL for ratio >0.3, 1.1 times higher than BV

If an inorganic analyte maximum exceeded the BV and the ratio of the maximum to the risk-based SL was greater than 0.3, a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the SLs found in Table 3-2 consistent with the NMED (2017) Tier II approach. Note that comparison to the UCL95s was made prior to incorporating area use factors (AUFs) into the analysis. Receptor-specific dietary composition is built into the receptor-specific ESLs. The concentrations for each of the samples in the duplicate pair 1 and 1 dup (Figure 1-1) were averaged and the UCL95 calculated with a sample size of 15.

UCL95 values for copper and mercury exceeded the NE ESL and LE ESL with UCL95/ESL ratios above 1 (Table 3-2). The median for thallium exceeded NE ESLs. The UCL95s for the other inorganics were below the minimum NE and LE ESL. This suggests some limited potential for adverse ecological effects at the Unit, and therefore these COPECs are evaluated in more detail in the uncertainty analysis in Section 3.4.8.

3.3.2. Dioxin and Furans

Dioxins and furans are evaluated in a multi-step process that takes the concentration of each congener and multiplies it by a TEF for mammals or birds (Table 3-3). The resulting TECi values are summed to obtain a TEQ. The TEQ is divided by the lowest mammalian and avian SL for species that could occur on the Site. Due to lack of its preferred riparian habitat and lack of dense cover, the montane shrew (*Sorex monticolus*) is not expected to occur, and the next lowest ESL for TCDD for mammals is used in this analysis. The mammalian NE ESL and LE ESL for TCDD used in this risk assessment are based on potential toxicity to the deer mouse (*Peromyscus maniculatus*). The avian NE ESL is from the ECORISK Database, Version 2.0 (LANL 2003) as reported in "Attachment H, Technical Area 16 Burn Ground Human Health and Ecological Risk-Screening Assessments (LA-UR-13-24177), Class 3 Permit Modification Request for Addition of an Open Burning Unit at Technical Area (TA) 16 to the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit, EPA ID No. NM0890010515. September 30, 2013. Refer To: WM-D0-13-0064, LAUR: 13-27579."

Dioxin and furans were detected in multiple samples in the September 2018 data set. The TEFs for birds and mammals were applied to calculate a TEQ for each sample. Four of 15 samples had TEQs that exceeded the NE ESL for TCDD for mammals (Table 3-4) resulting in a HQ >0.3, and one sample exceeded the LE ESL. None of the samples exceeded the NE ESL for birds (Table 3-5) when evaluated individually.

The potential for risk to mammalian species was then investigated further. A UCL95 based on the sample-specific data for each congener was calculated with ProUCL (EPA 2015) using both the detected and nondetected data, then multiplying each congener-specific UCL95 by the congener-specific TEFs and summing the products to obtain a TEQ (Table 3-6).Since this TEQ is the sum of UCLs, it is expected to be highly conservative. When the UCL95 was divided by the NE ESL for TCDD for mammals, the resulting ratio or HQ was one, as shown below:

Mammal		
UCL TEQ (mg/kg)	**NE ESL (mg/kg)**	**NE HQ[1]**
7.34E-07	5.8E-07	1

[1] – the NE HQ is the ratio of the UCL TEQ/NE ESL

The dioxin/furans do not present a potential risk to mammals or birds and are not further evaluated.

3.3.3. Other Organics

- Xylenes – the toxicity values for total xylenes were used to represent each of the individual fractions.

Maximum concentrations of five other organics exceeded the minimum ecological screening levels. These were benzoic acid, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, RDX, and TATB. UCL95 values were calculated and compared to the minimum NE ESLs and LE ESLs (Table 3-2).

There were only two detections of benzoic acid, and four detections of di-n-butylphthalate. The low detection frequency for these two constituents means that a robust UCL95 cannot be calculated. Therefore, a median of the detected concentrations and the reported detection limit values was calculated and used as the estimate of the EPC. This approach is consistent with ProUCL guidance (EPA 2015) that recommends use of alternative statistics when detection frequency is low.

UCL95 or median values for bis(2-ethylhexyl)phthalate and TATB exceeded the minimum NE ESLs, and bis(2-ethylhexyl)phthalate also exceeded the LE ESLs (Table 3-2). These two organics are further evaluated in the risk analysis in Section 3.4.8.

3.4. UNCERTAINTY ANALYSIS

3.4.1. Chemical Form

Inorganic analytes can speciate into different forms with varying degrees of toxicity. The assumptions used in the ESL derivations are conservative and not necessarily representative of actual conditions. These assumptions include maximum chemical bioavailability, maximum receptor ingestion rates, minimum bodyweight, and additive effects of multiple COPECs. These factors tend to result in conservative ESL estimates, which may lead to an overestimation of the potential risk. Toxicological data are typically based on the most toxic and bioavailable chemical species, which may or may not be found in the environment. The ESLs were calculated to ensure a conservative indication of potential risk (LANL 2012a), and the values are biased toward overestimating the potential risk to receptors.

The chemical form of the individual COPECs was not determined as part of the investigation. COPECs are generally not 100% bioavailable to receptors in the natural environment because of interference from other natural processes, such as the adsorption of chemical constituents to matrix surfaces (e.g., soil) or rapid oxidation or reduction changes that render harmful chemical forms unavailable to biotic processes.

3.4.2. Reporting Limits

The evaluation was focused on detected values. Reporting limits were adequate (i.e., below SLs) for all analytes with one exception, indicating that the data were adequate for use in the risk assessment:

Dinitrobenzene[1,3-]–

- This analyte was not detected in any sample. Reporting limits were less than the non-cancer based NMSSL for residents or workers.
- The reporting limits were two times higher than the minimum NE ESL.
- Reporting limits were below the minimum LE ESL.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

3.4.3. Exposure and Risk Estimates

Exposure parameters including the EPC and the intakes likely bias risk estimates high because they presume no movement of receptors in and out of source areas. Sampling focused on areas of known or expected contamination, which biases the EPC high. Receptors are assumed to spend 100% of their time in the contaminated area which results in conservative estimates of exposure.

Another source of uncertainty is inherent in the calculation of exposure and risk estimates. Although the toxicity values are expressed to more than one significant figure, it is unlikely that the toxicity data are this accurate, especially given that the data are extrapolated from laboratory animal studies to wildlife receptors that are mobile in the environment. Likewise, given all the variables inherent in assessing exposure, exposure intakes by ecological receptors also should not be considered more accurate than one significant figure. This means that an HQ identified as 0.8 or 1.2 is actually 1, and an HQ identified as 1.5 is actually 2.

Calculating risk for dioxins is a multi-step process that involves multiplying the measured concentration by a toxicity factor (TEF) to obtain a value called the TECi that when summed adjusts the measured congener concentrations to that relative to TCDD, where the sum of all TECi is called the TEQ. Nondetected congeners were not included in the TEQ calculation, which biases the TEQ high, and biases dioxin risk estimates high for any given sample. When calculating the UCL95 as the EPC, the TEQs can be used directly but this provides a UCL95 EPC based only on detected data. ProUCL (EPA 2015) accommodates both detected and nondetected results, reducing bias and uncertainty by not ignoring the influence of nondetects on the EPC. Therefore, UCL95s were calculated for each congener, then adjusted with the TEFs, and then TECi for each congener summed to obtain the TEQ as opposed to averaging the TEQs directly. This procedure of calculating UCL95s for each congener increased the TEQ and HQs slightly for mammals, and reduced the TEQ and HQ for birds, but was considered to be slightly more accurate.

3.4.4. Mixture Toxicity

The assumption of additive effects for multiple COPECs may result in an over- or under-estimation of the potential risk to receptors. Exposure to multiple contaminants may result in other than additive effects. Conservative assumptions made with regards to EPCs would tend to overestimate exposure to any given constituent, and this would suggest that the toxicity of multiple constituents would not be underestimated. Therefore, mixture toxicity is not likely to bias the risk results high or low.

3.4.5. COPECs without ESLs

ESLs were not available for the cations and anions generally regarded as nutrients calcium, magnesium, nitrate, potassium, and sodium. ESLs were also not available for iron, but human health risk ratios for residents were 0.2 or lower. Lack of ESLs for these inorganics is not expected to underestimate risk at the site.

Several organic chemicals do not have ESLs for any receptor in release 4.1 of the ECORISK Database (LANL 2017; LANL 2019). Predominantly, the constituents lacking ESLs are nondetected organics. In the absence of a chemical-specific ESL, concentrations can be compared with the ESLs for a surrogate chemical, if available. Comparison to surrogate ESLs provides an estimate of potential effects of a chemically related compound and a line of evidence to indicate the likelihood that ecological receptors are potentially impacted. Some chemicals without ESLs do not have chemical-specific toxicity data or surrogate chemicals to be used in the screening assessments and cannot be assessed quantitatively for potential ecological risk.

The chemical TATB was detected in all samples. TATB did not have any ESLs for use in the evaluation. The toxicity values for 1,3,5-trinitrobenzene (NE ESL = 1.2 mg/kg; LE ESL = 12 mg/kg) were used as a surrogate based on structural similarity. This is not expected to bias the risk assessment results.

Chemicals lacking ESLs are often infrequently detected across the site. In these cases, comparisons with human health SLs are presented as part of a qualitative assessment, if human health SLs are available. The comparison of concentrations to human health SLs is a viable alternative for several reasons. Animal studies are used as the basis of toxicity values for human health risk assessments, and are the basic premise of modern toxicology (EPA 1989). In addition, toxicity values derived for the calculation of human health SLs (e.g., histopathology or biochemical changes) may be based on potential adverse effects more sensitive than the ones typically used to derive ESLs (e.g., survival, growth, or reproductive effects). EPA also applies uncertainty factors or modifying factors to ensure the toxicity values are protective (i.e., toxicity values are divided by uncertainty factors resulting in values much lower than initial study results). Since there were no predicted adverse effects on human health, chemicals lacking ESLs are unlikely to pose an ecological risk.

There is no avian ESL for TCDD in the current (2019) LANL EcoRisk database. A value from the 2002 EcoRisk database (LANL 2003) was used as the NE ESL. The lowest ESL value is $4.1\text{x}10^{-6}$ mg/kg based on the robin feeding as an insectivore, which has previously been utilized in LANL risk assessments. A reported LOAEL-based ESL is $4.1\text{x}10^{-5}$ mg/kg. These values were used in the current risk assessment in the absence of more recent data.

3.4.6. **Small-Mammal Field Investigations**

Small mammal trapping and analysis of whole organisms were conducted in the area around unit TA-36 in 2010. This information was considered useful for the current analysis as an additional line of evidence. Field mice were collected around the site and analyzed for dioxins and furans as well as metals, and for polychlorinated biphenyls (PCBs) (Fresquez 2011). Small-mammal community and population parameters were also measured across the site (Bennett and Robinson 2011).

Small mammals expected at TA-36 are the deer mouse (*Peromyscus maniculatus*), brush mouse (*Peromyscus boylii*), pinyon mouse (*Peromyscus truei*), silky pocket mouse (*Perognathus flavescens*), western harvest mouse (*Reithrodontomys megalotis*), white-throated woodrat (*Neotoma albigula*), and the Mexican woodrat (*Neotoma mexicana*) (Bennett and Robinson 2011). The vegetation community consists of piñon (*Pinus edulis Engelm*.)-juniper (*Juniperus monosperma [Englem.] Sarg*.) with scattered ponderosa pine (*Pinus ponderosa C. Lawson*) and gambel oak (*Quercus gambelii Nutt*.) (Bennett and Robinson 2011). The capture rate and species diversity were highest at TA-36 relative to the control area, and five species were captured. There were no differences in deer mouse sex ratios between TA-36 and the control area. Average body weight of adult male deer mice was slightly higher at TA-26 than at the control area. The authors of the study concluded that there was no apparent adverse effects on small mammal populations at TA-36 relative to controls.

Radionuclides and chemical concentrations in biota were compared to regional statistical reference levels (RSRLs). RSRLs represent natural and fallout levels, and are the upper-level background concentrations (mean plus three standard deviations = 99% confidence level) for radionuclides and chemicals calculated from biota that was collected from regional locations away from the influence of the Laboratory (over nine miles away) (Fresquez 2011). The only analytes that exceeded RSRLs were barium (two out of three samples) and lead (three out of three samples). Dioxins/furans and explosives were not detected. These data suggest that there are no impacts to small mammal populations at TA-36.

3.4.7. **Avian Field Investigations**

Two western bluebird (*Sialia mexicana*) egg samples were obtained in 2018 from TA-36 and analyzed for inorganic elements (Gaukler and Stanek 2019).

Concentrations of inorganic elements were compared with the upper-level bounds of background concentrations in bird eggs. The data indicated aluminum, antimony, arsenic, beryllium, cadmium, lead, nickel, silver, or vanadium were not detected in eggs (Gaukler and Stanec 2019). Barium, calcium, chromium, cobalt, iron, magnesium, manganese, mercury, potassium, selenium, sodium, thallium, and zinc were detected but were all below the RSRL for avian eggs. Copper at 4.1 mg/kg in one egg exceeded the RSRL of 3.6 mg/kg. Copper EPCs based on the UCL95 were compared to the ESLs for birds and were all below ESLs, suggesting that there would be no impact to bird populations due to copper. One sample of mountain bluebird (*Sialia currucoides*) eggs was collected in 2019, and no analytes were above the RSRLs (Gaukler and Stanek 2020).

Avian population metrics also do not suggest that birds in the vicinity are being negatively impacted (Hathcock et al 2018). Metrics including species richness and diversity were not statistically different from the Unit than at the control area. Species diversity was higher than at the control area in 2014, and afterwards was similar. Abundance varied in the Unit and control area annually, but abundance in the Unit compared to controls were similar over time, and just slightly lower than controls in 2016 and 2017. Species composition appears more influenced by habitat type, and indicates little difference between the Unit and control sites.

Combined, the egg concentration data and population metrics suggest that adverse health effects are not expected at the observed concentrations.

3.4.8. **Area Use Factors**

The Unit is very small with an areal extent of 1.44 acres (0.58 hectares (ha)). This is approximately the size of the home range (HR) of an individual robin as shown in Table 3-7. The HR is used to calculate area use factors (AUFs) that are used in the EcoPRG equations (LANL 2017). Individual AUFs and population area use factors (PAUFs) may be used to modify the estimate of risk to wildlife receptors to allow estimates to be more site-specific. The application of AUFs or PAUFs reduces potential overestimation of risks for those receptors with HRs larger than the area of contamination being evaluated. The estimated ecological risk as indicated by the HQ or HI is multiplied by the AUF or PAUF. HQs for plants or invertebrates are not adjusted by area use.

Table 3-7 presents the area use hazard analysis based on NE ESLs. The NE ESLs for each COPC that failed the screening evaluation (i.e., because EPCs exceeded the SLs) are shown for each receptor. The site specific AUF and PAUFs are shown for an area equivalent to the Unit. The UCL95 EPC is divided by the ESL and multiplied by the PAUF to obtain revised HQs. The habitat is not suitable for Mexican Spotted Owls or other special status species, and so an AUF evaluation was not conducted.

There is one HQ above 1 for birds or mammals based on comparison of UCL95 values as the EPC to the NE ESLs for each receptor (Table 3-7). The HQ above 1 is for the American robin modeled as an insectivorous bird. The HQs for copper for plants and earthworms, and the HQ for mercury for earthworms, were greater than 1. The HQ for thallium for plants was greater than 1.

Table 3-8 presents the area use hazard analysis based on comparison of the UCL95 values as the EPC to the LE ESLs for each receptor. There are no HQs above 1. Table 3-9 presents HIs for NE and LE ESLs calculated by summing the HQs. Note that HIs are above 1 for robins, plants and earthworms for the NE ESL comparison. HIs are above 1 only for earthworms for the LE ESL comparison. Summing the HQs presumes effects will be additive, when effects may occur on different target organs and not be additive.

3.5. CONCLUSIONS

The ecological risk assessment used a tiered approach for determining if the Unit would present an ecological risk. The results of the initial and highly conservative screening step indicated several inorganics occurring above background concentrations, and several detected organics, would present a potential ecological risk. Maximum concentrations of eight detected inorganics (i.e., cadmium, chromium, copper, lead, mercury, silver, thallium, and zinc) exceeded background. Maximum concentrations of these inorganics also exceeded NE ESLs.

Dioxin/furans, some polynuclear aromatic hydrocarbons (PAHs), phthalates, benzoic acid, benzyl alcohol, and explosives were among the organics detected in the unit. Of the detected organics, only five (benzoic acid, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, RDX, and TATB) exceeded minimum ESLs in the initial screening level evaluation which compared maximum detected values to the minimum ESLs.

Further evaluation by statistically estimating UCL95's to use as EPCs in soil suggested few inorganics or organics would occur at concentrations hazardous to ecological receptors. Use of the UCL95 as the EPC provides a conservative estimate of average exposure across the Unit. Copper, mercury, and thallium were the only inorganics with an HQ above 1 based on dividing the UCL95 by the minimum NE ESL. UCL95's for bis(2-ethylhexyl)phthalate and TATB exceeded NE ESLs.

Additional consideration of site ecology and receptor-specific adjustments to exposure by considering home range and site area further reduced the analytes exceeding NE ESLs. Only HQs for copper for earthworms and plants, mercury for earthworms and robins, and thallium for plants were above 1 based on a site-specific hazard analysis and NE ESLs. The HQs above 1 occurred for robins modeled as insectivores, and for plants and earthworms for which the area use evaluation is not relevant as they are largely immobile in the environment. However, the Unit is not vegetated because of its designated use as an OD area, and so plants and invertebrates have no habitat in the Unit. Robins would be unable to forage totally within the unit due to lack of prey and forage items. The LE ESLs are not exceeded for any receptor for any individual constituents, but the HI for earthworms is 2.

Finally, there is no suggestion of human health risk at the Unit, and the Unit is small relative to surrounding habitat, being only 1.44 acres. Due to disturbance, ecological receptors are unlikely to remain within the Unit on a regular basis. The Unit is not likely to present an ecological risk to any receptor evaluated.

4. REFERENCES

ATSDR. 2012. Toxicological Profile for Chromium. September 2012. Pg 374.https://www.atsdr.cdc.gov/toxprofiles/tp7.pdf

Bennett, K., and R. Robinson. 2011. Small Mammal Sampling at Open-Detonation Firing Sites. LA-UR-11-00717. January 2011. (Bennett and Robinson 2011)

EPA (U.S. Environmental Protection Agency), December 1989. “Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final,” EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989)

EPA (U.S. Environmental Protection Agency), 1993. “Wildlife Exposure Factors Handbook,” U.S. Environmental Protection Agency document EPA/600/P93/187A, Office of Research and Development, Washington, D.C. (EPA 1993)

EPA (U.S. Environmental Protection Agency), June 5, 1997. “Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final,” U.S. Environmental Protection Agency, Environmental Response Team, Edison NJ. (EPA 1997)

EPA (U.S. Environmental Protection Agency), November 2003. “Guidance for Developing Ecological Soil Screening Levels, Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs, Attachment 1-3, U.S. Environmental Protection Agency document OSWER Directive 92857-55, Office of Solid Waste and Emergency Response. (EPA 2003)

EPA (U.S. Environmental Protection Agency), December 2010a. “Final Report Bioavailability of Dioxins and Dioxin-Like Compounds in Soil,” Office of Superfund Remediation and Technology Innovation, Environmental Response Team, West Las Vegas, Nevada (http://epa.gov/superfund/health/contaminants/dioxin/pdfs/Final_dioxin_RBA_Report_12_20_10.p df). (EPA 2010a)

EPA (U.S. Environmental Protection Agency), December 2010b. “Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8=Tetrachloro-p-dioxin and Dioxin-Like Compounds.” EPA/100/R 10/005. (EPA 2010b)

EPA (U.S. Environmental Protection Agency), January 2014. “Technical Fact Sheet – N-Nitroso-dimethylamine (NDMA)”. https://www.epa.gov/sites/production/files/2014-03/documents/ffrrofactsheet_contaminant_ndma_january2014_final.pdf . (EPA 2014)

EPA (U.S. Environmental Protection Agency), October 2015. “ProUCL Version 5.1.002 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations.” EPA/600/R-07/041. ORD Site Characterization and Monitoring Technical Support Center. (EPA 2015)

EPA (U.S. Environmental Protection Agency), August 2019. Regional Screening Levels (RSLs) – Generic Tables Dated May 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. (EPA 2019)

Fresquez, P.R. 2011. Chemical Concentrations In Field Mice Collected From Open-Detonation Firing Sites Ta-36 Minie And Ta-39 Point 6 At Los Alamos National Laboratory. LA-UR-11-10614. May 2011. (Fresquez 2011)

Gaukler, S. and J Stanek. 2019. “ Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory”. LA-UR-19-25647. June 2019. (Gaukler and Stanek 2019)

Gaukler, S. and J Stanek. 2020. “2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory.” March 25 2020. LA-UR-20-22529. (Gaukler and Stanek 2020)

Hathcock, C. D., Bartlow, A. W., and B.E. Thompson. 2018. “2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory”. 2018-04-30 (rev.1) LA-UR-18-22897. (Hathcock et al. 2018)

LANL (Los Alamos National Laboratory), September 1998. “Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico. (LANL 1998)

LANL (Los Alamos National Laboratory), November 2003. “ECORISK Database (Version 2.0),” on CD, Los Alamos, New Mexico. (LANL 2003)

LANL (Los Alamos National Laboratory), November 2012. “Screening-Level Ecological Risk Assessment Methods, Revision 3,” Los Alamos National Laboratory document LA-UR-12-24152, Los Alamos, New Mexico. (LANL 2012a)

LANL (Los Alamos National Laboratory), October 2012. “ECORISK Database (Release 3.1),” LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2012b)

LANL (Los Alamos National Laboratory), 2017. “ECORISK Database User Guide, Revision 1”. LA-UR-17-26376. Los Alamos National Laboratory, Los Alamos, New Mexico. September 2017. (LANL 2017)

LANL (Los Alamos National Laboratory), 2019. “ECORISK Database (Release 4.1),” March 2019 Release. (LANL 2019)

NMED (New Mexico Environment Department). 2017. Risk Assessment Guidance for Site Investigations and Remediation. Volume II. Soil Screening Guidance for Ecological Risk Assessments.2017 Revised. (NMED 2017)

NMED (New Mexico Environment Department). February 2019. Risk Assessment Guidance for Site Investigations and Remediation. Volume I. Soil Screening Guidance for Human Health Risk Assessments. February 2019. Rev. 1 (3/7/19) (NMED 2019)

Sample, B.E., Suter III, G.W., Efroymson, R.A., and Jones, D.A., May 1998. “A Guide to the ORNL Ecotoxicological Screening Benchmarks: Background, Development, and Application,” Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4783, ORNL/TM13615, Oak Ridge, TN. May 1998 (Sample et al. 1998)

Van den Berg et.al, 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency factors for Dioxin and Dioxin-like Compounds. ToxiSci Advance Access, July 7, 2006. (Van den Berg et al. 2006)

WHO (World Health Organization). September 2009. “Project For The Re-Evaluation Of Human And Mammalian Toxic Equivalency Factors (TEFS) Of Dioxins And Dioxin-Like Compounds”. International Programme on Chemical Safety. http://www.who.int/ipcs/assessment/tef_update/en/ (WHO 2009)

Tables

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Inorganics								
Aluminum	16	1.77E+03	4.14E+03	2.89E+03	7.00E+02	6.24E+00	6.84E+00	16
Antimony	16	3.08E-01	4.32E-01	3.25E-01	2.94E-02	3.03E-01	3.32E-01	0
Arsenic	16	8.44E-01	2.28E+00	1.41E+00	3.37E-01	3.12E-01	3.42E-01	16
Barium	16	2.58E+01	1.15E+02	5.80E+01	2.53E+01	9.18E-02	1.01E-01	16
Beryllium	16	2.08E-01	5.88E-01	3.48E-01	1.19E-01	1.85E-02	2.02E-02	16
Cadmium	16	9.18E-02	4.67E-01	1.41E-01	1.05E-01	9.18E-02	1.01E-01	3
Calcium	16	1.68E+03	5.74E+03	2.99E+03	1.07E+03	7.34E+00	8.05E+00	16
Chromium	16	3.82E+00	4.92E+01	9.05E+00	1.08E+01	1.38E-01	1.51E-01	16
Cobalt	16	2.28E+00	8.44E+00	3.56E+00	1.43E+00	1.38E-01	1.51E-01	16
Copper	16	8.21E+00	5.97E+02	7.06E+01	1.43E+02	2.75E-01	3.02E-01	16
Iron	16	6.51E+03	1.29E+04	8.82E+03	1.77E+03	7.34E+00	8.05E+00	16
Lead	16	4.00E+00	3.52E+01	9.08E+00	7.56E+00	3.03E-01	3.32E-01	16
Magnesium	16	8.53E+02	2.58E+03	1.36E+03	3.90E+02	7.80E+00	8.55E+00	16
Manganese	16	1.19E+02	2.99E+02	1.70E+02	4.59E+01	1.84E-01	2.01E-01	16
Mercury	16	3.43E-03	7.75E-01	5.51E-02	1.92E-01	3.43E-03	3.44E-02	6
Nickel	16	3.35E+00	8.01E+00	6.28E+00	1.43E+00	9.24E-02	1.01E-01	16
Perchlorate	16	4.98E-04	2.96E-02	5.25E-03	8.52E-03	4.96E-04	1.01E-03	11
Potassium	16	3.58E+02	1.26E+03	6.89E+02	2.78E+02	5.87E+00	6.44E+00	16
Selenium	16	4.78E-01	9.37E-01	6.15E-01	1.29E-01	3.33E-01	3.64E-01	16
Silver	16	1.25E-01	2.19E+00	4.25E-01	5.20E-01	9.18E-02	1.01E-01	16
Sodium	16	3.73E+01	9.85E+01	5.33E+01	1.56E+01	6.43E+00	7.04E+00	16
Thallium	16	1.29E-01	2.22E+00	2.77E-01	5.19E-01	1.29E-01	1.42E-01	3
Vanadium	16	9.50E+00	2.90E+01	1.73E+01	4.96E+00	9.18E-02	1.01E-01	16
Zinc	16	1.85E+01	5.32E+01	2.89E+01	1.11E+01	3.67E-01	4.02E-01	16
Organics								
2,4-Diamino-6-nitrotoluene	16	4.93E-01	5.00E-01	4.96E-01	2.93E-03	4.93E-01	5.00E-01	0
2,6-Diamino-4-nitrotoluene	16	6.50E-01	6.60E-01	6.54E-01	4.15E-03	6.50E-01	6.60E-01	0
3,5-Dinitroaniline	16	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Acenaphthene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Acenaphthylene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Acetone	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Amino-2,6-dinitrotoluene[4-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Amino-4,6-dinitrotoluene[2-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Aniline	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Anthracene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Azobenzene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Benzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Benzo(a)anthracene	18	1.00E-02	2.95E-02	1.21E-02	5.04E-03	1.00E-02	1.02E-02	5
Benzo(a)pyrene	18	1.00E-02	2.72E-02	1.19E-02	4.75E-03	1.00E-02	1.02E-02	4
Benzo(b)fluoranthene	18	1.00E-02	3.25E-02	1.33E-02	7.20E-03	1.00E-02	1.02E-02	4
Benzo(g,h,i)perylene	18	1.00E-02	2.21E-02	1.09E-02	2.88E-03	1.00E-02	1.02E-02	2
Benzo(k)fluoranthene	18	1.00E-02	1.48E-02	1.04E-02	1.12E-03	1.00E-02	1.02E-02	2
Benzoic Acid	18	1.67E-01	4.97E-01	2.03E-01	1.00E-01	1.67E-01	1.70E-01	2
Benzyl Alcohol	18	1.00E-01	4.98E-01	1.38E-01	1.03E-01	1.00E-01	1.02E-01	4
Bis(2-chloroethoxy)methane	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Bis(2-chloroethyl)ether	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Bis(2-ethylhexyl)phthalate	18	1.00E-02	1.32E+00	2.25E-01	4.36E-01	1.00E-02	1.02E-02	6
Bromobenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromochloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromodichloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromoform	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromophenyl-phenylether[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Butanone[2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Butylbenzene[n-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzene[sec-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzene[tert-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzylphthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Carbon Disulfide	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Carbon Tetrachloride	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloro-3-methylphenol[4-]	18	1.34E-01	1.36E-01	1.34E-01	6.16E-04	1.34E-01	1.36E-01	0
Chloroaniline[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorobenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chlorodibromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloroethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Chloroform	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloronaphthalene[2-]	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Chlorophenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorophenyl-phenyl[4-] Ether	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorotoluene[2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chlorotoluene[4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chrysene	18	1.00E-02	2.95E-02	1.19E-02	4.91E-03	1.00E-02	1.02E-02	3
Dibenz(a,h)anthracene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Dibenzofuran	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dibromo-3-Chloropropane[1,2-]	16	4.66E-04	5.06E-04	4.89E-04	1.05E-05	4.66E-04	5.06E-04	0
Dibromoethane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dibromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichlorobenzene[1,2-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzene[1,3-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzene[1,4-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzidine[3,3'-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dichlorodifluoromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethane[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[cis-1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[trans-1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichlorophenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dichloropropane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropane[1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropane[2,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[cis-1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[trans-1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Diethylphthalate	18	1.00E-02	1.44E-02	1.03E-02	1.02E-03	1.00E-02	1.02E-02	1
Dimethyl Phthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Dimethylphenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Di-n-butylphthalate	18	1.00E-02	7.44E-01	6.10E-02	1.74E-01	1.00E-02	1.02E-02	4
Dinitro-2-methylphenol[4,6-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dinitrobenzene[1,3-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Dinitrophenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dinitrotoluene[2,4-]	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Dinitrotoluene[2,6-]	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Di-n-octylphthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Diphenylamine	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Ethylbenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Fluoranthene	18	1.00E-02	5.33E-02	1.50E-02	1.16E-02	1.00E-02	1.02E-02	4
Fluorene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	16	6.82E-07	1.13E-04	1.74E-05	2.99E-05	1.66E-06	1.68E-06	16
Heptachlorodibenzodioxins (Total)	16	0.00E+00	8.48E-04	9.44E-05	2.10E-04			15
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	16	4.97E-07	4.02E-06	1.38E-06	1.28E-06	1.66E-06	1.68E-06	8
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Heptachlorodibenzofurans (Total)	16	0.00E+00	1.80E-05	4.30E-06	6.31E-06			10
Hexachlorobenzene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorobutadiene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorocyclopentadiene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	16	4.97E-07	6.79E-07	5.15E-07	4.87E-08	1.73E-06	1.75E-06	2
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	16	4.97E-07	1.45E-06	6.23E-07	2.74E-07	1.66E-06	1.68E-06	4
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	16	4.97E-07	1.11E-06	5.77E-07	1.90E-07	1.95E-06	1.97E-06	3
Hexachlorodibenzodioxins (Total)	16	0.00E+00	5.36E-05	6.26E-06	1.36E-05			9
Hexachlorodibenzofuran[1,2,3,4,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.71E-06	1.74E-06	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorodibenzofurans (Total)	16	0.00E+00	4.93E-06	9.46E-07	1.56E-06			6
Hexachloroethane	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexanone[2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
HMX	16	1.48E-01	3.87E+00	8.78E-01	9.83E-01	1.48E-01	1.50E-01	11
Indeno(1,2,3-cd)pyrene	18	1.00E-02	2.05E-02	1.08E-02	2.51E-03	1.00E-02	1.02E-02	2
Iodomethane	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Isophorone	18	1.00E-01	3.24E-01	1.13E-01	5.26E-02	1.00E-01	1.02E-01	1
Isopropylbenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Isopropyltoluene[4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Methyl-2-pentanone[4-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Methylene Chloride	16	1.55E-03	5.73E-03	2.55E-03	1.46E-03	1.55E-03	1.69E-03	5
Methylnaphthalene[2-]	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Methylphenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Methylphenol[3-,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Naphthalene	18	1.00E-02	1.51E-02	1.04E-02	1.18E-03	1.00E-02	1.02E-02	1
Nitroaniline[2-]	18	1.10E-01	1.12E-01	1.11E-01	4.16E-04	1.10E-01	1.12E-01	0
Nitroaniline[3-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitroaniline[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrobenzene	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Nitrophenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrophenol[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrosodimethylamine[N-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitroso-di-n-propylamine[N-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrotoluene[2-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Nitrotoluene[3-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Nitrotoluene[4-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	16	4.56E-06	9.20E-04	1.39E-04	2.40E-04	3.31E-06	3.36E-06	16
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	16	9.93E-07	1.63E-05	4.50E-06	5.06E-06	3.31E-06	3.36E-06	9
Oxybis(1-chloropropane)[2,2'-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Pentachlorodibenzodioxins (Total)	16	0.00E+00	6.85E-07	4.28E-08	1.71E-07			1
Pentachlorodibenzofuran[1,2,3,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Pentachlorodibenzofuran[2,3,4,7,8-]	16	4.97E-07	5.03E-07	4.99E-07	1.67E-09	1.75E-06	1.77E-06	0
Pentachlorodibenzofurans (Totals)	16	0.00E+00	1.17E-06	1.63E-07	3.63E-07			3
Pentachlorophenol	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
PETN	16	2.46E-01	2.50E-01	2.48E-01	1.69E-03	2.46E-01	2.50E-01	0
Phenanthrene	18	1.00E-02	2.78E-02	1.17E-02	4.34E-03	1.00E-02	1.02E-02	4
Phenol	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Propylbenzene[1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Pyrene	18	1.00E-02	5.57E-02	1.50E-02	1.18E-02	1.00E-02	1.02E-02	4
Pyridine	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
RDX	16	1.48E-01	4.76E+00	7.88E-01	1.33E+00	1.48E-01	1.50E-01	7
Styrene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
TATB	16	3.33E+00	2.22E+01	1.22E+01	4.73E+00	2.96E-01	1.50E+00	16
Tetrachlorodibenzodioxin[2,3,7,8-]	16	9.94E-08	1.12E-07	1.01E-07	3.28E-09	3.31E-07	3.36E-07	0
Tetrachlorodibenzodioxins (Total)	16	0.00E+00	2.42E-07	1.51E-08	6.05E-08			1
Tetrachlorodibenzofuran[2,3,7,8-]	16	1.10E-07	2.51E-07	1.83E-07	3.86E-08	3.31E-07	3.36E-07	8
Tetrachlorodibenzofurans (Totals)	16	0.00E+00	4.42E-07	1.50E-07	1.43E-07			10
Tetrachloroethane[1,1,1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetrachloroethane[1,1,2,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetrachloroethene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetryl	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Toluene	16	3.10E-04	2.23E-03	5.75E-04	6.22E-04	3.10E-04	3.37E-04	4
Trichloro-1,2,2-trifluoroethane[1,1,2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Trichlorobenzene[1,2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichloroethane[1,1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichloroethane[1,1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichloroethene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichlorofluoromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichlorophenol[2,4,5-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichlorophenol[2,4,6-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichloropropane[1,2,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trimethylbenzene[1,2,4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trimethylbenzene[1,3,5-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trinitrobenzene[1,3,5-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Trinitrotoluene[2,4,6-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Tris (o-cresyl) phosphate	16	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Vinyl Chloride	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Xylene[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Xylene[1,3-]+Xylene[1,4-]	16	6.21E-04	6.75E-04	6.53E-04	1.41E-05	6.21E-04	6.75E-04	0

Notes: Sample size (n) includes duplicate of WST39-18-162834 (WST39-18-162985) and multiple analytical methods.
Abbreviations:
MDL – Method detection limit

mg/kg – milligram per kilogram
SD – Standard deviation

Table 2-2. Human Health Screening Results for Comparison of Maximum Detected Exposure Point Concentrations Greater than Background

Parameter Name	Maximum (mg/kg)	Number of Detected Values	Background		Cancer				Noncancer			
			BV (mg/kg)	Maximum /BV Ratio	Res Cancer NMSSL (mg/kg)	Worker Cancer NMSSL (mg/kg)	Maximum/ Res Cancer Ratio	Maximum/ Worker Cancer Ratio	Res Noncancer NMSSL (mg/kg)	Worker Noncancer NMSSL (mg/kg)	Maximum/ Res Noncancer Ratio	Maximum/ Worker Noncancer Ratio
INORGANICS												
Aluminum	4.14E+03	16	29200	0.1								
Antimony	4.32E-01	0	0.83	0.5								
Arsenic	2.28E+00	16	8.17	0.3								
Barium	1.15E+02	16	295	0.4								
Beryllium	5.88E-01	16	1.83	0.3								
Cadmium	4.67E-01	3	0.4	1.2	8.6E+04	4.2E+05	5E-06	1E-06	7.1E+01	1.1E+03	7E-03	4E-04
Calcium	5.74E+03	16	6120	0.9								
Chromium	4.92E+01	16	19.3	2.5	0.0E+00	0.0E+00	NA	NA	1.2E+05	1.9E+06	4E-04	3E-05
Cobalt	8.44E+00	16	8.64	1.0								
Copper	5.97E+02	16	14.7	41	0.0E+00	0.0E+00	NA	NA	3.1E+03	5.2E+04	2E-01	1E-02
Iron	1.29E+04	16	21500	0.6								
Lead	3.52E+01	16	22.3	1.6	0.0E+00	0.0E+00	NA	NA	4.0E+02	8.0E+02	9E-02	4E-02
Magnesium	2.58E+03	16	4610	0.6								
Manganese	2.99E+02	16	671	0.4								
Mercury	7.75E-01	6	0.1	7.8	0.0E+00	0.0E+00	NA	NA	2.3E+01	3.9E+02	3E-02	2E-03
Nickel	8.01E+00	16	15.4	0.5								
Perchlorate	2.96E-02	11	0	NA								
Potassium	1.26E+03	16	3460	0.4								
Selenium	9.37E-01	16	1.52	0.6								
Silver	2.19E+00	16	1	2.2	0.0E+00	0.0E+00	NA	NA	3.9E+02	6.5E+03	6E-03	3E-04
Sodium	9.85E+01	16	915	0.1								
Thallium	2.22E+00	3	0.73	3.0	0.0E+00	0.0E+00	NA	NA	7.8E-01	1.3E+01	3E+00	2E-01
Vanadium	2.90E+01	16	39.6	0.7								
Zinc	5.32E+01	16	48.8	1.1	0.0E+00	0.0E+00	NA	NA	2.3E+04	3.9E+05	2E-03	1E-04
ORGANICS												
Benzo(a)anthracene	2.95E-02	5	NA	NA	1.5E+00	3.2E+01	2E-02	9E-04	0.0E+00	0.0E+00	NA	NA
Benzo(a)pyrene	2.72E-02	4	NA	NA	NA	NA	2E-02	1E-03	NA	NA	2E-03	1E-04
Benzo(b)fluoranthene	3.25E-02	4	NA	NA	1.5E+00	3.2E+01	2E-02	1E-03	0.0E+00	0.0E+00	NA	NA
Benzo(g,h,i)perylene	2.21E-02	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	1.48E-02	2	NA	NA	1.5E+01	3.2E+02	1E-03	5E-05	0.0E+00	0.0E+00	NA	NA
Benzoic Acid	4.97E-01	2	NA	NA	NA	NA	NA	NA	NA	NA	2E-06	2E-07

Table 2-2. Human Health Screening Results for Comparison of Maximum Detected Exposure Point Concentrations Greater than Background

Parameter Name	Maximum (mg/kg)	Number of Detected Values	Background		Cancer				Noncancer			
			BV (mg/kg)	Maximum /BV Ratio	Res Cancer NMSSL (mg/kg)	Worker Cancer NMSSL (mg/kg)	Maximum/ Res Cancer Ratio	Maximum/ Worker Cancer Ratio	Res Noncancer NMSSL (mg/kg)	Worker Noncancer NMSSL (mg/kg)	Maximum/ Res Noncancer Ratio	Maximum/ Worker Noncancer Ratio
Benzyl Alcohol	4.98E-01	4	NA	NA	NA	NA	NA	NA	NA	NA	8E-05	6E-06
Bis(2-ethylhexyl)phthalate	1.32E+00	6	NA	NA	3.8E+02	1.8E+03	3E-03	7E-04	1.2E+03	1.8E+04	1E-03	7E-05
Chrysene	2.95E-02	3	NA	NA	1.5E+02	3.2E+03	2E-04	9E-06	0.0E+00	0.0E+00	NA	NA
Diethylphthalate	1.44E-02	1	NA	NA	0.0E+00	0.0E+00	NA	NA	4.9E+04	7.3E+05	3E-07	2E-08
Di-n-butylphthalate	7.44E-01	4	NA	NA	0.0E+00	0.0E+00	NA	NA	6.2E+03	9.2E+04	1E-04	8E-06
Fluoranthene	5.33E-02	4	NA	NA	0.0E+00	0.0E+00	NA	NA	2.3E+03	3.4E+04	2E-05	2E-06
HMX	3.87E+00	11	NA	NA	0.0E+00	0.0E+00	NA	NA	3.8E+03	6.3E+04	1E-03	6E-05
Indeno(1,2,3-cd)pyrene	2.05E-02	2	NA	NA	1.5E+00	3.2E+01	1E-02	6E-04	0.0E+00	0.0E+00	NA	NA
Isophorone	3.24E-01	1	NA	NA	5.6E+03	2.7E+04	6E-05	1E-05	1.2E+04	1.8E+05	3E-05	2E-06
Methylene Chloride	5.73E-03	5	NA	NA	7.7E+02	1.4E+04	7E-06	4E-07	4.1E+02	5.1E+03	1E-05	1E-06
Naphthalene	1.51E-02	1	NA	NA	5.0E+01	2.4E+02	3E-04	6E-05	1.6E+02	8.4E+02	9E-05	2E-05
Phenanthrene	2.78E-02	4	NA	NA	0.0E+00	0.0E+00	NA	NA	1.7E+03	2.5E+04	2E-05	1E-06
Pyrene	5.57E-02	4	NA	NA	0.0E+00	0.0E+00	NA	NA	1.7E+03	2.5E+04	3E-05	2E-06
RDX	4.76E+00	7	NA	NA	8.31E+01	4.28E+02	6E-02	1E-02	3.0E+02	4.9E+03	2E-02	1E-03
TATB	2.22E+01	16	NA	NA	NA	NA	NA	NA	NA	NA	1E-02	7E-04
Toluene	2.23E-03	4	NA	NA	0.0E+00	0.0E+00	NA	NA	5.2E+03	6.1E+04	4E-07	4E-08
INORGANIC HI							**5E-06**	**1E-06**			**3E+00**	**2E-01**
ORGANIC HI							**1E-01**	**2E-02**			**3E-02**	**2E-03**

Notes:

All data in mg/kg

Shaded Max/BV cells indicate the maximum>BV

Bolded NMSSL cells indicate the EPA RSL for an HQ of 1 is used because a NMSSL is not available

Italics – a surrogate is applied. See Section 1.2.3

If the maximum <BV, no further evaluation is performed

Cancer ratio = Maximum/Cancer-based NMSSL

HQ = Maximum/Noncancer-based NMSSL

Abbreviations:

BV – Background value
EPA – U.S. Environmental Protection Agency
HQ – Noncancer hazard quotient
Max – Maximum reported result
NA – Not available
NC – Noncancer
NMSSL – New Mexico soil screening level
Res - Residential
RSL – Regional Screening level

Table 2-2. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Parameter Name	WST36-18-162834		WST36-18-162985		WST36-18-162986		WST36-18-162987		WST36-18-162988		WST36-18-162989	
	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.40E-07	1	6.82E-07	1	3.68E-06	1		1	1.74E-06	1	1.06E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	5.00E-07	0	4.97E-07	0	8.20E-07	1	1.49E-06	1	4.97E-07	0	4.97E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	5.61E-06	1	4.56E-06	1	3.41E-05	1	7.74E-05	1	1.40E-05	1	1.02E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	9.99E-07	0	9.94E-07	0	2.54E-06	1	5.55E-06	1	9.94E-07	0	9.94E-07	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	5.00E-07	0	4.97E-07	0	4.98E-07	0	5.03E-07	0	4.97E-07	0	4.97E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	9.99E-08	0	9.94E-08	0	9.95E-08	0	1.01E-07	0	9.94E-08	0	9.94E-08	0
Tetrachlorodibenzofuran[2,3,7,8-]	1.10E-07	1	1.75E-07	1	1.31E-07	1	2.27E-07	1	1.79E-07	1	1.87E-07	1

Notes:
DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	WST36-18-162834	WST36-18-162985	WST36-18-162986	WST36-18-162987	WST36-18-162988	WST36-18-162989
			TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	8.40E-09	6.82E-09	3.68E-08	7.96E-08	1.74E-08	1.06E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	ND	ND	8.20E-09	1.49E-08	ND	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	1.68E-09	1.37E-09	1.02E-08	2.32E-08	4.20E-09	3.06E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	ND	ND	7.62E-10	1.67E-09	ND	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	1.10E-08	1.75E-08	1.31E-08	2.27E-08	1.79E-08	1.87E-08
TEQ			2.11E-08	2.57E-08	6.91E-08	1.42E-07	3.95E-08	3.24E-08
NMED SL Residential (mg/kg) = 4.90E-05		**Risk Ratio =**	4E-04	5E-04	1E-03	3E-03	8E-04	7E-04
NMED SL Industrial (mg/kg) = 8.47E-03		**Risk Ratio =**	2E-06	3E-06	8E-06	2E-05	5E-06	4E-06

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Parameter Name	WST36-18-162990		WST36-18-162991		WST36-18-162992		WST36-18-162993		WST36-18-162994	
	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	1.11E-06	1	4.67E-06	1	2.20E-05	1	8.35E-06	1	4.84E-05	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	4.98E-07	0	4.99E-07	0	3.44E-06	1	1.29E-06	1	4.02E-06	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	5.85E-07	1
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-07	0	4.99E-07	0	6.27E-07	1	4.98E-07	0	1.09E-06	1
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	1.11E-06	1
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	1.01E-05	1	4.30E-05	1	1.82E-04	1	6.93E-05	1	3.90E-04	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	9.95E-07	0	1.33E-06	1	1.01E-05	1	3.95E-06	1	1.39E-05	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	4.98E-07	0	4.99E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	9.95E-08	0	9.99E-08	0	9.96E-08	0	9.97E-08	0	1.05E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	1.71E-07	1	1.44E-07	1	1.73E-07	0	1.67E-07	0	2.19E-07	0

Notes:

DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	WST36-18-162990	WST36-18-162991	WST36-18-162992	WST36-18-162993	WST36-18-162994
			TECi	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	1.11E-08	4.67E-08	2.20E-07	8.35E-08	4.84E-07
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	ND	ND	3.44E-08	1.29E-08	4.02E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND	ND	ND	ND	5.85E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND	ND	6.27E-08	ND	1.09E-07
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND	ND	ND	ND	1.11E-07
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	3.03E-09	1.29E-08	5.46E-08	2.08E-08	1.17E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	ND	3.99E-10	3.03E-09	1.19E-09	4.17E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	1.71E-08	1.44E-08	ND	ND	ND
TEQ			3.12E-08	7.44E-08	3.75E-07	1.18E-07	9.24E-07
NMED SL Residential (mg/kg) =	**5E-05**		6E-04	2E-03	8E-03	2E-03	2E-02
NMED SL Industrial (mg/kg) =	**8E-03**		4E-06	9E-06	4E-05	1E-05	1E-04

Parameter Name	WST36-18-162995		WST36-18-162996		WST36-18-162997		WST36-18-162998		WST36-18-162999	
	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	1.13E-04	1	4.70E-05	1	1.59E-05	1	7.51E-07	1	8.19E-07	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	3.66E-06	1	2.48E-06	1	9.11E-07	1	4.97E-07	0	5.01E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	6.79E-07	1	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	1.45E-06	1	8.22E-07	1	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	9.91E-07	1	6.55E-07	1	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	9.20E-04	1	3.40E-04	1	1.14E-04	1	5.49E-06	1	8.29E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	1.63E-05	1	8.97E-06	1	2.47E-06	1	9.93E-07	0	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	4.98E-07	0	4.98E-07	0	5.00E-07	0	4.97E-07	0	5.01E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	9.95E-08	0	9.95E-08	0	9.99E-08	0	1.12E-07	0	1.00E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	1.59E-07	0	2.51E-07	0	1.78E-07	0	2.13E-07	0	2.36E-07	0

Notes:
DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	WST36-18-162995	WST36-18-162996	WST36-18-162997	WST36-18-162998	WST36-18-162999
			TECi	TECi	TECi	TECi	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	1.13E-06	4.70E-07	1.59E-07	7.51E-09	8.19E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	3.66E-08	2.48E-08	9.11E-09	ND	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	6.79E-08	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	1.45E-07	8.22E-08	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	9.91E-08	6.55E-08	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	2.76E-07	1.02E-07	3.42E-08	1.65E-09	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	4.89E-09	2.69E-09	7.41E-10	ND	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	ND	ND	ND	ND	ND
TEQ			1.76E-06	7.47E-07	2.03E-07	9.16E-09	1.07E-08
NMED SL Residential (mg/kg)	**5E-05**		4E-02	2E-02	4E-03	2E-04	2E-04
NMED SL Industrial (mg/kg)	**8E-03**		2E-04	9E-05	2E-05	1E-06	1E-06

Notes: The TECi are summed in each column to obtain the TEQ. The TEQ is divided by the residential or the industrial SL for TCDD to obtain a risk ratio, shown directly under the TEQ. None of the TEQs exceeded the SLs.

All data in mg/kg

Table 3-1. Ecological Screening Evaluation

Parameter Name	Maximum (mg/kg)	Number of Detects	Background		ESL and Risk Ratios			
			BV (mg/kg)	Max/ BV Ratio	Minimum NE ESL (mg/kg)	Max/ NE ESL Ratio	Minimum LE ESL (mg/kg)	Max/ LE ESL Ratio
INORGANICS								
Cadmium	4.67E-01	3	0.4	1.2	2.70E-01	2E+00	1.60E+00	3E-01
Chromium	4.92E+01	16	19.3	2.5	2.30E+01	2E+00	7.30E+01	7E-01
Copper	5.97E+02	16	14.7	41	1.40E+01	4E+01	4.30E+01	1E+01
Lead	3.52E+01	16	22.3	1.6	1.10E+01	3E+00	2.30E+01	2E+00
Mercury	7.75E-01	6	0.1	7.8	1.30E-02	6E+01	1.30E-01	6E+00
Perchlorate	2.96E-02	11	0	NA	1.20E-01	2E-01	2.40E-01	1E-01
Silver	2.19E+00	16	1	2	2.60E+00	8E-01	2.60E+01	8E-02
Thallium	2.22E+00	3	0.73	3.0	5.00E-02	4E+01	5.00E-01	4E+00
Zinc	5.32E+01	16	48,8	1.1	4.70E+01	1E+00	1.20E+02	4E-01
ORGANICS								
Benzo(a)anthracene	2.95E-02	5	NA	NA	7.30E-01	4E-02	7.30E+00	4E-03
Benzo(a)pyrene	2.72E-02	4	NA	NA	6.20E+01	4E-04	1.90E+02	1E-04
Benzo(b)fluoranthene	3.25E-02	4	NA	NA	1.80E+01	2E-03	1.80E+02	2E-04
Benzo(g,h,i)perylene	2.21E-02	2	NA	NA	2.50E+01	9E-04	2.50E+02	9E-05
Benzo(k)fluoranthene	1.48E-02	2	NA	NA	7.10E+01	2E-04	7.10E+02	2E-05
Benzoic Acid	4.97E-01	2	NA	NA	1.00E+00	5E-01	1.00E+01	5E-02
Benzyl Alcohol	4.98E-01	4	NA	NA	1.20E+02	4E-03	1.20E+03	4E-04
Bis(2-ethylhexyl)phthalate	1.32E+00	6	NA	NA	2.00E-02	7E+01	2.00E-01	7E+00
Chrysene	2.95E-02	3	NA	NA	3.10E+00	1E-02	3.10E+01	1E-03
Diethylphthalate	1.44E-02	1	NA	NA	1.00E+02	1E-04	1.00E+03	1E-05
Di-n-butylphthalate	7.44E-01	4	NA	NA	1.10E-02	7E+01	1.10E-01	7E+00
Fluoranthene	5.33E-02	4	NA	NA	1.00E+01	5E-03	2.30E+01	2E-03
HMX	3.87E+00	11	NA	NA	1.60E+01	2E-01	1.60E+02	2E-02
Indeno(1,2,3-cd)pyrene	2.05E-02	2	NA	NA	7.10E+01	3E-04	7.10E+02	3E-05
Isophorone	3.24E-01	1	NA	NA	NA	NA	NA	NA
Methylene Chloride	5.73E-03	5	NA	NA	2.60E+00	2E-03	2.20E+01	3E-04
Naphthalene	1.51E-02	1	NA	NA	1.00E+00	2E-02	1.00E+01	2E-03
Phenanthrene	2.78E-02	4	NA	NA	5.50E+00	5E-03	1.20E+01	2E-03
Pyrene	5.57E-02	4	NA	NA	1.00E+01	6E-03	2.00E+01	3E-03
RDX	4.76E+00	7	NA	NA	2.30E+00	2E+00	4.30E+00	1E+00
TATB	2.22E+01	16	NA	NA	*1.20E+00*	2E+01	*1.20E+01*	2E+00
INORGANIC HI						2E+02		3E+01
ORGANIC HI						2E+02		2E+01

Notes:

Table 2-2 presents the comparison of maximum inorganic concentrations to BV. Only inorganics that exceeded BVs are shown in this table.

Shaded cells indicate the ratio > 0.3 for initial screening evaluation

Italics – a surrogate is used. See Section 1.2.3.

Only detected data and inorganics above background are reported and evaluated in this table.

Abbreviations:

BV – Background Value
ESL – Ecological Screening Value
Max– Maximum Exposure Point Concentration
mg/kg – Milligram per kilogram
LE – Low Effect
NE – No Effect

Table 3-2. Ecological Risk Evaluation Using UCL95 EPCs for COPCs.

Name	UCL95 (mg/kg)	UCL Type	Distribution	Minimum NE ESL (mg/kg)	UCL/ NE ESL Ratio	Minimum LE ESL (mg/kg)	UCL/ LE ESL Ratio
Cadmium	0.096	Median all data	NA - 3 detect	2.70E-01	4E-01	1.60E+00	6E-02
Chromium	21.78	95% Chebyshev (Mean, Sd) UCL	None	2.30E+01	9E-01	7.30E+01	3E-01
Copper	237.10	95% Chebyshev (Mean, Sd) UCL	Lognormal	1.40E+01	2E+01	4.30E+01	6E+00
Lead	13.1	95% Adjusted Gamma UCL	Approx Gamma	1.10E+01	1E+00	2.30E+01	6E-01
Mercury	0.598	99% KM (Chebyshev) UCL	None	1.30E-02	5E+01	1.30E-01	5E+00
Silver	0.678	95% H-UCL	Lognormal	2.60E+00	3E-01	2.60E+01	3E-02
Thallium	0.137	Median all data	NA - 3 detect	5.00E-02	3E+00	5.00E-01	3E-01
Zinc	35.81	95% Adjusted Gamma UCL	Adjusted Gamma	4.7E+01	8E-01	1.2E+02	3E-01
Benzoic Acid	0.168	Median all data	NA - 2 detects	1.00E+00	2E-01	1.00E+01	2E-02
Bis(2-ethylhexyl)phthalate	0.493	95% KM (t) UCL	Normal	2.00E-02	2E+01	2.00E-01	2E+00
Di-n-butylphthalate	0.010	Median all data	NA - 4 detects	1.10E-02	9E-01	1.10E-01	9E-02
RDX	1.48	95% KM (t) UCL	Normal	2.30E+00	6E-01	4.30E+00	3E-01
TATB	14.48	95% Student's-t UCL	Normal	1.20E+00	1E+01	1.20E+01	1E+00
Hazard Index					1E+02		2E+01

Notes:
Median - median of detects and MDLs once duplicates are averaged
Shaded cells represent HQs>1
HI is the sum of all HQs

Abbreviations:
ESL – Ecological Screening Level
HI – Hazard Index
LE – Low Effect
mg/kg – milligram per kilogram
NE – No Effect
UCL – Upper Confidence Limit

Table 3-3. Toxic Equivalency Factors (TEFs) Used for Calculating Ecological TCDD Equivalent Concentrations

Name	CAS	Mammalian TEF[a]	Avian TEF[b]
Chlorinated dibenzo-p-dioxins			
2,3,7,8-TCDD	1746-01-6	1	1
1,2,3,7,8-PeCDD	40321-76-4	1	1
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HpCDD	35822-46-9	0.01	0.001
OCDD	3268-87-9	0.0003	0.0001
Chlorinated dibenzofurans			
2,3,7,8-TCDF	51207-31-9	0.1	1
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1
2,3,4,7,8-PeCDF	57117-31-4	0.3	0.1
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	1
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01
OCDF	39001-02-0	0.0003	0.0001

[a] EPA (2010a,b); WHO (2009)
[b] Van den Berg et al. (1998)

Table 3-4. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Mammalian Risk Estimates by Sample

Parameter Name	**CAS**	**Point 1 (WST36-18-162834)**		**Point 1 Dup (WST36-18-162985)**		**Point 2 (WST36-18-162986)**		**Point 3 (WST36-18-162987)**		**Point 4 (WST36-18-162988)**		**Point 6 (WST36-18-162989)**	
		Result (mg/kg)	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.40E-07	8.40E-09	6.82E-07	6.82E-09	3.68E-06	3.68E-08	7.96E-06	7.96E-08	1.74E-06	1.74E-08	1.06E-06	1.06E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	5.00E-07	ND	4.97E-07	ND	8.20E-07	8.20E-09	1.49E-06	1.49E-08	4.97E-07	ND	4.97E-07	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	5.61E-06	1.68E-09	4.56E-06	1.37E-09	3.41E-05	1.02E-08	7.74E-05	2.32E-08	1.40E-05	4.20E-09	1.02E-05	3.06E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	9.99E-07	ND	9.94E-07	ND	2.54E-06	7.62E-10	5.55E-06	1.67E-09	9.94E-07	ND	9.94E-07	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.99E-08	ND	9.94E-08	ND	9.95E-08	ND	1.01E-07	ND	9.94E-08	ND	9.94E-08	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.10E-07	1.10E-08	1.75E-07	1.75E-08	1.31E-07	1.31E-08	2.27E-07	2.27E-08	1.79E-07	1.79E-08	1.87E-07	1.87E-08
TEQ (mg/kg)		2.11E-08		2.57E-08		6.91E-08		1.42E-07		3.95E-08		3.24E-08	
Mammalian NE ESL (mg/kg) =5.80E-07	HQ =	4E-02		4E-02		1E-01		2E-01		7E-02		6E-02	
Mammalian LE ESL (mg/kg) = 3.80E-06	HQ =	6E-03		7E-03		2E-02		4E-02		1E-02		9E-03	

Table 3-4. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Mammalian Risk Estimates by Sample

Parameter Name	**CAS**	**Point 7 (WST36-18-162990)**		**Point 8 (WST36-18-162991)**		**Point 9 (WST36-18-162992)**		**Point 10 (WST36-18-162993)**		**Point 11 (WST36-18-162994)**	
		Result (mg/kg)	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.11E-06	1.11E-08	4.67E-06	4.67E-08	2.20E-05	2.20E-07	8.35E-06	8.35E-08	4.84E-05	4.84E-07
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	4.98E-07	ND	4.99E-07	ND	3.44E-06	3.44E-08	1.29E-06	1.29E-08	4.02E-06	4.02E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	5.85E-07	5.85E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.98E-07	ND	4.99E-07	ND	6.27E-07	6.27E-08	4.98E-07	ND	1.09E-06	1.09E-07
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	1.11E-06	1.11E-07
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	1.01E-05	3.03E-09	4.30E-05	1.29E-08	1.82E-04	5.46E-08	6.93E-05	2.08E-08	3.90E-04	1.17E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	9.95E-07	ND	1.33E-06	3.99E-10	1.01E-05	3.03E-09	3.95E-06	1.19E-09	1.39E-05	4.17E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.95E-08	ND	9.99E-08	ND	9.96E-08	ND	9.97E-08	ND	1.05E-07	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.71E-07	1.71E-08	1.44E-07	1.44E-08	1.73E-07	ND	1.67E-07	ND	2.19E-07	ND
TEQ (mg/kg)		3.12E-08		7.44E-08		3.75E-07		1.18E-07		9.24E-07	
Mammalian NE ESL (mg/kg) = 5.80E-07	HQ =	5E-02		1E-01		6E-01		2E-01		2E+00	
Mammalian LE ESL (mg/kg) = 3.80E-06	HQ =	8E-03		2E-02		1E-01		3E-02		2E-01	

Table 3-4. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Mammalian Risk Estimates by Sample

Parameter Name	CAS	Point 12 (WST36-18-162995)		Point 13 (WST36-18-162996)		Point 14 (WST36-18-162997)		Point 15 (WST36-18-162998)		Point 5 (WST36-18-162999)	
		Result (mg/kg)	TECi	Result (mg/kg)	TECi	Result (mg/kg)	TECi	Result (mg/kg)	TECi	Result (mg/kg)	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.13E-04	1.13E-06	4.70E-05	4.70E-07	1.59E-05	1.59E-07	7.51E-07	7.51E-09	8.19E-07	8.19E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	3.66E-06	3.66E-08	2.48E-06	2.48E-08	9.11E-07	9.11E-09	4.97E-07	ND	5.01E-07	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	6.79E-07	6.79E-08	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.45E-06	1.45E-07	8.22E-07	8.22E-08	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	9.91E-07	9.91E-08	6.55E-07	6.55E-08	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	9.20E-04	2.76E-07	3.40E-04	1.02E-07	1.14E-04	3.42E-08	5.49E-06	1.65E-09	8.29E-06	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	1.63E-05	4.89E-09	8.97E-06	2.69E-09	2.47E-06	7.41E-10	9.93E-07	ND	1.00E-06	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.95E-08	ND	9.95E-08	ND	9.99E-08	ND	1.12E-07	ND	1.00E-07	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.59E-07	1.59E-08	2.51E-07	2.51E-08	1.78E-07	1.78E-08	2.13E-07	2.13E-08	2.36E-07	2.36E-08
TEQ		1.78E-06		7.72E-07		2.21E-07		3.05E-08		3.43E-08	
Mammalian NE ESL = 5.80E-07	HQ=	3E+00		1E+00		4E-01		5E-02		6E-02	
Mammalian LE ESL = 3.80E-06	HQ =	5E-01		2E-01		6E-02		8E-03		9E-03	

Notes: Sample locations are shown in Figure 1-1.
The result multiplied by the TEF (Table 3-3) is the TECi. The sum of the TECi values provides the TEQ. HQs are the TEQ divided by the NE or LE ESL. Shaded cells indicate the HQ is greater than 0.3
The deer mouse ESLs are used in lieu of shrew ESLs as this area is not preferred shrew habitat.
All data in mg/kg

Abbreviations:
Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient; ND – Not detected

Table 3-5. Dioxin-Furan TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Parameter Name	**CAS**	**Point 1 (WST36-18-162834)**		**Point 1 Dup (WST36-18-162985)**		**Point 2 (WST36-18-162986)**		**Point 3 (WST36-18-162987)**		**Point 4 (WST36-18-162988)**		**Point 6 (WST36-18-162989)**	
		Result (mg/kg)	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.40E-07	8.40E-10	6.82E-07	6.82E-10	3.68E-06	3.68E-09	7.96E-06	7.96E-09	1.74E-06	1.74E-09	1.06E-06	1.06E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	5.00E-07	ND	4.97E-07	ND	8.20E-07	8.20E-09	1.49E-06	1.49E-08	4.97E-07	ND	4.97E-07	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	5.61E-06	1.68E-10	4.56E-06	4.56E-10	3.41E-05	3.41E-09	7.74E-05	7.74E-09	1.40E-05	1.40E-09	1.02E-05	1.02E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	9.99E-07	ND	9.94E-07	ND	2.54E-06	2.54E-10	5.55E-06	5.55E-10	9.94E-07	ND	9.94E-07	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	5.00E-07	ND	4.97E-07	ND	4.98E-07	ND	5.03E-07	ND	4.97E-07	ND	4.97E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.99E-08	ND	9.94E-08	ND	9.95E-08	ND	1.01E-07	ND	9.94E-08	ND	9.94E-08	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.10E-07	1.10E-07	1.75E-07	1.75E-07	1.31E-07	1.31E-07	2.27E-07	2.27E-07	1.79E-07	1.79E-07	1.87E-07	1.87E-07
TEQ (mg/kg)			1.11E-07		1.76E-07		1.47E-07		2.58E-07		1.82E-07		1.89E-07
Avian NE ESL (mg/kg) =4.1E-06	HQ =	3E-02		4E-02		4E-02		6E-02		4E-02		5E-02	
Avian LE ESL (mg/kg) = 4.1E-05	HQ =	3E-03		4E-03		4E-03		6E-03		4E-03		5E-03	

Table 3-5. Dioxin-Furan TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Parameter Name	**CAS**	**Point 7 (WST36-18-162990)**		**Point 8 (WST36-18-162991)**		**Point 9 (WST36-18-162992)**		**Point 10 (WST36-18-162993)**		**Point 11 (WST36-18-162994)**	
		Result (mg/kg)	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.11E-06	1.11E-09	4.67E-06	4.67E-09	2.20E-05	2.20E-08	8.35E-06	8.35E-09	4.84E-05	4.84E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	4.98E-07	ND	4.99E-07	ND	3.44E-06	3.44E-08	1.29E-06	1.29E-08	4.02E-06	4.02E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	5.85E-07	2.93E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.98E-07	ND	4.99E-07	ND	6.27E-07	6.27E-09	4.98E-07	ND	1.09E-06	1.09E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	1.11E-06	1.11E-07
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	1.01E-05	1.01E-09	4.30E-05	4.30E-09	1.82E-04	1.82E-08	6.93E-05	6.93E-09	3.90E-04	3.90E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	9.95E-07	ND	1.33E-06	1.33E-10	1.01E-05	1.01E-09	3.95E-06	3.95E-10	1.39E-05	1.39E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	ND	4.99E-07	ND	4.98E-07	ND	4.98E-07	ND	4.98E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.95E-08	ND	9.99E-08	ND	9.96E-08	ND	9.97E-08	ND	1.05E-07	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.71E-07	1.71E-07	1.44E-07	1.44E-07	1.73E-07	ND	1.67E-07	ND	2.19E-07	ND
TEQ (mg/kg)		1.73E-07		1.53E-07		8.19E-08		2.86E-08		2.80E-07	
Avian NE ESL (mg/kg) = 4.1E-06	HQ=	4E-02		4E-02		2E-02		7E-03		7E-02	
Avian LE ESL (mg/kg) = 4.1E-05	HQ=	4E-03		4E-03		2E-03		7E-04		7E-03	

Table 3-5. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Parameter Name	**CAS**	**Point 12 (WST36-18-162995)**		**Point 13 (WST36-18-162996)**		**Point 14 (WST36-18-162997)**		**Point 15 (WST36-18-162998)**		**Point 5 (WST36-18-162999)**	
		Result (mg/kg)	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**	**Result (mg/kg)**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.13E-04	1.13E-07	4.70E-05	4.70E-08	1.59E-05	1.59E-08	7.51E-07	7.51E-10	8.19E-07	8.19E-10
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	3.66E-06	3.66E-08	2.48E-06	2.48E-08	9.11E-07	9.11E-09	4.97E-07	ND	5.01E-07	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	6.79E-07	3.40E-08	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.45E-06	1.45E-08	8.22E-07	8.22E-09	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	9.91E-07	9.91E-08	6.55E-07	6.55E-08	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	9.20E-04	9.20E-08	3.40E-04	3.40E-08	1.14E-04	1.14E-08	5.49E-06	5.49E-10	8.29E-06	8.29E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	1.63E-05	1.63E-09	8.97E-06	8.97E-10	2.47E-06	2.47E-10	9.93E-07	ND	1.00E-06	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	ND	4.98E-07	ND	5.00E-07	ND	4.97E-07	ND	5.01E-07	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.95E-08	ND	9.95E-08	ND	9.99E-08	ND	1.12E-07	ND	1.00E-07	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.59E-07	ND	2.51E-07	ND	1.78E-07	ND	2.13E-07	ND	2.36E-07	ND
TEQ		3.91E-07		1.80E-07		3.67E-08		1.30E-09		1.65E-09	
Avian NE ESL (mg/kg) = 4.1E-06	HQ =	1E-01		4E-02		9E-03		3E-04		4E-04	
Avian LE ESL (mg/kg) = 4.1E-05	HQ =	1E-02		4E-03		9E-04		3E-05		4E-05	

Notes: Sample locations are shown in Figure 1-1.
The result multiplied by the TEF (Table 3-3) is the TECi. The sum of the TECi values provides the TEQ. HQs are the TEQ divided by the NE or LE ESL. Shaded cells indicate the HQ is greater than 0.3
All data in mg/kg

Abbreviations:
Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient; ND – Not detected

Table 3-6. UCL95 Calculations for Dioxin/Furans for Mammals

Congener Name	CAS	UCL	UCL Type	Distribution
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	4.40E-05	95% Adjusted Gamma UCL	Gamma
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	2.05E-06	95% KM (t) UCL	Normal
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7		NA- all ND	NA - all ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.98E-07	Median - all data	NA - 2 detects
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.99E-07	Median - all data	NA - 4 detects
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.99E-07	Median - all data	NA - 3 detects
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9		NA- all ND	NA - all ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9		NA- all ND	NA - all ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9		NA- all ND	NA - all ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5		NA- all ND	NA - all ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	3.48E-04	95% Adjusted Gamma UCL	Gamma
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	7.14E-06	95% KM (t) UCL	Normal
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4		NA- all ND	NA - all ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6		NA- all ND	NA - all ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4		NA- all ND	NA - all ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6		NA- all ND	NA - all ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.74E-07	95% KM (t) UCL	Normal

Congener Name	CAS	TEF	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	4.40E-07
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	2.05E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	4.98E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	4.99E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	4.99E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	1.04E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	2.14E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	1.74E-08
TEQ			**7.34E-07**
NMED SSL Residential	**5E-05**	**HQ =**	1E-02
NMED SSL Industrial	**8E-03**	**HQ =**	9E-05

Note: the UCL is multiplied by the mammalian TEF to obtain the TECi. The TECi are summed to obtain the TEQ. The TEQ is divided by the ESL for TCDD to obtain An HQ. The HQs are less than 1, indicating no risk to mammals.

Table 3-7. Area Use Factor and Site-Specific Hazard Analysis for TA 36 Based on NE ESLs

COPC Name	CAS	No Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)									
		Kestrel (carnivore/insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Gray fox
Copper	Cu	80	34	14	20	63	260	80	70	42	4000
Mercury	Hg	0.058	0.067	0.013	0.022	3	23	0.05	34	1.7	76
Thallium	Tl	48	6.9	4.5	5.5	0.72	1.2	0	0.05	0.42	5
Bis(2-ethylhexyl)phthalate	117-81-7	0.096	16	0.02	0.04	1.1	1900	0	0	0.6	500
TATB		0	0	0	0	110	150	10	0	720	10000

Note: The TATB toxicity values are based on 1,3,5-trinitrobenzene as a surrogate

HR (ha)[a]	106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]	4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]	0.00014	0.035	0.035	0.035	0.19	0.005	NA	NA	0.037	0.000014
AUF[d]	0.0055	1.00	1.00	1.00	1.00	0.19	NA	NA	1.00	0.0006

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted NE ESL Hazard Quotients									
		Kestrel (carnivore/insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Red fox
Inorganics											
Copper	237.10	4E-04	2E-01	6E-01	4E-01	7E-01	4E-03	3E+00	3E+00	2E-01	8E-07
Mercury	0.60	1E-03	3E-01	2E+00	9E-01	4E-02	1E-04	1E+01	2E-02	1E-02	1E-07
Thallium	0.14	4E-07	7E-04	1E-03	9E-04	4E-02	5E-04	NA, No ESL	3E+00	1E-02	4E-07
Organics											
Bis(2-ethylhexyl)phthalate	0.49	7E-04	1E-03	9E-01	4E-01	8E-02	1E-06	NA, No ESL	NA, No ESL	3E-02	1E-08
TATB	14.48	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-02	5E-04	1E+00	NA, No ESL	7E-04	2E-08

Notes:

Area of Site (ha): 0.08

NA - Not applicable
ESLs - Ecological screening level
PAUF - Population area use factor
AUF - Area use factor
HR - Home range

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-8. Area Use Factors and Site-Specific Hazard Analysis for TA 36 Based on LE ESLs.

COPC Name	CAS	Low Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)									
		Kestrel (carnivore/insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Gray fox
Copper	Cu	240	100.0	43	60	100	430	530	490	70	6700
Mercury	Hg	0.58	0.7	0.13	0.22	30	230	0.5	64	17	760
Thallium	Tl	480	69.0	45	55	7.2	12	0	0.5	4.2	50
Bis(2-ethylhexyl)phthalate	117-81-7	0.96	160.0	0.2	0.4	11	19000	0	0	6	5000
TATB		0	0	0	0	1100	1500	28	0	7200	100000

Note: The TATB toxicity values are based on 1,3,5-trinitrobenzene as a surrogate

HR (ha)[a]		106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]		4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]		0.00014	0.035	0.035	0.035	0.19	0.005	NA	NA	0.037	0.000014
AUF[d]		0.0055	1.00	1.00	1.00	1.00	0.19	NA	NA	1.00	0.0006

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted LE ESL Hazard Quotients									
		Kestrel (carnivore/ insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Red fox
Inorganics											
Copper	237.10	1E-04	8E-02	2E-01	1E-01	4E-01	3E-03	4E-01	5E-01	1E-01	5E-07
Mercury	0.60	1E-04	3E-02	2E-01	9E-02	4E-03	1E-05	1E+00	9E-03	1E-03	1E-08
Thallium	0.14	4E-08	7E-05	1E-04	9E-05	4E-03	5E-05	NA, No ESL	3E-01	1E-03	4E-08
Organics											
Bis(2-ethylhexyl)phthalate	0.49	7E-05	1E-04	9E-02	4E-02	8E-03	1E-07	NA, No ESL	NA, No ESL	3E-03	1E-09
TATB	14.48	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-03	5E-05	5E-01	NA, No ESL	7E-05	2E-09

Notes:

Area of Site (ha): 0.015

NA - Not applicable	PAUF - Population area use factor	HR - Home range
ESLs - Ecological screening level	AUF - Area use factor	

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-9. Hazard Index Analysis by Receptor for Exposure Adjusted with Area Use Factors

Hazard Index	**Kestrel (carnivore/insectivore)**	**Robin (herbivore)**	**Robin (insectivore)**	**Robin (omnivore)**	**Deer mouse**	**Desert cottontail**	**Earthworm**	**Plant**	**Montane shrew**	**Red fox**
Hazard Index for NE ESL	3E-03	6E-01	3E+00	2E+00	9E-01	5E-03	2E+01	6E+00	3E-01	1E-06
Hazard Index for LE ESL	3E-04	1E-01	4E-01	3E-01	5E-01	3E-03	2E+00	8E-01	1E-01	5E-07

Figures

Figure 1-1. Sample Location Map for TA-36 OD Area

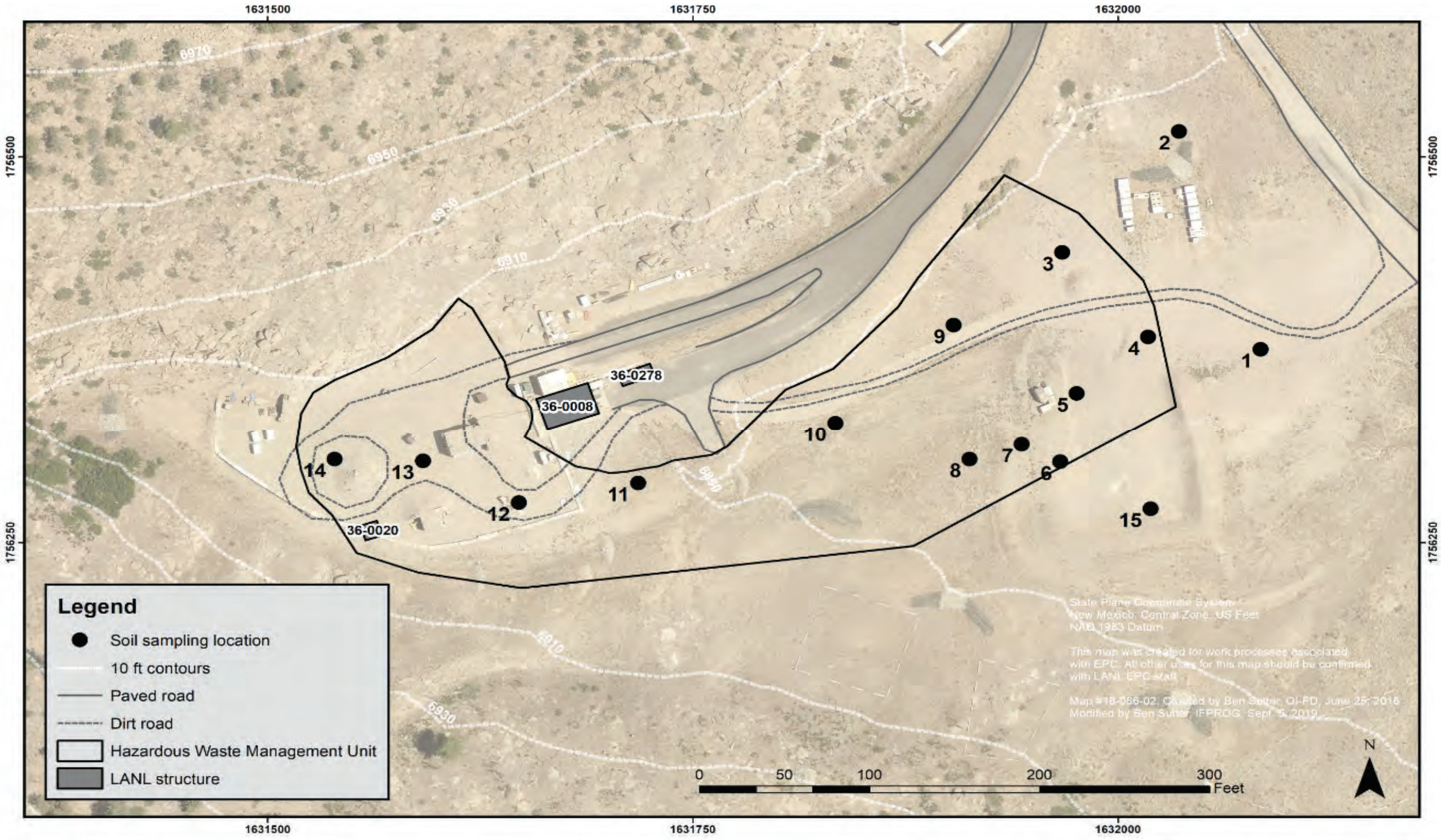
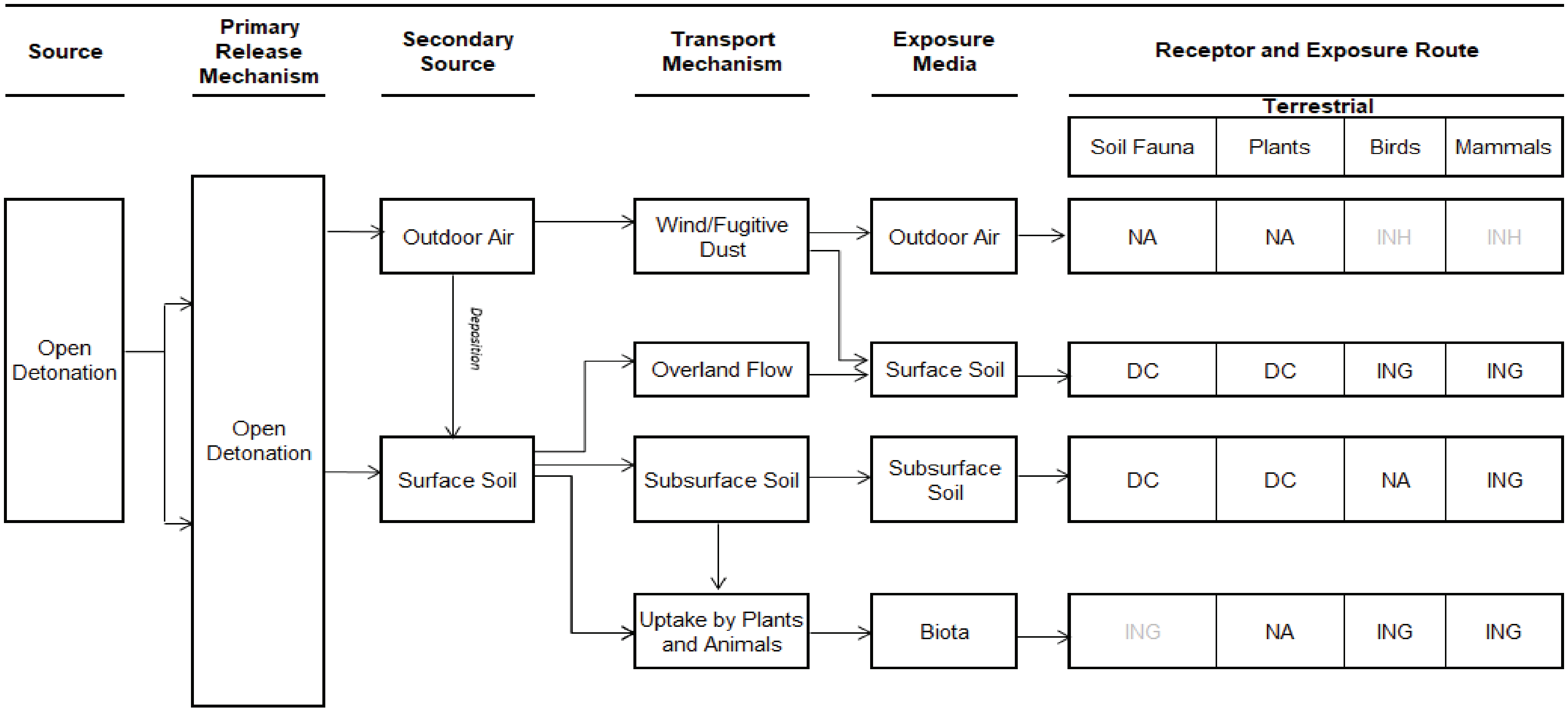


Figure 3-1. Conceptual Site Exposure Model (CSEM) for the Ecological Risk Assessment



Abbreviations

DC	Direct contact; applies to receptors for which toxic effects are addressed by exposure concentration and not dose
ING	Ingestion; typically quantified as dose for birds and mammals only
INH	Inhalation; recognized to occur, but not typically quantified as standard practice with the exception of evaluating burrow air exposure by burrowing mammals
NA	Pathway considered incomplete; not applicable

Notes:

Grayed text indicates pathways are recognized to potentially exist but are not quantified. Inhalation is considered minimal relative to dietary exposure. Ingestion by invertebrates is not typically quantified due to absence of accurate exposure parameters.

Attachment A. ProUCL Output for Upper Confidence Limit Calculations

```
UCL Statistics for Data Sets with Non-
Detects

User Selected Options
Date/Time of Computation                    ProUCL 5.19/27/2019 3:01:10 PM
From File                                   UCL Data TA 36.xls
Full Precision                              OFF
Confidence Coefficient                      95%
Number of Bootstrap Operations              2000
TL
General Statistics
Total Number of Observations          15    Number of Distinct Observations          10
Number of Detects                      3    Number of Non-Detects                    12
Number of Distinct Detects             3    Number of Distinct Non-Detects            7
Minimum Detect                     0.158    Minimum Non-Detect                    0.129
Maximum Detect                      2.22    Maximum Non-Detect                    0.141
Variance Detects                   1.337    Percent Non-Detects                     80%
Mean Detects                       0.887    SD Detects                            1.156
Median Detects                     0.282    CV Detects                            1.304
Skewness Detects                    1.71    Kurtosis Detects                        N/A
Mean of Logged Detects            -0.771    SD of Logged Detects                  1.389

Warning: Data set has only 3 Detected
Values.
This is not enough to compute meaningful or reliable
statistics and estimates.
Cd

General Statistics
Total Number of Observations          15    Number of Distinct Observations          15
Number of Detects                      3    Number of Non-Detects                    12
Number of Distinct Detects             3    Number of Distinct Non-Detects           12
Minimum Detect                     0.252    Minimum Non-Detect                   0.0918
Maximum Detect                     0.467    Maximum Non-Detect                    0.101
Variance Detects                  0.0137    Percent Non-Detects                     80%
Mean Detects                       0.333    SD Detects                            0.117
Median Detects                      0.28    CV Detects                            0.351
Skewness Detects                   1.621    Kurtosis Detects                        N/A
Mean of Logged Detects            -1.138    SD of Logged Detects                   0.33

Warning: Data set has only 3 Detected       This is not enough to compute meaningful or reliable
Values.                                                 statistics and estimates.

Cr

General Statistics
Total Number of Observations          15    Number of Distinct Observations          15
                                            Number of Missing Observations            0
Minimum                             3.82    Mean                                  9.194
Maximum                             49.2    Median                                 6.67
SD                                 11.19    Std. Error of Mean                    2.888
Coefficient of Variation           1.217    Skewness                              3.735

Normal GOF Test
Shapiro Wilk Test Statistic        0.415    Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value     0.881    Data Not Normal at 5% Significance Level
Lilliefors Test Statistic          0.401    Lilliefors GOF Test
5% Lilliefors Critical Value        0.22    Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
  95% Normal UCL                              95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL              14.28      95% Adjusted-CLT UCL (Chen-1995)      16.92
```

		95% Modified-t UCL (Johnson-1978)	14.74
Gamma GOF Test			
A-D Test Statistic	2.378	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.747	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.328	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.224	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2.033	k star (bias corrected MLE)	1.671
Theta hat (MLE)	4.523	Theta star (bias corrected MLE)	5.503
nu hat (MLE)	60.98	nu star (bias corrected)	50.12
MLE Mean (bias corrected)	9.194	MLE Sd (bias corrected)	7.113
		Approximate Chi Square Value (0.05)	34.86
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	33.3
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	13.22	95% Adjusted Gamma UCL (use when n<50)	13.84
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.701	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.274	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.34	Mean of logged Data	1.953
Maximum of Logged Data	3.896	SD of logged Data	0.595
Assuming Lognormal Distribution			
95% H-UCL	11.89	90% Chebyshev (MVUE) UCL	12.28
95% Chebyshev (MVUE) UCL	14.08	97.5% Chebyshev (MVUE) UCL	16.58
99% Chebyshev (MVUE) UCL	21.5		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	13.94	95% Jackknife UCL	14.28
95% Standard Bootstrap UCL	13.89	95% Bootstrap-t UCL	38.36
95% Hall's Bootstrap UCL	36.75	95% Percentile Bootstrap UCL	14.83
95% BCA Bootstrap UCL	18.15		
90% Chebyshev(Mean, Sd) UCL	17.86	95% Chebyshev(Mean, Sd) UCL	21.78
97.5% Chebyshev(Mean, Sd) UCL	27.23	99% Chebyshev(Mean, Sd) UCL	37.93
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	21.78		

Cu

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	0
Minimum	8.21	Mean	71.46
Maximum	597	Median	27.7
SD	147.1	Std. Error of Mean	37.99
Coefficient of Variation	2.059	Skewness	3.721
Normal GOF Test			
Shapiro Wilk Test Statistic	0.414	Shapiro Wilk GOF Test	

5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.383	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	138.4	95% Adjusted-CLT UCL (Chen-1995)	172.9
		95% Modified-t UCL (Johnson-1978)	144.5

Gamma GOF Test

A-D Test Statistic	1.652	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.773	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.239	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.23	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			

Gamma Statistics

k hat (MLE)	0.795	k star (bias corrected MLE)	0.68
Theta hat (MLE)	89.9	Theta star (bias corrected MLE)	105
nu hat (MLE)	23.85	nu star (bias corrected)	20.41
MLE Mean (bias corrected)	71.46	MLE Sd (bias corrected)	86.63
		Approximate Chi Square Value (0.05)	11.16
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	10.32

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	130.8	95% Adjusted Gamma UCL (use when n<50)	141.3

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.886	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.175	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			

Lognormal Statistics

Minimum of Logged Data	2.105	Mean of logged Data	3.522
Maximum of Logged Data	6.392	SD of logged Data	1.024

Assuming Lognormal Distribution

95% H-UCL	122.4	90% Chebyshev (MVUE) UCL	101.7
95% Chebyshev (MVUE) UCL	123.1	97.5% Chebyshev (MVUE) UCL	152.9
99% Chebyshev (MVUE) UCL	211.3		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	133.9	95% Jackknife UCL	138.4
95% Standard Bootstrap UCL	132.5	95% Bootstrap-t UCL	463.5
95% Hall's Bootstrap UCL	371.6	95% Percentile Bootstrap UCL	145.7
95% BCA Bootstrap UCL	186.5		
90% Chebyshev(Mean, Sd) UCL	185.4	95% Chebyshev(Mean, Sd) UCL	237.1
97.5% Chebyshev(Mean, Sd) UCL	308.7	99% Chebyshev(Mean, Sd) UCL	449.5

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	237.1		

Pb

General Statistics

Total Number of Observations	15	Number of Distinct Observations	15

		Number of Missing Observations	0
Minimum	4.085	Mean	9.414
Maximum	35.2	Median	6.52
SD	7.706	Std. Error of Mean	1.99
Coefficient of Variation	0.819	Skewness	3.017
Normal GOF Test			
Shapiro Wilk Test Statistic	0.615	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.284	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	12.92	95% Adjusted-CLT UCL (Chen-1995)	14.34
		95% Modified-t UCL (Johnson-1978)	13.18
Gamma GOF Test			
A-D Test Statistic	1.049	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.216	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.223	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data follow Appr. Gamma Distribution at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2.968	k star (bias corrected MLE)	2.419
Theta hat (MLE)	3.172	Theta star (bias corrected MLE)	3.892
nu hat (MLE)	89.04	nu star (bias corrected)	72.57
MLE Mean (bias corrected)	9.414	MLE Sd (bias corrected)	6.053
		Approximate Chi Square Value (0.05)	53.95
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	51.98
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	12.66	95% Adjusted Gamma UCL (use when n<50)	13.14
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.876	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.19	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.407	Mean of logged Data	2.064
Maximum of Logged Data	3.561	SD of logged Data	0.548
Assuming Lognormal Distribution			
95% H-UCL	12.5	90% Chebyshev (MVUE) UCL	13.04
95% Chebyshev (MVUE) UCL	14.85	97.5% Chebyshev (MVUE) UCL	17.35
99% Chebyshev (MVUE) UCL	22.27		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	12.69	95% Jackknife UCL	12.92
95% Standard Bootstrap UCL	12.69	95% Bootstrap-t UCL	18.14
95% Hall's Bootstrap UCL	25.22	95% Percentile Bootstrap UCL	13
95% BCA Bootstrap UCL	14.56		
90% Chebyshev(Mean, Sd) UCL	15.38	95% Chebyshev(Mean, Sd) UCL	18.09

97.5% Chebyshev(Mean, Sd) UCL	21.84	99% Chebyshev(Mean, Sd) UCL	29.21

Suggested UCL to Use

95% Adjusted Gamma UCL	13.14

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Hg
General Statistics

Total Number of Observations	15	Number of Distinct Observations	14
Number of Detects	6	Number of Non-Detects	9
Number of Distinct Detects	6	Number of Distinct Non-Detects	8
Minimum Detect	0.00476	Minimum Non-Detect	0.00343
Maximum Detect	0.775	Maximum Non-Detect	0.00396
Variance Detects	0.0968	Percent Non-Detects	60%
Mean Detects	0.141	SD Detects	0.311
Median Detects	0.0062	CV Detects	2.211
Skewness Detects	2.434	Kurtosis Detects	5.94
Mean of Logged Detects	-4.006	SD of Logged Detects	2.026

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.531	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.788	Detected Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.452	Lilliefors GOF Test
5% Lilliefors Critical Value	0.325	Detected Data Not Normal at 5% Significance Level

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0583	KM Standard Error of Mean	0.0543
KM SD	0.192	95% KM (BCA) UCL	0.162
95% KM (t) UCL	0.154	95% KM (Percentile Bootstrap) UCL	0.161
95% KM (z) UCL	0.148	95% KM Bootstrap t UCL	9.206
90% KM Chebyshev UCL	0.221	95% KM Chebyshev UCL	0.295
97.5% KM Chebyshev UCL	0.397	99% KM Chebyshev UCL	0.598

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	1.083	Anderson-Darling GOF Test
5% A-D Critical Value	0.762	Detected Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.388	Kolmogorov-Smirnov GOF
5% K-S Critical Value	0.355	Detected Data Not Gamma Distributed at 5% Significance Level

Detected Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.332	k star (bias corrected MLE)	0.277
Theta hat (MLE)	0.424	Theta star (bias corrected MLE)	0.508
nu hat (MLE)	3.98	nu star (bias corrected)	3.324
Mean (detects)	0.141		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.00476	Mean	0.0623
Maximum	0.775	Median	0.01
SD	0.197	CV	3.169
k hat (MLE)	0.412	k star (bias corrected MLE)	0.374

Theta hat (MLE)	0.151	Theta star (bias corrected MLE)	0.167
nu hat (MLE)	12.36	nu star (bias corrected)	11.22
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (11.22, α)	4.719	Adjusted Chi Square Value (11.22, β)	4.211
95% Gamma Approximate UCL (use when n>=50)	0.148	95% Gamma Adjusted UCL (use when n<50)	0.166

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.0583	SD (KM)	0.192
Variance (KM)	0.0368	SE of Mean (KM)	0.0543
k hat (KM)	0.0925	k star (KM)	0.118
nu hat (KM)	2.776	nu star (KM)	3.554
theta hat (KM)	0.631	theta star (KM)	0.493
80% gamma percentile (KM)	0.0504	90% gamma percentile (KM)	0.165
95% gamma percentile (KM)	0.333	99% gamma percentile (KM)	0.85

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (3.55, α)	0.554	Adjusted Chi Square Value (3.55, β)	0.432
95% Gamma Approximate KM-UCL (use when n>=50)	0.374	95% Gamma Adjusted KM-UCL (use when n<50)	0.48

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.735	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.788	Detected Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.361	Lilliefors GOF Test
5% Lilliefors Critical Value	0.325	Detected Data Not Lognormal at 5% Significance Level

Detected Data Not Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.0563	Mean in Log Scale	-7.708
SD in Original Scale	0.199	SD in Log Scale	3.389
95% t UCL (assumes normality of ROS data)	0.147	95% Percentile Bootstrap UCL	0.159
95% BCA Bootstrap UCL	0.214	95% Bootstrap t UCL	4.154
95% H-UCL (Log ROS)	108.7		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-5.008	KM Geo Mean	0.00669
KM SD (logged)	1.427	95% Critical H Value (KM-Log)	3.478
KM Standard Error of Mean (logged)	0.404	95% H-UCL (KM -Log)	0.0697
KM SD (logged)	1.427	95% Critical H Value (KM-Log)	3.478
KM Standard Error of Mean (logged)	0.404		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0574	Mean in Log Scale	-5.383
SD in Original Scale	0.199	SD in Log Scale	1.68
95% t UCL (Assumes normality)	0.148	95% H-Stat UCL	0.111

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution at 5% Significance Level

Suggested UCL to Use

99% KM (Chebyshev) UCL	0.598

Ag

General Statistics

Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	0
Minimum	0.125	Mean	0.436

Maximum	2.19	Median	0.266
SD	0.536	Std. Error of Mean	0.138
Coefficient of Variation	1.231	Skewness	2.924
Normal GOF Test			
Shapiro Wilk Test Statistic	0.582	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.323	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.679	95% Adjusted-CLT UCL (Chen-1995)	0.775
		95% Modified-t UCL (Johnson-1978)	0.697
Gamma GOF Test			
A-D Test Statistic	1.204	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.755	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.247	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.226	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.461	k star (bias corrected MLE)	1.214
Theta hat (MLE)	0.298	Theta star (bias corrected MLE)	0.359
nu hat (MLE)	43.84	nu star (bias corrected)	36.41
MLE Mean (bias corrected)	0.436	MLE Sd (bias corrected)	0.395
		Approximate Chi Square Value (0.05)	23.6
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	22.33
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	0.672	95% Adjusted Gamma UCL (use when n<50)	0.71
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.881	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.18	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-2.079	Mean of logged Data	-1.211
Maximum of Logged Data	0.784	SD of logged Data	0.788
Assuming Lognormal Distribution			
95% H-UCL	0.678	90% Chebyshev (MVUE) UCL	0.654
95% Chebyshev (MVUE) UCL	0.771	97.5% Chebyshev (MVUE) UCL	0.933
99% Chebyshev (MVUE) UCL	1.251		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	0.663	95% Jackknife UCL	0.679
95% Standard Bootstrap UCL	0.656	95% Bootstrap-t UCL	1.322
95% Hall's Bootstrap UCL	1.69	95% Percentile Bootstrap UCL	0.693
95% BCA Bootstrap UCL	0.852		
90% Chebyshev(Mean, Sd) UCL	0.851	95% Chebyshev(Mean, Sd) UCL	1.039
97.5% Chebyshev(Mean, Sd) UCL	1.3	99% Chebyshev(Mean, Sd) UCL	1.813

Suggested UCL to Use

95% H-UCL	0.678

ProUCL computes and outputs H-statistic based UCLs for
historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic
based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma
distribution.

BenzAc

General Statistics

Total Number of Observations	15	Number of Distinct Observations	6
Number of Detects	2	Number of Non-Detects	13
Number of Distinct Detects	2	Number of Distinct Non-Detects	4
Minimum Detect	0.458	Minimum Non-Detect	0.167
Maximum Detect	0.497	Maximum Non-Detect	0.17
Variance Detects	7.61E-04	Percent Non-Detects	86.67%
Mean Detects	0.478	SD Detects	0.0276
Median Detects	0.478	CV Detects	0.0578
Skewness Detects	N/A	Kurtosis Detects	N/A
Mean of Logged Detects	-0.74	SD of Logged Detects	0.0578

Warning: Data set has only 2 Detected
Values.
This is not enough to compute meaningful or reliable
statistics and estimates.

B2EHP

General Statistics

Total Number of Observations	15	Number of Distinct Observations	9
Number of Detects	6	Number of Non-Detects	9
Number of Distinct Detects	6	Number of Distinct Non-Detects	3
Minimum Detect	0.0255	Minimum Non-Detect	0.01
Maximum Detect	1.32	Maximum Non-Detect	0.0102
Variance Detects	0.315	Percent Non-Detects	60%
Mean Detects	0.655	SD Detects	0.561
Median Detects	0.616	CV Detects	0.858
Skewness Detects	0.0747	Kurtosis Detects	-2.718
Mean of Logged Detects	-1.05	SD of Logged Detects	1.523

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.866	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.263	Lilliefors GOF Test
5% Lilliefors Critical Value	0.325	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5%
Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.268	KM Standard Error of Mean	0.128
KM SD	0.453	95% KM (BCA) UCL	0.497
95% KM (t) UCL	0.493	95% KM (Percentile Bootstrap) UCL	0.484
95% KM (z) UCL	0.478	95% KM Bootstrap t UCL	0.521
90% KM Chebyshev UCL	0.652	95% KM Chebyshev UCL	0.826
97.5% KM Chebyshev UCL	1.067	99% KM Chebyshev UCL	1.541

Gamma GOF Tests on Detected Observations
Only

A-D Test Statistic	0.417	Anderson-Darling GOF Test
5% A-D Critical Value	0.717	Detected data appear Gamma Distributed at 5% Significance Level

K-S Test Statistic	0.275	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.342	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.93	k star (bias corrected MLE)	0.576
Theta hat (MLE)	0.704	Theta star (bias corrected MLE)	1.136
nu hat (MLE)	11.16	nu star (bias corrected)	6.915
Gamma ROS Statistics using Imputed Non-Detects			
Minimum	0.01	Mean	0.268
Maximum	1.32	Median	0.01
SD	0.468	CV	1.749
k hat (MLE)	0.359	k star (bias corrected MLE)	0.332
Theta hat (MLE)	0.746	Theta star (bias corrected MLE)	0.808
nu hat (MLE)	10.77	nu star (bias corrected)	9.948
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (9.95, α)	3.91	Adjusted Chi Square Value (9.95, β)	3.456
95% Gamma Approximate UCL (use when n>=50)	0.682	95% Gamma Adjusted UCL (use when n<50)	0.771
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.268	SD (KM)	0.453
Variance (KM)	0.205	SE of Mean (KM)	0.128
k hat (KM)	0.35	k star (KM)	0.325
nu hat (KM)	10.51	nu star (KM)	9.74
theta hat (KM)	0.765	theta star (KM)	0.825
80% gamma percentile (KM)	0.418	90% gamma percentile (KM)	0.782
95% gamma percentile (KM)	1.194	99% gamma percentile (KM)	2.255
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (9.74, α)	3.78	Adjusted Chi Square Value (9.74, β)	3.335
95% Gamma Approximate KM-UCL (use when n>=50)	0.69	95% Gamma Adjusted KM-UCL (use when n<50)	0.782
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.863	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.25	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.266	Mean in Log Scale	-3.773
SD in Original Scale	0.469	SD in Log Scale	2.692
95% t UCL (assumes normality of ROS data)	0.48	95% Percentile Bootstrap UCL	0.466
95% BCA Bootstrap UCL	0.517	95% Bootstrap t UCL	0.599
95% H-UCL (Log ROS)	61.91		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-3.183	KM Geo Mean	0.0415
KM SD (logged)	1.951	95% Critical H Value (KM-Log)	4.468
KM Standard Error of Mean (logged)	0.552	95% H-UCL (KM -Log)	2.859
KM SD (logged)	1.951	95% Critical H Value (KM-Log)	4.468
KM Standard Error of Mean (logged)	0.552		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.265	Mean in Log Scale	-3.593
SD in Original Scale	0.47	SD in Log Scale	2.334
95% t UCL (Assumes normality)	0.479	95% H-Stat UCL	10.91
DL/2 is not a recommended method, provided for comparisons and historical reasons			

Nonparametric Distribution Free UCL Statistics

Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	0.493

DNBP

General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	4	Number of Non-Detects	11
Number of Distinct Detects	4	Number of Distinct Non-Detects	3
Minimum Detect	0.0131	Minimum Non-Detect	0.01
Maximum Detect	0.744	Maximum Non-Detect	0.0102
Variance Detects	0.118	Percent Non-Detects	73.33%
Mean Detects	0.239	SD Detects	0.343
Median Detects	0.1	CV Detects	1.435
Skewness Detects	1.776	Kurtosis Detects	3.132
Mean of Logged Detects	-2.459	SD of Logged Detects	1.785

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.779	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.333	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0711	KM Standard Error of Mean	0.0549
KM SD	0.184	95% KM (BCA) UCL	N/A
95% KM (t) UCL	0.168	95% KM (Percentile Bootstrap) UCL	N/A
95% KM (z) UCL	0.161	95% KM Bootstrap t UCL	N/A
90% KM Chebyshev UCL	0.236	95% KM Chebyshev UCL	0.31
97.5% KM Chebyshev UCL	0.414	99% KM Chebyshev UCL	0.617

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.292	Anderson-Darling GOF Test	
5% A-D Critical Value	0.677	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.257	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.408	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.601	k star (bias corrected MLE)	0.317
Theta hat (MLE)	0.398	Theta star (bias corrected MLE)	0.755
nu hat (MLE)	4.805	nu star (bias corrected)	2.535
Mean (detects)	0.239		
Minimum	0.01	Mean	0.0711
Maximum	0.744	Median	0.01
SD	0.19	CV	2.678
k hat (MLE)	0.463	k star (bias corrected MLE)	0.415
Theta hat (MLE)	0.154	Theta star (bias corrected MLE)	0.172
nu hat (MLE)	13.88	nu star (bias corrected)	12.44
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (12.44, α)	5.517	Adjusted Chi Square Value (12.44, β)	4.96
95% Gamma Approximate UCL (use when n>=50)	0.16	95% Gamma Adjusted UCL (use when n<50)	N/A

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.0711	SD (KM)	0.184
Variance (KM)	0.0339	SE of Mean (KM)	0.0549
k hat (KM)	0.149	k star (KM)	0.164

nu hat (KM)	4.483	nu star (KM)	4.92
theta hat (KM)	0.476	theta star (KM)	0.434
80% gamma percentile (KM)	0.0829	90% gamma percentile (KM)	0.213
95% gamma percentile (KM)	0.384	99% gamma percentile (KM)	0.873
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (4.92, α)	1.115	Adjusted Chi Square Value (4.92, β)	0.912
95% Gamma Approximate KM-UCL (use when n>=50)	0.314	95% Gamma Adjusted KM-UCL (use when n<50)	0.384
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.972	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.204	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.064	Mean in Log Scale	-8.202
SD in Original Scale	0.193	SD in Log Scale	4.354
95% t UCL (assumes normality of ROS data)	0.152	95% Percentile Bootstrap UCL	0.16
95% BCA Bootstrap UCL	0.211	95% Bootstrap t UCL	1.471
95% H-UCL (Log ROS)	193999		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-4.033	KM Geo Mean	0.0177
KM SD (logged)	1.24	95% Critical H Value (KM-Log)	3.146
KM Standard Error of Mean (logged)	0.37	95% H-UCL (KM -Log)	0.109
KM SD (logged)	1.24	95% Critical H Value (KM-Log)	3.146
KM Standard Error of Mean (logged)	0.37		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0675	Mean in Log Scale	-4.534
SD in Original Scale	0.192	SD in Log Scale	1.536
95% t UCL (Assumes normality)	0.155	95% H-Stat UCL	0.158
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.168		

RDX

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	10
Number of Detects	6	Number of Non-Detects	9
Number of Distinct Detects	6	Number of Distinct Non-Detects	4
Minimum Detect	0.196	Minimum Non-Detect	0.148
Maximum Detect	4.76	Maximum Non-Detect	0.189
Variance Detects	3.142	Percent Non-Detects	60%
Mean Detects	1.841	SD Detects	1.773
Median Detects	1.549	CV Detects	0.963
Skewness Detects	0.881	Kurtosis Detects	-0.101
Mean of Logged Detects	0.0715	SD of Logged Detects	1.247

Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.872	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.257	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.825	KM Standard Error of Mean	0.373
KM SD	1.317	95% KM (BCA) UCL	1.437
95% KM (t) UCL	1.482	95% KM (Percentile Bootstrap) UCL	1.443
95% KM (z) UCL	1.438	95% KM Bootstrap t UCL	1.793
90% KM Chebyshev UCL	1.943	95% KM Chebyshev UCL	2.449
97.5% KM Chebyshev UCL	3.152	99% KM Chebyshev UCL	4.533

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.357	Anderson-Darling GOF Test	
5% A-D Critical Value	0.714	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.241	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.34	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.063	k star (bias corrected MLE)	0.643
Theta hat (MLE)	1.731	Theta star (bias corrected MLE)	2.864
nu hat (MLE)	12.76	nu star (bias corrected)	7.714
Mean (detects)	1.841		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.742
Maximum	4.76	Median	0.01
SD	1.409	CV	1.897
k hat (MLE)	0.285	k star (bias corrected MLE)	0.273
Theta hat (MLE)	2.602	Theta star (bias corrected MLE)	2.723
nu hat (MLE)	8.559	nu star (bias corrected)	8.181
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (8.18, α)	2.84	Adjusted Chi Square Value (8.18, β)	2.467
95% Gamma Approximate UCL (use when n>=50)	2.139	95% Gamma Adjusted UCL (use when n<50)	2.462

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.825	SD (KM)	1.317
Variance (KM)	1.735	SE of Mean (KM)	0.373
k hat (KM)	0.392	k star (KM)	0.358
nu hat (KM)	11.77	nu star (KM)	10.75
theta hat (KM)	2.103	theta star (KM)	2.303
80% gamma percentile (KM)	1.312	90% gamma percentile (KM)	2.374
95% gamma percentile (KM)	3.56	99% gamma percentile (KM)	6.578

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (10.75, α)	4.417	Adjusted Chi Square Value (10.75, β)	3.929
95% Gamma Approximate KM-UCL (use when n>=50)	2.009	95% Gamma Adjusted KM-UCL (use when n<50)	2.258

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.925	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.25	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.754	Mean in Log Scale	-2.331
SD in Original Scale	1.402	SD in Log Scale	2.297
95% t UCL (assumes normality of ROS data)	1.392	95% Percentile Bootstrap UCL	1.384
95% BCA Bootstrap UCL	1.651	95% Bootstrap t UCL	1.884
95% H-UCL (Log ROS)	32.06		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-1.118	KM Geo Mean	0.327
KM SD (logged)	1.209	95% Critical H Value (KM-Log)	3.091
KM Standard Error of Mean (logged)	0.342	95% H-UCL (KM -Log)	1.842
KM SD (logged)	1.209	95% Critical H Value (KM-Log)	3.091
KM Standard Error of Mean (logged)	0.342		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.782	Mean in Log Scale	-1.515
SD in Original Scale	1.387	SD in Log Scale	1.535
95% t UCL (Assumes normality)	1.413	95% H-Stat UCL	3.228

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	1.482

TATB

General Statistics

Total Number of Observations	15	Number of Distinct Observations	15
Number of Detects	15	Number of Missing Observations	0
Minimum	3.33	Mean	12.25
Maximum	22.2	Median	12.6
SD	4.896	Std. Error of Mean	1.264
Coefficient of Variation	0.4	Skewness	-0.177

Normal GOF Test

Shapiro Wilk Test Statistic	0.958	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.881	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.14	Lilliefors GOF Test
5% Lilliefors Critical Value	0.22	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	14.48	95% Adjusted-CLT UCL (Chen-1995)	14.27
		95% Modified-t UCL (Johnson-1978)	14.47

Gamma GOF Test

A-D Test Statistic	0.737	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.739	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.207	Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value	0.222	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.989	k star (bias corrected MLE)	4.036
Theta hat (MLE)	2.456	Theta star (bias corrected MLE)	3.036

```
nu hat (MLE)                                   149.7     nu star (bias corrected)                                  121.1
MLE Mean (bias corrected)                      12.25     MLE Sd (bias corrected)                                   6.098
                                                         Approximate Chi Square Value (0.05)                       96.67
Adjusted Level of Significance                0.0324     Adjusted Chi Square Value                                 93.98
Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when
n>=50))                                        15.34       95% Adjusted Gamma UCL (use when n<50)                  15.78
Lognormal GOF Test
Shapiro Wilk Test Statistic                    0.847     Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value                 0.881     Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic                      0.237     Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value                    0.22     Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data                         1.203     Mean of logged Data                                       2.402
Maximum of Logged Data                           3.1     SD of logged Data                                         0.522

Assuming Lognormal Distribution
  95% H-UCL                                    16.95       90% Chebyshev (MVUE) UCL                                17.76
  95% Chebyshev (MVUE) UCL                     20.13      97.5% Chebyshev (MVUE) UCL                               23.42
  99% Chebyshev (MVUE) UCL                     29.88

Nonparametric Distribution Free UCL
Statistics
Data appear to follow a Discernible
Distribution at 5% Significance Level
Nonparametric Distribution Free UCLs
  95% CLT UCL                                  14.33       95% Jackknife UCL                                       14.48
  95% Standard Bootstrap UCL                   14.22       95% Bootstrap-t UCL                                     14.24
  95% Hall's Bootstrap UCL                     14.47       95% Percentile Bootstrap UCL                            14.28
  95% BCA Bootstrap UCL                        14.26
  90% Chebyshev(Mean, Sd) UCL                  16.04       95% Chebyshev(Mean, Sd) UCL                             17.76
 97.5% Chebyshev(Mean, Sd) UCL                 20.15       99% Chebyshev(Mean, Sd) UCL                             24.83

Suggested UCL to Use
95% Student's-t UCL                            14.48

UCL Statistics for Data Sets with Non-Detects

User Selected Options
Date/Time of Computation                                    ProUCL 5.19/27/2019 4:28:00 PM
From File                                                   UCL Data TA 36.xls
Full Precision                                              OFF
Confidence Coefficient                                      95%
Number of Bootstrap Operations                              2000
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]
General Statistics
Total Number of Observations                          15    Number of Distinct Observations                          15
                                                            Number of Missing Observations                            0
Minimum                                         7.51E-07    Mean                                               1.85E-05
Maximum                                         1.13E-04    Median                                             4.67E-06
SD                                              3.06E-05    Std. Error of Mean                                 7.90E-06
Coefficient of Variation                           N/A      Skewness                                              2.458

Normal GOF Test
Shapiro Wilk Test Statistic                        0.643    Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value                     0.881    Data Not Normal at 5% Significance Level
Lilliefors Test Statistic                          0.296    Lilliefors GOF Test
5% Lilliefors Critical Value                        0.22    Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
  95% Normal UCL                                              95% UCLs (Adjusted for Skewness)
```

95% Student's-t UCL	3.24E-05	95% Adjusted-CLT UCL (Chen-1995)	3.68E-05
		95% Modified-t UCL (Johnson-1978)	3.32E-05

Gamma GOF Test

A-D Test Statistic	0.701	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.792	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.174	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.234	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.514	k star (bias corrected MLE)	0.456
Theta hat (MLE)	3.59E-05	Theta star (bias corrected MLE)	4.05E-05
nu hat (MLE)	15.43	nu star (bias corrected)	13.68
MLE Mean (bias corrected)	1.85E-05	MLE Sd (bias corrected)	2.74E-05
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	5.749

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	3.98E-05	95% Adjusted Gamma UCL (use when n<50)	4.40E-05

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.917	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.159	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-14.1	Mean of logged Data	-12.13
Maximum of Logged Data	-9.088	SD of logged Data	1.693

Assuming Lognormal Distribution

95% H-UCL	1.37E-04	90% Chebyshev (MVUE) UCL	4.70E-05
95% Chebyshev (MVUE) UCL	5.98E-05	97.5% Chebyshev (MVUE) UCL	7.75E-05
99% Chebyshev (MVUE) UCL	1.12E-04		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	3.15E-05	95% Jackknife UCL	3.24E-05
95% Standard Bootstrap UCL	3.14E-05	95% Bootstrap-t UCL	4.67E-05
95% Hall's Bootstrap UCL	6.32E-05	95% Percentile Bootstrap UCL	3.20E-05
95% BCA Bootstrap UCL	3.72E-05		
90% Chebyshev(Mean, Sd) UCL	4.22E-05	95% Chebyshev(Mean, Sd) UCL	5.29E-05
97.5% Chebyshev(Mean, Sd) UCL	6.78E-05	99% Chebyshev(Mean, Sd) UCL	9.71E-05

Suggested UCL to Use

95% Adjusted Gamma UCL	4.40E-05

Heptachlorodibenzofuran[1,2,3,4,6,7,8-]

General Statistics

Total Number of Observations	15	Number of Distinct Observations	13
Number of Detects	8	Number of Non-Detects	7
Number of Distinct Detects	8	Number of Distinct Non-Detects	5
Minimum Detect	8.20E-07	Minimum Non-Detect	4.97E-07
Maximum Detect	4.02E-06	Maximum Non-Detect	5.01E-07
Variance Detects	1.70E-12	Percent Non-Detects	46.67%
Mean Detects	2.26E-06	SD Detects	1.31E-06
Median Detects	1.99E-06	CV Detects	N/A
Skewness Detects	0.248	Kurtosis Detects	-2.044
Mean of Logged Detects	-13.17	SD of Logged Detects	0.64

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.878	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.818	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.223	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.283	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	1.44E-06	KM Standard Error of Mean	3.46E-07
KM SD	1.25E-06	95% KM (BCA) UCL	2.01E-06
95% KM (t) UCL	2.05E-06	95% KM (Percentile Bootstrap) UCL	2.00E-06
95% KM (z) UCL	2.01E-06	95% KM Bootstrap t UCL	2.24E-06
90% KM Chebyshev UCL	2.48E-06	95% KM Chebyshev UCL	2.95E-06
97.5% KM Chebyshev UCL	3.60E-06	99% KM Chebyshev UCL	4.88E-06

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.442	Anderson-Darling GOF Test
5% A-D Critical Value	0.721	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.211	Kolmogorov-Smirnov GOF
5% K-S Critical Value	0.296	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	3.137	k star (bias corrected MLE)	2.044
Theta hat (MLE)	7.22E-07	Theta star (bias corrected MLE)	1.11E-06
nu hat (MLE)	50.18	nu star (bias corrected)	32.7
Mean (detects)	2.26E-06		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	8.20E-07	Mean	0.00467
Maximum	0.01	Median	4.02E-06
SD	0.00516	CV	1.106
k hat (MLE)	0.194	k star (bias corrected MLE)	0.2
Theta hat (MLE)	0.024	Theta star (bias corrected MLE)	0.0234
nu hat (MLE)	5.83	nu star (bias corrected)	5.997
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (6.00, α)	1.638	Adjusted Chi Square Value (6.00, β)	1.375
95% Gamma Approximate UCL (use when n>=50)	0.0171	95% Gamma Adjusted UCL (use when n<50)	0.0204

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.44E-06	SD (KM)	1.25E-06
Variance (KM)	1.57E-12	SE of Mean (KM)	3.46E-07
k hat (KM)	1.318	k star (KM)	1.099
nu hat (KM)	39.54	nu star (KM)	32.96
theta hat (KM)	1.09E-06	theta star (KM)	1.31E-06
80% gamma percentile (KM)	2.30E-06	90% gamma percentile (KM)	3.24E-06
95% gamma percentile (KM)	4.17E-06	99% gamma percentile (KM)	6.32E-06

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (32.96, α)	20.84	Adjusted Chi Square Value (32.96, β)	19.65
95% Gamma Approximate KM-UCL (use when n>=50)	2.28E-06	95% Gamma Adjusted KM-UCL (use when n<50)	2.41E-06

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.894	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.818	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.195	Lilliefors GOF Test
5% Lilliefors Critical Value	0.283	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	1.37E-06	Mean in Log Scale	-13.97
SD in Original Scale	1.35E-06	SD in Log Scale	1.018
95% t UCL (assumes normality of ROS data)	1.99E-06	95% Percentile Bootstrap UCL	1.95E-06
95% BCA Bootstrap UCL	2.06E-06	95% Bootstrap t UCL	2.18E-06
95% H-UCL (Log ROS)	3.05E-06		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-13.8	KM Geo Mean	1.02E-06

KM SD (logged)	0.802	95% Critical H Value (KM-Log)	2.446
KM Standard Error of Mean (logged)	0.221	95% H-UCL (KM -Log)	2.38E-06
KM SD (logged)	0.802	95% Critical H Value (KM-Log)	2.446
KM Standard Error of Mean (logged)	0.221		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	1.32E-06	Mean in Log Scale	-14.12
SD in Original Scale	1.39E-06	SD in Log Scale	1.146
95% t UCL (Assumes normality)	1.96E-06	95% H-Stat UCL	3.56E-06

DL/2 is not a recommended method, provided for comparisons and historical reasons
Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use	
95% KM (t) UCL	2.05E-06

Heptachlorodibenzofuran[1,2,3,4,7,8,9-]

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Heptachlorodibenzofuran[1,2,3,4,7,8,9-] was not processed!

Hexachlorodibenzodioxin[1,2,3,4,7,8-]

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	9
Number of Detects	2	Number of Non-Detects	13
Number of Distinct Detects	2	Number of Distinct Non-Detects	7
Minimum Detect	5.85E-07	Minimum Non-Detect	4.97E-07
Maximum Detect	6.79E-07	Maximum Non-Detect	5.03E-07
Variance Detects	4.42E-15	Percent Non-Detects	86.67%
Mean Detects	6.32E-07	SD Detects	6.65E-08
Median Detects	6.32E-07	CV Detects	N/A
Skewness Detects	N/A	Kurtosis Detects	N/A
Mean of Logged Detects	-14.28	SD of Logged Detects	0.105

Warning: Data set has only 2 Detected Values.
This is not enough to compute meaningful or reliable statistics and estimates.
Normal GOF Test on Detects Only
Not Enough Data to Perform GOF Test

Hexachlorodibenzodioxin[1,2,3,6,7,8-]

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	11
Number of Detects	4	Number of Non-Detects	11
Number of Distinct Detects	4	Number of Distinct Non-Detects	7
Minimum Detect	6.27E-07	Minimum Non-Detect	4.97E-07
Maximum Detect	1.45E-06	Maximum Non-Detect	5.03E-07
Variance Detects	1.27E-13	Percent Non-Detects	73.33%
Mean Detects	9.97E-07	SD Detects	3.57E-07
Median Detects	9.56E-07	CV Detects	N/A
Skewness Detects	0.551	Kurtosis Detects	-0.748
Mean of Logged Detects	-13.87	SD of Logged Detects	0.361

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.977	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.188	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	6.30E-07	KM Standard Error of Mean	8.13E-08
KM SD	2.73E-07	95% KM (BCA) UCL	N/A
95% KM (t) UCL	7.74E-07	95% KM (Percentile Bootstrap) UCL	N/A
95% KM (z) UCL	7.64E-07	95% KM Bootstrap t UCL	N/A
90% KM Chebyshev UCL	8.74E-07	95% KM Chebyshev UCL	9.85E-07
97.5% KM Chebyshev UCL	1.14E-06	99% KM Chebyshev UCL	1.44E-06

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.206	Anderson-Darling GOF Test	
5% A-D Critical Value	0.657	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.192	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.395	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	10.47	k star (bias corrected MLE)	2.784
Theta hat (MLE)	9.53E-08	Theta star (bias corrected MLE)	3.58E-07
nu hat (MLE)	83.76	nu star (bias corrected)	22.27
Mean (detects)	9.97E-07		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	6.27E-07	Mean	0.00733
Maximum	0.01	Median	0.01
SD	0.00458	CV	0.624
k hat (MLE)	0.317	k star (bias corrected MLE)	0.298
Theta hat (MLE)	0.0232	Theta star (bias corrected MLE)	0.0246
nu hat (MLE)	9.495	nu star (bias corrected)	8.93
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (8.93, α)	3.285	Adjusted Chi Square Value (8.93, β)	2.876
95% Gamma Approximate UCL (use when n>=50)	0.0199	95% Gamma Adjusted UCL (use when n<50)	N/A

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	6.30E-07	SD (KM)	2.73E-07
Variance (KM)	7.44E-14	SE of Mean (KM)	8.13E-08
k hat (KM)	5.344	k star (KM)	4.32
nu hat (KM)	160.3	nu star (KM)	129.6
theta hat (KM)	1.18E-07	theta star (KM)	1.46E-07
80% gamma percentile (KM)	8.62E-07	90% gamma percentile (KM)	1.04E-06
95% gamma percentile (KM)	1.20E-06	99% gamma percentile (KM)	1.54E-06

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (129.59, α)	104.3	Adjusted Chi Square Value (129.59, β)	101.5
95% Gamma Approximate KM-UCL (use when n>=50)	7.83E-07	95% Gamma Adjusted KM-UCL (use when n<50)	8.05E-07

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.993	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.156	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	4.22E-07	Mean in Log Scale	-15
SD in Original Scale	3.99E-07	SD in Log Scale	0.778
95% t UCL (assumes normality of ROS data)	6.04E-07	95% Percentile Bootstrap UCL	6.09E-07
* 95% BCA Bootstrap UCL	6.37E-07	95% Bootstrap t UCL	7.91E-07
95% H-UCL (Log ROS)	6.85E-07		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-14.34	KM Geo Mean	5.91E-07
KM SD (logged)	0.329	95% Critical H Value (KM-Log)	1.906
KM Standard Error of Mean (logged)	0.0981	95% H-UCL (KM -Log)	7.37E-07
KM SD (logged)	0.329	95% Critical H Value (KM-Log)	1.906
KM Standard Error of Mean (logged)	0.0981		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	4.49E-07	Mean in Log Scale	-14.85
SD in Original Scale	3.80E-07	SD in Log Scale	0.635
95% t UCL (Assumes normality)	6.22E-07	95% H-Stat UCL	6.35E-07

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	7.74E-07

Hexachlorodibenzodioxin[1,2,3,7,8,9-]

General Statistics

Total Number of Observations	15	Number of Distinct Observations	10
Number of Detects	3	Number of Non-Detects	12
Number of Distinct Detects	3	Number of Distinct Non-Detects	7
Minimum Detect	6.55E-07	Minimum Non-Detect	4.97E-07
Maximum Detect	1.11E-06	Maximum Non-Detect	5.03E-07
Variance Detects	5.57E-14	Percent Non-Detects	80%
Mean Detects	9.19E-07	SD Detects	2.36E-07
Median Detects	9.91E-07	CV Detects	N/A
Skewness Detects	-1.25	Kurtosis Detects	N/A
Mean of Logged Detects	-13.92	SD of Logged Detects	0.278

Warning: Data set has only 3 Detected Values.
This is not enough to compute meaningful or reliable statistics and estimates.

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.93	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.767	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.287	Lilliefors GOF Test
5% Lilliefors Critical Value	0.425	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	5.81E-07	KM Standard Error of Mean	5.99E-08
KM SD	1.89E-07	95% KM (BCA) UCL	N/A
95% KM (t) UCL	6.87E-07	95% KM (Percentile Bootstrap) UCL	N/A
95% KM (z) UCL	6.80E-07	95% KM Bootstrap t UCL	N/A
90% KM Chebyshev UCL	7.61E-07	95% KM Chebyshev UCL	8.42E-07
97.5% KM Chebyshev UCL	9.55E-07	99% KM Chebyshev UCL	1.18E-06

Gamma GOF Tests on Detected Observations Only
Not Enough Data to Perform GOF Test

Gamma Statistics on Detected Data Only

k hat (MLE)	20.63	k star (bias corrected MLE)	N/A
Theta hat (MLE)	4.45E-08	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	123.8	nu star (bias corrected)	N/A
Mean (detects)	9.19E-07		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	6.55E-07	Mean	0.008
Maximum	0.01	Median	0.01
SD	0.00414	CV	0.517
k hat (MLE)	0.401	k star (bias corrected MLE)	0.365
Theta hat (MLE)	0.02	Theta star (bias corrected MLE)	0.0219
nu hat (MLE)	12.03	nu star (bias corrected)	10.95
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (10.95, α)	4.547	Adjusted Chi Square Value (10.95, β)	4.05
95% Gamma Approximate UCL (use when n>=50)	0.0193	95% Gamma Adjusted UCL (use when n<50)	N/A

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	5.81E-07	SD (KM)	1.89E-07
Variance (KM)	3.59E-14	SE of Mean (KM)	5.99E-08
k hat (KM)	9.421	k star (KM)	7.581
nu hat (KM)	282.6	nu star (KM)	227.4
theta hat (KM)	6.17E-08	theta star (KM)	7.67E-08
80% gamma percentile (KM)	7.48E-07	90% gamma percentile (KM)	8.63E-07
95% gamma percentile (KM)	9.66E-07	99% gamma percentile (KM)	1.18E-06

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (227.43, α)	193.5	Adjusted Chi Square Value (227.43, β)	189.7
95% Gamma Approximate KM-UCL (use when n>=50)	6.83E-07	95% Gamma Adjusted KM-UCL (use when n<50)	6.97E-07

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.902	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.767	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.308	Lilliefors GOF Test
5% Lilliefors Critical Value	0.425	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level
Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	3.85E-07	Mean in Log Scale	-14.98
SD in Original Scale	2.98E-07	SD in Log Scale	0.62
95% t UCL (assumes normality of ROS data)	5.21E-07	95% Percentile Bootstrap UCL	5.10E-07
95% BCA Bootstrap UCL	5.45E-07	95% Bootstrap t UCL	6.34E-07
95% H-UCL (Log ROS)	5.48E-07		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-14.4	KM Geo Mean	5.59E-07
KM SD (logged)	0.257	95% Critical H Value (KM-Log)	1.849
KM Standard Error of Mean (logged)	0.0812	95% H-UCL (KM -Log)	6.56E-07
KM SD (logged)	0.257	95% Critical H Value (KM-Log)	1.849
KM Standard Error of Mean (logged)	0.0812		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	3.83E-07	Mean in Log Scale	-14.95
SD in Original Scale	2.91E-07	SD in Log Scale	0.54
95% t UCL (Assumes normality)	5.16E-07	95% H-Stat UCL	5.05E-07

DL/2 is not a recommended method, provided for comparisons and historical reasons
Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	6.87E-07

Hexachlorodibenzofuran[1,2,3,4,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7

Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzofuran[1,2,3,4,7,8-] was not processed!

Hexachlorodibenzofuran[1,2,3,6,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzofuran[1,2,3,6,7,8-] was not processed!

Hexachlorodibenzofuran[1,2,3,7,8,9-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzofuran[1,2,3,7,8,9-] was not processed!

Hexachlorodibenzofuran[2,3,4,6,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzofuran[2,3,4,6,7,8-] was not processed!

Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	0
Minimum	5.09E-06	Mean	1.48E-04
Maximum	9.20E-04	Median	4.30E-05
SD	2.46E-04	Std. Error of Mean	6.34E-05
Coefficient of Variation	1.658	Skewness	2.563
Normal GOF Test			
Shapiro Wilk Test Statistic	0.638	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.289	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	2.60E-04	95% Adjusted-CLT UCL (Chen-1995)	2.97E-04
		95% Modified-t UCL (Johnson-1978)	2.67E-04

Gamma GOF Test

A-D Test Statistic	0.591	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.791	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.173	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.233	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.53	k star (bias corrected MLE)	0.468
Theta hat (MLE)	2.80E-04	Theta star (bias corrected MLE)	3.16E-04
nu hat (MLE)	15.9	nu star (bias corrected)	14.05
MLE Mean (bias corrected)	1.48E-04	MLE Sd (bias corrected)	2.17E-04
		Approximate Chi Square Value (0.05)	6.605
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	5.987

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	3.15E-04	95% Adjusted Gamma UCL (use when n<50)	3.48E-04

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.941	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.158	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-12.19	Mean of logged Data	-10.01
Maximum of Logged Data	-6.991	SD of logged Data	1.671

Assuming Lognormal Distribution

95% H-UCL	0.00105	90% Chebyshev (MVUE) UCL	3.78E-04
95% Chebyshev (MVUE) UCL	4.80E-04	97.5% Chebyshev (MVUE) UCL	6.22E-04
99% Chebyshev (MVUE) UCL	9.01E-04		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	2.53E-04	95% Jackknife UCL	2.60E-04
95% Standard Bootstrap UCL	2.50E-04	95% Bootstrap-t UCL	4.08E-04
95% Hall's Bootstrap UCL	6.05E-04	95% Percentile Bootstrap UCL	2.56E-04
95% BCA Bootstrap UCL	3.18E-04		
90% Chebyshev(Mean, Sd) UCL	3.39E-04	95% Chebyshev(Mean, Sd) UCL	4.25E-04
97.5% Chebyshev(Mean, Sd) UCL	5.44E-04	99% Chebyshev(Mean, Sd) UCL	7.79E-04

Suggested UCL to Use

95% Adjusted Gamma UCL	3.48E-04

Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]

General Statistics

Total Number of Observations	15	Number of Distinct Observations	14
Number of Detects	9	Number of Non-Detects	6
Number of Distinct Detects	9	Number of Distinct Non-Detects	5
Minimum Detect	1.33E-06	Minimum Non-Detect	9.93E-07
Maximum Detect	1.63E-05	Maximum Non-Detect	1.00E-06
Variance Detects	2.89E-11	Percent Non-Detects	40%
Mean Detects	7.23E-06	SD Detects	5.37E-06
Median Detects	5.55E-06	CV Detects	N/A
Skewness Detects	0.634	Kurtosis Detects	-0.993
Mean of Logged Detects	-12.13	SD of Logged Detects	0.866

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.909	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.829	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.179	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.274	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	4.74E-06	KM Standard Error of Mean	1.36E-06
KM SD	4.98E-06	95% KM (BCA) UCL	7.08E-06
95% KM (t) UCL	7.14E-06	95% KM (Percentile Bootstrap) UCL	6.86E-06
95% KM (z) UCL	6.98E-06	95% KM Bootstrap t UCL	7.89E-06
90% KM Chebyshev UCL	8.83E-06	95% KM Chebyshev UCL	1.07E-05
97.5% KM Chebyshev UCL	1.32E-05	99% KM Chebyshev UCL	1.83E-05
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.266	Anderson-Darling GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.161	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.283	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	1.834	k star (bias corrected MLE)	1.297
Theta hat (MLE)	3.95E-06	Theta star (bias corrected MLE)	5.58E-06
nu hat (MLE)	33.01	nu star (bias corrected)	23.34
Mean (detects)	7.23E-06		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	1.33E-06	Mean	0.004
Maximum	0.01	Median	1.39E-05
SD	0.00507	CV	1.265
k hat (MLE)	0.204	k star (bias corrected MLE)	0.207
Theta hat (MLE)	0.0197	Theta star (bias corrected MLE)	0.0193
nu hat (MLE)	6.112	nu star (bias corrected)	6.223
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (6.22, α)	1.755	Adjusted Chi Square Value (6.22, β)	1.48
95% Gamma Approximate UCL (use when n>=50)	0.0142	95% Gamma Adjusted UCL (use when n<50)	0.0168
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	4.74E-06	SD (KM)	4.98E-06
Variance (KM)	2.48E-11	SE of Mean (KM)	1.36E-06
k hat (KM)	0.907	k star (KM)	0.77
nu hat (KM)	27.21	nu star (KM)	23.1
theta hat (KM)	5.22E-06	theta star (KM)	6.15E-06
80% gamma percentile (KM)	7.76E-06	90% gamma percentile (KM)	1.16E-05
95% gamma percentile (KM)	1.56E-05	99% gamma percentile (KM)	2.50E-05
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (23.10, α)	13.16	Adjusted Chi Square Value (23.10, β)	12.25
95% Gamma Approximate KM-UCL (use when n>=50)	8.31E-06	95% Gamma Adjusted KM-UCL (use when n<50)	8.93E-06
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.948	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.829	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.167	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.274	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	4.58E-06	Mean in Log Scale	-13.02
SD in Original Scale	5.28E-06	SD in Log Scale	1.312
95% t UCL (assumes normality of ROS data)	6.98E-06	95% Percentile Bootstrap UCL	6.90E-06
95% BCA Bootstrap UCL	7.30E-06	95% Bootstrap t UCL	7.86E-06
95% H-UCL (Log ROS)	1.64E-05		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			

KM Mean (logged)	-12.81	KM Geo Mean	2.74E-06
KM SD (logged)	1.042	95% Critical H Value (KM-Log)	2.811
KM Standard Error of Mean (logged)	0.285	95% H-UCL (KM -Log)	1.03E-05
KM SD (logged)	1.042	95% Critical H Value (KM-Log)	2.811
KM Standard Error of Mean (logged)	0.285		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	4.54E-06	Mean in Log Scale	-13.09
SD in Original Scale	5.31E-06	SD in Log Scale	1.373
95% t UCL (Assumes normality)	6.95E-06	95% H-Stat UCL	1.84E-05

DL/2 is not a recommended method, provided for comparisons and historical reasons
Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	7.14E-06

Pentachlorodibenzodioxin[1,2,3,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Pentachlorodibenzodioxin[1,2,3,7,8-] was not processed!

Pentachlorodibenzofuran[1,2,3,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Pentachlorodibenzofuran[1,2,3,7,8-] was not processed!

Pentachlorodibenzofuran[2,3,4,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	7
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	7

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Pentachlorodibenzofuran[2,3,4,7,8-] was not processed!

Tetrachlorodibenzodioxin[2,3,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	10
Number of Detects	0	Number of Non-Detects	15
Number of Distinct Detects	0	Number of Distinct Non-Detects	10

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Tetrachlorodibenzodioxin[2,3,7,8-] was not processed!

Tetrachlorodibenzofuran[2,3,7,8-]
General Statistics

Total Number of Observations	15	Number of Distinct Observations	15
Number of Detects	7	Number of Non-Detects	8
Number of Distinct Detects	7	Number of Distinct Non-Detects	8
Minimum Detect	1.31E-07	Minimum Non-Detect	1.59E-07
Maximum Detect	2.27E-07	Maximum Non-Detect	2.51E-07
Variance Detects	1.09E-15	Percent Non-Detects	53.33%
Mean Detects	1.69E-07	SD Detects	3.31E-08
Median Detects	1.71E-07	CV Detects	N/A
Skewness Detects	0.755	Kurtosis Detects	0.255
Mean of Logged Detects	-15.61	SD of Logged Detects	0.191
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.932	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.202	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	1.58E-07	KM Standard Error of Mean	8.92E-09
KM SD	2.73E-08	95% KM (BCA) UCL	1.72E-07
95% KM (t) UCL	1.74E-07	95% KM (Percentile Bootstrap) UCL	1.74E-07
95% KM (z) UCL	1.73E-07	95% KM Bootstrap t UCL	1.75E-07
90% KM Chebyshev UCL	1.85E-07	95% KM Chebyshev UCL	1.97E-07
97.5% KM Chebyshev UCL	2.14E-07	99% KM Chebyshev UCL	2.47E-07
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.281	Anderson-Darling GOF Test	
5% A-D Critical Value	0.707	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.22	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.311	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	31.71	k star (bias corrected MLE)	18.22
Theta hat (MLE)	5.32E-09	Theta star (bias corrected MLE)	9.27E-09
nu hat (MLE)	444	nu star (bias corrected)	255
Mean (detects)	1.69E-07		
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	1.31E-07	Mean	0.00533
Maximum	0.01	Median	0.01
SD	0.00516	CV	0.968
k hat (MLE)	0.168	k star (bias corrected MLE)	0.179
Theta hat (MLE)	0.0318	Theta star (bias corrected MLE)	0.0299
nu hat (MLE)	5.032	nu star (bias corrected)	5.359
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (5.36, α)	1.322	Adjusted Chi Square Value (5.36, β)	1.093
95% Gamma Approximate UCL (use when n>=50)	0.0216	95% Gamma Adjusted UCL (use when n<50)	0.0261
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	1.58E-07	SD (KM)	2.73E-08
Variance (KM)	7.44E-16	SE of Mean (KM)	8.92E-09
k hat (KM)	33.51	k star (KM)	26.85
nu hat (KM)	1005	nu star (KM)	805.5
theta hat (KM)	4.71E-09	theta star (KM)	5.88E-09
80% gamma percentile (KM)	1.83E-07	90% gamma percentile (KM)	1.98E-07
95% gamma percentile (KM)	2.11E-07	99% gamma percentile (KM)	2.37E-07
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (805.52, α)	740.7	Adjusted Chi Square Value (805.52, β)	733
95% Gamma Approximate KM-UCL (use when n>=50)	1.72E-07	95% Gamma Adjusted KM-UCL (use when n<50)	1.74E-07
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.951	Shapiro Wilk GOF Test	

```
5% Shapiro Wilk Critical Value                       0.803   Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic                            0.202   Lilliefors GOF Test
5% Lilliefors Critical Value                         0.304   Detected Data appear Lognormal at 5% Significance Level
Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects
Mean in Original Scale                            1.58E-07   Mean in Log Scale                                   -15.67
SD in Original Scale                              2.45E-08   SD in Log Scale                                      0.141
  95% t UCL (assumes normality of ROS data)       1.69E-07     95% Percentile Bootstrap UCL                    1.68E-07
  95% BCA Bootstrap UCL                           1.71E-07     95% Bootstrap t UCL                             1.76E-07
  95% H-UCL (Log ROS)                             1.69E-07

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution
KM Mean (logged)                                    -15.67   KM Geo Mean                                       1.56E-07
KM SD (logged)                                       0.161     95% Critical H Value (KM-Log)                      1.784
KM Standard Error of Mean (logged)                  0.0537     95% H-UCL (KM -Log)                             1.70E-07
KM SD (logged)                                       0.161     95% Critical H Value (KM-Log)                      1.784
KM Standard Error of Mean (logged)                  0.0537
DL/2 Statistics
DL/2 Normal                                                  DL/2 Log-Transformed
Mean in Original Scale                            1.32E-07   Mean in Log Scale                                   -15.89
SD in Original Scale                              4.35E-08   SD in Log Scale                                      0.322
  95% t UCL (Assumes normality)                   1.52E-07     95% H-Stat UCL                                  1.56E-07
DL/2 is not a recommended method, provided for comparisons and historical reasons
Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use
95% KM (t) UCL                                    1.74E-07
```

ATTACHMENT B. LANL ECORISK DATABASE FOR INORGANICS AND ORGANICS (MG/KG)

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Tetrachlorodibenzodioxin[2,3,7,8-]	Deer mouse (Mammalian omnivore)	0.00000058	0.0000038	
Tetrachlorodibenzodioxin[2,3,7,8-]	Earthworm (Soil-dwelling invertebrate)	5	10	
Tetrachlorodibenzodioxin[2,3,7,8-]	Gray fox (Mammalian top carnivore)	0.0001	0.00068	
Tetrachlorodibenzodioxin[2,3,7,8-]	Montane shrew (Mammalian insectivore)	0.00000029	0.0000019	MINIMUM
Tetrachlorodibenzodioxin[2,3,7,8-]	Mountain cottontail (Mammalian herbivore)	0.00004	0.00027	
Amino-2,6-dinitrotoluene[4-]	Deer mouse (Mammalian omnivore)	23	230	
Amino-2,6-dinitrotoluene[4-]	Earthworm (Soil-dwelling invertebrate)	18	180	
Amino-2,6-dinitrotoluene[4-]	Generic plant (Terrestrial autotroph - producer)	33	330	
Amino-2,6-dinitrotoluene[4-]	Gray fox (Mammalian top carnivore)	6700	67000	
Amino-2,6-dinitrotoluene[4-]	Montane shrew (Mammalian insectivore)	12	120	MINIMUM
Amino-2,6-dinitrotoluene[4-]	Mountain cottontail (Mammalian herbivore)	320	3200	
Amino-4,6-dinitrotoluene[2-]	Deer mouse (Mammalian omnivore)	23	230	
Amino-4,6-dinitrotoluene[2-]	Earthworm (Soil-dwelling invertebrate)	43	430	
Amino-4,6-dinitrotoluene[2-]	Generic plant (Terrestrial autotroph - producer)	14	140	MINIMUM
Amino-4,6-dinitrotoluene[2-]	Gray fox (Mammalian top carnivore)	9700	97000	
Amino-4,6-dinitrotoluene[2-]	Montane shrew (Mammalian insectivore)	16	160	
Amino-4,6-dinitrotoluene[2-]	Mountain cottontail (Mammalian herbivore)	110	1100	
Dinitrobenzene[1,3-]	American kestrel (Avian top carnivore)	120	1200	
Dinitrobenzene[1,3-]	American kestrel (insectivore / carnivore)	9.3	93	
Dinitrobenzene[1,3-]	American robin (Avian herbivore)	0.079	0.79	
Dinitrobenzene[1,3-]	American robin (Avian insectivore)	1.6	16	
Dinitrobenzene[1,3-]	American robin (Avian omnivore)	0.15	1.5	
Dinitrobenzene[1,3-]	Deer mouse (Mammalian omnivore)	0.072	0.16	MINIMUM
Dinitrobenzene[1,3-]	Gray fox (Mammalian top carnivore)	82	190	
Dinitrobenzene[1,3-]	Montane shrew (Mammalian insectivore)	0.95	2.2	
Dinitrobenzene[1,3-]	Mountain cottontail (Mammalian herbivore)	0.091	0.21	
Dinitrotoluene[2,4-]	Deer mouse (Mammalian omnivore)	20	200	
Dinitrotoluene[2,4-]	Earthworm (Soil-dwelling invertebrate)	18	180	
Dinitrotoluene[2,4-]	Generic plant (Terrestrial autotroph - producer)	6	60	MINIMUM
Dinitrotoluene[2,4-]	Gray fox (Mammalian top carnivore)	2000	20000	
Dinitrotoluene[2,4-]	Montane shrew (Mammalian insectivore)	14	140	
Dinitrotoluene[2,4-]	Mountain cottontail (Mammalian herbivore)	74	740	
Dinitrotoluene[2,6-]	American kestrel (Avian top carnivore)	18000	180000	
Dinitrotoluene[2,6-]	American kestrel (insectivore / carnivore)	680	6800	
Dinitrotoluene[2,6-]	American robin (Avian herbivore)	52	520	
Dinitrotoluene[2,6-]	American robin (Avian insectivore)	130	1300	
Dinitrotoluene[2,6-]	American robin (Avian omnivore)	74	740	
Dinitrotoluene[2,6-]	Deer mouse (Mammalian omnivore)	4	40	MINIMUM
Dinitrotoluene[2,6-]	Earthworm (Soil-dwelling invertebrate)	30	44	
Dinitrotoluene[2,6-]	Gray fox (Mammalian top carnivore)	1300	13000	
Dinitrotoluene[2,6-]	Montane shrew (Mammalian insectivore)	7.6	76	
Dinitrotoluene[2,6-]	Mountain cottontail (Mammalian herbivore)	6.7	67	
HMX	Deer mouse (Mammalian omnivore)	290	790	
HMX	Earthworm (Soil-dwelling invertebrate)	16	160	MINIMUM
HMX	Generic plant (Terrestrial autotroph - producer)	2700	3500	
HMX	Gray fox (Mammalian top carnivore)	59000	150000	
HMX	Montane shrew (Mammalian insectivore)	1100	2900	
HMX	Mountain cottontail (Mammalian herbivore)	410	1100	
Nitroglycerine	Deer mouse (Mammalian omnivore)	70	740	
Nitroglycerine	Earthworm (Soil-dwelling invertebrate)	13	130	MINIMUM
Nitroglycerine	Generic plant (Terrestrial autotroph - producer)	21	210	
Nitroglycerine	Gray fox (Mammalian top carnivore)	69000	730000	
Nitroglycerine	Montane shrew (Mammalian insectivore)	1200	13000	
Nitroglycerine	Mountain cottontail (Mammalian herbivore)	88	930	
Nitrotoluene[2-]	Deer mouse (Mammalian omnivore)	9.8	98	MINIMUM
Nitrotoluene[2-]	Gray fox (Mammalian top carnivore)	6000	60000	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Nitrotoluene[2-]	Montane shrew (Mammalian insectivore)	22	220	
Nitrotoluene[2-]	Mountain cottontail (Mammalian herbivore)	15	150	
Nitrotoluene[3-]	Deer mouse (Mammalian omnivore)	12	120	MINIMUM
Nitrotoluene[3-]	Gray fox (Mammalian top carnivore)	7000	70000	
Nitrotoluene[3-]	Montane shrew (Mammalian insectivore)	19	190	
Nitrotoluene[3-]	Mountain cottontail (Mammalian herbivore)	21	210	
Nitrotoluene[4-]	Deer mouse (Mammalian omnivore)	21	210	MINIMUM
Nitrotoluene[4-]	Gray fox (Mammalian top carnivore)	13000	130000	
Nitrotoluene[4-]	Montane shrew (Mammalian insectivore)	41	410	
Nitrotoluene[4-]	Mountain cottontail (Mammalian herbivore)	36	360	
PETN	Deer mouse (Mammalian omnivore)	100	1000	MINIMUM
PETN	Gray fox (Mammalian top carnivore)	47000	470000	
PETN	Montane shrew (Mammalian insectivore)	1000	10000	
PETN	Mountain cottontail (Mammalian herbivore)	120	1200	
RDX	American kestrel (Avian top carnivore)	780	1400	
RDX	American kestrel (insectivore / carnivore)	11	22	
RDX	American robin (Avian herbivore)	2.3	4.3	MINIMUM
RDX	American robin (Avian insectivore)	2.4	4.5	
RDX	American robin (Avian omnivore)	2.3	4.4	MINIMUM
RDX	Deer mouse (Mammalian omnivore)	16	51	
RDX	Earthworm (Soil-dwelling invertebrate)	8.4	15	
RDX	Gray fox (Mammalian top carnivore)	7000	22000	
RDX	Montane shrew (Mammalian insectivore)	16	53	
RDX	Mountain cottontail (Mammalian herbivore)	38	120	
Tetryl	Deer mouse (Mammalian omnivore)	1.5	7.2	MINIMUM
Tetryl	Gray fox (Mammalian top carnivore)	960	4600	
Tetryl	Montane shrew (Mammalian insectivore)	60	280	
Tetryl	Mountain cottontail (Mammalian herbivore)	1.8	8.9	
Trinitrobenzene[1,3,5-]	Deer mouse (Mammalian omnivore)	110	1100	
Trinitrobenzene[1,3,5-]	Earthworm (Soil-dwelling invertebrate)	10	28	MINIMUM
Trinitrobenzene[1,3,5-]	Gray fox (Mammalian top carnivore)	10000	100000	
Trinitrobenzene[1,3,5-]	Montane shrew (Mammalian insectivore)	720	7200	
Trinitrobenzene[1,3,5-]	Mountain cottontail (Mammalian herbivore)	150	1500	
Trinitrotoluene[2,4,6-]	American kestrel (Avian top carnivore)	3100	5700	
Trinitrotoluene[2,4,6-]	American kestrel (insectivore / carnivore)	1300	2400	
Trinitrotoluene[2,4,6-]	American robin (Avian herbivore)	7.5	13	MINIMUM
Trinitrotoluene[2,4,6-]	American robin (Avian insectivore)	120	220	
Trinitrotoluene[2,4,6-]	American robin (Avian omnivore)	14	26	
Trinitrotoluene[2,4,6-]	Deer mouse (Mammalian omnivore)	95	440	
Trinitrotoluene[2,4,6-]	Earthworm (Soil-dwelling invertebrate)	32	58	
Trinitrotoluene[2,4,6-]	Generic plant (Terrestrial autotroph - producer)	62	120	
Trinitrotoluene[2,4,6-]	Gray fox (Mammalian top carnivore)	26000	120000	
Trinitrotoluene[2,4,6-]	Montane shrew (Mammalian insectivore)	1900	9100	
Trinitrotoluene[2,4,6-]	Mountain cottontail (Mammalian herbivore)	110	540	
Aluminum	American kestrel (Avian top carnivore)			
Aluminum	American kestrel (insectivore / carnivore)			
Aluminum	American robin (Avian herbivore)			
Aluminum	American robin (Avian insectivore)			
Aluminum	American robin (Avian omnivore)			
Aluminum	Deer mouse (Mammalian omnivore)			
Aluminum	Earthworm (Soil-dwelling invertebrate)			
Aluminum	Generic plant (Terrestrial autotroph - producer)			
Aluminum	Gray fox (Mammalian top carnivore)			
Aluminum	Montane shrew (Mammalian insectivore)			
Aluminum	Mountain cottontail (Mammalian herbivore)			
Antimony	Deer mouse (Mammalian omnivore)	2.3	23	MINIMUM
Antimony	Earthworm (Soil-dwelling invertebrate)	78	780	
Antimony	Generic plant (Terrestrial autotroph - producer)	11	58	
Antimony	Gray fox (Mammalian top carnivore)	46	460	
Antimony	Montane shrew (Mammalian insectivore)	7.9	79	
Antimony	Mountain cottontail (Mammalian herbivore)	2.7	27	
Arsenic	American kestrel (Avian top carnivore)	740	7400	
Arsenic	American kestrel (insectivore / carnivore)	100	1000	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Arsenic	American robin (Avian herbivore)	34	340	
Arsenic	American robin (Avian insectivore)	15	150	
Arsenic	American robin (Avian omnivore)	21	210	
Arsenic	Deer mouse (Mammalian omnivore)	32	51	
Arsenic	Earthworm (Soil-dwelling invertebrate)	6.8	68	MINIMUM
Arsenic	Generic plant (Terrestrial autotroph - producer)	18	91	
Arsenic	Gray fox (Mammalian top carnivore)	820	1300	
Arsenic	Montane shrew (Mammalian insectivore)	19	31	
Arsenic	Mountain cottontail (Mammalian herbivore)	110	180	
Barium	American kestrel (Avian top carnivore)	24000	44000	
Barium	American kestrel (insectivore / carnivore)	7500	13000	
Barium	American robin (Avian herbivore)	720	1200	
Barium	American robin (Avian insectivore)	820	1400	
Barium	American robin (Avian omnivore)	770	1300	
Barium	Deer mouse (Mammalian omnivore)	1800	8700	
Barium	Earthworm (Soil-dwelling invertebrate)	330	3200	
Barium	Generic plant (Terrestrial autotroph - producer)	110	260	MINIMUM
Barium	Gray fox (Mammalian top carnivore)	41000	190000	
Barium	Montane shrew (Mammalian insectivore)	2100	10000	
Barium	Mountain cottontail (Mammalian herbivore)	2900	14000	
Beryllium	Deer mouse (Mammalian omnivore)	56	560	
Beryllium	Earthworm (Soil-dwelling invertebrate)	40	400	
Beryllium	Generic plant (Terrestrial autotroph - producer)	2.5	25	MINIMUM
Beryllium	Gray fox (Mammalian top carnivore)	420	4200	
Beryllium	Montane shrew (Mammalian insectivore)	35	350	
Beryllium	Mountain cottontail (Mammalian herbivore)	89	890	
Boron	American kestrel (Avian top carnivore)	960	4700	
Boron	American kestrel (insectivore / carnivore)	37	180	
Boron	American robin (Avian herbivore)	2	10	MINIMUM
Boron	American robin (Avian insectivore)	7.1	35	
Boron	American robin (Avian omnivore)	3.1	15	
Boron	Deer mouse (Mammalian omnivore)	55	550	
Boron	Generic plant (Terrestrial autotroph - producer)	36	86	
Boron	Gray fox (Mammalian top carnivore)	21000	210000	
Boron	Montane shrew (Mammalian insectivore)	130	1300	
Boron	Mountain cottontail (Mammalian herbivore)	84	840	
Cadmium	American kestrel (Avian top carnivore)	430	2300	
Cadmium	American kestrel (insectivore / carnivore)	1.3	7.7	
Cadmium	American robin (Avian herbivore)	4.3	23	
Cadmium	American robin (Avian insectivore)	0.29	1.6	
Cadmium	American robin (Avian omnivore)	0.54	3	
Cadmium	Deer mouse (Mammalian omnivore)	0.5	6.8	
Cadmium	Earthworm (Soil-dwelling invertebrate)	140	760	
Cadmium	Generic plant (Terrestrial autotroph - producer)	32	160	
Cadmium	Gray fox (Mammalian top carnivore)	550	7400	
Cadmium	Montane shrew (Mammalian insectivore)	0.27	3.6	MINIMUM
Cadmium	Mountain cottontail (Mammalian herbivore)	10	140	
Chromium (total)	American kestrel (Avian top carnivore)	860	2700	
Chromium (total)	American kestrel (insectivore / carnivore)	170	560	
Chromium (total)	American robin (Avian herbivore)	51	160	
Chromium (total)	American robin (Avian insectivore)	23	73	MINIMUM
Chromium (total)	American robin (Avian omnivore)	32	100	
Chromium (total)	Deer mouse (Mammalian omnivore)	110	11000	
Chromium (total)	Gray fox (Mammalian top carnivore)	1800	180000	
Chromium (total)	Montane shrew (Mammalian insectivore)	63	6300	
Chromium (total)	Mountain cottontail (Mammalian herbivore)	410	41000	
Chromium(+6)	American kestrel (Avian top carnivore)	3600	36000	
Chromium(+6)	American kestrel (insectivore / carnivore)	1400	14000	
Chromium(+6)	American robin (Avian herbivore)	210	2100	
Chromium(+6)	American robin (Avian insectivore)	140	1400	
Chromium(+6)	American robin (Avian omnivore)	160	1600	
Chromium(+6)	Deer mouse (Mammalian omnivore)	850	5500	
Chromium(+6)	Earthworm (Soil-dwelling invertebrate)	0.34	3.4	MINIMUM

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Chromium(+6)	Generic plant (Terrestrial autotroph - producer)	0.35	4	
Chromium(+6)	Gray fox (Mammalian top carnivore)	7200	46000	
Chromium(+6)	Montane shrew (Mammalian insectivore)	510	3300	
Chromium(+6)	Mountain cottontail (Mammalian herbivore)	1600	10000	
Cobalt	American kestrel (Avian top carnivore)	2300	5200	
Cobalt	American kestrel (insectivore / carnivore)	620	1400	
Cobalt	American robin (Avian herbivore)	130	300	
Cobalt	American robin (Avian insectivore)	76	170	
Cobalt	American robin (Avian omnivore)	97	210	
Cobalt	Deer mouse (Mammalian omnivore)	400	1000	
Cobalt	Generic plant (Terrestrial autotroph - producer)	13	130	MINIMUM
Cobalt	Gray fox (Mammalian top carnivore)	5400	14000	
Cobalt	Montane shrew (Mammalian insectivore)	240	640	
Cobalt	Mountain cottontail (Mammalian herbivore)	1000	2800	
Copper	American kestrel (Avian top carnivore)	1100	3500	
Copper	American kestrel (insectivore / carnivore)	80	240	
Copper	American robin (Avian herbivore)	34	100	
Copper	American robin (Avian insectivore)	14	43	MINIMUM
Copper	American robin (Avian omnivore)	20	60	
Copper	Deer mouse (Mammalian omnivore)	63	100	
Copper	Earthworm (Soil-dwelling invertebrate)	80	530	
Copper	Generic plant (Terrestrial autotroph - producer)	70	490	
Copper	Gray fox (Mammalian top carnivore)	4000	6700	
Copper	Montane shrew (Mammalian insectivore)	42	70	
Copper	Mountain cottontail (Mammalian herbivore)	260	430	
Cyanide (total)	American kestrel (Avian top carnivore)	0.59	5.9	
Cyanide (total)	American kestrel (insectivore / carnivore)	0.36	3.6	
Cyanide (total)	American robin (Avian herbivore)	0.1	1	
Cyanide (total)	American robin (Avian insectivore)	0.098	0.98	MINIMUM
Cyanide (total)	American robin (Avian omnivore)	0.099	0.99	
Cyanide (total)	Deer mouse (Mammalian omnivore)	330	3300	
Cyanide (total)	Gray fox (Mammalian top carnivore)	3300	33000	
Cyanide (total)	Montane shrew (Mammalian insectivore)	330	3300	
Cyanide (total)	Mountain cottontail (Mammalian herbivore)	790	7900	
Lead	American kestrel (Avian top carnivore)	540	1000	
Lead	American kestrel (insectivore / carnivore)	83	160	
Lead	American robin (Avian herbivore)	18	36	
Lead	American robin (Avian insectivore)	11	23	MINIMUM
Lead	American robin (Avian omnivore)	14	28	
Lead	Deer mouse (Mammalian omnivore)	120	230	
Lead	Earthworm (Soil-dwelling invertebrate)	1700	8400	
Lead	Generic plant (Terrestrial autotroph - producer)	120	570	
Lead	Gray fox (Mammalian top carnivore)	3700	7000	
Lead	Montane shrew (Mammalian insectivore)	93	170	
Lead	Mountain cottontail (Mammalian herbivore)	310	600	
Manganese	American kestrel (Avian top carnivore)	60000	120000	
Manganese	American kestrel (insectivore / carnivore)	24000	50000	
Manganese	American robin (Avian herbivore)	1300	2700	
Manganese	American robin (Avian insectivore)	2200	4700	
Manganese	American robin (Avian omnivore)	1600	3500	
Manganese	Deer mouse (Mammalian omnivore)	1400	5400	
Manganese	Earthworm (Soil-dwelling invertebrate)	450	4500	
Manganese	Generic plant (Terrestrial autotroph - producer)	220	1100	MINIMUM
Manganese	Gray fox (Mammalian top carnivore)	40000	150000	
Manganese	Montane shrew (Mammalian insectivore)	2800	10000	
Manganese	Mountain cottontail (Mammalian herbivore)	2000	7500	
Mercury (inorganic)	American kestrel (Avian top carnivore)	0.32	3.2	
Mercury (inorganic)	American kestrel (insectivore / carnivore)	0.058	0.58	
Mercury (inorganic)	American robin (Avian herbivore)	0.067	0.67	
Mercury (inorganic)	American robin (Avian insectivore)	0.013	0.13	MINIMUM
Mercury (inorganic)	American robin (Avian omnivore)	0.022	0.22	
Mercury (inorganic)	Deer mouse (Mammalian omnivore)	3	30	
Mercury (inorganic)	Earthworm (Soil-dwelling invertebrate)	0.05	0.5	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Mercury (inorganic)	Generic plant (Terrestrial autotroph - producer)	34	64	
Mercury (inorganic)	Gray fox (Mammalian top carnivore)	76	760	
Mercury (inorganic)	Montane shrew (Mammalian insectivore)	1.7	17	
Mercury (inorganic)	Mountain cottontail (Mammalian herbivore)	23	230	
Mercury (methyl)	American kestrel (Avian top carnivore)	0.009	0.09	
Mercury (methyl)	American kestrel (insectivore / carnivore)	0.0015	0.015	
Mercury (methyl)	American robin (Avian herbivore)	0.066	0.66	
Mercury (methyl)	American robin (Avian insectivore)	0.00035	0.0035	MINIMUM
Mercury (methyl)	American robin (Avian omnivore)	0.00071	0.0071	
Mercury (methyl)	Deer mouse (Mammalian omnivore)	0.0062	0.031	
Mercury (methyl)	Earthworm (Soil-dwelling invertebrate)	2.5	12	
Mercury (methyl)	Gray fox (Mammalian top carnivore)	0.14	0.74	
Mercury (methyl)	Montane shrew (Mammalian insectivore)	0.0031	0.015	
Mercury (methyl)	Mountain cottontail (Mammalian herbivore)	1.9	9.8	
Molybdenum	American kestrel (Avian top carnivore)	1100	11000	
Molybdenum	American kestrel (insectivore / carnivore)	90	900	
Molybdenum	American robin (Avian herbivore)	18	180	
Molybdenum	American robin (Avian insectivore)	15	150	MINIMUM
Molybdenum	American robin (Avian omnivore)	16	160	
Nickel	American kestrel (Avian top carnivore)	2000	8100	
Nickel	American kestrel (insectivore / carnivore)	110	440	
Nickel	American robin (Avian herbivore)	120	500	
Nickel	American robin (Avian insectivore)	20	81	
Nickel	American robin (Avian omnivore)	35	130	
Nickel	Deer mouse (Mammalian omnivore)	20	40	
Nickel	Earthworm (Soil-dwelling invertebrate)	280	1300	
Nickel	Generic plant (Terrestrial autotroph - producer)	38	270	
Nickel	Gray fox (Mammalian top carnivore)	1200	2500	
Nickel	Montane shrew (Mammalian insectivore)	10	21	MINIMUM
Nickel	Mountain cottontail (Mammalian herbivore)	270	540	
Perchlorate Ion	American kestrel (Avian top carnivore)	2	4	
Perchlorate Ion	American kestrel (insectivore / carnivore)	3.9	8	
Perchlorate Ion	American robin (Avian herbivore)	0.12	0.24	MINIMUM
Perchlorate Ion	American robin (Avian insectivore)	31	64	
Perchlorate Ion	American robin (Avian omnivore)	0.24	0.49	
Perchlorate Ion	Deer mouse (Mammalian omnivore)	0.21	1	
Perchlorate Ion	Earthworm (Soil-dwelling invertebrate)	3.5	35	
Perchlorate Ion	Generic plant (Terrestrial autotroph - producer)	40	80	
Perchlorate Ion	Gray fox (Mammalian top carnivore)	3.3	16	
Perchlorate Ion	Montane shrew (Mammalian insectivore)	31	150	
Perchlorate Ion	Mountain cottontail (Mammalian herbivore)	0.26	1.3	
Selenium	American kestrel (Avian top carnivore)	74	140	
Selenium	American kestrel (insectivore / carnivore)	3.7	7.5	
Selenium	American robin (Avian herbivore)	0.98	1.9	
Selenium	American robin (Avian insectivore)	0.71	1.4	
Selenium	American robin (Avian omnivore)	0.83	1.6	
Selenium	Deer mouse (Mammalian omnivore)	0.82	1.2	
Selenium	Earthworm (Soil-dwelling invertebrate)	4.1	41	
Selenium	Generic plant (Terrestrial autotroph - producer)	0.52	3	MINIMUM
Selenium	Gray fox (Mammalian top carnivore)	92	130	
Selenium	Montane shrew (Mammalian insectivore)	0.7	1	
Selenium	Mountain cottontail (Mammalian herbivore)	2.2	3.4	
Silver	American kestrel (Avian top carnivore)	600	6000	
Silver	American kestrel (insectivore / carnivore)	13	130	
Silver	American robin (Avian herbivore)	10	100	
Silver	American robin (Avian insectivore)	2.6	26	MINIMUM
Silver	American robin (Avian omnivore)	4.1	41	
Silver	Deer mouse (Mammalian omnivore)	24	240	
Silver	Generic plant (Terrestrial autotroph - producer)	560	2800	
Silver	Gray fox (Mammalian top carnivore)	4400	44000	
Silver	Montane shrew (Mammalian insectivore)	14	140	
Silver	Mountain cottontail (Mammalian herbivore)	150	1500	
Thallium	American kestrel (Avian top carnivore)	100	1000	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Thallium	American kestrel (insectivore / carnivore)	48	480	
Thallium	American robin (Avian herbivore)	6.9	69	
Thallium	American robin (Avian insectivore)	4.5	45	
Thallium	American robin (Avian omnivore)	5.5	55	
Thallium	Deer mouse (Mammalian omnivore)	0.72	7.2	
Thallium	Generic plant (Terrestrial autotroph - producer)	0.05	0.5	MINIMUM
Thallium	Gray fox (Mammalian top carnivore)	5	50	
Thallium	Montane shrew (Mammalian insectivore)	0.42	4.2	
Thallium	Mountain cottontail (Mammalian herbivore)	1.2	12	
Vanadium	American kestrel (Avian top carnivore)	110	230	
Vanadium	American kestrel (insectivore / carnivore)	56	110	
Vanadium	American robin (Avian herbivore)	6.8	13	
Vanadium	American robin (Avian insectivore)	4.7	9.5	MINIMUM
Vanadium	American robin (Avian omnivore)	5.5	11	
Vanadium	Deer mouse (Mammalian omnivore)	470	1000	
Vanadium	Generic plant (Terrestrial autotroph - producer)	60	80	
Vanadium	Gray fox (Mammalian top carnivore)	3200	6900	
Vanadium	Montane shrew (Mammalian insectivore)	290	610	
Vanadium	Mountain cottontail (Mammalian herbivore)	740	1500	
Zinc	American kestrel (Avian top carnivore)	2600	7000	
Zinc	American kestrel (insectivore / carnivore)	220	590	
Zinc	American robin (Avian herbivore)	330	120	
Zinc	American robin (Avian insectivore)	47	120	MINIMUM
Zinc	American robin (Avian omnivore)	83	220	
Zinc	Deer mouse (Mammalian omnivore)	170	1700	
Zinc	Earthworm (Soil-dwelling invertebrate)	120	930	
Zinc	Generic plant (Terrestrial autotroph - producer)	160	810	
Zinc	Gray fox (Mammalian top carnivore)	9600	94000	
Zinc	Montane shrew (Mammalian insectivore)	99	980	
Zinc	Mountain cottontail (Mammalian herbivore)	1800	18000	
Acenaphthene	Deer mouse (Mammalian omnivore)	160	1600	
Acenaphthene	Generic plant (Terrestrial autotroph - producer)	0.25	2	MINIMUM
Acenaphthene	Gray fox (Mammalian top carnivore)	29000	290000	
Acenaphthene	Montane shrew (Mammalian insectivore)	130	1300	
Acenaphthene	Mountain cottontail (Mammalian herbivore)	530	5300	
Acenaphthylene	Deer mouse (Mammalian omnivore)	160	1600	
Acenaphthylene	Gray fox (Mammalian top carnivore)	28000	280000	
Acenaphthylene	Montane shrew (Mammalian insectivore)	120	1200	MINIMUM
Acenaphthylene	Mountain cottontail (Mammalian herbivore)	540	5400	
Anthracene	Deer mouse (Mammalian omnivore)	300	3000	
Anthracene	Generic plant (Terrestrial autotroph - producer)	6.8	9	MINIMUM
Anthracene	Gray fox (Mammalian top carnivore)	38000	380000	
Anthracene	Montane shrew (Mammalian insectivore)	210	2100	
Anthracene	Mountain cottontail (Mammalian herbivore)	1200	12000	
Benzo(a)anthracene	American kestrel (Avian top carnivore)	28	280	
Benzo(a)anthracene	American kestrel (insectivore / carnivore)	6.4	64	
Benzo(a)anthracene	American robin (Avian herbivore)	0.73	7.3	MINIMUM
Benzo(a)anthracene	American robin (Avian insectivore)	0.88	8.8	
Benzo(a)anthracene	American robin (Avian omnivore)	0.8	8	
Benzo(a)anthracene	Deer mouse (Mammalian omnivore)	3.4	34	
Benzo(a)anthracene	Generic plant (Terrestrial autotroph - producer)	18	180	
Benzo(a)anthracene	Gray fox (Mammalian top carnivore)	110	1100	
Benzo(a)anthracene	Montane shrew (Mammalian insectivore)	4	40	
Benzo(a)anthracene	Mountain cottontail (Mammalian herbivore)	6.1	61	
Benzo(a)pyrene	Deer mouse (Mammalian omnivore)	84	260	
Benzo(a)pyrene	Gray fox (Mammalian top carnivore)	3400	11000	
Benzo(a)pyrene	Montane shrew (Mammalian insectivore)	62	190	MINIMUM
Benzo(a)pyrene	Mountain cottontail (Mammalian herbivore)	260	830	
Benzo(b)fluoranthene	Deer mouse (Mammalian omnivore)	51	510	
Benzo(b)fluoranthene	Generic plant (Terrestrial autotroph - producer)	18	180	MINIMUM
Benzo(b)fluoranthene	Gray fox (Mammalian top carnivore)	2400	24000	
Benzo(b)fluoranthene	Montane shrew (Mammalian insectivore)	44	440	
Benzo(b)fluoranthene	Mountain cottontail (Mammalian herbivore)	130	1300	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Benzo(g,h,i)perylene	Deer mouse (Mammalian omnivore)	46	460	
Benzo(g,h,i)perylene	Gray fox (Mammalian top carnivore)	3600	36000	
Benzo(g,h,i)perylene	Montane shrew (Mammalian insectivore)	25	250	MINIMUM
Benzo(g,h,i)perylene	Mountain cottontail (Mammalian herbivore)	470	4700	
Benzo(k)fluoranthene	Deer mouse (Mammalian omnivore)	99	990	
Benzo(k)fluoranthene	Gray fox (Mammalian top carnivore)	4300	43000	
Benzo(k)fluoranthene	Montane shrew (Mammalian insectivore)	71	710	MINIMUM
Benzo(k)fluoranthene	Mountain cottontail (Mammalian herbivore)	330	3300	
Chrysene	Deer mouse (Mammalian omnivore)	3.1	31	
Chrysene	Gray fox (Mammalian top carnivore)	110	1100	
Chrysene	Montane shrew (Mammalian insectivore)	3.1	31	MINIMUM
Chrysene	Mountain cottontail (Mammalian herbivore)	6.3	63	
Dibenzo(a,h)anthracene	Deer mouse (Mammalian omnivore)	22	220	
Dibenzo(a,h)anthracene	Gray fox (Mammalian top carnivore)	850	8500	
Dibenzo(a,h)anthracene	Montane shrew (Mammalian insectivore)	14	140	MINIMUM
Dibenzo(a,h)anthracene	Mountain cottontail (Mammalian herbivore)	84	840	
Fluoranthene	Deer mouse (Mammalian omnivore)	38	380	
Fluoranthene	Earthworm (Soil-dwelling invertebrate)	10	23	MINIMUM
Fluoranthene	Gray fox (Mammalian top carnivore)	3900	39000	
Fluoranthene	Montane shrew (Mammalian insectivore)	22	220	
Fluoranthene	Mountain cottontail (Mammalian herbivore)	270	2700	
Fluorene	Deer mouse (Mammalian omnivore)	340	680	
Fluorene	Earthworm (Soil-dwelling invertebrate)	3.7	19	MINIMUM
Fluorene	Gray fox (Mammalian top carnivore)	50000	100000	
Fluorene	Montane shrew (Mammalian insectivore)	250	510	
Fluorene	Mountain cottontail (Mammalian herbivore)	1100	2300	
Indeno(1,2,3-cd)pyrene	Deer mouse (Mammalian omnivore)	110	1100	
Indeno(1,2,3-cd)pyrene	Gray fox (Mammalian top carnivore)	4600	46000	
Indeno(1,2,3-cd)pyrene	Montane shrew (Mammalian insectivore)	71	710	MINIMUM
Indeno(1,2,3-cd)pyrene	Mountain cottontail (Mammalian herbivore)	510	5100	
Methylnaphthalene[2-]	Deer mouse (Mammalian omnivore)	24	240	
Methylnaphthalene[2-]	Gray fox (Mammalian top carnivore)	4900	49000	
Methylnaphthalene[2-]	Montane shrew (Mammalian insectivore)	16	160	MINIMUM
Methylnaphthalene[2-]	Mountain cottontail (Mammalian herbivore)	110	1100	
Naphthalene	American kestrel (Avian top carnivore)	2100	21000	
Naphthalene	American kestrel (insectivore / carnivore)	78	780	
Naphthalene	American robin (Avian herbivore)	3.4	34	
Naphthalene	American robin (Avian insectivore)	15	150	
Naphthalene	American robin (Avian omnivore)	5.7	57	
Naphthalene	Deer mouse (Mammalian omnivore)	9.6	27	
Naphthalene	Generic plant (Terrestrial autotroph - producer)	1	10	MINIMUM
Naphthalene	Gray fox (Mammalian top carnivore)	5800	16000	
Naphthalene	Montane shrew (Mammalian insectivore)	28	79	
Naphthalene	Mountain cottontail (Mammalian herbivore)	14	40	
Phenanthrene	Deer mouse (Mammalian omnivore)	15	150	
Phenanthrene	Earthworm (Soil-dwelling invertebrate)	5.5	12	MINIMUM
Phenanthrene	Gray fox (Mammalian top carnivore)	1900	19000	
Phenanthrene	Montane shrew (Mammalian insectivore)	11	110	
Phenanthrene	Mountain cottontail (Mammalian herbivore)	62	620	
Pyrene	American kestrel (Avian top carnivore)	3000	30000	
Pyrene	American kestrel (insectivore / carnivore)	160	1600	
Pyrene	American robin (Avian herbivore)	68	680	
Pyrene	American robin (Avian insectivore)	33	330	
Pyrene	American robin (Avian omnivore)	44	440	
Pyrene	Deer mouse (Mammalian omnivore)	31	310	
Pyrene	Earthworm (Soil-dwelling invertebrate)	10	20	MINIMUM
Pyrene	Gray fox (Mammalian top carnivore)	3100	31000	
Pyrene	Montane shrew (Mammalian insectivore)	23	230	
Pyrene	Mountain cottontail (Mammalian herbivore)	110	1100	
Aroclor-1016	Deer mouse (Mammalian omnivore)	2	5.9	
Aroclor-1016	Gray fox (Mammalian top carnivore)	250	720	
Aroclor-1016	Montane shrew (Mammalian insectivore)	1.1	3.1	MINIMUM
Aroclor-1016	Mountain cottontail (Mammalian herbivore)	48	130	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Aroclor-1242	American kestrel (Avian top carnivore)	6.2	62	
Aroclor-1242	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1242	American robin (Avian herbivore)	0.92	9.2	
Aroclor-1242	American robin (Avian insectivore)	0.041	0.41	MINIMUM
Aroclor-1242	American robin (Avian omnivore)	0.078	0.78	
Aroclor-1242	Deer mouse (Mammalian omnivore)	0.75	3	
Aroclor-1242	Gray fox (Mammalian top carnivore)	100	400	
Aroclor-1242	Montane shrew (Mammalian insectivore)	0.39	1.5	
Aroclor-1242	Mountain cottontail (Mammalian herbivore)	27	110	
Aroclor-1248	American kestrel (Avian top carnivore)	6.3	63	
Aroclor-1248	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1248	American robin (Avian herbivore)	0.94	9.4	
Aroclor-1248	American robin (Avian insectivore)	0.041	0.41	
Aroclor-1248	American robin (Avian omnivore)	0.078	0.78	
Aroclor-1248	Deer mouse (Mammalian omnivore)	0.014	0.14	
Aroclor-1248	Gray fox (Mammalian top carnivore)	1.9	19	
Aroclor-1248	Montane shrew (Mammalian insectivore)	0.0073	0.073	MINIMUM
Aroclor-1248	Mountain cottontail (Mammalian herbivore)	0.53	5.3	
Aroclor-1254	American kestrel (Avian top carnivore)	7.6	76	
Aroclor-1254	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1254	American robin (Avian herbivore)	1.1	11	
Aroclor-1254	American robin (Avian insectivore)	0.041	0.41	MINIMUM
Aroclor-1254	American robin (Avian omnivore)	0.079	0.79	
Aroclor-1254	Deer mouse (Mammalian omnivore)	0.87	4.8	
Aroclor-1254	Generic plant (Terrestrial autotroph - producer)	160	620	
Aroclor-1254	Gray fox (Mammalian top carnivore)	7.2	72	
Aroclor-1254	Montane shrew (Mammalian insectivore)	0.45	2.4	
Aroclor-1254	Mountain cottontail (Mammalian herbivore)	44	240	
Aroclor-1260	American kestrel (Avian top carnivore)	400	560	
Aroclor-1260	American kestrel (insectivore / carnivore)	4.2	5.9	
Aroclor-1260	American robin (Avian herbivore)	37	52	
Aroclor-1260	American robin (Avian insectivore)	0.88	1.2	MINIMUM
Aroclor-1260	American robin (Avian omnivore)	1.7	2.4	
Aroclor-1260	Deer mouse (Mammalian omnivore)	20	48	
Aroclor-1260	Gray fox (Mammalian top carnivore)	15	150	
Aroclor-1260	Montane shrew (Mammalian insectivore)	10	24	
Aroclor-1260	Mountain cottontail (Mammalian herbivore)	1800	4500	
Benzoic Acid	Deer mouse (Mammalian omnivore)	1.3	13	
Benzoic Acid	Gray fox (Mammalian top carnivore)	2000	20000	
Benzoic Acid	Montane shrew (Mammalian insectivore)	1	10	MINIMUM
Benzoic Acid	Mountain cottontail (Mammalian herbivore)	4.6	46	
Bis(2-ethylhexyl)phthalate	American kestrel (Avian top carnivore)	9.3	93	
Bis(2-ethylhexyl)phthalate	American kestrel (insectivore / carnivore)	0.096	0.96	
Bis(2-ethylhexyl)phthalate	American robin (Avian herbivore)	16	160	
Bis(2-ethylhexyl)phthalate	American robin (Avian insectivore)	0.02	0.2	MINIMUM
Bis(2-ethylhexyl)phthalate	American robin (Avian omnivore)	0.04	0.4	
Bis(2-ethylhexyl)phthalate	Deer mouse (Mammalian omnivore)	1.1	11	
Bis(2-ethylhexyl)phthalate	Gray fox (Mammalian top carnivore)	500	5000	
Bis(2-ethylhexyl)phthalate	Montane shrew (Mammalian insectivore)	0.6	6	
Bis(2-ethylhexyl)phthalate	Mountain cottontail (Mammalian herbivore)	1900	19000	
Butyl Benzyl Phthalate	Deer mouse (Mammalian omnivore)	160	1600	
Butyl Benzyl Phthalate	Gray fox (Mammalian top carnivore)	23000	230000	
Butyl Benzyl Phthalate	Montane shrew (Mammalian insectivore)	90	900	MINIMUM
Butyl Benzyl Phthalate	Mountain cottontail (Mammalian herbivore)	2400	24000	
Carbazole	Deer mouse (Mammalian omnivore)	79	790	MINIMUM
Carbazole	Gray fox (Mammalian top carnivore)	13000	130000	
Carbazole	Montane shrew (Mammalian insectivore)	110	1100	
Carbazole	Mountain cottontail (Mammalian herbivore)	140	1400	
Chlorobenzene	Deer mouse (Mammalian omnivore)	53	530	
Chlorobenzene	Earthworm (Soil-dwelling invertebrate)	2.4	24	MINIMUM
Chlorobenzene	Gray fox (Mammalian top carnivore)	25000	250000	
Chlorobenzene	Montane shrew (Mammalian insectivore)	43	430	
Chlorobenzene	Mountain cottontail (Mammalian herbivore)	170	1700	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Chlorophenol[2-]	American kestrel (Avian top carnivore)	310	3100	
Chlorophenol[2-]	American kestrel (insectivore / carnivore)	14	140	
Chlorophenol[2-]	American robin (Avian herbivore)	0.39	3.9	MINIMUM
Chlorophenol[2-]	American robin (Avian insectivore)	2.6	26	
Chlorophenol[2-]	American robin (Avian omnivore)	0.68	6.8	
Chlorophenol[2-]	Deer mouse (Mammalian omnivore)	0.54	5.4	
Chlorophenol[2-]	Gray fox (Mammalian top carnivore)	340	3400	
Chlorophenol[2-]	Montane shrew (Mammalian insectivore)	2.3	23	
Chlorophenol[2-]	Mountain cottontail (Mammalian herbivore)	0.74	7.4	
Dibenzofuran	Generic plant (Terrestrial autotroph - producer)	6.1	61	MINIMUM
Diethyl Phthalate	Deer mouse (Mammalian omnivore)	3600	36000	
Diethyl Phthalate	Generic plant (Terrestrial autotroph - producer)	100	1000	MINIMUM
Diethyl Phthalate	Gray fox (Mammalian top carnivore)	2500000	25000000	
Diethyl Phthalate	Montane shrew (Mammalian insectivore)	3600	36000	
Diethyl Phthalate	Mountain cottontail (Mammalian herbivore)	8800	88000	
Dimethyl Phthalate	Deer mouse (Mammalian omnivore)	38	460	
Dimethyl Phthalate	Earthworm (Soil-dwelling invertebrate)	10	100	MINIMUM
Dimethyl Phthalate	Gray fox (Mammalian top carnivore)	48000	590000	
Dimethyl Phthalate	Montane shrew (Mammalian insectivore)	80	980	
Dimethyl Phthalate	Mountain cottontail (Mammalian herbivore)	60	740	
Di-n-Butyl Phthalate	American kestrel (Avian top carnivore)	2	20	
Di-n-Butyl Phthalate	American kestrel (insectivore / carnivore)	0.052	0.52	
Di-n-Butyl Phthalate	American robin (Avian herbivore)	0.38	3.8	
Di-n-Butyl Phthalate	American robin (Avian insectivore)	0.011	0.11	MINIMUM
Di-n-Butyl Phthalate	American robin (Avian omnivore)	0.021	0.21	
Di-n-Butyl Phthalate	Deer mouse (Mammalian omnivore)	360	860	
Di-n-Butyl Phthalate	Generic plant (Terrestrial autotroph - producer)	160	600	
Di-n-Butyl Phthalate	Gray fox (Mammalian top carnivore)	62000	140000	
Di-n-Butyl Phthalate	Montane shrew (Mammalian insectivore)	180	450	
Di-n-Butyl Phthalate	Mountain cottontail (Mammalian herbivore)	17000	40000	
Di-n-octylphthalate	Deer mouse (Mammalian omnivore)	1.8	18	
Di-n-octylphthalate	Gray fox (Mammalian top carnivore)	1300	13000	
Di-n-octylphthalate	Montane shrew (Mammalian insectivore)	0.91	9.1	MINIMUM
Di-n-octylphthalate	Mountain cottontail (Mammalian herbivore)	8400	84000	
Methylphenol[2-]	Deer mouse (Mammalian omnivore)	580	5800	
Methylphenol[2-]	Generic plant (Terrestrial autotroph - producer)	0.67	7	MINIMUM
Methylphenol[2-]	Gray fox (Mammalian top carnivore)	160000	1600000	
Methylphenol[2-]	Montane shrew (Mammalian insectivore)	1500	15000	
Methylphenol[2-]	Mountain cottontail (Mammalian herbivore)	880	8800	
Methylphenol[3-]	Generic plant (Terrestrial autotroph - producer)	0.69	7	MINIMUM
Nitroaniline[2-]	Deer mouse (Mammalian omnivore)	5.3	10	MINIMUM
Nitroaniline[2-]	Gray fox (Mammalian top carnivore)	2200	4400	
Nitroaniline[2-]	Montane shrew (Mammalian insectivore)	6.5	13	
Nitroaniline[2-]	Mountain cottontail (Mammalian herbivore)	11	22	
Nitrobenzene	Deer mouse (Mammalian omnivore)	4.8	48	
Nitrobenzene	Earthworm (Soil-dwelling invertebrate)	2.2	22	MINIMUM
Nitrobenzene	Gray fox (Mammalian top carnivore)	4100	41000	
Nitrobenzene	Montane shrew (Mammalian insectivore)	21	210	
Nitrobenzene	Mountain cottontail (Mammalian herbivore)	6.7	67	
Pentachloronitrobenzene	American kestrel (Avian top carnivore)	110	1100	
Pentachloronitrobenzene	American kestrel (insectivore / carnivore)	3.3	33	
Pentachloronitrobenzene	American robin (Avian herbivore)	21	210	
Pentachloronitrobenzene	American robin (Avian insectivore)	0.7	7	MINIMUM
Pentachloronitrobenzene	American robin (Avian omnivore)	1.3	13	
Pentachloronitrobenzene	Deer mouse (Mammalian omnivore)	22	220	
Pentachloronitrobenzene	Gray fox (Mammalian top carnivore)	3500	35000	
Pentachloronitrobenzene	Montane shrew (Mammalian insectivore)	11	110	
Pentachloronitrobenzene	Mountain cottontail (Mammalian herbivore)	930	9300	
Pentachlorophenol	American kestrel (Avian top carnivore)	57	570	
Pentachlorophenol	American kestrel (insectivore / carnivore)	1.7	17	
Pentachlorophenol	American robin (Avian herbivore)	29	290	
Pentachlorophenol	American robin (Avian insectivore)	0.36	3.6	MINIMUM
Pentachlorophenol	American robin (Avian omnivore)	0.72	7.2	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Pentachlorophenol	Deer mouse (Mammalian omnivore)	1.5	15	
Pentachlorophenol	Earthworm (Soil-dwelling invertebrate)	31	150	
Pentachlorophenol	Generic plant (Terrestrial autotroph - producer)	5	50	
Pentachlorophenol	Gray fox (Mammalian top carnivore)	230	2300	
Pentachlorophenol	Montane shrew (Mammalian insectivore)	0.81	8.1	
Pentachlorophenol	Mountain cottontail (Mammalian herbivore)	180	1800	
Phenol	Deer mouse (Mammalian omnivore)	37	370	
Phenol	Earthworm (Soil-dwelling invertebrate)	1.8	18	
Phenol	Generic plant (Terrestrial autotroph - producer)	0.79	8	MINIMUM
Phenol	Gray fox (Mammalian top carnivore)	43000	430000	
Phenol	Montane shrew (Mammalian insectivore)	640	6400	
Phenol	Mountain cottontail (Mammalian herbivore)	47	470	
Acetone	American kestrel (Avian top carnivore)	66000	660000	
Acetone	American kestrel (insectivore / carnivore)	840	8400	
Acetone	American robin (Avian herbivore)	7.5	75	
Acetone	American robin (Avian insectivore)	170	1700	
Acetone	American robin (Avian omnivore)	14	140	
Acetone	Deer mouse (Mammalian omnivore)	1.2	6.3	MINIMUM
Acetone	Gray fox (Mammalian top carnivore)	7800	39000	
Acetone	Montane shrew (Mammalian insectivore)	15	79	
Acetone	Mountain cottontail (Mammalian herbivore)	1.6	8	
Benzene	Deer mouse (Mammalian omnivore)	24	240	MINIMUM
Benzene	Gray fox (Mammalian top carnivore)	18000	180000	
Benzene	Montane shrew (Mammalian insectivore)	49	490	
Benzene	Mountain cottontail (Mammalian herbivore)	38	380	
Benzyl Alcohol	Deer mouse (Mammalian omnivore)	120	1200	MINIMUM
Benzyl Alcohol	Gray fox (Mammalian top carnivore)	110000	1100000	
Benzyl Alcohol	Montane shrew (Mammalian insectivore)	270	2700	
Benzyl Alcohol	Mountain cottontail (Mammalian herbivore)	190	1900	
Butanone[2-]	Deer mouse (Mammalian omnivore)	350	920	MINIMUM
Butanone[2-]	Gray fox (Mammalian top carnivore)	1300000	3500000	
Butanone[2-]	Montane shrew (Mammalian insectivore)	2700	6900	
Butanone[2-]	Mountain cottontail (Mammalian herbivore)	470	1200	
Carbon Disulfide	Deer mouse (Mammalian omnivore)	0.81	8.1	MINIMUM
Carbon Disulfide	Gray fox (Mammalian top carnivore)	190	1900	
Carbon Disulfide	Montane shrew (Mammalian insectivore)	1.2	12	
Carbon Disulfide	Mountain cottontail (Mammalian herbivore)	1.4	14	
Chloroaniline[4-]	Earthworm (Soil-dwelling invertebrate)	1.8	18	
Chloroaniline[4-]	Generic plant (Terrestrial autotroph - producer)	1	10	MINIMUM
Chloroform	Deer mouse (Mammalian omnivore)	8	21	MINIMUM
Chloroform	Gray fox (Mammalian top carnivore)	8900	24000	
Chloroform	Montane shrew (Mammalian insectivore)	8.2	22	
Chloroform	Mountain cottontail (Mammalian herbivore)	19	52	
Dichlorobenzene[1,2-]	Deer mouse (Mammalian omnivore)	1.5	15	
Dichlorobenzene[1,2-]	Gray fox (Mammalian top carnivore)	480	4800	
Dichlorobenzene[1,2-]	Montane shrew (Mammalian insectivore)	0.92	9.2	MINIMUM
Dichlorobenzene[1,2-]	Mountain cottontail (Mammalian herbivore)	12	120	
Dichlorobenzene[1,3-]	Deer mouse (Mammalian omnivore)	1.2	12	
Dichlorobenzene[1,3-]	Gray fox (Mammalian top carnivore)	380	3800	
Dichlorobenzene[1,3-]	Montane shrew (Mammalian insectivore)	0.74	7.4	MINIMUM
Dichlorobenzene[1,3-]	Mountain cottontail (Mammalian herbivore)	13	130	
Dichlorobenzene[1,4-]	Deer mouse (Mammalian omnivore)	1.5	6	
Dichlorobenzene[1,4-]	Earthworm (Soil-dwelling invertebrate)	1.2	12	
Dichlorobenzene[1,4-]	Gray fox (Mammalian top carnivore)	470	1800	
Dichlorobenzene[1,4-]	Montane shrew (Mammalian insectivore)	0.89	3.5	MINIMUM
Dichlorobenzene[1,4-]	Mountain cottontail (Mammalian herbivore)	12	49	
Dichloroethane[1,1-]	Deer mouse (Mammalian omnivore)	210	2100	MINIMUM
Dichloroethane[1,1-]	Gray fox (Mammalian top carnivore)	250000	2500000	
Dichloroethane[1,1-]	Montane shrew (Mammalian insectivore)	290	2900	
Dichloroethane[1,1-]	Mountain cottontail (Mammalian herbivore)	410	4100	
Dichloroethane[1,2-]	American kestrel (Avian top carnivore)	1300	2700	
Dichloroethane[1,2-]	American kestrel (insectivore / carnivore)	22	44	
Dichloroethane[1,2-]	American robin (Avian herbivore)	0.85	1.6	MINIMUM

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Dichloroethane[1,2-]	American robin (Avian insectivore)	4.5	9	
Dichloroethane[1,2-]	American robin (Avian omnivore)	1.4	2.8	
Dichloroethane[1,2-]	Deer mouse (Mammalian omnivore)	27	270	
Dichloroethane[1,2-]	Gray fox (Mammalian top carnivore)	36000	360000	
Dichloroethane[1,2-]	Montane shrew (Mammalian insectivore)	91	910	
Dichloroethane[1,2-]	Mountain cottontail (Mammalian herbivore)	39	390	
Dichloroethene[1,1-]	Deer mouse (Mammalian omnivore)	14	140	
Dichloroethene[1,1-]	Gray fox (Mammalian top carnivore)	14000	140000	
Dichloroethene[1,1-]	Montane shrew (Mammalian insectivore)	11	110	MINIMUM
Dichloroethene[1,1-]	Mountain cottontail (Mammalian herbivore)	44	440	
Dichloroethene[cis/trans-1,2-]	Deer mouse (Mammalian omnivore)	25	250	
Dichloroethene[cis/trans-1,2-]	Gray fox (Mammalian top carnivore)	25000	250000	
Dichloroethene[cis/trans-1,2-]	Montane shrew (Mammalian insectivore)	24	240	MINIMUM
Dichloroethene[cis/trans-1,2-]	Mountain cottontail (Mammalian herbivore)	64	640	
Diphenylamine	American kestrel (Avian top carnivore)	3900	6500	
Diphenylamine	American kestrel (insectivore / carnivore)	49	81	
Diphenylamine	American robin (Avian herbivore)	78	130	
Diphenylamine	American robin (Avian insectivore)	10	16	MINIMUM
Diphenylamine	American robin (Avian omnivore)	17	29	
Hexachlorobenzene	American kestrel (Avian top carnivore)	12	120	
Hexachlorobenzene	American kestrel (insectivore / carnivore)	0.37	3.7	
Hexachlorobenzene	American robin (Avian herbivore)	83	830	
Hexachlorobenzene	American robin (Avian insectivore)	0.079	0.79	MINIMUM
Hexachlorobenzene	American robin (Avian omnivore)	0.15	1.5	
Hexachlorobenzene	Deer mouse (Mammalian omnivore)	0.39	3.9	
Hexachlorobenzene	Earthworm (Soil-dwelling invertebrate)	10	100	
Hexachlorobenzene	Generic plant (Terrestrial autotroph - producer)	10	100	
Hexachlorobenzene	Gray fox (Mammalian top carnivore)	59	590	
Hexachlorobenzene	Montane shrew (Mammalian insectivore)	0.2	2	
Hexachlorobenzene	Mountain cottontail (Mammalian herbivore)	910	9100	
Hexanone[2-]	American kestrel (Avian top carnivore)	290	2900	
Hexanone[2-]	American kestrel (insectivore / carnivore)	1.7	17	
Hexanone[2-]	American robin (Avian herbivore)	0.47	4.7	
Hexanone[2-]	American robin (Avian insectivore)	0.36	3.6	MINIMUM
Hexanone[2-]	American robin (Avian omnivore)	0.41	4.1	
Hexanone[2-]	Deer mouse (Mammalian omnivore)	6.1	23	
Hexanone[2-]	Gray fox (Mammalian top carnivore)	5900	22000	
Hexanone[2-]	Montane shrew (Mammalian insectivore)	5.4	20	
Hexanone[2-]	Mountain cottontail (Mammalian herbivore)	17	65	
Iodomethane	American kestrel (Avian top carnivore)	46	92	
Iodomethane	American kestrel (insectivore / carnivore)	0.29	0.59	
Iodomethane	American robin (Avian herbivore)	0.038	0.076	MINIMUM
Iodomethane	American robin (Avian insectivore)	0.062	0.12	
Iodomethane	American robin (Avian omnivore)	0.047	0.095	
Methyl-2-pentanone[4-]	Deer mouse (Mammalian omnivore)	9.7	97	MINIMUM
Methyl-2-pentanone[4-]	Gray fox (Mammalian top carnivore)	18000	180000	
Methyl-2-pentanone[4-]	Montane shrew (Mammalian insectivore)	15	150	
Methyl-2-pentanone[4-]	Mountain cottontail (Mammalian herbivore)	17	170	
Methylene Chloride	Deer mouse (Mammalian omnivore)	2.6	22	MINIMUM
Methylene Chloride	Generic plant (Terrestrial autotroph - producer)	1600	16000	
Methylene Chloride	Gray fox (Mammalian top carnivore)	4300	36000	
Methylene Chloride	Montane shrew (Mammalian insectivore)	9.2	79	
Methylene Chloride	Mountain cottontail (Mammalian herbivore)	3.8	32	
Styrene	Earthworm (Soil-dwelling invertebrate)	1.2	12	MINIMUM
Styrene	Generic plant (Terrestrial autotroph - producer)	3.2	32	
Tetrachloroethene	Deer mouse (Mammalian omnivore)	0.35	1.7	
Tetrachloroethene	Generic plant (Terrestrial autotroph - producer)	10	100	
Tetrachloroethene	Gray fox (Mammalian top carnivore)	120	630	
Tetrachloroethene	Montane shrew (Mammalian insectivore)	0.18	0.94	MINIMUM
Tetrachloroethene	Mountain cottontail (Mammalian herbivore)	9.5	47	
Toluene	Deer mouse (Mammalian omnivore)	25	250	
Toluene	Generic plant (Terrestrial autotroph - producer)	200	2000	
Toluene	Gray fox (Mammalian top carnivore)	12000	120000	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Toluene	Montane shrew (Mammalian insectivore)	23	230	MINIMUM
Toluene	Mountain cottontail (Mammalian herbivore)	66	660	
Trichlorobenzene[1,2,4-]	Deer mouse (Mammalian omnivore)	0.51	5.1	
Trichlorobenzene[1,2,4-]	Earthworm (Soil-dwelling invertebrate)	1.2	12	
Trichlorobenzene[1,2,4-]	Gray fox (Mammalian top carnivore)	110	1100	
Trichlorobenzene[1,2,4-]	Montane shrew (Mammalian insectivore)	0.27	2.7	MINIMUM
Trichlorobenzene[1,2,4-]	Mountain cottontail (Mammalian herbivore)	12	120	
Trichloroethane[1,1,1-]	Deer mouse (Mammalian omnivore)	400	4000	
Trichloroethane[1,1,1-]	Gray fox (Mammalian top carnivore)	310000	3100000	
Trichloroethane[1,1,1-]	Montane shrew (Mammalian insectivore)	260	2600	MINIMUM
Trichloroethane[1,1,1-]	Mountain cottontail (Mammalian herbivore)	2000	20000	
Trichloroethene	Deer mouse (Mammalian omnivore)	54	540	
Trichloroethene	Gray fox (Mammalian top carnivore)	42000	420000	
Trichloroethene	Montane shrew (Mammalian insectivore)	42	420	MINIMUM
Trichloroethene	Mountain cottontail (Mammalian herbivore)	190	1900	
Trichlorofluoromethane	Deer mouse (Mammalian omnivore)	97	650	
Trichlorofluoromethane	Gray fox (Mammalian top carnivore)	62000	420000	
Trichlorofluoromethane	Montane shrew (Mammalian insectivore)	52	350	MINIMUM
Trichlorofluoromethane	Mountain cottontail (Mammalian herbivore)	1800	12000	
Vinyl Chloride	Deer mouse (Mammalian omnivore)	0.13	1.3	
Vinyl Chloride	Gray fox (Mammalian top carnivore)	110	1100	
Vinyl Chloride	Montane shrew (Mammalian insectivore)	0.12	1.2	MINIMUM
Vinyl Chloride	Mountain cottontail (Mammalian herbivore)	0.34	3.4	
Xylene (Total)	American kestrel (Avian top carnivore)	13000	130000	
Xylene (Total)	American kestrel (insectivore / carnivore)	190	1900	
Xylene (Total)	American robin (Avian herbivore)	89	890	
Xylene (Total)	American robin (Avian insectivore)	41	410	
Xylene (Total)	American robin (Avian omnivore)	56	560	
Xylene (Total)	Deer mouse (Mammalian omnivore)	1.9	2.4	
Xylene (Total)	Generic plant (Terrestrial autotroph - producer)	100	1000	
Xylene (Total)	Gray fox (Mammalian top carnivore)	750	930	
Xylene (Total)	Montane shrew (Mammalian insectivore)	1.4	1.8	MINIMUM
Xylene (Total)	Mountain cottontail (Mammalian herbivore)	7.6	9.5	

27. LANL (Los Alamos National Laboratory), June 2020g. Supplement 4-8 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Open Detonation Unit at Technical Area 39 Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. (LANL 2020g)

Supplement 4-8

Open Detonation Unit at Technical Area 39 Human Health and Ecological Risk Screening Assessments

OPEN DETONATION UNIT AT TECHNICAL AREA 39
HUMAN HEALTH AND ECOLOGICAL RISK-SCREENING ASSESSMENTS

June 16, 2020

EXECUTIVE SUMMARY

The area around the open detonation (OD) area near Building 6 at Technical Area (TA) 39 (the TA-39-6 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-39-6 OD Unit is referred to as "the Unit" in the remainder of this risk assessment. Surface soil and tuff samples were collected in September 2018 and analyzed for inorganic and organic compounds. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

For the human health risk assessment, residential and industrial exposure scenarios were evaluated by comparing the maximum exposure point concentration for each analyte to the New Mexico Environment Department (NMED) soil screening levels (NMSSLs). The following conclusions are made:

- **Detected inorganics were compared to background values (BVs) and risk-based screening levels (NMSSLs).** Six detected inorganics exceeded background, although four of those were only 1.2 to 1.3 times higher than background. No inorganics exceeded risk-based screening levels (SLs).
- **Detected organics were compared to risk-based NMSSLs.** There are no individual constituents that exceed SLs.
- **Hazard Indices (HI) were calculated.** The sum of the cancer risk ratios or the noncancer hazard quotients (HQs) is called a HI. The HIs for inorganics or organics do not exceed a value of one.
- **The screening evaluation indicates that hypothetical future residents or workers are not at risk due to exposure to soils at the Unit.**

Potential risk to ecological receptors was evaluated by analyzing different lines of evidence that were weighed to draw a conclusion regarding potential for adverse ecological effects. This included:

- **Comparing maximum exposure point concentrations (EPC) to minimum no effect (NE) and low effect (LE) ecological screening levels (ESLs).** There were nine analytes that exceeded NE ESLs, and seven analytes that exceeded LE ESLs, to produce HQs greater than 0.3. There were no ESLs for calcium, which was detected and slightly elevated above background.
- **Comparing upper 95th percentile confidence limits (UCL95) as the EPC to minimum NE and LE ESLs.** There were three analytes for which the UCL95 EPC exceeded NE ESLs, and two that also exceeded LE ESLs.
- **Calculating HIs.** The HIs for NE ESL and LE ESL comparisons exceeded 1.
- **Application of site-specific area use factors.** Only plants and earthworms had HQs of 1 under the area use factor analysis. There were no analytes that exceeded LE ESLs once the areal extent of the Unit was taken into consideration in conjunction with typical home range for ecological receptors. The HIs for plants and earthworms were 2 and 3 respectively for NE ESLs, and less than 1 for LE ESLs. Plants and earthworms are not expected to occur in the Unit due to intended use and bare ground.
- **Avian and mammalian population and tissue data.** There was no indication that bird or mammal populations are being affected. Tissue concentrations were not elevated relative to regional statistical reference levels (RSRLs).
- **There is no apparent risk to ecological receptors at the Unit.**

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

AUF	Area Use Factor
BMP	Best Management Practice
BV	Background Value
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSEM	Conceptual Site Exposure Model
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESL	Ecological Screening Level
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Cyclotetramethylene-tetranitramine
HQ	Hazard Quotient
HR	Home Range
LANL	Los Alamos National Laboratory
LD50	Lethal Dose for Half of the Population
LE	Low Effect
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
NE	No Effect
NMED	New Mexico Environment Department
NMSSL	New Mexico Soil Screening Levels
NOAEL	No Observed Adverse Effect Level
OD	Open Detonation
PAUF	Population Area Use Factor
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RSL	Regional Screening Level
RSRL	Regional Statistical Reference Levels
SD	Standard Deviation
SF	Cancer Slope Factor
SL	Screening Level
TA	Technical Area
TATB	2,4,6-Triamino-1,3,5-trinitrobenzene
TECi	Toxicity Equivalent Concentration for congener ***i***
TEF	Toxicity Equivalency Factor
TEQ	Toxicity Equivalent Quotient
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
UCL95	95% Upper Confidence Limit of The Mean
WHO	World Health Organization

1. INTRODUCTION

The area around the open detonation (OD) area near Building 6 at Technical Area (TA) 39 (the TA-39-6 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-39-6 OD Unit is referred to as “the Unit” in the remainder of this risk assessment.

The Unit is a hazardous waste management unit located in the southern portion of LANL (Figure 1-1). The Unit consists of a relatively flat, sand covered area that measures approximately 40 feet by 40 feet, and is located directly to the west of Building 6 (the control building) (Figure 1-2). The Unit has historically been used for experimental, sanitization, and waste treatment OD activities.

Steep canyon walls that rise to heights of 100 feet or higher form a semicircle around the Unit and act to attenuate the force of the detonations. Although the Unit is used to treat both solid and liquid explosive hazardous waste, the primary use of the unit is for nontreatment-related experimental test detonations. The last hazardous waste treatment shot at the site occurred on December 9, 2014. Upgrades to the firing pad at the Unit in recent years include a concrete retaining wall and storm water best management practices (BMPs) that improve fragment capture and minimize runoff from the firing site to the surrounding areas, respectively.

One surface soil sampling event of the top 2 inches of soil and tuff at 12 discrete locations (Figure 1-2) was conducted in and around the Unit on September 27, 2018. Sample collection included soil both in and out of potential run-off areas; however, sample collection did not include rocks, debris, or vegetation. Data from these samples were used to conduct human health and ecological risk assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

The results of the risk assessments are presented in the following sections.

2. HUMAN HEALTH RISK ASSESSMENT

2.1. CONCEPTUAL SITE MODEL

The primary land use is industrial because only authorized Laboratory workers currently have access to the area around the Unit. Laboratory workers are the primary human receptors, and the industrial scenario is the defining scenario for the human health risk-screening assessment (i.e., the scenario on which decisions are based). Because the site is located within the boundaries of an operational facility (TA-39), the reasonably foreseeable future land use will continue to be industrial. A Hypothetical Future Residential exposure is also assessed and provided for comparison purposes.

The release of contaminants from open detonation operations has potentially occurred for many years. Releases are transported primarily by wind, which rapidly disperses the material in ambient air. Most material is likely deposited close to the source(s), and concentrations are expected to decrease with distance from the source. Exposure to a site worker may occur through various surface soil contact pathways. Potential exposure pathways are:

- Incidental ingestion of surface soil
- Inhalation of fugitive dust or volatiles emanating from surface soil
- Dermal contact with surface soil

2.2. IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2.2.1. Sampling and Data Analysis

Twelve surface soil samples and one duplicate were collected September 27, 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 to 2 inches below ground surface. The duplicate pair was point 1 and 1 dup (field sample identification WST39-18-162832 and WST39-18-162973). Each sample set was analyzed for the following:

- Semi-Volatile Organic Compounds (SVOCs)
- Volatile Organic Compounds (VOCs)
- Total Metals
- Dioxins/Furans
- High Explosives

A staged approach was used for the risk assessment. Duplicates were handled consistent with the New Mexico Environment Department (NMED) guidance (NMED 2019) which states that in the initial screening assessment the maximum and not the average of the duplicate pair must be used. The approach was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to background values (BVs). Analytes less than BVs were eliminated from further evaluation.
- The screening approach then used the maximum of all detected data for the initial screening evaluation. The maximum concentration of each analyte was divided by its screening level (SL). For the HHRA, this meant using two SLs based on toxicity endpoints, i.e., a cancer and noncancer SL were used to obtain a cancer ratio and noncancer hazard quotient (HQ).
- All analytes that exceeded the SLs were considered to have "failed" the initial screen. These are considered to be contaminants of potential concern (COPCs).
- A refinement of the exposure point concentrations (EPCs) was performed. Duplicates were averaged prior to calculating an upper 95th percent confidence limit on the mean (UCL95). The UCL95 concentrations were compared to SLs, and any analytes above the SLs would be evaluated further if necessary.

Figure 1-1 shows a map of the site location, and Figure 1-2 shows site features and the current sampling locations from which data were obtained for use in the risk assessment.

2.2.2. Evaluation of Inorganic Analytes

Inorganic analytes are first compared to BVs established for the site (LANL 1998). No further evaluation is necessary for analytes for which the maximum is less than the BV, and these data are not compared to risk-based SLs. For analytes for which the maximum exceeded the BV but did not exceed risk-based SLs known as the New Mexico Soil Screening Levels (NMSSLs) (NMED 2019), no further evaluation is necessary. If the maximum exceeded the BV and one or more risk-based SLs as indicated by a ratio of the maximum to the SL being > 1, a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the SLs. The toxicity of the various constituents analyzed in this investigation is incorporated into the screening levels.

Where an NMSSL was not available, the USEPA Regional Screening Level (RSL) was used. If an RSL was also not available, a suitable surrogate is proposed if toxicity and physicochemical data are sufficient to allow identifying a suitable surrogate. The following inorganic analytes required surrogates:

- Calcium, sodium, potassium, magnesium – these are macronutrient inorganic constituents that are relatively nontoxic, so unless concentrations greatly exceed background they are not evaluated for toxicity. SLs are not available.
- Chromium (Cr) - the toxicity values based on NMED CrIII were used since NMED has no SLs specifically for total Cr, and the site is unlikely to have significant CrVI because CrIII is more stable in the environment than CrVI, and CrVI is most often associated with industrial processes (ATSDR 2012).
- Mercury – the toxicity values for NMED mercuric salts was used for the SL as this is the form expected in arid soils.
- Lead – The EPA toxicity values of 400 mg/kg for residents and 800 mg/kg for workers were applied for lead.

All reporting limits were adequate for nondetected inorganics as indicated by ratios of the maximum reporting limit to minimum screening level being 1 or less. There were no rejected (R-qualified) inorganic data in the dataset.

2.2.3. Evaluation of Organic Analytes

Twelve soil samples and one duplicate were collected for analysis of organics, but some organic analytes were evaluated by more than one method, resulting in an apparently higher sample count (i.e., 2,4- and 2,6- dinitrotoluene, nitrobenzene). The maximum concentration regardless of the method was used as the EPC.

Organic analytes are not compared to background values as a matter of standard practice, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based SLs. Where a SL was not available, a suitable surrogate is proposed. Surrogates were obtained for the following analytes:

- Acenapthylene – there are no NMSSLs or RSLs for this chemical. The NMSSL for naphthalene was used as a surrogate.
- Benzoic Acid – there are no NMSSLs. The EPA RSLs were used to represent noncancer health effects.
- Benzyl Alcohol – there are no NMSSLs. The EPA RSLs were used to represent noncancer health effects.
- Butylbenzylphthalate – there are no NMSSLs and the EPA RSLs were used to represent cancer and noncancer health effects
- 2,4,6-triamino-1,3,5- trinitrobenzene (TATB) – there is no NMSSL or RSL for TATB. RSLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.
- 1,2 and 1,4 Xylene [m,p-xylenes] – the toxicity values for m-xylene (1,3-xylene) were used as the basis of the screening levels as it is just slightly more conservative than using values for p-xylene (1,4-xylene).

Reporting limits were adequate for all analytes with the exception of nitrosodimethylamine[N-], for which the reporting limit to residential SL ratio was 4 for every sample. This analyte was not detected in any of the samples, and all reporting limits were similar and exceeded the screening level. It is subject to photodecomposition, and degrades with heat or biological processes (EPA 2014). Therefore, it is not expected to be stable in the environment and is not expected to occur at the Unit. This chemical is not considered further. There were no rejected (R-qualified) inorganic data in the dataset used in the risk assessment.

2.3. EXPOSURE POINT CONCENTRATIONS

A phased approach was used to establish the EPCs. First the maximum detected value for each analyte was used as the EPC and was compared to a screening level. Analytes for which the maximum value was less than the lowest screening level are not evaluated further. If the maximum EPC exceeded screening levels, evaluation was continued with the UCL95 used as the EPC for the comparison. If there were too few detected concentrations reported to allow calculation of a UCL95 (i.e., number of detects <6), the median of all the data for the analyte including the detected concentrations and the method detection limits (MDLs) was used.

Guidance from NMED was used to evaluate the potential toxicity of the dioxin/furans. This guidance relies on the 2005 World Health Organization (WHO) toxicity equivalency factors (TEF) (Van den berg et al. 2006) approach. The TEFs are multiplied by the measured concentration to obtain a congener-specific product called the toxicity equivalent concentration (TECi), and the product for each (TECi) is summed for each sample location. This sum is referred to as the toxicity equivalent quotient (TEQ). The TEQ is divided by the NMED screening level for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) to obtain a risk ratio.

2.4. SCREENING EVALUATION

The following sections present the human health risk-screening assessment for the Unit. The summary statistics and maximum values used as EPCs are presented in Table 2-1.

The EPC for each detected analyte was compared with the industrial and residential soil SLs to obtain a HQ, and the hazard index (HI) was calculated by summing the HQs (NMED 2019). The chemical SLs used in the evaluations were obtained from current NMED guidance (NMED 2019) or the most recent EPA regional screening levels (RSLs) (EPA 2019) if an NMED value was not available. The NMSSLs for carcinogens are equivalent to a 1×10^{-5} cancer risk, and for noncarcinogens the NMSSLs correlate to a ratio or HQ of 1. The cancer-based EPA RSLs were multiplied by 10 to adjust them to a cancer risk level of $1x10^{-5}$, consistent with the NMSSLs. Any detected organic analytes that exceeded the SLs were considered COPCs. Any inorganic analytes that exceeded both background and the SL were also considered COPCs.

2.4.1. Background Data

The background data used in this evaluation were obtained from LANL “Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico, September 1998. The background data are used in the RCRA corrective action process to distinguish between contaminated and uncontaminated media and have been accepted by NMED. As stated in LANL (1998) on page 4, section 3.1.1,

> Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for inorganic chemical analyses. These samples provide information about the varied soils and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, 05702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms.

The locations sampled as part of the background study were not impacted by deposition from the historical operation of the OD units or other firing sites. Benchmarks termed BVs were obtained from this document to use in comparison to site data.

2.4.2. Data Analysis

Table 2-1 presents summary statistics for the 12 surface soil samples and one duplicate collected September 27, 2018. However, including data from the duplicate pair at point 1, and including analysis by different methods for certain analytes, results in an increased apparent sample size above 12 for some analytes (Table 2-1). Maximum concentrations in the soil samples analyzed for inorganics were compared to the established soil BVs (LANL 1998) (Table 2-2).

Inorganics

For detected inorganic analytes, the maximum detected reported result was used as the initial EPC (Table 2-1). Background values for the site are from the 1998 background report (LANL 1998), and soil screening levels are NMSSLs or other values as previously described in Section 2.2.2 (Table 2-2). The maximum concentration for the following detected inorganics exceeded BVs:

- Chromium – 2 times above BV
- Copper – 12 times above BV

There were four other inorganics that were approximately equivalent to or slightly elevated above BVs. These were as follows:

- Calcium – 1.2 times above BV
- Mercury – 1.3 times above BV
- Vanadium – 1.2 times above BV
- Zinc – 1.3 times above BV

All other inorganics were equal to or lower than BVs.

None of the inorganics exceeded either the residential or worker NMSSLs (NMED 2019). There was therefore no elevated cancer risk or noncancer hazard indicated for the Unit for any inorganic.

HIs were calculated for inorganics and organics separately. The noncancer-based sum of the screening level HQs for maximum detected soil concentrations of inorganics above background was 0.2 for the hypothetical future resident, and 0.01 for workers (Table 2-2).

Organics

Numerous organics were detected in the surface soil samples (Table 2-1). These include energetics or explosives (e.g., HMX [cyclotetramethylene-tetranitramine] and TATB). The SVOCs fluoranthene and pyrene were detected in one sample. Phthalates (e.g., butylbenzyl- and di-n-butylphthalate were also detected (Table 2-1), as were benzyl alcohol and benzoic acid.

No individual constituents exceeded NMSSLs (NMED 2019). The HI for the evaluation of maximum detected soil concentrations of organics for cancer-based health effects was 0.001 for hypothetical future residents, and 0.0002 for workers (Table 2-2). This is not a cancer risk estimate in terms of cancer probability, but an indication of how soil concentrations compare to screening levels based on a $1x10^{-5}$ target cancer risk. Since the HI is less than 1, the associated cancer risk is less than $1x10^{-5}$ which is NMEDs threshold. The noncancer-based sum of the screening level HQs for maximum detected soil concentrations of organics was 0.0.005 for residents, and 0.0003 for workers (Table 2-2).

Dioxin/Furans

The dioxin/furans are organics but are evaluated in the analysis differently than other organics. Dioxins/furans were detected in the surface soil samples (Table 2-3). The evaluation of the dioxin/furans is summarized in Table 2-3. The measured detected concentration or the MDL for nondetects is shown for each congener in each sample. The detection status is indicated by a zero for nondetect, and a 1 for a detected value. The TEFs are shown for each congener, and multiplying the TEF by the concentration produces the TECi. Summing the TECi yields the TEQ. Dividing the TEQ for each sample by the residential or industrial SL also shown in Table 2-3 produces a ratio which for all samples was 1 or less. Therefore, the dioxins and furans do not exceed risk-based SLs. The total HI for organics, including the dioxin/furans, was 0.006 for the hypothetical future resident and 0.0003 for the worker.

Data Analysis Conclusions

The initial risk analysis for all inorganic and organic analytes was based on comparison of the maximum detected value as the EPC. There are no individual constituents that exceed NMED or EPA residential or industrial SLs. The HIs do not exceed a value of one. The screening evaluation indicates that hypothetical future residents or workers are not at risk due to exposure to soils at the Unit.

2.5. UNCERTAINTY ANALYSIS

The human health risk assessment has inherent uncertainties associated with data and data evaluation, exposure assessment, and the toxicity values on which the SLs are based. Each or all of these uncertainties may affect the assessment results, biasing the risk assessment results high or low.

2.5.1. Data and Data Analysis

Uncertainties in the data or its analysis may include errors in sampling, laboratory analysis, and data analysis. Data evaluation uncertainties are expected to have little effect on the assessment results because the data have undergone validation to minimize errors, and any errors are not expected to bias the results high or low. The J-flagged (estimated) qualification of detected concentrations of some organic COPCs does not affect the assessment. The data represent deposition from more than 60 years of operation into 2019. Therefore, the data and subsequently the screening assessment results represent current baseline conditions.

The use of a judgemental sampling design biases the risk results high since samples were targeted to locations where contamination was most likely to occur or known to occur from past sampling events.

The use of the maximum or a UCL95 as the COPC EPC for each COPC is also expected to bias risk estimates high, erring towards being conservative. Use of the maximum as the EPC overestimates exposure, as by definition all other concentrations are below this value. Use of the UCL95 may also result in an overestimation of risk since by definition true mean values are nearly always going to be less than this value.

2.5.2. Exposure Assessment

The exposure assessment assumptions bias the risk results high (i.e., overestimate risk). The assumptions for the industrial SLs are that the potentially exposed individual is a Laboratory worker who is outside at the site for 8 hours per day for 225 days per year (NMED 2019), and who spends the entire 8 hours on-site within the contaminated area. Assumptions for the residential SLs are that the potentially exposed individual is a hypothetical future resident who is present 24 hours per day for 350 days per year (NMED 2019) and spends the entire 24 hours on-site within the contaminated area. Because it is unlikely the worker or resident would be within the contaminated area for the entire time, the screening assessments overestimate the exposure. As a result, risks may be overestimated.

Assumptions underlying the exposure parameters, routes of exposure, and intake rates for routes of exposure are consistent with NMED parameters and default values (NMED 2019). In the absence of site-specific data, several upper-bound values for the assumptions may be combined to estimate exposure for any one pathway, and the resulting risk estimate can exceed the 99th percentile. Therefore, uncertainties in the assumptions underlying the exposure pathways may contribute to risk assessments that overestimate the reasonably expected risk levels.

2.5.3. Toxicity Values

The primary uncertainty associated with the screening values is related to the derivation of toxicity values used in their calculation. Toxicity values (slope factors [SFs] and reference doses [RfDs]) were used to derive the risk-based screening values used in the screening evaluation (NMED 2019). Uncertainties were identified in four areas with respect to the toxicity values: (1) extrapolation from animals to humans, (2) variability between individuals in the human population, (3) the derivation of RfDs and SFs, and (4) the chemical form of the COPC.

The SFs and RfDs are often determined by extrapolation from animal data to humans, which may result in uncertainties in toxicity values because differences exist between animals and humans in chemical absorption, metabolism, excretion, and toxic responses. Differences in body weight, surface area, and pharmacokinetic relationships between animals and humans are taken into account to address these uncertainties in the dose-response relationship. However, conservatism is usually incorporated in each of these steps, potentially biasing the estimate high and resulting in the overestimation of potential risk.

For noncarcinogenic effects, the degree of variability in human physical characteristics is important both in determining the risks that can be expected at low exposures and in defining the no observed adverse effect level (NOAEL). The NOAEL uncertainty factor approach incorporates a 10-fold factor to reflect individual variability within the human population that can contribute to uncertainty in the risk assessment. This factor of 10 is generally considered to result in a conservative estimate of risk for noncarcinogenic COPCs.

The RfDs and SFs for different chemicals are derived from experiments conducted by different laboratories that may have different accuracy and precision that could lead to an over- or underestimation of risk. The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. For carcinogens, the weight of evidence classification indicates the likelihood that a contaminant is a human carcinogen.

COPCs may be bound to the environmental matrix and not be available for absorption into the human body following ingestion. However, the exposure scenarios typically default to the assumption that the COPCs are bioavailable. This assumption can lead to an overestimation of the total exposure and overestimate risk.

2.5.4. Additive Approach

For noncarcinogens, the effects of exposure to multiple chemicals are generally unknown and possible interactions could be synergistic or antagonistic, resulting in either an underestimation or overestimation of the potential risk by assuming additivity. Additionally, RfDs used in the risk calculations typically are not based on the same endpoints with respect to severity, effects, or target organs. Therefore, the potential for noncarcinogenic effects may be overestimated by the HI considering individual COPCs act by different mechanisms and on different target organs but are addressed additively. Cancer risks are typically assumed to be additive.

2.6. CONCLUSIONS

Inorganics were compared to BVs and risk-based SLs. Six inorganics equaled or exceeded background. No inorganics exceeded risk-based SLs. The cancer and noncancer screening level HIs for inorganics for workers or hypothetical residents were less than 1.

Organics were compared to risk-based SLs. There were numerous organics detected, including some energetics, some SVOCs, and dioxin/furans. However, maximum concentrations of any of the detected analytes were below SLs for all constituents. None of the TEQs for dioxin/furans exceeded the TCDD SL. The Unit does not present an elevated cancer risk or noncancer hazard to human health due to exposure to soils. The following interpretation can be made from the analysis:

- Based on an industrial scenario, inorganics above background, and maximum detected concentrations for each analyte, the total noncancer (0.01) and cancer-based (0.0003) HIs are less than the NMED target level of 1. This means that the sum of the ratios for maximum concentrations divided by SLs correlate to a cancer risk less than 1×10^{-5} and a noncancer hazard less than 1.
- For the hypothetical future residential scenario, inorganics above background, and maximum detected concentrations for each analyte, the total noncancer HI (0.2) is less than the NMED target level of 1. The total cancer HI of 0.006 is also below the NMED target level of 1.
- The concentration of each dioxin/furan congener was summed to obtain a TEQ which was compared to the NMED NMSSL for TCDD. The maximum ratio was 0.004 for residential use and 0.00003 for industrial use.
- Summing the maximum dioxin/furan ratio with the other cancer risk HIs provides a total HI for residential use of 0.006 and an HI for industrial use of 0.0003.
- The maximum lead concentration of 15.6 mg/kg is less than the background value of 22.3 mg/kg, and is much less than the residential SSL (400 mg/kg).
- There are no elevated human health risks for exposure to soils based on this evaluation.

3. ECOLOGICAL SCREENING ASSESSMENT

3.1. INTRODUCTION

The ecological risk assessment (ERA) for the Unit is presented in the following sections. The ecological risk-screening evaluation identifies chemicals of potential ecological concern (COPECs) and is based on the comparison of EPCs with Ecological Screening Levels (ESLs) in accordance with Laboratory guidance (LANL 2012a) and NMED (2017) guidance. Site information including ESLs, biological studies, and historical information were reviewed and a site visit was conducted. A preliminary conceptual site exposure model (CSEM) was prepared.

The ESLs obtained from the ECORISK Database, Version 4.1 (LANL 2017; LANL 2019) are presented in Table 3-1. The ESLs are based on toxicity data for laboratory species similar to those expected to occur at the site, and are derived from experimentally determined NOAELs, lowest observed adverse effect levels (LOAELs), or doses determined to be lethal to 50% of the test population (LD50s). Information relevant to the calculation of ESLs, including concentration equations, dose equations, bioconcentration factors, transfer factors, and toxicity reference values, are presented in the ECORISK Database, Versions 2.0, 3.1, and 4.1 (LANL 2003; LANL 2012b; LANL 2017).

The screening evaluation is conducted by dividing the EPCs by the ESLs to obtain a HQ calculated for each COPEC and screening receptor. As a generalization, the higher the contaminant levels relative to the ESLs, the higher the potential risk to receptors; conversely, the higher the ESLs relative to the contaminant levels, the lower the potential risk to receptors. The analysis begins with a comparison of the minimum ESL for each COPEC to the EPC. HQs greater than 0.3 are used to identify COPECs requiring additional evaluation (LANL 2012a).

Individual HQs for a receptor are summed to derive a HI. An HI greater than 1 indicates that further assessment may be needed to ensure exposure to multiple COPECs at a site will not lead to potential adverse impacts to a given receptor population. The HQ and HI analysis provide a conservative indication of potential adverse effects and are designed to minimize the potential of overlooking possible COPECs at the site.

3.2. PROBLEM FORMULATION AND CONCEPTUAL SITE EXPOSURE MODEL

The Unit is a terrestrial ecosystem. The area is disturbed with little to no vegetation present. Vegetation increases with distance from the OD area and consists of grasses and shrubs. There are likely terrestrial birds and small mammals including deer mice (*Peromyscus maniculatus*) or ground squirrels using the area, although intermittently due to the lack of food or cover. There is not enough vegetation within the Unit to support large herbivores.

Due to the site history, there is the potential for energetic compounds or their breakdown products to be present in surface soils. Terrestrial animals and plants may contact surface soils and be exposed. This possibility led to the collection of data and ecological risk assessment.

3.2.1. Data Summary

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- VOCs –12 samples and one duplicate
- SVOCs –12 samples and one duplicate
- Total Metals –12 samples and one duplicate
- Dioxins/Furans –12 samples and one duplicate
- High Explosives –12 samples and one duplicate

Some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dichlorobenzenes). Figure 1-2 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment, and habitat in the immediate site vicinity is also shown in Figure 1-2.

3.2.2. Receptors and Pathways

Exposure pathways are considered complete if all of the following components are present (US EPA, 1989; NMED, 2017):

- A source and mechanism for hazardous waste/constituent release into the environment;

- An environmental transport medium or mechanism;
- A point of contact directly between the receptor and site-related contaminated media, or indirectly via dietary ingestion of prey or forage items contaminated by contact with site related contaminants; and
- An exposure route leading to interaction of the contaminant with target organs within the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site.

The primary potentially complete ecological exposure pathways are based on direct or indirect contact with surface soils. These include root uptake, incidental ingestion of soil, and biotic uptake leading to food-web transport. Exposure of plants and soil invertebrates is not related to dietary pathways but is the result of direct contact with, and uptake from, the surrounding medium. For terrestrial wildlife, most exposure is through the oral pathway from the diet and incidental ingestion of soil (Sample et al. 1998). The dermal contact and inhalation pathways are not typically assessed quantitatively in ecological risk assessments, based on guidance indicating the ingestion route is most important to terrestrial animals (EPA 1997; EPA 2003). Dermal exposure to wildlife is mitigated by the fur or feathers covering the bodies of most vertebrates and the incidental consumption of soil during grooming is included in the direct soil ingestion estimates.

Although inhalation is recognized to occur, it is typically considered insignificant relative to ingestion and only quantified for burrowing animals where volatile organics are present in the subsurface. Respirable dust particles are most likely ingested rather than inhaled, and this pathway is considered negligible (EPA 1997; EPA 2003), while non-respirable dust is ingested and accounted for in incidental soil ingestion values for wildlife species (EPA 1993; EPA 2003). Therefore, the exposure pathways considered in the development of the ecological screening levels (ESLs) used in the risk-screening assessment capture the primary exposure for wildlife receptors.

A CSEM was developed for the site (Figure 3-1). The primary contaminant source is the testing of explosives and detonation of explosives for waste management at the site. Any uncombusted material, if present, could remain in soil or be released to air as fugitive dust. Materials in surface soil could potentially be carried by overland flow or percolate into the subsurface with rain, whereas material in air could be transported by wind. Receptors could contact contaminants within the immediate site area, up to the site boundary, or slightly beyond. The use of stormwater BMPs reduces the potential for migration beyond the Unit.

Terrestrial flora (i.e., plants) and fauna (e.g., invertebrates, birds, and mammals) are the general categories of ecological receptors that could be exposed.

3.2.3. Technical Decision Point and Recommendations

Because of the ecological habitat near the Unit boundaries, and because of the potential for exposure, the data were used to perform a quantitative screening level ecological evaluation.

3.3. SCREENING EVALUATION

The summary statistics for the data are presented in Table 2-1. Maximum detected concentrations of each analyte are used as the initial EPC. The EPCs and the screening results for the ecological screening assessment are presented in Table 3-1. Any analytes for which the measured maximum detected value exceeded the minimum SL were considered COPECs and were evaluated further by calculating UCL95s and comparing the UCL95s to the SLs. The approach was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to BVs. Analytes less than BVs were eliminated from further evaluation.
- The screening approach then used the maximum of all detected data for the initial screening evaluation. The maximum concentration of each analyte was divided by the minimum ESL for all receptors.
- All analytes that exceeded the ESLs were considered to have “failed” the initial screen. These are considered to be COPECs.
- A refinement of the EPCs was performed. Duplicates were averaged prior to calculating a UCL95. The UCL95 concentrations were compared to ESLs, and any analytes above the ESLs would be evaluated further if necessary.

3.3.1. Inorganics

There are two inorganics that exceed site BVs by a factor of 2 or more, and four that are slightly above background. The maximum concentration of each of these was compared to the minimum no effect (NE) ESL, if one was available, to determine if the resulting HQ >0.3. These analytes also exceeded the low effect (LE) ESL to produce an HQ >0.3. The analytes that exceed ecological SLs are as follows (Table 3-1):

- Calcium – no ESLs, and only 1.2 times above BV. Not evaluated further due to lack of ESLs and likelihood of low toxicity
- Chromium – exceeds NE and LE ESLs for ratio > 0.3; 2 times higher than BV
- Copper – exceeds NE ESLs and LE ESLs; 12 times higher than BV
- Mercury – exceeds NE ESLs and LE ESLs for ratio > 0.3; 1.3 times higher than BV
- Vanadium - exceeds NE ESLs and LE ESLs for ratio > 0.3; 1.2 times higher than BV
- Zinc– exceeds NE ESLs and LE ESLs; 1.3 times higher than BV

If the maximum exceeded the BV and the ratio of the maximum to the risk-based SL was greater than 0.3, a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the ESLs (Table 3-2) consistent with the NMED (2017) Tier II approach. Note that comparison to the UCL95s was made prior to incorporating area use factors (AUFs) into the analysis. Receptor-specific dietary composition is built into the receptor-specific ESLs. The concentrations for each of the samples in the duplicate pair 1 and 1 dup (Figure 1-2) were averaged and the UCL95 calculated with a sample size of 12.

UCL95 values for copper, mercury, and vanadium exceeded the NE ESL with UCL95/ESL ratios above 1, but only UCL95s for copper and vanadium exceeded the LE ESL as well. The HI for the NE ESL was 20, and the HI for the LE ESL was 7, for the sum of the HQs for inorganics. This suggests some limited potential for adverse ecological effects at the Unit, and therefore the COPECs producing HQs above 1 are evaluated in more detail in the uncertainty analysis.

3.3.2. Dioxin and Furans

Dioxins and furans are evaluated in a multi-step process that takes the concentration of each congener in each sample and multiplies it by a TEF for mammals or birds (Table 3-3). The resulting TECi values are summed to obtain a TEQ.

The TEQ is divided by the lowest mammalian and avian ESL for species that could occur on the Site. The lowest ESL is based on the montane shrew (*Sorex monticolus*). Due to lack of its preferred riparian habitat and lack of dense cover, the montane shrew is not expected to occur, and the next lowest ESL for TCDD for mammals is used in this analysis. The mammalian NE ESL and LE ESL used in this risk assessment for TCDD are based on potential toxicity to the deer mouse. The avian NE ESL is from the ECORISK Database, Version 2.0 (LANL 2003) as reported in Attachment H, Technical Area 16 Burn Ground Human Health and Ecological Risk-Screening Assessments (LA-UR-13-24177), Class 3 Permit Modification Request for Addition of an Open Burning Unit at Technical Area (TA) 16 to the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit, EPA ID No. NM0890010515. September 30, 2013. Refer To: WM-D0-13-0064, LAUR: 13-27579.

Dioxin and furans were detected in multiple samples in the September 2018 data set. The TEFs for birds and mammals were applied to calculate a TEQ for each sample. Only one of 12 samples had TEQs that exceeded the NE ESL for TCDD for mammals (Table 3-4) resulting in a HQ >0.3, and no samples exceeded the LE ESL. None of the samples exceeded the NE ESL for birds (Table 3-5) when evaluated individually.

The potential for risk to mammalian species was then investigated further. A UCL95 for each congener based on the sample-specific data was calculated with ProUCL (EPA 2015) using both the detected and nondetected data. The UCL95 sample concentrations were used with the TEFs to obtain UCL95 TECi, which were summed to obtain a UCL95 TEQ (Table 3-6). If the data for a given congener were completely nondetected, a UCL95 was not calculated. Since this TEQ is the sum of UCLs, it is expected to be highly conservative. When the UCL95 was divided by the NE ESL for TCDD for mammals, the resulting ratio or HQ was less than one, as shown below:

Mammal		
UCL TEQ (mg/kg)	**NE ESL (mg/kg)**	**NE HQ[1]**
1.27E-7	5.80E-07	0.2

[1] – the NE HQ is the ratio of the UCL TEQ/NE ESL

The dioxin/furans do not present a potential risk to mammals or birds and are not further evaluated.

3.3.3. Other Organics

For this risk assessment, the highest concentration found, regardless of the method used, or whether the sample was a primary sample or a duplicate, was used as the basis of the EPC in the initial screening-level assessment. This is considered conservative for the evaluation of potential risks.

Organic analytes are not compared to any background values, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based ecological SLs. Where an SL was not available, a suitable surrogate is proposed. The following surrogates were required for the ERA:

- TATB - ESLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.

- Xylenes – the toxicity values for total xylenes were used to represent each of the fractions.

Maximum concentrations of four organics exceeded the minimum ecological screening levels (Table 3-1). These were benzoic acid, di-n-butylphthalate, HMX, and TATB. UCL95 values were calculated and compared to the minimum NE ESLs and LE ESLs (Table 3-2).

There was only one detection of benzoic acid, and five detections of di-n-butylphthalate. The low detection frequency means that a robust UCL95 cannot be calculated. Therefore, a median of the detected concentrations and the reported detection limit values was calculated and used as the estimate of the EPC. This approach is consistent with ProUCL guidance (EPA 2015) that recommends use of alternative statistics when detection frequency is low.

UCL95 or median values for organics did not exceed the minimum NE ESLs or the LE ESLs and are not considered further. The highest ratio was 0.9 for di-n-butylphthalate, which while higher than the ratio of 0.3 used in the initial screening step, is not indicative of a potential ecological risk for this compound. The ratio for di-n-butylphthalate for the LE ESL was 0.1. Organics do not require further evaluation in the risk analysis and are not further evaluated.

3.4. UNCERTAINTY ANALYSIS

3.4.1. Chemical Form

Inorganic analytes can speciate into different forms with varying degrees of toxicity. The assumptions used in the ESL derivations are conservative and not necessarily representative of actual conditions. These assumptions include maximum chemical bioavailability, maximum receptor ingestion rates, minimum bodyweight, and additive effects of multiple COPECs. These factors tend to result in conservative ESL estimates, which may lead to an overestimation of the potential risk. Toxicological data are typically based on the most toxic and bioavailable chemical species, which may or may not be found in the environment. The ESLs were calculated to ensure a conservative indication of potential risk (LANL 2012a), and the values are biased toward overestimating the potential risk to receptors.

The chemical form of the individual COPECs was not determined as part of the investigation. COPECs are generally not 100% bioavailable to receptors in the natural environment because of interference from other natural processes, such as the adsorption of chemical constituents to matrix surfaces (e.g., soil) or rapid oxidation or reduction changes that render harmful chemical forms unavailable to biotic processes.

3.4.2. Reporting Limits

The evaluation was focused on detected values. Reporting limits were adequate (i.e., below SLs) for all analytes with three exceptions, indicating that the data were adequate for use in the risk assessment:

Bis(2-ethylhexyl)phthalate –

- This analyte was not detected in any sample. Reporting limits were less than the cancer or noncancer based NMSSL for residents or workers.
- The maximum MDL (0.0101 mg/kg) was less than the minimum NE ESL (0.02).
- The maximum nondetected value was flagged as having blank contamination, and may be biased high.

- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Dinitrobenzene[1,3-] –

- This analyte was not detected in any sample. Reporting limits were less than the cancer or noncancer based NMSSL for residents or workers.
- The maximum reporting limit (0.15 mg/kg) was two times higher than the minimum NE ESL. All reporting limits were similar.
- No reporting limits exceeded the minimum LE ESL.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Nitrosodimethylamine[N-] –

- This analyte was not detected in any sample. Reporting limits were up to 4 times higher than the cancer-based NMSSL for residents, but below the NMSSL for workers.
- The reporting limits were below the noncancer-based NMSSL, which would be more appropriate for ecological receptors.
- There were no ESLs for this analyte, and the comparison to NMSSLs was justified in the absence of other data.
- This uncertainty will not bias the risk assessment low or high.

3.4.3. Exposure Parameters and Risk Estimates

Exposure parameters including the EPC and the intakes likely bias risk estimates high because they presume no movement of receptors in and out of source areas. Sampling focused on areas of known or expected contamination, which biases the EPC high. Receptors are assumed to spend 100% of their time in the contaminated area which results in conservative estimates of exposure.

Another source of uncertainty is inherent in the calculation of exposure and risk estimates. Although the toxicity values are expressed to more than one significant figure, it is unlikely that the toxicity data are this accurate, especially given that the data are extrapolated from laboratory animal studies to wildlife receptors that are mobile in the environment. Likewise, given all the variables inherent in assessing exposure, exposure intakes by ecological receptors also should not be considered more accurate than one significant figure. This means that an HQ identified as 0.95 or 1.2 is actually 1, and an HQ identified as 1.5 is actually 2.

Calculating risk for dioxins is a multi-step process that involves multiplying the measured concentration by a toxicity factor (TEF) to obtain a value called the TECi that when summed adjusts the measured congener concentrations to that relative to TCDD, where the sum of all TECi is called the TEQ. Nondetected congeners were not included in the TEQ calculation, which biases the TEQ high, and biases dioxin risk estimates high for any given sample. When calculating the UCL95 as the EPC, the TEQs can be used directly but this provides a UCL95 EPC based only on detected data. ProUCL (EPA 2015) accommodates both detected and nondetected results, reducing bias and uncertainty by not ignoring the influence of nondetects on the EPC. Therefore, UCL95s were calculated for each congener, then adjusted with the TEFs, and then TECi for each congener summed to obtain the TEQ as opposed to averaging the TEQs directly. This procedure of calculating UCL95s for each congener was considered to be slightly more accurate.

3.4.4. Mixture Toxicity

The assumption of additive effects for multiple COPECs may result in an over- or under-estimation of the potential risk to receptors. Exposure to multiple contaminants may result in other than additive effects. Conservative assumptions made with regards to EPCs would tend to overestimate exposure to any given constituent, and this would suggest that the toxicity of multiple constituents would not be underestimated. Therefore, mixture toxicity is not likely to bias the risk results high or low.

3.4.5. COPECs without ESLs

ESLs were not available for the cations and anions generally regarded as nutrients calcium, magnesium, nitrate, potassium, and sodium. ESLs were also not available for iron, but human health risk ratios for residents were 0.4 or lower. Only calcium was above background levels established for the site with a ratio of site maximum to background of 1.2. Lack of ESLs for these inorganics is not expected to underestimate risk at the site.

Several organic chemicals do not have ESLs for any receptor in release 4.1 of the ECORISK Database (LANL 2017; LANL 2019). Predominantly, the constituents lacking ESLs are nondetected organics. In the absence of a chemical-specific ESL, concentrations can be compared with the ESLs for a surrogate chemical, if available. Comparison to surrogate ESLs provides an estimate of potential effects of a chemically related compound and a line of evidence to indicate the likelihood that ecological receptors are potentially impacted. Some chemicals without ESLs do not have chemical-specific toxicity data or surrogate chemicals to be used in the screening assessments and cannot be assessed quantitatively for potential ecological risk.

The chemical TATB was detected in six samples. TATB did not have any ESLs for use in the evaluation. The toxicity values for 1,3,5-trinitrobenzene (NE ESL = 1.2 mg/kg; LE ESL = 12 mg/kg) were used as a surrogate based on structural similarity.

Chemicals lacking ESLs are often infrequently detected across the site. In these cases, comparisons with human health SLs are presented as part of a qualitative assessment, if human health SLs are available. The comparison of concentrations to human health SLs is a viable alternative for several reasons. Animal studies are used as the basis of toxicity values for human health risk assessments, and are the basic premise of modern toxicology (EPA 1989). In addition, toxicity values derived for the calculation of human health SLs (e.g., histopathology or biochemical changes) may be based on potential adverse effects more sensitive than the ones typically used to derive ESLs (e.g., survival, growth, or reproductive effects). EPA also applies uncertainty factors or modifying factors to ensure the toxicity values are protective (i.e., toxicity values are divided by uncertainty factors resulting in values much lower than initial study results).

Since there were no predicted adverse effects on human health, chemicals lacking ESLs are unlikely to pose an ecological risk.

There is no avian ESL for TCDD in the current LANL EcoRisk database (LANL 2019). A value from the 2002 EcoRisk database (LANL 2003) was used as the NE ESL. The lowest ESL value is 4.1×10^{-6} mg/kg based on the robin feeding as an insectivore, which has previously been utilized in LANL risk assessments. A reported LOAEL-based ESL is 4.1×10^{-5} mg/kg. These values were used in the current risk assessment in the absence of more recent data.

3.4.1. Small-Mammal Field Investigations

Small mammal trapping and analysis of whole organisms were conducted in the area around the Unit in August and September, 2010 to evaluate small mammal abundance and occurrence relative to background. Small-mammal community and population parameters were also measured across the site (Bennett and Robinson 2011). This information was considered useful for the current analysis as an additional line of evidence. Field mice were collected around the site and analyzed for dioxins and furans as well as metals, and for polychlorinated biphenyls (PCBs) (Fresquez 2011).

Small mammals that could occur at the Unit are the deer mouse (*Peromyscus maniculatus*), brush mouse (*Peromyscus boylii*), pinyon mouse (*Peromyscus truei*), silky pocket mouse (*Perognathus flavescens*), western harvest mouse (*Reithrodontomys megalotis*), white-throated woodrat (*Neotoma albigula*), and the Mexican woodrat (*Neotoma mexicana*) (Bennett and Robinson 2011). The Unit is located at the bottom of Ancho Canyon. The vegetation community consists of piñon (*Pinus edulis Engelm*.)-juniper (*Juniperus monosperma [Englem.] Sarg*.) with scattered ponderosa pine (*Pinus ponderosa C. Lawson*) and gambel oak (*Quercus gambelii Nutt*.) (Bennett and Robinson 2011).

The capture rate was higher at the Unit relative to the control area, but the Unit exhibited lower diversity and lower eveness. There were five species captured, including the rock pocket mouse (*Chaetodipus intermedius*) which had never been caught at LANL before. In addition, Mexican woodrats, deer mice, harvest mice, and brush mice were collected. There were no differences in deer mouse sex ratios or body weight between the Unit and the control area. The authors of the study concluded that there was no apparent adverse effects on small mammal populations at the Unit relative to controls.

Radionuclides and chemical concentrations in biota were compared to regional statistical reference levels (RSRLs). RSRLs represent natural and fallout levels, and are the upper-level background concentrations (mean plus three standard deviations = 99% confidence level) for radionuclides and chemicals calculated from biota that was collected from regional locations away from the influence of the Laboratory (over nine miles away) (Fresquez 2011). The only analytes that exceeded RSRLs were barium (two out of three samples) and lead (three out of three samples). Barium and lead soil concentrations were below BVs in the current data set. Dioxins/furans and explosives were not detected. These data suggest that there are no impacts to small mammal populations at the Unit.

3.4.2. Avian Field Investigations

One western bluebird (*Sialia mexicana*) and one ash-throated flycatcher (*Myiarchus cinerascens*) egg sample were obtained in 2018 from the Unit and analyzed for inorganic elements (Gaukler and Stanek 2019). Concentrations of inorganic elements were compared with the upper-level bounds of background concentrations in bird eggs as represented by the RSRL. The data indicated aluminum, antimony, arsenic, beryllium, cadmium, chromium, lead, nickel, silver, thallium, or vanadium were not detected in eggs (Gaukler and Stanec 2019). Barium, cobalt, and zinc were detected, but were below the RSRL.

Calcium, copper, iron, magnesium, manganese, mercury, potassium, selenium and sodium, were detected in bluebird eggs above the RSRL for avian eggs. Whereas mercury and selenium egg concentrations were below LOAELs, no benchmarks were available for copper, iron, or manganese (Gaukler and Stanek 2019). The other inorganics are considered macronutrients. Most of these inorganics above RSRLs in eggs were either not detected in soils or were detected with maximum soil concentrations below soil BVs. Only copper, mercury, and vanadium soil UCL95 EPCs exceeded NE ESLs, and copper and vanadium soil UCL95s exceeded LE ESLs. In the current data set analyzed for this report, none of the UCL95 EPCs for soil for the detected inorganics above BVs were above NE ESLs once area use factors were incorporated into the analysis. One sample consisting of four western bluebird eggs was collected in 2019, and no detected analytes were above the RSRLs (Gaukler and Stanek 2020).

Avian population metrics also do not suggest that birds in the vicinity are being negatively impacted (Hathcock et al 2018). The avian population transect at the Unit was in a canyon bottom, whereas the control areas were on mesa tops. This could lead to differences in species identified and population metrics between the Unit and control areas. Species diversity was significantly higher at the Unit in 2013, 2014, and 2016 than at the control areas. Abundance varied in the Unit and control areas annually, but abundance in the Unit compared to controls was similar over time. Combined, the egg concentration data and population metrics suggest that adverse health effects are not expected at the observed concentrations.

3.4.3. Area Use Factors

The Unit is very small with an aerial extent of 40 by 40 feet (0.037 acres or 0.015 hectares (ha)). This is less than the size of the home range (HR) of an individual robin or a deer mouse as shown in Table 3-7. The HR is used to calculate area use factors (AUFs) that are used in the EcoPRG equations (LANL 2017). Individual AUFs and population area use factors (PAUFs) may be used to modify the estimate of risk to wildlife receptors to allow estimates to be more site-specific. The application of AUFs or PAUFs reduces potential overestimation of risks for those receptors with HRs larger than the area of contamination being evaluated. The estimated ecological risk as indicated by the HQ or HI is multiplied by the AUF or PAUF. HQs for plants or invertebrates are not adjusted by area use.

Table 3-7 presents the area use hazard analysis based on NE ESLs. The NE ESLs for each COPC that failed the screening evaluation (i.e., because EPCs exceeded the SLs) are shown for each receptor. The site specific AUF and PAUFs are shown for an area equivalent to the Unit. The UCL95 EPC is divided by the ESL and multiplied by the PAUF to obtain revised HQs. The habitat is not suitable for Mexican Spotted Owls or other special status species, and so an AUF evaluation was not conducted.

There were no HQs above 1, or even above 0.3, for birds or mammals based on comparison of UCL95 values as the EPC to the NE ESLs for each receptor (Table 3-7). The HQs for copper for plants and earthworms, and the HQ for mercury for earthworms, were 1. Table 3-8 presents the area use hazard analysis based on comparison of the UCL95 values as the EPC to the LE ESLs for each receptor. There are no HQs above 1. The HI analysis (Table 3-9) indicates that no HIs exceeded 1 for the avian or mammalian receptors. The HIs for earthworms and plants were 3 and 2, respectively.

3.5. CONCLUSIONS

The ecological risk assessment used a tiered approach for determining if the Unit would present an ecological risk. The results of the initial and highly conservative screening step indicated several inorganics occurring above background concentrations, and several detected organics, would present an ecological risk. Maximum concentrations of six detected inorganics exceeded background (calcium, chromium, copper, mercury, vanadium, and zinc). There is no ESL for calcium, but maximum concentrations of these other inorganics exceeded NE ESLs.

Dioxin/furans, some polynuclear aromatic hydrocarbons (PAHs), phthalates, benzoic acid, benzyl alcohol, volatile organics, and two explosives were detected in the unit. Of the detected organics, only four (benzoic acid, di-n-butylphthalate, HMX, and TATB) exceeded minimum ESLs in the initial screening level evaluation which compared maximum detected values to the minimum ESLs.

Further evaluation by statistically estimating UCL95's to use as EPCs in soil suggested few inorganics or organics would occur at concentrations hazardous to ecological receptors. Use of the UCL95 as the EPC provides a conservative estimate of average exposure across the Unit. Copper, mercury, and vanadium were the only inorganics with an HQ above 1 based on dividing the UCL95 by the ESL. None of the UCL95's for organics exceeded ESLs.

Additional consideration of site ecology and receptor-specific adjustments to exposure by considering home range and site area further reduced the analytes exceeding NE ESLs. Only HQs for copper and mercury were as high as 1. This was for plants and earthworms for which the area use evaluation is not relevant as they are immobile in the environment. However, the Unit is not vegetated because of its designated use as an OD area, and so plants and invertebrates have no habitat in the Unit. The LE ESLs are not exceeded for any receptor.

The Unit does not present an ecological risk to any receptor evaluated.

4. REFERENCES

ATSDR. 2012. Toxicological Profile for Chromium. September 2012. Pg 374. https://www.atsdr.cdc.gov/toxprofiles/tp7.pdf

Bennett, K., and R. Robinson. 2011. Small Mammal Sampling at Open-Detonation Firing Sites. LA-UR-11-00717. January 2011. (Bennett and Robinson 2011)

EPA (U.S. Environmental Protection Agency), December 1989. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final," EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989)

EPA (U.S. Environmental Protection Agency), 1993. "Wildlife Exposure Factors Handbook," U.S. Environmental Protection Agency document EPA/600/P93/187A, Office of Research and Development, Washington, D.C. (EPA 1993)

EPA (U.S. Environmental Protection Agency), June 5, 1997. "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final," U.S. Environmental Protection Agency, Environmental Response Team, Edison NJ. (EPA 1997)

EPA (U.S. Environmental Protection Agency), November 2003. "Guidance for Developing Ecological Soil Screening Levels, Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs, Attachment 1-3, U.S. Environmental Protection Agency document OSWER Directive 92857-55, Office of Solid Waste and Emergency Response. (EPA 2003)

EPA (U.S. Environmental Protection Agency), December 2010a. "Final Report Bioavailability of Dioxins and Dioxin-Like Compounds in Soil," Office of Superfund Remediation and Technology Innovation, Environmental Response Team, West Las Vegas, Nevada (http://epa.gov/superfund/health/contaminants/dioxin/pdfs/Final_dioxin_RBA_Report_12_20_10.p df). (EPA 2010a)

EPA (U.S. Environmental Protection Agency), December 2010b. "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8=Tetrachloro-p-dioxin and Dioxin-Like Compounds." EPA/100/R 10/005. (EPA 2010b)

EPA (U.S. Environmental Protection Agency), January 2014. “Technical Fact Sheet – N-Nitroso-dimethylamine (NDMA)”. https://www.epa.gov/sites/production/files/2014-03/documents/ffrrofactsheet_contaminant_ndma_january2014_final.pdf . (EPA 2014)

EPA (U.S. Environmental Protection Agency), October 2015. “ProUCL Version 5.1.002 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations.” EPA/600/R-07/041. ORD Site Characterization and Monitoring Technical Support Center. (EPA 2015)

EPA (U.S. Environmental Protection Agency), August 2019. Regional Screening Levels (RSLs) – Generic Tables Dated September 2018. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. (EPA 2019)

Fresquez, P.R. 2011. Chemical Concentrations In Field Mice Collected From Open-Detonation Firing Sites Ta-36 Minie And Ta-39 Point 6 At Los Alamos National Laboratory. LA-UR-11-10614. May 2011. (Fresquez 2011)

Gaukler, S. and J Stanek. 2019. “ Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory”. LA-UR-19-25647. June 2019. (Gaukler and Stanek 2019)

Gaukler, S. and J Stanek. 2020. “2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory.” March 25 2020. LA-UR-20-22529. (Gaukler and Stanek 2020)

Hathcock, C. D., Bartlow, A. W., and B.E. Thompson. 2018. “2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory”. 2018-04-30 (rev.1) LA-UR-18-22897. (Hathcock et al. 2018)

LANL (Los Alamos National Laboratory), September 1998. “Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico. (LANL 1998)

LANL (Los Alamos National Laboratory), November 2003. “ECORISK Database (Version 2.0),” on CD, Los Alamos, New Mexico. (LANL 2003)

LANL (Los Alamos National Laboratory), November 2012. “Screening-Level Ecological Risk Assessment Methods, Revision 3,” Los Alamos National Laboratory document LA-UR-12-24152, Los Alamos, New Mexico. (LANL 2012a)

LANL (Los Alamos National Laboratory), October 2012. “ECORISK Database (Release 3.1),” LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2012b)

LANL (Los Alamos National Laboratory), 2017. “ECORISK Database User Guide, Revision 1”. LA-UR-17-26376. Los Alamos National Laboratory, Los Alamos, New Mexico. September 2017. (LANL 2017)

LANL (Los Alamos National Laboratory), 2019. “ECORISK Database (Release 4.1),”March 2019 Release. (LANL 2019)

NMED (New Mexico Environment Department). 2017. Risk Assessment Guidance for Site Investigations and Remediation. Volume II. Soil Screening Guidance for Ecological Risk Assessments.2017 Revised. (NMED 2017)

NMED (New Mexico Environment Department). February 2019. Risk Assessment Guidance for Site Investigations and Remediation. Volume I. Soil Screening Guidance for Human Health Risk Assessments. February 2019. Rev. 1 (3/7/19) (NMED 2019)

Sample, B.E., Suter III, G.W., Efroymson, R.A., and Jones, D.A., May 1998. "A Guide to the ORNL Ecotoxicological Screening Benchmarks: Background, Development, and Application," Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4783, ORNL/TM13615, Oak Ridge, TN. May 1998 (Sample et al. 1998)

Van den Berg et.al, 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency factors for Dioxin and Dioxin-like Compounds. ToxiSci Advance Access, July 7, 2006. (Van den Berg et al. 2006)

WHO (World Health Organization). September 2009. "Project For The Re-Evaluation Of Human And Mammalian Toxic Equivalency Factors (TEFS) Of Dioxins And Dioxin-Like Compounds". International Programme on Chemical Safety. http://www.who.int/ipcs/assessment/tef_update/en/ (WHO 2009)

Tables

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
INORGANICS								
Aluminum	13	1.76E+03	5.28E+03	3.90E+03	8.48E+02	6.24E+00	6.82E+00	13
Antimony	13	3.07E-01	3.24E+00	1.82E+00	1.45E+00	3.07E-01	3.24E+00	0
Arsenic	13	3.65E-01	1.28E+00	8.13E-01	2.07E-01	3.10E-01	3.36E-01	13
Barium	13	1.68E+01	8.86E+01	4.29E+01	1.75E+01	9.17E-02	1.00E-01	13
Beryllium	13	1.43E-01	2.32E-01	1.90E-01	2.68E-02	1.83E-02	1.99E-02	13
Cadmium	13	9.17E-02	1.00E-01	9.52E-02	2.23E-03	9.17E-02	1.00E-01	0
Calcium	13	5.88E+02	7.16E+03	4.67E+03	1.76E+03	7.34E+00	8.02E+00	13
Chromium	13	3.22E+00	4.79E+01	1.64E+01	1.18E+01	1.38E-01	1.50E-01	13
Cobalt	13	2.25E+00	8.95E+00	5.59E+00	1.85E+00	1.38E-01	1.50E-01	13
Copper	13	4.92E+00	1.74E+02	5.78E+01	5.23E+01	2.75E-01	3.01E-01	13
Iron	13	9.03E+03	2.14E+04	1.49E+04	3.77E+03	7.34E+00	8.02E+00	13
Lead	13	5.83E+00	1.56E+01	8.98E+00	2.88E+00	3.03E-01	3.31E-01	13
Magnesium	13	3.75E+02	3.74E+03	2.40E+03	8.21E+02	7.80E+00	8.52E+00	13
Manganese	13	1.47E+02	2.81E+02	2.14E+02	3.80E+01	1.83E-01	2.01E-01	13
Mercury	13	3.55E-03	1.31E-01	3.37E-02	4.50E-02	3.48E-03	3.93E-03	7
Nickel	13	1.27E+00	1.38E+01	8.19E+00	2.94E+00	9.17E-02	9.95E-02	13
Perchlorate	13	4.86E-04	5.04E-04	4.94E-04	5.39E-06	4.86E-04	5.04E-04	0
Potassium	13	3.74E+02	8.12E+02	6.21E+02	1.18E+02	5.87E+00	6.42E+00	13
Selenium	13	3.30E-01	3.58E-01	3.46E-01	9.48E-03	3.30E-01	3.58E-01	0
Silver	13	1.67E-01	6.85E-01	3.77E-01	1.65E-01	9.17E-02	1.00E-01	0
Sodium	13	1.28E+02	3.99E+02	2.76E+02	6.65E+01	6.42E+00	7.02E+00	13
Thallium	13	1.28E-01	1.39E-01	1.34E-01	3.84E-03	1.28E-01	1.39E-01	0
Vanadium	13	1.14E+01	4.83E+01	3.17E+01	1.10E+01	9.17E-02	1.00E-01	13
Zinc	13	2.44E+01	6.25E+01	3.89E+01	1.15E+01	3.67E-01	4.01E-01	13
ORGANICS								
2,4-Diamino-6-nitrotoluene	13	4.93E-01	5.00E-01	4.97E-01	2.94E-03	4.93E-01	5.00E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
2,6-Diamino-4-nitrotoluene	13	6.50E-01	6.60E-01	6.56E-01	4.17E-03	6.50E-01	6.60E-01	0
3,5-Dinitroaniline	13	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Acenaphthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Acenaphthylene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Acetone	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Amino-2,6-dinitrotoluene[4-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Amino-4,6-dinitrotoluene[2-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Aniline	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Azobenzene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Benzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Benzo(a)anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(a)pyrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(b)fluoranthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(g,h,i)perylene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(k)fluoranthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzoic Acid	13	1.67E-01	4.83E-01	1.92E-01	8.75E-02	1.67E-01	1.68E-01	1
Benzyl Alcohol	13	1.00E-01	1.65E+00	3.93E-01	4.81E-01	1.00E-01	1.01E-01	7
Bis(2-chloroethoxy)methane	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Bis(2-chloroethyl)ether	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Bis(2-ethylhexyl)phthalate	13	1.00E-02	3.05E-02	1.23E-02	5.70E-03	1.00E-02	1.01E-02	0
Bromobenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromochloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromodichloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromoform	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromophenyl-phenylether[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Butanone[2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Butylbenzene[n-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzene[sec-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzene[tert-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzylphthalate	13	1.00E-02	6.35E-02	1.59E-02	1.56E-02	1.00E-02	1.01E-02	2
Carbon Disulfide	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Carbon Tetrachloride	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloro-3-methylphenol[4-]	13	1.34E-01	1.34E-01	1.34E-01	3.73E-09	1.34E-01	1.34E-01	0
Chloroaniline[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorobenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chlorodibromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloroethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloroform	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloronaphthalene[2-]	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Chlorophenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorophenyl-phenyl[4-] Ether	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorotoluene[2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chlorotoluene[4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chrysene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dibenz(a,h)anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dibenzofuran	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dibromo-3-Chloropropane[1,2-]	13	4.93E-04	5.04E-04	4.99E-04	4.97E-06	4.93E-04	5.04E-04	0
Dibromoethane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dibromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichlorobenzene[1,2-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0
Dichlorobenzene[1,3-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Dichlorobenzene[1,4-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0
Dichlorobenzidine[3,3'-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dichlorodifluoromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethane[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[cis-1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[trans-1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichlorophenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dichloropropane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropane[1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropane[2,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[cis-1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[trans-1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Diethylphthalate	13	1.00E-02	1.28E-02	1.03E-02	7.62E-04	1.00E-02	1.01E-02	0
Dimethyl Phthalate	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dimethylphenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Di-n-butylphthalate	13	1.00E-02	1.00E-01	2.30E-02	2.63E-02	1.00E-02	1.01E-02	5
Dinitro-2-methylphenol[4,6-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dinitrobenzene[1,3-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Dinitrophenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dinitrotoluene[2,4-]	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Dinitrotoluene[2,6-]	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Di-n-octylphthalate	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Diphenylamine	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Ethylbenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	**n**	**Minimum (mg/kg)**	**Maximum (mg/kg)**	**Mean (mg/kg)**	**SD (mg/kg)**	**Minimum MDL (mg/kg)**	**Maximum MDL (mg/kg)**	**Number of Detects**
Fluoranthene	13	1.00E-02	1.87E-02	1.07E-02	2.39E-03	1.00E-02	1.01E-02	1
Fluorene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	13	5.01E-07	1.17E-05	4.91E-06	3.79E-06	1.65E-06	1.67E-06	12
Heptachlorodibenzodioxins (Total)	13	0.00E+00	2.07E-05	8.49E-06	7.03E-06			11
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	13	4.96E-07	2.21E-06	7.84E-07	4.81E-07	1.65E-06	1.67E-06	6
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Heptachlorodibenzofurans (Total)	13	0.00E+00	1.22E-05	1.82E-06	3.35E-06			7
Hexachlorobenzene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorobutadiene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorocyclopentadiene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.73E-06	1.75E-06	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.94E-06	1.97E-06	0
Hexachlorodibenzodioxins (Total)	13	0.00E+00	1.10E-06	2.06E-07	4.06E-07			3
Hexachlorodibenzofuran[1,2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.71E-06	1.73E-06	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzofurans (Total)	13	0.00E+00	1.36E-06	2.48E-07	4.30E-07			4
Hexachloroethane	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexanone[2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
HMX	13	1.48E-01	6.66E+00	9.80E-01	1.80E+00	1.48E-01	1.50E-01	7
Indeno(1,2,3-cd)pyrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Iodomethane	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Isophorone	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Isopropylbenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Isopropyltoluene[4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Methyl-2-pentanone[4-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Methylene Chloride	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Methylnaphthalene[2-]	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Methylphenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Methylphenol[3-,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Naphthalene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Nitroaniline[2-]	13	1.10E-01	1.11E-01	1.11E-01	4.39E-04	1.10E-01	1.11E-01	0
Nitroaniline[3-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitroaniline[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrobenzene	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Nitrophenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrophenol[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrosodimethylamine[N-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitroso-di-n-propylamine[N-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrotoluene[2-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Nitrotoluene[3-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Nitrotoluene[4-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	13	1.96E-06	9.57E-05	4.10E-05	3.26E-05	3.31E-06	3.35E-06	13
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	13	9.93E-07	1.92E-05	2.99E-06	4.94E-06	3.31E-06	3.35E-06	7
Oxybis(1-chloropropane)[2,2'-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Pentachlorodibenzodioxins (Total)	13	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0
Pentachlorodibenzofuran[1,2,3,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Pentachlorodibenzofuran[2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.75E-06	1.77E-06	0
Pentachlorodibenzofurans (Totals)	13	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0
Pentachlorophenol	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
PETN	13	2.46E-01	2.50E-01	2.49E-01	1.61E-03	2.46E-01	2.50E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Phenanthrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Phenol	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Propylbenzene[1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Pyrene	13	1.00E-02	1.61E-02	1.05E-02	1.67E-03	1.00E-02	1.01E-02	1
Pyridine	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
RDX	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Styrene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
TATB	13	2.96E-01	6.76E+00	1.37E+00	1.97E+00	2.96E-01	3.00E-01	6
Tetrachlorodibenzodioxin[2,3,7,8-]	13	9.93E-08	1.00E-07	9.98E-08	2.18E-10	3.31E-07	3.35E-07	0
Tetrachlorodibenzodioxins (Total)	13	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0
Tetrachlorodibenzofuran[2,3,7,8-]	13	1.05E-07	5.60E-07	2.67E-07	1.62E-07	3.31E-07	3.35E-07	11
Tetrachlorodibenzofurans (Totals)	13	0.00E+00	6.28E-07	1.91E-07	1.84E-07			9
Tetrachloroethane[1,1,1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetrachloroethane[1,1,2,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetrachloroethene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetryl	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Toluene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloro-1,2,2-trifluoroethane[1,1,2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Trichlorobenzene[1,2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichloroethane[1,1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloroethane[1,1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloroethene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichlorofluoromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichlorophenol[2,4,5-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichlorophenol[2,4,6-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichloropropane[1,2,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trimethylbenzene[1,2,4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Trimethylbenzene[1,3,5-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trinitrobenzene[1,3,5-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Trinitrotoluene[2,4,6-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Tris (o-cresyl) phosphate	13	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Vinyl Chloride	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Xylene[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Xylene[1,3-]+Xylene[1,4-]	13	6.57E-04	6.73E-04	6.65E-04	6.86E-06	6.57E-04	6.73E-04	0

Notes: Sample size (n) includes duplicate of WST39-18-162832 (WST39-18-162973) and multiple analytical methods.

Table 2-2. Human Health Screening Results for Comparison of Maximum Detected Exposure Point Concentrations Greater than Background

Parameter Name	Maximum Reported Result (mg/kg)	Number of Detects	Background		Cancer				Noncancer			
			BV (mg/kg)	Max / BV Ratio	Res Cancer NMSSL (mg/kg)	Worker Cancer NMSSL (mg/kg)	Max Res Cancer Ratio	Max Worker Cancer Ratio	Res NC NMSSL (mg/kg)	Worker NC NMSSL (mg/kg)	Max Res HQ	Max Worker HQ
INORGANICS												
Aluminum	5.28E+03	13	29200	0.2								
Arsenic	1.28E+00	13	8.17	0.2								
Barium	8.86E+01	13	295	0.3								
Beryllium	2.32E-01	13	1.83	0.1								
Calcium	7.16E+03	13	6120	1.2	NA	NA	NA	NA	1.3E+07	3.2E+07	5E-04	2E-04
Chromium	4.79E+01	13	19.3	2	NA	NA	NA	NA	1.2E+05	1.9E+06	4E-04	2E-05
Cobalt	8.95E+00	13	8.64	1								
Copper	1.74E+02	13	14.7	12	NA	NA	NA	NA	3.1E+03	5.2E+04	6E-02	3E-03
Iron	2.14E+04	13	21500	1								
Lead	1.56E+01	13	22.3	0.7								
Magnesium	3.74E+03	13	4610	0.8								
Manganese	2.81E+02	13	671	0.4								
Mercury	1.31E-01	7	0.1	1.3	NA	NA	NA	NA	2.3E+01	3.9E+02	6E-03	3E-04
Nickel	1.38E+01	13	15.4	0.9								
Potassium	8.12E+02	13	3460	0.2								
Sodium	3.99E+02	13	915	0.4								
Vanadium	4.83E+01	13	39.6	1.2	NA	NA	NA	NA	3.9E+02	6.5E+03	1E-01	7E-03

Table 2-2. Human Health Screening Results for Comparison of Maximum Detected Exposure Point Concentrations Greater than Background

Parameter Name	Maximum Reported Result (mg/kg)	Number of Detects	Background		Cancer				Noncancer			
			BV (mg/kg)	Max / BV Ratio	Res Cancer NMSSL (mg/kg)	Worker Cancer NMSSL (mg/kg)	Max Res Cancer Ratio	Max Worker Cancer Ratio	Res NC NMSSL (mg/kg)	Worker NC NMSSL (mg/kg)	Max Res HQ	Max Worker HQ
Zinc	6.25E+01	13	48.8	1.3	NA	NA	NA	NA	2.3E+04	3.9E+05	3E-03	2E-04
ORGANICS												
Acetone	3.05E-02	1	NA	NA	NA	NA	NA	NA	6.6E+04	9.6E+05	5E-07	3E-08
Benzoic Acid	4.83E-01	1	NA	NA	NA	NA	NA	NA	**2.5E+05**	**3.3E+06**	2E-06	1E-07
Benzyl Alcohol	1.65E+00	7	NA	NA	NA	NA	NA	NA	**6.3E+03**	**8.2E+04**	3E-04	2E-05
Butanone[2-]	2.89E-03	1	NA	NA	NA	NA	NA	NA	3.7E+04	4.1E+05	8E-08	7E-09
Butylbenzylphthalate	6.35E-02	2	NA	NA	**2.9E+03**	**1.2E+04**	2E-05	5E-06	**1.3E+04**	**1.6E+05**	5E-06	4E-07
Di-n-butylphthalate	1.00E-01	5	NA	NA	NA	NA	NA	NA	6.2E+03	9.2E+04	2E-05	1E-06
Fluoranthene	1.87E-02	1	NA	NA	NA	NA	NA	NA	2.3E+03	3.4E+04	8E-06	6E-07
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	1.17E-05	12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlorodibenzodioxins (Total)	2.07E-05	11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	2.21E-06	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlorodibenzofurans (Total)	1.22E-05	7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorodibenzodioxins (Total)	1.10E-06	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorodibenzofurans (Total)	1.36E-06	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HMX	6.66E+00	7	NA	NA	NA	NA	NA	NA	3.8E+03	6.3E+04	2E-03	1E-04
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	9.57E-05	13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	1.92E-05	7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2-2. Human Health Screening Results for Comparison of Maximum Detected Exposure Point Concentrations Greater than Background

Parameter Name	**Maximum Reported Result (mg/kg)**	**Number of Detects**	**Background**		**Cancer**				**Noncancer**			
			BV (mg/kg)	**Max / BV Ratio**	**Res Cancer NMSSL (mg/kg)**	**Worker Cancer NMSSL (mg/kg)**	**Max Res Cancer Ratio**	**Max Worker Cancer Ratio**	**Res NC NMSSL (mg/kg)**	**Worker NC NMSSL (mg/kg)**	**Max Res HQ**	**Max Worker HQ**
Pyrene	1.61E-02	1	NA	NA	NA	NA	NA	NA	1.7E+03	2.5E+04	9E-06	6E-07
TATB	6.76E+00	6	NA	NA	NA	NA	NA	NA	***2.2E+03***	***3.2E+04***	3E-03	2E-04
Tetrachlorodibenzofuran[2,3,7,8-]	5.60E-07	11	NA	NA	4.9E-04	2.4E-03	1E-03	2E-04	NA	NA	NA	NA
Tetrachlorodibenzofurans (Totals)	6.28E-07	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Inorganic Hazard Index							NA	NA			0.2	0.01
Organic Hazard Index							0.001	0.0002			0.005	0.003

Notes:
All data in mg/kg. Shaded Max/BV cells indicate the maximum>BV
Bolded NMSSL cells indicate the EPA RSL for an HQ of 1 is used because a NMSSL is not available
Italics – a surrogate is applied. See Section 1.2.3
If the maximum <BV, no further evaluation is performed
Cancer ratio = Maximum/Cancer-based NMSSL
HQ = Maximum/Noncancer-based NMSSL

Abbreviations:
BV – Background value
EPA – U.S. Environmental Protection Agency
HQ – Noncancer hazard quotient
Max – Maximum reported result
NA – Not available
NC – Noncancer
NMSSL – New Mexico soil screening level
Res - Residential
RSL – Regional Screening level

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Parameter Name	**Point 1 WST39-18-162832**		**Point 1 Dup WST39-18-162973**		**Point 2 WST39-18-162974**		**Point 3 WST39-18-162975**		**Point 4 WST39-18-162976**		**Point 5 WST39-18-162977**	
	Result (mg/kg)	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.52E-06	1	9.83E-06	1	4.57E-06	1	3.49E-06	1	5.01E-07	0	8.28E-07	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	9.01E-07	1	1.00E-06	1	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	7.21E-05	1	8.89E-05	1	3.58E-05	1	2.99E-05	1	1.96E-06	1	5.50E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	2.49E-06	1	2.73E-06	1	1.38E-06	1	9.97E-07	0	1.00E-06	0	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	0	1.00E-07	0	1.00E-07	0	9.97E-08	0	1.00E-07	0	1.00E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	3.65E-07	1	3.63E-07	1	2.01E-07	1	2.57E-07	1	1.05E-07	0	1.36E-07	1

Notes:
DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	Point 1 WST39-18-162832	Point 1 Dup WST39-18-162973	Point 2 WST39-18-162974	Point 3 WST39-18-162975	Point 4 WST39-18-162976	Point 5 WST39-18-162977
			TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	8.52E-08	9.83E-08	4.57E-08	3.49E-08	ND	8.28E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	9.01E-09	1.00E-08	ND	ND	ND	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	2.16E-08	2.67E-08	1.07E-08	8.97E-09	5.88E-10	1.65E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	7.47E-10	8.19E-10	4.14E-10	ND	ND	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	3.65E-08	3.63E-08	2.01E-08	2.57E-08	ND	1.36E-08
TEQ			**1.53E-07**	**1.72E-07**	**7.70E-08**	**6.96E-08**	**5.88E-10**	**2.35E-08**
NMED SL Residential =4.90E-05		**Risk Ratio =**	**3E-03**	**4E-03**	**2E-03**	**1E-03**	**1E-05**	**5E-04**
NMED SL Industrial =8.47E-03		**Risk Ratio =**	**2E-05**	**2 E-05**	**9E-06**	**8E-06**	**7E-08**	**3E-06**

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Parameter Name	Point 6 WST39-18-162978		Point 7 WST39-18-162979		Point 8 WST39-18-162980		Point 9 WST39-18-162981		Point 10 WST39-18-162982	
	Result (mg/kg)	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**	**Result (mg/kg)**	**DC**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.60E-06	1	5.86E-06	1	1.13E-06	1	6.07E-07	1	5.21E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	7.97E-07	1	2.21E-06	1	4.98E-07	0	4.98E-07	0	6.88E-07	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	5.49E-05	1	6.84E-05	1	9.66E-06	1	3.91E-06	1	4.10E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	2.51E-06	1	1.92E-05	1	9.97E-07	0	9.96E-07	0	1.18E-06	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1.00E-07	0	9.97E-08	0	9.97E-08	0	9.96E-08	0	9.97E-08	0
Tetrachlorodibenzofuran[2,3,7,8-]	1.87E-07	1	1.16E-07	0	1.44E-07	1	1.06E-07	1	5.50E-07	1

Notes:
DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	Point 6 WST39-18-162978	Point 7 WST39-18-162979	Point 8 WST39-18-162980	Point 9 WST39-18-162981	Point 10 WST39-18-162982
			TECi	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	8.60E-08	5.86E-08	1.13E-08	6.07E-09	5.21E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	7.97E-09	2.21E-08	ND	ND	6.88E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	1.65E-08	2.05E-08	2.90E-09	1.17E-09	1.23E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	7.53E-10	5.76E-09	ND	ND	3.54E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	1.87E-08	ND	1.44E-08	1.06E-08	5.50E-08
TEQ			**1.30E-07**	**1.07E-07**	**2.86E-08**	**1.78E-08**	**1.27E-07**
NMED SL Residential =	**5E-05**		**3E-03**	**2E-03**	**6E-04**	**4E-04**	**3E-03**
NMED SL Industrial =	**8E-03**		**2E-05**	**1E-05**	**3E-06**	**2E-06**	**1E-05**

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Parameter Name	Parameter Code	Point 11 WST39-18-162983		Point 12 WST39-18-162984	
		Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.17E-05	1	3.01E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	1.10E-06	1	4.96E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	0	4.96E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	9.57E-05	1	2.49E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	3.40E-06	1	9.93E-07	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	0	4.96E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	0	4.96E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	0	4.96E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.96E-08	0	9.93E-08	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	5.60E-07	1	3.75E-07	1

Notes:
DC- Detect code (1 = detected, 0 = not detected)

Table 2-3. Dioxin/Furan Data, Human Health TEFs, and Screening Results by Sample

Congener Name	CAS	TEF	Point 11 WST39-18-162983	Point 12 WST39-18-162984
			TECi	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	1.17E-07	3.01E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	1.10E-08	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	2.87E-08	7.47E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	1.02E-09	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	5.60E-08	3.75E-08
TEQ			**2.14E-07**	**7.51E-08**
NMED SL Residential	**5E-05**		**4E-03**	**2E-03**
NMED SL Industrial	**8E-03**		**3E-05**	**9E-06**

Notes: The TECi are summed in each column to obtain the TEQ. The TEQ is divided by the residential or the industrial SL for TCDD to obtain a risk ratio, shown directly under the TEQ. None of the TEQs exceeded the SLs.
All data in mg/kg

Table 3-1. Ecological Screening Evaluation

Parameter Name	**Maximum (mg/kg)**	**Number of Detects**	**Background**		**ESL and Risk Ratios**			
			BV (mg/kg)	**Max/ BV Ratio**	**Minimum NE ESL**	**Max/ NE ESL Ratio**	**Minimum LE ESL**	**Max/ LE ESL Ratio**
INORGANICS								
Calcium	7.16E+03	13	6120	1.2	NA	NA	NA	NA
Chromium	4.79E+01	13	19.3	2	2.30E+01	2 E+00	7.30E+01	7E-01
Copper	1.74E+02	13	14.7	12	1.40E+01	1E+01	4.30E+01	4E+00
Mercury	1.31E-01	7	0.1	1.3	1.30E-02	1E+01	1.30E-01	1E+00
Vanadium	4.83E+01	13	39.6	1.2	4.70E+00	1E+01	9.50E+00	5E+00
Zinc	6.25E+01	13	48.8	1.3	4.70E+01	1E+00	1.20E+02	5E-01
ORGANICS								
Acetone	3.05E-02	1	NA	NA	1.20E+00	3E-02	6.30E+00	5E-03
Benzoic Acid	4.83E-01	1	NA	NA	1.00E+00	5E-01	1.00E+01	5E-02
Benzyl Alcohol	1.65E+00	7	NA	NA	1.20E+02	1E-02	1.20E+03	1E-03
Butanone[2-]	2.89E-03	1	NA	NA	3.50E+02	8E-06	9.20E+02	3E-06
Butylbenzylphthalate	6.35E-02	2	NA	NA	9.00E+01	7E-04	9.00E+02	7E-05
Di-n-butylphthalate	1.00E-01	5	NA	NA	1.10E-02	9E+00	1.10E-01	9E-01
Fluoranthene	1.87E-02	1	NA	NA	1.00E+01	2E-03	2.30E+01	8E-04
HMX	6.66E+00	7	NA	NA	1.60E+01	4E-01	1.60E+02	4E-02
Pyrene	1.61E-02	1	NA	NA	1.00E+01	2E-03	2.00E+01	8E-04
TATB	6.76E+00	6	NA	NA	1.00E+01	1E+00	2.80E+01	2E-01
Hazard Index						**7E+01**		**2E+01**

Notes:
Shaded cells indicate the ratio > 0.3 for initial screening evaluation
Italics – a surrogate is used. See Section 1.2.3.
Only detected data and inorganics above background are reported.

Abbreviations:

BV – Background Value	*mg/kg – Milligram per Kilogram*
ESL – Ecological Screening Value	*LE – Low Effect*
Max– Maximum Exposure Point Concentration	*NE – No Effect*

Table 3-2. Ecological Risk Evaluation Using UCL95 EPCs for COPCs.

Name	**UCL95 (mg/kg)**	**UCL Type**	**Distribution**	**Minimum NE ESL (mg/kg)**	**UCL/ NE ESL Ratio**	**Minimum LE ESL (mg/kg)**	**UCL/ LE ESL Ratio**
Calcium	5458.00	95% Student's-t UCL	Normal	NV	NA	NV	NA
Chromium	23.24	95% Student's-t UCL	Normal	23	1	73	0.3
Copper	87.30	95% Student's-t UCL	Normal	14	6	43	2
Mercury	0.0519	95% KM (t) UCL	Normal	0.013	4	0	0.4
Vanadium	38.08	95% Student's-t UCL	Normal	5	8	9.50	4
Zinc	45.38	95% Student's-t UCL	Normal	47	1	120.00	0.4
Benzoic Acid	0.17	Median of Detect and RLs	NA, Detects<6	1	0.2	10.00	0.02
Di-n-butylphthalate	0.01	Median of Detect and RLs	NA, Detects<6	0.01	0.9	0.11	0.1
HMX	3.697	95% KM Bootstrap t UCL	Gamma	16	0.2	160.00	0.02
TATB	1.857	95% KM (t) UCL	Approx. Normal	10	0.2	28.00	0.1
Hazard Index (HI)					**22**		**7**

Notes:
Shaded cells represent HQs>1
HI is the sum of all HQs

Abbreviations:
ESL – Ecological Screening Level
HI – Hazard Index
LE – Low Effect
mg/kg – milligram per kilogram
NE – No Effect
UCL – Upper Confidence Limit

Table 3-3. Toxic Equivalency Factors (TEFs) Used for Calculating Ecological TCDD Equivalent Concentrations

Name	CAS	Mammalian TEF[a]	Avian TEF[b]
Chlorinated dibenzo-p-dioxins			
2,3,7,8-TCDD	1746-01-6	1	1
1,2,3,7,8-PeCDD	40321-76-4	1	1
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HpCDD	35822-46-9	0.01	0.001
OCDD	3268-87-9	0.0003	0.0001
Chlorinated dibenzofurans			
2,3,7,8-TCDF	51207-31-9	0.1	1
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1
2,3,4,7,8-PeCDF	57117-31-4	0.3	0.1
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	1
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01
OCDF	39001-02-0	0.0003	0.0001

[a] *EPA (2010a,b); WHO (2009)*
[b] *Van den Berg et al. (1998)*

Table 3-4. Dioxin-Furan TECi, TEQs, SLs, and Mammalian Risk Estimates by Sample

Congener Name	**CAS**	**Point 1 WST39-18-162832**	**Point 1 Dup WST39-18-162973**	**Point 2 WST39-18-162974**	**Point 3 WST39-18-162975**	**Point 4 WST39-18-162976**	**Point 5 WST39-18-162977**
		TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.52E-08	9.83E-08	4.57E-08	3.49E-08	ND	8.28E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	9.01E-09	1.00E-08	ND	ND	ND	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	2.16E-08	2.67E-08	1.07E-08	8.97E-09	5.88E-10	1.65E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	7.47E-10	8.19E-10	4.14E-10	ND	ND	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	3.65E-08	3.63E-08	2.01E-08	2.57E-08	ND	1.36E-08
TEQ		**1.53E-07**	**1.72E-07**	**7.70E-08**	**6.96E-08**	**5.88E-10**	**2.35E-08**
Mammalian No Effect ESL= 5.80E-07	**Risk Ratio=**	**3E-01**	**3E-01**	**1E-01**	**1E-01**	**1E-03**	**4E-02**
Mammalian Low Effect ESL= 3.80E-06	**Risk Ratio=**	**4E-02**	**5E-02**	**2E-02**	**2E-02**	**2E-04**	**6E-03**

Table 3-4. Dioxin-Furan TECi, TEQs, SLs, and Mammalian Risk Estimates by Sample

Congener Name	CAS	Point 6 WST39-18-162978	Point 7 WST39-18-162979	Point 8 WST39-18-162980	Point 9 WST39-18-162981	Point 10 WST39-18-162982	Point 11 WST39-18-162983	Point 12 WST39-18-162984
		TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.60E-08	5.86E-08	1.13E-08	6.07E-09	5.21E-08	1.17E-07	3.01E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	7.97E-09	2.21E-08	ND	ND	6.88E-09	1.10E-08	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	ND	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	1.65E-08	2.05E-08	2.90E-09	1.17E-09	1.23E-08	2.87E-08	7.47E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	7.53E-10	5.76E-09	ND	ND	3.54E-10	1.02E-09	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	ND	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	ND	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	ND	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	ND	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.87E-08	ND	1.44E-08	1.06E-08	5.50E-08	5.60E-08	3.75E-08
TEQ		**1.30E-07**	**1.07E-07**	**2.86E-08**	**1.78E-08**	**1.27E-07**	**2.14E-07**	**7.51E-08**
Mammalian No Effect ESL	**5.80E-07**	**2E-01**	**2E-01**	**5E-02**	**3E-02**	**2E-01**	**4E-01**	**1E-01**
Mammalian Low Effect ESL	**3.80E-06**	**3E-02**	**3E-02**	**8E-03**	**5E-03**	**3E-02**	**6E-02**	**2E-02**

Notes: The data and detection status were reported in Table 2-1 and 2-3. The TEFs for mammals are reported in Table 3-3.
The TECi are summed in each column to obtain the TEQ. The TEQ is divided by the NE and LE mammalian ESLs for TCDD to obtain a risk ratio, shown directly under the TEQ. Shaded cells indicate the ratio of the TEQ/SSL exceeds 1
The deer mouse ESLs are used in lieu of shrew ESLs as this area is not preferred shrew habitat
All data in mg/kg. DC= Detect Code = 1 is detected, 0 is not detected

Abbreviations:Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient

Table 3-5. Dioxin-Furan TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Congener Name	CAS	Point 1 WST39-18-162832	Point 1 Dup WST39-18-162973	Point 2 WST39-18-162974	Point 3 WST39-18-162975	Point 4 WST39-18-162976	Point 5 WST39-18-162977
		TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.52E-09	9.83E-09	4.57E-09	3.49E-09	ND	8.28E-10
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	9.01E-09	1.00E-08	ND	ND	ND	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	7.21E-09	8.89E-09	3.58E-09	2.99E-09	1.96E-10	5.50E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	2.49E-10	2.73E-10	1.38E-10	ND	ND	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	3.65E-07	3.63E-07	2.01E-07	2.57E-07	ND	1.36E-07
TEQ		**3.90E-07**	**3.92E-07**	**2.09E-07**	**2.63E-07**	**1.96E-10**	**1.37E-07**
Avian No Effect ESL = 4.1 E-06	**Risk Ratio=**	**1E-01**	**1E-01**	**5E-02**	**6E-02**	**4E-05**	**3E-02**

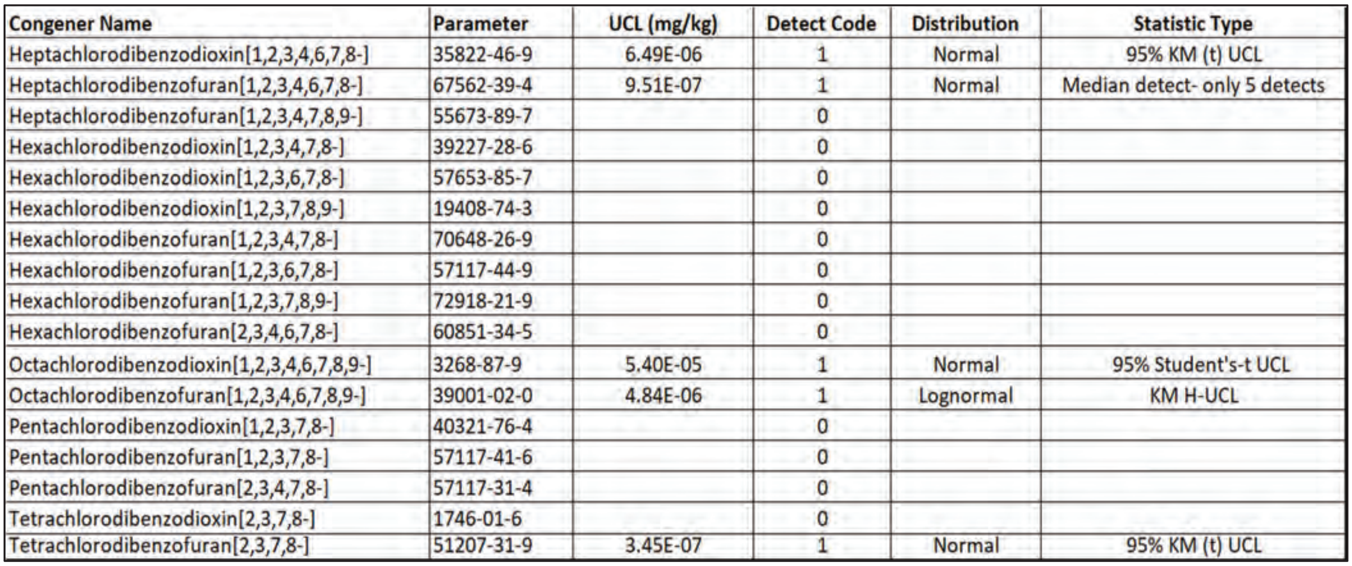
Table 3-5. Dioxin-Furan TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Congener Name	CAS	Point 6 WST39-18-162978	Point 7 WST39-18-162979	Point 8 WST39-18-162980	Point 9 WST39-18-162981	Point 10 WST39-18-162982	Point 11 WST39-18-162983	Point 12 WST39-18-162984
		TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	8.60E-09	5.86E-09	1.13E-09	6.07E-10	5.21E-09	1.17E-08	3.01E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	7.97E-09	2.21E-08	ND	ND	6.88E-09	1.10E-08	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	ND	ND	ND	ND	ND	ND	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	ND	ND	ND	ND	ND	ND	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	5.49E-09	6.84E-09	9.66E-10	3.91E-10	4.10E-09	9.57E-09	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	2.51E-10	1.92E-09	ND	ND	1.18E-10	3.40E-10	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	ND	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	ND	ND	ND	ND	ND	ND	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	ND	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	ND	ND	ND	ND	ND	ND	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.87E-07	ND	1.44E-07	1.06E-07	5.50E-07	5.60E-07	3.75E-07
TEQ		**2.09E-07**	**3.67E-08**	**1.46E-07**	**1.07E-07**	**5.66E-07**	**5.93E-07**	**3.81E-07**
Avian No Effect ESL = 4.1E-06		**5E-02**	**9E-03**	**4E-02**	**3E-02**	**1E-01**	**1E-01**	**9E-02**

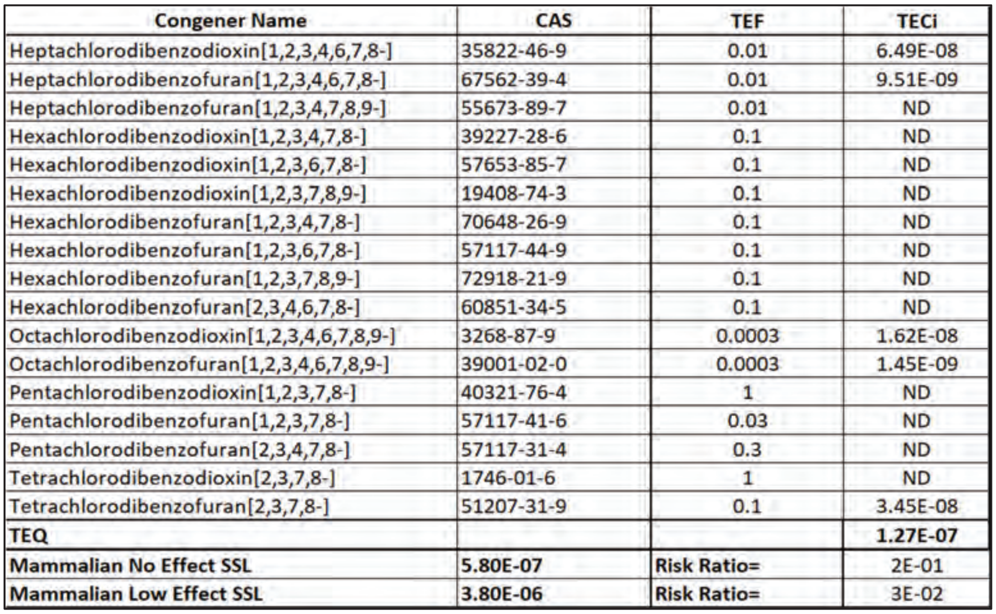
Notes: The data and detection status were reported in Table 2-1 and 2-3. The TEFs for birds are reported in Table 3-3.
The TECi are summed in each column to obtain the TEQ. The TEQ is divided by the residential or the industrial SSLs for TCDD to obtain a risk ratio, shown directly under the TEQ. Shaded cells indicate the ratio of the TEQ/SSL exceeds 1. See Table 3-4 for sample-specific concentrations.
All data in mg/kg.
An avian LE ESL was not reviewed because dioxin/furan risks for the NE ESL were less than 0.3.

Abbreviations:
Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient

Table 3-6. UCL Calculations for Dioxin/Furans for Mammals



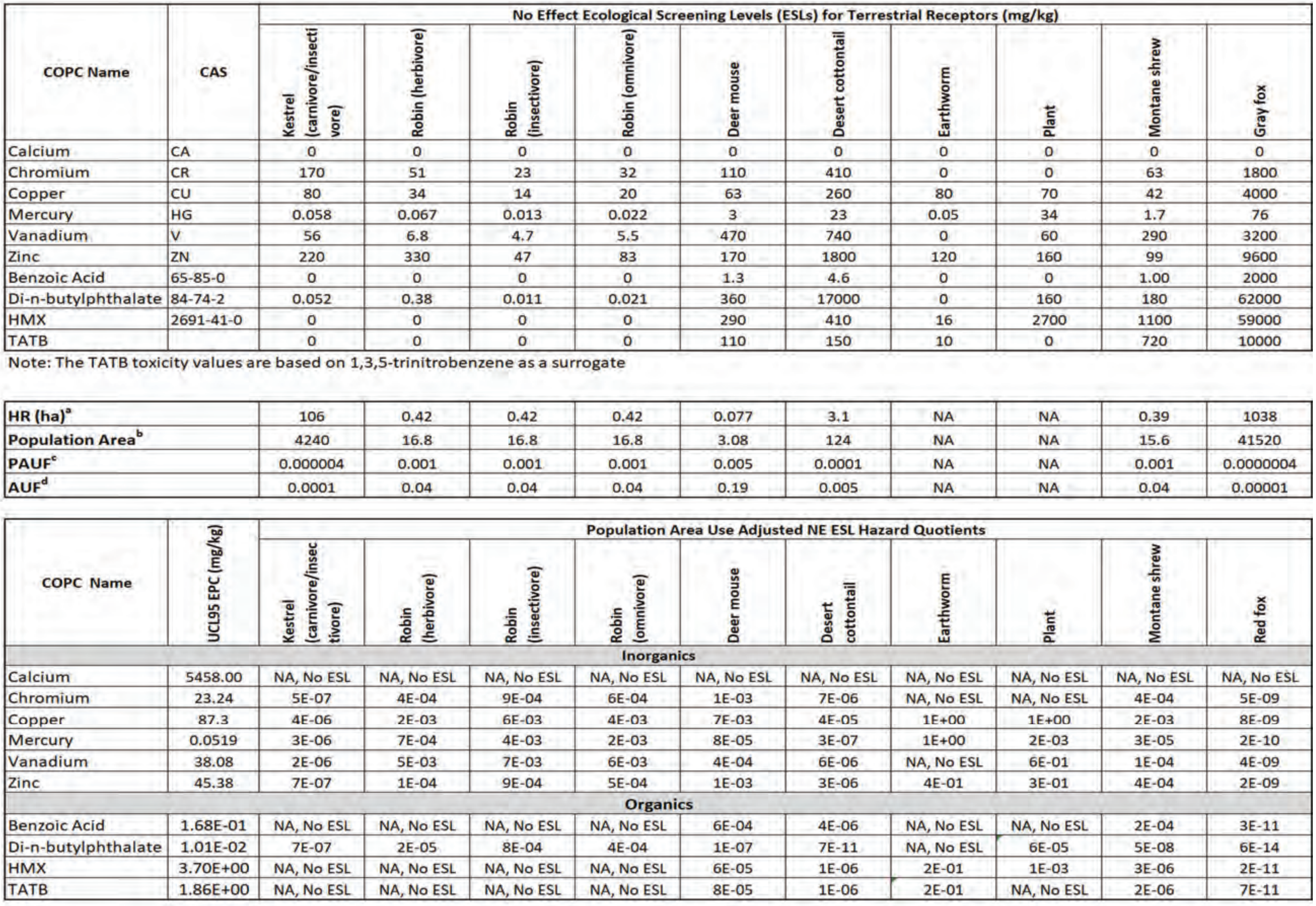
Congener Name	Parameter	UCL (mg/kg)	Detect Code	Distribution	Statistic Type
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	6.49E-06	1	Normal	95% KM (t) UCL
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	9.51E-07	1	Normal	Median detect- only 5 detects
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7		0		
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6		0		
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7		0		
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3		0		
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9		0		
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9		0		
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9		0		
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5		0		
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	5.40E-05	1	Normal	95% Student's-t UCL
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	4.84E-06	1	Lognormal	KM H-UCL
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4		0		
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6		0		
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4		0		
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6		0		
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	3.45E-07	1	Normal	95% KM (t) UCL



Congener Name	CAS	TEF	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	6.49E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	9.51E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	1.62E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	1.45E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	3.45E-08
TEQ			**1.27E-07**
Mammalian No Effect SSL	**5.80E-07**	**Risk Ratio=**	2E-01
Mammalian Low Effect SSL	**3.80E-06**	**Risk Ratio=**	3E-02

Note: the UCL is multiplied by the mammalian TEF to obtain the TECi. The TECi are summed to obtain the TEQ. The TEQ is divided by the ESL for TCDD to obtain a risk ratio. The risk ratios are less than 1, indicating no risk to mammals.

Table 3-7. Area Use Factors for TA 39-6 and Risks based on the NE ESL



COPC Name	CAS	No Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)									
		Kestrel (carnivore/insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Gray fox
Calcium	CA	0	0	0	0	0	0	0	0	0	0
Chromium	CR	170	51	23	32	110	410	0	0	63	1800
Copper	CU	80	34	14	20	63	260	80	70	42	4000
Mercury	HG	0.058	0.067	0.013	0.022	3	23	0.05	34	1.7	76
Vanadium	V	56	6.8	4.7	5.5	470	740	0	60	290	3200
Zinc	ZN	220	330	47	83	170	1800	120	160	99	9600
Benzoic Acid	65-85-0	0	0	0	0	1.3	4.6	0	0	1.00	2000
Di-n-butylphthalate	84-74-2	0.052	0.38	0.011	0.021	360	17000	0	160	180	62000
HMX	2691-41-0	0	0	0	0	290	410	16	2700	1100	59000
TATB		0	0	0	0	110	150	10	0	720	10000

Note: The TATB toxicity values are based on 1,3,5-trinitrobenzene as a surrogate

HR (ha)[a]	106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]	4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]	0.000004	0.001	0.001	0.001	0.005	0.0001	NA	NA	0.001	0.0000004
AUF[d]	0.0001	0.04	0.04	0.04	0.19	0.005	NA	NA	0.04	0.00001

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted NE ESL Hazard Quotients									
		Kestrel (carnivore/insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Red fox
Inorganics											
Calcium	5458.00	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL
Chromium	23.24	5E-07	4E-04	9E-04	6E-04	1E-03	7E-06	NA, No ESL	NA, No ESL	4E-04	5E-09
Copper	87.3	4E-06	2E-03	6E-03	4E-03	7E-03	4E-05	1E+00	1E+00	2E-03	8E-09
Mercury	0.0519	3E-06	7E-04	4E-03	2E-03	8E-05	3E-07	1E+00	2E-03	3E-05	2E-10
Vanadium	38.08	2E-06	5E-03	7E-03	6E-03	4E-04	6E-06	NA, No ESL	6E-01	1E-04	4E-09
Zinc	45.38	7E-07	1E-04	9E-04	5E-04	1E-03	3E-06	4E-01	3E-01	4E-04	2E-09
Organics											
Benzoic Acid	1.68E-01	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	6E-04	4E-06	NA, No ESL	NA, No ESL	2E-04	3E-11
Di-n-butylphthalate	1.01E-02	7E-07	2E-05	8E-04	4E-04	1E-07	7E-11	NA, No ESL	6E-05	5E-08	6E-14
HMX	3.70E+00	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	6E-05	1E-06	2E-01	1E-03	3E-06	2E-11
TATB	1.86E+00	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	8E-05	1E-06	2E-01	NA, No ESL	2E-06	7E-11

Table 3-8. Area Use Factors for TA 39-6 and Risks based on the LE ESL.

COPC Name	**CAS**	**Low Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)**									
		Kestrel (carnivore/insectivore)	**Robin (herbivore)**	**Robin (insectivore)**	**Robin (omnivore)**	**Deer mouse**	**Desert cottontail**	**Earthworm**	**Plant**	**Montane shrew**	**Gray fox**
Calcium	CA	0	0	0	0	0	0	0	0	0	0
Chromium	CR	560	160.00	73	100	11000	41000	0	0	6300	180000
Copper	CU	240	100.00	43	60	100	430	530	490	70	6700
Mercury	HG	0.58	0.67	0.13	0.22	30	230	0.5	64	17	760
Vanadium	V	110	13.00	9.5	11	1000	1500	0	80	610	6900
Zinc	ZN	590	120.00	120	220	1700	18000	930	810	980	94000
Benzoic Acid	65-85-0	0	0.00	0	0	13	46	0	0	10	20000
Di-n-butylphthalate	84-74-2	0.52	3.80	0.11	0.21	860	40000	0	600	450	140000
HMX	2691-41-0	0	0	0	0	790	1100	160	3500	2900	150000
TATB		0	0	0	0	1100	1500	28	0	7200	100000

Note: The TATB toxicity values are based on 1,3,5-trinitrobenzene as a surrogate

HR (ha)[a]	106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]	4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]	0.00002	0.005	0.005	0.005	0.03	0.001	NA	NA	0.005	0.000002
AUF[d]	0.0008	0.19	0.19	0.19	1.00	0.03	NA	NA	0.21	0.0001

COPC Name	**UCL95 EPC (mg/kg)**	**Population Area Use Adjusted LE ESL Hazard Quotients**									
		Kestrel (carnivore/insectivore)	**Robin (herbivore)**	**Robin (insectivore)**	**Robin (omnivore)**	**Deer mouse**	**Desert cottontail**	**Earthworm**	**Plant**	**Montane shrew**	**Red fox**
Inorganics											
Calcium	5458	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL
Chromium	23.24	8E-07	7E-04	2E-03	1E-03	5E-05	4E-07	NA, No ESL	NA, No ESL	2E-05	2E-10
Copper	87.3	7E-06	4E-03	1E-02	7E-03	2E-02	1E-04	2E-01	2E-01	6E-03	3E-08
Mercury	0.0519	2E-06	4E-04	2E-03	1E-03	4E-05	1E-07	1E-01	8E-04	2E-05	1E-10
Vanadium	38.08	7E-06	1E-02	2E-02	2E-02	1E-03	2E-05	NA, No ESL	5E-01	3E-04	1E-08
Zinc	45.38	1E-06	2E-03	2E-03	1E-03	7E-04	2E-06	5E-02	6E-02	2E-04	9E-10
Organics											
Benzoic Acid	1.68E-01	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	3E-04	2E-06	NA, No ESL	NA, No ESL	9E-05	2E-11
Di-n-butylphthalate	1.01E-02	4E-07	1E-05	4E-04	2E-04	3E-07	2E-10	NA, No ESL	2E-05	1E-07	1E-13
HMX	3.70E+00	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	1E-04	2E-06	2E-02	1E-03	7E-06	5E-11
TATB	1.86E+00	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	4E-05	8E-07	7E-02	NA, No ESL	1E-06	4E-11

Notes:

Area of Site (ha): 0.08

NA - Not applicable
ESLs - Ecological screening level
PAUF - Population area use factor
AUF - Area use factor
HR - Home range

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-9. Hazard Index Analysis by Receptor for Exposure Adjusted with Area Use Factors

Hazard Index	**Kestrel (carnivore/insectivore)**	**Robin (herbivore)**	**Robin (insectivore)**	**Robin (omnivore)**	**Deer mouse**	**Desert cottontail**	**Earthworm**	**Plant**	**Montane shrew**	**Red fox**
Hazard Index for NE ESL	1E-05	9E-03	2E-02	1E-02	1E-02	6E-05	3E+00	2E+00	3E-03	2E-08
Hazard Index for LE ESL	2E-05	2E-02	3E-02	3E-02	3E-02	2E-04	4E-01	7E-01	7E-03	4E-08

Figures

Figure 1-1. Location of TA-39 at the Los Alamos National Laboratory

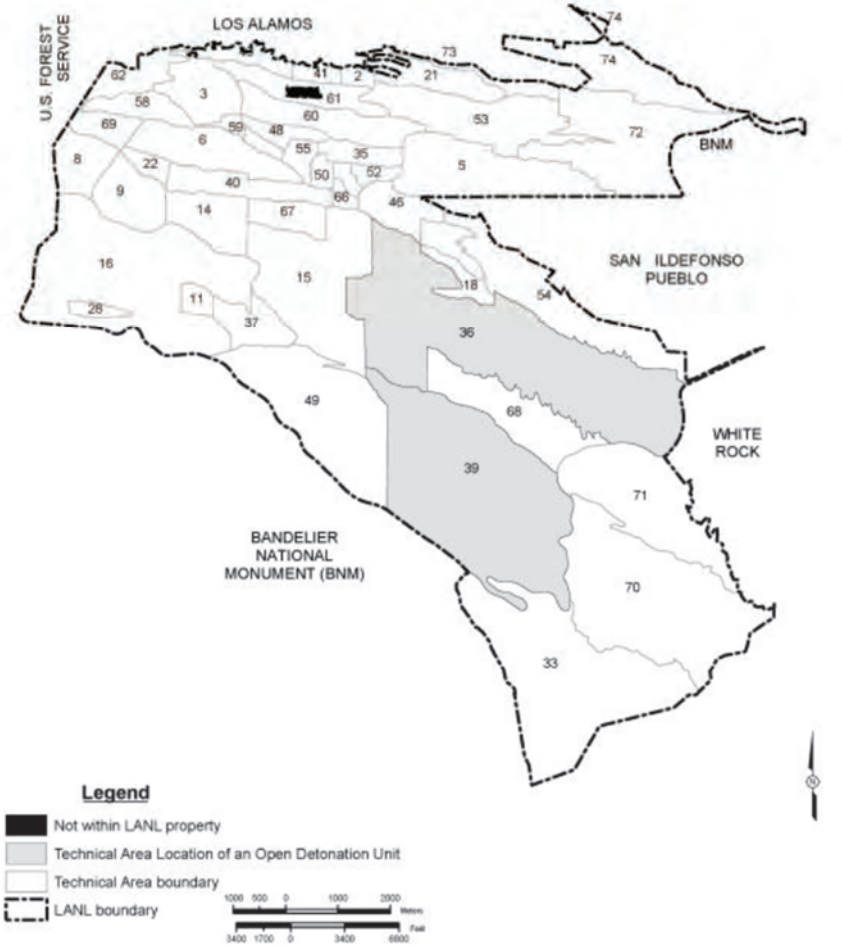
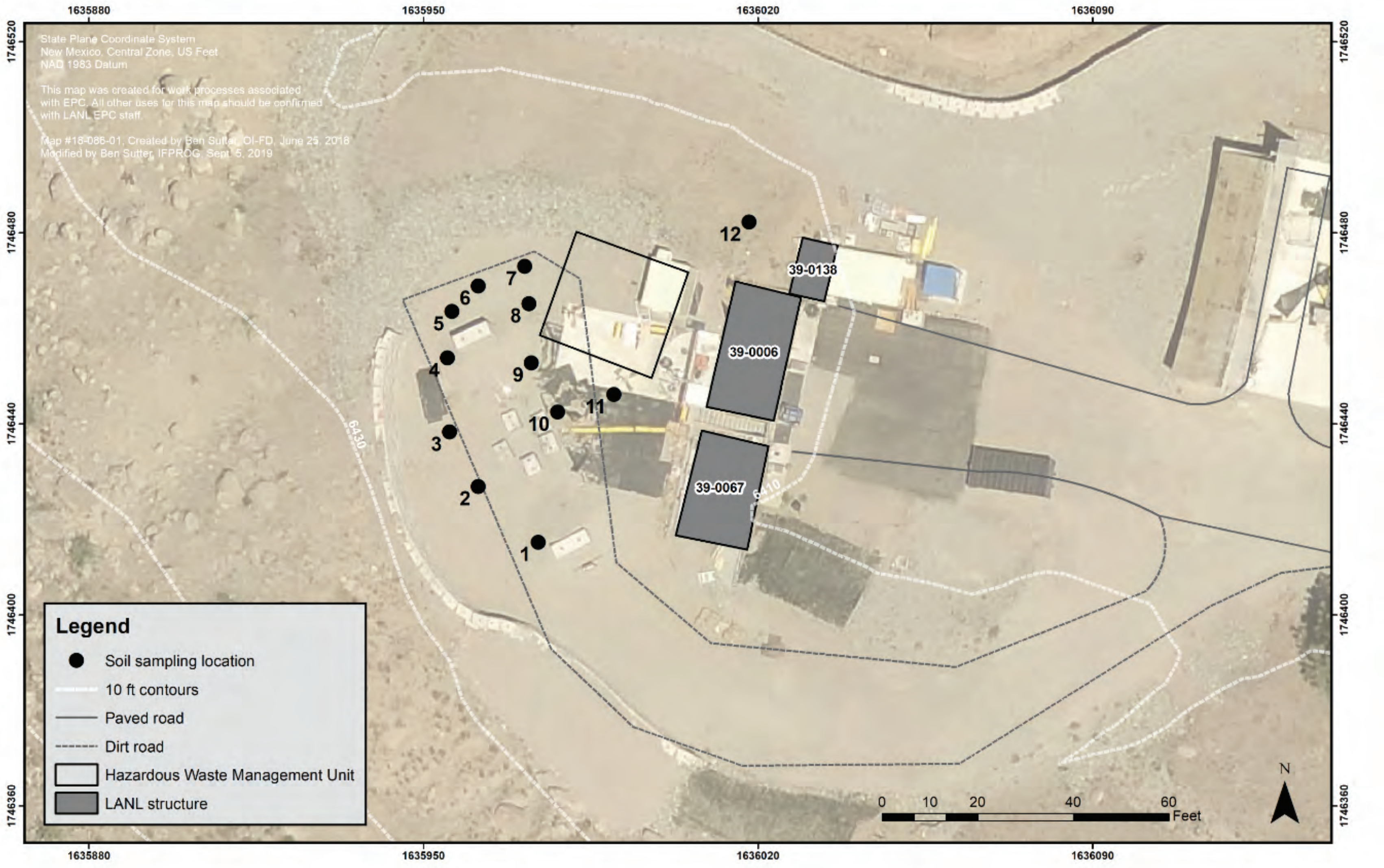


Figure 1-2. Sample Location Map for TA-39-6 OD Area

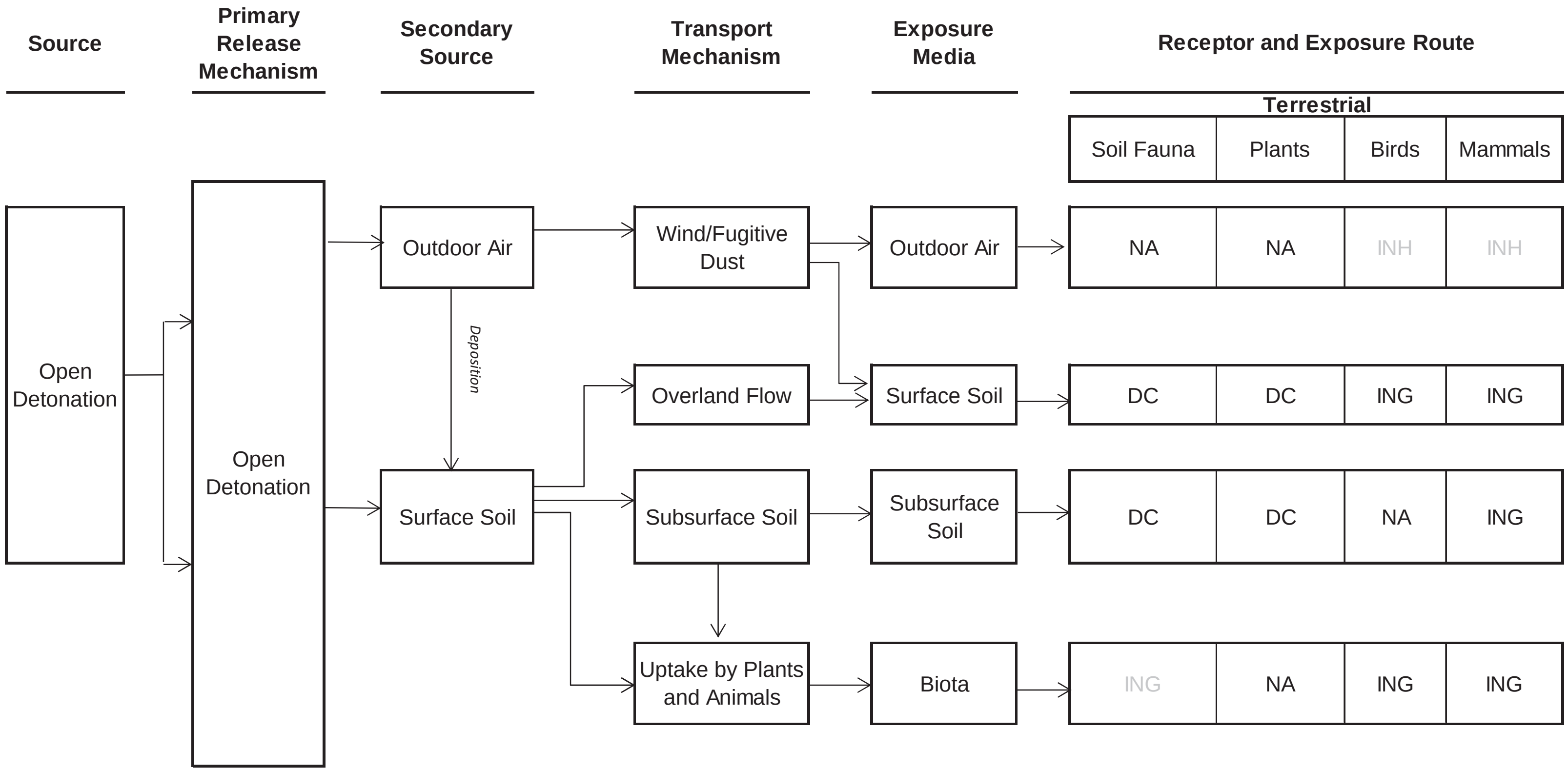


State Plane Coordinate System
New Mexico, Central Zone, US Feet
NAD 1983 Datum

This map was created for work processes associated with EPC. All other uses for this map should be confirmed with LANL EPC staff.

Map #18-086-01, Created by Ben Sutter, OI-FD, June 25, 2018
Modified by Ben Sutter, IFPROG, Sept. 5, 2019

Figure 3-1. Conceptual Site Exposure Model for the ERA



Abbreviations

DC	Direct contact; applies to receptors for which toxic effects are addressed by exposure concentration and not dose
ING	Ingestion; typically quantified as dose for birds and mammals only
INH	Inhalation; recognized to occur, but not typically quantified as standard practice with the exception of evaluating burrow air exposure by burrowing mammals
NA	Pathway considered incomplete; not applicable

Notes:

Grayed text indicates pathways are recognized to potentially exist but are not quantified. Inhalation is considered minimal relative to dietary exposure. Ingestion by invertebrates is not typically quantified due to absence of accurate exposure parameters.

Attachment A. ProUCL Output for Upper Confidence Limit Calculations

```
UCL Statistics for Data Sets with Non-Detects
User Selected Options
Date/Time of Computation                          ProUCL 5.18/23/2019 3:00:31 PM
From File                                         WorkSheet.xls
Full Precision                                    OFF
Confidence Coefficient                                95%
Number of Bootstrap Operations                        2000
Ca
General Statistics
Total Number of Observations                      12        Number of Distinct Observations                 12
                                                            Number of Missing Observations                   1
Minimum                                          588        Mean                                          4567
Maximum                                         6780        Median                                        4925
SD                                              1720        Std. Error of Mean                           496.6
Coefficient of Variation                       0.377        Skewness                                    -1.071
Normal GOF Test
Shapiro Wilk Test Statistic                    0.921        Shapiro Wilk GOF Test
                                                            Data appear Normal at 5% Significance
5% Shapiro Wilk Critical Value                 0.859        Level
Lilliefors Test Statistic                       0.15        Lilliefors GOF Test
                                                            Data appear Normal at 5% Significance
5% Lilliefors Critical Value                   0.243        Level
Data appear Normal at 5% Significance Level
Assuming Normal Distribution
  95% Normal UCL                                              95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                           5458          95% Adjusted-CLT UCL (Chen-1995)            5219
                                                              95% Modified-t UCL (Johnson-1978)           5433
Gamma GOF Test
A-D Test Statistic                             0.968        Anderson-Darling Gamma GOF Test
                                                            Data Not Gamma Distributed at 5%
5% A-D Critical Value                          0.736        Significance Level
K-S Test Statistic                             0.198        Kolmogorov-Smirnov Gamma GOF Test
                                                            Detected data appear Gamma Distributed at 5%
5% K-S Critical Value                          0.246        Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level
Gamma Statistics
k hat (MLE)                                    4.013        k star (bias corrected MLE)                  3.065
Theta hat (MLE)                                 1138        Theta star (bias corrected MLE)               1490
nu hat (MLE)                                   96.31        nu star (bias corrected)                     73.57
MLE Mean (bias corrected)                       4567        MLE Sd (bias corrected)                       2608
                                                            Approximate Chi Square Value (0.05)          54.81
Adjusted Level of Significance                 0.029        Adjusted Chi Square Value                    52.35
Assuming Gamma Distribution
                                                              95% Adjusted Gamma UCL (use when
  95% Approximate Gamma UCL (use when n>=50))   6129        n<50)                                         6417
Lognormal GOF Test
Shapiro Wilk Test Statistic                    0.687        Shapiro Wilk Lognormal GOF Test
                                                            Data Not Lognormal at 5% Significance
5% Shapiro Wilk Critical Value                 0.859        Level
Lilliefors Test Statistic                      0.249        Lilliefors Lognormal GOF Test
                                                            Data Not Lognormal at 5% Significance
5% Lilliefors Critical Value                   0.243        Level
Data Not Lognormal at 5% Significance Level
Lognormal Statistics
Minimum of Logged Data                         6.377        Mean of logged Data                          8.297
Maximum of Logged Data                         8.822        SD of logged Data                            0.657
Assuming Lognormal Distribution
  95% H-UCL                                     7929          90% Chebyshev (MVUE) UCL                    7752
  95% Chebyshev (MVUE) UCL                      9056         97.5% Chebyshev (MVUE) UCL                  10866
  99% Chebyshev (MVUE) UCL                     14420
Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level
Nonparametric Distribution Free UCLs
  95% CLT UCL                                   5383          95% Jackknife UCL                           5458
  95% Standard Bootstrap UCL                    5331          95% Bootstrap-t UCL                         5303
  95% Hall's Bootstrap UCL                      5263          95% Percentile Bootstrap UCL                5309
  95% BCA Bootstrap UCL                         5221
```

90% Chebyshev(Mean, Sd) UCL	6056	95% Chebyshev(Mean, Sd) UCL	6731
97.5% Chebyshev(Mean, Sd) UCL	7668	99% Chebyshev(Mean, Sd) UCL	9508

Suggested UCL to Use

95% Student's-t UCL	5458		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

Cr

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	1
Minimum	3.22	Mean	16.91
Maximum	47.9	Median	12.25
SD	12.21	Std. Error of Mean	3.525
Coefficient of Variation	0.722	Skewness	1.746

Normal GOF Test

Shapiro Wilk Test Statistic	0.818	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.232	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	2.32E+01	95% Adjusted-CLT UCL (Chen-1995)	24.61
		95% Modified-t UCL (Johnson-1978)	23.54

Gamma GOF Test

A-D Test Statistic	0.425	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.184	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.248	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.542	k star (bias corrected MLE)	1.962
Theta hat (MLE)	6.652	Theta star (bias corrected MLE)	8.618
nu hat (MLE)	6.10E+01	nu star (bias corrected)	47.09
MLE Mean (bias corrected)	16.91	MLE Sd (bias corrected)	12.07
		Approximate Chi Square Value (0.05)	32.34
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	30.49

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	24.62	95% Adjusted Gamma UCL (use when n<50)	26.12

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.952	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.184	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	2.43E-01	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.169	Mean of logged Data	2.618
Maximum of Logged Data	3.869	SD of logged Data	0.684

Assuming Lognormal Distribution

95% H-UCL	28.39	90% Chebyshev (MVUE) UCL	27.39
95% Chebyshev (MVUE) UCL	32.12	97.5% Chebyshev (MVUE) UCL	38.69
99% Chebyshev (MVUE) UCL	51.6		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	22.71	95% Jackknife UCL	23.24
95% Standard Bootstrap UCL	22.47	95% Bootstrap-t UCL	29.12
95% Hall's Bootstrap UCL	55.27	95% Percentile Bootstrap UCL	23.07
95% BCA Bootstrap UCL	24.39		
90% Chebyshev(Mean, Sd) UCL	27.49	95% Chebyshev(Mean, Sd) UCL	32.28

97.5% Chebyshev(Mean, Sd) UCL	38.92	99% Chebyshev(Mean, Sd) UCL	51.99

Suggested UCL to Use

95% Student's-t UCL	23.24

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Cu

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	1
Minimum	4.92	Mean	59.28
Maximum	174	Median	46.18
SD	54.05	Std. Error of Mean	15.6
Coefficient of Variation	0.912	Skewness	1.445

Normal GOF Test

Shapiro Wilk Test Statistic	0.813	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.227	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	8.73E+01	95% Adjusted-CLT UCL (Chen-1995)	91.9
		95% Modified-t UCL (Johnson-1978)	88.39

Gamma GOF Test

A-D Test Statistic	0.255	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.748	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.125	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.25	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.408	k star (bias corrected MLE)	1.111
Theta hat (MLE)	42.12	Theta star (bias corrected MLE)	53.35
nu hat (MLE)	33.78	nu star (bias corrected)	26.67
MLE Mean (bias corrected)	5.93E+01	MLE Sd (bias corrected)	56.24
		Approximate Chi Square Value (0.05)	15.9
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	14.64

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	99.46	95% Adjusted Gamma UCL (use when n<50)	108

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.964	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.11	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.593	Mean of logged Data	3.687
Maximum of Logged Data	5.159	SD of logged Data	0.996

Assuming Lognormal Distribution

95% H-UCL	1.57E+02	90% Chebyshev (MVUE) UCL	119.1
95% Chebyshev (MVUE) UCL	145	97.5% Chebyshev (MVUE) UCL	180.9
99% Chebyshev (MVUE) UCL	251.5		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	84.95	95% Jackknife UCL	87.3
95% Standard Bootstrap UCL	83.64	95% Bootstrap-t UCL	111.3
95% Hall's Bootstrap UCL	247.7	95% Percentile Bootstrap UCL	85.08
95% BCA Bootstrap UCL	90.62		
90% Chebyshev(Mean, Sd) UCL	106.1	95% Chebyshev(Mean, Sd) UCL	127.3
97.5% Chebyshev(Mean, Sd) UCL	156.7	99% Chebyshev(Mean, Sd) UCL	214.5

Suggested UCL to Use

95% Student's-t UCL	8.73E+01

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Hg

General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	1
Number of Detects	6	Number of Non-Detects	6
Number of Distinct Detects	6	Number of Distinct Non-Detects	5
Minimum Detect	0.00507	Minimum Non-Detect	0.00355
Maximum Detect	0.131	Maximum Non-Detect	0.0039
Variance Detects	0.00254	Percent Non-Detects	50%
Mean Detects	0.0536	SD Detects	0.0504
Median Detects	0.038	CV Detects	0.94
Skewness Detects	0.751	Kurtosis Detects	-1.048
Mean of Logged Detects	-3.449	SD of Logged Detects	1.241

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.895	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.253	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0286	KM Standard Error of Mean	0.013
KM SD	0.041	95% KM (BCA) UCL	0.0516
95% KM (t) UCL	0.0519	95% KM (Percentile Bootstrap) UCL	0.0495
95% KM (z) UCL	0.0499	95% KM Bootstrap t UCL	0.0722
90% KM Chebyshev UCL	0.0675	95% KM Chebyshev UCL	0.0851
97.5% KM Chebyshev UCL	0.11	99% KM Chebyshev UCL	0.158

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.262	Anderson-Darling GOF Test	
5% A-D Critical Value	0.714	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.218	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.34	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.094	k star (bias corrected MLE)	0.658
Theta hat (MLE)	0.049	Theta star (bias corrected MLE)	0.0814
nu hat (MLE)	13.13	nu star (bias corrected)	7.898
Mean (detects)	0.0536		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.00507	Mean	0.0318
Maximum	0.131	Median	0.01
SD	0.0409	CV	1.286
k hat (MLE)	0.998	k star (bias corrected MLE)	0.804
Theta hat (MLE)	0.0319	Theta star (bias corrected MLE)	0.0395
nu hat (MLE)	23.96	nu star (bias corrected)	19.3
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (19.30, α)	10.34	Adjusted Chi Square Value (19.30, β)	9.35
95% Gamma Approximate UCL (use when n>=50)	0.0594	95% Gamma Adjusted UCL (use when n<50)	0.0656

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.0286	SD (KM)	0.041
Variance (KM)	0.00168	SE of Mean (KM)	0.013
k hat (KM)	0.485	k star (KM)	0.419
nu hat (KM)	11.64	nu star (KM)	10.06
theta hat (KM)	0.0589	theta star (KM)	0.0681
80% gamma percentile (KM)	0.0463	90% gamma percentile (KM)	0.08
95% gamma percentile (KM)	0.117	99% gamma percentile (KM)	0.209

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (10.06, α)	3.981	Adjusted Chi Square Value (10.06, β)	3.418

95% Gamma Approximate KM-UCL (use when n>=50)	0.0722	95% Gamma Adjusted KM-UCL (use when n<50)	0.0841

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.946	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.18	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.0273	Mean in Log Scale	-5.232
SD in Original Scale	0.0437	SD in Log Scale	2.062
95% t UCL (assumes normality of ROS data)	0.0499	95% Percentile Bootstrap UCL	0.0491
95% BCA Bootstrap UCL	0.0536	95% Bootstrap t UCL	0.0775
95% H-UCL (Log ROS)	1.064		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-4.545	KM Geo Mean	0.0106
KM SD (logged)	1.358	95% Critical H Value (KM-Log)	3.603
KM Standard Error of Mean (logged)	0.429	95% H-UCL (KM -Log)	0.117
KM SD (logged)	1.358	95% Critical H Value (KM-Log)	3.603
KM Standard Error of Mean (logged)	0.429		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0277	Mean in Log Scale	-4.866
SD in Original Scale	0.0434	SD in Log Scale	1.701
95% t UCL (Assumes normality)	0.0502	95% H-Stat UCL	0.299

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	0.0519

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

V

General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	1
Minimum	11	Mean	32.14
Maximum	48	Median	30
SD	11.46	Std. Error of Mean	3.308
Coefficient of Variation	0.357	Skewness	-0.104

Normal GOF Test

Shapiro Wilk Test Statistic	0.944	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.162	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	38.08	95% Adjusted-CLT UCL (Chen-1995)	37.47
		95% Modified-t UCL (Johnson-1978)	38.06

Gamma GOF Test

A-D Test Statistic	0.344	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.161	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.246	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.238	k star (bias corrected MLE)	5.484
Theta hat (MLE)	4.44	Theta star (bias corrected MLE)	5.861
nu hat (MLE)	173.7	nu star (bias corrected)	131.6
MLE Mean (bias corrected)	32.14	MLE Sd (bias corrected)	13.72
		Approximate Chi Square Value (0.05)	106.1

```
Adjusted Level of Significance                          0.029   Adjusted Chi Square Value                          102.6
Assuming Gamma Distribution
                                                                  95% Adjusted Gamma UCL (use when
  95% Approximate Gamma UCL (use when n>=50))           39.86   n<50)                                              41.22
Lognormal GOF Test
Shapiro Wilk Test Statistic                             0.898   Shapiro Wilk Lognormal GOF Test
                                                                Data appear Lognormal at 5% Significance
5% Shapiro Wilk Critical Value                          0.859   Level
Lilliefors Test Statistic                               0.147   Lilliefors Lognormal GOF Test
                                                                Data appear Lognormal at 5% Significance
5% Lilliefors Critical Value                            0.243   Level
Data appear Lognormal at 5% Significance Level
Lognormal Statistics
Minimum of Logged Data                                  2.398   Mean of logged Data                                3.399
Maximum of Logged Data                                  3.871   SD of logged Data                                  0.418
Assuming Lognormal Distribution
  95% H-UCL                                             42.31     90% Chebyshev (MVUE) UCL                         44.38
  95% Chebyshev (MVUE) UCL                               49.8    97.5% Chebyshev (MVUE) UCL                        57.31
  99% Chebyshev (MVUE) UCL                              72.08
Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level
Nonparametric Distribution Free UCLs
  95% CLT UCL                                           37.58     95% Jackknife UCL                                38.08
  95% Standard Bootstrap UCL                            37.43     95% Bootstrap-t UCL                                 38
  95% Hall's Bootstrap UCL                              37.43     95% Percentile Bootstrap UCL                     37.33
  95% BCA Bootstrap UCL                                 37.08
  90% Chebyshev(Mean, Sd) UCL                           42.06     95% Chebyshev(Mean, Sd) UCL                      46.55
 97.5% Chebyshev(Mean, Sd) UCL                          52.79     99% Chebyshev(Mean, Sd) UCL                      65.05
Suggested UCL to Use
95% Student's-t UCL                                     38.08
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not
be
reliable.  Chen's and Johnson's methods provide adjustments for positvely skewed data sets.
Zn
General Statistics
Total Number of Observations                               12   Number of Distinct Observations                       12
                                                                Number of Missing Observations                         1
Minimum                                                  24.4   Mean                                               39.19
Maximum                                                  62.5   Median                                             37.55
SD                                                      11.94   Std. Error of Mean                                 3.447
Coefficient of Variation                                0.305   Skewness                                           0.723
Normal GOF Test
Shapiro Wilk Test Statistic                             0.933   Shapiro Wilk GOF Test
                                                                Data appear Normal at 5% Significance
5% Shapiro Wilk Critical Value                          0.859   Level
Lilliefors Test Statistic                               0.156   Lilliefors GOF Test
                                                                Data appear Normal at 5% Significance
5% Lilliefors Critical Value                            0.243   Level
Data appear Normal at 5% Significance Level
Assuming Normal Distribution
  95% Normal UCL                                                  95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                                   45.38     95% Adjusted-CLT UCL (Chen-1995)                 45.62
                                                                  95% Modified-t UCL (Johnson-1978)                 45.5

Gamma GOF Test
A-D Test Statistic                                      0.234   Anderson-Darling Gamma GOF Test
                                                                Detected data appear Gamma Distributed at 5%
5% A-D Critical Value                                   0.731   Significance Level
K-S Test Statistic                                      0.118   Kolmogorov-Smirnov Gamma GOF Test
                                                                Detected data appear Gamma Distributed at 5%
5% K-S Critical Value                                   0.245   Significance Level
Detected data appear Gamma Distributed at 5% Significance Level
Gamma Statistics
k hat (MLE)                                             12.31   k star (bias corrected MLE)                         9.29
Theta hat (MLE)                                         3.183   Theta star (bias corrected MLE)                    4.218
nu hat (MLE)                                            295.5   nu star (bias corrected)                             223
```

MLE Mean (bias corrected)	39.19	MLE Sd (bias corrected)	12.86
		Approximate Chi Square Value (0.05)	189.4
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	184.7
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	46.13	95% Adjusted Gamma UCL (use when n<50)	47.31
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.961	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.101	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	3.195	Mean of logged Data	3.627
Maximum of Logged Data	4.135	SD of logged Data	0.298
Assuming Lognormal Distribution			
95% H-UCL	46.76	90% Chebyshev (MVUE) UCL	49.38
95% Chebyshev (MVUE) UCL	54.01	97.5% Chebyshev (MVUE) UCL	60.43
99% Chebyshev (MVUE) UCL	73.05		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	44.86	95% Jackknife UCL	45.38
95% Standard Bootstrap UCL	44.63	95% Bootstrap-t UCL	47.07
95% Hall's Bootstrap UCL	47.84	95% Percentile Bootstrap UCL	45.16
95% BCA Bootstrap UCL	45.42		
90% Chebyshev(Mean, Sd) UCL	49.53	95% Chebyshev(Mean, Sd) UCL	54.21
97.5% Chebyshev(Mean, Sd) UCL	60.71	99% Chebyshev(Mean, Sd) UCL	73.48
Suggested UCL to Use			
95% Student's-t UCL	45.38		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

HMX

General Statistics			
Total Number of Observations	12	Number of Distinct Observations	9
		Number of Missing Observations	100.00%
Number of Detects	7	Number of Non-Detects	5
Number of Distinct Detects	7	Number of Distinct Non-Detects	2
Minimum Detect	0.172	Minimum Non-Detect	0.149
Maximum Detect	6.66	Maximum Non-Detect	0.15
Variance Detects	5.265	Percent Non-Detects	41.67%
Mean Detects	1.683	SD Detects	2.295
Median Detects	1.14	CV Detects	1.363
Skewness Detects	2.198	Kurtosis Detects	5.159
Mean of Logged Detects	-0.217	SD of Logged Detects	1.34
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.704	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.314	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data Not Normal at 5% Significance Level	
Detected Data Not Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	1.044	KM Standard Error of Mean	0.558
KM SD	1.79	95% KM (BCA) UCL	2.049
95% KM (t) UCL	2.046	95% KM (Percentile Bootstrap) UCL	2.046
95% KM (z) UCL	1.962	95% KM Bootstrap t UCL	3.697
90% KM Chebyshev UCL	2.718	95% KM Chebyshev UCL	3.477
97.5% KM Chebyshev UCL	4.53	99% KM Chebyshev UCL	6.598
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.394	Anderson-Darling GOF Test	
5% A-D Critical Value	0.734	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.22	Kolmogorov-Smirnov GOF	

5% K-S Critical Value	0.322	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.804	k star (bias corrected MLE)	0.555
Theta hat (MLE)	2.093	Theta star (bias corrected MLE)	3.034
nu hat (MLE)	11.26	nu star (bias corrected)	7.766
Mean (detects)	1.683		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	0.986
Maximum	6.66	Median	0.194
SD	1.901	CV	1.928
k hat (MLE)	0.334	k star (bias corrected MLE)	0.306
Theta hat (MLE)	2.955	Theta star (bias corrected MLE)	3.225
nu hat (MLE)	8.007	nu star (bias corrected)	7.339
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (7.34, α)	2.358	Adjusted Chi Square Value (7.34, β)	1.951
95% Gamma Approximate UCL (use when n>=50)	3.068	95% Gamma Adjusted UCL (use when n<50)	3.709
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	1.044	SD (KM)	1.79
Variance (KM)	3.204	SE of Mean (KM)	0.558
k hat (KM)	0.34	k star (KM)	0.311
nu hat (KM)	8.162	nu star (KM)	7.455
theta hat (KM)	3.07	theta star (KM)	3.361
80% gamma percentile (KM)	1.614	90% gamma percentile (KM)	3.066
95% gamma percentile (KM)	4.722	99% gamma percentile (KM)	9.009
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (7.45, α)	2.423	Adjusted Chi Square Value (7.45, β)	2.009
95% Gamma Approximate KM-UCL (use when n>=50)	3.211	95% Gamma Adjusted KM-UCL (use when n<50)	3.874
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.927	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.202	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.993	Mean in Log Scale	-1.753
SD in Original Scale	1.897	SD in Log Scale	2.196
95% t UCL (assumes normality of ROS data)	1.976	95% Percentile Bootstrap UCL	2
95% BCA Bootstrap UCL	2.542	95% Bootstrap t UCL	3.884
95% H-UCL (Log ROS)	68.69		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-0.92	KM Geo Mean	0.399
KM SD (logged)	1.26	95% Critical H Value (KM-Log)	3.41
KM Standard Error of Mean (logged)	0.393	95% H-UCL (KM -Log)	3.223
KM SD (logged)	1.26	95% Critical H Value (KM-Log)	3.41
KM Standard Error of Mean (logged)	0.393		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	1.013	Mean in Log Scale	-1.207
SD in Original Scale	1.886	SD in Log Scale	1.573
95% t UCL (Assumes normality)	1.991	95% H-Stat UCL	7.039
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Gamma Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM Bootstrap t UCL	3.697	Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	3.874
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

TATB

General Statistics

Total Number of Observations	12	Number of Distinct Observations	8
		Number of Missing Observations	100%
Number of Detects	5	Number of Non-Detects	7
Number of Distinct Detects	5	Number of Distinct Non-Detects	3
Minimum Detect	0.791	Minimum Non-Detect	0.296
Maximum Detect	5.535	Maximum Non-Detect	0.3
Variance Detects	3.981	Percent Non-Detects	58.33%
Mean Detects	2.042	SD Detects	1.995
Median Detects	1.06	CV Detects	0.977
Skewness Detects	2.017	Kurtosis Detects	4.113
Mean of Logged Detects	0.424	SD of Logged Detects	0.786

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.713	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.336	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Approximate Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	1.024	KM Standard Error of Mean	0.464
KM SD	1.438	95% KM (BCA) UCL	1.848
95% KM (t) UCL	1.857	95% KM (Percentile Bootstrap) UCL	1.837
95% KM (z) UCL	1.787	95% KM Bootstrap t UCL	2.743
90% KM Chebyshev UCL	2.416	95% KM Chebyshev UCL	3.047
97.5% KM Chebyshev UCL	3.922	99% KM Chebyshev UCL	5.642

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.595	Anderson-Darling GOF Test	
5% A-D Critical Value	0.685	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.31	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.361	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.873	k star (bias corrected MLE)	0.883
Theta hat (MLE)	1.09	Theta star (bias corrected MLE)	2.314
nu hat (MLE)	18.73	nu star (bias corrected)	8.826
Mean (detects)	2.042		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.857
Maximum	5.535	Median	0.01
SD	1.595	CV	1.861
k hat (MLE)	0.294	k star (bias corrected MLE)	0.276
Theta hat (MLE)	2.916	Theta star (bias corrected MLE)	3.105
nu hat (MLE)	7.051	nu star (bias corrected)	6.622
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (6.62, α)	1.965	Adjusted Chi Square Value (6.62, β)	1.603
95% Gamma Approximate UCL (use when n>=50)	2.887	95% Gamma Adjusted UCL (use when n<50)	3.539

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.024	SD (KM)	1.438
Variance (KM)	2.068	SE of Mean (KM)	0.464
k hat (KM)	0.507	k star (KM)	0.436
nu hat (KM)	12.16	nu star (KM)	10.45
theta hat (KM)	2.02	theta star (KM)	2.35
80% gamma percentile (KM)	1.666	90% gamma percentile (KM)	2.846
95% gamma percentile (KM)	4.129	99% gamma percentile (KM)	7.325

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (10.45, α)	4.226	Adjusted Chi Square Value (10.45, β)	3.642

95% Gamma Approximate KM-UCL (use when n>=50)	2.531	95% Gamma Adjusted KM-UCL (use when n<50)	2.938
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.851	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.279	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.93	Mean in Log Scale	-1.077
SD in Original Scale	1.554	SD in Log Scale	1.48
95% t UCL (assumes normality of ROS data)	1.736	95% Percentile Bootstrap UCL	1.724
95% BCA Bootstrap UCL	2.159	95% Bootstrap t UCL	3.195
95% H-UCL (Log ROS)	5.697		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-0.533	KM Geo Mean	0.587
KM SD (logged)	0.928	95% Critical H Value (KM-Log)	2.786
KM Standard Error of Mean (logged)	0.299	95% H-UCL (KM -Log)	1.967
KM SD (logged)	0.928	95% Critical H Value (KM-Log)	2.786
KM Standard Error of Mean (logged)	0.299		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.938	Mean in Log Scale	-0.933
SD in Original Scale	1.548	SD in Log Scale	1.288
95% t UCL (Assumes normality)	1.741	95% H-Stat UCL	3.464
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Approximate Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	1.857		
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
Number of Detects	11	Number of Non-Detects	1
Number of Distinct Detects	11	Number of Distinct Non-Detects	1
Minimum Detect	6.07E-07	Minimum Non-Detect	5.01
Maximum Detect	1.17E-05	Maximum Non-Detect	5.01E-07
Variance Detects	1.34E-11	Percent Non-Detects	8.33%
Mean Detects	4.93E-06	SD Detects	3.66E-06
Median Detects	4.57E-06	CV Detects	N/A
Skewness Detects	0.558	Kurtosis Detects	-0.629
Mean of Logged Detects	-12.58	SD of Logged Detects	1.007
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.935	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.127	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	4.56E-06	KM Standard Error of Mean	1.08E-06
KM SD	3.56E-06	95% KM (BCA) UCL	6.38E-06
95% KM (t) UCL	6.49E-06	95% KM (Percentile Bootstrap) UCL	6.38E-06
95% KM (z) UCL	6.33E-06	95% KM Bootstrap t UCL	7.12E-06
90% KM Chebyshev UCL	7.79E-06	95% KM Chebyshev UCL	9.25E-06
97.5% KM Chebyshev UCL	1.13E-05	99% KM Chebyshev UCL	1.53E-05
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.299	Anderson-Darling GOF Test	
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.152	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.26	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	1.525	k star (bias corrected MLE)	1.17

Theta hat (MLE)	3.23E-06	Theta star (bias corrected MLE)	4.21E-06
nu hat (MLE)	33.55	nu star (bias corrected)	25.73
Mean (detects)	4.93E-06		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	6.07E-07	Mean	8.38E-04
Maximum	0.01	Median	4.89E-06
SD	0.00289	CV	3.444
k hat (MLE)	0.158	k star (bias corrected MLE)	0.174
Theta hat (MLE)	0.00531	Theta star (bias corrected MLE)	0.00482
nu hat (MLE)	3.788	nu star (bias corrected)	4.174
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (4.17, α)	0.792	Adjusted Chi Square Value (4.17, β)	0.598
95% Gamma Approximate UCL (use when n>=50)	0.00442	95% Gamma Adjusted UCL (use when n<50)	0.00585

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	4.56E-06	SD (KM)	3.56E-06
Variance (KM)	1.27E-11	SE of Mean (KM)	1.08E-06
k hat (KM)	1.639	k star (KM)	1.285
nu hat (KM)	39.33	nu star (KM)	30.83
theta hat (KM)	2.78E-06	theta star (KM)	3.55E-06
80% gamma percentile (KM)	7.17E-06	90% gamma percentile (KM)	9.86E-06
95% gamma percentile (KM)	1.25E-05	99% gamma percentile (KM)	1.85E-05

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (30.83, α)	19.15	Adjusted Chi Square Value (30.83, β)	17.75
95% Gamma Approximate KM-UCL (use when n>=50)	7.34E-06	95% Gamma Adjusted KM-UCL (use when n<50)	7.91E-06

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.91	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.176	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	4.54E-06	Mean in Log Scale	-12.78
SD in Original Scale	3.74E-06	SD in Log Scale	1.183
95% t UCL (assumes normality of ROS data)	6.48E-06	95% Percentile Bootstrap UCL	6.28E-06
95% BCA Bootstrap UCL	6.42E-06	95% Bootstrap t UCL	6.79E-06
95% H-UCL (Log ROS)	1.81E-05		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-12.74	KM Geo Mean	2.92E-06
KM SD (logged)	1.062	95% Critical H Value (KM-Log)	3.027
KM Standard Error of Mean (logged)	0.321	95% H-UCL (KM -Log)	1.35E-05
KM SD (logged)	1.062	95% Critical H Value (KM-Log)	3.027
KM Standard Error of Mean (logged)	0.321		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	4.54E-06	Mean in Log Scale	-12.8
SD in Original Scale	3.74E-06	SD in Log Scale	1.221
95% t UCL (Assumes normality)	6.48E-06	95% H-Stat UCL	1.98E-05

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	6.49E-06

Heptachlorodibenzofuran[1,2,3,4,6,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	9
Number of Detects	5	Number of Non-Detects	7
Number of Distinct Detects	5	Number of Distinct Non-Detects	4
Minimum Detect	6.88E-07	Minimum Non-Detect	4.96E-07
Maximum Detect	2.21E-06	Maximum Non-Detect	5.02E-07
Variance Detects	3.76E-13	Percent Non-Detects	58.33%

Mean Detects	1.15E-06	SD Detects	6.13E-07
Median Detects	9.51E-07	CV Detects	N/A
Skewness Detects	1.888	Kurtosis Detects	3.751
Mean of Logged Detects	-13.77	SD of Logged Detects	0.453
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.782	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.332	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	7.68E-07	KM Standard Error of Mean	1.54E-07
KM SD	4.79E-07	95% KM (BCA) UCL	1.05E-06
95% KM (t) UCL	1.05E-06	95% KM (Percentile Bootstrap) UCL	1.02E-06
95% KM (z) UCL	1.02E-06	95% KM Bootstrap t UCL	1.13E-06
90% KM Chebyshev UCL	1.23E-06	95% KM Chebyshev UCL	1.44E-06
97.5% KM Chebyshev UCL	1.73E-06	99% KM Chebyshev UCL	2.30E-06
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.476	Anderson-Darling GOF Test	
5% A-D Critical Value	0.68	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.284	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.358	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	5.617	k star (bias corrected MLE)	2.38
Theta hat (MLE)	2.05E-07	Theta star (bias corrected MLE)	4.83E-07
nu hat (MLE)	56.17	nu star (bias corrected)	23.8
Mean (detects)	1.15E-06		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	6.88E-07	Mean	0.00583
Maximum	0.01	Median	0.01
SD	0.00515	CV	0.883
k hat (MLE)	0.221	k star (bias corrected MLE)	0.221
Theta hat (MLE)	0.0264	Theta star (bias corrected MLE)	0.0264
nu hat (MLE)	5.303	nu star (bias corrected)	5.31
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (5.31, α)	1.298	Adjusted Chi Square Value (5.31, β)	1.023
95% Gamma Approximate UCL (use when n>=50)	0.0239	95% Gamma Adjusted UCL (use when n<50)	0.0303
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	7.68E-07	SD (KM)	4.79E-07
Variance (KM)	2.29E-13	SE of Mean (KM)	1.54E-07
k hat (KM)	2.576	k star (KM)	1.988
nu hat (KM)	61.84	nu star (KM)	47.71
theta hat (KM)	2.98E-07	theta star (KM)	3.86E-07
80% gamma percentile (KM)	1.15E-06	90% gamma percentile (KM)	1.50E-06
95% gamma percentile (KM)	1.83E-06	99% gamma percentile (KM)	2.56E-06
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (47.71, α)	32.86	Adjusted Chi Square Value (47.71, β)	30.98
95% Gamma Approximate KM-UCL (use when n>=50)	1.12E-06	95% Gamma Adjusted KM-UCL (use when n<50)	1.18E-06
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.887	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.258	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			

Mean in Original Scale	6.23E-07	Mean in Log Scale	-14.63
SD in Original Scale	5.96E-07	SD in Log Scale	0.845
95% t UCL (assumes normality of ROS data)	9.32E-07	95% Percentile Bootstrap UCL	9.32E-07
95% BCA Bootstrap UCL	1.01E-06	95% Bootstrap t UCL	1.14E-06
95% H-UCL (Log ROS)	1.24E-06		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-14.2	KM Geo Mean	6.78E-07
KM SD (logged)	0.452	95% Critical H Value (KM-Log)	2.084
KM Standard Error of Mean (logged)	0.146	95% H-UCL (KM -Log)	9.97E-07
KM SD (logged)	0.452	95% Critical H Value (KM-Log)	2.084
KM Standard Error of Mean (logged)	0.146		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	6.24E-07	Mean in Log Scale	-14.61
SD in Original Scale	5.93E-07	SD in Log Scale	0.788
95% t UCL (Assumes normality)	9.32E-07	95% H-Stat UCL	1.13E-06

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	1.05E-06

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

Heptachlorodibenzofuran[1,2,3,4,7,8,9-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Heptachlorodibenzofuran[1,2,3,4,7,8,9-] was not processed!

Hexachlorodibenzodioxin[1,2,3,4,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzodioxin[1,2,3,4,7,8-] was not processed!

Hexachlorodibenzodioxin[1,2,3,6,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzodioxin[1,2,3,6,7,8-] was not processed!

Hexachlorodibenzodioxin[1,2,3,7,8,9-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Hexachlorodibenzodioxin[1,2,3,7,8,9-] was not processed!

Hexachlorodibenzofuran[1,2,3,4,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!

The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Hexachlorodibenzofuran[1,2,3,4,7,8-] was not processed!

Hexachlorodibenzofuran[1,2,3,6,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Hexachlorodibenzofuran[1,2,3,6,7,8-] was not processed!

Hexachlorodibenzofuran[1,2,3,7,8,9-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Hexachlorodibenzofuran[1,2,3,7,8,9-] was not processed!

Hexachlorodibenzofuran[2,3,4,6,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Hexachlorodibenzofuran[2,3,4,6,7,8-] was not processed!

Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	1.96E-06	Mean	3.77E-05
Maximum	9.57E-05	Median	3.29E-05
SD	3.15E-05	Std. Error of Mean	9.09E-06
Coefficient of Variation	N/A	Skewness	0.58

Normal GOF Test

Shapiro Wilk Test Statistic	0.923	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.146	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	5.40E-05	95% Adjusted-CLT UCL (Chen-1995)	5.43E-05
		95% Modified-t UCL (Johnson-1978)	5.43E-05

Gamma GOF Test

A-D Test Statistic	0.319	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.755	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.141	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.252	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.065	k star (bias corrected MLE)	0.855
Theta hat (MLE)	3.54E-05	Theta star (bias corrected MLE)	4.41E-05
nu hat (MLE)	25.57	nu star (bias corrected)	20.51
MLE Mean (bias corrected)	3.77E-05	MLE Sd (bias corrected)	4.08E-05
		Approximate Chi Square Value (0.05)	11.23
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	10.19

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	6.88E-05	95% Adjusted Gamma UCL (use when n<50)	7.58E-05

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.906	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.205	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-13.14	Mean of logged Data	-10.72
Maximum of Logged Data	-9.254	SD of logged Data	1.284

Assuming Lognormal Distribution

95% H-UCL	1.91E-04	90% Chebyshev (MVUE) UCL	9.96E-05
95% Chebyshev (MVUE) UCL	1.24E-04	97.5% Chebyshev (MVUE) UCL	1.59E-04
99% Chebyshev (MVUE) UCL	2.26E-04		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	5.26E-05	95% Jackknife UCL	5.40E-05
95% Standard Bootstrap UCL	5.20E-05	95% Bootstrap-t UCL	5.71E-05
95% Hall's Bootstrap UCL	5.44E-05	95% Percentile Bootstrap UCL	5.18E-05
95% BCA Bootstrap UCL	5.22E-05		
90% Chebyshev(Mean, Sd) UCL	6.50E-05	95% Chebyshev(Mean, Sd) UCL	7.73E-05
97.5% Chebyshev(Mean, Sd) UCL	9.45E-05	99% Chebyshev(Mean, Sd) UCL	1.28E-04

Suggested UCL to Use

95% Student's-t UCL	5.40E-05

Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	10
Number of Detects	6	Number of Non-Detects	6
Number of Distinct Detects	6	Number of Distinct Non-Detects	4
Minimum Detect	1.18E-06	Minimum Non-Detect	9.93E-07
Maximum Detect	1.92E-05	Maximum Non-Detect	1.00E-06
Variance Detects	4.88E-11	Percent Non-Detects	50%
Mean Detects	5.05E-06	SD Detects	6.98E-06
Median Detects	2.56E-06	CV Detects	N/A
Skewness Detects	2.373	Kurtosis Detects	5.708
Mean of Logged Detects	-12.72	SD of Logged Detects	0.999

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.607	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.427	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data Not Normal at 5% Significance Level	

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	3.02E-06	KM Standard Error of Mean	1.56E-06
KM SD	4.94E-06	95% KM (BCA) UCL	6.00E-06
95% KM (t) UCL	5.83E-06	95% KM (Percentile Bootstrap) UCL	5.84E-06
95% KM (z) UCL	5.59E-06	95% KM Bootstrap t UCL	1.59E-05
90% KM Chebyshev UCL	7.71E-06	95% KM Chebyshev UCL	9.83E-06
97.5% KM Chebyshev UCL	1.28E-05	99% KM Chebyshev UCL	1.86E-05

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.795	Anderson-Darling GOF Test	
5% A-D Critical Value	0.714	Detected Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.355	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.34	Detected Data Not Gamma Distributed at 5% Significance Level	

Detected Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.084	k star (bias corrected MLE)	0.653
Theta hat (MLE)	4.66E-06	Theta star (bias corrected MLE)	7.73E-06
nu hat (MLE)	13	nu star (bias corrected)	7.836
Mean (detects)	5.05E-06		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	1.18E-06	Mean	0.005
Maximum	0.01	Median	0.00501
SD	0.00522	CV	1.043
k hat (MLE)	0.216	k star (bias corrected MLE)	0.218
Theta hat (MLE)	0.0232	Theta star (bias corrected MLE)	0.023
nu hat (MLE)	5.183	nu star (bias corrected)	5.22
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (5.22, α)	1.255	Adjusted Chi Square Value (5.22, β)	0.986
95% Gamma Approximate UCL (use when n>=50)	0.0208	95% Gamma Adjusted UCL (use when n<50)	0.0265

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	3.02E-06	SD (KM)	4.94E-06
Variance (KM)	2.44E-11	SE of Mean (KM)	1.56E-06
k hat (KM)	0.373	k star (KM)	0.336
nu hat (KM)	8.961	nu star (KM)	8.054
theta hat (KM)	8.09E-06	theta star (KM)	9.00E-06
80% gamma percentile (KM)	4.75E-06	90% gamma percentile (KM)	8.78E-06
95% gamma percentile (KM)	1.33E-05	99% gamma percentile (KM)	2.50E-05

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (8.05, α)	2.766	Adjusted Chi Square Value (8.05, β)	2.316
95% Gamma Approximate KM-UCL (use when n>=50)	8.79E-06	95% Gamma Adjusted KM-UCL (use when n<50)	1.05E-05

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.843	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.28	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	2.62E-06	Mean in Log Scale	-14.15
SD in Original Scale	5.35E-06	SD in Log Scale	1.661
95% t UCL (assumes normality of ROS data)	5.39E-06	95% Percentile Bootstrap UCL	5.42E-06
95% BCA Bootstrap UCL	7.28E-06	95% Bootstrap t UCL	1.29E-05
95% H-UCL (Log ROS)	2.38E-05		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-13.27	KM Geo Mean	1.72E-06
KM SD (logged)	0.847	95% Critical H Value (KM-Log)	2.647
KM Standard Error of Mean (logged)	0.268	95% H-UCL (KM -Log)	4.84E-06
KM SD (logged)	0.847	95% Critical H Value (KM-Log)	2.647
KM Standard Error of Mean (logged)	0.268		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	2.77E-06	Mean in Log Scale	-13.62
SD in Original Scale	5.27E-06	SD in Log Scale	1.151
95% t UCL (Assumes normality)	5.51E-06	95% H-Stat UCL	7.16E-06

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Lognormal Distributed at 5% Significance Level

Suggested UCL to Use

KM H-UCL	4.84E-06

Pentachlorodibenzodioxin[1,2,3,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!

Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!

The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Pentachlorodibenzodioxin[1,2,3,7,8-] was not processed!

Pentachlorodibenzofuran[1,2,3,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Pentachlorodibenzofuran[1,2,3,7,8-] was not processed!

Pentachlorodibenzofuran[2,3,4,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	6
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	6

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Pentachlorodibenzofuran[2,3,4,7,8-] was not processed!

Tetrachlorodibenzodioxin[2,3,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	5
Number of Detects	0	Number of Non-Detects	12
Number of Distinct Detects	0	Number of Distinct Non-Detects	5

Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
The data set for variable Tetrachlorodibenzodioxin[2,3,7,8-] was not processed!

Tetrachlorodibenzofuran[2,3,7,8-]

General Statistics

Total Number of Observations	12	Number of Distinct Observations	12
Number of Detects	10	Number of Non-Detects	2
Number of Distinct Detects	10	Number of Distinct Non-Detects	2
Minimum Detect	1.06E-07	Minimum Non-Detect	1.05E-07
Maximum Detect	5.60E-07	Maximum Non-Detect	1.16E-07
Variance Detects	2.80E-14	Percent Non-Detects	16.67%
Mean Detects	2.88E-07	SD Detects	1.67E-07
Median Detects	2.29E-07	CV Detects	N/A
Skewness Detects	0.741	Kurtosis Detects	-0.85
Mean of Logged Detects	-15.21	SD of Logged Detects	0.589

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.878	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.842	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.199	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.262	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	2.58E-07	KM Standard Error of Mean	4.87E-08
KM SD	1.60E-07	95% KM (BCA) UCL	3.43E-07
95% KM (t) UCL	3.45E-07	95% KM (Percentile Bootstrap) UCL	3.38E-07
95% KM (z) UCL	3.38E-07	95% KM Bootstrap t UCL	3.71E-07
90% KM Chebyshev UCL	4.04E-07	95% KM Chebyshev UCL	4.70E-07
97.5% KM Chebyshev UCL	5.62E-07	99% KM Chebyshev UCL	7.42E-07

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.352	Anderson-Darling GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.17	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.268	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	3.408	k star (bias corrected MLE)	2.452
Theta hat (MLE)	8.45E-08	Theta star (bias corrected MLE)	1.17E-07
nu hat (MLE)	68.16	nu star (bias corrected)	49.05
Mean (detects)	2.88E-07		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	1.06E-07	Mean	0.00167
Maximum	0.01	Median	3.11E-07
SD	0.00389	CV	2.335
k hat (MLE)	0.113	k star (bias corrected MLE)	0.141
Theta hat (MLE)	0.0147	Theta star (bias corrected MLE)	0.0119
nu hat (MLE)	2.721	nu star (bias corrected)	3.374
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (3.37, α)	0.491	Adjusted Chi Square Value (3.37, β)	0.358
95% Gamma Approximate UCL (use when n>=50)	0.0114	95% Gamma Adjusted UCL (use when n<50)	0.0157
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	2.58E-07	SD (KM)	1.60E-07
Variance (KM)	2.56E-14	SE of Mean (KM)	4.87E-08
k hat (KM)	2.59	k star (KM)	1.998
nu hat (KM)	62.16	nu star (KM)	47.95
theta hat (KM)	9.94E-08	theta star (KM)	1.29E-07
80% gamma percentile (KM)	3.86E-07	90% gamma percentile (KM)	5.01E-07
95% gamma percentile (KM)	6.11E-07	99% gamma percentile (KM)	8.55E-07
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (47.95, α)	33.06	Adjusted Chi Square Value (47.95, β)	31.18
95% Gamma Approximate KM-UCL (use when n>=50)	3.74E-07	95% Gamma Adjusted KM-UCL (use when n<50)	3.96E-07
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.939	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.842	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.145	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.262	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	2.51E-07	Mean in Log Scale	-15.43
SD in Original Scale	1.74E-07	SD in Log Scale	0.738
95% t UCL (assumes normality of ROS data)	3.41E-07	95% Percentile Bootstrap UCL	3.30E-07
95% BCA Bootstrap UCL	3.41E-07	95% Bootstrap t UCL	3.76E-07
95% H-UCL (Log ROS)	4.53E-07		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-15.36	KM Geo Mean	2.14E-07
KM SD (logged)	0.601	95% Critical H Value (KM-Log)	2.272
KM Standard Error of Mean (logged)	0.183	95% H-UCL (KM -Log)	3.87E-07
KM SD (logged)	0.601	95% Critical H Value (KM-Log)	2.272
KM Standard Error of Mean (logged)	0.183		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	2.49E-07	Mean in Log Scale	-15.46
SD in Original Scale	1.76E-07	SD in Log Scale	0.79
95% t UCL (Assumes normality)	3.41E-07	95% H-Stat UCL	4.83E-07
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	3.45E-07		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

ATTACHMENT B. LANL ECORISK DATABASE FOR INORGANICS AND ORGANICS (MG/KG)

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Tetrachlorodibenzodioxin[2,3,7,8-]	Deer mouse (Mammalian omnivore)	0.00000058	0.0000038	
Tetrachlorodibenzodioxin[2,3,7,8-]	Earthworm (Soil-dwelling invertebrate)	5	10	
Tetrachlorodibenzodioxin[2,3,7,8-]	Gray fox (Mammalian top carnivore)	0.0001	0.00068	
Tetrachlorodibenzodioxin[2,3,7,8-]	Montane shrew (Mammalian insectivore)	0.00000029	0.0000019	MINIMUM
Tetrachlorodibenzodioxin[2,3,7,8-]	Mountain cottontail (Mammalian herbivore)	0.00004	0.00027	
Amino-2,6-dinitrotoluene[4-]	Deer mouse (Mammalian omnivore)	23	230	
Amino-2,6-dinitrotoluene[4-]	Earthworm (Soil-dwelling invertebrate)	18	180	
Amino-2,6-dinitrotoluene[4-]	Generic plant (Terrestrial autotroph - producer)	33	330	
Amino-2,6-dinitrotoluene[4-]	Gray fox (Mammalian top carnivore)	6700	67000	
Amino-2,6-dinitrotoluene[4-]	Montane shrew (Mammalian insectivore)	12	120	MINIMUM
Amino-2,6-dinitrotoluene[4-]	Mountain cottontail (Mammalian herbivore)	320	3200	
Amino-4,6-dinitrotoluene[2-]	Deer mouse (Mammalian omnivore)	23	230	
Amino-4,6-dinitrotoluene[2-]	Earthworm (Soil-dwelling invertebrate)	43	430	
Amino-4,6-dinitrotoluene[2-]	Generic plant (Terrestrial autotroph - producer)	14	140	MINIMUM
Amino-4,6-dinitrotoluene[2-]	Gray fox (Mammalian top carnivore)	9700	97000	
Amino-4,6-dinitrotoluene[2-]	Montane shrew (Mammalian insectivore)	16	160	
Amino-4,6-dinitrotoluene[2-]	Mountain cottontail (Mammalian herbivore)	110	1100	
Dinitrobenzene[1,3-]	American kestrel (Avian top carnivore)	120	1200	
Dinitrobenzene[1,3-]	American kestrel (insectivore / carnivore)	9.3	93	
Dinitrobenzene[1,3-]	American robin (Avian herbivore)	0.079	0.79	
Dinitrobenzene[1,3-]	American robin (Avian insectivore)	1.6	16	
Dinitrobenzene[1,3-]	American robin (Avian omnivore)	0.15	1.5	
Dinitrobenzene[1,3-]	Deer mouse (Mammalian omnivore)	0.072	0.16	MINIMUM
Dinitrobenzene[1,3-]	Gray fox (Mammalian top carnivore)	82	190	
Dinitrobenzene[1,3-]	Montane shrew (Mammalian insectivore)	0.95	2.2	
Dinitrobenzene[1,3-]	Mountain cottontail (Mammalian herbivore)	0.091	0.21	
Dinitrotoluene[2,4-]	Deer mouse (Mammalian omnivore)	20	200	
Dinitrotoluene[2,4-]	Earthworm (Soil-dwelling invertebrate)	18	180	
Dinitrotoluene[2,4-]	Generic plant (Terrestrial autotroph - producer)	6	60	MINIMUM
Dinitrotoluene[2,4-]	Gray fox (Mammalian top carnivore)	2000	20000	
Dinitrotoluene[2,4-]	Montane shrew (Mammalian insectivore)	14	140	
Dinitrotoluene[2,4-]	Mountain cottontail (Mammalian herbivore)	74	740	
Dinitrotoluene[2,6-]	American kestrel (Avian top carnivore)	18000	180000	
Dinitrotoluene[2,6-]	American kestrel (insectivore / carnivore)	680	6800	
Dinitrotoluene[2,6-]	American robin (Avian herbivore)	52	520	
Dinitrotoluene[2,6-]	American robin (Avian insectivore)	130	1300	
Dinitrotoluene[2,6-]	American robin (Avian omnivore)	74	740	
Dinitrotoluene[2,6-]	Deer mouse (Mammalian omnivore)	4	40	MINIMUM
Dinitrotoluene[2,6-]	Earthworm (Soil-dwelling invertebrate)	30	44	
Dinitrotoluene[2,6-]	Gray fox (Mammalian top carnivore)	1300	13000	
Dinitrotoluene[2,6-]	Montane shrew (Mammalian insectivore)	7.6	76	
Dinitrotoluene[2,6-]	Mountain cottontail (Mammalian herbivore)	6.7	67	
HMX	Deer mouse (Mammalian omnivore)	290	790	
HMX	Earthworm (Soil-dwelling invertebrate)	16	160	MINIMUM
HMX	Generic plant (Terrestrial autotroph - producer)	2700	3500	
HMX	Gray fox (Mammalian top carnivore)	59000	150000	
HMX	Montane shrew (Mammalian insectivore)	1100	2900	
HMX	Mountain cottontail (Mammalian herbivore)	410	1100	
Nitroglycerine	Deer mouse (Mammalian omnivore)	70	740	
Nitroglycerine	Earthworm (Soil-dwelling invertebrate)	13	130	MINIMUM
Nitroglycerine	Generic plant (Terrestrial autotroph - producer)	21	210	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Nitroglycerine	Gray fox (Mammalian top carnivore)	69000	730000	
Nitroglycerine	Montane shrew (Mammalian insectivore)	1200	13000	
Nitroglycerine	Mountain cottontail (Mammalian herbivore)	88	930	
Nitrotoluene[2-]	Deer mouse (Mammalian omnivore)	9.8	98	MINIMUM
Nitrotoluene[2-]	Gray fox (Mammalian top carnivore)	6000	60000	
Nitrotoluene[2-]	Montane shrew (Mammalian insectivore)	22	220	
Nitrotoluene[2-]	Mountain cottontail (Mammalian herbivore)	15	150	
Nitrotoluene[3-]	Deer mouse (Mammalian omnivore)	12	120	MINIMUM
Nitrotoluene[3-]	Gray fox (Mammalian top carnivore)	7000	70000	
Nitrotoluene[3-]	Montane shrew (Mammalian insectivore)	19	190	
Nitrotoluene[3-]	Mountain cottontail (Mammalian herbivore)	21	210	
Nitrotoluene[4-]	Deer mouse (Mammalian omnivore)	21	210	MINIMUM
Nitrotoluene[4-]	Gray fox (Mammalian top carnivore)	13000	130000	
Nitrotoluene[4-]	Montane shrew (Mammalian insectivore)	41	410	
Nitrotoluene[4-]	Mountain cottontail (Mammalian herbivore)	36	360	
PETN	Deer mouse (Mammalian omnivore)	100	1000	MINIMUM
PETN	Gray fox (Mammalian top carnivore)	47000	470000	
PETN	Montane shrew (Mammalian insectivore)	1000	10000	
PETN	Mountain cottontail (Mammalian herbivore)	120	1200	
RDX	American kestrel (Avian top carnivore)	780	1400	
RDX	American kestrel (insectivore / carnivore)	11	22	
RDX	American robin (Avian herbivore)	2.3	4.3	MINIMUM
RDX	American robin (Avian insectivore)	2.4	4.5	
RDX	American robin (Avian omnivore)	2.3	4.4	MINIMUM
RDX	Deer mouse (Mammalian omnivore)	16	51	
RDX	Earthworm (Soil-dwelling invertebrate)	8.4	15	
RDX	Gray fox (Mammalian top carnivore)	7000	22000	
RDX	Montane shrew (Mammalian insectivore)	16	53	
RDX	Mountain cottontail (Mammalian herbivore)	38	120	
Tetryl	Deer mouse (Mammalian omnivore)	1.5	7.2	MINIMUM
Tetryl	Gray fox (Mammalian top carnivore)	960	4600	
Tetryl	Montane shrew (Mammalian insectivore)	60	280	
Tetryl	Mountain cottontail (Mammalian herbivore)	1.8	8.9	
Trinitrobenzene[1,3,5-]	Deer mouse (Mammalian omnivore)	110	1100	
Trinitrobenzene[1,3,5-]	Earthworm (Soil-dwelling invertebrate)	10	28	MINIMUM
Trinitrobenzene[1,3,5-]	Gray fox (Mammalian top carnivore)	10000	100000	
Trinitrobenzene[1,3,5-]	Montane shrew (Mammalian insectivore)	720	7200	
Trinitrobenzene[1,3,5-]	Mountain cottontail (Mammalian herbivore)	150	1500	
Trinitrotoluene[2,4,6-]	American kestrel (Avian top carnivore)	3100	5700	
Trinitrotoluene[2,4,6-]	American kestrel (insectivore / carnivore)	1300	2400	
Trinitrotoluene[2,4,6-]	American robin (Avian herbivore)	7.5	13	MINIMUM
Trinitrotoluene[2,4,6-]	American robin (Avian insectivore)	120	220	
Trinitrotoluene[2,4,6-]	American robin (Avian omnivore)	14	26	
Trinitrotoluene[2,4,6-]	Deer mouse (Mammalian omnivore)	95	440	
Trinitrotoluene[2,4,6-]	Earthworm (Soil-dwelling invertebrate)	32	58	
Trinitrotoluene[2,4,6-]	Generic plant (Terrestrial autotroph - producer)	62	120	
Trinitrotoluene[2,4,6-]	Gray fox (Mammalian top carnivore)	26000	120000	
Trinitrotoluene[2,4,6-]	Montane shrew (Mammalian insectivore)	1900	9100	
Trinitrotoluene[2,4,6-]	Mountain cottontail (Mammalian herbivore)	110	540	
Aluminum	American kestrel (Avian top carnivore)			
Aluminum	American kestrel (insectivore / carnivore)			
Aluminum	American robin (Avian herbivore)			
Aluminum	American robin (Avian insectivore)			
Aluminum	American robin (Avian omnivore)			
Aluminum	Deer mouse (Mammalian omnivore)			

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Aluminum	Earthworm (Soil-dwelling invertebrate)			
Aluminum	Generic plant (Terrestrial autotroph - producer)			
Aluminum	Gray fox (Mammalian top carnivore)			
Aluminum	Montane shrew (Mammalian insectivore)			
Aluminum	Mountain cottontail (Mammalian herbivore)			
Antimony	Deer mouse (Mammalian omnivore)	2.3	23	MINIMUM
Antimony	Earthworm (Soil-dwelling invertebrate)	78	780	
Antimony	Generic plant (Terrestrial autotroph - producer)	11	58	
Antimony	Gray fox (Mammalian top carnivore)	46	460	
Antimony	Montane shrew (Mammalian insectivore)	7.9	79	
Antimony	Mountain cottontail (Mammalian herbivore)	2.7	27	
Arsenic	American kestrel (Avian top carnivore)	740	7400	
Arsenic	American kestrel (insectivore / carnivore)	100	1000	
Arsenic	American robin (Avian herbivore)	34	340	
Arsenic	American robin (Avian insectivore)	15	150	
Arsenic	American robin (Avian omnivore)	21	210	
Arsenic	Deer mouse (Mammalian omnivore)	32	51	
Arsenic	Earthworm (Soil-dwelling invertebrate)	6.8	68	MINIMUM
Arsenic	Generic plant (Terrestrial autotroph - producer)	18	91	
Arsenic	Gray fox (Mammalian top carnivore)	820	1300	
Arsenic	Montane shrew (Mammalian insectivore)	19	31	
Arsenic	Mountain cottontail (Mammalian herbivore)	110	180	
Barium	American kestrel (Avian top carnivore)	24000	44000	
Barium	American kestrel (insectivore / carnivore)	7500	13000	
Barium	American robin (Avian herbivore)	720	1200	
Barium	American robin (Avian insectivore)	820	1400	
Barium	American robin (Avian omnivore)	770	1300	
Barium	Deer mouse (Mammalian omnivore)	1800	8700	
Barium	Earthworm (Soil-dwelling invertebrate)	330	3200	
Barium	Generic plant (Terrestrial autotroph - producer)	110	260	MINIMUM
Barium	Gray fox (Mammalian top carnivore)	41000	190000	
Barium	Montane shrew (Mammalian insectivore)	2100	10000	
Barium	Mountain cottontail (Mammalian herbivore)	2900	14000	
Beryllium	Deer mouse (Mammalian omnivore)	56	560	
Beryllium	Earthworm (Soil-dwelling invertebrate)	40	400	
Beryllium	Generic plant (Terrestrial autotroph - producer)	2.5	25	MINIMUM
Beryllium	Gray fox (Mammalian top carnivore)	420	4200	
Beryllium	Montane shrew (Mammalian insectivore)	35	350	
Beryllium	Mountain cottontail (Mammalian herbivore)	89	890	
Boron	American kestrel (Avian top carnivore)	960	4700	
Boron	American kestrel (insectivore / carnivore)	37	180	
Boron	American robin (Avian herbivore)	2	10	MINIMUM
Boron	American robin (Avian insectivore)	7.1	35	
Boron	American robin (Avian omnivore)	3.1	15	
Boron	Deer mouse (Mammalian omnivore)	55	550	
Boron	Generic plant (Terrestrial autotroph - producer)	36	86	
Boron	Gray fox (Mammalian top carnivore)	21000	210000	
Boron	Montane shrew (Mammalian insectivore)	130	1300	
Boron	Mountain cottontail (Mammalian herbivore)	84	840	
Cadmium	American kestrel (Avian top carnivore)	430	2300	
Cadmium	American kestrel (insectivore / carnivore)	1.3	7.7	
Cadmium	American robin (Avian herbivore)	4.3	23	
Cadmium	American robin (Avian insectivore)	0.29	1.6	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Cadmium	American robin (Avian omnivore)	0.54	3	
Cadmium	Deer mouse (Mammalian omnivore)	0.5	6.8	
Cadmium	Earthworm (Soil-dwelling invertebrate)	140	760	
Cadmium	Generic plant (Terrestrial autotroph - producer)	32	160	
Cadmium	Gray fox (Mammalian top carnivore)	550	7400	
Cadmium	Montane shrew (Mammalian insectivore)	0.27	3.6	MINIMUM
Cadmium	Mountain cottontail (Mammalian herbivore)	10	140	
Chromium (total)	American kestrel (Avian top carnivore)	860	2700	
Chromium (total)	American kestrel (insectivore / carnivore)	170	560	
Chromium (total)	American robin (Avian herbivore)	51	160	
Chromium (total)	American robin (Avian insectivore)	23	73	MINIMUM
Chromium (total)	American robin (Avian omnivore)	32	100	
Chromium (total)	Deer mouse (Mammalian omnivore)	110	11000	
Chromium (total)	Gray fox (Mammalian top carnivore)	1800	180000	
Chromium (total)	Montane shrew (Mammalian insectivore)	63	6300	
Chromium (total)	Mountain cottontail (Mammalian herbivore)	410	41000	
Chromium(+6)	American kestrel (Avian top carnivore)	3600	36000	
Chromium(+6)	American kestrel (insectivore / carnivore)	1400	14000	
Chromium(+6)	American robin (Avian herbivore)	210	2100	
Chromium(+6)	American robin (Avian insectivore)	140	1400	
Chromium(+6)	American robin (Avian omnivore)	160	1600	
Chromium(+6)	Deer mouse (Mammalian omnivore)	850	5500	
Chromium(+6)	Earthworm (Soil-dwelling invertebrate)	0.34	3.4	MINIMUM
Chromium(+6)	Generic plant (Terrestrial autotroph - producer)	0.35	4	
Chromium(+6)	Gray fox (Mammalian top carnivore)	7200	46000	
Chromium(+6)	Montane shrew (Mammalian insectivore)	510	3300	
Chromium(+6)	Mountain cottontail (Mammalian herbivore)	1600	10000	
Cobalt	American kestrel (Avian top carnivore)	2300	5200	
Cobalt	American kestrel (insectivore / carnivore)	620	1400	
Cobalt	American robin (Avian herbivore)	130	300	
Cobalt	American robin (Avian insectivore)	76	170	
Cobalt	American robin (Avian omnivore)	97	210	
Cobalt	Deer mouse (Mammalian omnivore)	400	1000	
Cobalt	Generic plant (Terrestrial autotroph - producer)	13	130	MINIMUM
Cobalt	Gray fox (Mammalian top carnivore)	5400	14000	
Cobalt	Montane shrew (Mammalian insectivore)	240	640	
Cobalt	Mountain cottontail (Mammalian herbivore)	1000	2800	
Copper	American kestrel (Avian top carnivore)	1100	3500	
Copper	American kestrel (insectivore / carnivore)	80	240	
Copper	American robin (Avian herbivore)	34	100	
Copper	American robin (Avian insectivore)	14	43	MINIMUM
Copper	American robin (Avian omnivore)	20	60	
Copper	Deer mouse (Mammalian omnivore)	63	100	
Copper	Earthworm (Soil-dwelling invertebrate)	80	530	
Copper	Generic plant (Terrestrial autotroph - producer)	70	490	
Copper	Gray fox (Mammalian top carnivore)	4000	6700	
Copper	Montane shrew (Mammalian insectivore)	42	70	
Copper	Mountain cottontail (Mammalian herbivore)	260	430	
Cyanide (total)	American kestrel (Avian top carnivore)	0.59	5.9	
Cyanide (total)	American kestrel (insectivore / carnivore)	0.36	3.6	
Cyanide (total)	American robin (Avian herbivore)	0.1	1	
Cyanide (total)	American robin (Avian insectivore)	0.098	0.98	MINIMUM
Cyanide (total)	American robin (Avian omnivore)	0.099	0.99	
Cyanide (total)	Deer mouse (Mammalian omnivore)	330	3300	
Cyanide (total)	Gray fox (Mammalian top carnivore)	3300	33000	
Cyanide (total)	Montane shrew (Mammalian insectivore)	330	3300	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Cyanide (total)	Mountain cottontail (Mammalian herbivore)	790	7900	
Lead	American kestrel (Avian top carnivore)	540	1000	
Lead	American kestrel (insectivore / carnivore)	83	160	
Lead	American robin (Avian herbivore)	18	36	
Lead	American robin (Avian insectivore)	11	23	MINIMUM
Lead	American robin (Avian omnivore)	14	28	
Lead	Deer mouse (Mammalian omnivore)	120	230	
Lead	Earthworm (Soil-dwelling invertebrate)	1700	8400	
Lead	Generic plant (Terrestrial autotroph - producer)	120	570	
Lead	Gray fox (Mammalian top carnivore)	3700	7000	
Lead	Montane shrew (Mammalian insectivore)	93	170	
Lead	Mountain cottontail (Mammalian herbivore)	310	600	
Manganese	American kestrel (Avian top carnivore)	60000	120000	
Manganese	American kestrel (insectivore / carnivore)	24000	50000	
Manganese	American robin (Avian herbivore)	1300	2700	
Manganese	American robin (Avian insectivore)	2200	4700	
Manganese	American robin (Avian omnivore)	1600	3500	
Manganese	Deer mouse (Mammalian omnivore)	1400	5400	
Manganese	Earthworm (Soil-dwelling invertebrate)	450	4500	
Manganese	Generic plant (Terrestrial autotroph - producer)	220	1100	MINIMUM
Manganese	Gray fox (Mammalian top carnivore)	40000	150000	
Manganese	Montane shrew (Mammalian insectivore)	2800	10000	
Manganese	Mountain cottontail (Mammalian herbivore)	2000	7500	
Mercury (inorganic)	American kestrel (Avian top carnivore)	0.32	3.2	
Mercury (inorganic)	American kestrel (insectivore / carnivore)	0.058	0.58	
Mercury (inorganic)	American robin (Avian herbivore)	0.067	0.67	
Mercury (inorganic)	American robin (Avian insectivore)	0.013	0.13	MINIMUM
Mercury (inorganic)	American robin (Avian omnivore)	0.022	0.22	
Mercury (inorganic)	Deer mouse (Mammalian omnivore)	3	30	
Mercury (inorganic)	Earthworm (Soil-dwelling invertebrate)	0.05	0.5	
Mercury (inorganic)	Generic plant (Terrestrial autotroph - producer)	34	64	
Mercury (inorganic)	Gray fox (Mammalian top carnivore)	76	760	
Mercury (inorganic)	Montane shrew (Mammalian insectivore)	1.7	17	
Mercury (inorganic)	Mountain cottontail (Mammalian herbivore)	23	230	
Mercury (methyl)	American kestrel (Avian top carnivore)	0.009	0.09	
Mercury (methyl)	American kestrel (insectivore / carnivore)	0.0015	0.015	
Mercury (methyl)	American robin (Avian herbivore)	0.066	0.66	
Mercury (methyl)	American robin (Avian insectivore)	0.00035	0.0035	MINIMUM
Mercury (methyl)	American robin (Avian omnivore)	0.00071	0.0071	
Mercury (methyl)	Deer mouse (Mammalian omnivore)	0.0062	0.031	
Mercury (methyl)	Earthworm (Soil-dwelling invertebrate)	2.5	12	
Mercury (methyl)	Gray fox (Mammalian top carnivore)	0.14	0.74	
Mercury (methyl)	Montane shrew (Mammalian insectivore)	0.0031	0.015	
Mercury (methyl)	Mountain cottontail (Mammalian herbivore)	1.9	9.8	
Molybdenum	American kestrel (Avian top carnivore)	1100	11000	
Molybdenum	American kestrel (insectivore / carnivore)	90	900	
Molybdenum	American robin (Avian herbivore)	18	180	
Molybdenum	American robin (Avian insectivore)	15	150	MINIMUM
Molybdenum	American robin (Avian omnivore)	16	160	
Nickel	American kestrel (Avian top carnivore)	2000	8100	
Nickel	American kestrel (insectivore / carnivore)	110	440	
Nickel	American robin (Avian herbivore)	120	500	
Nickel	American robin (Avian insectivore)	20	81	
Nickel	American robin (Avian omnivore)	35	130	
Nickel	Deer mouse (Mammalian omnivore)	20	40	
Nickel	Earthworm (Soil-dwelling invertebrate)	280	1300	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Nickel	Generic plant (Terrestrial autotroph - producer)	38	270	
Nickel	Gray fox (Mammalian top carnivore)	1200	2500	
Nickel	Montane shrew (Mammalian insectivore)	10	21	MINIMUM
Nickel	Mountain cottontail (Mammalian herbivore)	270	540	
Perchlorate Ion	American kestrel (Avian top carnivore)	2	4	
Perchlorate Ion	American kestrel (insectivore / carnivore)	3.9	8	
Perchlorate Ion	American robin (Avian herbivore)	0.12	0.24	MINIMUM
Perchlorate Ion	American robin (Avian insectivore)	31	64	
Perchlorate Ion	American robin (Avian omnivore)	0.24	0.49	
Perchlorate Ion	Deer mouse (Mammalian omnivore)	0.21	1	
Perchlorate Ion	Earthworm (Soil-dwelling invertebrate)	3.5	35	
Perchlorate Ion	Generic plant (Terrestrial autotroph - producer)	40	80	
Perchlorate Ion	Gray fox (Mammalian top carnivore)	3.3	16	
Perchlorate Ion	Montane shrew (Mammalian insectivore)	31	150	
Perchlorate Ion	Mountain cottontail (Mammalian herbivore)	0.26	1.3	
Selenium	American kestrel (Avian top carnivore)	74	140	
Selenium	American kestrel (insectivore / carnivore)	3.7	7.5	
Selenium	American robin (Avian herbivore)	0.98	1.9	
Selenium	American robin (Avian insectivore)	0.71	1.4	
Selenium	American robin (Avian omnivore)	0.83	1.6	
Selenium	Deer mouse (Mammalian omnivore)	0.82	1.2	
Selenium	Earthworm (Soil-dwelling invertebrate)	4.1	41	
Selenium	Generic plant (Terrestrial autotroph - producer)	0.52	3	MINIMUM
Selenium	Gray fox (Mammalian top carnivore)	92	130	
Selenium	Montane shrew (Mammalian insectivore)	0.7	1	
Selenium	Mountain cottontail (Mammalian herbivore)	2.2	3.4	
Silver	American kestrel (Avian top carnivore)	600	6000	
Silver	American kestrel (insectivore / carnivore)	13	130	
Silver	American robin (Avian herbivore)	10	100	
Silver	American robin (Avian insectivore)	2.6	26	MINIMUM
Silver	American robin (Avian omnivore)	4.1	41	
Silver	Deer mouse (Mammalian omnivore)	24	240	
Silver	Generic plant (Terrestrial autotroph - producer)	560	2800	
Silver	Gray fox (Mammalian top carnivore)	4400	44000	
Silver	Montane shrew (Mammalian insectivore)	14	140	
Silver	Mountain cottontail (Mammalian herbivore)	150	1500	
Thallium	American kestrel (Avian top carnivore)	100	1000	
Thallium	American kestrel (insectivore / carnivore)	48	480	
Thallium	American robin (Avian herbivore)	6.9	69	
Thallium	American robin (Avian insectivore)	4.5	45	
Thallium	American robin (Avian omnivore)	5.5	55	
Thallium	Deer mouse (Mammalian omnivore)	0.72	7.2	
Thallium	Generic plant (Terrestrial autotroph - producer)	0.05	0.5	MINIMUM
Thallium	Gray fox (Mammalian top carnivore)	5	50	
Thallium	Montane shrew (Mammalian insectivore)	0.42	4.2	
Thallium	Mountain cottontail (Mammalian herbivore)	1.2	12	
Vanadium	American kestrel (Avian top carnivore)	110	230	
Vanadium	American kestrel (insectivore / carnivore)	56	110	
Vanadium	American robin (Avian herbivore)	6.8	13	
Vanadium	American robin (Avian insectivore)	4.7	9.5	MINIMUM
Vanadium	American robin (Avian omnivore)	5.5	11	
Vanadium	Deer mouse (Mammalian omnivore)	470	1000	
Vanadium	Generic plant (Terrestrial autotroph - producer)	60	80	
Vanadium	Gray fox (Mammalian top carnivore)	3200	6900	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Vanadium	Montane shrew (Mammalian insectivore)	290	610	
Vanadium	Mountain cottontail (Mammalian herbivore)	740	1500	
Zinc	American kestrel (Avian top carnivore)	2600	7000	
Zinc	American kestrel (insectivore / carnivore)	220	590	
Zinc	American robin (Avian herbivore)	330	120	
Zinc	American robin (Avian insectivore)	47	120	MINIMUM
Zinc	American robin (Avian omnivore)	83	220	
Zinc	Deer mouse (Mammalian omnivore)	170	1700	
Zinc	Earthworm (Soil-dwelling invertebrate)	120	930	
Zinc	Generic plant (Terrestrial autotroph - producer)	160	810	
Zinc	Gray fox (Mammalian top carnivore)	9600	94000	
Zinc	Montane shrew (Mammalian insectivore)	99	980	
Zinc	Mountain cottontail (Mammalian herbivore)	1800	18000	
Acenaphthene	Deer mouse (Mammalian omnivore)	160	1600	
Acenaphthene	Generic plant (Terrestrial autotroph - producer)	0.25	2	MINIMUM
Acenaphthene	Gray fox (Mammalian top carnivore)	29000	290000	
Acenaphthene	Montane shrew (Mammalian insectivore)	130	1300	
Acenaphthene	Mountain cottontail (Mammalian herbivore)	530	5300	
Acenaphthylene	Deer mouse (Mammalian omnivore)	160	1600	
Acenaphthylene	Gray fox (Mammalian top carnivore)	28000	280000	
Acenaphthylene	Montane shrew (Mammalian insectivore)	120	1200	MINIMUM
Acenaphthylene	Mountain cottontail (Mammalian herbivore)	540	5400	
Anthracene	Deer mouse (Mammalian omnivore)	300	3000	
Anthracene	Generic plant (Terrestrial autotroph - producer)	6.8	9	MINIMUM
Anthracene	Gray fox (Mammalian top carnivore)	38000	380000	
Anthracene	Montane shrew (Mammalian insectivore)	210	2100	
Anthracene	Mountain cottontail (Mammalian herbivore)	1200	12000	
Benzo(a)anthracene	American kestrel (Avian top carnivore)	28	280	
Benzo(a)anthracene	American kestrel (insectivore / carnivore)	6.4	64	
Benzo(a)anthracene	American robin (Avian herbivore)	0.73	7.3	MINIMUM
Benzo(a)anthracene	American robin (Avian insectivore)	0.88	8.8	
Benzo(a)anthracene	American robin (Avian omnivore)	0.8	8	
Benzo(a)anthracene	Deer mouse (Mammalian omnivore)	3.4	34	
Benzo(a)anthracene	Generic plant (Terrestrial autotroph - producer)	18	180	
Benzo(a)anthracene	Gray fox (Mammalian top carnivore)	110	1100	
Benzo(a)anthracene	Montane shrew (Mammalian insectivore)	4	40	
Benzo(a)anthracene	Mountain cottontail (Mammalian herbivore)	6.1	61	
Benzo(a)pyrene	Deer mouse (Mammalian omnivore)	84	260	
Benzo(a)pyrene	Gray fox (Mammalian top carnivore)	3400	11000	
Benzo(a)pyrene	Montane shrew (Mammalian insectivore)	62	190	MINIMUM
Benzo(a)pyrene	Mountain cottontail (Mammalian herbivore)	260	830	
Benzo(b)fluoranthene	Deer mouse (Mammalian omnivore)	51	510	
Benzo(b)fluoranthene	Generic plant (Terrestrial autotroph - producer)	18	180	MINIMUM
Benzo(b)fluoranthene	Gray fox (Mammalian top carnivore)	2400	24000	
Benzo(b)fluoranthene	Montane shrew (Mammalian insectivore)	44	440	
Benzo(b)fluoranthene	Mountain cottontail (Mammalian herbivore)	130	1300	
Benzo(g,h,i)perylene	Deer mouse (Mammalian omnivore)	46	460	
Benzo(g,h,i)perylene	Gray fox (Mammalian top carnivore)	3600	36000	
Benzo(g,h,i)perylene	Montane shrew (Mammalian insectivore)	25	250	MINIMUM
Benzo(g,h,i)perylene	Mountain cottontail (Mammalian herbivore)	470	4700	
Benzo(k)fluoranthene	Deer mouse (Mammalian omnivore)	99	990	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Benzo(k)fluoranthene	Gray fox (Mammalian top carnivore)	4300	43000	
Benzo(k)fluoranthene	Montane shrew (Mammalian insectivore)	71	710	MINIMUM
Benzo(k)fluoranthene	Mountain cottontail (Mammalian herbivore)	330	3300	
Chrysene	Deer mouse (Mammalian omnivore)	3.1	31	
Chrysene	Gray fox (Mammalian top carnivore)	110	1100	
Chrysene	Montane shrew (Mammalian insectivore)	3.1	31	MINIMUM
Chrysene	Mountain cottontail (Mammalian herbivore)	6.3	63	
Dibenzo(a,h)anthracene	Deer mouse (Mammalian omnivore)	22	220	
Dibenzo(a,h)anthracene	Gray fox (Mammalian top carnivore)	850	8500	
Dibenzo(a,h)anthracene	Montane shrew (Mammalian insectivore)	14	140	MINIMUM
Dibenzo(a,h)anthracene	Mountain cottontail (Mammalian herbivore)	84	840	
Fluoranthene	Deer mouse (Mammalian omnivore)	38	380	
Fluoranthene	Earthworm (Soil-dwelling invertebrate)	10	23	MINIMUM
Fluoranthene	Gray fox (Mammalian top carnivore)	3900	39000	
Fluoranthene	Montane shrew (Mammalian insectivore)	22	220	
Fluoranthene	Mountain cottontail (Mammalian herbivore)	270	2700	
Fluorene	Deer mouse (Mammalian omnivore)	340	680	
Fluorene	Earthworm (Soil-dwelling invertebrate)	3.7	19	MINIMUM
Fluorene	Gray fox (Mammalian top carnivore)	50000	100000	
Fluorene	Montane shrew (Mammalian insectivore)	250	510	
Fluorene	Mountain cottontail (Mammalian herbivore)	1100	2300	
Indeno(1,2,3-cd)pyrene	Deer mouse (Mammalian omnivore)	110	1100	
Indeno(1,2,3-cd)pyrene	Gray fox (Mammalian top carnivore)	4600	46000	
Indeno(1,2,3-cd)pyrene	Montane shrew (Mammalian insectivore)	71	710	MINIMUM
Indeno(1,2,3-cd)pyrene	Mountain cottontail (Mammalian herbivore)	510	5100	
Methylnaphthalene[2-]	Deer mouse (Mammalian omnivore)	24	240	
Methylnaphthalene[2-]	Gray fox (Mammalian top carnivore)	4900	49000	
Methylnaphthalene[2-]	Montane shrew (Mammalian insectivore)	16	160	MINIMUM
Methylnaphthalene[2-]	Mountain cottontail (Mammalian herbivore)	110	1100	
Naphthalene	American kestrel (Avian top carnivore)	2100	21000	
Naphthalene	American kestrel (insectivore / carnivore)	78	780	
Naphthalene	American robin (Avian herbivore)	3.4	34	
Naphthalene	American robin (Avian insectivore)	15	150	
Naphthalene	American robin (Avian omnivore)	5.7	57	
Naphthalene	Deer mouse (Mammalian omnivore)	9.6	27	
Naphthalene	Generic plant (Terrestrial autotroph - producer)	1	10	MINIMUM
Naphthalene	Gray fox (Mammalian top carnivore)	5800	16000	
Naphthalene	Montane shrew (Mammalian insectivore)	28	79	
Naphthalene	Mountain cottontail (Mammalian herbivore)	14	40	
Phenanthrene	Deer mouse (Mammalian omnivore)	15	150	
Phenanthrene	Earthworm (Soil-dwelling invertebrate)	5.5	12	MINIMUM
Phenanthrene	Gray fox (Mammalian top carnivore)	1900	19000	
Phenanthrene	Montane shrew (Mammalian insectivore)	11	110	
Phenanthrene	Mountain cottontail (Mammalian herbivore)	62	620	
Pyrene	American kestrel (Avian top carnivore)	3000	30000	
Pyrene	American kestrel (insectivore / carnivore)	160	1600	
Pyrene	American robin (Avian herbivore)	68	680	
Pyrene	American robin (Avian insectivore)	33	330	
Pyrene	American robin (Avian omnivore)	44	440	
Pyrene	Deer mouse (Mammalian omnivore)	31	310	
Pyrene	Earthworm (Soil-dwelling invertebrate)	10	20	MINIMUM
Pyrene	Gray fox (Mammalian top carnivore)	3100	31000	
Pyrene	Montane shrew (Mammalian insectivore)	23	230	
Pyrene	Mountain cottontail (Mammalian herbivore)	110	1100	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Aroclor-1016	Deer mouse (Mammalian omnivore)	2	5.9	
Aroclor-1016	Gray fox (Mammalian top carnivore)	250	720	
Aroclor-1016	Montane shrew (Mammalian insectivore)	1.1	3.1	MINIMUM
Aroclor-1016	Mountain cottontail (Mammalian herbivore)	48	130	
Aroclor-1242	American kestrel (Avian top carnivore)	6.2	62	
Aroclor-1242	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1242	American robin (Avian herbivore)	0.92	9.2	
Aroclor-1242	American robin (Avian insectivore)	0.041	0.41	MINIMUM
Aroclor-1242	American robin (Avian omnivore)	0.078	0.78	
Aroclor-1242	Deer mouse (Mammalian omnivore)	0.75	3	
Aroclor-1242	Gray fox (Mammalian top carnivore)	100	400	
Aroclor-1242	Montane shrew (Mammalian insectivore)	0.39	1.5	
Aroclor-1242	Mountain cottontail (Mammalian herbivore)	27	110	
Aroclor-1248	American kestrel (Avian top carnivore)	6.3	63	
Aroclor-1248	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1248	American robin (Avian herbivore)	0.94	9.4	
Aroclor-1248	American robin (Avian insectivore)	0.041	0.41	
Aroclor-1248	American robin (Avian omnivore)	0.078	0.78	
Aroclor-1248	Deer mouse (Mammalian omnivore)	0.014	0.14	
Aroclor-1248	Gray fox (Mammalian top carnivore)	1.9	19	
Aroclor-1248	Montane shrew (Mammalian insectivore)	0.0073	0.073	MINIMUM
Aroclor-1248	Mountain cottontail (Mammalian herbivore)	0.53	5.3	
Aroclor-1254	American kestrel (Avian top carnivore)	7.6	76	
Aroclor-1254	American kestrel (insectivore / carnivore)	0.19	1.9	
Aroclor-1254	American robin (Avian herbivore)	1.1	11	
Aroclor-1254	American robin (Avian insectivore)	0.041	0.41	MINIMUM
Aroclor-1254	American robin (Avian omnivore)	0.079	0.79	
Aroclor-1254	Deer mouse (Mammalian omnivore)	0.87	4.8	
Aroclor-1254	Generic plant (Terrestrial autotroph - producer)	160	620	
Aroclor-1254	Gray fox (Mammalian top carnivore)	7.2	72	
Aroclor-1254	Montane shrew (Mammalian insectivore)	0.45	2.4	
Aroclor-1254	Mountain cottontail (Mammalian herbivore)	44	240	
Aroclor-1260	American kestrel (Avian top carnivore)	400	560	
Aroclor-1260	American kestrel (insectivore / carnivore)	4.2	5.9	
Aroclor-1260	American robin (Avian herbivore)	37	52	
Aroclor-1260	American robin (Avian insectivore)	0.88	1.2	MINIMUM
Aroclor-1260	American robin (Avian omnivore)	1.7	2.4	
Aroclor-1260	Deer mouse (Mammalian omnivore)	20	48	
Aroclor-1260	Gray fox (Mammalian top carnivore)	15	150	
Aroclor-1260	Montane shrew (Mammalian insectivore)	10	24	
Aroclor-1260	Mountain cottontail (Mammalian herbivore)	1800	4500	
Benzoic Acid	Deer mouse (Mammalian omnivore)	1.3	13	
Benzoic Acid	Gray fox (Mammalian top carnivore)	2000	20000	
Benzoic Acid	Montane shrew (Mammalian insectivore)	1	10	MINIMUM
Benzoic Acid	Mountain cottontail (Mammalian herbivore)	4.6	46	
Bis(2-ethylhexyl)phthalate	American kestrel (Avian top carnivore)	9.3	93	
Bis(2-ethylhexyl)phthalate	American kestrel (insectivore / carnivore)	0.096	0.96	
Bis(2-ethylhexyl)phthalate	American robin (Avian herbivore)	16	160	
Bis(2-ethylhexyl)phthalate	American robin (Avian insectivore)	0.02	0.2	MINIMUM
Bis(2-ethylhexyl)phthalate	American robin (Avian omnivore)	0.04	0.4	
Bis(2-ethylhexyl)phthalate	Deer mouse (Mammalian omnivore)	1.1	11	
Bis(2-ethylhexyl)phthalate	Gray fox (Mammalian top carnivore)	500	5000	
Bis(2-ethylhexyl)phthalate	Montane shrew (Mammalian insectivore)	0.6	6	
Bis(2-ethylhexyl)phthalate	Mountain cottontail (Mammalian herbivore)	1900	19000	
Butyl Benzyl Phthalate	Deer mouse (Mammalian omnivore)	160	1600	
Butyl Benzyl Phthalate	Gray fox (Mammalian top carnivore)	23000	230000	
Butyl Benzyl Phthalate	Montane shrew (Mammalian insectivore)	90	900	MINIMUM

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Butyl Benzyl Phthalate	Mountain cottontail (Mammalian herbivore)	2400	24000	
Carbazole	Deer mouse (Mammalian omnivore)	79	790	MINIMUM
Carbazole	Gray fox (Mammalian top carnivore)	13000	130000	
Carbazole	Montane shrew (Mammalian insectivore)	110	1100	
Carbazole	Mountain cottontail (Mammalian herbivore)	140	1400	
Chlorobenzene	Deer mouse (Mammalian omnivore)	53	530	
Chlorobenzene	Earthworm (Soil-dwelling invertebrate)	2.4	24	MINIMUM
Chlorobenzene	Gray fox (Mammalian top carnivore)	25000	250000	
Chlorobenzene	Montane shrew (Mammalian insectivore)	43	430	
Chlorobenzene	Mountain cottontail (Mammalian herbivore)	170	1700	
Chlorophenol[2-]	American kestrel (Avian top carnivore)	310	3100	
Chlorophenol[2-]	American kestrel (insectivore / carnivore)	14	140	
Chlorophenol[2-]	American robin (Avian herbivore)	0.39	3.9	MINIMUM
Chlorophenol[2-]	American robin (Avian insectivore)	2.6	26	
Chlorophenol[2-]	American robin (Avian omnivore)	0.68	6.8	
Chlorophenol[2-]	Deer mouse (Mammalian omnivore)	0.54	5.4	
Chlorophenol[2-]	Gray fox (Mammalian top carnivore)	340	3400	
Chlorophenol[2-]	Montane shrew (Mammalian insectivore)	2.3	23	
Chlorophenol[2-]	Mountain cottontail (Mammalian herbivore)	0.74	7.4	
Dibenzofuran	Generic plant (Terrestrial autotroph - producer)	6.1	61	MINIMUM
Diethyl Phthalate	Deer mouse (Mammalian omnivore)	3600	36000	
Diethyl Phthalate	Generic plant (Terrestrial autotroph - producer)	100	1000	MINIMUM
Diethyl Phthalate	Gray fox (Mammalian top carnivore)	2500000	25000000	
Diethyl Phthalate	Montane shrew (Mammalian insectivore)	3600	36000	
Diethyl Phthalate	Mountain cottontail (Mammalian herbivore)	8800	88000	
Dimethyl Phthalate	Deer mouse (Mammalian omnivore)	38	460	
Dimethyl Phthalate	Earthworm (Soil-dwelling invertebrate)	10	100	MINIMUM
Dimethyl Phthalate	Gray fox (Mammalian top carnivore)	48000	590000	
Dimethyl Phthalate	Montane shrew (Mammalian insectivore)	80	980	
Dimethyl Phthalate	Mountain cottontail (Mammalian herbivore)	60	740	
Di-n-Butyl Phthalate	American kestrel (Avian top carnivore)	2	20	
Di-n-Butyl Phthalate	American kestrel (insectivore / carnivore)	0.052	0.52	
Di-n-Butyl Phthalate	American robin (Avian herbivore)	0.38	3.8	
Di-n-Butyl Phthalate	American robin (Avian insectivore)	0.011	0.11	MINIMUM
Di-n-Butyl Phthalate	American robin (Avian omnivore)	0.021	0.21	
Di-n-Butyl Phthalate	Deer mouse (Mammalian omnivore)	360	860	
Di-n-Butyl Phthalate	Generic plant (Terrestrial autotroph - producer)	160	600	
Di-n-Butyl Phthalate	Gray fox (Mammalian top carnivore)	62000	140000	
Di-n-Butyl Phthalate	Montane shrew (Mammalian insectivore)	180	450	
Di-n-Butyl Phthalate	Mountain cottontail (Mammalian herbivore)	17000	40000	
Di-n-octylphthalate	Deer mouse (Mammalian omnivore)	1.8	18	
Di-n-octylphthalate	Gray fox (Mammalian top carnivore)	1300	13000	
Di-n-octylphthalate	Montane shrew (Mammalian insectivore)	0.91	9.1	MINIMUM
Di-n-octylphthalate	Mountain cottontail (Mammalian herbivore)	8400	84000	
Methylphenol[2-]	Deer mouse (Mammalian omnivore)	580	5800	
Methylphenol[2-]	Generic plant (Terrestrial autotroph - producer)	0.67	7	MINIMUM
Methylphenol[2-]	Gray fox (Mammalian top carnivore)	160000	1600000	
Methylphenol[2-]	Montane shrew (Mammalian insectivore)	1500	15000	
Methylphenol[2-]	Mountain cottontail (Mammalian herbivore)	880	8800	
Methylphenol[3-]	Generic plant (Terrestrial autotroph - producer)	0.69	7	MINIMUM
Nitroaniline[2-]	Deer mouse (Mammalian omnivore)	5.3	10	MINIMUM

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Nitroaniline[2-]	Gray fox (Mammalian top carnivore)	2200	4400	
Nitroaniline[2-]	Montane shrew (Mammalian insectivore)	6.5	13	
Nitroaniline[2-]	Mountain cottontail (Mammalian herbivore)	11	22	
Nitrobenzene	Deer mouse (Mammalian omnivore)	4.8	48	
Nitrobenzene	Earthworm (Soil-dwelling invertebrate)	2.2	22	MINIMUM
Nitrobenzene	Gray fox (Mammalian top carnivore)	4100	41000	
Nitrobenzene	Montane shrew (Mammalian insectivore)	21	210	
Nitrobenzene	Mountain cottontail (Mammalian herbivore)	6.7	67	
Pentachloronitrobenzene	American kestrel (Avian top carnivore)	110	1100	
Pentachloronitrobenzene	American kestrel (insectivore / carnivore)	3.3	33	
Pentachloronitrobenzene	American robin (Avian herbivore)	21	210	
Pentachloronitrobenzene	American robin (Avian insectivore)	0.7	7	MINIMUM
Pentachloronitrobenzene	American robin (Avian omnivore)	1.3	13	
Pentachloronitrobenzene	Deer mouse (Mammalian omnivore)	22	220	
Pentachloronitrobenzene	Gray fox (Mammalian top carnivore)	3500	35000	
Pentachloronitrobenzene	Montane shrew (Mammalian insectivore)	11	110	
Pentachloronitrobenzene	Mountain cottontail (Mammalian herbivore)	930	9300	
Pentachlorophenol	American kestrel (Avian top carnivore)	57	570	
Pentachlorophenol	American kestrel (insectivore / carnivore)	1.7	17	
Pentachlorophenol	American robin (Avian herbivore)	29	290	
Pentachlorophenol	American robin (Avian insectivore)	0.36	3.6	MINIMUM
Pentachlorophenol	American robin (Avian omnivore)	0.72	7.2	
Pentachlorophenol	Deer mouse (Mammalian omnivore)	1.5	15	
Pentachlorophenol	Earthworm (Soil-dwelling invertebrate)	31	150	
Pentachlorophenol	Generic plant (Terrestrial autotroph - producer)	5	50	
Pentachlorophenol	Gray fox (Mammalian top carnivore)	230	2300	
Pentachlorophenol	Montane shrew (Mammalian insectivore)	0.81	8.1	
Pentachlorophenol	Mountain cottontail (Mammalian herbivore)	180	1800	
Phenol	Deer mouse (Mammalian omnivore)	37	370	
Phenol	Earthworm (Soil-dwelling invertebrate)	1.8	18	
Phenol	Generic plant (Terrestrial autotroph - producer)	0.79	8	MINIMUM
Phenol	Gray fox (Mammalian top carnivore)	43000	430000	
Phenol	Montane shrew (Mammalian insectivore)	640	6400	
Phenol	Mountain cottontail (Mammalian herbivore)	47	470	
Acetone	American kestrel (Avian top carnivore)	66000	660000	
Acetone	American kestrel (insectivore / carnivore)	840	8400	
Acetone	American robin (Avian herbivore)	7.5	75	
Acetone	American robin (Avian insectivore)	170	1700	
Acetone	American robin (Avian omnivore)	14	140	
Acetone	Deer mouse (Mammalian omnivore)	1.2	6.3	MINIMUM
Acetone	Gray fox (Mammalian top carnivore)	7800	39000	
Acetone	Montane shrew (Mammalian insectivore)	15	79	
Acetone	Mountain cottontail (Mammalian herbivore)	1.6	8	
Benzene	Deer mouse (Mammalian omnivore)	24	240	MINIMUM
Benzene	Gray fox (Mammalian top carnivore)	18000	180000	
Benzene	Montane shrew (Mammalian insectivore)	49	490	
Benzene	Mountain cottontail (Mammalian herbivore)	38	380	
Benzyl Alcohol	Deer mouse (Mammalian omnivore)	120	1200	MINIMUM
Benzyl Alcohol	Gray fox (Mammalian top carnivore)	110000	1100000	
Benzyl Alcohol	Montane shrew (Mammalian insectivore)	270	2700	
Benzyl Alcohol	Mountain cottontail (Mammalian herbivore)	190	1900	
Butanone[2-]	Deer mouse (Mammalian omnivore)	350	920	MINIMUM
Butanone[2-]	Gray fox (Mammalian top carnivore)	1300000	3500000	
Butanone[2-]	Montane shrew (Mammalian insectivore)	2700	6900	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Butanone[2-]	Mountain cottontail (Mammalian herbivore)	470	1200	
Carbon Disulfide	Deer mouse (Mammalian omnivore)	0.81	8.1	MINIMUM
Carbon Disulfide	Gray fox (Mammalian top carnivore)	190	1900	
Carbon Disulfide	Montane shrew (Mammalian insectivore)	1.2	12	
Carbon Disulfide	Mountain cottontail (Mammalian herbivore)	1.4	14	
Chloroaniline[4-]	Earthworm (Soil-dwelling invertebrate)	1.8	18	
Chloroaniline[4-]	Generic plant (Terrestrial autotroph - producer)	1	10	MINIMUM
Chloroform	Deer mouse (Mammalian omnivore)	8	21	MINIMUM
Chloroform	Gray fox (Mammalian top carnivore)	8900	24000	
Chloroform	Montane shrew (Mammalian insectivore)	8.2	22	
Chloroform	Mountain cottontail (Mammalian herbivore)	19	52	
Dichlorobenzene[1,2-]	Deer mouse (Mammalian omnivore)	1.5	15	
Dichlorobenzene[1,2-]	Gray fox (Mammalian top carnivore)	480	4800	
Dichlorobenzene[1,2-]	Montane shrew (Mammalian insectivore)	0.92	9.2	MINIMUM
Dichlorobenzene[1,2-]	Mountain cottontail (Mammalian herbivore)	12	120	
Dichlorobenzene[1,3-]	Deer mouse (Mammalian omnivore)	1.2	12	
Dichlorobenzene[1,3-]	Gray fox (Mammalian top carnivore)	380	3800	
Dichlorobenzene[1,3-]	Montane shrew (Mammalian insectivore)	0.74	7.4	MINIMUM
Dichlorobenzene[1,3-]	Mountain cottontail (Mammalian herbivore)	13	130	
Dichlorobenzene[1,4-]	Deer mouse (Mammalian omnivore)	1.5	6	
Dichlorobenzene[1,4-]	Earthworm (Soil-dwelling invertebrate)	1.2	12	
Dichlorobenzene[1,4-]	Gray fox (Mammalian top carnivore)	470	1800	
Dichlorobenzene[1,4-]	Montane shrew (Mammalian insectivore)	0.89	3.5	MINIMUM
Dichlorobenzene[1,4-]	Mountain cottontail (Mammalian herbivore)	12	49	
Dichloroethane[1,1-]	Deer mouse (Mammalian omnivore)	210	2100	MINIMUM
Dichloroethane[1,1-]	Gray fox (Mammalian top carnivore)	250000	2500000	
Dichloroethane[1,1-]	Montane shrew (Mammalian insectivore)	290	2900	
Dichloroethane[1,1-]	Mountain cottontail (Mammalian herbivore)	410	4100	
Dichloroethane[1,2-]	American kestrel (Avian top carnivore)	1300	2700	
Dichloroethane[1,2-]	American kestrel (insectivore / carnivore)	22	44	
Dichloroethane[1,2-]	American robin (Avian herbivore)	0.85	1.6	MINIMUM
Dichloroethane[1,2-]	American robin (Avian insectivore)	4.5	9	
Dichloroethane[1,2-]	American robin (Avian omnivore)	1.4	2.8	
Dichloroethane[1,2-]	Deer mouse (Mammalian omnivore)	27	270	
Dichloroethane[1,2-]	Gray fox (Mammalian top carnivore)	36000	360000	
Dichloroethane[1,2-]	Montane shrew (Mammalian insectivore)	91	910	
Dichloroethane[1,2-]	Mountain cottontail (Mammalian herbivore)	39	390	
Dichloroethene[1,1-]	Deer mouse (Mammalian omnivore)	14	140	
Dichloroethene[1,1-]	Gray fox (Mammalian top carnivore)	14000	140000	
Dichloroethene[1,1-]	Montane shrew (Mammalian insectivore)	11	110	MINIMUM
Dichloroethene[1,1-]	Mountain cottontail (Mammalian herbivore)	44	440	
Dichloroethene[cis/trans-1,2-]	Deer mouse (Mammalian omnivore)	25	250	
Dichloroethene[cis/trans-1,2-]	Gray fox (Mammalian top carnivore)	25000	250000	
Dichloroethene[cis/trans-1,2-]	Montane shrew (Mammalian insectivore)	24	240	MINIMUM
Dichloroethene[cis/trans-1,2-]	Mountain cottontail (Mammalian herbivore)	64	640	
Diphenylamine	American kestrel (Avian top carnivore)	3900	6500	
Diphenylamine	American kestrel (insectivore / carnivore)	49	81	
Diphenylamine	American robin (Avian herbivore)	78	130	
Diphenylamine	American robin (Avian insectivore)	10	16	MINIMUM
Diphenylamine	American robin (Avian omnivore)	17	29	
Hexachlorobenzene	American kestrel (Avian top carnivore)	12	120	
Hexachlorobenzene	American kestrel (insectivore / carnivore)	0.37	3.7	
Hexachlorobenzene	American robin (Avian herbivore)	83	830	
Hexachlorobenzene	American robin (Avian insectivore)	0.079	0.79	MINIMUM

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Hexachlorobenzene	American robin (Avian omnivore)	0.15	1.5	
Hexachlorobenzene	Deer mouse (Mammalian omnivore)	0.39	3.9	
Hexachlorobenzene	Earthworm (Soil-dwelling invertebrate)	10	100	
Hexachlorobenzene	Generic plant (Terrestrial autotroph - producer)	10	100	
Hexachlorobenzene	Gray fox (Mammalian top carnivore)	59	590	
Hexachlorobenzene	Montane shrew (Mammalian insectivore)	0.2	2	
Hexachlorobenzene	Mountain cottontail (Mammalian herbivore)	910	9100	
Hexanone[2-]	American kestrel (Avian top carnivore)	290	2900	
Hexanone[2-]	American kestrel (insectivore / carnivore)	1.7	17	
Hexanone[2-]	American robin (Avian herbivore)	0.47	4.7	
Hexanone[2-]	American robin (Avian insectivore)	0.36	3.6	MINIMUM
Hexanone[2-]	American robin (Avian omnivore)	0.41	4.1	
Hexanone[2-]	Deer mouse (Mammalian omnivore)	6.1	23	
Hexanone[2-]	Gray fox (Mammalian top carnivore)	5900	22000	
Hexanone[2-]	Montane shrew (Mammalian insectivore)	5.4	20	
Hexanone[2-]	Mountain cottontail (Mammalian herbivore)	17	65	
Iodomethane	American kestrel (Avian top carnivore)	46	92	
Iodomethane	American kestrel (insectivore / carnivore)	0.29	0.59	
Iodomethane	American robin (Avian herbivore)	0.038	0.076	MINIMUM
Iodomethane	American robin (Avian insectivore)	0.062	0.12	
Iodomethane	American robin (Avian omnivore)	0.047	0.095	
Methyl-2-pentanone[4-]	Deer mouse (Mammalian omnivore)	9.7	97	MINIMUM
Methyl-2-pentanone[4-]	Gray fox (Mammalian top carnivore)	18000	180000	
Methyl-2-pentanone[4-]	Montane shrew (Mammalian insectivore)	15	150	
Methyl-2-pentanone[4-]	Mountain cottontail (Mammalian herbivore)	17	170	
Methylene Chloride	Deer mouse (Mammalian omnivore)	2.6	22	MINIMUM
Methylene Chloride	Generic plant (Terrestrial autotroph - producer)	1600	16000	
Methylene Chloride	Gray fox (Mammalian top carnivore)	4300	36000	
Methylene Chloride	Montane shrew (Mammalian insectivore)	9.2	79	
Methylene Chloride	Mountain cottontail (Mammalian herbivore)	3.8	32	
Styrene	Earthworm (Soil-dwelling invertebrate)	1.2	12	MINIMUM
Styrene	Generic plant (Terrestrial autotroph - producer)	3.2	32	
Tetrachloroethene	Deer mouse (Mammalian omnivore)	0.35	1.7	
Tetrachloroethene	Generic plant (Terrestrial autotroph - producer)	10	100	
Tetrachloroethene	Gray fox (Mammalian top carnivore)	120	630	
Tetrachloroethene	Montane shrew (Mammalian insectivore)	0.18	0.94	MINIMUM
Tetrachloroethene	Mountain cottontail (Mammalian herbivore)	9.5	47	
Toluene	Deer mouse (Mammalian omnivore)	25	250	
Toluene	Generic plant (Terrestrial autotroph - producer)	200	2000	
Toluene	Gray fox (Mammalian top carnivore)	12000	120000	
Toluene	Montane shrew (Mammalian insectivore)	23	230	MINIMUM
Toluene	Mountain cottontail (Mammalian herbivore)	66	660	
Trichlorobenzene[1,2,4-]	Deer mouse (Mammalian omnivore)	0.51	5.1	
Trichlorobenzene[1,2,4-]	Earthworm (Soil-dwelling invertebrate)	1.2	12	
Trichlorobenzene[1,2,4-]	Gray fox (Mammalian top carnivore)	110	1100	
Trichlorobenzene[1,2,4-]	Montane shrew (Mammalian insectivore)	0.27	2.7	MINIMUM
Trichlorobenzene[1,2,4-]	Mountain cottontail (Mammalian herbivore)	12	120	
Trichloroethane[1,1,1-]	Deer mouse (Mammalian omnivore)	400	4000	
Trichloroethane[1,1,1-]	Gray fox (Mammalian top carnivore)	310000	3100000	
Trichloroethane[1,1,1-]	Montane shrew (Mammalian insectivore)	260	2600	MINIMUM
Trichloroethane[1,1,1-]	Mountain cottontail (Mammalian herbivore)	2000	20000	
Trichloroethene	Deer mouse (Mammalian omnivore)	54	540	

Analyte Name	ESL Receptor	No Effect ESL	Low Effect ESL	Minimum ESL
Trichloroethene	Gray fox (Mammalian top carnivore)	42000	420000	
Trichloroethene	Montane shrew (Mammalian insectivore)	42	420	MINIMUM
Trichloroethene	Mountain cottontail (Mammalian herbivore)	190	1900	
Trichlorofluoromethane	Deer mouse (Mammalian omnivore)	97	650	
Trichlorofluoromethane	Gray fox (Mammalian top carnivore)	62000	420000	
Trichlorofluoromethane	Montane shrew (Mammalian insectivore)	52	350	MINIMUM
Trichlorofluoromethane	Mountain cottontail (Mammalian herbivore)	1800	12000	
Vinyl Chloride	Deer mouse (Mammalian omnivore)	0.13	1.3	
Vinyl Chloride	Gray fox (Mammalian top carnivore)	110	1100	
Vinyl Chloride	Montane shrew (Mammalian insectivore)	0.12	1.2	MINIMUM
Vinyl Chloride	Mountain cottontail (Mammalian herbivore)	0.34	3.4	
Xylene (Total)	American kestrel (Avian top carnivore)	13000	130000	
Xylene (Total)	American kestrel (insectivore / carnivore)	190	1900	
Xylene (Total)	American robin (Avian herbivore)	89	890	
Xylene (Total)	American robin (Avian insectivore)	41	410	
Xylene (Total)	American robin (Avian omnivore)	56	560	
Xylene (Total)	Deer mouse (Mammalian omnivore)	1.9	2.4	
Xylene (Total)	Generic plant (Terrestrial autotroph - producer)	100	1000	
Xylene (Total)	Gray fox (Mammalian top carnivore)	750	930	
Xylene (Total)	Montane shrew (Mammalian insectivore)	1.4	1.8	MINIMUM
Xylene (Total)	Mountain cottontail (Mammalian herbivore)	7.6	9.5	

28. LANL (Los Alamos National Laboratory), June 2020k. Supplement 4-12 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Screening Level Air Modeling Analysis and Risk Evaluation for Open Burning Operations at Los Alamos National Laboratory*. LA-UR-20-24479. (LANL 2020k)

Supplement 4-12

Screening Level Air Modeling Analysis and Risk Evaluation for Open Burning Operations at Los Alamos National Laboratory

LA-UR-20-24479

Screening Level Air Modeling Analysis and Risk Evaluation for Open Burning Operations at Los Alamos National Laboratory

Operated by:

Triad National Security, LLC

Los Alamos National Laboratory

Los Alamos, New Mexico 87545

Owned by:

U.S. Department of Energy

National Nuclear Security Administration

Office of Los Alamos Site Operations

Los Alamos, New Mexico 87544

[This page has been left intentionally blank.]

TABLE OF CONTENTS

List of Tables

List of Figures

List of Attachments

List of Acronyms

AIEC	acute inhalation exposure concentrations
CCS	Chemical Compliance Systems, Inc.
DOE	U.S. Department of Energy
EF	emission factor
EPA	U.S. Environmental Protection Agency
ESL	ecological screening level
GLC	ground level concentration
LANL	Los Alamos National Laboratory
NAAQS	National Ambient Air Quality Standards
NMAAQS	New Mexico Ambient Air Quality Standards
NMED	New Mexico Environment Department
OBODM	Open Burn Open Detonation Model
REL	Reference Exposure Levels
RSL	Regional Screening Level
SR	State Road
SSL	Soil Screening Levels
TA	Technical Area

[This page has been left intentionally blank.]

1.0 INTRODUCTION

This report describes the air modeling analysis and risk evaluation for open burning operations conducted at Technical Area (TA)-16 located at Los Alamos National Laboratory (LANL). The purpose of this air modeling analysis is to simulate, study, and develop reasonable, yet conservative estimates, of potential air quality impacts from current and future open burning waste treatment operations at LANL.

LANL is located in Los Alamos County in north-central New Mexico. It is approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. The Facility and the associated residential and commercial areas of Los Alamos County are situated on the Pajarito Plateau. The Facility is owned and co-operated by the U.S. Department of Energy (DOE) and is co-operated by Triad National Security, LLC (LANL). The location of the open burning unit at LANL that is addressed in this report is shown in Figure 1-1.

1.1 Description of Open Burning Unit

The TA-16-388 Flash Pad is located at the TA-16 Burn Ground in the southwestern quadrant of LANL. The TA-16 Burn Ground is bounded on the northern side by Cañon de Valle and on the southern side by Water Canyon. The unit is used for the open burning treatment of detonable quantities of explosives waste and explosives-contaminated wastes.

The unit consists of a 22-foot (ft) by 22-ft concrete pad that has 3-ft high concrete walls along the back and two sides. Each of the three walls has a 5-ft long forced air propane burner mounted on it. The propane burners provide the heat and fuel for efficient waste treatment operations at the TA-16-388 Flash Pad. A picture of the unit is included as Figure 1-2. Treatment operations are most often conducted using the two side burners to treat waste placed in a steel tray. A retractable steel structure covers the concrete pad, burners and trays when the unit is not in use. The location coordinates of open burn unit in Universal Trans Mercator (UTM) Zone 13, NAD83 Datum coordinates are:

Unit	X-Coordinate	Y-Coordinate
TA-16-388 Flash Pad	379670.0	3967821.0

The unit is only used for treatment of explosives waste and explosives-contaminated waste. All treatment events utilize at least two propane burners and an average treatment operation lasts 30 minutes.

1.2 Waste Streams Treated Through Open Burning

The TA-16-388 Flash Pad is used to treat explosives waste and explosives-contaminated waste which are generated at LANL primarily from explosives processing operations, such as machining and pressing; research and development activities; and decommissioning and demolition activities. The waste streams include homogenous and heterogeneous wastes and are described in the following paragraphs.

<u>Explosives machining waste</u>

This waste stream consists of explosives machining chips or cuttings, water, filters, and filter solids that result primarily from the filtration of water used during the machining of explosives. Approximately one-third of this waste stream is water. Cloth filters are sometimes present in the waste. The waste stream is generated during explosives machining and explosives processing and may include plastic bags or wrapping. Water is used as a coolant during the machining process; therefore, explosives machining chips or cuttings and filters that are used to filter the water for reuse are generated as a wet high explosives waste stream.

Excess explosives

This waste stream includes large and small pieces of excess conventional explosives. Explosives may be in the form of flakes, granules, crystals, powders, pressings, plastic bonded, putties, rubberized solids, or extrudable solids. Explosives infrequently contain barium or ammonium nitrate mixed with more than 0.2% combustible substances. Other materials that may be present in this waste stream include plastic bags, wrapping, and casings; cardboard and paper; and fiberboard containers. A fraction of the waste stream may contain metals such as aluminum, brass, steel, stainless steel, and copper. This waste stream can include waste generated from inventory reduction efforts, off-specification explosives, damaged explosives, and salvaged explosives.

Explosives-contaminated combustible debris

This waste stream includes detonable explosives-contaminated debris generated in research laboratories, processing areas and prep rooms. Debris may include filters removed from laboratory equipment or may contain trace amounts of solvents. Other materials that may be present in this waste stream include plastic pieces, bags, wrapping and tubing; weigh boats; latex or nitrile gloves; glass or plastic vials; cardboard and paper; fiberboard containers; Kimwipes, rags, and swabs; glassware; and metal. Metal constituents may include aluminum, stainless steel, steel, brass and copper. Solvents in the waste stream may include trace quantities of ethanol, acetone, methanol, ethyl acetate, toluene, cyclohexanone, benzene, chloroform, 1,2-dichloroethane, 1,2-dichloroethylene, methyl ethyl ketone, fluor-inerts or trichloroethylene.

Explosives-contaminated solvent waste

This waste stream consists of dimethyl sulfoxide (DMSO) that contains dissolved explosives. It is generated primarily by dissolving of explosives and polymers in support of research and development activities.

Explosives-contaminated noncombustible debris

This waste stream consists of explosives-contaminated equipment that includes discarded, noncombustible equipment, debris from firing sites, noncombustible material from decommissioning and demolition activities, and material from explosives processing areas. This waste stream is typically recycled after treatment. Most often this waste stream consists of metal equipment or sand/carbon from water filtration activities. Because generation of this waste stream is related to maintenance and decommissioning and demolition activities, in many years none of this waste is generated. However, during decommissioning or maintenance activities at explosives processing buildings, noncombustible debris (including surplus equipment) will be generated. Any oil present within the equipment is drained, and the equipment is then disassembled and/or steam cleaned if it can be done safely.

Waste containers for all of the explosives waste streams described above generally consist of plastic bags, paper-lined cardboard boxes, plywood boxes, or plastic buckets. The preceding discussion describes typical waste treated through open burning at LANL. Up to 95% of the wastes treated by open burning within a year are explosives machining waste. Excess explosives including off-specification, damaged, and salvaged explosives make up an estimated annual quantity of approximately 5-15% of waste treated through open burning. The precise percentages vary somewhat depending on LANL strategic, research, and operational processes in the given year; however, it should be noted that the other three waste streams identified are treated infrequently.

1.3 Typical Open Burning Treatment Operations Compared to Modeled Parameters

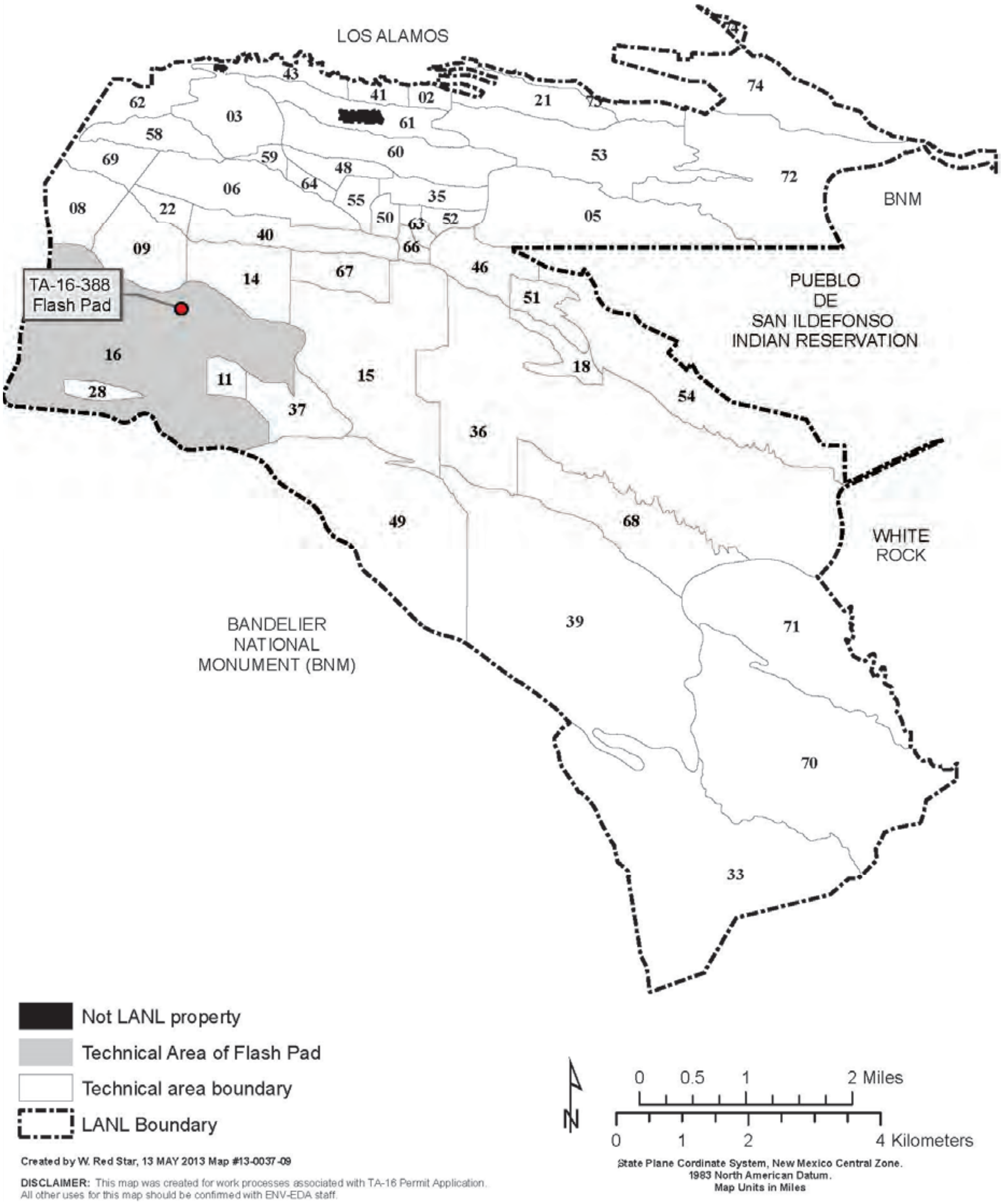
Attachment B (*Part A Application*) of the LANL Hazardous Waste Facility Permit (NMED, 2010), lists the capacity for the TA-16-388 Flash Pad as 100 gallons or 1,000 pounds per burn (lbs/burn). Annual burn limits for the TA-16-388 Flash Pad are not listed in the Permit and to date, have not been included in permit application documents. The modeling parameters detailed in Section 2.6 of this report, assume that a maximum amount of

200 lbs of explosives waste can be treated at the TA-16-388 Flash Pad at any one time. This weight does not take into account other noncombustible solids that may be present during a treatment event so that a representation of the maximum amount of waste that can be treated at one time could be analyzed for air impacts. Additionally, this air impact analysis report assumes that the maximum amount of explosives waste treated annually is 6,000 lbs. This approach allows for the calculation of annual air impacts for a potential maximum volume of waste per year and the calculation of the cumulative effects associated with that potential maximum.

The actual waste quantities treated at the TA-16-388 Flash Pad are generally much less than the quantities of waste modeled in this analysis. Average quantities per burn at the TA-16-388 Flash Pad are approximately 52 lbs/burn. This is roughly 26% of the 200 lbs/ burn modeled for this air impacts assessment. The average annual quantity of waste treated at the two units that operated over the past eight years at the TA-16 Burn Ground has been less than 3,000 lbs. The most that has been treated within a single year since 2003 was 5,345 lbs in 2010 during explosives inventory reduction efforts. In 2008, only 1,061 lbs were treated due to decreased production activities for the year. These variances demonstrate that to model a 6,000 lb maximum annual treatment volume for explosives wastes is a reasonable but still very conservative action. The quantity modeled is greater than the actual volumes treated in recent history, but is still close enough to represent a potential possibility for the unit. However, there is added conservatism to this quantity as 2010 waste treatment quantities utilized two open burning units at the TA-16 Burn Ground rather than the single unit (TA-16-388 Flash Pad) that the DOE/Triad are seeking to permit.

The number of treatment operations and the amount of time it takes to complete treatment operations at the TA-16-388 Flash Pad were also overestimated as part of this air impacts analysis. Modeling of air impacts assumed that the unit conducts treatment operations for a full hour and operated continuously from 8 AM to 5 PM for an entire year in order to ensure the maximum hourly annual air concentration was captured by the modeling. The operating conditions at the TA-16-388 Flash Pad are much less frequent than those modeled. Most treatment events are conducted in approximately 30 minutes, in the morning when the wind is generally the lowest of the day, and only one burn is conducted per day.

Also, as described in Section 3.0 of this report, the waste streams actually treated at the TA-16-388 Flash Pad are different from and in general less hazardous to human health and the environment than the waste streams that the emissions factors used in this analysis are based upon. No attempt was made to eliminate non-characteristic emissions from the analysis, which increases the conservative nature of the analysis. Waste stream emissions factors that have been chosen for this analysis estimate a higher air impact than would actually be released from day-to-day operations at the TA-16-388 Flash Pad.



Created by W. Red Star, 13 MAY 2013 Map #13-0037-09

DISCLAIMER: This map was created for work processes associated with TA-16 Permit Application. All other uses for this map should be confirmed with ENV-EDA staff.

Figure 1-2

Location Map of Open Buring Unit at Los Alamos National Laboratory

Figure 1-2
Photograph of Technical Area 16- 388 (TA-16-388) Flash Pad

2.0 AIR DISPERSION MODELING

Air dispersion modeling was conducted to estimate the ground level concentrations (GLCs) that occur downwind following an open burn event. The GLC is required to compare potential air quality impacts of open burning operations with health-based screening levels for air and soil. Dispersion modeling is a standard technique accepted by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) to estimate downwind concentrations.

2.1 Model Selection

The NMED specified this air modeling analysis should be conducted using the Open Burn and Open Detonation Model (OBODM). The EPA has approved the use of OBODM for modeling open burn/open detonation operations. Historically, NMED used OBODM to model air emissions from LANL's TA-16 Burn Ground during the previous Resource Conservation and Recovery Act (RCRA) permit application process.

Models used for predicting downwind concentrations, such as OBODM, assume dispersion follows a uniform Gaussian distribution within the plume. In reality, atmospheric dispersion is far more complex and is dependent on more unique source and terrain features than a model is capable of considering. Nevertheless, dispersion models are accepted tools to assess source impacts for regulatory purposes.

Considering numerous studies over time, the EPA states in Title 40 of the Code of Federal Regulations 51, *Appendix W – Guideline on Air Quality Models* that models are reasonably reliable for estimating the magnitude of the highest concentrations occurring within an area. Errors in the highest estimated concentrations of ± 10 to 40 percent are typical. However, estimates of concentrations that occur at a specific time and location are less reliable. Models are also more reliable in estimating longer time-averaged concentrations, such as annual averages, than for estimating short-term concentrations at specific locations.

OBODM is intended for use in evaluating the potential air quality impacts of the open-air burning and open detonation of obsolete munitions and solid propellants at U.S. Department of Defense and DOE installations (Bjorklund, et al., 1998a). OBODM predicts the downwind transport of pollutants using cloud rise and dispersion model algorithms from existing dispersion models. A complete description of the plume rise and dispersion algorithms used in OBODM is found in Volume II of the user's manual (Bjorklund, et al., 1998b). The OBODM allows for a simplistic representation of local meteorology and includes a screening-level complex terrain algorithm. All OBODM source and receptor locations are defined relative to a rectangular or a polar coordinate system in which north (0 degrees) is the positive Y-axis and east (90 degrees) is the positive X-axis. All vertical (z) coordinates are heights above ground level except when the OBODM complex terrain screening mode is used, in which case the z coordinates are terrain heights above mean sea level.

2.2 Methodology Steps

OBODM runs were conducted to determine the maximum GLC for acute and chronic exposures. Emission factors (EFs) for specific contaminants potentially generated by open burning operations were applied to model results to obtain concentrations for comparison to ambient air quality standards and human health soil screening levels. The methodology was comprised of the following steps:

1. A source strength model input file was prepared for short-term GLCs using the maximum quantity of hourly waste treated and propane used. The input file contained this maximum quantity for each hour from 8 AM to 5 PM for each day of the year.

2. Using a one-year continuous hourly on-site meteorological data set, OBODM was run using the hourly source strength file for the short-term 1-, 3-, 8-, and 24-hour averaging periods.
3. The hourly model results were used to create a source strength input file for estimating annual or chronic GLCs. In a descending order, maximum hourly waste quantities were assigned to the hours of the year with the highest predicted GLC from the hourly model runs. This was done until the sum of the hourly values equaled the maximum annual waste and propane quantity.
4. OBODM was run using the annual source strength file and the same one-year on-site meteorological data set for the annual averaging period.
5. In each model run, the contaminant emission rate was set at 1 gram per second (1 g/sec). Thus, the maximum GLC predicted was for a contaminant emission rate of 1 g/sec. The maximum GLC over the 1-g/sec emission rate, referenced as the X/Q value, and units of µg/m^3 per 1 g/sec.
6. EFs together with maximum waste and propane quantities were used to calculate the emission rate in g/sec for each specific pollutant or contaminant projected to occur from a burn.
7. Contaminant-specific GLCs for all averaging periods were calculated by multiplying the model result X/Q value (µg/m^3 divided by g/sec) times each chemical-specific emission rate (g/sec).
8. The calculated GLCs were compared to ambient air quality standards and human health and ecological risk screening levels for soil.

2.3 Model Input Values

The input values used in the model runs are summarized in Table 2-1. The fuel heat content for waste burned is representative of the range of wastes treated. However, the heat content of propane used to assist each burn is much higher than waste heat content. The calculated propane heat content assumes 1 gallon of propane is burned each minute during the 30-minute burn with a weight of 4.24 lb/gallon. This yields 127.2 lb/propane per burn. A representative propane heat content is 6,030 kcal/liter or 11,893 cal/g (AP-42, 2008). The fuel quantities are maximum hourly and annual values. The fuel burn rates were calculated from the hourly fuel quantity divided by the fuel burn time. A release height of 0.5 meters was specified.

Table 2-1

Model Input Values

Parameter	Input Value
Fuel Heat Content, cal/g	12,893 (1000 waste, 11,893 propane)
Hourly Fuel Quantity, lbs	327.2 (200 waste, 127.2 propane)
Annual Fuel Quantity, lbs	9816 (6000 waste, 3816 propane)
Fuel Burn Time, sec	1800
Fuel Burn Rate, lb/sec	0.18
Fuel Burn Rate, g/sec	82.5
Contaminant Emission Rate, g/sec	1

2.4 Meteorological Data

LANL maintains a network of on-site meteorological stations that is adequate to predict maximum downwind concentrations from open burning operations when using a full year of meteorological data. The centrally located TA-6 station is the official meteorological station for LANL and data from it are reported to the National Weather Service. The station consists of a 92-meter tower instrumented for wind and temperature at four levels. A one-year continuous hourly record from this station was used in the model input. This data set has been approved for use by NMED for all LANL air quality permitting and was used by NMED in the modeling and human health screening for the first TA-16 Burn Ground RCRA application in 2007. The TA-16 Burn Ground site elevation is 7,500 ft and the elevation of the TA-6 Meteorological Station is 7,424 ft. The TA-6 station is also the closest LANL meteorological station to the burn ground being at a distance of approximately 1.5 miles from the TA-16 Burn Ground. The use of an official meteorological station consistently lessens uncertainty and increases the ability to compare current, previous, and future modeling.

2.5 Receptors

Receptors are locations on-site or off-site where an individual may be exposed to contaminants within or from the air due to a stationary source of contamination to the air. Receptors with terrain elevations were established to ensure the maximum downwind concentrations were captured in the model runs. A Cartesian receptor grid was set up with the burn ground being the center point of a 2,000- by 2,000-meter grid with 100-meter spacing between receptors. Public receptors included nearby roadways, recreation areas, schools, hospitals, and tribal land. A list of public receptors is shown in Table 2-2.

Figure 2-1 shows the LANL property boundary, roadways, and the location of the on-site and off-site receptors used in the analysis. LANL property is shaded darker than the surrounding land in the figure. The sites and associated receptor grid are indicated in the black grid squares. Public receptors are indicated in yellow.

Table 2-2

Public Receptors

Receptor	X-Coordinate[1] (meters)	Y-Coordinate[1] (meters)	Elevation (meters)
Bandelier Entrance at State Road (SR) 4	384789.7	3962060.7	2031.2
Bandelier Visitor Center	385202.9	3960086.4	1845.1
San Ildefonso West of SR 4	388891.3	3967279.6	2006.7
White Rock Overlook Park	393146.0	3965274.7	1911.6
Piñon Elementary School, White Rock	390207.5	3964769.6	1981.0
Royal Crest Trailer Park	382432.8	3970723.1	2228.0
Los Alamos Medical Center	381001.8	3971679.6	2226.7
West Jemez Road	377585.0	3969284.5	2386.7
Ponderosa Campground	377386.1	3966238.8	2311.2
LANL SE Boundary	388723.0	3958724.3	1643.8
SR 4 SE	387161.9	3961999.5	1993.5
SR 4 SE	387131.3	3963223.8	1952.0
SR 4 SE	388019.0	3963805.4	1985.6
Pajarito Rd	388416.9	3965488.9	2003.9
Pajarito Rd	386702.8	3966284.8	2035.8
Pajarito Rd	385417.2	3967692.8	2130.0
Pajarito Rd	383764.3	3968549.8	2180.4
Pajarito Rd	382142.0	3969498.7	2220.6
West Jemez Rd	377367.0	3967907.1	2364.6
West Jemez Rd	378132.2	3970600.7	2406.3
SR 4 SW	383427.6	3962917.7	2105.2
SR 4 SW	382264.4	3964080.9	2156.9
SR 4 SW	380948.2	3965427.7	2208.7
SR 4 SW	379142.3	3966223.5	2260.6

[1] All Universal Transverse Mercator (UTM) coordinates are based on the datum, North American Datum (NAD) 83.

2.6 Model Methodology Description

OBODM runs were conducted to determine the maximum 1-, 3-, 8-, and 24-hour and annual air concentrations. The annual air concentration was used to calculate the 10-year soil concentration from pollutant deposition. Details of the approach taken are provided below.

Open burning operations occur from 8 AM to 5 PM local time in the summer and from 9 AM to 4 PM in the winter. Up to 200 lbs of explosives waste is treated in each burn; and a maximum of 6,000 lbs of waste can be treated per year. Due to preparation, only one burn per hour is conducted.

As noted in Section 1.3 of this report, typically only one burn occurs on the same day. However, to ensure the maximum hourly concentration was captured all hours of the year from 8 AM to 5 PM were modeled. This was done by using as input a source strength file with the maximum hourly explosives waste quantity of 200 lbs for each hour of the year from 8 AM to 5 PM. All other hours were specified as 0 lbs of waste.

Propane assist from two burners is used for each burn. Accordingly, the weight of propane burned per hour (127.2 lbs) was added to each hourly waste quantity for a total of 327.2 lbs/waste per burn.

To ensure the maximum annual air concentration was captured by the analysis, an annual source strength file was created based on the results of the hourly model run. Using an annual file with 8,760 hours per year, hourly waste quantities were used for the hour of the year, which corresponded to the hours that showed the highest concentrations in the hourly model runs. This model was run in a descending manner starting with the hour showing the highest concentration and down to the hourly results until the annual waste quantities of 6,000 lbs/yr were reached. The weight of propane was also added to each hourly input waste quantity.

In all model runs, a 1-g/sec contaminant emission rate was specified. The contaminant for model purposes was non-specific and the model results for this analysis were not dependent on specification of a particular contaminant or pollutant. The model does not consider any reactivity or unique characteristic of a pollutant as it travels downwind for the emission source. Although within OBODM a user can specify the molecular weight for a specific pollutant, the value is only used by the model if results are requested in terms of parts per million, which was not the case in this analysis where results in $\mu g/m^3$ (parts per billion or ppb) were used.

The density of a pollutant can also be specified if deposition due to gravitational settling is desired. For this analysis, OBODM could not be used to estimate deposition because the model will not calculate deposition except in flat terrain. For the complex terrain in this analysis with terrain elevations assigned to receptors, the model will not run if results for deposition are requested.

Each run was conducted using the appropriate source strength file as described above, the one-year hourly meteorological data set from the LANL TA-6 station, and the receptors described in Section 2.5. Table 2-3 summarizes the two scenarios modeled.

Table 2-3

Model Scenarios

Averaging Time	Waste Quantity (pounds of waste per burn)	Input/output File Name[1]
1, 3, 8, and 24 hours[2]	327.2 (200 waste, 127.2 propane)	388H8.INP 388H8.OUT
Annual	9816 (6000 waste, 3816 propane)	388A1.INP 388A1.OUT

[1] OBODM input and output files, the accompanying hourly source strength files, and the model-ready meteorological data file have been provided to the NMED in electronic format for review purposes.

[2] The 1-, 3-, 8-, and 24-hour averaging periods were needed to assess compliance with ambient air quality standards for those averaging times.

2.7 Model Results

The maximum GLCs from model runs for each averaging period are shown in Table 2-4 together with the X and Y coordinates for each value. All maximum GLCs occurred close to the burn ground on LANL property at the five receptors within the 2,000- by 2,000-meter receptor grid centered on the burn site. The highest single GLC for the nearby public receptors is also shown for each averaging period together with the location of the public receptor. The values shown represent results using the 1-g/sec contaminant emission rates. Specific concentrations for individual pollutants were calculated using these results. Each of these locations with the predicted maximum GLC is shown on Figure 2-2.

Table 2-4

Maximum Ground Level Concentrations and Locations

	Maximum GLC (μg/m³)	X-Coordinate (meters)	Y-Coordinate (meters)	Public Receptor Maximum GLC (μg/m³)	Public Receptor Location
TA16 Burn Ground		379670.0	3967821.0		
1-hour	1.05E+01	379270.0	3968121.0	2.78E+00	SR 4 SW
3-hour	3.95E+00	379370.0	3968021.0	9.47E-01	SR 4 SW
8-hour	2.21E+00	379670.0	3968221.0	5.08E-01	SR 4 SW
24-hour	7.73E-01	380070.0	3967821.0	1.72E-01	SR 4 SW
Annual	9.32E-03	379370.00	3967821.0	1.93E-03	West Jemez Rd

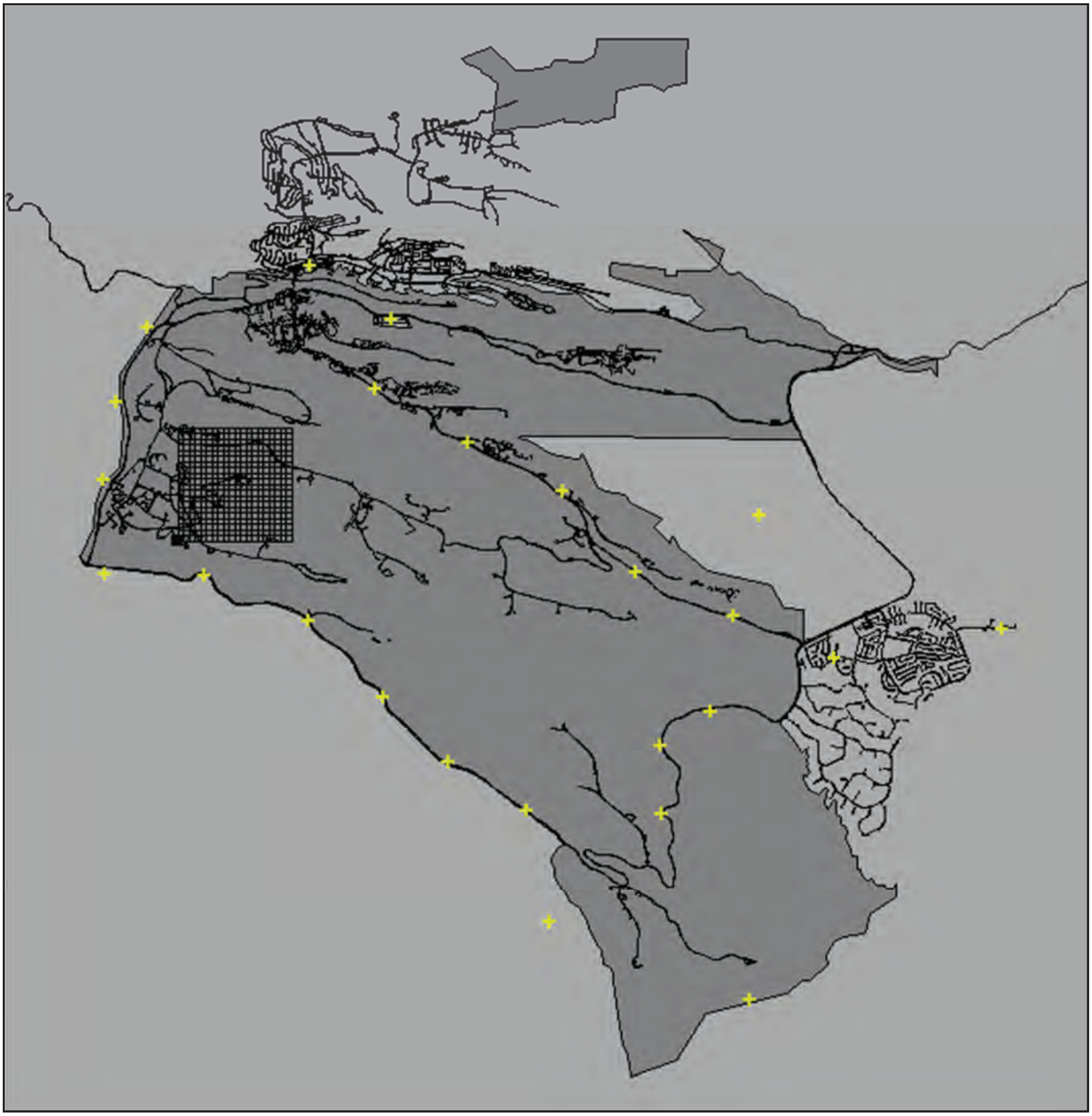


Figure 2-1

Location of Public Receptors and Receptor Grid

(Black grid squares are the site location and the yellow plus signs are public receptors.)

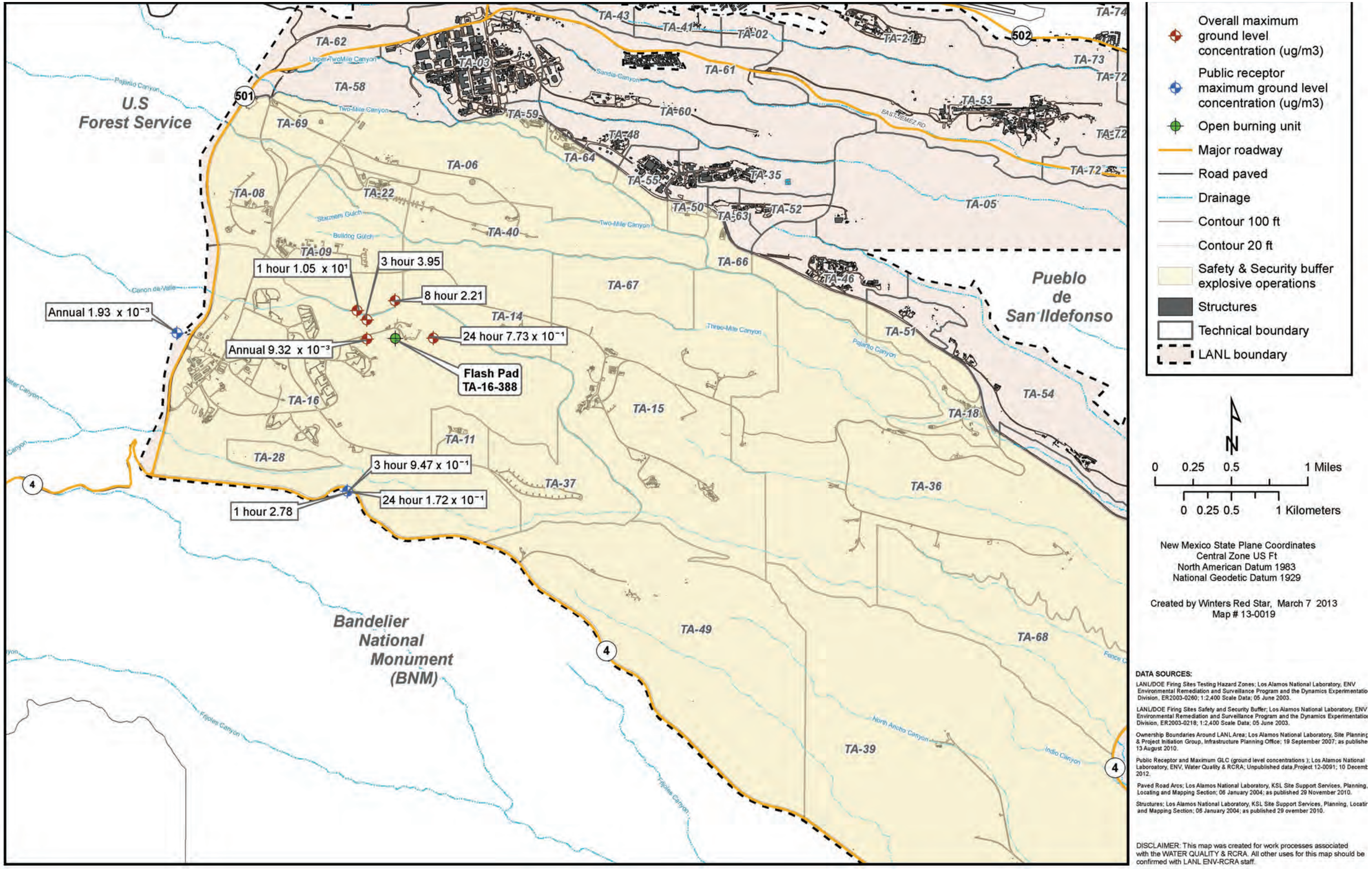


Figure 2-2

Locations of Highest Predicted Ground Level Concentrations from TA-16-388 Flash Pad Open Burning Unit

[This page has been left intentionally blank.]

3.0 EMISSION FACTORS FOR OPEN BURNING

This section describes the sources of emission factors and the emission factors applied to each waste stream treated by open burning. Waste streams treated by open burning are described in Section 1.2 of this document. An emissions factor is a documented representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Based on the waste streams described, emission factors were chosen for pollutants that had air quality limits. Emission factors are not shown for pre-treatment and post-treatment emissions such as fugitive dust, because no equipment operates off-road, earth-moving operations are not part of the open burning/open detonation activities, and ash generation is routinely negligible from open burning operations. Additionally, emission factors for the detonation of explosives, where more recent research has been conducted and is available, were not considered for use because detonation has processes, such as fragment formation, that do not occur during open burning.

Materials burned at the TA-16-388 Flash Pad may vary in composition from consisting mostly-to-all explosives and explosives pieces, to small quantities of explosives on contaminated combustible solids or noncombustible solids. Most of the emissions products (over 99 percent) associated with open burning are carbon, nitrogen, and oxygen. In fact, emission products from most energetic material treated by open burning can be adequately represented by the following analytes: carbon dioxide, carbon monoxide, nitrogen oxide, and nitrogen dioxide; with only trace quantities of total saturated hydrocarbons, acetylene, ethylene, propene, benzene, toluene, and particulates (EPA, 1998).

In order to characterize the potential impact to the site from air dispersion and depositions, the minimal fractions of contaminants that may be produced during open burning treatment activities have been estimated using calculations and emission factors from documented sources. The maximum amount of burnable material that can be treated at the TA-16-388 Flash Pad is 200 lbs per burn and 6,000 lbs per year. In order to reasonably, but conservatively represent waste treatment activities at the TA-16-388 Flash Pad, a combined waste stream was developed that encompasses the most conservative emission factors from surrogates that represent the waste streams treated by open burning. This methodology sufficiently covers the worst-case scenario for emissions from the unit.

Surrogate waste streams described below and chosen to represent each waste stream detailed in Section 1.2, were chosen from one of the limited documented sources. The waste stream-specific emission factors were combined to create a single surrogate waste stream that encompasses all waste streams that may be treated at the TA-16-388 Flash Pad. This waste stream is represented by the combined emission factors located in Column 7 of Table 3-1. Emission factors for the propane that is used as fuel for open burning waste treatment are shown separately, but are included with the waste stream surrogate as part of the air impact assessment.

3.1 Emission Factors for Excess Explosives, Explosives Machining Waste, and Explosives-Contaminated Noncombustible Debris

Approximately 99 percent of the waste treated at the TA-16-388 Flash Pad is a combination of explosives machining waste, excess explosives waste, and explosives-contaminated noncombustible debris. As described in Section 1.2, the excess explosives waste stream consists of pure explosives that may be held within plastic bags, cardboard, or paper in some cases; the explosives machining waste stream consist of pure explosives shavings or cuttings, water, and sometimes cloth filters; and the explosives-contaminated noncombustible debris consists primarily of metal piping, equipment, concrete, or soil generated during decommissioning and environmental restoration activities. Because the non-combustible materials themselves do not burn, the only emissions result from the burning of the explosives.

The specific types of explosives treated by open burning vary depending primarily on research and development (R&D) and stockpile stewardship activities. The primary types of explosives treated are 1,3,5 triamino 2,4,6 trinitrobenzene (TATB), cyclotetramethylenetetranitramine (HMX), trinitrotoluene (TNT), and cyclonite (RDX). Emission factors are not available for all of the explosives treated.

TNT is the least oxygenated; therefore, it is an explosive that burns less completely ("dirtier") than others treated at the TA-16-388 Flash Pad. Emission factors for burning TNT are available in Chapter 6, Section 3, Table 6.3-1 of EPA's Compilation of Air Pollutant Emission Factors (EPA, 1983). There are no toxic air pollutant emission factors for TNT in AP-42; therefore, the emission factors available from the Open Burn/Open Detonation Dispersion Model (OBODM) User's Guide (Bjorklund, et.al., 1998a.) for burning types of explosives similar to those burned at the TA-16-388 Flash Pad were reviewed. The types of materials in the EPA document that can be considered to be most similar to those treated at LANL are:

- M-43, which contains RDX;
- PBXN-110, which contains HMX; and
- M31A1E1, a mixture of explosives.

While these waste stream surrogates contain some of the explosives treated by open burning at LANL, a number of contaminants are present within the surrogates that are not be present in LANL explosives treated at the site. However, no attempt has been made to eliminate these extraneous contaminants from this analysis which provides an even more conservative estimate of potential emissions from treated waste. Emission factors from each of the waste stream surrogates are used as published for this assessment to provide a conservative emissions estimate. The highest pollutant-specific emission factor for any of the three waste stream surrogates was chosen for inclusion in this air impact assessment. Columns 2 through 5 of Table 3-1 summarize the emission factors used to represent this waste stream in grams (g) of pollutant per g of waste (g/g) and identify the waste surrogate of origin.

3.2 Emission Factors for Combustible Solids

Emission factors from the diesel and dunnage surrogate waste in the OBODM User's Guide (Bjorklund, et.al., 1998a) were used for this waste category. The diesel and dunnage waste consisted of scrap wood, dead branches from trees and shrubs, Styrofoam™ packing material, other combustibles, and diesel fuel. These emission factors, shown in Column 6 of Table 3-1, should be much higher than those produced from the typical treatment of explosives contaminated combustible waste stream at LANL. In contrast to the diesel and dunnage surrogate waste, the explosives contaminated combustible debris waste stream at LANL is characterized by dry waste, no vegetation, no diesel, a high heating value from the explosives in the waste, and clean supplemental fuel (propane burners).

While reviewing available surrogate waste streams from the OBODM User's Guide, initially it was determined that the aluminized ammonium perchlorate (AP) propellant manufacturing waste category may be a better fit as a surrogate for the LANL explosives-contaminated combustible debris waste stream. The manufacturing surrogate waste was conceptually designed to simulate the mix of AP-contaminated plastic gloves, cotton rags, paper wipes, wood towel rods and similar materials that result from the clean-up of the vessels used to manufacture AP-based propellants (EPA, 1998). As a general description, this surrogate gets far closer to the waste stream treated at LANL than the diesel and dunnage waste surrogate. However, there are two major reasons this surrogate was not ultimately selected to represent this LANL waste stream. The first reason is that LANL does not treat AP through open burning so these emission factors are not accurately representative of the wastes treated at LANL. The second and more important reason for not choosing this waste surrogate is that the trial-run execution for the development of emission factors for the AP-manufacturing surrogate waste was determined to be erroneously flawed and thus was not used to represent any waste stream that is treated by open burning at LANL.

Specifically, it was determined that the surrogate waste used for the trials was not truly representative of a real manufacturing waste because of the way the propellant was placed in contact with the combustible materials. One-inch cubes were placed randomly on top and in contact with the combustible materials rather than dispersed on the materials as a powder as the waste stream would actually be generated. Because of this type of cube dispersion all of the trials resulted in holes in the stainless steel pan. The unique mix of emission products, the melted plastic, and the rate of conversion of N to NOx observed for the surrogate AP-manufacturing waste demonstrated that this burn was very different from all other burns that involved energetic materials (EPA, 1998).

An additional consideration taken into account during the development of an emission factor list for this waste stream is the potential for dioxin and furan formation. Dioxins and furans are formed from burning almost any kind of material, including forest fires, residential wood combustion, and residential oil heating (EPA 1997a). The factors that affect dioxin formation include temperature, time and turbulence, oxygen, carbon, chlorine, bromine, catalysts, and humidity. Precursors to the formation of dioxins/furans within the lower range of temperatures (200-400 ^{o}C), rely heavily on the presence of the products of incomplete combustion to include chlorine compounds, halogens, soot or fly ash, and metals (Zhang et. al, 2017). These compounds generally are not present in the waste treated by open burning for the reasons described below, and the temperature at which treatment events occur is sustained well above this lower temperature range. The temperature of the propane burners is in excess of 1400 degrees Fahrenheit (^{o}F) or 760 ^{o}C. The temperature of the burn area stays consistently above 1800 ^{o}F (approximately 982 ^{o}C). The types of explosives burned at the TA-16-388 Flash Pad most often range in burn temperature from approximately 1070-2030 ^{o}C and often make up a large percentage of the waste being treated. Temperatures exceeding 400 ^{o}C are documented to provide destruction at a faster pace than formation (Zhang et. al, 2017). At higher temperatures (650–900 °C), there is a very close dependence of the formation of chlorinated and nonchlorinated aromatic compounds with residence time in a combustion and/or afterburning chamber with the presence of the necessary parameters (Wielgosiński, 2011). Again, this is not the case in treatment events at the TA-16-388 Flash Pad. Because of the system design and operations of the propane burning, there is minimal residence time for gases (and soot/carbon if present) to be trapped with catalysts (metals). Additionally, the air turbulence of the operation of two propane burners in an open air environment decrease any residence time further. Also, due to the system design and operations of the treatment process, there is sufficient available oxygen for complete combustion, while carbon is present fundamentally as a part of an explosive waste stream, it is actively being burned by the appropriate treatment method rather than smoldering and generating any char or soot as necessary to form dioxin/furan compounds. Chlorine and halogens are generally not present in the waste treated by open burning. Paper and small plastic bags (making up less than 1%) may be the only materials for potentially chlorine-producing compounds treated at LANL. While metals are present within some of the waste streams treated by open burning, the intent of the waste treatment activity is to burn any explosives contamination off of the metal, not to vaporize the metal. Lastly, though most of the waste treated by controlled open burning at the TA-16-388 Flash Pad is wetted waste, the water present is evaporated off the waste explosive as the waste is burned. The temperature of the burn is high enough that there is no smoldering, char, or soot formation within the process, that would be necessary for dioxin formation. Very little ash is generated by the treatment process overall.

Dioxin/furan formation can be avoided by ensuring that the process of combustion is complete. To ensure complete combustion an adequate oxygen supply is necessary as well as ensuring the three T's of combustion (temperature, time, and turbulence). This documented temperature of treatment events is more than sufficient to ensure that the reactive characteristic (explosives content) within the waste is eliminated. The TA-16-388 Flash Pad internal operating procedures require that, for all burn events, the waste must continue to be treated until the certified operator determines visually that the waste is fully treated. The multidirectional propane burners ensure that high combustion turbulence is maintained throughout the treatment event. Therefore, it is unlikely that dioxins and furans could be formed during the OB operations currently conducted at LANL.

3.3 Emission Factors for Open Burning of Liquids

The explosives-contaminated solvent waste stream historically consisted of oils and solvents contaminated with explosives. Due to changes in processes and improved waste characterization, this waste stream has decreased considerably in recent history. No oils and most solvents will not be treated by open burning in the future. The only solvent that may be treated at the TA-16-388 Flash Pad is dimethyl sulfoxide (DMSO) which contains 25 percent or greater dissolved explosives.

No emission factors were identified for burning explosives-contaminated liquids. Also, DMSO is not a petroleum product; therefore, emission factors from burning of fuel oil used in past analyses are not applicable. This waste stream is treated infrequently so no emission factors specific to DMSO have been incorporated into the assessment. The trace solvents discussed for the surrogate waste streams above serve as solvent representation.

3.4 Emission Factors for Open Burning of Propane

Propane is burned to improve combustion efficiency of explosives and explosives-contaminated waste streams. A typical burn uses two burners at a time for approximately 30 minutes per burn. The two burners together consume approximately 1 gallon of propane per minute for a total of 30 gallons (127.2 lbs) per burn. Emissions from burning the propane are additive to the emissions from burning the waste. The emission factors were obtained from Chapter 1.5, Table 1.5-1 of AP-42 (EPA, 2008). The commercial boiler emission factors were used because the heat input capacities for commercial boilers are generally between 0.3 and 10 million British Thermal Units per hour. No toxic air pollutant emission factors were located, but propane is a very clean-burning fuel and products of incomplete combustion should be minimal. Emission factors are shown in Table 3-2.

Table 3-1.

Emission Factors by Surrogate Waste Streams and Combined Waste Stream

Name of Pollutant	TNT Emission Factor [1]	M31A1E1 Emission Factor	M-43 Emission Factor	PBXN-110 Emission Factor	Diesel and Dunnage Emission Factor	Combined Emission Factor[2]	Surrogate Name of Max Emission Factor
1,2,4-Trimethylbenzene			3.87E-07	4.25E-07	2.43E-04	2.43E-04	Diesel and Dunnage
sec-Butylbenzene		3.43E-07	4.53E-07	1.10E-06	5.09E-04	5.09E-04	Diesel and Dunnage
1,3,5-Trimethylbenzene		4.29E-08	9.07E-08	2.99E-07	5.57E-04	5.57E-04	Diesel and Dunnage
1,3-Butadiene			9.07E-08	4.98E-07	1.34E-06	1.34E-06	Diesel and Dunnage
1-Butene		2.29E-07	2.72E-07	5.97E-07	4.69E-06	4.69E-06	Diesel and Dunnage
1-Hexene		1.07E-07			2.19E-06	2.19E-06	Diesel and Dunnage
1-Pentene		3.55E-08	9.07E-08	9.95E-08	1.72E-06	1.72E-06	Diesel and Dunnage
2,2,4-Trimethylpentane		1.29E-07			6.97E-06	6.97E-06	Diesel and Dunnage
2,2-Dimethylbutane		4.29E-08				4.29E-08	M31A1E1
2,3,4-Trimethylpentane					1.38E-06	1.38E-06	Diesel and Dunnage
2,3-Dimethylbutane		3.55E-08			2.06E-06	2.06E-06	Diesel and Dunnage
2,3-Dimethylhexane					5.40E-06	5.40E-06	Diesel and Dunnage
2,3-Dimethylpentane					3.33E-06	3.33E-06	Diesel and Dunnage
2,4,4-Trimethyl-1-pentene		8.58E-08	9.07E-08	1.99E-07		1.99E-07	PBXN-110
2,4-Dimethylhexane				1.99E-07	6.42E-06	6.42E-06	Diesel and Dunnage
2,4-Dimethylpentane					2.16E-06	2.16E-06	Diesel and Dunnage
2,5-Dimethylhexane					1.11E-05	1.11E-05	Diesel and Dunnage
2-Methyl-1-butene			9.07E-08	1.99E-07	1.05E-06	1.05E-06	Diesel and Dunnage
2-Methyl-2-butene			9.07E-08			9.07E-08	M-43
2-Methylheptane		3.44E-08	9.07E-08		4.42E-05	4.42E-05	Diesel and Dunnage
2-Methylhexane		4.29E-08	1.81E-07		1.38E-05	1.38E-05	Diesel and Dunnage
2-Methylnaphthalene					2.18E-05	2.18E-05	Diesel and Dunnage
2-Methylpentane		6.89E-08			9.47E-06	9.47E-06	Diesel and Dunnage
3-Ethylhexane, 3-Methylheptane		1.07E-07	9.07E-08		5.90E-05	5.90E-05	Diesel and Dunnage

Table 3-1. Emission Factors by Surrogate Waste Streams and Combined Waste Stream (continued)

Name of Pollutant	TNT Emission Factor [1]	M31A1E1 Emission Factor	M-43 Emission Factor	PBXN-110 Emission Factor	Diesel and Dunnage Emission Factor	Combined Emission Factor[2]	Surrogate Name of Max Emission Factor
3-Methyl-1-butene			9.07E-08	1.99E-07		1.99E-07	PBXN-110
3-Methylhexane					1.55E-05	1.55E-05	Diesel and Dunnage
3-Methylpentane		3.77E-08			5.08E-06	5.08E-06	Diesel and Dunnage
Acenaphthylene					6.71E-06	6.71E-06	Diesel and Dunnage
Acetophenone					1.74E-07	1.74E-07	Diesel and Dunnage
Acetylene		1.02E-06	5.89E-06	3.09E-06	9.52E-05	9.52E-05	Diesel and Dunnage
Aluminum					7.13E-07	7.13E-07	Diesel and Dunnage
Anthracene					1.02E-07	1.02E-07	Diesel and Dunnage
Aromative (e.g. Styrene)		5.43E-05	2.81E-06	7.07E-06	2.29E-03	2.29E-03	Diesel and Dunnage
Barium		4.20E-07			1.61E-07	4.20E-07	M31A1E1
Benzene		9.98E-07	1.76E-06	4.88E-06	7.84E-05	7.84E-05	Diesel and Dunnage
Benzo(a)anthracene					9.81E-07	9.81E-07	Diesel and Dunnage
Benzo(a)pyrene					7.42E-07	7.42E-07	Diesel and Dunnage
Benzo(b)fluoranthene					7.84E-07	7.84E-07	Diesel and Dunnage
Benzo(ghi)perylene					3.45E-07	3.45E-07	Diesel and Dunnage
Benzo(k)fluoranthene					7.46E-07	7.46E-07	Diesel and Dunnage
Benzyl alcohol		1.91E-09			3.96E-05	3.96E-05	Diesel and Dunnage
Biphenyl					6.45E-06	6.45E-06	Diesel and Dunnage
Butylbenzyl phthalate(85-68-7)					1.22E-07	1.22E-07	Diesel and Dunnage
Carbon Tetrachloride		6.89E-08				6.89E-08	Diesel and Dunnage
Chromium		3.97E-07				3.97E-07	M31A1E1
Chrysene					9.33E-07	9.33E-07	Diesel and Dunnage
cis-2-Butene		1.29E-07	9.07E-08	1.99E-07		1.99E-07	PBXN-110
cis-2-Pentene			9.07E-08			9.07E-08	M-43
CO	2.80E-02	1.66E-04	1.40E-03	2.32E-02	2.98E-02	2.98E-02	Diesel and Dunnage
CO2		6.45E-01	7.73E-01	1.04E+00	1.63E+00	1.63E+00	Diesel and Dunnage
Copper		6.31E-06				6.31E-06	M31A1E1
Cyclohexane		3.55E-08	9.07E-08		2.67E-05	2.67E-05	Diesel and Dunnage

Table 3-1. Emission Factors by Surrogate Waste Streams and Combined Waste Stream (continued)

Name of Pollutant	TNT Emission Factor [1]	M31A1E1 Emission Factor	M-43 Emission Factor	PBXN-110 Emission Factor	Diesel and Dunnage Emission Factor	Combined Emission Factor[2]	Surrogate Name of Max Emission Factor
Cyclopentane		4.29E-08	9.07E-08	9.95E-08	1.53E-06	1.53E-06	Diesel and Dunnage
Dibenz(a,h)anthracene					2.00E-07	2.00E-07	Diesel and Dunnage
Diethyl phthalate		6.58E-08			7.00E-08	7.00E-08	Diesel and Dunnage
Dimethyl phthalate					1.88E-07	1.88E-07	Diesel and Dunnage
Di-n-butyl phthalate		3.30E-07			1.46E-07	3.30E-07	M31A1E1
Di-n-octyl phthalate					9.19E-07	9.19E-07	Diesel and Dunnage
Ethane		6.38E-08	1.81E-07	9.95E-07	1.15E-05	1.15E-05	Diesel and Dunnage
Ethyl chloride		6.89E-08				6.89E-08	M31A1E1
Ethylbenzene		4.44E-07	3.42E-07	7.96E-07	5.49E-05	5.49E-05	Diesel and Dunnage
Ethylene		9.78E-07	4.81E-06	6.67E-06	7.43E-05	7.43E-05	Diesel and Dunnage
Fluoranthene					7.85E-07	7.85E-07	Diesel and Dunnage
HCL			9.97E-04	1.79E-04		9.97E-04	M-43
i-Butane		7.11E-08			1.24E-06	1.24E-06	Diesel and Dunnage
i-Butene		1.51E-07	5.44E-07	1.29E-06	2.26E-06	2.26E-06	Diesel and Dunnage
Indeno(1,2,3-cd)pyrene					2.83E-07	2.83E-07	Diesel and Dunnage
i-Pentane			9.07E-08		1.08E-05	1.08E-05	Diesel and Dunnage
i-Propylbenzene					1.03E-04	1.03E-04	Diesel and Dunnage
m- & p-Xylene		1.33E-06	6.83E-07	7.96E-07	4.52E-04	4.52E-04	Diesel and Dunnage
Methane					8.72E-05	8.72E-05	Diesel and Dunnage
Methyl chloroform		3.44E-08				3.44E-08	M31A1E1
Methylchloride		2.84E-07		1.81E-07		2.84E-07	M31A1E1
Methylcyclohexane		3.30E-07			1.56E-04	1.56E-04	Diesel and Dunnage
Methylcyclopentane					9.93E-06	9.93E-06	Diesel and Dunnage
Methylenechloride		7.46E-07				7.46E-07	M31A1E1
m-Ethyltoluene		8.58E-08		1.99E-07	1.28E-04	1.28E-04	Diesel and Dunnage
Naphthalene					8.38E-05	8.38E-05	Diesel and Dunnage
n-Butane		3.44E-07	9.07E-08	9.95E-08	4.60E-06	4.60E-06	Diesel and Dunnage
n-Decane		3.55E-08	8.16E-07	1.29E-06	1.97E-03	1.97E-03	Diesel and Dunnage

Table 3-1. Emission Factors by Surrogate Waste Streams and Combined Waste Stream (continued)

Name of Pollutant	TNT Emission Factor [1]	M31A1E1 Emission Factor	M-43 Emission Factor	PBXN-110 Emission Factor	Diesel and Dunnage Emission Factor	Combined Emission Factor[2]	Surrogate Name of Max Emission Factor
n-Heptane			9.07E-08		5.90E-05	5.90E-05	Diesel and Dunnage
n-Hexane			9.07E-08		1.60E-05	1.60E-05	Diesel and Dunnage
Nitrogen dioxide (peroxide)		9.67E-05	4.69E-04	2.82E-04	5.07E-05	4.69E-04	M-43
Nitrogen Oxide		1.18E-03	6.28E-03	2.62E-03	7.99E-04	6.28E-03	M-43
Nitrogen Oxides	7.50E-02					7.50E-02	TNT
n-Nonane		4.29E-08		1.99E-07	1.03E-03	1.03E-03	Diesel and Dunnage
n-Octane		3.55E-08	9.07E-08		2.48E-04	2.48E-04	Diesel and Dunnage
Non-methane Organic Compound		1.03E-07	4.99E-05	1.07E-04	7.84E-03	7.84E-03	Diesel and Dunnage
n-Pentane					9.05E-06	9.05E-06	Diesel and Dunnage
n-Propylbenzene		1.72E-07		9.95E-08	8.16E-05	8.16E-05	Diesel and Dunnage
OCDD					1.03E-11	1.03E-11	Diesel and Dunnage
o-Ethyltoluene		3.90E-07		2.99E-07		3.90E-07	M31A1E1
o-Xylene		3.44E-07	9.07E-08	3.75E-07	1.25E-04	1.25E-04	Diesel and Dunnage
Particulates	9.00E-02					9.00E-02	TNT
Perylene					1.72E-07	1.72E-07	Diesel and Dunnage
p-Ethyltoluene		7.11E-08	1.81E-07	4.25E-07	1.53E-04	1.53E-04	Diesel and Dunnage
Phenanthrene					7.17E-06	7.17E-06	Diesel and Dunnage
Phenol					1.56E-05	1.56E-05	Diesel and Dunnage
PM10		9.10E-01	1.18E-03	4.87E-01	5.44E-03	9.10E-01	M31A1E1
Propane		3.08E-07		2.99E-07	2.22E-06	2.22E-06	Diesel and Dunnage
Propene			1.09E-06	2.99E-06	1.30E-05	1.30E-05	Diesel and Dunnage
Pyrene					7.06E-07	7.06E-07	Diesel and Dunnage
Styrene		2.57E-07			4.99E-05	4.99E-05	Diesel and Dunnage
Sulfur Dioxide		1.22E-03	1.18E-04	3.47E-04	1.88E-04	1.22E-03	M31A1E1
Toluene		2.84E-07	5.44E-07		1.22E-04	1.22E-04	Diesel and Dunnage
Total Alkanes (Paraffins)		2.33E-06	5.44E-07		3.50E-03	3.50E-03	Diesel and Dunnage
Total Alkenes (Olefins)		2.57E-06	1.33E-05	1.59E-05	1.93E-04	1.93E-04	Diesel and Dunnage

Table 3-1. Emission Factors by Surrogate Waste Streams and Combined Waste Stream (continued)

Name of Pollutant	TNT Emission Factor [1]	M31A1E1 Emission Factor	M-43 Emission Factor	PBXN-110 Emission Factor	Diesel and Dunnage Emission Factor	Combined Emission Factor[2]	Surrogate Name of Max Emission Factor
Total Non-methane Hydrocarbons/NMHC		9.88E-05	4.13E-05	5.11E-05	1.20E-02	1.20E-02	Diesel and Dunnage
Total Unidentified Hydrocarbons		1.92E-05	2.47E-05	4.41E-05	6.04E-03	6.04E-03	Diesel and Dunnage
trans-2-Butene		5.19E-08	1.81E-07	3.98E-07	2.91E-06	2.91E-06	Diesel and Dunnage
trans-2-Pentene					1.08E-06	1.08E-06	Diesel and Dunnage
Vinyl Chloride				2.23E-07		2.23E-07	PBXN-110
Vinylidene Chloride		2.15E-07				2.15E-07	M31A1E1
Volatile Organic Compounds	5.50E-04					5.50E-04	TNT
Zinc		4.14E-07			6.26E-05	6.26E-05	Diesel and Dunnage

[1] Emission factors are displayed as a fraction of grams of pollutant per grams of waste treated.

[2] The highest emission factor of all the surrogate waste streams was included within the combined emission factor to provide the most conservative set of emission factors possible.

Table 3-2
Emission Factors for Propane

Contaminant	Emission Factor (lb/1000 gal)	Emission Factor (lb/lb)
Nitrogen Oxides	13	3.07E-03
Carbon Monoxide	7.5	1.77E-03
PM10	0.7	1.65E-04
PM2.5	0.7	1.65E-04
Sulfur Dioxide	9	2.12E-03
Nonmethane Hydrocarbons	1	2.36E-04

4.0 SCREENING LEVELS

Screening levels for air and soil were used to evaluate the potential impacts of contaminants from the air emissions of open burning treatment activities to human health and the environment. The *Draft Final Open Burning/Open Detonation Permitting Guidelines* (EPA 2002b) drafted by the EPA suggest that compliance with ambient air quality standards (AAQS) should be evaluated by determining the maximum off-site exposure. The maximum on-site and off-site exposures should be evaluated for toxic air pollutants. Screening levels additional to those of AAQS are shown in Table 4-1.

4.1 Ambient Air Quality Standards

EPA has established national AAQS (NAAQS) for particulate matter (PM_{10} and $PM_{2.5}$), lead, sulfur dioxide, carbon monoxide, nitrogen dioxide, and ozone. New Mexico Ambient Air Quality Standards (NMAAQS) are established for sulfur dioxide, carbon monoxide, and nitrogen dioxide. Both the NAAQS and NMAAQS are set for multiple averaging periods ranging from 1 hour to an annual basis. For EPA and NMED air permitting purposes, the ambient standards do not apply within the boundary of the permitted facility. This analysis followed this long-standing protocol.

The screening analysis did not include the NAAQS for ozone. Dispersion models such as OBODM do not simulate photochemical reactions and ozone formation impacts are not considered significant (EPA, 2002). NMED does not require modeling for ozone as part of the air quality permit process. Also, based on LANL waste minimization procedures and pollution prevention practices to eliminate lead from explosives processes to the extent practicable, a screening analysis was not conducted for the lead NAAQS because no lead emissions are predicted to occur from open burning.

4.2 Toxic Air Pollutant Screening Levels

The *Draft Final Open Burning/Open Detonation Permitting Guidelines* (EPA 2002b) suggest evaluating both long-term (chronic and cancer) and short-term (acute) risk-based impacts as follows:

Short-term impacts were evaluated using the acute inhalation exposure concentrations (AIEC) from the Human Health Risk Assessment Protocol Companion Database (HHRAP Database) to EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA, 2016). This database includes the acute inhalation sources listed in Section 4.1.4 of the *Draft Final Open Burning/Open Detonation Permitting Guidelines* (EPA, 2002b). The Non-Cancer Acute Inhalation RELs for Airborne Toxicants were also listed as established in the Air Toxics Hot Spots Program's Guidance Manual for Preparation of Health Risk Assessments (Appendix L) developed by the California Office of Environmental Health Hazard Assessment (CA OEHHA, 2015). The available data from the HHRAP Database (AEIC) or the datasets for the RELs (CA OEHHA, 2019) were used for the assessments in Table 5-3 and 5-4. Where both databases provided a value for a given constituent, the lesser and more conservative of the two values was applied. The CA OEHHA data was also used for the Non-Cancer Chronic Inhalation RELs.

Long-term chronic non-cancer impacts were evaluated using the Regional Screening Levels (RSLs) - Generic Tables (EPA, 2019). For the EPA RSLs, the Non-Cancer Resident Air RSL Chronic value for THI = 0.1 was listed in Table 4.1 and in Attachment A. This value was compared to the CA-OEHHA non-cancer chronic reference exposure level (REL) (CA OEHHA, 2019) provided in $\mu g/m^3$. Where the two databases provided a chronic RSL for the same chemical constituent, the lesser and more conservative of the two values was used to compare to the annual impact concentrations.

4.3 Deposition Screening Levels

Screening levels for soil deposition were compared to an estimated 10-year impact to show a quantitative estimate over the anticipated lifetime of the permit. Deposition of pollutants was compared to the NMED Human Health Residential Soil Screening Levels (SSLs) (NMED, 2019) where available as a Cancer Residential Soil Screening Level or as a Noncancer Residential Soil Screening Level. Where NMED values for Cancer or Noncancer Resident Soil Screening Levels were not listed or available, the lesser of EPA RSLs for Carcinogenic Target Risk and/or Noncancer Child Hazard Index (also known as Target Hazard Index) (EPA, 2019) were evaluated where available. The estimated 10-year soil concentrations were also compared to the LANL-derived ecological screening levels (ESLs) obtained from ECORISK Database, Version 3.1 (LANL, 2019). Comparing the estimated 10-year impact to soil for these screening levels in Table 4-1 covers the potential impact to any human or ecological receptors that come in contact with the area surrounding the TA-16-388 Flash Pad.

Table 4-1

Open Burning Screening Levels for Acute, Chronic, and Soil - TA-16-388 Flash Pad

Name of Pollutant	CAS #	Air Inhalation Emission Concentration (1) (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Acute Reference Exposure Level (2) (REL) (µg/m^3)	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (3) (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for (4) THI = 0.1 (µg/m3)	NMED Cancer - Residential Soil TR=1E-05 (5) (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (5) (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (4) (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (5) (mg/kg)	Minimum LANL ESL (6) mg/kg
1,2,4-Trimethylbenzene	95-63-6	NA	NA	NA	6.30E+00	NA	NA	7.80E+01	5.00E+01	NA
sec-Butylbenzene	135-98-8	NA	NA	NA	NA	NA	NA	NA	7.80E+02	NA
1,3,5-Trimethylbenzene	108-67-8	1.25E+05	NA	NA	6.30E+00	NA	NA	NA	2.70E+01	NA
1,3-Butadiene	106-99-0	NA	6.60E+02	2.00E+00	2.10E-01	6.86E-01	2.30E+00	7.60E-02	1.80E-01	NA
1-Butene	106-98-9	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	91-57-6	NA	NA	NA	NA	NA	2.32E+02	NA	2.40E+01	1.60E+01
2-Methylpentane	107-83-5	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	NA	NA	NA	NA	NA	NA	1.20E+02

Table 4-1 (continued)
Open Burning Screening Levels for Acute, Chronic, and Soil - TA-16-388 Flash Pad

Name of Pollutant	CAS #	Air Inhalation Emission Concentration (1) (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Acute Reference Exposure Level (2) (REL) (µg/m^3)	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (3) (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for (4) THI = 0.1 (µg/m3)	NMED Cancer - Residential Soil TR=1E-05 (5) (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (5) (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (4) (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (5) (mg/kg)	Minimum LANL ESL (6) mg/kg
Acetophenone	98-86-2	3.00E+04	NA	NA	NA	NA	7.82E+03	NA	7.80E+02	NA
Acetylene	74-86-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aluminum	7429-90-5	NA	NA	NA	5.20E-01	NA	7.80E+04	NA	7.70E+03	NA
Anthracene	120-12-7	6.00E+03	NA	NA	NA	NA	1.74E+04	NA	1.80E+03	6.80E+00
Aromative (e.g. Styrene)			NA	NA	NA	NA	NA	NA	NA	NA
Barium	7440-39-3	1.50E+03	NA	NA	5.20E-02	NA	1.56E+04	NA	1.50E+03	1.10E+02
Benzene	71-43-2	1.30E+03	2.70E+01	3.00E+00	3.10E+00	1.78E+01	1.14E+02	1.20E+00	8.20E+00	2.40E+01
Benzo(a)anthracene	56-55-3	3.00E+02	NA	NA	NA	1.53E+00	NA	1.10E+00	NA	7.30E-01
Benzo(a)pyrene	50-32-8	6.00E+02	NA	NA	2.10E-04	NA	NA	1.10E-01	1.80E+00	6.20E+01
Benzo(b)fluoranthene	205-99-2	6.00E+02	NA	NA	NA	1.53E+00		1.10E+00	NA	1.80E+01
Benzo(ghi)perylene	191-24-2	NA	NA	NA	NA	NA	NA	NA	NA	2.50E+01
Benzo(k)fluoranthene	207-08-9	6.00E+02	NA	NA	NA	1.53E+01	NA	1.10E+01	NA	7.10E+01
Benzyl alcohol	100-51-6	6.00E+04	NA	NA	NA	NA	NA	NA	6.30E+02	1.20E+02
Biphenyl, 1,1'-	92-52-4	NA	NA	NA	4.20E-02	8.48E+02	3.91E+04	8.70E+01	4.70E+00	NA
Butyl benzyl phthalate	85-68-7	1.50E+04	NA	NA	NA	NA	NA	2.90E+02	1.30E+03	9.00E+01
Carbon Tetrachloride	56-23-5	1.90E+03	1.90E+03	4.00E+01	1.00E+01	1.07E+01	1.44E+02	6.50E-01	1.00E+01	NA
Chromium	7440-47-3	1.50E+03	NA	NA	NA	9.66E+01	4.52E+04	NA	NA	2.30E+01
Chrysene	218-01-9	6.00E+02	NA	NA	NA	1.53E+02	NA	1.10E+02	NA	3.10E+00
cis-2-Butene	590-18-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA	NA	NA	NA	NA	NA	NA
CO (2)	630-08-0	NA	2.30E+04	NA	NA	NA	NA	NA	NA	NA
CO2	124-38-9	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	7440-50-8	NA	NA	NA	NA	NA	3.13E+03	NA	3.10E+02	1.40E+01
Cyclohexane	110-82-7	NA	NA	NA	6.30E+02	NA	NA	NA	6.50E+02	NA
Cyclopentane	287-92-3	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	53-70-3	3.00E+04	NA	NA	NA	1.53E-01	NA	1.10E-01	NA	1.40E+01
Diethyl phthalate	84-66-2	1.50E+04	NA	NA	NA	NA	4.93E+04	NA	5.10E+03	1.00E+02
Dimethyl phthalate	113-11-3	1.50E+04	NA	NA	NA	NA	NA	NA	NA	1.00E+01
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	1.50E+04	NA	NA	NA	NA	6.16E+03	NA	6.30E+02	1.10E-02
Di-n-octyl phthalate	117-84-0	5.00E+04	NA	NA	NA	NA	NA	NA	6.30E+01	9.10E-01
Ethane	74-84-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl chloride	75-00-3	2.50E+06	NA	3.00E+04	1.00E+03	NA	1.90E+04	NA	1.40E+03	NA

Table 4-1 (continued)
Open Burning Screening Levels for Acute, Chronic, and Soil - TA-16-388 Flash Pad

Name of Pollutant	CAS #	Air Inhalation Emission Concentration (1) (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Acute Reference Exposure Level (2) (REL) (µg/m^3)	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (3) (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for (4) THI = 0.1 (µg/m3)	NMED Cancer - Residential Soil TR=1E-05 (5) (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (5) (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (4) (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (5) (mg/kg)	Minimum LANL ESL (6) mg/kg
Ethylbenzene	100-41-4	5.00E+05	NA	2.00E+03	1.00E+02	7.51E+01	3.93E+03	5.80E+00	3.40E+02	NA
Ethylene	74-85-1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	206-44-0	1.50E+01	NA	NA	NA	NA	2.32E+03	NA	2.40E+02	1.00E+01
HCL / Hydrogen Chloride	7647-01-0	2.10E+03	2.10E+03	9.00E+00	2.10E+00	NA	NA	NA	2.80E+06	NA
i-Butane	75-28-5	NA	NA	NA	NA	NA	NA	NA	NA	NA
i-Butene	115-11-7	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	5.00E+02	NA	NA	NA	1.53E+00	NA	1.10E+00	NA	7.10E+01
i-Pentane	78-78-4	NA	NA	NA		NA	NA	NA	NA	NA
i-Propylbenzene / Cumene	98-82-8	2.46E+05	NA	NA	4.20E+01	NA	2.36E+03	NA	1.90E+02	NA
m- & p-Xylene	108-38-3 & 106-42-3	2.20E+04	NA	NA	1.00E+01	NA	7.64E+02	NA	5.50E+01	1.40E+00
Methane	74-82-8	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	6.80E+04	6.80E+04	1.00E+03	5.20E+02	NA	1.44E+04	NA	8.10E+02	2.60E+02
Methylchloride / Chloromethane	74-87-3	2.00E+05	NA	NA	9.40E+00	4.11E+01	2.68E+02	NA	1.10E+01	NA
Methylcyclohexane /	108-87-2	NA	NA	NA	NA	NA	5.50E+03	NA	NA	NA
Methylcyclopentane	96-37-7	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	75-09-2	1.40E+04	1.40E+04	4.00E+02	6.30E+01	7.66E+02	4.09E+02	5.70E+01	3.50E+01	2.60E+00
m-Ethyltoluene	620-14-4	NA	NA	NA		NA	NA	NA	NA	NA
Naphthalene	91-20-3	7.50E+04	NA	9.00E+00	3.10E-01	4.97E+01	1.62E+02	3.80E+00	1.30E+01	1.00E+00
n-Butane	106-97-8	NA	NA	NA		NA	NA	NA	NA	NA
n-Decane	124-18-5	NA	NA	NA		NA	NA	NA	NA	NA
n-Heptane	142-82-5	NA	NA	NA	4.20E+01	NA	NA	NA	2.20E+00	NA
n-Hexane	110-54-3	NA	NA	7.00E+03	7.30E+01	NA	6.15E+02	NA	6.10E+01	NA
Nitrogen dioxide (peroxide)	10102-44-0	NA	4.70E+02	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide	10024-97-2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxides (2)		NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nonane	111-84-2	NA	NA	NA	2.10E+00	NA	NA	NA	1.10E+00	NA
n-Octane	111-65-9	NA	NA	NA	NA	NA	NA	NA	NA	NA
Non-methane Organic Compound/NMHC (2)		NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4-1 (continued)
Open Burning Screening Levels for Acute, Chronic, and Soil - TA-16-388 Flash Pad

Name of Pollutant	CAS #	Air Inhalation Emission Concentration (1) (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Acute Reference Exposure Level (2) (REL) (µg/m^3)	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (3) (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for (4) THI = 0.1 (µg/m3)	NMED Cancer - Residential Soil TR=1E-05 (5) (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (5) (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (4) (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (5) (mg/kg)	Minimum LANL ESL (6) mg/kg
n-Pentane	109-66-0	NA	NA	NA	1.00E+02	NA	NA	NA	8.10E+01	NA
n-Propylbenzene	103-65-1	NA	NA	NA	1.00E+02	NA	NA	NA	3.80E+02	NA
OCDD *Screening Limits are for TCDD,2,3,7,8-	TCDD CAS no. 1746-01-6	1.50E+00	NA	NA	4.20E-06	4.90E-05	5.06E-05	4.80E-06	5.10E-06	2.90E-07
o-Ethyltoluene	611-14-3	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	95-47-6	2.20E+04	NA	NA	1.00E+01	NA	8.05E+02	NA	6.50E+01	1.40E+00
Perylene	198-55-0	NA	NA	NA	NA	NA	NA	NA	NA	NA
p-Ethyltoluene	622-96-8	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	85-01-8	1.00E+03	NA	NA	NA	NA	1.74E+03	NA	NA	5.50E+00
Phenol	108-95-2	5.80E+03	5.80E+03	2.00E+02	2.10E+01	NA	1.85E+04	NA	1.90E+03	7.90E-01
PM10 (2)(3)		NA	NA	NA	NA	NA	NA	NA	NA	NA
Propane	74-98-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propene / Propylene	115-07-1	NA	NA	3.00E+03	3.10E+02	NA	NA	NA	2.20E+02	NA
Pyrene	129-00-0	1.50E+04	NA	NA	NA	NA	1.74E+03	NA	1.80E+02	1.00E+01
Styrene	100-42-5	2.10E+04	2.10E+04	9.00E+02	1.00E+02	NA	7.26E+03	NA	6.00E+02	1.20E+00
Sulfur Dioxide (2)	7446-09-5	NA	6.60E+02	NA	NA	NA	NA	NA	NA	NA
Toluene	108-88-3	3.70E+04	3.70E+04	3.00E+02	5.20E+02	NA	5.23E+03	NA	4.90E+02	2.30E+01
Total Alkanes (Paraffins)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Non-methane Hydrocarbons / NMHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Unidentified Hydrocarbons	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl Chloride	75-01-4	1.80E+05	1.80E+05	NA	1.00E+01	7.42E-01	1.13E+02	5.90E-02	7.00E+00	1.20E-01
Vinylidene Chloride / Dichloroethylene (1,1)	75-35-4	7.50E+04	NA	7.00E+01	2.10E+01	NA	4.40E+02	NA	2.30E+01	1.10E+01
Volatile Organic Compounds		NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	7440-66-6	3.00E+04	NA	NA	NA		2.35E+04	NA	2.30E+03	4.70E+01

Notes:

Table 4-1 (continued)
Open Burning Screening Levels for Acute, Chronic, and Soil - TA-16-388 Flash Pad

Name of Pollutant	CAS #	Air Inhalation Emission Concentration (1) (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Acute Reference Exposure Level (2) (REL) (µg/m^3)	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (3) (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for (4) THI = 0.1 (µg/m3)	NMED Cancer - Residential Soil TR=1E-05 (5) (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (5) (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (4) (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (5) (mg/kg)	Minimum LANL ESL (6) mg/kg

1. Screening concentrations from acute (1 hr) inhalation exposures concentrations (AIEC) from the Companion Database to EPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA 2016). https://archive.epa.gov/epawaste/hazard/tsd/td/web/mdb/05hhrapchemdat.mdb

2. REL acute 1-hour screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

3. REL chronic annual screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

4. U.S. EPA resident air non-carcinogenic SLs, and resident soil non-carcinogenic and carcinogenic screening levels are from the Regional Screening Levels (RSLs) – Generic Tables. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

5. NMED resident soil carcinogenic and non-carcinogenic screening levels are from the New Mexico Environment Department Risk Assessment Guidance for Site Investigations and Remediation. Volume I Soil Screening Guidance for Human Health Risk Assessments. Feb. 2019 (Rev. 2, 6/19/2019). https://www.env.nm.gov/wp-content/uploads/sites/12/2016/11/Final-NMED-SSG-VOL-I_-Rev.2-6_19_19.pdf
6. ESL minimum values and effected receptors are recorded in the LANL ECORSK Database, on CD, LA-UR-12-24548, Los Alamos National Laboratory, Los Alamos, New Mexico, 2019.

5.0 RESULTS

Modeled impacts through the use of OBODM in this report assumed the plume from open burning travels in a straight line in each given hour. This conservatively calculates the maximum impact at a given receptor by maintaining the target receptor along the plume centerline for the averaging period with the least amount of dispersion. The reality for receptors in complex terrain is that this is unlikely to occur due to additional dispersion. Also, the modeling approach used did not utilize any option to reduce downwind concentrations through either deposition or depletion of the plume as it moves from the site to a given receptor. In reality, these mechanisms would substantially lower projected impacts.

EXCEL® spreadsheets were used to calculate constituent-specific air and soil concentrations and for comparison to appropriate screening levels (see Attachment A). The following calculations and comparisons were made:

- Maximum 1-, 3-, 8-, and 24-hour concentrations and annual average concentrations were calculated and compared to the NAAQS and NMAAQS for public receptors;
- Maximum 1-hour concentrations were calculated and compared to AIEC acute values or CA-OEHHA acute RELs, or the lesser of the two where both values exist;
- Annual average air concentrations were calculated and compared to the lesser of the CA-OEHHA Non-Cancer Reference Exposure Level (REL) Chronic (µg/m3) and EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3);
- Soil concentrations from deposition were calculated and compared to NMED Human Health Cancer and Non-Cancer Residential Soil SSLs. Where NMED data was not available, EPA RSL screening levels for Residential Soil were applied. Where both Cancer and Non-Cancer values existed, the lesser of the two was listed in the table provided in Attachment A. EPA Carcinogenic SL values are based on a target risk of TR=1E^{-06} and Non-Carcinogenic SL Child values are based on a Target Hazard Index (THI) of 0.1 (mg/kg). The LANL-derived ESLs are also included for review and comparison and in some cases was the only value available for soil concentrations.
- Concentrations for emission products were calculated whether there was a screening level or not. A comparison of the calculated values from model results with the EPA and NMED ambient air quality standards are summarized in Tables 5-1. In cases where there is a NAAQS and NMAAQS for the same pollutant and same averaging period, the more stringent standard is referenced in the tables. Background concentrations for all forms of particulate matter and sulfur dioxide have been added to model results as specified by NMED and the total value is shown in the tables for comparison to standards (NMED, 2019a).

This analysis was conducted using the highest maximum model result that occurred at any public receptor location. Receptors on LANL property were not used, as is the protocol under NMED modeling guidelines when demonstrating compliance with ambient air quality standards for permit purposes (NMED 2019a). In this respect, NMED follows EPA direction in regards to the definition of *ambient air* which defines where the air quality standards are applicable.

As demonstrated in the Table 5-1, no AAQS are projected to be exceeded by the model results, and all results are conservatively predicted.

Table 5-2a, -2b, and -2c contain a comparison of the calculated values from model results with the acute and chronic air health screening levels and the human health and ecological soil deposition screening levels. Because OBODM cannot estimate deposition in complex terrain such as present within the LANL site, an alternative approach was needed. Gravitational deposition would be significant only for relatively large particles deposited close to the open burning treatment unit. Wet deposition should be insignificant for open burning which occurs infrequently and never during precipitation events. Thus, non-gravitational dry deposition should be the major contributor to contaminant soil concentrations. This type of deposition was conservatively estimated using the calculation provided by the California EPA for air toxics analyses found in the document *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (CA OEHHA, 2015).

There are several levels of conservatism present in the deposition estimates using this approach. First, the annual contaminant air concentration used in the calculation is based on running OBODM using the maximum permitted annual waste burned within the hours of the year predicted to yield maximum concentrations from the hourly air concentration model runs. Second, the single maximum annual air concentration is used which is a non-depleted value, e.g. there is no removal of contaminant mass from the plume as a function of downwind distance. In the calculation, it is assumed there is no degradation of organic compounds in the soil over time which also results in an over prediction of soil concentrations during the 10-year estimate. The deposition rate or Dep-rate used was the California EPA recommended value for an uncontrolled source is 0.05 meters/second.

Using this procedure, soil concentrations were calculated using the maximum annual air concentrations for each contaminant predicted by OBODM. The calculation is shown below:

C_s = Dep * X / (K_s * SD * BD * T_t)

Dep = Deposition on the affected soil area per day (ug/m^2/d)

Dep = GLC * Dep-rate * 86,400

GLC = The chemical specific annual ground level concentration from OBODM result and emission factor (ug/m^3)

Dep-rate = 0.05 m/sec (default value for uncontrolled source)

86,400 = Seconds per day conversion factor

X = [{$e^{-Ks * Tf}$ - $e^{-Ks * To}$} / K_s] + T_t

e = 2.718

K_s = Soil elimination constant = 6.93 x 10^{-9} (no degradation of contaminant in soil assumed)

T_f = End of evaluation period (d) = 3650

T_o = Beginning of evaluation period (d) = 0

T_t = Total days of exposure period T_f - T_o (d) = 3650 (ten-year period)

SD = Soil mixing depth (m) = 0.01 for soil ingestion or dermal pathway (analysis is on Laboratory property)

BD = Soil bulk density (kg/m^3) = 1,333

Table 5-1
TA-16-388 Flash Pad Screening Analysis Worksheet for Ambient Air Quality Standards

Basis	
200	lb waste/hr
6000	lb waste/yr
127.2	lb propane/hr
3816.0	lb propane/yr
1	g/sec contaminant emission rate
odel Results (X/Q)	
2.78E+00	1-hour maximum value, ug/m^3 per g/sec contaminant
8.35E-01	8th highest overall 1-hour maximum value, ug/m^3 per g/sec contaminant (as applied to 1-hour NO_2 NAAQS)
9.47E-01	3-hour maximum value, ug/m^3 per g/sec contaminant
5.08E-01	8-hour maximum value, ug/m^3 per g/sec contaminant
1.72E-01	24-hour maximum value, ug/m^3 per g/sec contaminant
1.57E-01	High 2nd high 24-hour maximum value, ug/m^3 per g/sec contaminant (as applied to 24-hr PM_{10})
3.86E-02	8th highest overall 24-hour maximum value, ug/m^3 per g/sec contaminant (as applied to 24-hour $PM_{2.5}$ NAAQS)(3)
1.93E-03	Annual maximum value, ug/m^3 per g/sec contaminant

Pollutant	Averaging Time	OB Waste Emisson Factor, lb/lb waste	OB Waste Emission Rate, g/sec	OB Waste Maximum Concentration, ug/m^3	Propane Emission Factor, lb/lb propane	Propane Emission Rate, g/sec	Propane Maximum Concentration, ug/m^3	Maximum Concentration, Total ug/m^3	NAAQS ug/m^3	NMAAQS ug/m^3	Air Quality Standard Exceeded?
Nitrogen Dioxide		7.50E-02			3.07E-03						
(As NOX)	1-hour (3)		1.89E+00	1.58E+00		4.91E-02	4.10E-02	1.6	188.03	none	No
	24-hour		1.89E+00	3.25E-01		4.91E-02	8.44E-03	0.3	none	188.03	No
	Annual		6.47E-03	1.25E-05		1.68E-04	3.25E-07	0.00001	99.66	94.02	No
Carbon Monoxide		2.98E-02			1.77E-03						
	1-hour		7.51E-01	2.09E+00		2.84E-02	7.88E-02	2.2	40069.6	14997.5	No
	8-hour		7.51E-01	3.81E-01		2.84E-02	1.44E-02	0.4	10303.6	9960.1	No
Sulfur Dioxide		1.22E-03			2.12E-03						
	1-hour		3.07E-02	8.54E-02		3.40E-02	9.45E-02				
Background(11)	1-hour			1.32E+01							
Total	1-hour			1.33E+01				13.38	196.40	none	No
	3-hour		3.07E-02	2.91E-02		3.40E-02	3.22E-02	0.06	1309.30	none	No
	24-hour		3.07E-02	5.28E-03		3.40E-02	5.84E-03	0.01	none	261.90	No
	Annual		1.05E-04	2.03E-07		1.17E-04	2.25E-07	0.0000004	none	52.40	No
PM_{10}		9.10E-01			1.65E-04						
	24-hour		2.29E+01	3.61E+00		2.65E-03	4.16E-04				
Background(8)	24-hour			2.30E+01							
Total	24-hour			2.66E+01				26.61	150	none	No
$PM_{2.5}$		9.10E-01			1.65E-04						
	24-hour(3)		2.29E+01	8.85E-01		2.65E-03	1.02E-04				
Background(9)	24-hour			9.45E+00							
Total	24-hour(3)			1.03E+01				10.33	35	none	No
	Annual		7.85E-02	1.52E-04		9.06E-06	1.75E-08				
Background(10)	Annual			4.32E+00							
Total	Annual			4.32E+00				4.32	12	none	No

Notes

1 Maximum concentrations are from public receptors off LANL property for all ambient standards analyses.

2 Calculated maximum concentrations for NMAAQS are based on the first high value from OBODM model runs.

3 Calculated maximum concentrations for the 1-hour NO_2 and 24-hour $PM_{2.5}$ NAAQS are based on the 8th high overall value from OBODM model runs
which is more conservative than the high 8th high as specified by NMED Air Dispersion Modeling Guideline, June 2019.
OBODM cannot estimate the 8th highest concentration at any one receptor, only the high and second high values.

4 Calculated maximum concentration for the 24-hour PM_{10} NAAQS is based on high 2nd high from OBODM model runs
as specified by NMED Air Dispersion Modeling Guideline, March 2019.

5 Emission factor for PM_{10} used also for $PM_{2.5}$ which overpredicts $PM_{2.5}$ concentrations.

6 Particulate matter background concentrations added as specified from NMED Air Dispersion Modeling Guidelines, March 2019.

7 Ambient standards for gases in ug/m^3 are from Table 6.A in the NMED Air Dispersion Modeling Guideline, June 2019.

8 PM10 24-hr background - 2019 JUNE - North Central - Santa Fe - 23 ug/m3 max.

9 PM2.5 24-hr background - 2019 JUNE - North Central - Santa Fe - 98 percentile - 9.45 ug/m3

10 PM2.5 Annual background - 2019 JUNE - North Central - Santa Fe - 4.32 ug/m3

11 SO2 1hr-background - 2019 JUNE - Albuquerque Region - 1-hr background - 15.8 ug/m3 and 1-hour background 99th percentile - 13.2 ug/m3

12 The standard is calculated similarly to the NO2 1-hour standard instructions in section 2.6.4.4,
but the fourth highest is used in place of the eighth highest (and 99th percentile is substituted for 98th percentile)

Table 5-2a

Health Screening Level Comparisons – 1-Hour Acute Exposures

Contaminant	CAS No.	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
1,2,4-Trimethylbenzene	95-63-6	NA	NA	NA
sec-Butylbenzene	135-98-8	NA	NA	NA
1,3,5-Trimethylbenzene	108-67-8	1.25E+05	NA	No
1,3-Butadiene	106-99-0	NA	6.60E+02	No
1-Butene	106-98-9	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA
2-Methylnaphthalene	91-57-6	NA	NA	NA
2-Methylpentane	107-83-5	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	NA
Acetophenone	98-86-2	3.00E+04	NA	No
Acetylene	74-86-2	NA	NA	NA
Aluminum	7429-90-5	NA	NA	NA
Anthracene	120-12-7	6.00E+03	NA	No
Aromative (e.g. Styrene)			NA	NA
Barium	7440-39-3	1.50E+03	NA	No
Benzene	71-43-2	1.30E+03	2.70E+01	No
Benzo(a)anthracene	56-55-3	3.00E+02	NA	No
Benzo(a)pyrene	50-32-8	6.00E+02	NA	No
Benzo(b)fluoranthene	205-99-2	6.00E+02	NA	No
Benzo(ghi)perylene	191-24-2	NA	NA	NA
Benzo(k)fluoranthene	207-08-9	6.00E+02	NA	No
Benzyl alcohol	100-51-6	6.00E+04	NA	No
Biphenyl	92-52-4	NA	NA	NA
Butyl benzyl phthalate	85-68-7	1.50E+04	NA	No
Carbon Tetrachloride	56-23-5	1.90E+03	1.90E+03	No
Chromium	7440-47-3	1.50E+03	NA	No
Chrysene	218-01-9	6.00E+02	NA	No
cis-2-Butene	590-18-1	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA

Table 5-2a (continued)

Health Screening Level Comparisons – 1-Hour Acute Exposures

Contaminant	CAS No.	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Carbon Monoxide (2)	630-08-0	NA	2.30E+04	No
Carbon Dioxide	124-38-9	NA	NA	NA
Copper	7440-50-8	NA	NA	NA
Cyclohexane	110-82-7	NA	NA	NA
Cyclopentane	287-92-3	NA	NA	NA
Dibenz(a,h)anthracene / Dibenzo(a,h)anthracene	53-70-3	3.00E+04	NA	No
Diethyl phthalate	84-66-2	1.50E+04	NA	No
Dimethyl phthalate	113-11-3	1.50E+04	NA	No
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	1.50E+04	NA	No
Di-n-octyl phthalate	117-84-0	5.00E+04	NA	No
Ethane	74-84-0	NA	NA	-
Ethyl chloride / Chloroethane	75-00-3	2.50E+06	NA	No
Ethylbenzene	100-41-4	5.00E+05	NA	No
Ethylene	74-85-1	NA	NA	NA
Fluoranthene	206-44-0	1.50E+01	NA	No
HCL - Hydrochloric Acid	7647-01-0	2.10E+03	2.10E+03	No
i-Butane	75-28-5	NA	NA	NA
i-Butene	115-11-7	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	5.00E+02	NA	No
i-Pentane	78-78-4	NA	NA	NA
i-Propylbenzene / Cumene	98-82-8	2.46E+05	NA	No
m- & p-Xylene	108-38-3 & 106-42-3	2.20E+04	NA	No
Methane	74-82-8	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	6.80E+04	6.80E+04	No
Methyl chloride	74-87-3	2.00E+05	NA	No
Methylcyclohexane	108-87-2	NA	NA	NA
Methylcyclopentane	96-37-7	NA	NA	NA
Methylene chloride / dichloromethane	75-09-2	1.40E+04	1.40E+04	No
m-Ethyltoluene	620-14-4	NA	NA	NA
Naphthalene	91-20-3	7.50E+04	NA	No
n-Butane	106-97-8	NA	NA	NA
n-Decane	124-18-5	NA	NA	NA
n-Heptane	142-82-5	NA	NA	NA
n-Hexane	110-54-3	NA	NA	NA
Nitrogen dioxide / Nitrogen peroxide	10102-44-0	NA	4.70E+02	No
Nitrogen Oxide	10024-97-2	NA	NA	NA
Nitrogen Oxides (2)		NA	NA	NA
n-Nonane	111-84-2	NA	NA	NA
n-Octane	111-65-9	NA	NA	NA
Non-methane Organic Compound /NMHC (2)		NA	NA	NA
n-Pentane	109-66-0	NA	NA	NA
n-Propylbenzene	103-65-1	NA	NA	NA
OCDD *Screening Limits are for TetraCDD, 2,3,7,8-	TCDD CAS no. 1746-01-6	1.50E+00	NA	No
o-Ethyltoluene	611-14-3	NA	NA	NA

Table 5-2a (continued)

Health Screening Level Comparisons – 1-Hour Acute Exposures

Contaminant	CAS No.	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
o-Xylene	95-47-6	2.20E+04	NA	No
Perylene	198-55-0	NA	NA	NA
p-Ethyltoluene	622-96-8	NA	NA	NA
Phenanthrene	85-01-8	1.00E+03	NA	No
Phenol	108-95-2	5.80E+03	5.80E+03	No
PM10 (2)		NA	NA	NA
Propane	74-98-6	NA	NA	NA
Propene	115-07-1	NA	NA	NA
Pyrene	129-00-0	1.50E+04	NA	No
Styrene	100-42-5	2.10E+04	2.10E+04	No
Sulfur Dioxide (2)	7446-09-5	NA	6.60E+02	No
Toluene	108-88-3	3.70E+04	3.70E+04	No
Total Alkanes (Paraffins)	NA	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	NA	NA	NA
Total Non-methane Hydrocarbons - TNMHC	NA	NA	NA	NA
Total Unidentified Hydrocarbons	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA
Vinyl Chloride	75-01-4	1.80E+05	1.80E+05	**No**
Vinylidene Chloride / Dichloroethylene, 1,1-	75-35-4	7.50E+04	NA	No
Volatile Organic Compounds		NA	NA	NA
Zinc	7440-66-6	3.00E+04	NA	No

Notes:

1. NA - Chemical Not Available in database
2. Impacts from propane combustion have been added to waste impact concentrations for nitrogen oxides, carbon monoxide, PM10, sulfur dioxide and NMHC.
3. PM10 emissions factor and emissions are the same for PM2.5
3. Screening concentrations from acute (1 hr) inhalation exposures concentrations (AIEC) from the Companion Database to EPA's Human Health Risk Assessment
Protocol for Hazardous Waste Combustion Facilities (EPA 2016). https://archive.epa.gov/epawaste/hazard/tsd/td/web/mdb/05hhrapchemdat.mdb

4. REL 1-hour acute screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values,
November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

Table 5-2b
Health Screening Level Comparisons – Annual Chronic Exposures

Contaminant	CAS No.	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
1,2,4-Trimethylbenzene	95-63-6	NA	6.30E+00	No
sec-Butylbenzene	135-98-8	NA	NA	NA
1,3,5-Trimethylbenzene	108-67-8	NA	6.30E+00	No
1,3-Butadiene	106-99-0	2.00E+00	2.10E-01	No
1-Butene	106-98-9	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA
2-Methylnaphthalene	91-57-6	NA	NA	NA
2-Methylpentane	107-83-5	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	NA
Acetophenone	98-86-2	NA	NA	NA
Acetylene	74-86-2	NA	NA	NA
Aluminum	7429-90-5	NA	5.20E-01	No
Anthracene	120-12-7	NA	NA	NA
Aromative (e.g. Styrene)		NA	NA	NA
Barium	7440-39-3	NA	5.20E-02	No
Benzene	71-43-2	3.00E+00	3.10E+00	No
Benzo(a)anthracene	56-55-3	NA	NA	NA
Benzo(a)pyrene	50-32-8	NA	2.10E-04	No
Benzo(b)fluoranthene	205-99-2	NA	NA	NA
Benzo(ghi)perylene	191-24-2	NA	NA	NA
Benzo(k)fluoranthene	207-08-9	NA	NA	NA
Benzyl alcohol	100-51-6	NA	NA	NA
Biphenyl, 1,1'-	92-52-4	NA	4.20E-02	No
Butyl benzyl phthalate	85-68-7	NA	NA	NA
Carbon Tetrachloride	56-23-5	4.00E+01	1.00E+01	No
Chromium	7440-47-3	NA	NA	NA
Chrysene	218-01-9	NA	NA	NA
cis-2-Butene	590-18-1	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA

Table 5-2b (continued)

Health Screening Level Comparisons – Annual Chronic Exposures

Contaminant	CAS No.	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
CO (2)	630-08-0	NA	NA	NA
CO2	124-38-9	NA	NA	NA
Copper	7440-50-8	NA	NA	NA
Cyclohexane	110-82-7	NA	6.30E+02	No
Cyclopentane	287-92-3	NA	NA	NA
Dibenz(a,h)anthracene	53-70-3	NA	NA	NA
Diethyl phthalate	84-66-2	NA	NA	NA
Dimethyl phthalate	113-11-3	NA	NA	NA
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	NA	NA	NA
Di-n-octyl phthalate	117-84-0	NA	NA	NA
Ethane	74-84-0	NA	NA	NA
Ethyl chloride	75-00-3	3.00E+04	1.00E+03	No
Ethylbenzene	100-41-4	2.00E+03	1.00E+02	No
Ethylene	74-85-1	NA	NA	NA
Fluoranthene	206-44-0	NA	NA	NA
HCL / Hydrogen Chloride	7647-01-0	9.00E+00	2.10E+00	No
i-Butane	75-28-5	NA	NA	NA
i-Butene	115-11-7	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	NA	NA	NA
i-Pentane	78-78-4	NA		NA
i-Propylbenzene / Cumene	98-82-8	NA	4.20E+01	No
m- & p-Xylene	108-38-3 & 106-42-3	NA	1.00E+01	No
Methane	74-82-8	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	1.00E+03	5.20E+02	No
Methylchloride / Chloromethane	74-87-3	NA	9.40E+00	No
Methylcyclohexane /	108-87-2	NA	NA	NA
Methylcyclopentane	96-37-7	NA	NA	NA
Methylene chloride	75-09-2	4.00E+02	6.30E+01	No
m-Ethyltoluene	620-14-4	NA		NA
Naphthalene	91-20-3	9.00E+00	3.10E-01	No
n-Butane	106-97-8	NA		NA
n-Decane	124-18-5	NA		NA
n-Heptane	142-82-5	NA	4.20E+01	No
n-Hexane	110-54-3	7.00E+03	7.30E+01	No
Nitrogen dioxide (peroxide)	10102-44-0	NA	NA	NA
Nitrogen Oxide	10024-97-2	NA	NA	NA
Nitrogen Oxides (2)		NA	NA	NA
n-Nonane	111-84-2	NA	2.10E+00	No
n-Octane	111-65-9	NA	NA	NA
Non-methane Organic Compound/NMHC (2)		NA	NA	NA
n-Pentane	109-66-0	NA	1.00E+02	No
n-Propylbenzene	103-65-1	NA	1.00E+02	No
OCDD *Screening Limits are for TCDD,2,3,7,8-	TCDD CAS no. 1746-01-6	NA	4.20E-06	No
o-Ethyltoluene	611-14-3	NA	NA	-
o-Xylene	95-47-6	NA	1.00E+01	No
Perylene	198-55-0	NA	NA	NA

Table 5-2b (continued)

Health Screening Level Comparisons – Annual Chronic Exposures

Contaminant	CAS No.	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
p-Ethyltoluene	622-96-8	NA	NA	NA
Phenanthrene	85-01-8	NA	NA	NA
Phenol	108-95-2	2.00E+02	2.10E+01	No
PM10 (2)(3)		NA	NA	NA
Propane	74-98-6	NA	NA	NA
Propene / Propylene	115-07-1	3.00E+03	3.10E+02	No
Pyrene	129-00-0	NA	NA	NA
Styrene	100-42-5	9.00E+02	1.00E+02	No
Sulfur Dioxide (2)	7446-09-5	NA	NA	NA
Toluene	108-88-3	3.00E+02	5.20E+02	No
Total Alkanes (Paraffins)	NA	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	NA	NA	NA
Total Non-methane Hydrocarbons / NMHC	NA	NA	NA	NA
Total Unidentified Hydrocarbons	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA
Vinyl Chloride	75-01-4	NA	1.00E+01	No
Vinylidene Chloride / Dichloroethylene (1,1)	75-35-4	7.00E+01	2.10E+01	No
Volatile Organic Compounds	NA	NA	NA	NA
Zinc	7440-66-6	NA	NA	NA

Notes

1. NA - Chemical Not Available in database
2. Impacts from propane combustion have been added to waste impact concentrations for nitrogen oxides, carbon monoxide, PM10, sulfur dioxide and NMHC.
3. PM10 emissions factor and emissions are the same for PM2.5.
4. Chronic REL annual screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf
5. U.S. EPA air non-carcinogenic screening levels are from the Regional Screening Levels (RSLs) – Generic Tables. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

Table 5-2c
Health and Ecological Screening Level Comparisons – 10-year Residential Soil Exposures

Contaminant	CAS Nos.	Lesser of NMED Cancer or NonCancer Residential Soil SL (mg/kg)	EPA RSLs - Lesser of the Cancer or NonCancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	NMED, EPA, or LANL ESL Screening Levels Exceeded?
1,2,4-Trimethylbenzene	95-63-6	NA	5.00E+01	NA	No
sec-Butylbenzene	135-98-8	NA	7.80E+02	NA	No
1,3,5-Trimethylbenzene	108-67-8	NA	2.70E+01	NA	No
1,3-Butadiene	106-99-0	6.86E-01	7.60E-02	NA	No
1-Butene	106-98-9	NA	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	NA	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA	NA
2-Methylnaphthalene	91-57-6	2.32E+02	2.40E+01	1.60E+01	No
2-Methylpentane	107-83-5	NA	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	NA	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	1.20E+02	No
Acetophenone	98-86-2	7.82E+03	7.80E+02	NA	No
Acetylene	74-86-2	NA	NA	NA	NA
Aluminum	7429-90-5	7.80E+04	7.70E+03	NA	No
Anthracene	120-12-7	1.74E+04	1.80E+03	6.80E+00	No
Aromative (e.g. Styrene)		NA	NA	NA	NA
Barium	7440-39-3	1.56E+04	1.50E+03	1.10E+02	No
Benzene	71-43-2	1.78E+01	1.20E+00	2.40E+01	No
Benzo(a)anthracene	56-55-3	1.53E+00	1.10E+00	7.30E-01	No
Benzo(a)pyrene	50-32-8	NA	1.10E-01	6.20E+01	No
Benzo(b)fluoranthene	205-99-2	1.53E+00	1.10E+00	1.80E+01	No
Benzo(ghi)perylene	191-24-2	NA	NA	2.50E+01	No
Benzo(k)fluoranthene	207-08-9	1.53E+01	1.10E+01	7.10E+01	No
Benzyl alcohol	100-51-6	NA	6.30E+02	1.20E+02	No
Biphenyl	92-52-4	8.48E+02	4.70E+00	NA	No
Butylbenzyl phthalate	85-68-7	NA	2.90E+02	9.00E+01	No
Carbon Tetrachloride	56-23-5	1.07E+01	6.50E-01	NA	No
Chromium (total)	7440-47-3	9.66E+01	NA	2.30E+01	No

Table 5-2c (continued)
Health and Ecological Screening Level Comparisons – 10-year Residential Soil Exposures

Contaminant	CAS Nos.	Lesser of NMED Cancer or NonCancer Residential Soil SL (mg/kg)	EPA RSLs - Lesser of the Cancer or NonCancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	NMED, EPA, or LANL ESL Screening Levels Exceeded?
Chrysene	218-01-9	1.53E+02	1.10E+02	3.10E+00	No
cis-2-Butene	590-18-1	NA	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA	NA
CO	630-08-0	NA	NA	NA	NA
CO2	124-38-9	NA	NA	NA	NA
Copper	7440-50-8	3.13E+03	3.10E+02	1.40E+01	No
Cyclohexane	110-82-7	NA	6.50E+02	NA	No
Cyclopentane	287-92-3	NA	NA	NA	NA
Dibenz(a,h)anthracene	53-70-3	1.53E-01	1.10E-01	1.40E+01	No
Diethyl phthalate	84-66-2	4.93E+04	5.10E+03	1.00E+02	No
Dimethyl phthalate	113-11-3	NA	NA	1.00E+01	No
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	6.16E+03	6.30E+02	1.10E-02	No
Di-n-octyl phthalate	117-84-0	NA	6.30E+01	9.10E-01	No
Ethane	74-84-0	NA	NA	NA	NA
Ethyl chloride	75-00-3	1.90E+04	1.40E+03	NA	No
Ethylbenzene	100-41-4	7.51E+01	5.80E+00	NA	No
Ethylene	74-85-1	NA	NA	NA	NA
Fluoranthene	206-44-0	2.32E+03	2.40E+02	1.00E+01	No
HCL / Hydrogen Chloride	7647-01-0	NA	2.80E+06	NA	No
i-Butane	75-28-5	NA	NA	NA	NA
i-Butene	115-11-7	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	1.53E+00	1.10E+00	7.10E+01	No
i-Pentane	78-78-4	NA	NA	NA	NA
i-Propylbenzene / Cumene	98-82-8	2.36E+03	1.90E+02	NA	No
m- & p-Xylene	108-38-3 & 106-42-3	7.64E+02	5.50E+01	1.40E+00	No
Methane	74-82-8	NA	NA	NA	NA
Methyl chloroform	71-55-6	1.44E+04	8.10E+02	2.60E+02	No
Methyl chloride	74-87-3	4.11E+01	1.10E+01	NA	No
Methyl cyclohexane	108-87-2	5.50E+03	NA	NA	No
Methyl cyclopentane	96-37-7	NA	NA	NA	NA
Methylene chloride	75-09-2	4.09E+02	3.50E+01	2.60E+00	No
m-Ethyltoluene	620-14-4	NA	NA	NA	NA
Naphthalene	91-20-3	4.97E+01	3.80E+00	1.00E+00	No
n-Butane	106-97-8	NA	NA	NA	NA
n-Decane	124-18-5	NA	NA	NA	NA
n-Heptane	142-82-5	NA	2.20E+00	NA	No
n-Hexane	110-54-3	6.15E+02	6.10E+01	NA	No
Nitrogen dioxide (peroxide)	10102-44-0	NA	NA	NA	NA
Nitrogen Oxide	10024-97-2	NA	NA	NA	NA
Nitrogen Oxides		NA	NA	NA	NA
n-Nonane	111-84-2	NA	1.10E+00	NA	No
n-Octane	111-65-9	NA	NA	NA	NA
Non-methane Organic Compound		NA	NA	NA	NA
n-Pentane	109-66-0	NA	8.10E+01	NA	No
n-Propylbenzene	103-65-1	NA	3.80E+02	NA	No

Table 5-2c (continued)
Health and Ecological Screening Level Comparisons – 10-year Residential Soil Exposures

Contaminant	CAS Nos.	Lesser of NMED Cancer or NonCancer Residential Soil SL (mg/kg)	EPA RSLs - Lesser of the Cancer or NonCancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	NMED, EPA, or LANL ESL Screening Levels Exceeded?
OCDD *Screening Limits are for TCDD, 2,3,7,8	TCDD CAS no. 1746-01-6	4.90E-05	4.80E-06	2.90E-07	No
o-Ethyltoluene	611-14-3	NA	NA	NA	NA
o-Xylene	95-47-6	8.05E+02	6.50E+01	1.40E+00	No
Perylene	198-55-0	NA	NA	NA	NA
p-Ethyltoluene	622-96-8	NA	NA	NA	NA
Phenanthrene	85-01-8	1.74E+03	NA	5.50E+00	No
Phenol	108-95-2	1.85E+04	1.90E+03	7.90E-01	No
PM10		NA	NA	NA	NA
Propane	74-98-6	NA	NA	NA	NA
Propene / Propylene	115-07-1	NA	2.20E+02	NA	No
Pyrene	129-00-0	1.74E+03	1.80E+02	1.00E+01	No
Styrene / Ethenylbenzene	100-42-5	7.26E+03	6.00E+02	1.20E+00	No
Sulfur Dioxide	7446-09-5	NA	NA	NA	NA
Toluene / Methylbenzene	108-88-3	5.23E+03	4.90E+02	2.30E+01	No
Total Alkanes (Paraffins)	NA	NA	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	NA	NA	NA	NA
Total Non-methane Hydrocarbons / NMHC	NA	NA	NA	NA	NA
Total Unidentified Hydrocarbons	NA	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA	NA
Vinyl Chloride	75-01-4	7.42E-01	5.90E-02	1.20E-01	No
Vinylidene Chloride / Dichloroethylene, 1,1-	75-35-4	4.40E+02	2.30E+01	1.10E+01	No
Volatile Organic Compounds	NA	NA	NA	NA	NA
Zinc	7440-66-6	2.35E+04	2.30E+03	4.70E+01	No

Notes

1. NA - Chemical Not Available in database
2. U.S. EPA soil carcinogenic and non-carcinogenic screening levels are from the Regional Screening Levels (RSLs) –
   Generic Tables. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
3. NMED soil carcinogenic and non-carcinogenic screening levels are from the New Mexico Environment Department
   Risk Assessment Guidance for Site Investigations and Remediation. Volume I Soil Screening Guidance
   for Human Health Risk Assessments. Feb. 2019 (Rev. 2, 6/19/2019).
   https:/www.env.nm.gov/wp-content/uploads/sites/12/2016/11/Final-NMED-SSG-VOL-I_-Rev.2-6_19_19.pdf
4. ESL minimum values and effected receptors are recorded in the LANL ECORSK Database, on CD, LA-UR-12-24548,
   Los Alamos National Laboratory, Los Alamos, New Mexico, 2019.
5. PM10 emissions factor and emissions are the same for PM2.5.

5.1 Discussion of Results

Dispersion modeling was used to predict maximum GLCs of contaminants that occur downwind from the open burning site. Model input parameters were selected that conservatively reflect the characteristics of waste streams treated through open burning at the site. Receptors were used in the modeling to estimate air concentrations close to the site as well as public receptors nearby. The hourly and annual maximum waste quantities to be treated were also used in the model input. Model results indicated the air concentrations and maximum GLCs occur on LANL property within the receptor grid adjacent to the site. Predicted deposition concentrations at public receptors were far less than concentrations within the LANL property boundary. Thus, the maximum impact used in the health screening analysis was the maximum value on LANL property. Impacts at receptors in public areas would be much less.

Model results were applied to emission factors for each predicted contaminant. The air concentration results calculated were compared to air quality standards and recommended human health screening levels where they were identified. All calculations are included in Attachment A and summarized in Tables 5-1 and 5-2a, -2b, and -2c. The results show predicted impacts for acute and annual air concentrations to be below all health screening levels. Additionally, predicted soil deposition for 10-year residential soil exposures over a 10-year period shows impacts to soil concentrations to be less than human health and ecological screening levels.

The air screening analysis conducted by LANL and detailed within this report was designed to provide a very conservative air dispersion and deposition analysis for open burning waste treatment operations conducted at LANL. Input parameters were used as conservatively as deemed reasonable, emission factors were obtained from published information sources that can be utilized as surrogates for waste treated by open burning at LANL, and the quantity of waste assessed was the maximum amount of waste that could possibly be treated at the open burning unit at one time (200 lbs) or over an entire year (6,000 lbs). Based on the conservative criteria above, all potential impacts were calculated to be below identified air and soil screening levels. Additionally, routine burn ground operations are far less than the quantity assessed through this screening analysis. Proposed current and future operations are described within the LANL permit application for the open burning unit. Due to the factors outlined here, current and future operations at the burn ground do not require a more refined risk-based analysis to assess the potential for adverse effects due to migration of waste constituents in the air. Waste treatment operations at the TA-16 Burn Ground can be conducted and considered protective of human health and the environment.

6.0 REFERENCES

Booher, L.E. and Janke, B., 1997. *Air Emissions from Petroleum Hydrocarbon Fires During Controlled Burning*. American Industrial Hygiene Association Journal, 58:359-365. May 1997.

Bjorklund, et.al., 1998a. Bjorklund, J. R., J. F. Bowers, G. C. Dodd, and J. M. White, 1998a. Open Burn/Open Detonation Model (OBODM) User's Guide, Volume I, User's Instructions, DPG Document No. DPG-TR-96-008a, February 1998. https://apps.dtic.mil/dtic/tr/fulltext/u2/a353602.pdf

Bjorklund, et.al., 1998b. Bjorklund, J. R., J. F. Bowers, G. C. Dodd, and J. M. White, 1998b. Open Burn/Open Detonation Model (OBODM) User's Guide, Volume II, Technical Description. DPG Document No. DPGTR-96-008b, April 1998. https://apps.dtic.mil/dtic/tr/fulltext/u2/a345376.pdf

Briggs, G.A., 1970. “Some recent analyses of plume rise observations”. Preprint of Paper No. ME-8E presented at the Second International Clean Air Congress, Washington, D.C. 6-11 December 1970.

Briggs, G.A., 1971. “Some recent analyses of plume rise observations”. In Proceedings of the Second International Clean Air Congress, Academic Press, New York, 1029-1032.

Briggs, G.A., 1971. “Some recent analyses of plume rise observations”. In Proceedings of the Second International Clean Air Congress, Academic Press, New York, 1029-1032.

Briggs, G.A., 1973. “Diffusion estimates for small emissions (Draft)”. Air Resources Atmospheric Turbulence and Diffusion Laboratory. ATOL No. 79.

Briggs, G.A., 1975. “Plume rise predictions”. In: *Lectures on Air Pollution and Environmental Impact Analyses*. American Meteorological Society, Boston, MA, pp. 59-111.

CA OEHHA, 2015. The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. February 2015. https://oehha.ca.gov/media/downloads/crnr/2015guidancemanual.pdf

CA OEHHA, 2019. Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

Cramer, H.E., H.V. Geary, and J.F. Bowers, 1975. *Diffusion model calculations of long-term and short-term ground-level SO2 concentrations in Allegheny County, Pennsylvania*. Report No. EPA-903/9-75-018, U.S. Environmental Protection Agency, Region III, Philadelphia, PA.

Scire, J.S. et.al., 2000. *A User’s Guide for the CALPUFF Dispersion Model (Version 5).* Earth Tech, Inc., Concord, MA, 01742.

EPA, 1983. U.S. EPA AP-42, Compilation of Air Pollutant Emission Factors, Chapter 6, Section 3, Table 6.3-1.

EPA, 2008. U.S. EPA AP-42, Fifth Edition, Volume 1, Chapter 1.5, Liquified Petroleum Gas Combustion, Table 1.5-1.

EPA, 2010. *Course: Basic Concepts in Environmental Sciences, Module 6: Air Pollutants/Control Techniques. Air Pollution Training Institute (APTI).* U.S. Environmental Protection Agency funded, Cooperative Assistance Agreement CT-825724 to North Carolina State University. http://www.epa.gov/apti/bces/module6/dioxins/dioxins.htm. January 29, 2010.

EPA, 2016. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Final. Office of Solid Waste and Emergency Response, EPA520-R-05-006, February 2016.

https://archive.epa.gov/epawaste/hazard/tsd/td/web/html/risk.html#hhrad / https://archive.epa.gov/epawaste/hazard/tsd/td/web/mdb/05hhrapchemdat.mdb

EPA, 2019. Regional Screening Levels (RSLs) – Generic Tables. U.S. Environmental Protection Agency. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

EPA, 2002a. *Emissions of Organic Air Toxics from Open Burning*. EPA/600/R-02/076, October 2002.

EPA, 2002b. "Draft Final Open Burning/Open Detonation Permitting Guidelines," February 2002.

EPA, 1997a. "Locating and Estimating Air Emissions from Sources of Dioxins and Furans," EPA-454/R-97-003, http://www.epa.gov/ttnchie1/le/dioxin.pdf, May 1997.

EPA, 1997b. "Chlorinated Dioxin and Furan Formation, Control, and Monitoring," Presented at ICCR Meeting, Research Triangle Park, September 17, 1997

EPA, 1998. "Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD)," EPA/600/R-98/103, August 1998.

LANL, 2019. ECORSK Database, on CD, LA-UR-12-24548, Los Alamos National Laboratory, Los Alamos, New Mexico, 2019.

NMED, 2019a. Air Dispersion Modeling Guidelines. Revised June 6, 2019. https://www.env.nm.gov/wp-content/uploads/sites/2/2017/01/NM_AirDispersionModelingGuidelines_6June2019.pdf

NMED 2010. Los Alamos National Laboratory Hazardous Waste Facility Permit. New Mexico Environment Department, Santa Fe, New Mexico. November 2010 and updates.

NMED, 2019b. New Mexico Environment Department (NMED), 2019. *New Mexico Environment Department Risk Assessment Guidance for Site Investigations and Remediation. Volume I Soil Screening Guidance for Human Health Risk Assessments.* February 2019 (Revision 2, 6/19/2019). https://www.env.nm.gov/wp-content/uploads/sites/12/2016/11/Final-NMED-SSG-VOL-I_-Rev.2-6_19_19.pdf

Grzegorz Wielgosiński, 2011. The Reduction of Dioxin Emissions from the Processes of Heat and Power Generation, Journal of the Air & Waste Management Association, 61:5, 511-526, DOI: 10.3155/1047-3289.61.5.511. (https://doi.org/10.3155/1047-3289.61.5.511)

Mengmei Zhang, Alfons Buekens & Xiaodong Li, 2017. Open burning as a source of dioxins, Critical Reviews in Environmental Science and Technology, 47:8, 543-620, DOI: 10.1080/10643389.2017.1320154. (https://doi.org/10.1080/10643389.2017.1320154)

[This page has been left intentionally blank.]

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for 1-hour Air Concentration

Basis	
200	lb/hr waste burn
127.2	lb propane/hr
1	g/sec contaminant emission rate
Model Result (X/Q)	
1.05E+01	1-hour maximum value, µg/m3 per g/sec contaminant

Contaminant	CAS No.	Emission Factor (lb/lb of waste)	Emission Rate (g/sec)	Maximum 1-hour Concentration (2) (µg/m^3)	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
1,2,4-Trimethylbenzene	95-63-6	2.43E-04	6.12E-03	6.43E-02	NA	NA	NA
sec-Butylbenzene	135-98-8	5.09E-04	1.28E-02	1.35E-01	NA	NA	NA
1,3,5-Trimethylbenzene	108-67-8	5.57E-04	1.40E-02	1.47E-01	1.25E+05	NA	No
1,3-Butadiene	106-99-0	1.34E-06	3.38E-05	3.55E-04	NA	6.60E+02	No
1-Butene	106-98-9	4.69E-06	1.18E-04	1.24E-03	NA	NA	NA
1-Hexene	592-41-6	2.19E-06	5.52E-05	5.79E-04	NA	NA	NA
1-Pentene	109-67-1	1.72E-06	4.33E-05	4.55E-04	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	6.97E-06	1.76E-04	1.84E-03	NA	NA	NA
2,2-Dimethylbutane	75-83-2	4.29E-08	1.08E-06	1.14E-05	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	1.38E-06	3.48E-05	3.65E-04	NA	NA	NA
2,3-Dimethylbutane	79-29-8	2.06E-06	5.19E-05	5.45E-04	NA	NA	NA
2,3-Dimethylhexane	584-94-1	5.40E-06	1.36E-04	1.43E-03	NA	NA	NA
2,3-Dimethylpentane	565-59-3	3.33E-06	8.39E-05	8.81E-04	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	1.99E-07	5.01E-06	5.27E-05	NA	NA	NA
2,4-Dimethylhexane	589-43-5	6.42E-06	1.62E-04	1.70E-03	NA	NA	NA
2,4-Dimethylpentane	108-08-7	2.16E-06	5.44E-05	5.72E-04	NA	NA	NA
2,5-Dimethylhexane	592-13-2	1.11E-05	2.80E-04	2.94E-03	NA	NA	NA
2-Methyl-1-butene	563-46-2	1.05E-06	2.65E-05	2.78E-04	NA	NA	NA
2-Methyl-2-butene	513-35-9	9.07E-08	2.29E-06	2.40E-05	NA	NA	NA
2-Methylheptane	592-27-8	4.42E-05	1.11E-03	1.17E-02	NA	NA	NA
2-Methylhexane	591-76-4	1.38E-05	3.48E-04	3.65E-03	NA	NA	NA
2-Methylnaphthalene	91-57-6	2.18E-05	5.49E-04	5.77E-03	NA	NA	NA

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for 1-hour Air Concentration (continued)

Contaminant	CAS No.	Emission Factor (lb/lb of waste)	Emission Rate (g/sec)	Maximum 1-hour Concentration (2) (µg/m^3)	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
2-Methylpentane	107-83-5	9.47E-06	2.39E-04	2.51E-03	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	5.90E-05	1.49E-03	1.56E-02	NA	NA	NA
3-Methyl-1-butene	563-45-1	1.99E-07	5.01E-06	5.27E-05	NA	NA	NA
3-Methylhexane	589-34-4	1.55E-05	3.91E-04	4.10E-03	NA	NA	NA
3-Methylpentane	96-14-0	5.08E-06	1.28E-04	1.34E-03	NA	NA	NA
Acenaphthylene	208-96-8	6.71E-06	1.69E-04	1.78E-03	NA	NA	NA
Acetophenone	98-86-2	1.74E-07	4.38E-06	4.60E-05	3.00E+04	NA	No
Acetylene	74-86-2	9.52E-05	2.40E-03	2.52E-02	NA	NA	NA
Aluminum	7429-90-5	7.13E-07	1.80E-05	1.89E-04	NA	NA	NA
Anthracene	120-12-7	1.02E-07	2.57E-06	2.70E-05	6.00E+03	NA	No
Aromative (e.g. Styrene)		2.29E-03	5.77E-02	6.06E-01		NA	NA
Barium	7440-39-3	4.20E-07	1.06E-05	1.11E-04	1.50E+03	NA	No
Benzene	71-43-2	7.84E-05	1.98E-03	2.07E-02	1.30E+03	2.70E+01	No
Benzo(a)anthracene	56-55-3	9.81E-07	2.47E-05	2.60E-04	3.00E+02	NA	No
Benzo(a)pyrene	50-32-8	7.42E-07	1.87E-05	1.96E-04	6.00E+02	NA	No
Benzo(b)fluoranthene	205-99-2	7.84E-07	1.98E-05	2.07E-04	6.00E+02	NA	No
Benzo(ghi)perylene	191-24-2	3.45E-07	8.69E-06	9.13E-05	NA	NA	NA
Benzo(k)fluoranthene	207-08-9	7.46E-07	1.88E-05	1.97E-04	6.00E+02	NA	No
Benzyl alcohol	100-51-6	3.96E-05	9.98E-04	1.05E-02	6.00E+04	NA	No
Biphenyl	92-52-4	6.45E-06	1.63E-04	1.71E-03	NA	NA	NA
Butyl benzyl phthalate	85-68-7	1.22E-07	3.07E-06	3.23E-05	1.50E+04	NA	No
Carbon Tetrachloride	56-23-5	6.89E-08	1.74E-06	1.82E-05	1.90E+03	1.90E+03	No
Chromium	7440-47-3	3.97E-07	1.00E-05	1.05E-04	1.50E+03	NA	No
Chrysene	218-01-9	9.33E-07	2.35E-05	2.47E-04	6.00E+02	NA	No
cis-2-Butene	590-18-1	1.99E-07	5.01E-06	5.27E-05	NA	NA	NA
cis-2-Pentene	627-20-3	9.07E-08	2.29E-06	2.40E-05	NA	NA	NA
Carbon Monoxide (2)	630-08-0	2.98E-02	7.51E-01	8.18E+00	NA	2.30E+04	No
Carbon Dioxide	124-38-9	1.63E+00	4.11E+01	4.31E+02	NA	NA	NA
Copper	7440-50-8	6.31E-06	1.59E-04	1.67E-03	NA	NA	NA
Cyclohexane	110-82-7	2.67E-05	6.73E-04	7.06E-03	NA	NA	NA
Cyclopentane	287-92-3	1.53E-06	3.86E-05	4.05E-04	NA	NA	NA
Dibenz(a,h)anthracene / Dibenzo(a,h)anthracene	53-70-3	2.00E-07	5.04E-06	5.29E-05	3.00E+04	NA	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for 1-hour Air Concentration (continued)

Contaminant	CAS No.	Emission Factor (lb/lb of waste)	Emission Rate (g/sec)	Maximum 1-hour Concentration (2) (μg/m³)	Air Inhalation Emission Concentration (AIEC) - acute (μg/m³)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (μg/m³)	Screening Level Exceeded?
Diethyl phthalate	84-66-2	7.00E-08	1.76E-06	1.85E-05	1.50E+04	NA	No
Dimethyl phthalate	113-11-3	1.88E-07	4.74E-06	4.97E-05	1.50E+04	NA	No
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	3.30E-07	8.32E-06	8.73E-05	1.50E+04	NA	No
Di-n-octyl phthalate	117-84-0	9.19E-07	2.32E-05	2.43E-04	5.00E+04	NA	No
Ethane	74-84-0	1.15E-05	2.90E-04	3.04E-03	NA	NA	-
Ethyl chloride / Chloroethane	75-00-3	6.89E-08	1.74E-06	1.82E-05	2.50E+06	NA	No
Ethylbenzene	100-41-4	5.49E-05	1.38E-03	1.45E-02	5.00E+05	NA	No
Ethylene	74-85-1	7.43E-05	1.87E-03	1.97E-02	NA	NA	NA
Fluoranthene	206-44-0	7.85E-07	1.98E-05	2.08E-04	1.50E+01	NA	No
HCL - Hydrochloric Acid	7647-01-0	9.97E-04	2.51E-02	2.64E-01	2.10E+03	2.10E+03	No
i-Butane	75-28-5	1.24E-06	3.12E-05	3.28E-04	NA	NA	NA
i-Butene	115-11-7	2.26E-06	5.70E-05	5.98E-04	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	2.83E-07	7.13E-06	7.49E-05	5.00E+02	NA	No
i-Pentane	78-78-4	1.08E-05	2.72E-04	2.86E-03	NA	NA	NA
i-Propylbenzene / Cumene	98-82-8	1.03E-04	2.60E-03	2.73E-02	2.46E+05	NA	No
m- & p-Xylene	108-38-3 & 106-42-3	4.52E-04	1.14E-02	1.20E-01	2.20E+04	NA	No
Methane	74-82-8	8.72E-05	2.20E-03	2.31E-02	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	3.44E-08	8.67E-07	9.10E-06	6.80E+04	6.80E+04	No
Methyl chloride	74-87-3	2.84E-07	7.16E-06	7.51E-05	2.00E+05	NA	No
Methylcyclohexane	108-87-2	1.56E-04	3.93E-03	4.13E-02	NA	NA	NA
Methylcyclopentane	96-37-7	9.93E-06	2.50E-04	2.63E-03	NA	NA	NA
Methylene chloride / dichloromethane	75-09-2	7.46E-07	1.88E-05	1.97E-04	1.40E+04	1.40E+04	No
m-Ethyltoluene	620-14-4	1.28E-04	3.23E-03	3.39E-02	NA	NA	NA
Naphthalene	91-20-3	8.38E-05	2.11E-03	2.22E-02	7.50E+04	NA	No
n-Butane	106-97-8	4.60E-06	1.16E-04	1.22E-03	NA	NA	NA
n-Decane	124-18-5	1.97E-03	4.96E-02	5.21E-01	NA	NA	NA
n-Heptane	142-82-5	5.90E-05	1.49E-03	1.56E-02	NA	NA	NA
n-Hexane	110-54-3	1.60E-05	4.03E-04	4.23E-03	NA	NA	NA
Nitrogen dioxide / Nitrogen peroxide	10102-44-0	4.69E-04	1.18E-02	1.24E-01	NA	4.70E+02	No
Nitrogen Oxide	10024-97-2	6.28E-03	1.58E-01	1.66E+00	NA	NA	NA

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for 1-hour Air Concentration (continued)

Contaminant	CAS No.	Emission Factor (lb/lb of waste)	Emission Rate (g/sec)	Maximum 1-hour Concentration (2) (µg/m^3)	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Nitrogen Oxides (2)		7.50E-02	1.89E+00	2.04E+01	NA	NA	NA
n-Nonane	111-84-2	1.03E-03	2.60E-02	2.73E-01	NA	NA	NA
n-Octane	111-65-9	2.48E-04	6.25E-03	6.56E-02	NA	NA	NA
Non-methane Organic Compound /NMHC (2)		7.84E-03	1.98E-01	2.11E+00	NA	NA	NA
n-Pentane	109-66-0	9.05E-06	2.28E-04	2.39E-03	NA	NA	NA
n-Propylbenzene	103-65-1	8.16E-05	2.06E-03	2.16E-02	NA	NA	NA
OCDD *Screening Limits are for TetraCDD, 2,3,7,8-	TCDD CAS no. 1746-01-6	1.03E-11	2.60E-10	2.73E-09	1.50E+00	NA	No
o-Ethyltoluene	611-14-3	3.90E-07	9.83E-06	1.03E-04	NA	NA	NA
o-Xylene	95-47-6	1.25E-04	3.15E-03	3.31E-02	2.20E+04	NA	No
Perylene	198-55-0	1.72E-07	4.33E-06	4.55E-05	NA	NA	NA
p-Ethyltoluene	622-96-8	1.53E-04	3.86E-03	4.05E-02	NA	NA	NA
Phenanthrene	85-01-8	7.17E-06	1.81E-04	1.90E-03	1.00E+03	NA	No
Phenol	108-95-2	1.56E-05	3.93E-04	4.13E-03	5.80E+03	5.80E+03	No
PM10 (2)		9.10E-01	2.29E+01	2.41E+02	NA	NA	NA
Propane	74-98-6	2.22E-06	5.59E-05	5.87E-04	NA	NA	NA
Propene	115-07-1	1.30E-05	3.28E-04	3.44E-03	NA	NA	NA
Pyrene	129-00-0	7.06E-07	1.78E-05	1.87E-04	1.50E+04	NA	No
Styrene	100-42-5	4.99E-05	1.26E-03	1.32E-02	2.10E+04	2.10E+04	No
Sulfur Dioxide (2)	7446-09-5	1.22E-03	3.07E-02	6.80E-01	NA	6.60E+02	No
Toluene	108-88-3	1.22E-04	3.07E-03	3.23E-02	3.70E+04	3.70E+04	No
Total Alkanes (Paraffins)	NA	3.50E-03	8.82E-02	9.26E-01	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	1.93E-04	4.86E-03	5.11E-02	NA	NA	NA
Total Non-methane Hydrocarbons - TNMHC	NA	1.20E-02	3.02E-01	3.21E+00	NA	NA	NA
Total Unidentified Hydrocarbons	NA	6.04E-03	1.52E-01	1.60E+00	NA	NA	NA
trans-2-Butene	624-64-6	2.91E-06	7.33E-05	7.70E-04	NA	NA	NA
trans-2-Pentene	646-04-8	1.08E-06	2.72E-05	2.86E-04	NA	NA	NA
Vinyl Chloride	75-01-4	2.23E-07	5.62E-06	5.90E-05	1.80E+05	1.80E+05	**No**
Vinylidene Chloride / Dichloroethylene, 1,1-	75-35-4	2.15E-07	5.42E-06	5.69E-05	7.50E+04	NA	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for 1-hour Air Concentration (continued)

Contaminant	CAS No.	Emission Factor (lb/lb of waste)	Emission Rate (g/sec)	Maximum 1-hour Concentration (2) (µg/m^3)	Air Inhalation Emission Concentration (AIEC) - acute (µg/m^3)	CA-OEHHA Non-Cancer Reference Exposure Level (REL) - Acute (µg/m^3)	Screening Level Exceeded?
Volatile Organic Compounds		5.50E-04	1.39E-02	1.46E-01	NA	NA	NA
Zinc	7440-66-6	6.26E-05	1.58E-03	1.66E-02	3.00E+04	NA	No

Notes

1. NA - Chemical Not Available in database
2. Impacts from propane combustion have been added to waste impact concentrations for nitrogen oxides, carbon monoxide, PM10, sulfur dioxide and NMHC.
3. PM10 emissions factor and emissions are the same for PM2.5
3. Screening concentrations from acute (1 hr) inhalation exposures concentrations (AIEC) from the Companion Database to EPA's Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA 2016). https://archive.epa.gov/epawaste/hazard/tsd/td/web/mdb/05hhrapchemdat.mdb
4. REL 1-hour acute screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Annual Air Concentration

Basis	
6,000	lb waste/yr
1	g/sec contaminant emission rate
Model Result (X/Q)	
9.32E-03	Annual maximum value, ug/m3 per g/sec contaminant

Contaminant	CAS No.	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration µg/m³	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
1,2,4-Trimethylbenzene	95-63-6	2.43E-04	2.10E-05	1.95E-07	NA	6.30E+00	No
sec-Butylbenzene	135-98-8	5.09E-04	4.39E-05	4.09E-07	NA	NA	NA
1,3,5-Trimethylbenzene	108-67-8	5.57E-04	4.81E-05	4.48E-07	NA	6.30E+00	No
1,3-Butadiene	106-99-0	1.34E-06	1.16E-07	1.08E-09	2.00E+00	2.10E-01	No
1-Butene	106-98-9	4.69E-06	4.05E-07	3.77E-09	NA	NA	NA
1-Hexene	592-41-6	2.19E-06	1.89E-07	1.76E-09	NA	NA	NA
1-Pentene	109-67-1	1.72E-06	1.48E-07	1.38E-09	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	6.97E-06	6.02E-07	5.61E-09	NA	NA	NA
2,2-Dimethylbutane	75-83-2	4.29E-08	3.70E-09	3.45E-11	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	1.38E-06	1.19E-07	0.00E+00	NA	NA	NA
2,3-Dimethylbutane	79-29-8	2.06E-06	1.78E-07	1.66E-09	NA	NA	NA
2,3-Dimethylhexane	584-94-1	5.40E-06	4.66E-07	4.34E-09	NA	NA	NA
2,3-Dimethylpentane	565-59-3	3.33E-06	2.87E-07	2.68E-09	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	1.99E-07	1.72E-08	1.60E-10	NA	NA	NA
2,4-Dimethylhexane	589-43-5	6.42E-06	5.54E-07	5.16E-09	NA	NA	NA
2,4-Dimethylpentane	108-08-7	2.16E-06	1.86E-07	1.74E-09	NA	NA	NA
2,5-Dimethylhexane	592-13-2	1.11E-05	9.58E-07	8.93E-09	NA	NA	NA
2-Methyl-1-butene	563-46-2	1.05E-06	9.06E-08	8.45E-10	NA	NA	NA
2-Methyl-2-butene	513-35-9	9.07E-08	7.83E-09	7.30E-11	NA	NA	NA
2-Methylheptane	592-27-8	4.42E-05	3.81E-06	3.56E-08	NA	NA	NA
2-Methylhexane	591-76-4	1.38E-05	1.19E-06	1.11E-08	NA	NA	NA
2-Methylnaphthalene	91-57-6	2.18E-05	1.88E-06	1.75E-08	NA	NA	NA
2-Methylpentane	107-83-5	9.47E-06	8.17E-07	7.62E-09	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	5.90E-05	5.09E-06	4.75E-08	NA	NA	NA
3-Methyl-1-butene	563-45-1	1.99E-07	1.72E-08	1.60E-10	NA	NA	NA

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for Annual Air Concentration (continued)

Contaminant	CAS No.	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration $\mu g/m^3$	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
3-Methylhexane	589-34-4	1.55E-05	1.34E-06	1.25E-08	NA	NA	NA
3-Methylpentane	96-14-0	5.08E-06	4.38E-07	4.09E-09	NA	NA	NA
Acenaphthylene	208-96-8	6.71E-06	5.79E-07	5.40E-09	NA	NA	NA
Acetophenone	98-86-2	1.74E-07	1.50E-08	1.40E-10	NA	NA	NA
Acetylene	74-86-2	9.52E-05	8.22E-06	7.66E-08	NA	NA	NA
Aluminum	7429-90-5	7.13E-07	6.15E-08	5.73E-10	NA	5.20E-01	No
Anthracene	120-12-7	1.02E-07	8.80E-09	8.20E-11	NA	NA	NA
Aromative (e.g. Styrene)		2.29E-03	1.98E-04	1.84E-06	NA	NA	NA
Barium	7440-39-3	4.20E-07	3.62E-08	3.38E-10	NA	5.20E-02	No
Benzene	71-43-2	7.84E-05	6.77E-06	6.31E-08	3.00E+00	3.10E+00	No
Benzo(a)anthracene	56-55-3	9.81E-07	8.47E-08	7.89E-10	NA	NA	NA
Benzo(a)pyrene	50-32-8	7.42E-07	6.40E-08	5.97E-10	NA	2.10E-04	No
Benzo(b)fluoranthene	205-99-2	7.84E-07	6.77E-08	6.31E-10	NA	NA	NA
Benzo(ghi)perylene	191-24-2	3.45E-07	2.98E-08	2.77E-10	NA	NA	NA
Benzo(k)fluoranthene	207-08-9	7.46E-07	6.44E-08	6.00E-10	NA	NA	NA
Benzyl alcohol	100-51-6	3.96E-05	3.42E-06	3.19E-08	NA	NA	NA
Biphenyl, 1,1'-	92-52-4	6.45E-06	5.57E-07	5.19E-09	NA	4.20E-02	No
Butyl benzyl phthalate	85-68-7	1.22E-07	1.05E-08	9.81E-11	NA	NA	NA
Carbon Tetrachloride	56-23-5	6.89E-08	5.95E-09	5.54E-11	4.00E+01	1.00E+01	No
Chromium	7440-47-3	3.97E-07	3.43E-08	3.19E-10	NA	NA	NA
Chrysene	218-01-9	9.33E-07	8.05E-08	7.50E-10	NA	NA	NA
cis-2-Butene	590-18-1	1.99E-07	1.72E-08	1.60E-10	NA	NA	NA
cis-2-Pentene	627-20-3	9.07E-08	7.83E-09	7.30E-11	NA	NA	NA
CO (2)	630-08-0	2.98E-02	2.57E-03	2.49E-05	NA	NA	NA
CO2	124-38-9	1.63E+00	1.41E-01	1.31E-03	NA	NA	NA
Copper	7440-50-8	6.31E-06	5.45E-07	5.08E-09	NA	NA	NA
Cyclohexane	110-82-7	2.67E-05	2.30E-06	2.15E-08	NA	6.30E+02	No
Cyclopentane	287-92-3	1.53E-06	1.32E-07	1.23E-09	NA	NA	NA
Dibenz(a,h)anthracene	53-70-3	2.00E-07	1.73E-08	1.61E-10	NA	NA	NA
Diethyl phthalate	84-66-2	7.00E-08	6.04E-09	5.63E-11	NA	NA	NA
Dimethyl phthalate	113-11-3	1.88E-07	1.62E-08	1.51E-10	NA	NA	NA
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	3.30E-07	2.85E-08	2.65E-10	NA	NA	NA
Di-n-octyl phthalate	117-84-0	9.19E-07	7.93E-08	7.39E-10	NA	NA	NA

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for Annual Air Concentration (continued)

Contaminant	CAS No.	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration µg/m^3	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
Ethane	74-84-0	1.15E-05	9.92E-07	9.25E-09	NA	NA	NA
Ethyl chloride	75-00-3	6.89E-08	5.95E-09	5.54E-11	3.00E+04	1.00E+03	No
Ethylbenzene	100-41-4	5.49E-05	4.74E-06	4.42E-08	2.00E+03	1.00E+02	No
Ethylene	74-85-1	7.43E-05	6.41E-06	5.98E-08	NA	NA	NA
Fluoranthene	206-44-0	7.85E-07	6.77E-08	6.31E-10	NA	NA	NA
HCL / Hydrogen Chloride	7647-01-0	9.97E-04	8.60E-05	8.02E-07	9.00E+00	2.10E+00	No
i-Butane	75-28-5	1.24E-06	1.07E-07	9.97E-10	NA	NA	NA
i-Butene	115-11-7	2.26E-06	1.95E-07	1.82E-09	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	2.83E-07	2.44E-08	2.28E-10	NA	NA	NA
i-Pentane	78-78-4	1.08E-05	9.32E-07	8.69E-09	NA		NA
i-Propylbenzene / Cumene	98-82-8	1.03E-04	8.89E-06	8.28E-08	NA	4.20E+01	No
m- & p-Xylene	108-38-3 & 106-42-3	4.52E-04	3.90E-05	3.64E-07	NA	1.00E+01	No
Methane	74-82-8	8.72E-05	7.53E-06	7.01E-08	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	3.44E-08	2.97E-09	2.77E-11	1.00E+03	5.20E+02	No
Methylchloride / Chloromethane	74-87-3	2.84E-07	2.45E-08	2.28E-10	NA	9.40E+00	No
Methylcyclohexane /	108-87-2	1.56E-04	1.35E-05	1.25E-07	NA	NA	NA
Methylcyclopentane	96-37-7	9.93E-06	8.57E-07	7.99E-09	NA	NA	NA
Methylene chloride	75-09-2	7.46E-07	6.44E-08	6.00E-10	4.00E+02	6.30E+01	No
m-Ethyltoluene	620-14-4	1.28E-04	1.10E-05	1.03E-07	NA		NA
Naphthalene	91-20-3	8.38E-05	7.23E-06	6.74E-08	9.00E+00	3.10E-01	No
n-Butane	106-97-8	4.60E-06	3.97E-07	3.70E-09	NA		NA
n-Decane	124-18-5	1.97E-03	1.70E-04	1.58E-06	NA		NA
n-Heptane	142-82-5	5.90E-05	5.09E-06	4.75E-08	NA	4.20E+01	No
n-Hexane	110-54-3	1.60E-05	1.38E-06	1.29E-08	7.00E+03	7.30E+01	No
Nitrogen dioxide (peroxide)	10102-44-0	4.69E-04	4.05E-05	3.77E-07	NA	NA	NA
Nitrogen Oxide	10024-97-2	6.28E-03	5.42E-04	5.05E-06	NA	NA	NA
Nitrogen Oxides (2)		7.50E-02	6.47E-03	6.19E-05	NA	NA	NA
n-Nonane	111-84-2	1.03E-03	8.89E-05	8.28E-07	NA	2.10E+00	No
n-Octane	111-65-9	2.48E-04	2.14E-05	1.99E-07	NA	NA	NA
Non-methane Organic Compound/NMHC (2)		7.84E-03	6.77E-04	6.43E-06	NA	NA	NA
n-Pentane	109-66-0	9.05E-06	7.81E-07	7.28E-09	NA	1.00E+02	No
n-Propylbenzene	103-65-1	8.16E-05	7.04E-06	6.56E-08	NA	1.00E+02	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16-388 Flash Pad Screening Analysis Worksheet for Annual Air Concentration (continued)

Contaminant	CAS No.	Emission Factor lb/lb waste	Emission Rate g/sec	Maximum Annual Concentration $\mu g/m^3$	CA-OEHHA Non-Cancer Chronic Reference Exposure Level (REL) (µg/m3)	EPA Resident Air Non-carcinogenic SL for THI = 0.1 (µg/m3)	Screening Level Exceeded?
OCDD *Screening Limits are for TCDD,2,3,7,8-	TCDD CAS no. 1746-01-6	1.03E-11	8.89E-13	8.28E-15	NA	4.20E-06	No
o-Ethyltoluene	611-14-3	3.90E-07	3.37E-08	3.14E-10	NA	NA	-
o-Xylene	95-47-6	1.25E-04	1.08E-05	1.01E-07	NA	1.00E+01	No
Perylene	198-55-0	1.72E-07	1.48E-08	1.38E-10	NA	NA	NA
p-Ethyltoluene	622-96-8	1.53E-04	1.32E-05	1.23E-07	NA	NA	NA
Phenanthrene	85-01-8	7.17E-06	6.19E-07	5.77E-09	NA	NA	NA
Phenol	108-95-2	1.56E-05	1.35E-06	1.25E-08	2.00E+02	2.10E+01	No
PM10 (2)(3)		9.10E-01	7.85E-02	7.32E-04	NA	NA	NA
Propane	74-98-6	2.22E-06	1.92E-07	1.79E-09	NA	NA	NA
Propene / Propylene	115-07-1	1.30E-05	1.12E-06	1.05E-08	3.00E+03	3.10E+02	No
Pyrene	129-00-0	7.06E-07	6.09E-08	5.68E-10	NA	NA	NA
Styrene	100-42-5	4.99E-05	4.31E-06	4.01E-08	9.00E+02	1.00E+02	No
Sulfur Dioxide (2)	7446-09-5	1.22E-03	1.05E-04	2.07E-06	NA	NA	NA
Toluene	108-88-3	1.22E-04	1.05E-05	9.81E-08	3.00E+02	5.20E+02	No
Total Alkanes (Paraffins)	NA	3.50E-03	3.02E-04	2.82E-06	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	1.93E-04	1.67E-05	1.55E-07	NA	NA	NA
Total Non-methane Hydrocarbons / NMHC	NA	1.20E-02	1.04E-03	9.77E-06	NA	NA	NA
Total Unidentified Hydrocarbons	NA	6.04E-03	5.21E-04	4.86E-06	NA	NA	NA
trans-2-Butene	624-64-6	2.91E-06	2.51E-07	2.34E-09	NA	NA	NA
trans-2-Pentene	646-04-8	1.08E-06	9.32E-08	8.69E-10	NA	NA	NA
Vinyl Chloride	75-01-4	2.23E-07	1.92E-08	1.79E-10	NA	1.00E+01	No
Vinylidene Chloride / Dichloroethylene (1,1)	75-35-4	2.15E-07	1.86E-08	1.73E-10	7.00E+01	2.10E+01	No
Volatile Organic Compounds	NA	5.50E-04	4.75E-05	4.42E-07	NA	NA	NA
Zinc	7440-66-6	6.26E-05	5.40E-06	5.04E-08	NA	NA	NA

Notes

1. NA - Chemical Not Available in database
2. Impacts from propane combustion have been added to waste impact concentrations for nitrogen oxides, carbon monoxide, PM10, sulfur dioxide and NMHC.
3. PM10 emissions factor and emissions are the same for PM2.5.
4. Chronic REL annual screening concentrations are from the CA OEHHA, 2019, Consolidated Table Of OEHHA/ARB Approved Risk Assessment Health Values, November 2019. https://ww3.arb.ca.gov/toxics/healthval/contable.pdf
5. U.S. EPA air non-carcinogenic screening levels are from the Regional Screening Levels (RSLs) – Generic Tables. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition

Basis

6,000	lb waste/yr
1	g/sec contaminant emission rate
Model Result (X/Q)	
9.32E-03	Annual maximum value, ug/m3 per g/sec contaminant

For each deposition calculation, the following variables are applied. See Excel worksheet for further details and calculations.

1.00E+08	t1/2 days
6.93E-09	Ks
4.62E-02	X

Contaminant	CAS No.	Maximum Annual Concentration ug/m³	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
1,2,4-Trimethylbenzene	95-63-6	1.95E-07	8.44E-04	1.16E-04	NA	NA	NA	7.80E+01	5.00E+01	5.00E+01	NA	NA	No
sec-Butylbenzene	135-98-8	4.09E-07	1.77E-03	2.42E-04	NA	NA	NA	NA	7.80E+02	7.80E+02	NA	NA	No
1,3,5-Trimethylbenzene	108-67-8	4.48E-07	1.94E-03	2.65E-04	NA	NA	NA	NA	2.70E+01	2.70E+01	NA	NA	No
1,3-Butadiene	106-99-0	1.08E-09	4.66E-06	6.37E-07	6.86E-01	2.30E+00	6.86E-01	7.60E-02	1.80E-01	7.60E-02	NA	NA	No
1-Butene	106-98-9	3.77E-09	1.63E-05	2.23E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Hexene	592-41-6	1.76E-09	7.61E-06	1.04E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Pentene	109-67-1	1.38E-09	5.98E-06	8.18E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m³	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
2,2,4-Trimethylpentane	540-84-1	5.61E-09	2.42E-05	3.32E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2-Dimethylbutane	75-83-2	3.45E-11	1.49E-07	2.04E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	6.97E-06	3.01E-02	4.12E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylbutane	79-29-8	1.66E-09	7.16E-06	9.80E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylhexane	584-94-1	4.34E-09	1.88E-05	2.57E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylpentane	565-59-3	2.68E-09	1.16E-05	1.58E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,4-Trimethyl-1-pentene	107-39-1	1.60E-10	6.91E-07	9.47E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylhexane	589-43-5	5.16E-09	2.23E-05	3.05E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylpentane	108-08-7	1.74E-09	7.51E-06	1.03E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,5-Dimethylhexane	592-13-2	8.93E-09	3.86E-05	5.28E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-1-butene	563-46-2	8.45E-10	3.65E-06	5.00E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-2-butene	513-35-9	7.30E-11	3.15E-07	4.31E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylheptane	592-27-8	3.56E-08	1.54E-04	2.10E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylhexane	591-76-4	1.11E-08	4.80E-05	6.56E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	91-57-6	1.75E-08	7.57E-05	1.04E-05	NA	2.32E+02	2.32E+02	NA	2.40E+01	2.40E+01	1.60E+01	Montane Shrew	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
2-Methylpentane	107-83-5	7.62E-09	3.29E-05	4.51E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Ethylhexane, 3-Methylheptane	589-81-1	4.75E-08	2.05E-04	2.81E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methyl-1-butene	563-45-1	1.60E-10	6.91E-07	9.47E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylhexane	589-34-4	1.25E-08	5.39E-05	7.37E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylpentane	96-14-0	4.09E-09	1.77E-05	2.42E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	208-96-8	5.40E-09	2.33E-05	3.19E-06	NA	NA	NA	NA	NA	NA	1.20E+02	Montane Shrew	No
Acetophenone	98-86-2	1.40E-10	6.05E-07	8.28E-08	NA	7.82E+03	7.82E+03	NA	7.80E+02	7.80E+02	NA	NA	No
Acetylene	74-86-2	7.66E-08	3.31E-04	4.53E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aluminum	7429-90-5	5.73E-10	2.48E-06	3.39E-07	NA	7.80E+04	7.80E+04	NA	7.70E+03	7.70E+03	NA	NA	No
Anthracene	120-12-7	8.20E-11	3.54E-07	4.85E-08	NA	1.74E+04	1.74E+04	NA	1.80E+03	1.80E+03	6.80E+00	Generic Plant	No
Aromative (e.g. Styrene)		1.84E-06	7.96E-03	1.09E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium	7440-39-3	3.38E-10	1.46E-06	2.00E-07	NA	1.56E+04	1.56E+04	NA	1.50E+03	1.50E+03	1.10E+02	Generic Plant	No
Benzene	71-43-2	6.31E-08	2.72E-04	3.73E-05	1.78E+01	1.14E+02	1.78E+01	1.20E+00	8.20E+00	1.20E+00	2.40E+01	Deer Mouse	No
Benzo(a)anthracene	56-55-3	7.89E-10	3.41E-06	4.67E-07	1.53E+00	NA	1.53E+00	1.10E+00	NA	1.10E+00	7.30E-01	American Robin	No
Benzo(a)pyrene	50-32-8	5.97E-10	2.58E-06	3.53E-07	NA	NA	NA	1.10E-01	1.80E+00	1.10E-01	6.20E+01	Montane Shrew	No
Benzo(b)fluoranthene	205-99-2	6.31E-10	2.72E-06	3.73E-07	1.53E+00		1.53E+00	1.10E+00	NA	1.10E+00	1.80E+01	Generic Plant	No

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
Benzo(ghi)perylene	191-24-2	2.77E-10	1.20E-06	1.64E-07	NA	NA	NA	NA	NA	NA	2.50E+01	Montane Shrew	No
Benzo(k)fluoranthene	207-08-9	6.00E-10	2.59E-06	3.55E-07	1.53E+01	NA	1.53E+01	1.10E+01	NA	1.10E+01	7.10E+01	Montane Shrew	No
Benzyl alcohol	100-51-6	3.19E-08	1.38E-04	1.88E-05	NA	NA	NA	NA	6.30E+02	6.30E+02	1.20E+02	Deer Mouse	No
Biphenyl	92-52-4	5.19E-09	2.24E-05	3.07E-06	8.48E+02	3.91E+04	8.48E+02	8.70E+01	4.70E+00	4.70E+00	NA	NA	No
Butyl benzyl phthalate	85-68-7	9.81E-11	4.24E-07	5.80E-08	NA	NA	NA	2.90E+02	1.30E+03	2.90E+02	9.00E+01	Montane Shrew	No
Carbon Tetrachloride	56-23-5	5.54E-11	2.39E-07	3.28E-08	1.07E+01	1.44E+02	1.07E+01	6.50E-01	1.00E+01	6.50E-01	NA	NA	No
Chromium	7440-47-3	3.19E-10	1.38E-06	1.89E-07	9.66E+01	4.52E+04	9.66E+01	NA	NA	NA	2.30E+01	American Robin	No
Chrysene	218-01-9	7.50E-10	3.24E-06	4.44E-07	1.53E+02	NA	1.53E+02	1.10E+02	NA	1.10E+02	3.10E+00	Montane Shrew	No
cis-2-Butene	590-18-1	1.60E-10	6.91E-07	9.47E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-2-Pentene	627-20-3	7.30E-11	3.15E-07	4.31E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Monoxide (2)	630-08-0	2.49E-05	1.07E-01	1.47E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Dioxide	124-38-9	1.31E-03	5.66E+00	7.75E-01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	7440-50-8	5.08E-09	2.19E-05	3.00E-06	NA	3.13E+03	3.13E+03	NA	3.10E+02	3.10E+02	1.40E+01	American Robin	No
Cyclohexane	110-82-7	2.15E-08	9.28E-05	1.27E-05	NA	NA	NA	NA	6.50E+02	6.50E+02	NA	NA	No
Cyclopentane	287-92-3	1.23E-09	5.32E-06	7.28E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene /	53-70-3	1.61E-10	6.95E-07	9.51E-08	1.53E-01	NA	1.53E-01	1.10E-01	NA	1.10E-01	1.40E+01	Montane Shrew	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
Dibenzo(a,h)anthracene													
Diethyl phthalate	84-66-2	5.63E-11	2.43E-07	3.33E-08	NA	4.93E+04	4.93E+04	NA	5.10E+03	5.10E+03	1.00E+02	Generic Plant	No
Dimethyl phthalate	113-11-3	1.51E-10	6.53E-07	8.94E-08	NA	NA	NA	NA	NA	NA	1.00E+01	Earthworm	No
Di-n-butyl phthalate / Dibutyl Phthalate	84-74-2	2.65E-10	1.15E-06	1.57E-07	NA	6.16E+03	6.16E+03	NA	6.30E+02	6.30E+02	1.10E-02	American Robin	No
Di-n-octyl phthalate	117-84-0	7.39E-10	3.19E-06	4.37E-07	NA	NA	NA	NA	6.30E+01	6.30E+01	9.10E-01	Montane Shrew	No
Ethane	74-84-0	9.25E-09	4.00E-05	5.47E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl chloride / Chloroethane	75-00-3	5.54E-11	2.39E-07	3.28E-08	NA	1.90E+04	1.90E+04	NA	1.40E+03	1.40E+03	NA	NA	No
Ethylbenzene	100-41-4	4.42E-08	1.91E-04	2.61E-05	7.51E+01	3.93E+03	7.51E+01	5.80E+00	3.40E+02	5.80E+00	NA	NA	No
Ethylene	74-85-1	5.98E-08	2.58E-04	3.53E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	206-44-0	6.31E-10	2.73E-06	3.73E-07	NA	2.32E+03	2.32E+03	NA	2.40E+02	2.40E+02	1.00E+01	Earthworm	No
HCL - Hydrochloric Acid	7647-01-0	8.02E-07	3.46E-03	4.74E-04	NA	NA	NA	NA	2.80E+06	2.80E+06	NA	NA	No
i-Butane	75-28-5	9.97E-10	4.31E-06	5.90E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
i-Butene	115-11-7	1.82E-09	7.85E-06	1.08E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	193-39-5	2.28E-10	9.83E-07	1.35E-07	1.53E+00	NA	1.53E+00	1.10E+00	NA	1.10E+00	7.10E+01	Montane Shrew	No
i-Pentane	78-78-4	8.69E-09	3.75E-05	5.14E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
i-Propylbenzene / Cumene	98-82-8	8.28E-08	3.58E-04	4.90E-05	NA	2.36E+03	2.36E+03	NA	1.90E+02	1.90E+02	NA	NA	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
m- & p-Xylene	108-38-3 & 106-42-3	3.64E-07	1.57E-03	2.15E-04	NA	7.64E+02	7.64E+02	NA	5.50E+01	5.50E+01	1.40E+00	Montane Shrew	No
Methane	74-82-8	7.01E-08	3.03E-04	4.15E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl chloroform / Trichloroethane, 1,1,1-	71-55-6	2.77E-11	1.20E-07	1.64E-08	NA	1.44E+04	1.44E+04	NA	8.10E+02	8.10E+02	2.60E+02	Montane Shrew	No
Methyl chloride	74-87-3	2.28E-10	9.87E-07	1.35E-07	4.11E+01	2.68E+02	4.11E+01	NA	1.10E+01	1.10E+01	NA	NA	No
Methylcyclohexane	108-87-2	1.25E-07	5.42E-04	7.42E-05	NA	5.50E+03	5.50E+03	NA	NA	NA	NA	NA	No
Methylcyclopentane	96-37-7	7.99E-09	3.45E-05	4.72E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride / dichloromethane	75-09-2	6.00E-10	2.59E-06	3.55E-07	7.66E+02	4.09E+02	4.09E+02	5.70E+01	3.50E+01	3.50E+01	2.60E+00	Deer Mouse	No
m-Ethyltoluene	620-14-4	1.03E-07	4.45E-04	6.09E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	91-20-3	6.74E-08	2.91E-04	3.99E-05	4.97E+01	1.62E+02	4.97E+01	3.80E+00	1.30E+01	3.80E+00	1.00E+00	Generic Plant	No
n-Butane	106-97-8	3.70E-09	1.60E-05	2.19E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Decane	124-18-5	1.58E-06	6.85E-03	9.37E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Heptane	142-82-5	4.75E-08	2.05E-04	2.81E-05	NA	NA	NA	NA	2.20E+00	2.20E+00	NA	NA	No
n-Hexane	110-54-3	1.29E-08	5.56E-05	7.61E-06	NA	6.15E+02	6.15E+02	NA	6.10E+01	6.10E+01	NA	NA	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
Nitrogen dioxide / Nitrogen peroxide	10102-44-0	3.77E-07	1.63E-03	2.23E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide	10024-97-2	5.05E-06	2.18E-02	2.99E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxides (2)		6.19E-05	2.67E-01	3.66E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nonane	111-84-2	8.28E-07	3.58E-03	4.90E-04	NA	NA	NA	NA	1.10E+00	1.10E+00	NA	NA	No
n-Octane	111-65-9	1.99E-07	8.62E-04	1.18E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Non-methane Organic Compound /NMHC (2)		6.31E-06	2.72E-02	3.73E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Pentane	109-66-0	7.28E-09	3.14E-05	4.31E-06	NA	NA	NA	NA	8.10E+01	8.10E+01	NA	NA	No
n-Propylbenzene	103-65-1	6.56E-08	2.84E-04	3.88E-05	NA	NA	NA	NA	3.80E+02	3.80E+02	NA	NA	No
OCDD *Screening Limits are for TetraCDD, 2,3,7,8-	TCDD CAS no. 1746-01-6	8.28E-15	3.58E-11	4.90E-12	4.90E-05	5.06E-05	4.90E-05	4.80E-06	5.10E-06	4.80E-06	2.90E-07	Montane Shrew	No
o-Ethyltoluene	611-14-3	3.14E-10	1.36E-06	1.86E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	95-47-6	1.01E-07	4.34E-04	5.95E-05	NA	8.05E+02	8.05E+02	NA	6.50E+01	6.50E+01	1.40E+00	Montane Shrew	No
Perylene	198-55-0	1.38E-10	5.98E-07	8.18E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA
p-Ethyltoluene	622-96-8	1.23E-07	5.32E-04	7.28E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	85-01-8	5.77E-09	2.49E-05	3.41E-06	NA	1.74E+03	1.74E+03	NA	NA	NA	5.50E+00	Earthworm	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
Phenol	108-95-2	1.25E-08	5.42E-05	7.42E-06	NA	1.85E+04	1.85E+04	NA	1.90E+03	1.90E+03	7.90E-01	Generic Plant	No
PM10 (2)		7.32E-04	3.16E+00	4.33E-01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propane	74-98-6	1.79E-09	7.71E-06	1.06E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propene	115-07-1	1.05E-08	4.52E-05	6.18E-06	NA	NA	NA	NA	2.20E+02	2.20E+02	NA	NA	No
Pyrene	129-00-0	5.68E-10	2.45E-06	3.36E-07	NA	1.74E+03	1.74E+03	NA	1.80E+02	1.80E+02	1.00E+01	Earthworm	No
Styrene	100-42-5	4.01E-08	1.73E-04	2.37E-05	NA	7.26E+03	7.26E+03	NA	6.00E+02	6.00E+02	1.20E+00	Earthworm	No
Sulfur Dioxide (2)	7446-09-5	2.07E-06	8.93E-03	1.22E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	108-88-3	9.81E-08	4.24E-04	5.80E-05	NA	5.23E+03	5.23E+03	NA	4.90E+02	4.90E+02	2.30E+01	Montane Shrew	No
Total Alkanes (Paraffins)	NA	2.82E-06	1.22E-02	1.67E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Alkenes (Olefins) (e.g. Ethylene)	NA	1.55E-07	6.71E-04	9.18E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Non-methane Hydrocarbons - TNMHC	NA	9.77E-06	4.22E-02	5.78E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Unidentified Hydrocarbons	NA	4.86E-06	2.10E-02	2.87E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Butene	624-64-6	2.34E-09	1.01E-05	1.38E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Pentene	646-04-8	8.69E-10	3.75E-06	5.14E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl Chloride	75-01-4	1.79E-10	7.75E-07	1.06E-07	7.42E-01	1.13E+02	7.42E-01	5.90E-02	7.00E+00	5.90E-02	1.20E-01	Montane Shrew	No

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?
Vinylidene Chloride / Dichloroethylene, 1,1-	75-35-4	1.73E-10	7.47E-07	1.02E-07	NA	4.40E+02	4.40E+02	NA	2.30E+01	2.30E+01	1.10E+01	Montane Shrew	No
Volatile Organic Compounds	NA	4.42E-07	1.91E-03	2.62E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	7440-66-6	5.04E-08	2.18E-04	2.98E-05	NA	2.35E+04	2.35E+04	NA	2.30E+03	2.30E+03	4.70E+01	American Robin	No

Notes

Soil concentrations calculated from annual model result using procedures from *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, CA OEHHA, February 2015.

No degradation is assumed using half-live of 1.00E+08 which overpredicts for organic compounds.

Calculation used described below.

C_s = Dep * X / (K_s * SD * BD * T_t)

Dep = Deposition on the affected soil area per day (ug/m^2/d)

Dep = GLC * Dep-rate * 86,400

GLC = The chemical specific annual ground level concentration from OBODM result and emission factor (ug/m^3)

Dep-rate = 0.05 m/sec (default value for uncontrolled source)

86,400 = Seconds per day conversion factor

X = [{$e^{-Ks * Tf}$ - $e^{-Ks * To}$} / K_s] + T_t

e = 2.718

K_s = Soil elimination constant

3650 T_f = End of evaluation period (d)

0 T_o = Beginning of evaluation period (d)

3650 T_t = Total days of exposure period T_f - T_o (d)

Additional default values

0.01 SD = Soil mixing depth (m) = 0.01 for soil ingestion or dermal pathway (analysis is on Laboratory property)

Attachment A
EXCEL Table Results Used for Model Results Evaluation

TA-16 Burn Ground Screening Analysis Worksheet for Soil Deposition (continued)

Contaminant	CAS No.	Maximum Annual Concentration ug/m^3	Deposition (Dep) ug/m2/day	10 Year Soil Concentration mg/kg	NMED Cancer - Residential Soil TR=1E-05 (mg/kg)	NMED Non-Cancer Residential Soil Screening Level (mg/kg)	Lesser of NMED Cancer or Non Cancer Residential Soil SL (mg/kg)	Carcinogenic Target Risk - EPA SL - Resident Soil based on TR=1E-06 (mg/kg)	Noncancer Child HI EPA RSLs - Resident Soil based on THI =0.1 (mg/kg)	EPA RSLs - the lesser of the Cancer or Non Cancer Residential Soil - RSL (mg/kg)	Minimum LANL ESL mg/kg	Receptor	NMED, EPA, LANL ESL Screening Levels Exceeded?

1,333 BD = Soil bulk density (kg/m^3)

1. NA - Chemical Not Available in database
2. U.S. EPA soil carcinogenic and non-carcinogenic screening levels are from the Regional Screening Levels (RSLs) – Generic Tables. November 2019. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
3. NMED soil carcinogenic and non-carcinogenic screening levels are from the New Mexico Environment Department Risk Assessment Guidance for Site Investigations and Remediation. Volume I Soil Screening Guidance for Human Health Risk Assessments. February 2019 (Revision 2, 6/19/2019). https://www.env.nm.gov/wp-content/uploads/sites/12/2016/11/Final-NMED-SSG-VOL-I_-Rev.2-6_19_19.pdf
4. ESL minimum values and effected receptors are recorded in the LANL ECORSK Database, on CD, LA-UR-12-24548, Los Alamos National Laboratory, Los Alamos, New Mexico, 2019.
5. PM10 emissions factor and emissions are the same for PM2.5.

29. LANL (Los Alamos National Laboratory), June 2020l. Supplement 4-14 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Thermal Measurements at the TA-16-388 Flash Pad*. LA-UR-20-24479. (LANL 2020l)

Supplement 4-14

Thermal Measurements at the TA-16-388 Flash Pad

Table of Contents

Contents

1.0 Introduction

The single remaining active open burning treatment unit at the Los Alamos National Laboratory is known as the TA-16-388 Flash Pad and is used to treat explosives and explosives-contaminated hazardous waste utilizing two propane burners in an open air environment. As part of the Resource Conservation and Recovery Act (RCRA) application process for this unit, the U.S. Department of Energy (DOE) and the Los Alamos National Security, LLC (LANS) have determined that an exercise to verify treatment temperatures at the unit was necessary. This report details the thermal measurements collected from two open burning treatment events conducted at the TA-16-388 Flash Pad and discusses how those temperatures may have an effect on combustion products from treatment events at the unit. The treatment events occurred on April 3, 2013 and April 18, 2013. The wastes treated during the test were the most routinely treated waste stream for open burning.

In order to provide definitive verification of the burner output temperature, three different measurement types were used. Type K thermocouples provided contact measurements on and around the screen or cage that surrounds the waste within the burn tray. Non-contact temperature measurements were made using an infrared pyrometer and an infrared thermal imager. Two different pyrometers were used during testing, one during each of the two tests. All three measurement methodologies were used for each test.

2.0 Thermal Measurement Set-Up and Methodology

Three different measurement methods were employed in order to give the most comprehensive thermal profile of the burn in the treatment unit. For all treatment events, waste material is placed within a screen cage inside the burn tray to minimize the escape of any embers from the area during treatment. Thermocouples were arranged around the screen in which the waste material is placed for burning. A pyrometer was aimed at the screen in the first test and at a graphite target in the second test. The graphite target was utilized in the second test to lessen the variation of the pyrometer signal that was present during the April 3rd test due to turbulence. The graphite target created a larger mass for the pyrometer to be aimed at that was less susceptible to movement created by the burner outputs. Finally, a thermal imager was placed where it could view the entire burning area in the unit. This placement provided both spot measurements and a complete picture of the treatment temperatures achieved in the unit. All equipment used in the two tests is either itself NIST (National Institute of Standards and Technology)-traceable, or was verified using NIST-traceable equipment. Signals from the thermocouples and the pyrometers were data-logged using a Graphtec GL800 midi Data Logger. All signals were logged at a rate of 5 per second.

A thermocouple is a temperature measurement device consisting of a junction of two dissimilar metals. When the junction is heated, a voltage will be created that is temperature-dependent. This voltage is then converted to a calibrated temperature reading. The type K thermocouples used during testing have a temperature range from -330°F to 2100°F. In both tests, Type K thermocouples were placed at several points in and around the burn tray (Figure 1).

A pyrometer was set up to measure temperature at the surface of the screen (Figure 1). A pyrometer is a non-contact temperature measurement device that detects thermal radiation to determine the temperature of an object's surface without contacting the object. The measurement of the thermal radiation is output as a current signal that is converted to the corresponding temperature by the data logger. Two different pyrometers were used in each of the two tests, one reading from 1652°F to 4532°F and the other reading from 914°F to 3632°F.

A thermal imager works in a manner similar to a pyrometer. It is a non-contact device that detects infrared energy and converts it to an electrical signal. The images created depict different temperatures as different colors and are included within Attachments A and B of this report. A color key for the images is shown on each page. In each thermogram, the waste screen or cage (Ar1) is outlined in blue. The pyrometer was aimed at the waste; the approximate target area is indicated by the crosshairs (marked as “Sp1” on each thermogram). The thermal imager was set to capture an image every 10 seconds.

3.0 Data Analysis

The following sections describe the temperature verification activities associated with each of the waste treatment events measured. The sections include a general description of the waste treated, the location and type of instruments used to measure temperature, and a description of the type of data obtained from each test. Excerpts from the images that were generated from the thermal imager are included as Attachments A and B of this report. Full sets of images and data from the pyrometers and thermocouples are included with the electronic copy of the permit modification request to the New Mexico Environment Department- Hazardous Waste Bureau (NMED-HWB) only and are not included as part of this report due to their size.

3.1 Temperature Verification Test – April 3, 2013

On April 3, 2013, 22.7 pounds of hazardous waste were treated at the TA-16-388 Flash Pad. The waste stream treated consisted of explosives-contaminated filter socks that are generated during explosives machining operations. The filter socks are used to filter explosives from water used as a cooling agent during machining operations. Types of explosives that may be present in the machining waste include PBX 9501, PBX 9502, TNT, COMP-B, PETN, PBX 9404, PBX 9407, X-0211, LX-07 and XTX-8003. The waste stream is characterized with the Environmental Protection Agency (EPA) Hazardous Waste Number D003. The waste stream is part of the routinely treated explosives machining waste stream and the treatment event took place for 38 minutes. As shown in Figure 2, the burners were briefly turned off and re-started three times near the end of this test so the operator could visually check for the presence of unburned waste material.

Type K thermocouples were used to record the temperatures at several locations around the waste material. Thermocouples were placed on the east, west, and north sides of the screen enclosing the material (Figure 1). In this test the pyrometer was aimed directly at the waste screen/flames. The pyrometer used for this test begins measuring temperature at 1650°F. Within one minute, the waste temperature as measured with the pyrometer rose to over 1900°F, and to over 2300°F within four minutes.

Figure 2 presents all thermocouple and pyrometer data obtained during the April 3, 2013 test. The temperature during the 38 minute treatment process remains relatively steady during the treatment process with the exception of the times that the burners are turned off. Figure 2 also shows the loss of data when the north and east thermocouples lost connection due to damage by the direct flame. The variability in the data depicted by the green and purple lines, as well as the strong dips in the purple line while the propane burners are on, are indicative of data loss even though the lines follow the same general pattern of the still working thermocouples. However, the exact point at which the thermocouple connection was lost during the treatment process is unknown.

The thermal images (thermograms) in Attachment A of this report depict the overall thermal profile of the burn area throughout the test[1]. The thermal imager was set to capture an image every 10 seconds, and the data shows that the temperature of the screened or waste cage area (shown as Ar1) rose to over 2000°F within one minute. The thermograms within Attachment A in addition to the thermocouple and pyrometer data in Figure 2 show that the temperature within the burn cage stays at a relatively constant temperature throughout the treatment process.

3.2 Temperature Verification Test – April 18, 2013

On April 18, 2013, 40 pounds of the explosive PBX 9501 and 36.5 pounds of the explosive PBX 9502 were treated at the TA-16-388 Flash Pad. The waste treated is also part of the routinely treated explosives machining waste stream and consisted of explosives generated from machining operations and was a mixture of PBX 9501 and PBX 9502 explosives cuttings and shavings with water. The waste stream is characterized with the EPA Hazardous Waste Number D003. The waste treatment event took place for 43 minutes. The burners were briefly turned off and re-started twice near the end of this test in order to visually determine the presence of unburned waste material.

Type K thermocouples were placed in the same locations used during the April 3 test, with the addition of a thermocouple on the north side of the waste containment screen or cage (Figure 1). For this burning operation, thermocouples with longer sheath material were used in order to prevent the connection point burn out that occurred in the April 3, 2013 test. Data was again collected from the north, west, and south thermocouples (Figure 1).

The pyrometer used during this tests begins measuring temperature at 914°F. In this test, the pyrometer was aimed at a ½ inch thick graphite target. Due to the presence of this target, the ramp time of the

---

[1] *Note that the time stamp shown in each thermal image is 1 hour behind the time shown in the corresponding Figure 2 data, because the thermal imager's clock had not been re-set to Daylight Savings Time (e.g., 7:55am on the thermogram corresponds to 8:55 am on Figure 2).*

pyrometer was slower during this test than the April 3 test. It took approximately two minutes for the pyrometer temperature to rise above 1500°F due to the thermal mass of the graphite target. The pyrometer temperature reached 2000°F within 5 minutes of turning the burners on. The decrease in peak temperature compared to the April 3 test was due to the graphite target being measured rather than the direct flame.

Figure 3 presents the pyrometer and thermocouple data obtained during this test. During the 43 minute treatment event, the temperatures within the screen are well above 1500°F and remain relatively steady while the propane burners are on. The slower rise in temperature that was mentioned in the north, west, and south thermocouples was due to inadvertent contact of the thermocouples with the steel burn tray used to contain the waste materials. Due to the large thermal mass of the tray, the time necessary to bring that mass to temperature is considerably longer than the time required to bring the material and area around it up to the normal operating temperature.

The thermal imager was placed in approximately the same location as the April 3 burn and the thermograms within Attachment B of this report show that the temperature of the cage area containing the waste material (shown as Ar1) rose to over 2000°F. Images were captured every 10 seconds[2] and showed a steady temperature profile. Additionally, after the propane burners were turned off initially, only one of the burners was reignited to finish the treatment process. Temperature measurements after that point still indicate a greater than 2000°F maximum overall temperature for the screened area and a temperature above 1900°F in the middle of the screened area.

4.0 Results

The data collected during these tests demonstrated that the waste is being fully treated in the TA-16-388 Flash Pad at an operating temperature above 2000 °F. The thermal image data collected, along with the pyrometer data, show that the overall temperature in the unit rises quickly and consistently operates at above 2000°F during open burning waste treatment operations. The geometry of the burn pan is such that flames from the two propane burners intersect the waste inside the burn cage that is within the burn tray. The data indicate that the waste temperature rises rapidly – from ambient to above 1500 ˚F – in approximately 60 seconds as shown in Figure 2.

As the temperature begins to rise, the waste begins to lose water via evaporation, as the water in both of the waste streams tested is heated by the two propane burners. Organics, including the explosives within the waste, begin thermal decomposition into gaseous products at the same time that the water is evaporating. In general, the combustion products or emissions from most energetic materials treated by open burning in an unconfined state will be represented by water, carbon dioxide, carbon monoxide, oxides of nitrogen. Saturated short chain hydrocarbons, acetylene, ethylene, propene, benzene, toluene, and particulate matter may also be formed, but are rapidly oxidized to primarily water and

---

[2] *Note that the time stamp shown in each thermal image is 1 hour behind the time shown in the corresponding Figure 3 data, because the thermal imager's clock had not been re-set to Daylight Savings Time (e.g., 7:38am on the thermogram corresponds to 8:38 am on Figure 3).*

carbon dioxide. Chlorinated materials in the waste, such as plastics or the binders within the explosives, also undergo the thermal decomposition process. (Mitchell & Suggs, 1998)

The thermal images and thermocouple/pyrometer graphs show that during the initial 60 seconds after the start of the burn, temperatures inside the screened area in the burn tray holding the waste are between 400 and 1400˚F. After this point in the burn test, temperatures within the burn cage area are consistently above 1500˚F. In each of the burn test events, high temperatures, over 1500˚F were maintained and the each of the tests occurred for more than 30 minutes. Most treatment events at the TA-16-388 Flash Pad last approximately 30 minutes.

One of the concerns about emissions products associated with open burning treatment activities is the potential to produce dioxins and furan congeners. Products of incomplete combustion, like dioxins and furans, form at a temperature range of approximately 550 to 1115 ˚F (Kulkarni, Crespo, and Afonso, 2007). Dioxins and furans are destroyed at temperatures above 1400˚F (EPA, 2010) and will be decomposed predominantly into gaseous combustion products such as the oxidized compounds of carbon and nitrogen, water, and minute quantities of diatomic chlorine and hydrogen chloride can be expected.

Additional information on the formation and destruction of dioxins and furans can be found from the American Chemistry Council’s (2003) *Dioxin Fact Sheet.* The sheet highlights that there are three conditions necessary to prevent formation and increase the destruction of any dioxins and furans present due to incomplete combustion of waste:

1. The waste must be combusted at a high temperature to ensure efficient waste destruction,
2. The waste must have adequate combustion time, and
3. The heat must be distributed evenly through turbulence in the combustion zone.

During the ramp-up of temperature in the first 60 seconds of an open burning treatment, the temperature within the screened area will pass through the temperature zone necessary for dioxin and furan formation. However, because the waste within the burn tray is also coming up to temperature, incomplete combustion products will be minimized during that time frame. Additionally, the thermographs in Attachments A and B show that waste temperature rises above 1500 ˚F by the time 60 seconds have elapsed. The waste temperature continues to rise to above 2000 ˚F, where it is maintained for the rest of the 30-minute duration of a burn cycle. At high combustion temperatures, dioxins are not thermodynamically stable and decomposition is favored (Huan and Buekens, 1995). The temperature necessary for destruction of dioxin and furan congeners is met in every burn operation. In addition, the propane burners are fixed at the burn tray that contains the waste for the entire treatment event; therefore, the waste receives sufficient dwell time within the combustion zone to further reduce the potential for dioxin/furan formation.

The third condition, turbulence in the area where waste treatment is occurring, is induced by the combination of flames directed at the waste from the two propane burners and the formation of combustion gases immediately above the waste. The thermographs clearly depict the turbulence of the gases immediately above the waste cage throughout the burn event. They show that the temperature of combustion gases exceeds 2000˚F within 30 seconds after the burners are ignited. Within 50 seconds after ignition, gas temperatures are greater than 2300 ˚F.

Also, dwell time for air surrounding the screened burn area is relatively short when compared to a confined environment. The availability of air surrounding the treatment event and the turbulence created by the propane burners, lead to quick cooling time as gaseous combustion products escape from the immediate burn area. Fast cooling of these gases minimizes the likelihood of dioxin and furan formation when compared to that of a confined environment (Environment Australia, 1999) for every open burning treatment operation.

5.0 Conclusions

This report provides evidence that the thermal treatment unit at the TA-16-388 Flash Pad is capable of providing sufficient temperatures and time to treat the explosive and explosive contaminated waste streams managed at the unit. Temperatures attained at the unit exceed 1400°F within 60 seconds of the start of the burn and temperatures above 1500°F (>2000°F routinely) can be maintained continuously for the duration of the burn while the propane burners are in operation. The temperatures observed in the tests resulted in decomposition of the waste streams and the data provided objective feedback regarding burn conditions and operational factors that potentially affect the burns. These included determining the range of burn duration times and other factors associated with the potential production of combustion products.

Dioxins and furans that may be formed as incomplete combustion products due to open burning treatment operations are decomposed during the 30 minute treatment period. Thermal data collected using thermocouples, pyrometers, and a thermal imager show the temperature within the burn tray where the waste is held reaches and sustains temperatures that are great enough to decompose dioxins and furans. Standard operations for waste treatment at the unit also meet three other factors that are known to minimize the potential for the formation of dioxins and furans during thermal treatment. Therefore, the thermal data and images from both tests clearly demonstrate that conditions to prevent formation of dioxins and furans are present throughout every open burning treatment operation at the TA-16-388 Flash Pad open burning treatment unit. The amount of dioxins and furans expected to be added to the air due to open burning treatment events will be minimal, not measurable, and likely not contribute to ground level concentrations.

6.0 References

Environment Australia, 1999. *Incineration and Dioxins: Review of Formation Processes,* consultancy report prepared by Environmental and Safety Services for Environment Australia, Commonwealth Department of the Environment and Heritage, Canberra.

Environmental Protection Agency (EPA), 2010. Course: Basic Concepts in Environmental Sciences, Module 6: Air Pollutants/Control Techniques. Air Pollution Training Institute (APTI). U.S.

Environmental Protection Agency funded, Cooperative Assistance Agreement CT-825724 to North Carolina State University. January 29, 2010.

Huan, H., and A. Buekens, 1995. *On the Mechanisms of Dioxin Formation in Combustion Processes.* Chemosphere, Vol. 31, No. 9, pp. 4099-4117. Department of Chemical Engineering and Industrial Chemistry, Free University of Brussels, Pleinlaan 2, 1050 Brussels, Belgium. 1995

Mitchell, W.J., Jack Suggs. 1998. *Emission Factors for the Disposal of Energetic Materials by Open Burning and Open detonation (OB/OD)*. EPA/600/R-98/103. Research Triangle Park, NC. August 1998.

Kulkarni, Prashant S., João G. Crespo, Carlos A. M. Afonso. 2007. *Dioxins sources and current remediation technologies – A review.* Science Direct. Environmental International 34 (2008) 139-153. September 2007.

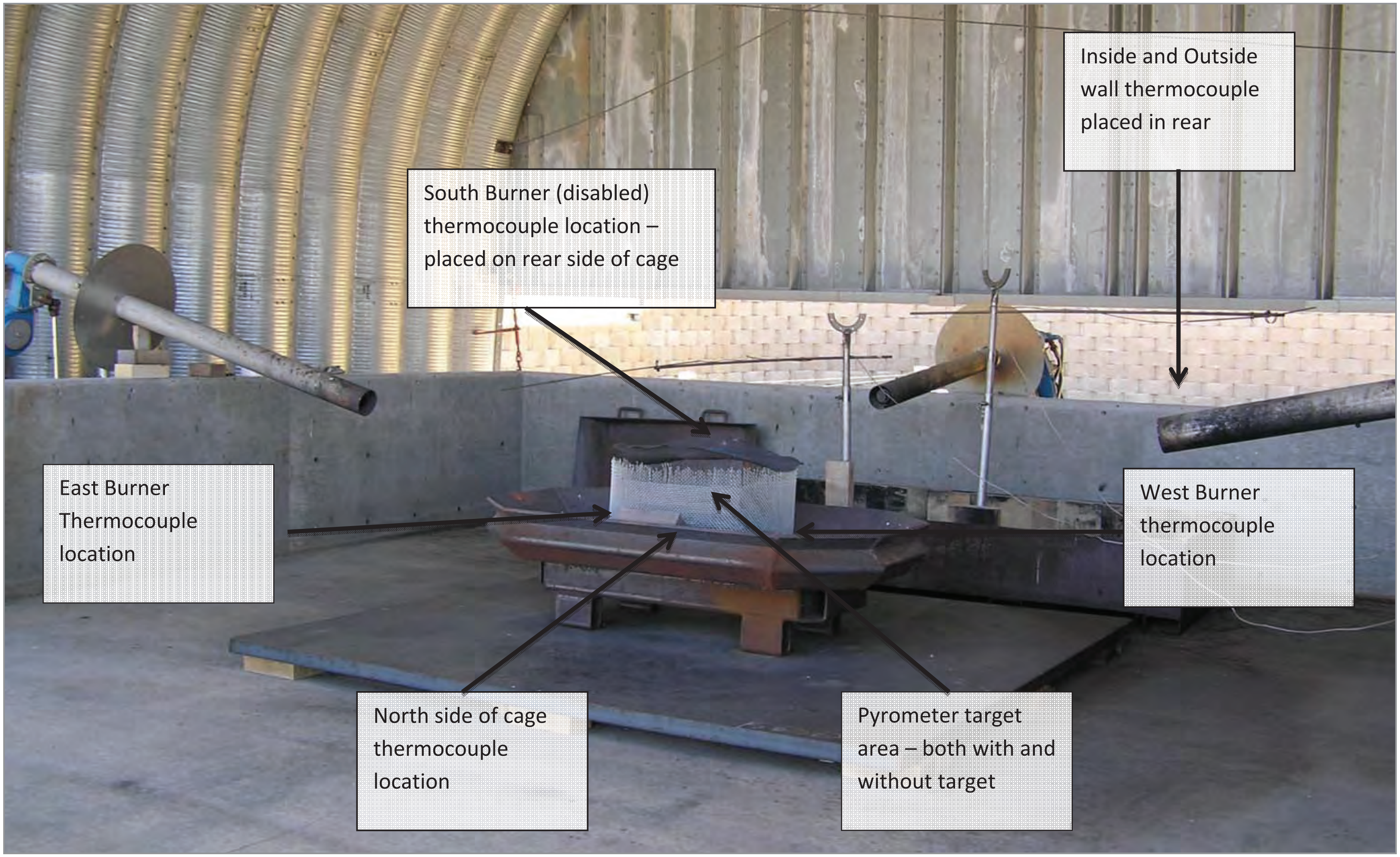
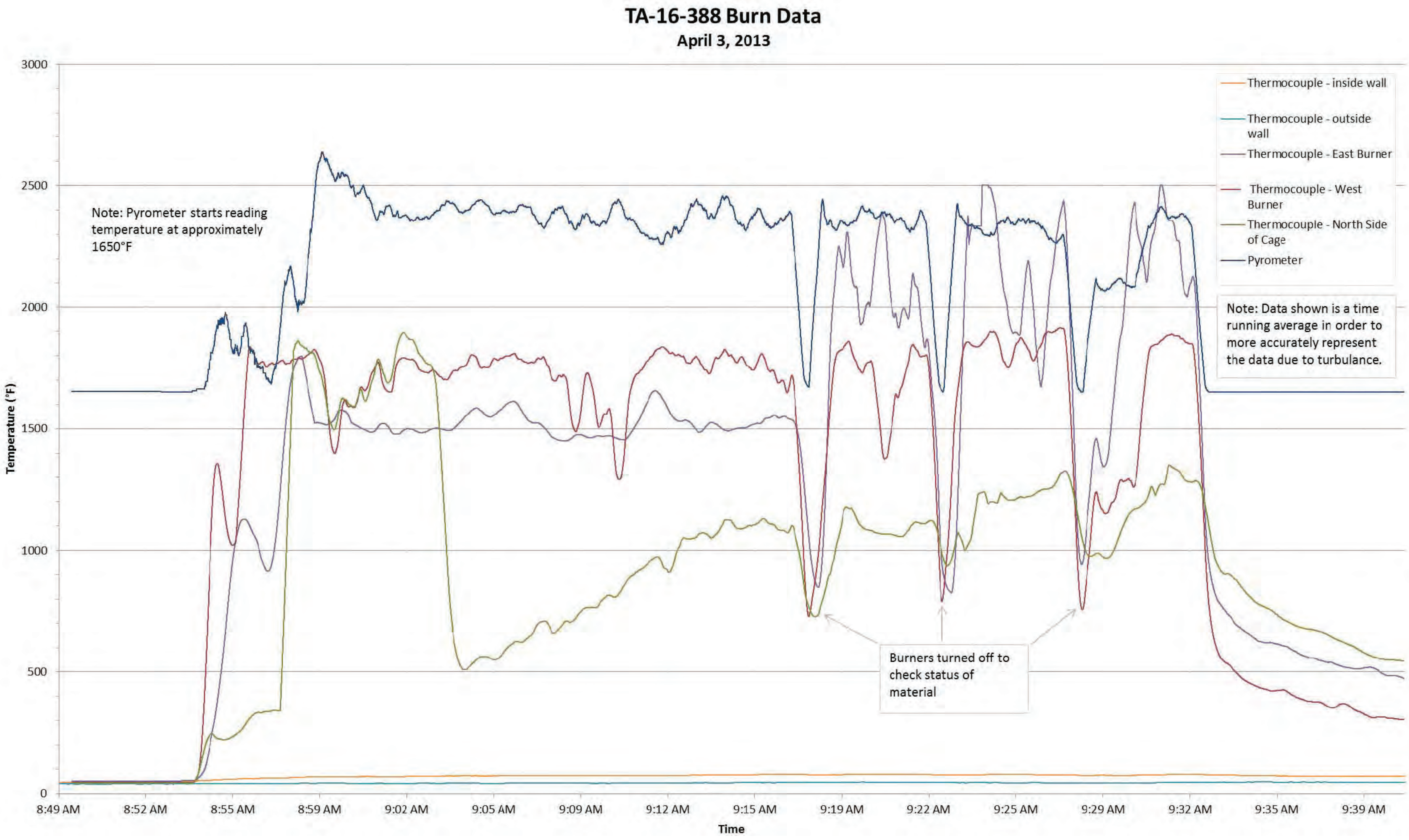


FIGURE 1 – MEASUREMENT LOCATIONS

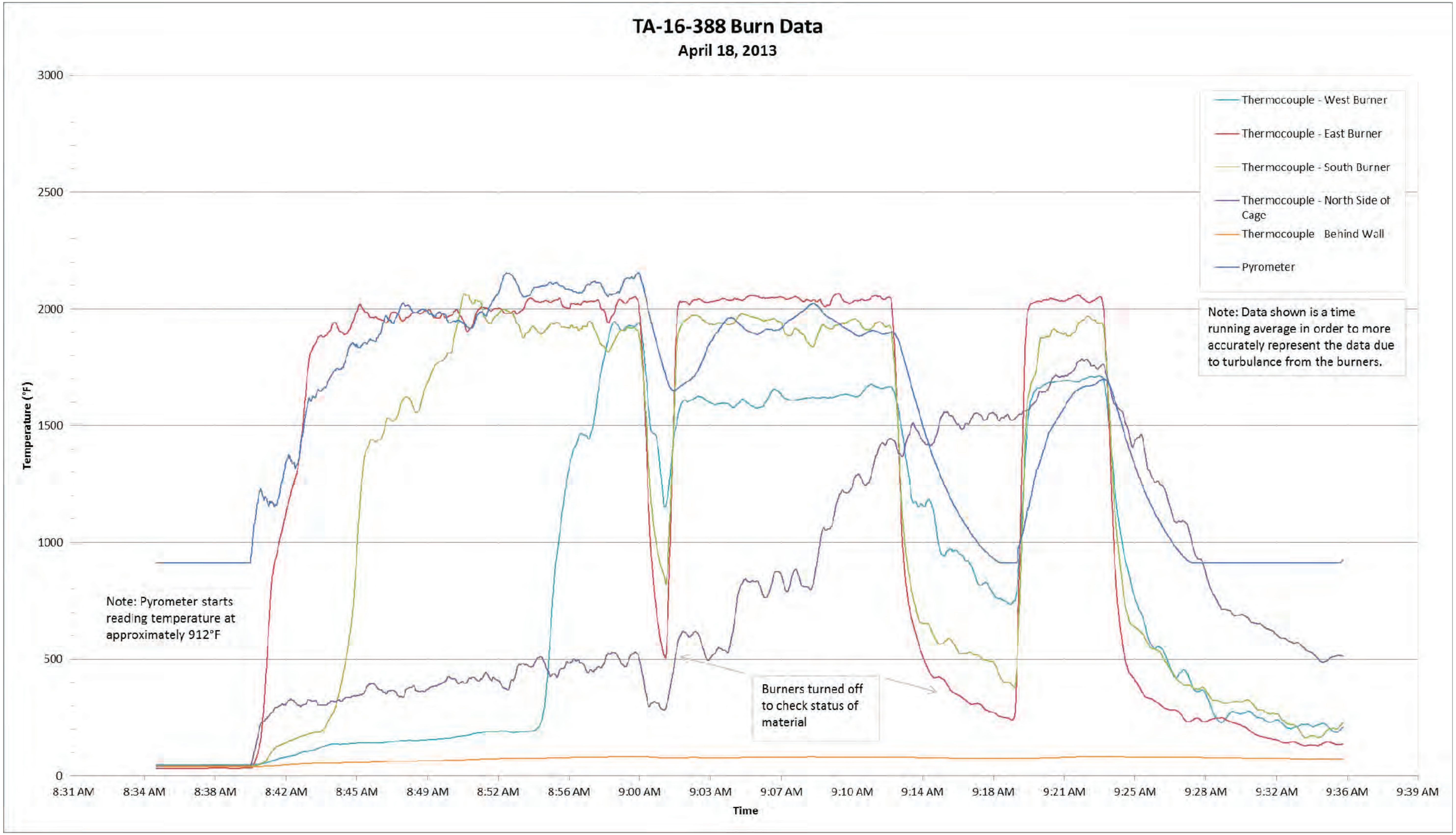


Note: Pyrometer starts reading temperature at approximately 1650°F

Note: Data shown is a time running average in order to more accurately represent the data due to turbulance.

Burners turned off to check status of material

FIGURE 2 - APRIL 3, 2013



Note: Data shown is a time running average in order to more accurately represent the data due to turbulance from the burners.

Note: Pyrometer starts reading temperature at approximately 912°F

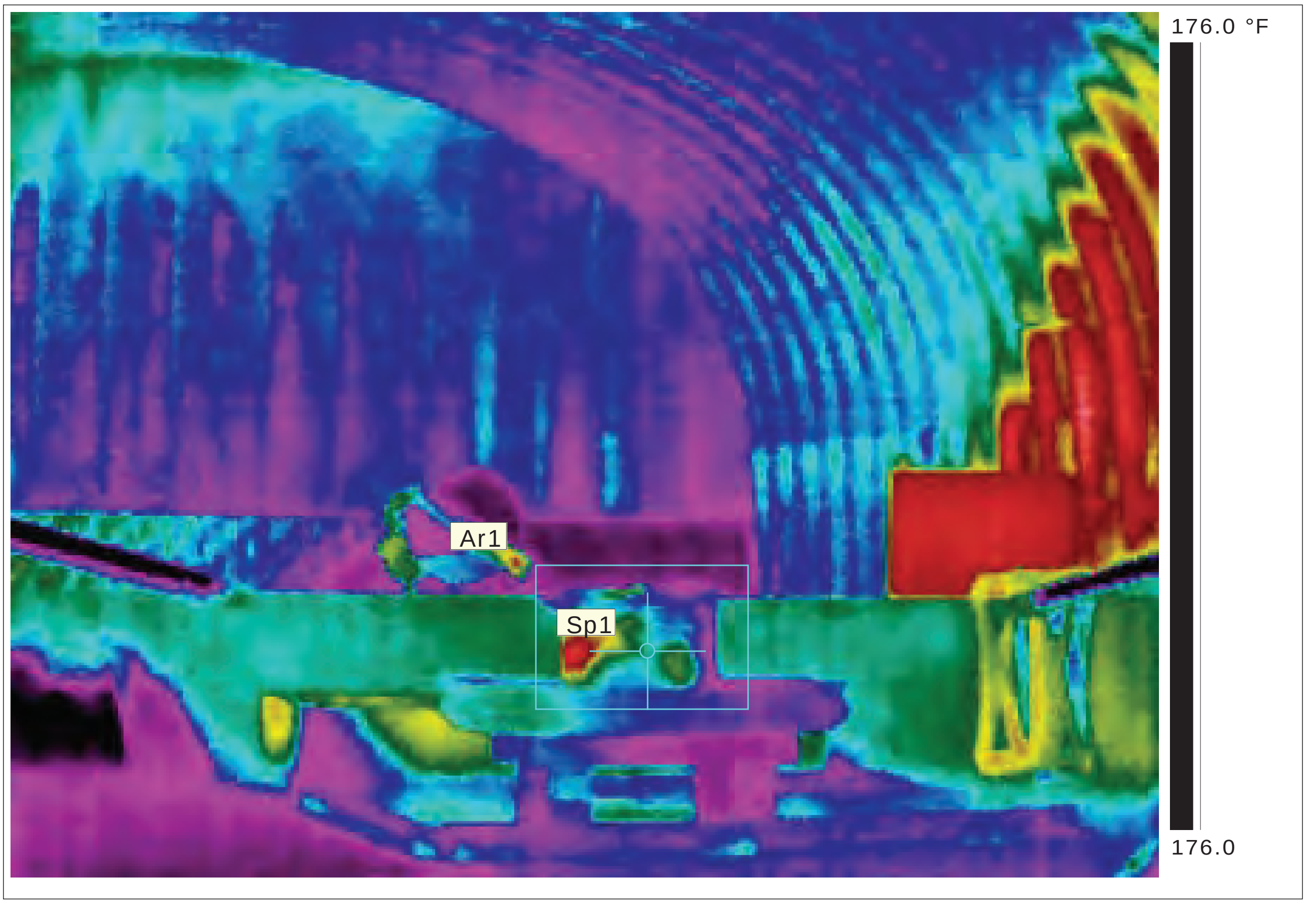
Burners turned off to check status of material

FIGURE 3 - APRIL 18, 2013

Attachment A – Excerpt of April 3, 2013 Thermal Images

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013

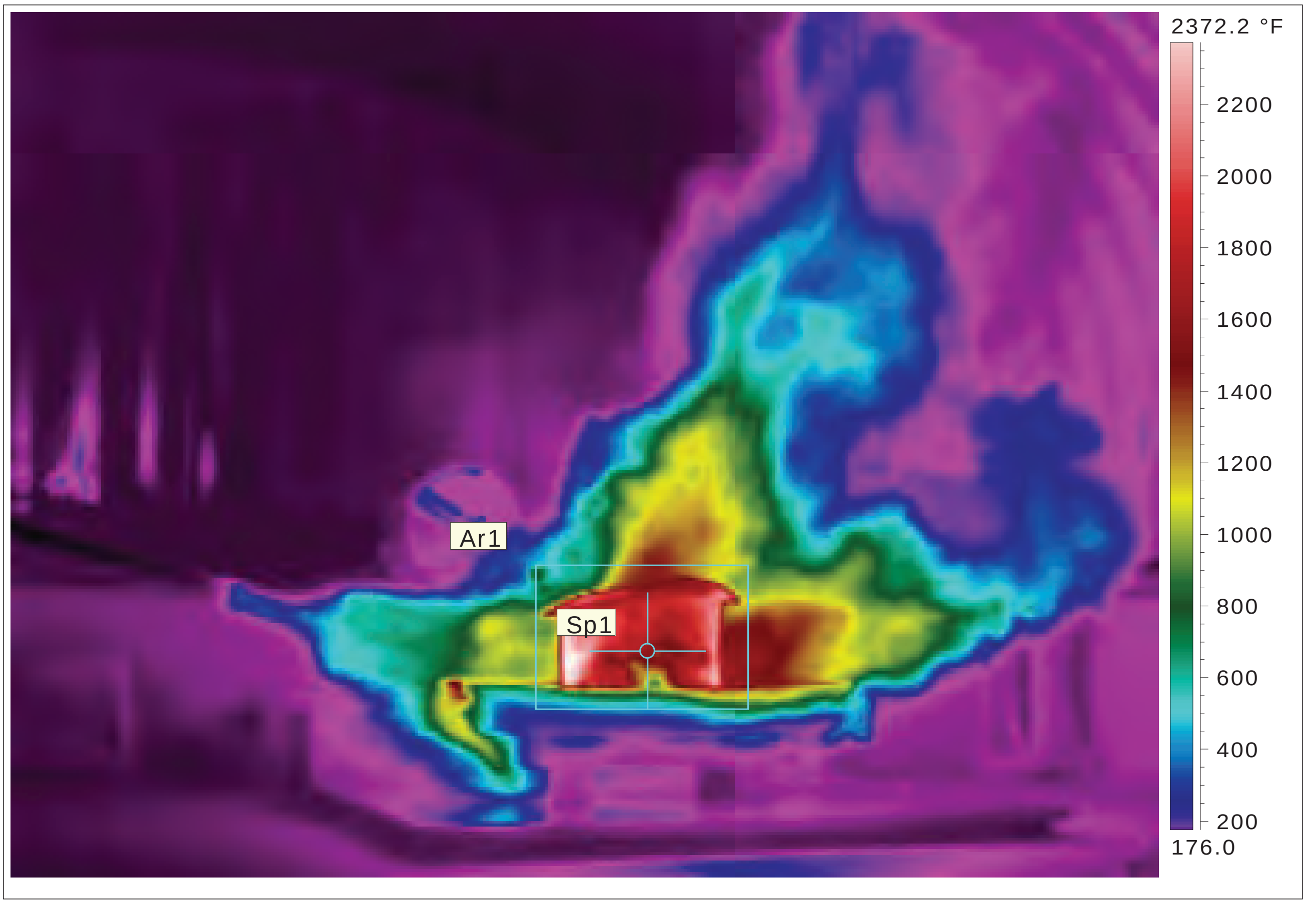


Ar1 Max. Temperature	<176.0 °F
Sp1 Temperature	<176.0 °F
Date	4/3/2013
Image Time	7:55:16 AM
Emissivity	0.69

Directly before burn start

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** June 5, 2013

Thermogram Image.Date 4/3/2013

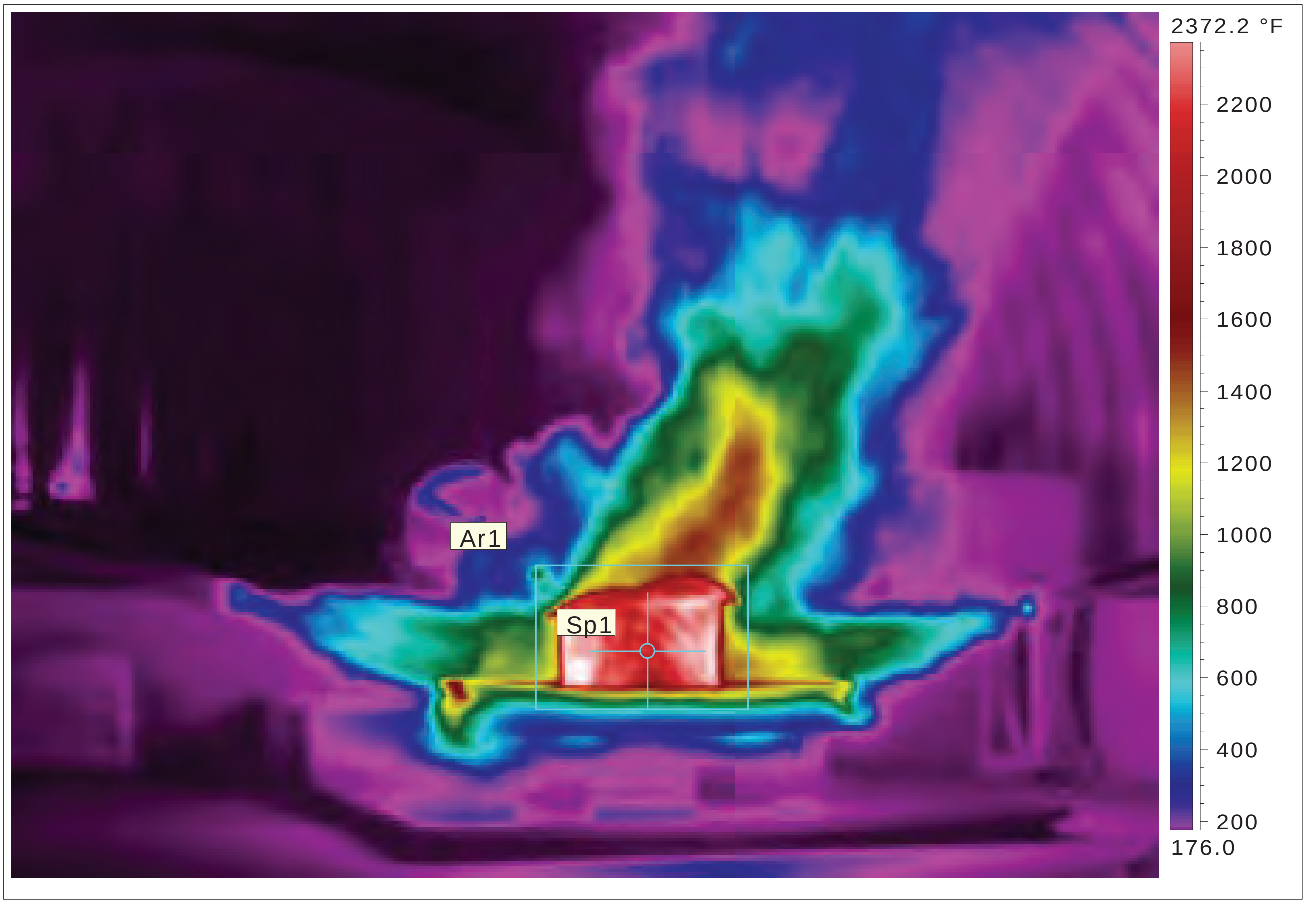


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1495.6 °F
Date	4/3/2013
Image Time	7:59:08 AM
Emissivity	0.69

Approximately 4 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013

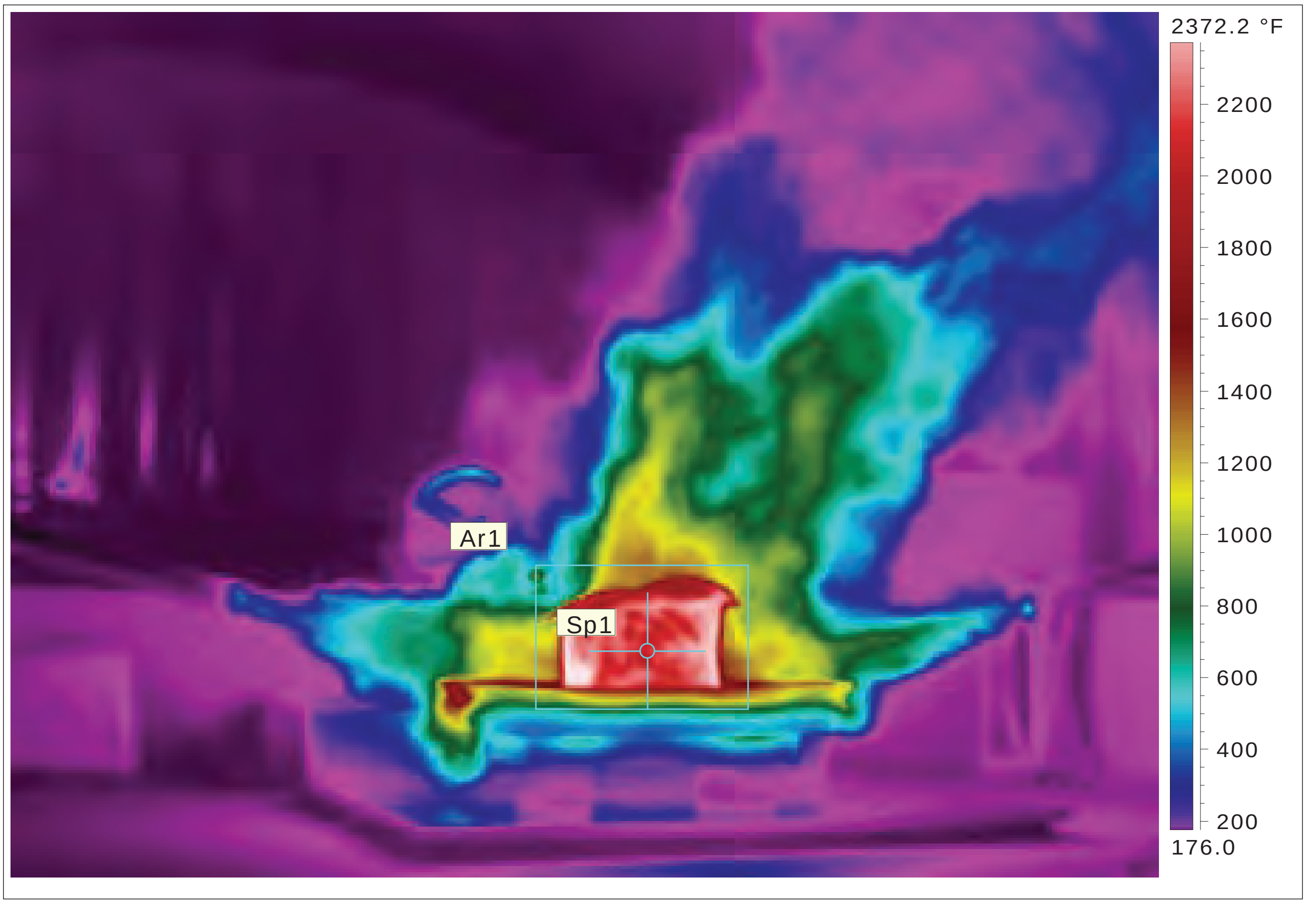


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	2131.8 °F
Date	4/3/2013
Image Time	8:02:09 AM
Emissivity	0.69

Approximately 7 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013

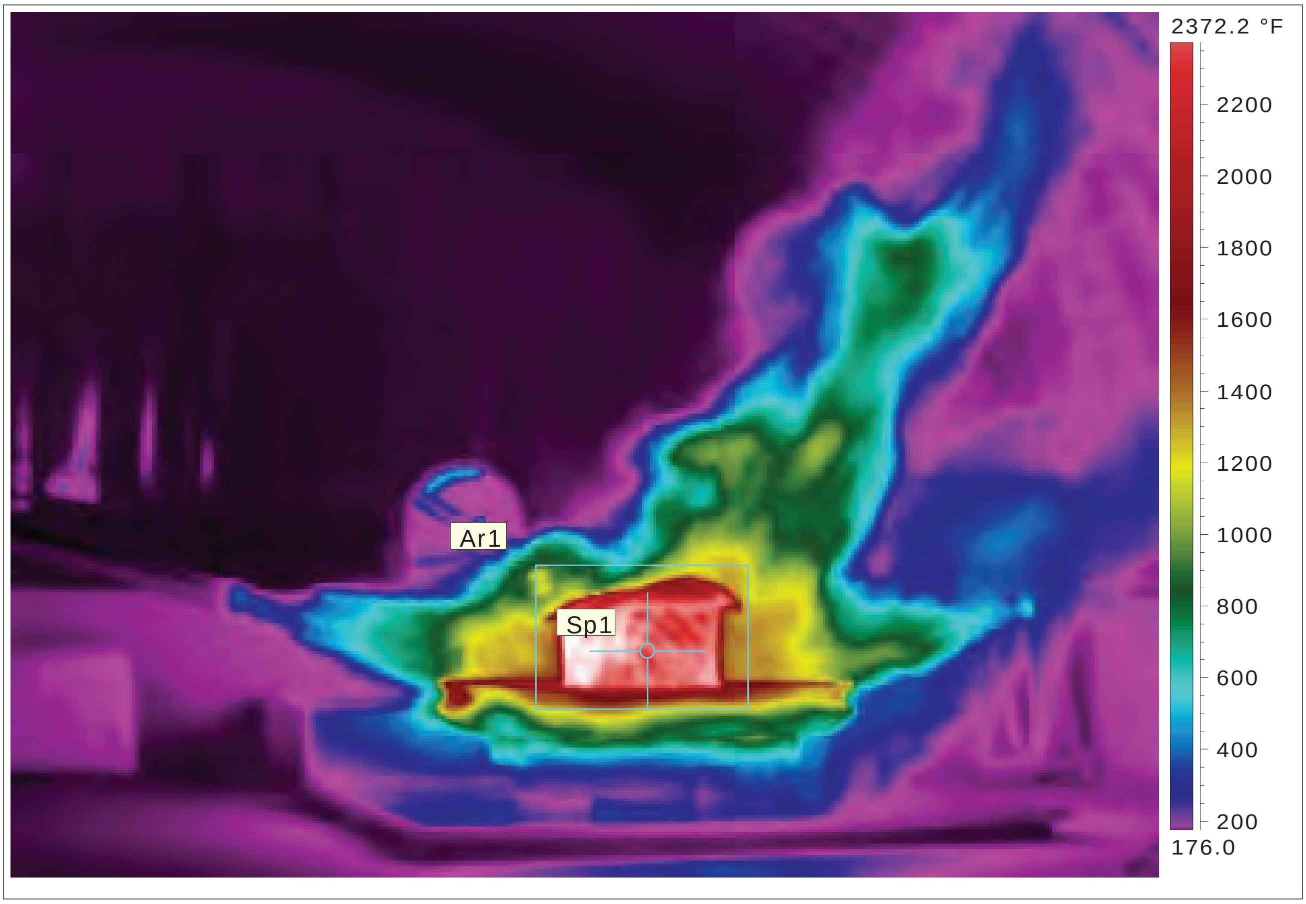


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	2082.6 °F
Date	4/3/2013
Image Time	8:05:00 AM
Emissivity	0.69

Approximately 10 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013

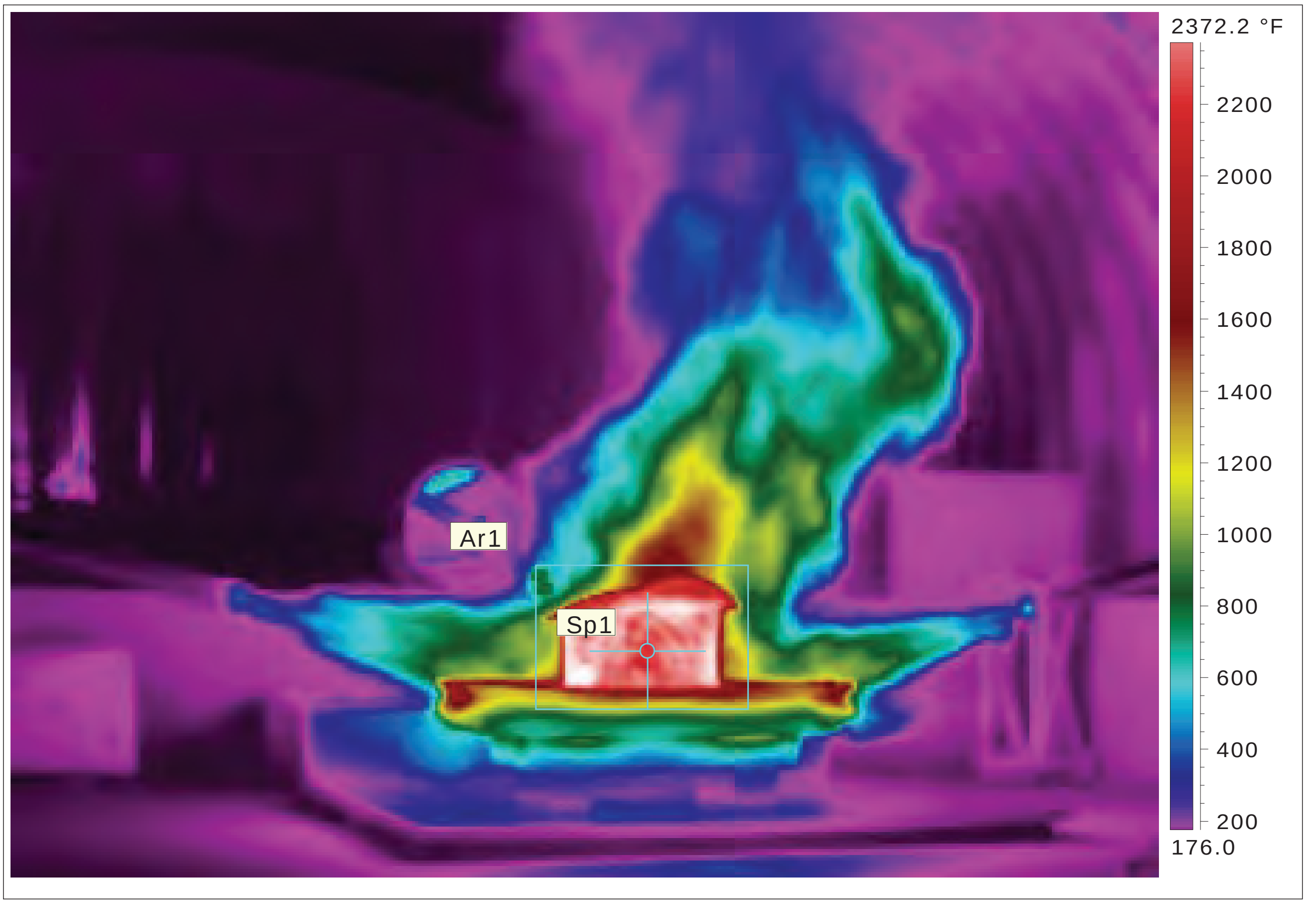


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	*2329.3 °F
Date	4/3/2013
Image Time	8:09:02 AM
Emissivity	0.69

Approximately 14 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

Thermogram Image.Date 4/3/2013

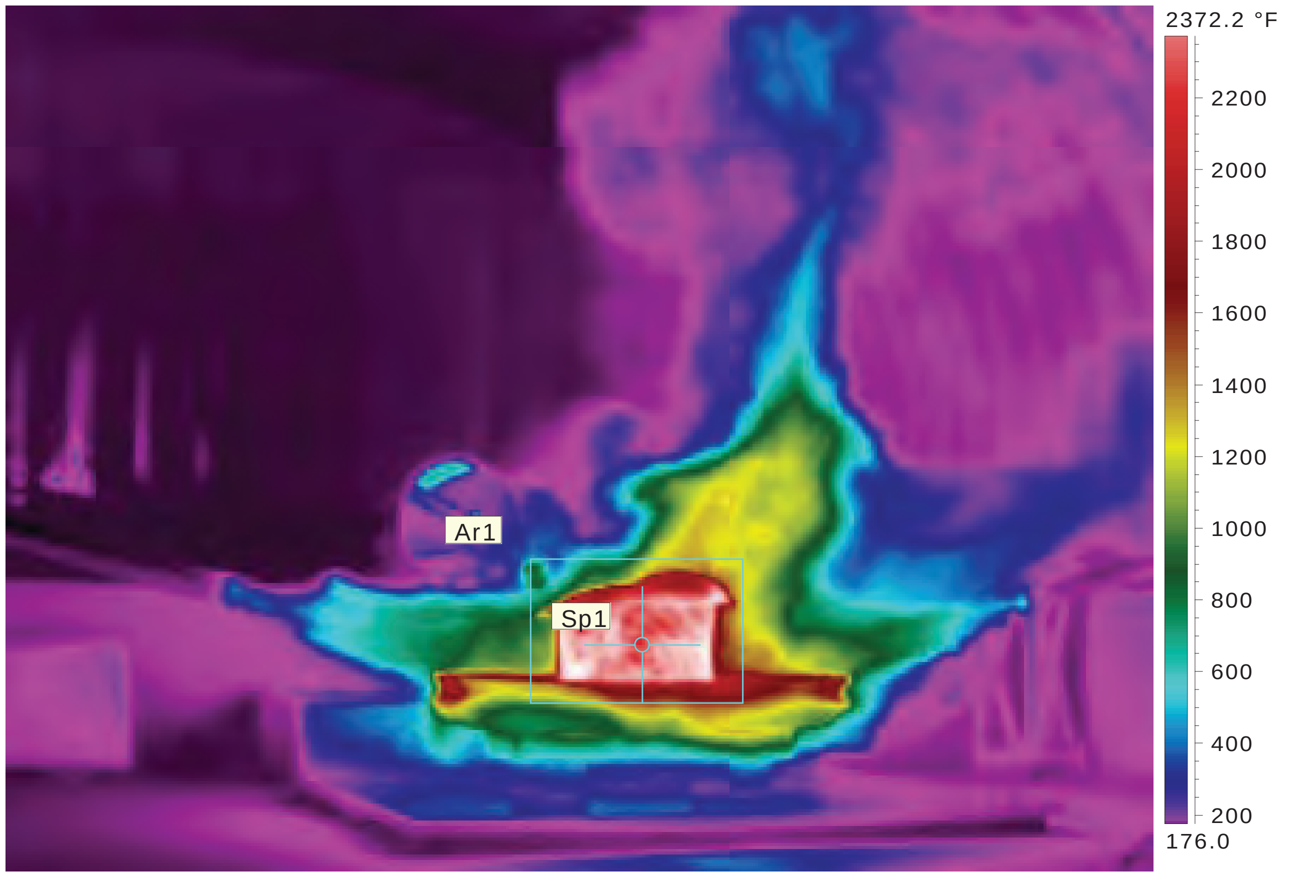


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	*2225.3 °F
Date	4/3/2013
Image Time	8:12:03 AM
Emissivity	0.69

Approximately 17 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

Thermogram Image.Date 4/3/2013

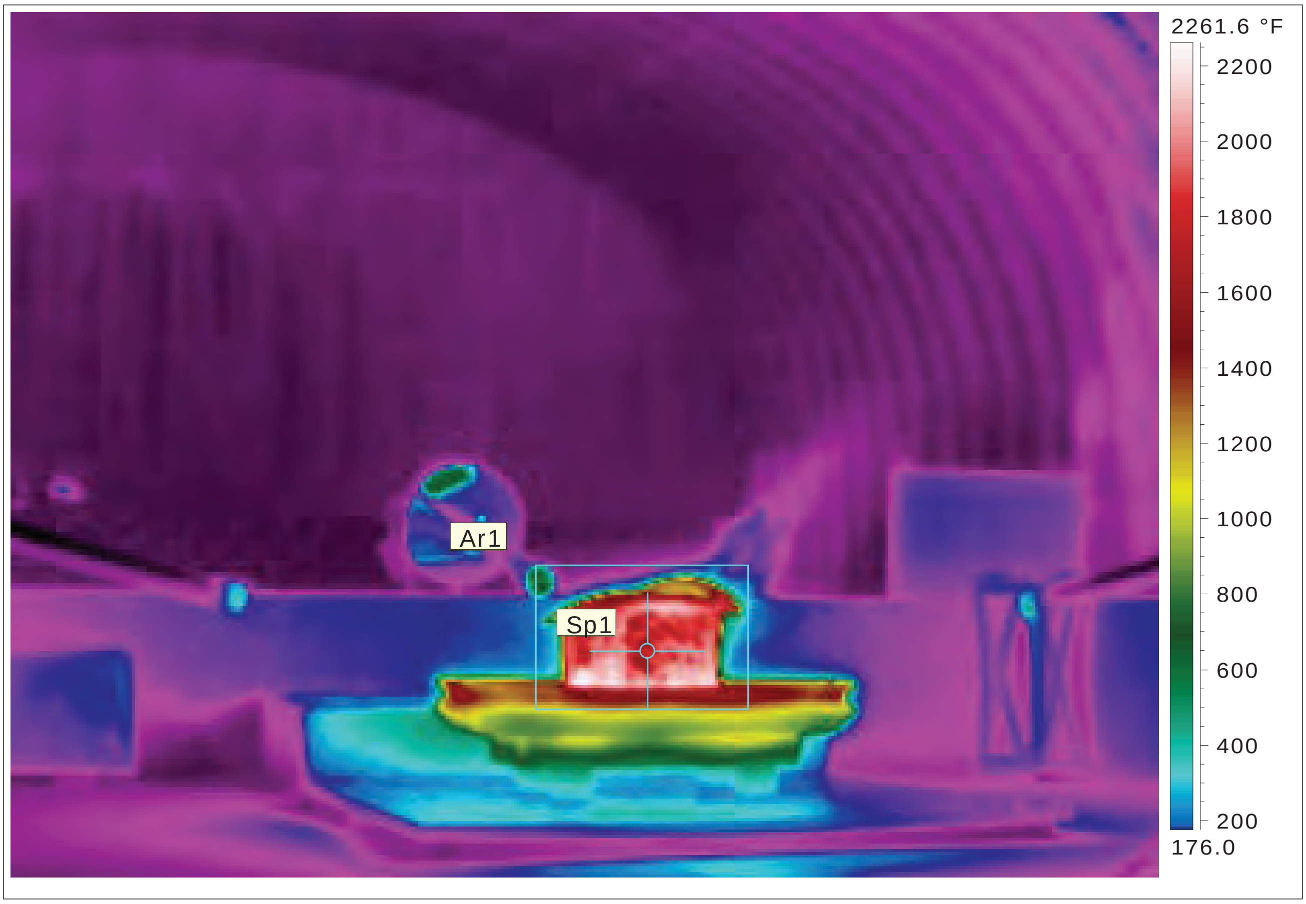


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	*2290.4 °F
Date	4/3/2013
Image Time	8:15:00 AM
Emissivity	0.69

Approximately 20 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013



Ar1 Max. Temperature	*2241.4 °F
Sp1 Temperature	1823.8 °F
Date	4/3/2013
Image Time	8:18:37 AM
Emissivity	0.69

Approximately 24 minutes after burn start time

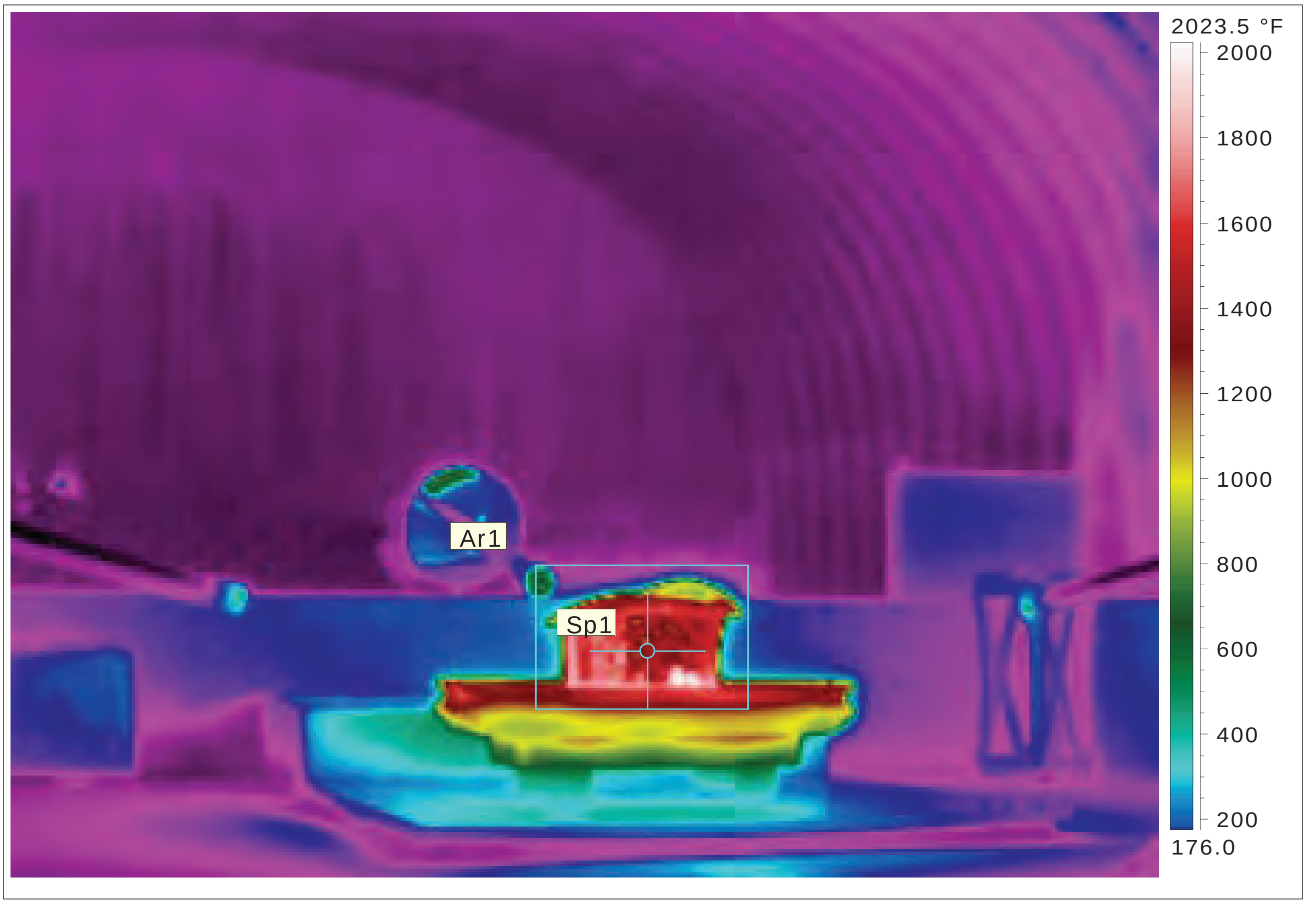
Thermography Inspection
at

TA-16 388 Open Burn Site

Report Date:

June 5, 2013

Thermogram Image.Date 4/3/2013

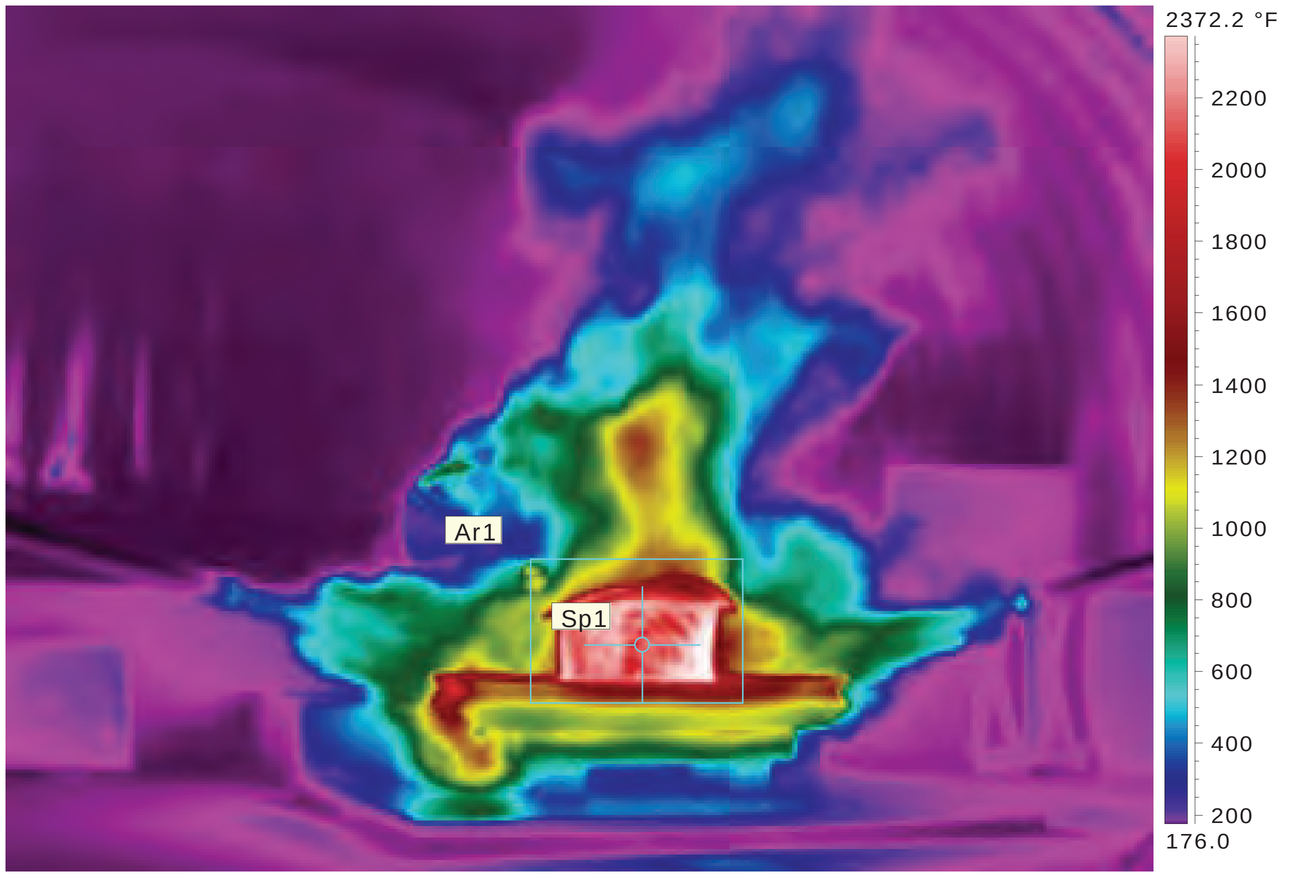


Ar1 Max. Temperature	2013.7 °F
Sp1 Temperature	1445.1 °F
Date	4/3/2013
Image Time	8:23:49 AM
Emissivity	0.69

Approximately 29 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	**Thermography Inspection** **at** **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

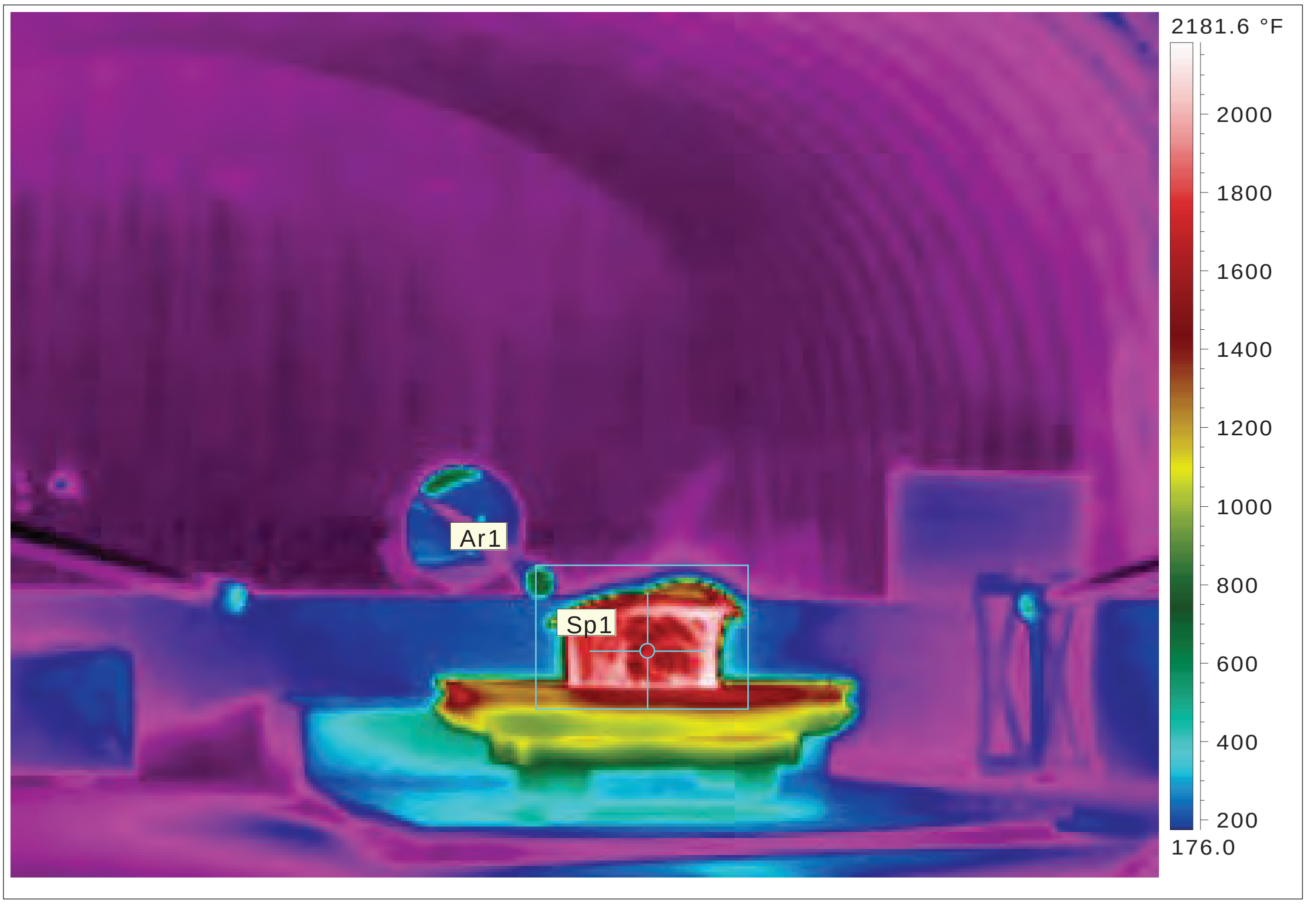
Thermogram Image.Date 4/3/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	2115.1 °F
Date	4/3/2013
Image Time	8:25:00 AM
Emissivity	0.69

Approximately 30 minutes after burn start time

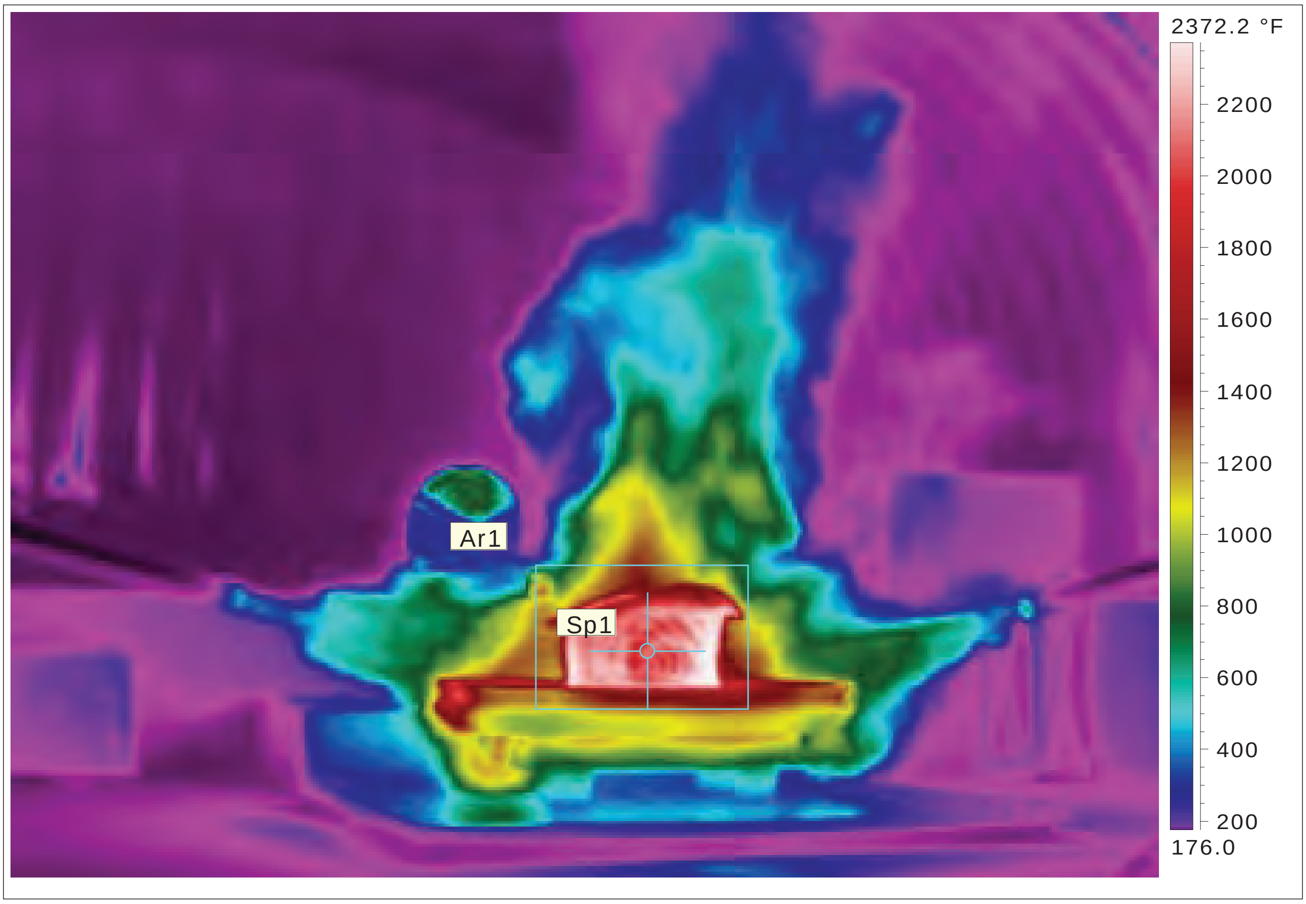
Thermogram Image.Date 4/3/2013



Ar1 Max. Temperature	2177.0 °F
Sp1 Temperature	1720.0 °F
Date	4/3/2013
Image Time	8:29:02 AM
Emissivity	0.69

Approximately 34 minutes after burn start time

Thermogram Image.Date 4/3/2013

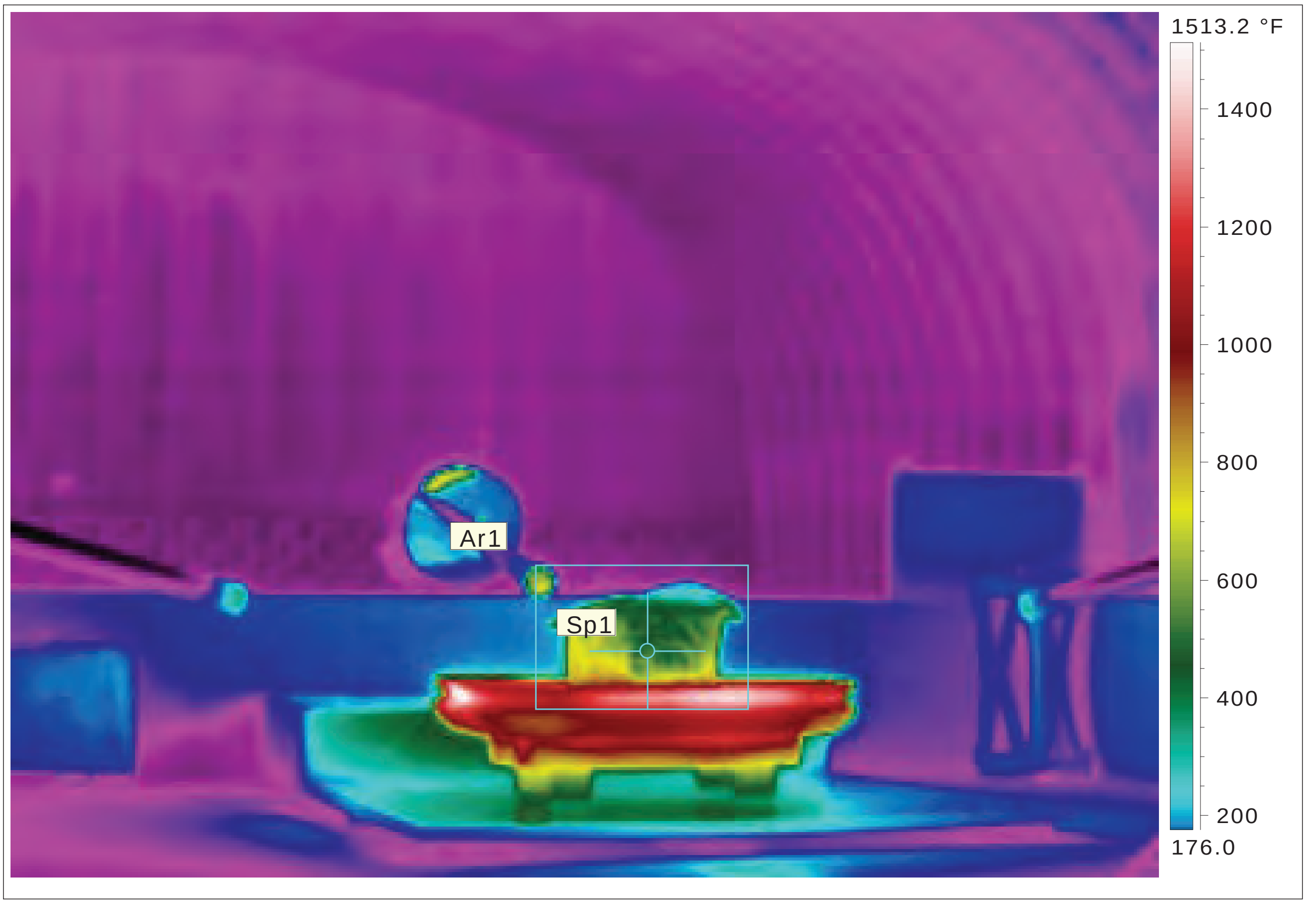


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	2110.3 °F
Date	4/3/2013
Image Time	8:32:13 AM
Emissivity	0.69

Approximately 37 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: **June 5, 2013**

Thermogram Image.Date 4/3/2013

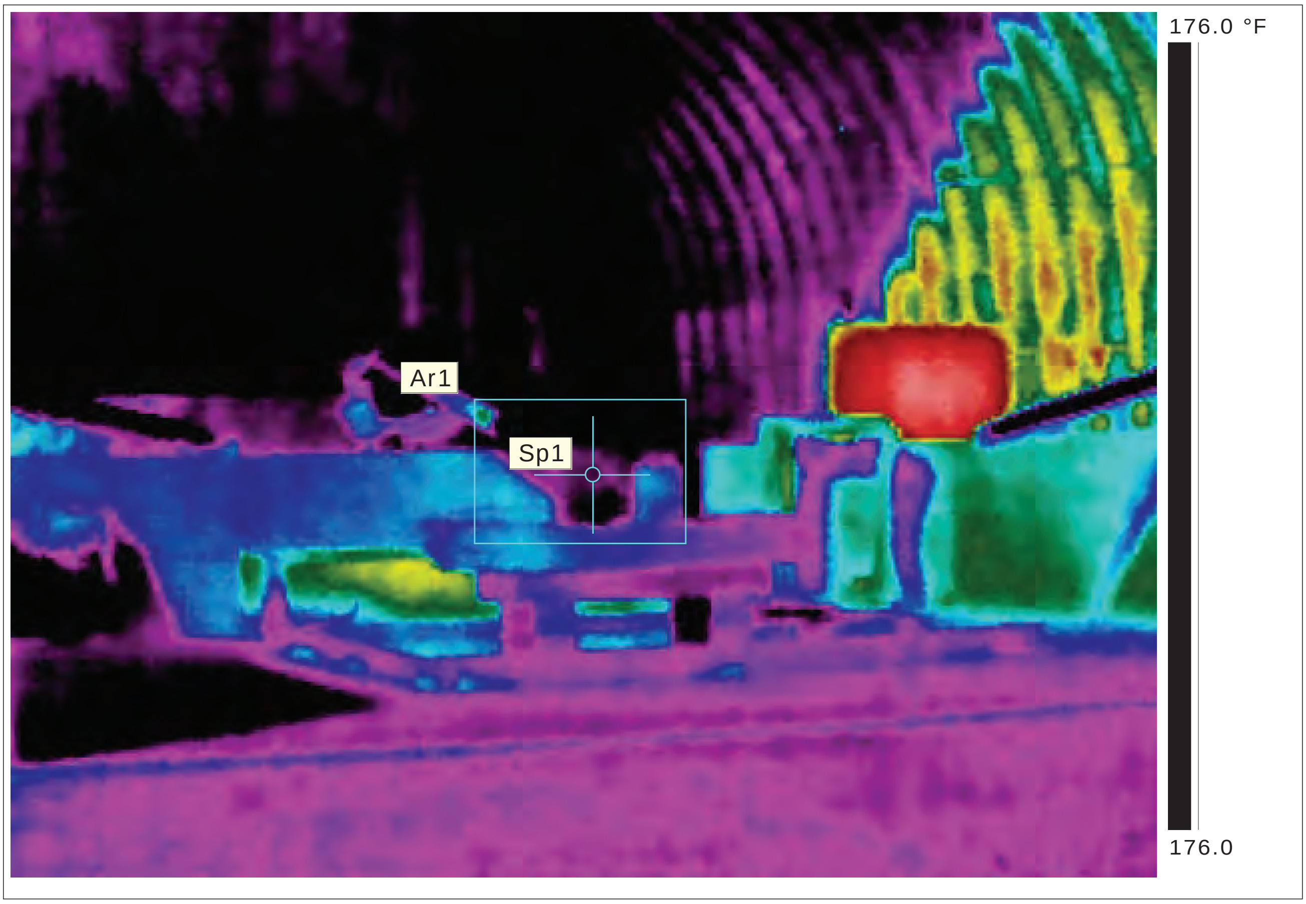


Ar1 Max. Temperature	1439.3 °F
Sp1 Temperature	530.5 °F
Date	4/3/2013
Image Time	8:35:10 AM
Emissivity	0.69

Approximately 40 minutes after burn start time

Attachment B – Excerpt of April 18, 2013 Thermal Images

Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	<176.0 °F
Sp1 Temperature	<176.0 °F
Date	4/18/2013
Image Time	7:38:50 AM
Emissivity	0.69

Directly before burn start

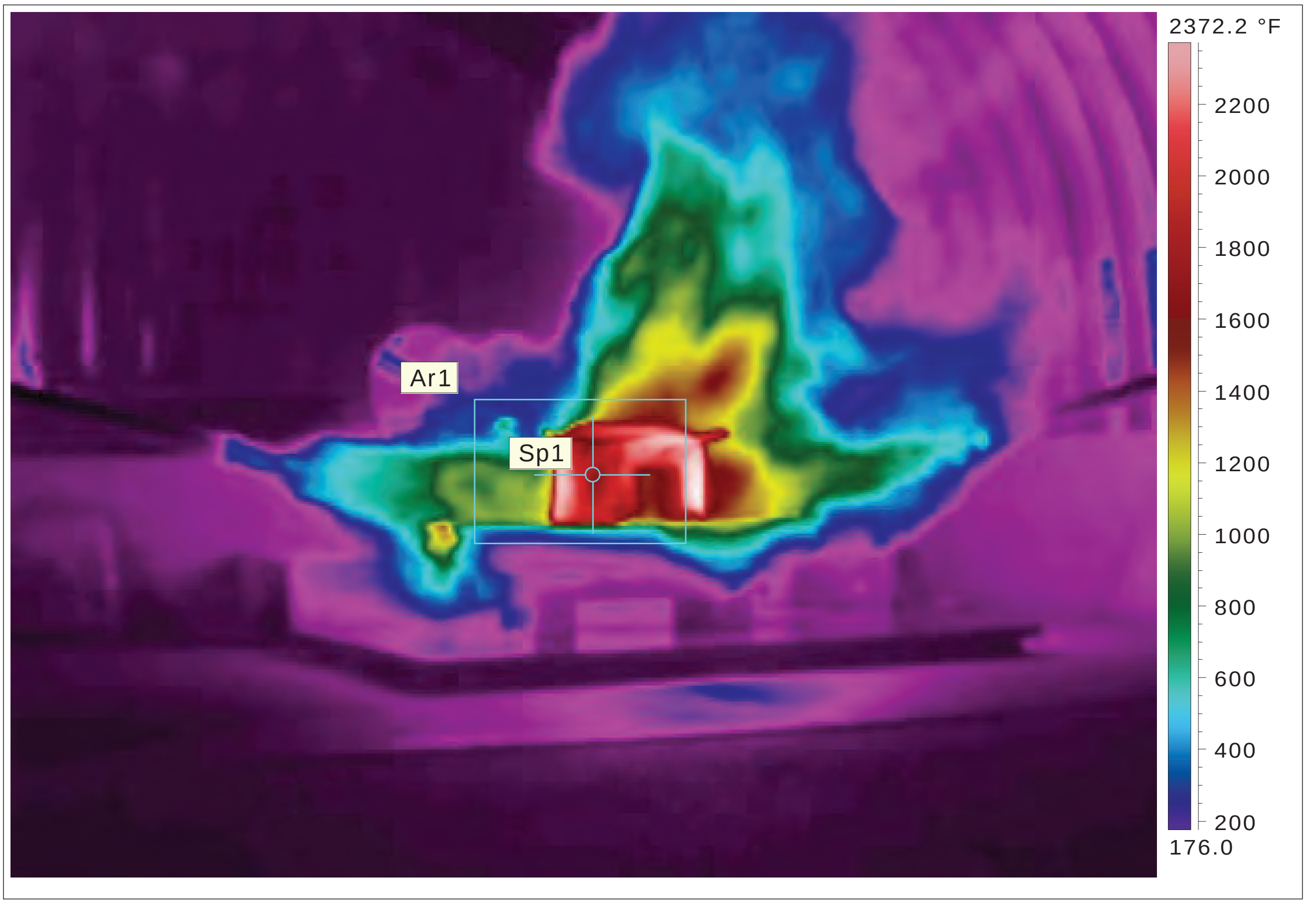
Thermography Inspection
at

TA-16 388 Open Burn Site

Report Date:

June 5, 2013

Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1721.2 °F
Date	4/18/2013
Image Time	7:42:02 AM
Emissivity	0.69

Approximately 3 minutes after burn start time

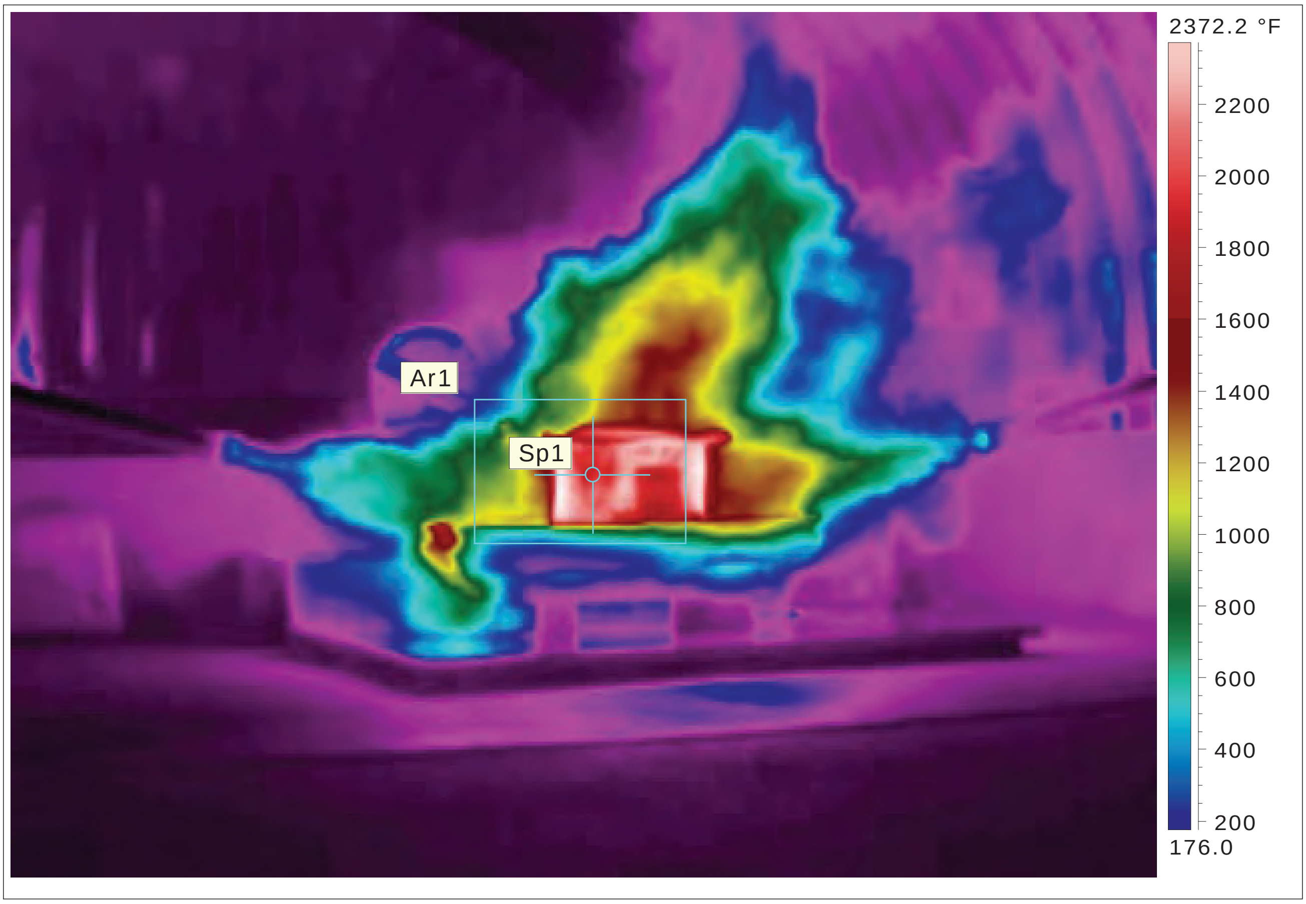
Thermography Inspection
at

TA-16 388 Open Burn Site

Report Date:

June 5, 2013

Thermogram Image.Date 4/18/2013

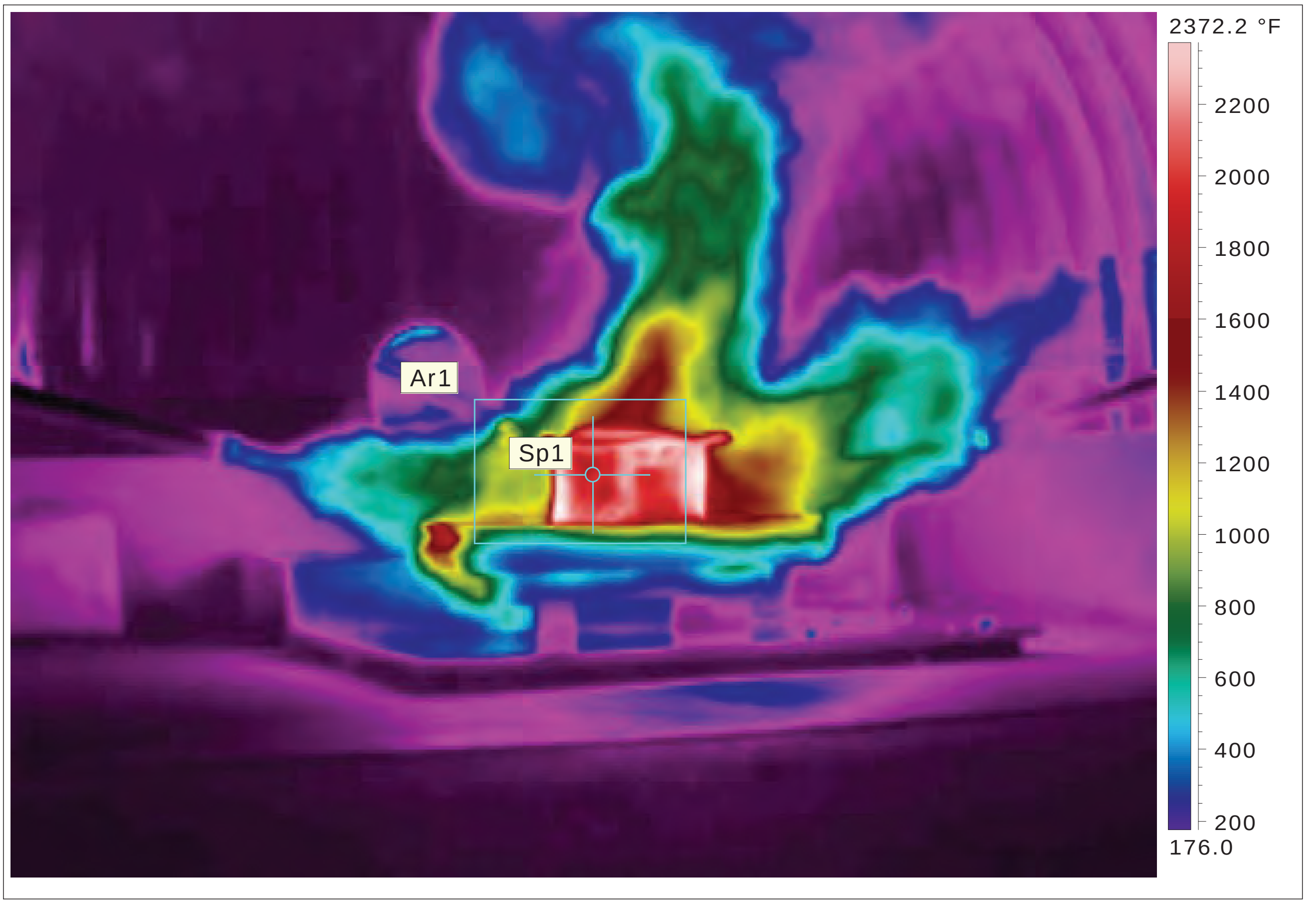


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1951.0 °F
Date	4/18/2013
Image Time	7:45:04 AM
Emissivity	0.69

Approximately 6 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST.1943	Thermography Inspection at **TA-16 388 Open Burn Site**	Report Date: June 5, 2013

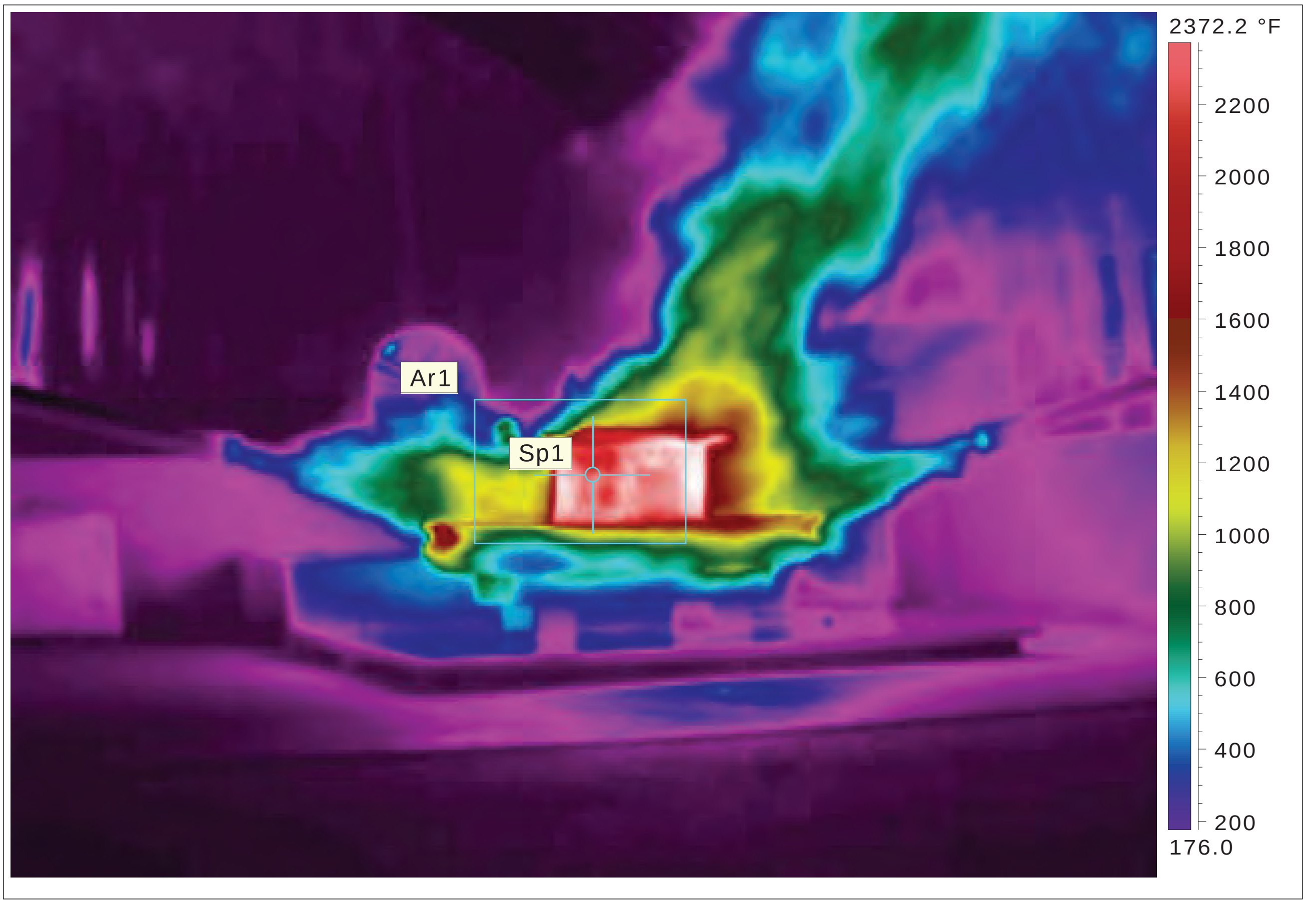
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1953.0 °F
Date	4/18/2013
Image Time	7:49:06 AM
Emissivity	0.69

Approximately 10 minutes after burn start time

Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	*2319.1 °F
Date	4/18/2013
Image Time	7:52:07 AM
Emissivity	0.69

Approximately 13 minutes after burn start time

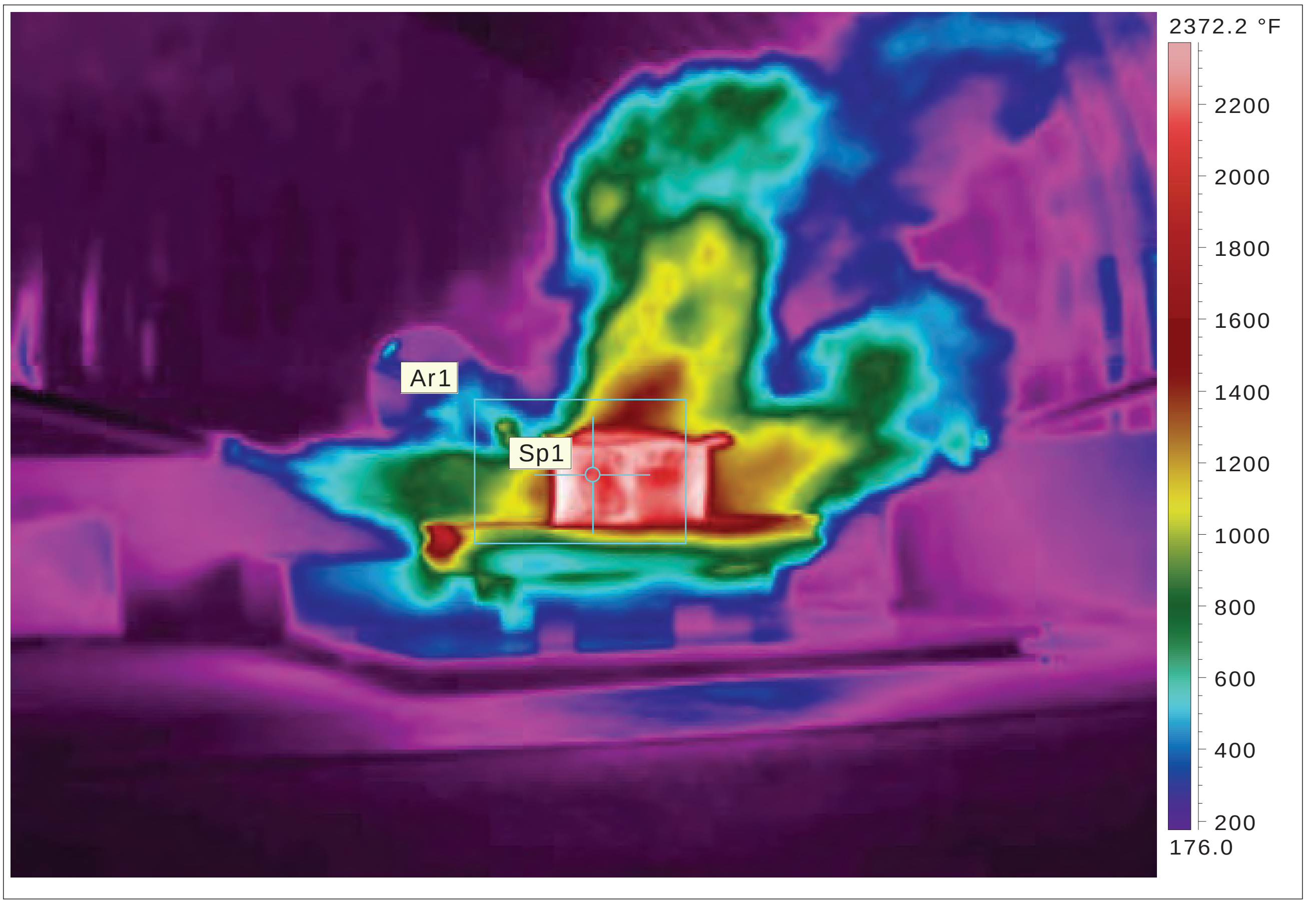
Thermography Inspection
at

TA-16 388 Open Burn Site

Report Date:

June 5, 2013

Thermogram Image.Date 4/18/2013

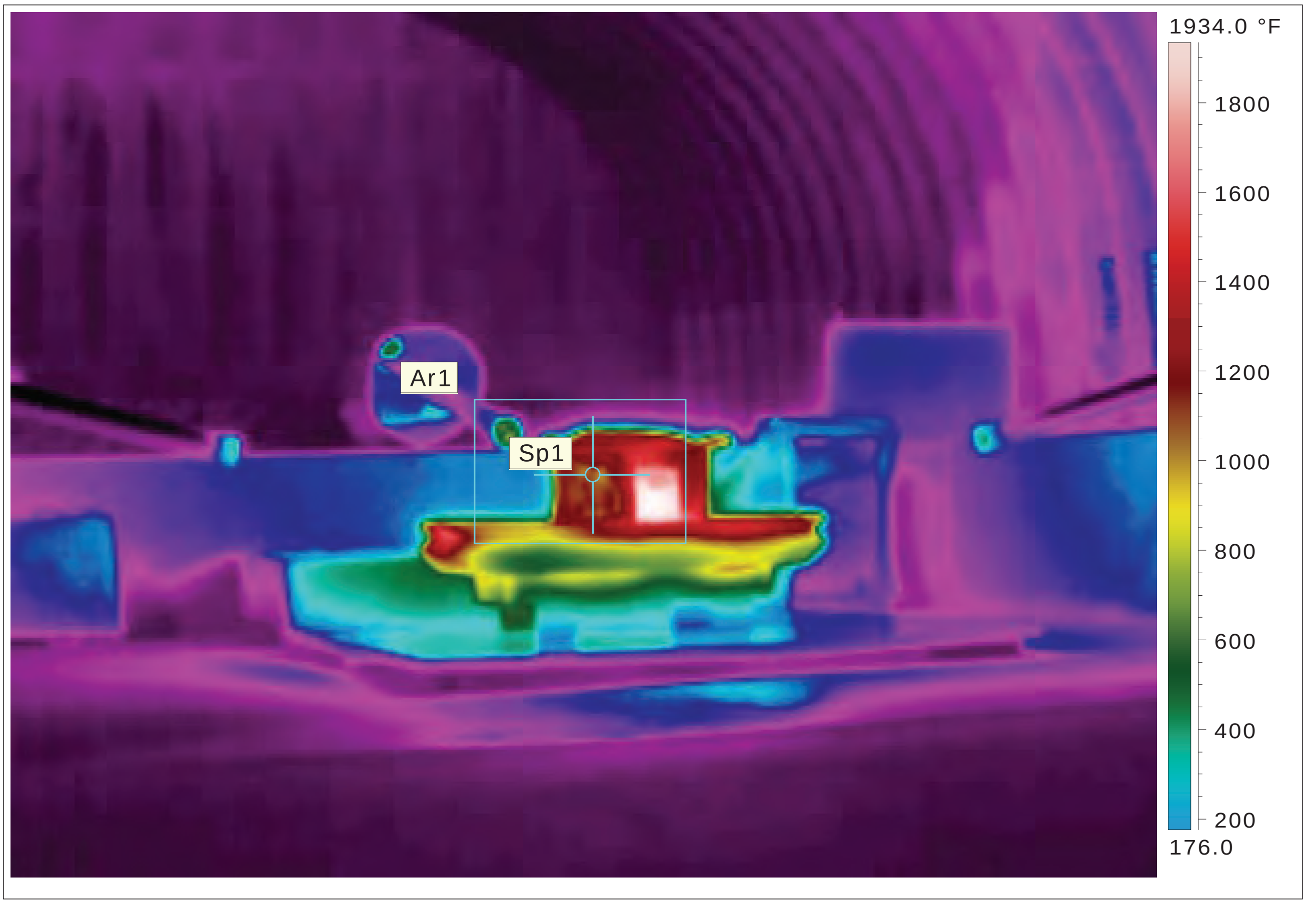


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	2166.0 °F
Date	4/18/2013
Image Time	7:56:09 AM
Emissivity	0.69

Approximately 17 minutes after burn start time

	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** June 5, 2013

Thermogram Image.Date 4/18/2013

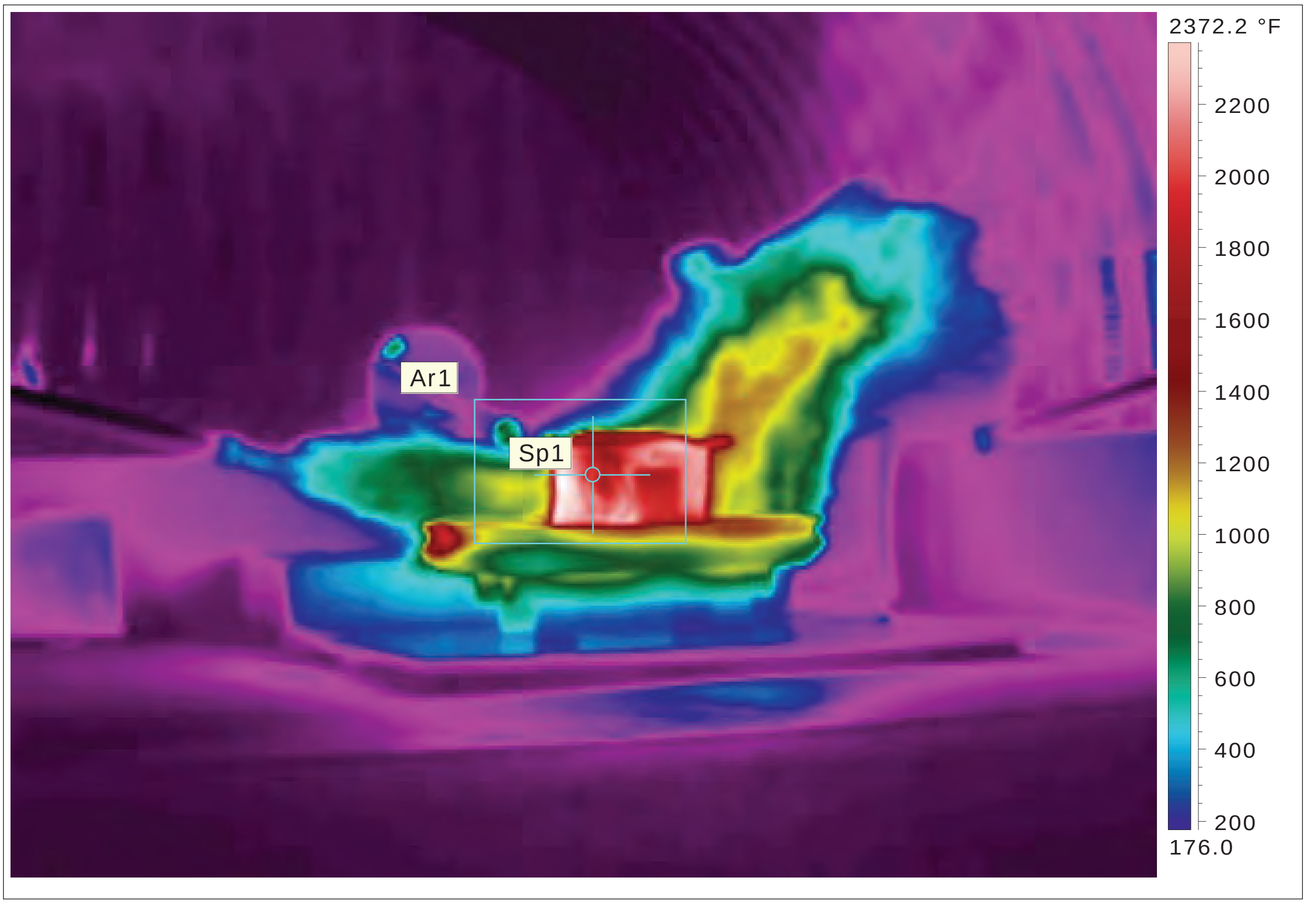


Ar1 Max. Temperature	1930.6 °F
Sp1 Temperature	1056.3 °F
Date	4/18/2013
Image Time	7:59:00 AM
Emissivity	0.69

Approximately 20 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

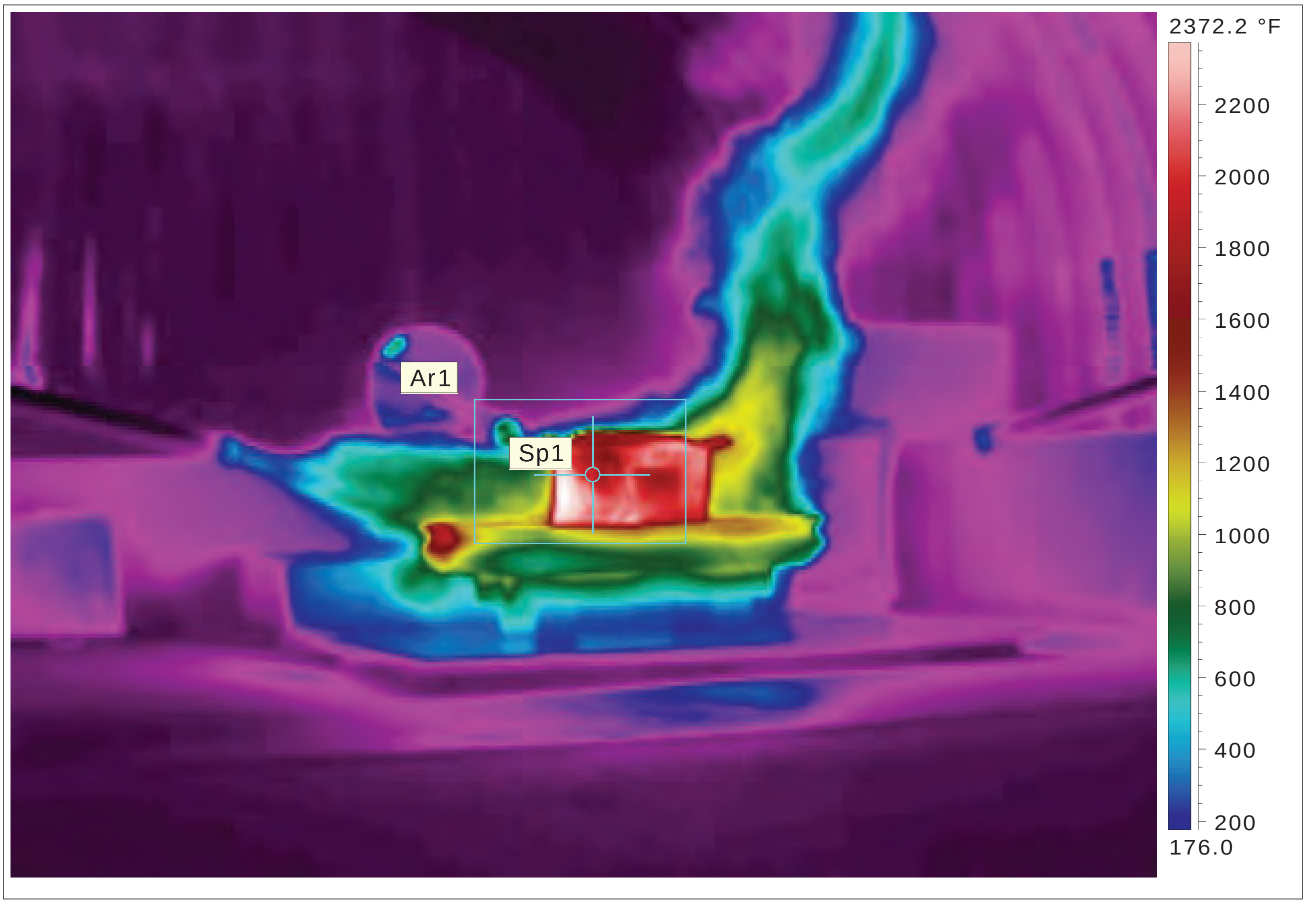
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1939.9 °F
Date	4/18/2013
Image Time	8:01:52 AM
Emissivity	0.69

Approximately 23 minutes after burn start time

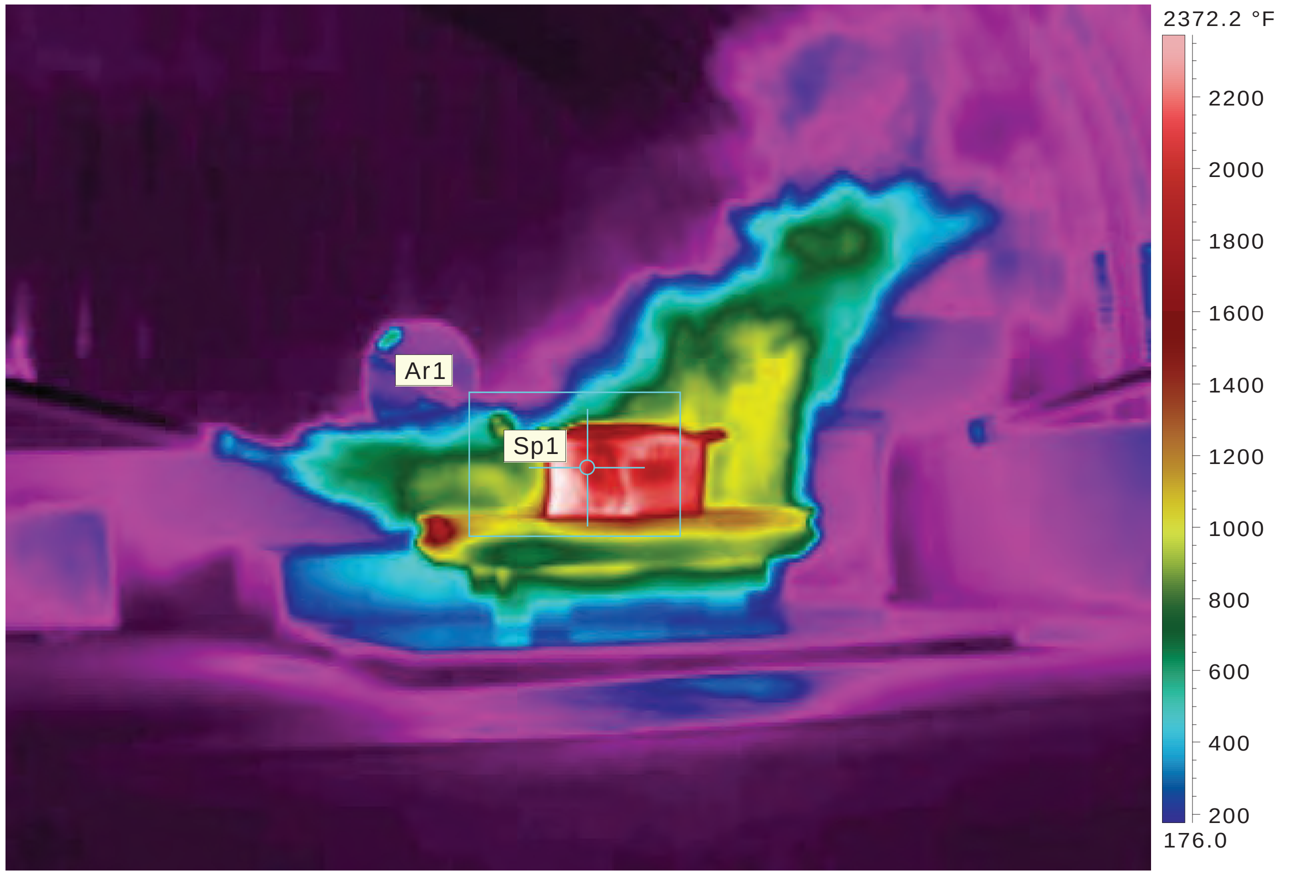
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1914.3 °F
Date	4/18/2013
Image Time	8:03:02 AM
Emissivity	0.69

Approximately 24 minutes after burn start time

Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1967.0 °F
Date	4/18/2013
Image Time	8:07:09 AM
Emissivity	0.69

Approximately 28 minutes after burn start time

Los Alamos
NATIONAL LABORATORY
EST. 1943

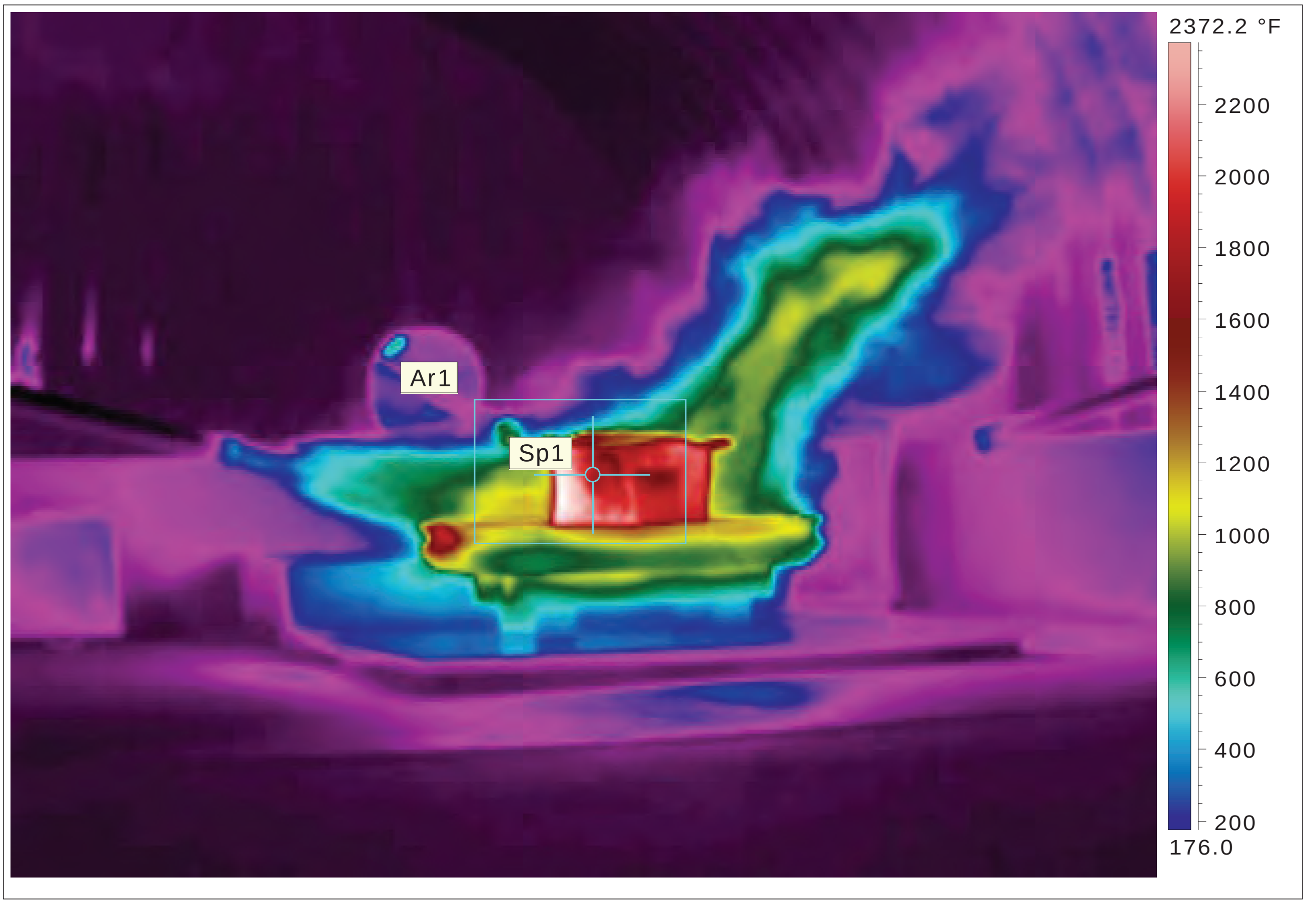
Thermography Inspection
at

TA-16 388 Open Burn Site

Report Date:

June 5, 2013

Thermogram Image.Date 4/18/2013

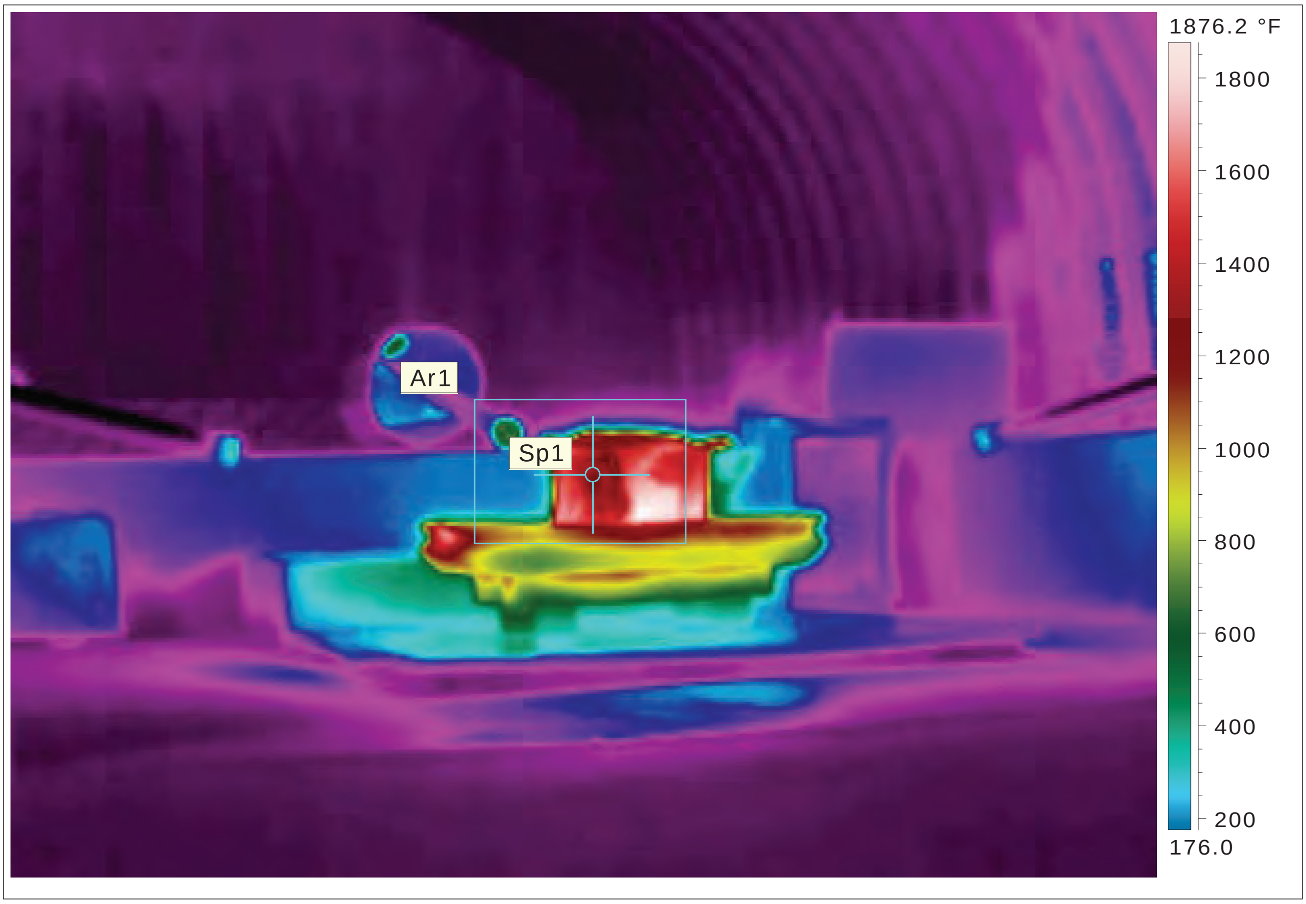


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1756.0 °F
Date	4/18/2013
Image Time	8:10:01 AM
Emissivity	0.69

Approximately 31 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

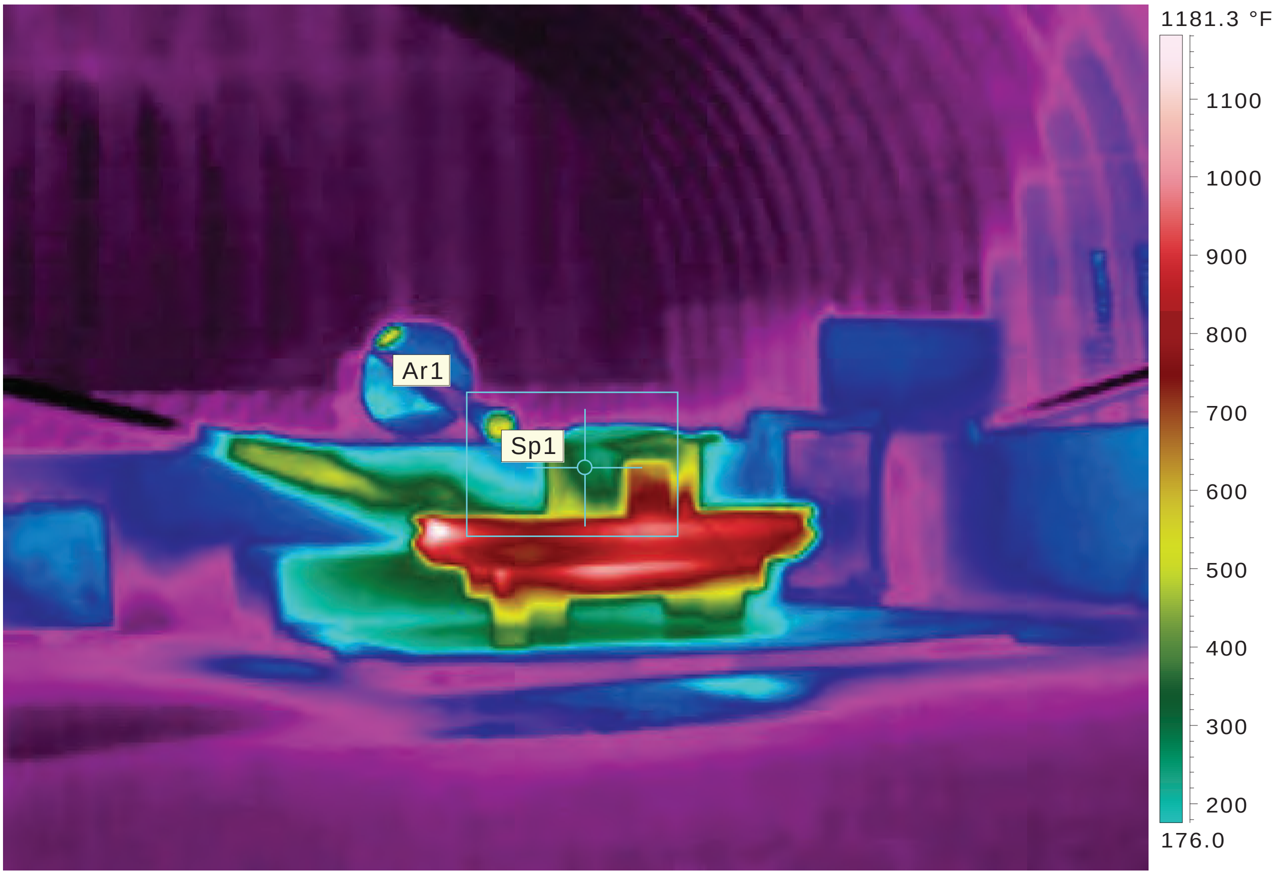
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	1870.1 °F
Sp1 Temperature	1194.2 °F
Date	4/18/2013
Image Time	8:11:41 AM
Emissivity	0.69

Approximately 33 minutes after burn start time

Thermogram Image.Date 4/18/2013

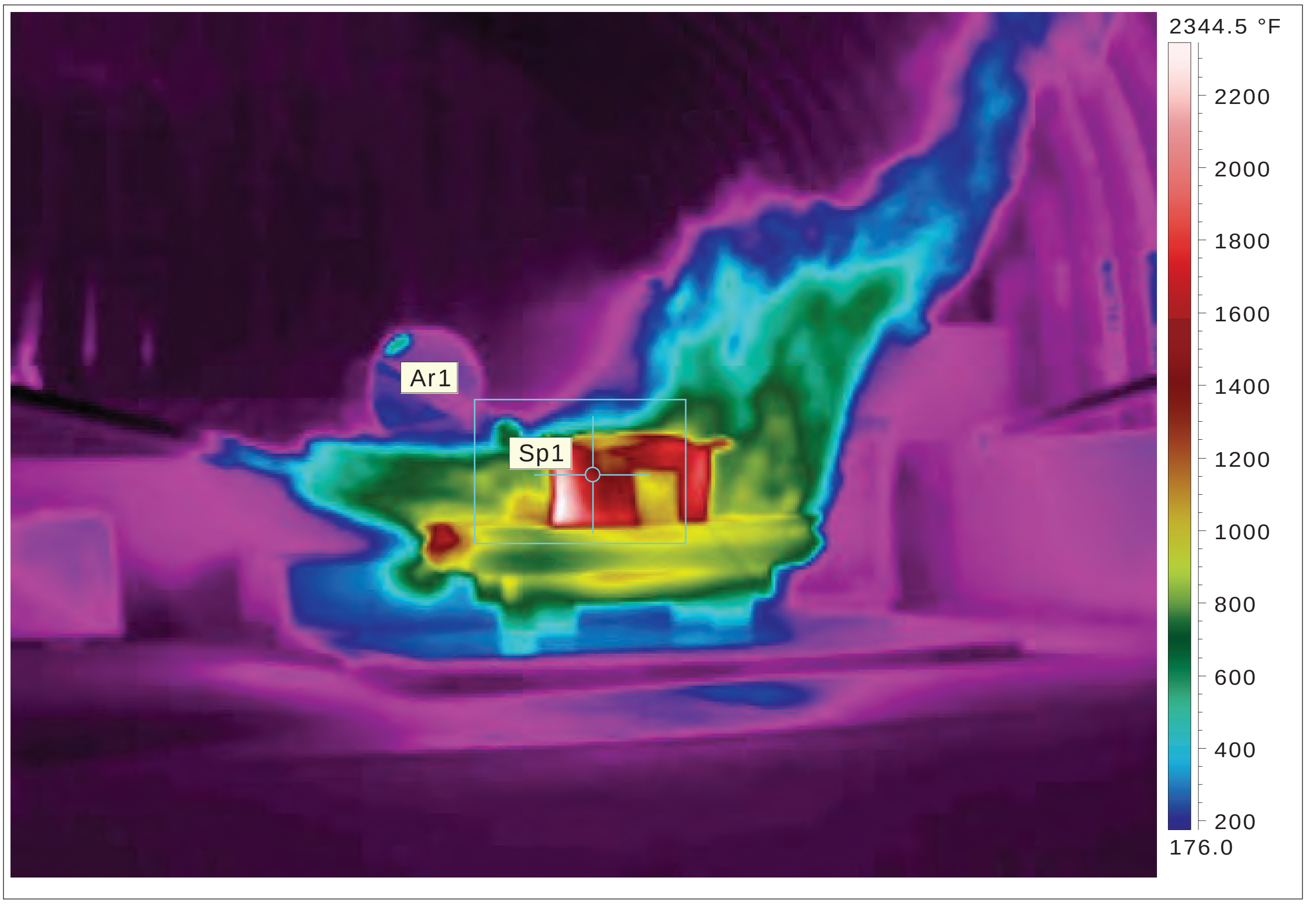


Ar1 Max. Temperature	968.4 °F
Sp1 Temperature	*293.3 °F
Date	4/18/2013
Image Time	8:17:49 AM
Emissivity	0.69

Approximately 39 minutes after burn start time

Los Alamos NATIONAL LABORATORY EST. 1943	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** June 5, 2013

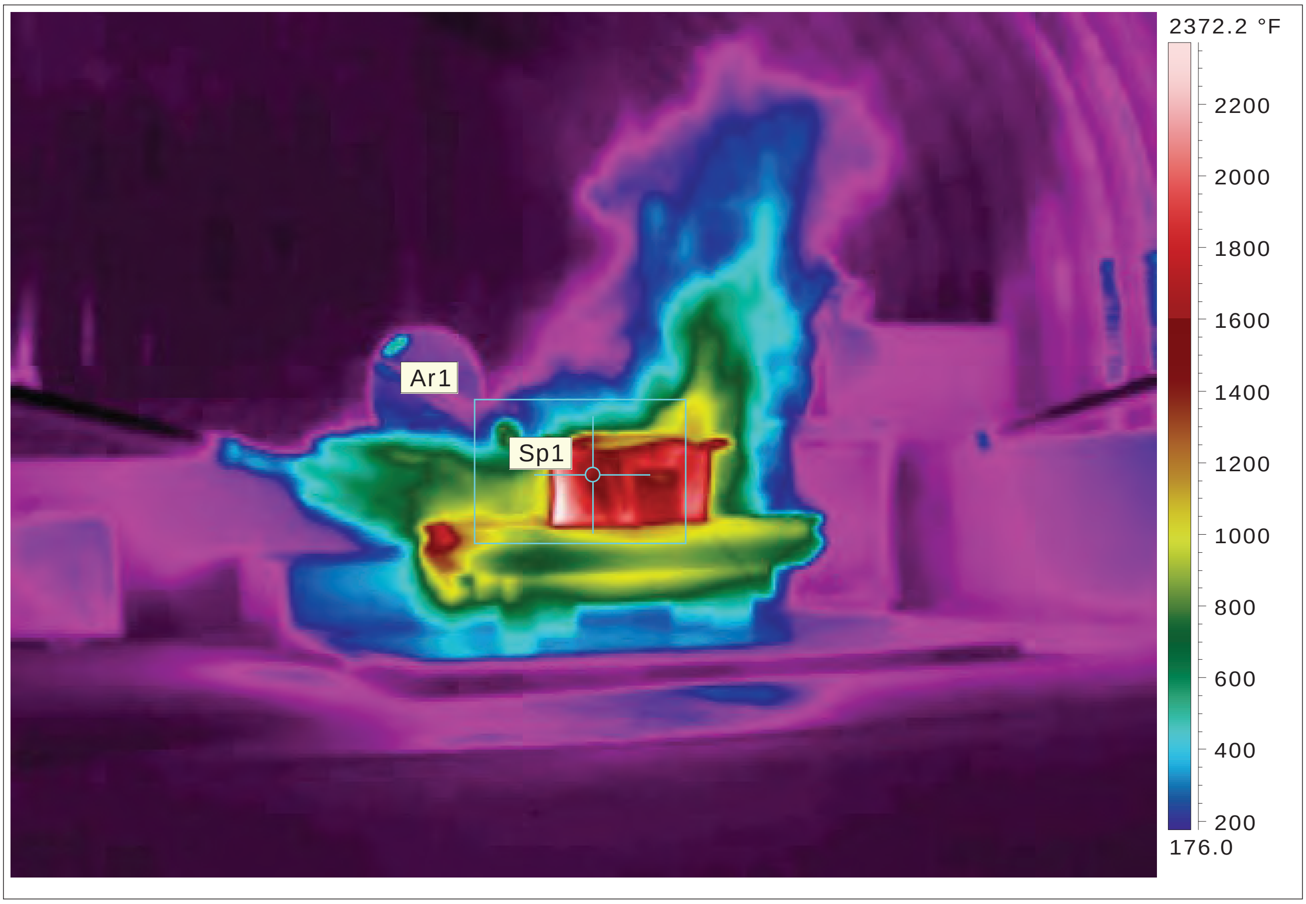
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	*2368.1 °F
Sp1 Temperature	1527.4 °F
Date	4/18/2013
Image Time	8:18:06 AM
Emissivity	0.69

Approximately 39 minutes after burn start time

Thermogram Image.Date 4/18/2013

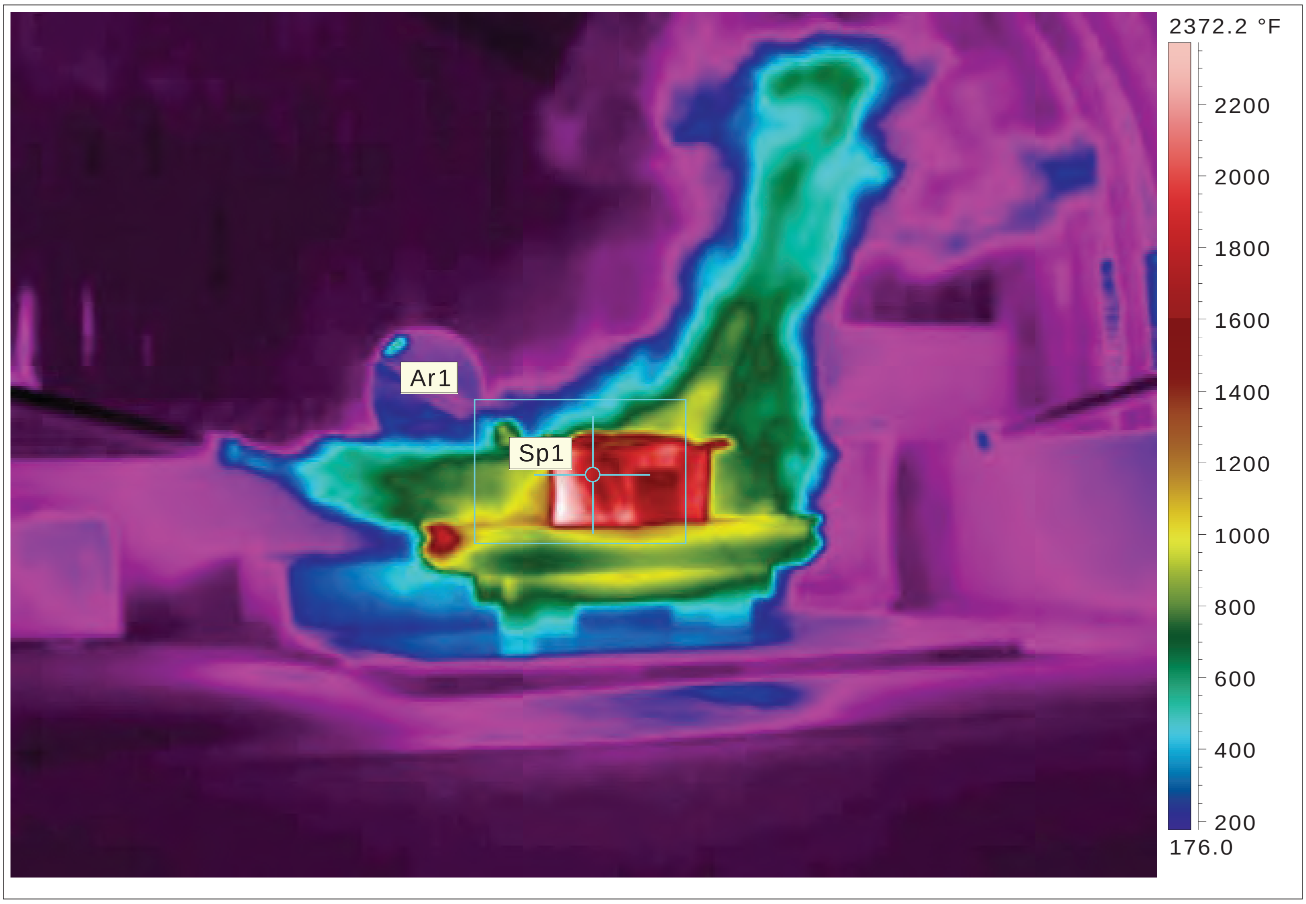


Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1470.5 °F
Date	4/18/2013
Image Time	8:21:07 AM
Emissivity	0.69

Approximately 42 minutes after burn start time

	Thermography Inspection at **TA-16 388 Open Burn Site**	**Report Date:** **June 5, 2013**

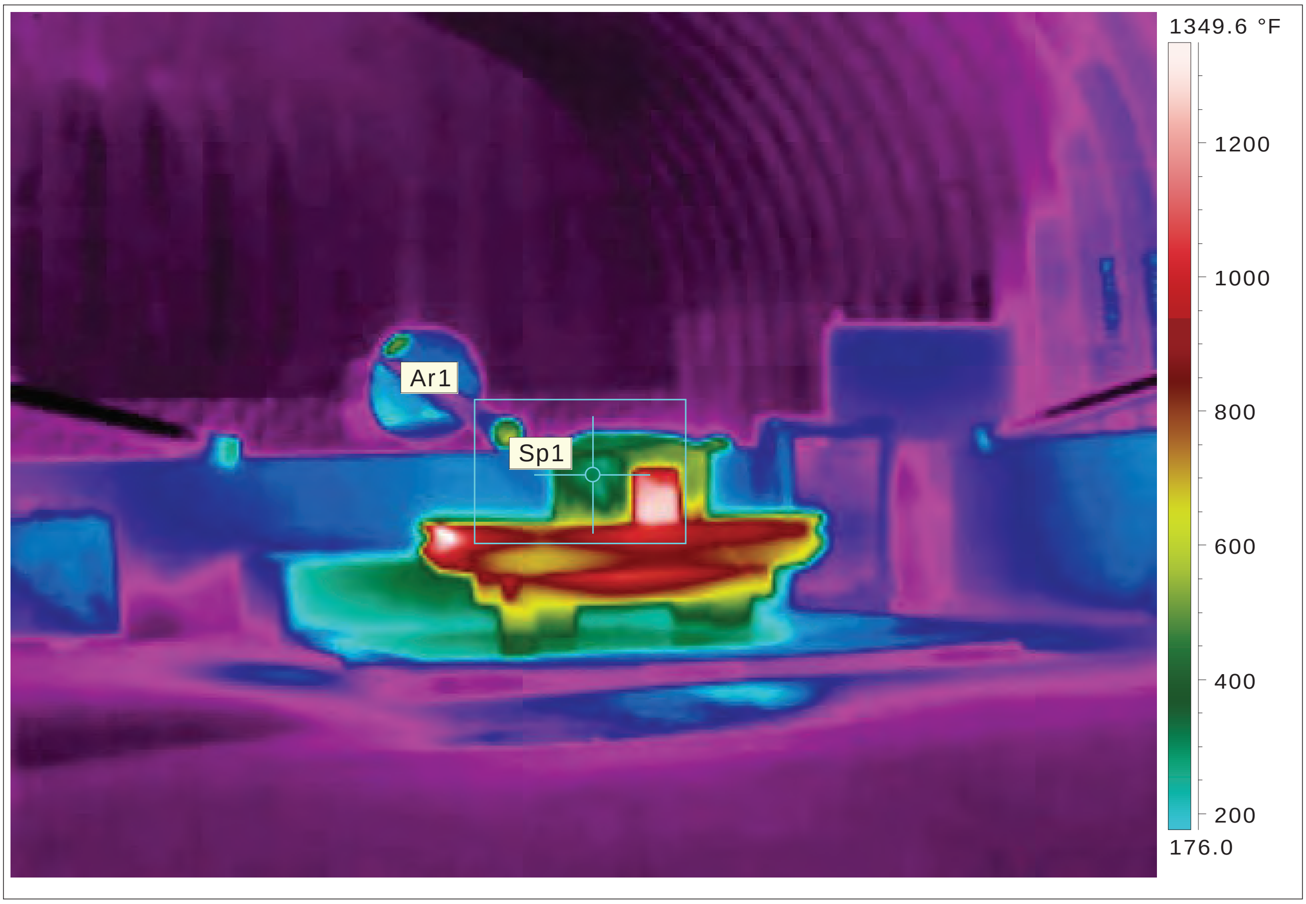
Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	>2372.2 °F
Sp1 Temperature	1757.1 °F
Date	4/18/2013
Image Time	8:22:08 AM
Emissivity	0.69

Approximately 43 minutes after burn start time

Thermogram Image.Date 4/18/2013



Ar1 Max. Temperature	1274.8 °F
Sp1 Temperature	*316.9 °F
Date	4/18/2013
Image Time	8:23:38 AM
Emissivity	0.69

Approximately 44 minutes after burn start time

30. LANL (Los Alamos National Laboratory), June 2020n. Supplement 4-16 to Part B Permit Application for Renewal of the Los Alamos National Laboratory Hazardous Waste Facility Permit, EPA ID #NM0890010515. *Technical Area 16 - Open Burn/Open Detonation (OB/OD) Area - Technical Area 16-388 Flash Pad Human Health and Ecological Risk Screening Assessments*. LA-UR-20-24479. (LANL 2020n)

Supplement 4-16

Technical Area 16 - Open Burn/Open Detonation (OB/OD) Area - Technical Area 16-388 Flash Pad Human Health and Ecological Risk Screening Assessments

TECHNICAL AREA 16 - OPEN BURN/OPEN DETONATION (OB/OD) AREA -

TA-16-388 FLASH PAD

HUMAN HEALTH AND ECOLOGICAL RISK-SCREENING ASSESSMENTS

June 15, 2020

EXECUTIVE SUMMARY

Open burn hazardous waste treatment operations requiring a permit under the Resource Conservation and Recovery Act (RCRA) are conducted at the Los Alamos National Laboratory (LANL or Lab) at Technical Area 16. As part of the application process for a permit to perform hazardous waste treatment operations, and in accordance with the requirements of Title 40 of the Code of Federal Regulations, Part 264.601(b) (40 CFR § 264.601(b)), LANL performed soil monitoring activities to assist with site characterization. The area around the open burn (OB) unit at Technical Area 16-388 (TA-16-388) Flash Pad within the LANL was investigated in Fall 2018. Currently the TA-16-388 Flash Pad is the only OB treatment unit that is currently operational. The TA-16-388 unit has been used exclusively for OB treatment of explosive waste streams. The goal of the site characterization and risk assessments is to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

The study boundary is composed of the Flash Pad unit where past explosives processing activities have occurred, and/or the location of past waste management units. Surface soil samples were collected in September 2018 and analyzed for inorganic and organic chemicals. No radionuclide data were collected. Data from these samples were used to conduct human health and ecological risk-screening assessments for this report.

For the human health risk-screening assessment, residential and industrial exposure scenarios were evaluated by comparing the maximum exposure point concentration (EPC) for each analyte to the New Mexico Environment Department (NMED) soil screening levels (SSLs). The following conclusions are made:

- There were no hazard quotients (HQs) >0.1
- There were no cancer risks >$1x10^{-5}$
- Based on the Fall 2018 data set, there was no elevated risk to human health for exposure to soils identified as the result of this screening analysis using maximum detected concentrations.

Potential risk to ecological receptors was evaluated by analyzing different lines of evidence that were weighed to draw a conclusion regarding potential for adverse ecological effects. This included:

- Comparing maximum EPCs to minimum no effect (NE) and low effect (LE) ecological screening levels (ESLs) and to background values (BVs),
- Comparing upper 95th percentile confidence limit EPCs (UCL95 EPCs) to minimum NE and LE ESLs,
- Calculating hazard indices,
- Consideration of site-specific biological sampling, and long term avian and mammalian monitoring data,
- Application of site-specific area use factors.

The following conclusions are made:

Based on the Fall 2018 TA-16 388 data set, there is minimal potential risk to ecological receptors for exposure to soils identified as the result of this screening analysis. Barium concentrations in surface soils exceeded both background and the LE ESL to produce HQs greater than 1 for plants in five samples (grid points 6, 8, 9, 10, 12). Barium was 10 times higher than background in one of these samples (grid point 9). Dioxins/furans exceeded the LE ESL for mammals and the NE ESL for birds in one sample (grid point 3).

Other lines of evidence were evaluated in addition to the measured analytical data. Recent field studies found no adverse impacts to the small mammal population, and field observations made during the site visit revealed the plant community is healthy with no indications of chemical stress where plants are present. Avian surveys were conducted and avian abundance and diversity was comparable to or greater than reference areas. Nonviable eggs were tested for inorganic analytes. Barium concentrations were three to seven times higher than the Regional Statistical Reference Level (RSRL).

With the exception of barium, the contaminants of potential ecological concern (COPECs) identified in this risk assessment were all below the RSRL in eggs collected and analyzed from 2016 to 2019. Hatching success was similar to that previously reported for the area. Dioxin/furans were also identified as COPECs, and one congener was detected in nestling tissue approximately three times higher than the RSRL; however, when adjusted for toxicity relative to TCDD, the concentration was much lower than the TCDD lowest observed adverse effect level (LOAEL) for eggs. Together these results suggest inorganics or dioxin/furans will not adversely affect breeding bird populations.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

BV	Background Value
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CSEM	Conceptual Site Exposure Model
EPC	Exposure Point Concentration
ESL	Ecological Screening Level
HI	Hazard Index
HQ	Hazard Quotient
LANL	Los Alamos National Laboratory
LD50	Lethal Dose for Half of the Population
LE	Low Effect
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
NE	No Effect
NMED	New Mexico Environment Department
NMSSL	New Mexico Soil Screening Levels
NOAEL	No Observed Adverse Effect Level
OB	Open Burn
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RSRL	Regional Statistical Reference Levels
SAP	Sampling and Analysis Plan
SF	Cancer Slope Factor
SL	Screening Level
SSLs	Soil Screening Levels
SVOC	Semi-Volatile Organic Chemical
SWMU	Solid Waste Management Unit
TA	Technical Area
TECi	Toxicity Equivalent Concentration for congener ***i***
TEF	Toxicity Equivalency Factor
TEQ	Toxicity Equivalent Quotient
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
UCL95	95% Upper Confidence Limit On The Mean
VOC	Volatile Organic Chemical
WHO	World Health Organization

1. INTRODUCTION

Technical Area (TA) -16 is located in the southwestern portion of Los Alamos National Laboratory (LANL) at the west end of the Pajarito Plateau near the foothills of the Jemez Mountains (Figure 1-1). TA-16 is composed of the Open Burn (OB) unit and the surrounding solid waste management units (SWMUs) where past explosives processing activities have occurred, and/or the location of past waste management units.

The hazardous waste management unit consists of the TA-16-388 Flash Pad and the TA-16-399 Burn Tray. The TA-16-388 Flash Pad is the only part of TA-16 addressed by this risk assessment. The TA-16-388 Flash Pad consists of a 22-foot (ft) by 22-ft concrete pad located in the northeast portion of TA-16. The concrete pad measures 12 inches thick at the base and sits atop a 45-milliliter Hypalon secondary containment liner that is situated 6 inches below the bottom of the pad. The pad is also equipped with a retractable steel roof that covers the unit when it is not in use. Dry and wet explosives, and waste that is contaminated with explosives, are treated at the TA-16-388 Flash Pad to destroy the characteristic of reactivity (D003).

An initial site characterization assessment at the TA-16-388 Flash Pad by soil sampling was performed in June 2009 and a follow-up was conducted in August 2009. Additional soil monitoring events occurred in 2012 and 2013. Only the most recent Fall 2018 data was used to provide a current site characterization, and aid in establishing whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment. The Fall 2018 data are considered to most accurately reflect current site conditions. Sampling events did not include rocks, debris, or vegetation.

Data were collected within the boundaries of the TA-16-388 OB unit and in the surrounding SWMUs where past explosives processing activities occurred. Only surface soil data were collected. Sampling locations were selected based on a defined area where deposition of particulates from air to soil and areas of potential storm water runoff is most likely to occur. Additional discrete grab sample locations northeast of the Flash Pad where a dioxin/furan contaminated hotspot was identified during previous soil monitoring events were also selected. This judgmental sampling design is considered to be conservative and likely to bias risk results high.

Human health and ecological risk-screening assessments were conducted using the most recent surface soil data. These data were collected in September 2018. Data from historical sampling events were not utilized since the most recent data reflect current conditions at the site. The results of the risk-screening assessments are presented in the following sections.

2. HUMAN HEALTH RISK ASSESSMENT

2.1. HUMAN HEALTH CONCEPTUAL SITE MODEL

Only authorized laboratory workers currently have access to the area around the TA-16 Flash Pad, and therefore the primary land use is industrial. Laboratory workers are the primary human receptors, and the industrial scenario is the defined scenario for the human health risk-screening assessment (i.e., the scenario on which decisions are based). Because the site is located within the boundaries of an operational facility (TA-16), the reasonably foreseeable future land use will continue to be industrial. A Hypothetical Future Residential exposure was also assessed and provided for comparison purposes.

The release of contaminants from OB operations has occurred for more than 50 years. Releases are transported primarily by wind, which rapidly disperses the material in ambient air. Most material is likely deposited close to the source(s), and fugitive dust concentrations will decrease with distance from the source. Exposure to a site worker may occur through various surface soil contact pathways. Potential human health exposure pathways evaluated in this risk assessment include:

- Incidental ingestion of surface soil,
- Inhalation of fugitive dust or volatiles emanating from surface soil, and
- Dermal contact with surface soil.

2.2. IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2.2.1. Sampling

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- Volatile Organic Compounds (VOCs) –12 samples and one duplicate
- Semi-Volatile Organic Compounds (SVOCs) –12 samples
- Total Metals –12 samples and one duplicate
- Dioxins/Furans –12 samples and one duplicate
- High Explosives –12 samples and one duplicate

In addition, some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dinitrobenzenes). Figure 1-1 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment.

2.2.2. Evaluation of Inorganic Analytes

Inorganic analytes are first compared to background values (BV) established for the site (LANL 1998). For analytes with maximum concentrations less than the BV, no further evaluation is necessary and the data are not compared to risk-based screening levels (SLs). For analytes where the maximums exceeded the benchmark termed the background value (BV), but did not exceed risk-based SLs known as the New Mexico Soil Screening Levels (NMSSLs) (NMED 2019), no further evaluation is necessary. For analytes where the maximum values exceeded the BV and also exceeded one or more risk-based SLs (as indicated by a ratio of the maximum to the SL being greater than 1), a 95% upper confidence level (UCL95) was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the SLs. The toxicity of the various constituents analyzed in this investigation is incorporated into the screening levels.

Where an NMSSL was not available, the USEPA Regional Screening Level (RSL) was used. If an RSL was also not available, a suitable surrogate is proposed if toxicity and physicochemical data are sufficient to allow identifying a suitable surrogate. The following inorganic analytes required surrogates:

- Calcium, sodium, potassium, magnesium – these are typically considered non-toxic macronutrients, so unless concentrations exceed background they are not evaluated in risk assessments, and SLs are lacking.

- Chromium (Cr) - the toxicity values based on NMED CrIII were used since NMED has no SLs for total Cr, and the site is unlikely to have significant amounts of the CrVI form.
- Mercury – the toxicity values for NMED mercuric salts was used as the screening level basis of the screening level as this should be the form would be most expected in arid soils.

2.2.3. Evaluation of Organic Analytes

For this risk assessment, the highest concentration found, regardless of the method used, or whether the sample was a primary sample or a duplicate, was used as the basis of the exposure point concentration (EPC) in the screening-level assessment. This is considered conservative for the evaluation of potential risks.

Organic analytes are not compared to any background values, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based SLs. Where an SL was not available, a suitable surrogate is proposed. Surrogates were obtained for the following analytes:

Human Health

- Acenapthylene – There are no NMSSLs or RSLs for acenapthylene. Napthalene toxicity values are used as a surrogate.
- 2,4,6-triamino-1,3,5- trinitrobenzene (TATB) – There is no NMSSL or RSL for TATB. RSLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.
- 1,2- and 1,4 -Xylene [o-, p-xylenes] - the toxicity values for 1,3-xylene (m-xylene) were used as the screening level as they are just slightly more conservative than using those for p-xylene (1,4-xylene).

2.3. EXPOSURE POINT CONCENTRATIONS

A phased approach was used to establish the EPCs. First the maximum detected value for each analyte was compared to a SL. Analytes for which the maximum value was less than the lowest SL are not evaluated further. If the maximum EPC exceeded SL, evaluation was continued with the UCL95 used as the EPC for the comparison. All non-rejected data were used to calculate the 95% UCLs for the risk-screening assessments, if appropriate. If there were too few detected concentrations reported to allow calculation of a UCL95 (i.e., sample number (n) <6), the median of all the data for the analyte including the detected concentrations and the method detection limits (MDLs) was used.

Guidance from NMED was applied to evaluate the potential toxicity of the dioxins/furans. This guidance relies on the 2005 World Health Organization (WHO) toxicity equivalency factors (TEF) (Van den berg et al. 2006) approach. The TEFs are multiplied by the measured concentration to obtain a congener-specific product called the toxicity equivalent concentration (TECi). The TECi values are then summed for each sample location. This sum is referred to as the toxicity equivalent quotient (TEQ). The TEQ is divided by the NMED screening level for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) to obtain a risk ratio.

The following sections present the human health risk-screening assessments for TA-16-388.

2.4. SCREENING EVALUATION

The EPC (Table 2-1) was divided by the carcinogenic and noncarcinogenic SL for residents and industrial workers to obtain a hazard quotient (HQ), and the hazard index (HI) was calculated by summing the HQs (NMED 2019). The SLs used in the evaluation were obtained from current NMED guidance (NMED

2019) or the most recent EPA regional screening levels (RSLs) (EPA 2018) if an NMED value was not available. The SLs for carcinogens are equivalent to a 1×10^{-5} cancer risk, and for noncarcinogens the SLs correlate to a hazard quotient (HQ) of 1. To be consistent with the NMSSLs, the EPA RSLs based on a cancer endpoint were multiplied by 10 to adjust them to a cancer risk level of $1x10^{-5}$.

Any detected organic analytes that exceeded the SLs were considered contaminants of potential concern (COPCs). Any detected inorganic analytes that exceeded both background and the SL were also considered COPCs.

2.4.1. Background Data

The background data used in this evaluation were obtained from LANL "Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico, September 1998. The background data are used in the RCRA corrective action process to distinguish between contaminated and uncontaminated media and have been accepted by NMED. As stated in LANL (1998) on page 4, section 3.1.1,

> Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for inorganic chemical analyses. These samples provide information about the varied soils and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, 05702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms.

The locations sampled as part of the background study were not impacted by deposition from the historical operation of the OD units or other firing sites. Benchmarks termed BVs were obtained from this document to use in comparison to site data.

2.4.2. Fall 2018 Data Analysis

Table 2-1 presents summary statistics for the 2018 soil data. There were 12 samples included in this data set collected in September 2018. However, including data from duplicate pair for grid point 3 and including analysis by different methods results in an increased apparent sample size above 12 for some analytes (Table 2-1). Maximum concentrations in the soil samples analyzed for inorganics were compared to the established soil BVs (LANL 1998) (Table 2-1).

Background values for the site were obtained from the 1998 background report (LANL, 1998), and SLs were obtained from New Mexico (NMSSLs) (Table 2-2). The maximum concentration for the following inorganics exceeded the BV, although none of the inorganics exceeded either the residential or worker NMSSLs as indicated in Table 2-2:

- Antimony
- Barium
- Cobalt
- Copper
- Lead
- Nickel
- Silver

- Zinc

There were few organics detected in any samples. The following organics were detected in one or more samples:

- 4-Amino-2,6-dinitrotoluene[4-]
- Anthracene
- Cyclotetramethylene-tetranitramine (HMX)
- Dioxin/furan congeners
- 4-Isopropyltoluene[4-]
- Cyclotrimethylene-trinitramine (RDX)
- 1,3,5-Triamino-2,4,6-trinitrobenzene (TATB)
- Toluene
- 2,4,6-Trinitrotoluene[2,4,6-] (TNT)

Four of these constituents are energetics or explosives (i.e., HMX, RDX, TNT, and TATB). 4-Amino-2,6-dinitrotoluene[4-] is a degradation product of TNT. None of these detected organics exceeded the human health SLs for residential or industrial use.

The evaluation of the dioxin/furans is summarized in Table 2-3. The measured concentration or the MDL for nondetected samples is shown for each congener in each sample. The detection status is indicated by a zero for nondetect, and a 1 for a detected value. The TEFs are shown for each congener, and multiplying the TEF by the concentration produces the TECi. Summing the TECi yields the TEQ. Dividing the TEQ by the residential or industrial SL for TCDD produces a ratio. If the ratio exceeds 1, then the dioxin/furan concentrations are higher than SLs and must be evaluated further. If less than 1, no further evaluation is required. Table 2-3 indicates the TEQ for all samples was below 1, and no further evaluation of dioxin/furans is needed.

The analysis was based on comparison of the maximum detected value as the EPC. Because there were no analytes in the Fall 2018 data set for which the maximum EPC exceeded SLs, UCL95 values were not calculated for the screening level human health risk assessment.

2.5. UNCERTAINTY ANALYSIS

The human health risk assessment has inherent uncertainties associated with data, the analysis process, exposure assessment, and the toxicity values on which the SLs are based. Each or all of these uncertainties may affect the assessment results, biasing the risk assessment results high or low. These uncertainties are discussed in more detail in the following sections.

2.5.1. Data and Data Analysis

Uncertainties in the data and/or its analysis may include errors in sampling, laboratory processing, analysis, and or data evaluation. Data evaluation uncertainties are expected to have little effect on the assessment results because the data have undergone validation to minimize errors, and any errors are not expected to bias the results high or low. The J-flagged (estimated) qualification of detected concentrations off some organic COPCs does not affect the assessment. The data represent deposition from more than 60 years of operation into 2019. Therefore, the data and subsequently the screening assessment results represent current baseline conditions.

The use of a judgemental sampling design biases the risk results high since samples were targeted to locations where contamination was most likely to occur or known to occur from past sampling events.

The use of the maximum or a UCL95 as the COPC EPC for each COPC is also expected to bias risk estimates high, erring towards being conservative. Use of the maximum as the EPC overestimates exposure, as by definition all other concentrations are below this value. Use of the UCL95 may also result in an overestimation of risk since by definition true mean values are nearly always going to be less than this value.

2.5.2. Exposure Assessment

The exposure assessment assumptions bias the risk results high (i.e., overestimate risk). Assumptions for the Industrial SLs assume that a potentially exposed individual is a LANL worker who is outside at the site for eight hours/day (h/d) for 225 days/year (d/yr) (NMED 2019), and who spends the entire time on-site within the contaminated area. Assumptions for the residential SLs are that the potentially exposed individual is a resident who is present 24 h/d for 350 d/yr (NMED 2019) and spends the entire time on-site within the contaminated area. Because it is unlikely the worker or resident would be within the TA-16 contaminated area for the entire time, the resultant screening assessments overestimate the exposure. As a result, risks may be overestimated or biased high.

Assumptions underlying the exposure parameters, routes of exposure, and intake rates for routes of exposure are consistent with NMED parameters and default values (NMED 2019). In the absence of site-specific data, several upper-bound values for the assumptions may be combined to estimate exposure for any one pathway, and the resulting risk estimate can exceed the 99th percentile. Therefore, uncertainties in the assumptions underlying the exposure pathways may contribute to risk assessments that overestimate the reasonably expected risk levels.

2.5.3. Toxicity Values

The primary uncertainty associated with the screening values is related to the derivation of toxicity values used in their calculation. Toxicity values (i.e., slope factors [SFs] and reference doses [RfDs]) are used to derive the risk-based screening values used in the screening evaluation (NMED 2019). Uncertainties were identified in four areas with respect to the toxicity values: (1) extrapolation from animals to humans, (2) variability between individuals in the human population, (3) the derivation of RfDs and SFs, and (4) the chemical form of the COPC.

The SFs and RfDs are often determined by extrapolation from animal data to humans, which may result in uncertainties in toxicity values because of differences that exist between animals and humans in chemical absorption, metabolism, excretion, and toxic responses. Differences in body weight, surface area, and pharmacokinetic relationships between animals and humans are taken into account to address these uncertainties in the dose-response relationship. However, conservatism is usually incorporated in development of the SFs and RfDs from the underlying toxicological studies, potentially biasing the estimate high and resulting in the overestimation of potential risk.

For noncarcinogenic effects, the degree of variability in human physical characteristics is important both in determining the risks that can be expected at low exposures and in defining the no observed adverse effect level (NOAEL). An uncertainty factor of 10 is applied to RfDs by USEPA to reflect individual variability within the human population that can contribute to uncertainty in the risk assessment. This factor of 10 is generally considered to result in a conservative estimate of risk for noncarcinogenic COPCs.

The RfDs and SFs for various chemicals are derived from experiments conducted by different laboratories that may have varying accuracy and precision that could lead to an over- or under-estimation of risk. The uncertainty associated with an RfD is measured by the magnitude of the uncertainty factors, the modifying factor, and the confidence level. For carcinogens, the weight of evidence classification indicates the likelihood that a contaminant is a human carcinogen.

An additional assumption that introduces uncertainty into the risk assessment is that the RfD or SF derived from laboratory animal studies or human health occupational epidemiology studies adequately and accurately represents environmental exposure. Bioavailability from environmental media may not be the same for a given COPC as bioavailability in a laboratory study or occupational exposure. For example, COPCs may be bound to the environmental matrix and not be available for absorption into the human body following ingestion. However, for most COPCs the exposure scenarios typically default to the assumption that the COPCs are fully bioavailable. This assumption can lead to an overestimation of the total exposure and overestimate risk.

2.5.4. Additive Approach

For noncarcinogens, the effects of exposure to multiple chemicals are generally unknown and possible interactions could be synergistic or antagonistic, resulting in either an underestimation or overestimation of the potential risk by assuming additivity. Additionally, RfDs used in the risk calculations typically are not based on the same endpoints with respect to severity, effects, or target organs. Therefore, the potential for noncarcinogenic effects may be overestimated by the HI considering individual COPCs act by different mechanisms and on different target organs but are addressed additively. Cancer risks are typically assumed to be additive.

2.6. CONCLUSIONS

Inorganics were compared to BVs and risk-based SLs. Concentrations for eight inorganics exceeded background; however no inorganics exceeded risk-based NMSSLs.

The few organics that were detected were compared to risk-based SLs. For all of the detected analytes, maximum concentrations were below SLs. The cancer risk and noncancer HIs were below the target levels of $1x10^{-5}$ and 1, respectively. None of the TEQs for dioxin/furans exceeded the TCDD SL. The following interpretation can be made from the analysis:

- Based on an industrial scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer (0.1) and cancer-based (0.005) HIs are less than the NMED target level of 1. This means that the sum of the ratios for maximum concentrations divided by SLs correlate to a cancer risk less than $1x10^{-5}$ and a noncancer hazard less than 1.
- For the residential scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer and cancer HIs (1 and 0.02) are at or less than the NMED target level of 1.
- The concentration of each dioxin/furan congener was summed to obtain a TEQ which was compared to the NMED NMSSL for TCDD. The maximum ratio was 0.7 for residential use and 0.004 for industrial use.
- Summing the maximum dioxin/furan ratio with the other cancer risk HIs provides an HI for residential use of 0.8 and an HI for industrial use of 0.009.
- The maximum lead concentration of 26.7 mg/kg at TA-39-388 is just slightly above the background value of 22.3 mg/kg, and is much less than the residential SSL (400 mg/kg).

- There are no elevated human health risks for exposure to soils based on this evaluation.

3. ECOLOGICAL SCREENING ASSESSMENT

The ecological risk-screening assessments for TA-16 is presented in the following sections.

3.1. INTRODUCTION

The ecological risk-screening evaluation identifies chemicals of potential ecological concern (COPECs) and is based on the comparison of EPCs with Ecological Screening Levels (ESLs) in accordance with Laboratory (LANL 2012a) and NMED (NMED 2017) guidance.

Site information including ESLs, biological studies, and historical information were reviewed and a site visit was conducted. A preliminary conceptual site exposure model (CSEM) was prepared.

The ESLs obtained from the ECORISK Database, Version 4.1 (LANL 2017) are presented in Table 3-1. The ESLs are based on toxicity data for laboratory species similar to those expected to occur at the site, and are derived from experimentally determined NOAELs, lowest observed adverse effect levels (LOAELs), or doses determined to be lethal to 50% of the test population (LD50s). Information relevant to the calculation of ESLs, including concentration equations, dose equations, bioconcentration factors, transfer factors, and toxicity reference values, are presented in the ECORISK Database, Versions 2.0, 3.1, and 4.1 (LANL 2003; LANL 2012b; LANL 2017).

The ecological risk analysis begins with a comparison of the minimum ESL to the maximum concentration as the EPC. The EPCs are divided by the ESLs to obtain a HQ calculated for each analyte. As a generalization, the higher the contaminant levels relative to the ESLs, the higher the potential risk to receptors. Conversely, the higher the ESLs relative to the contaminant levels, the lower the potential risk to receptors. HQs greater than 0.3 are used to identify COPECs requiring additional evaluation (LANL 2012a).

Individual HQs for a receptor are summed to derive a HI; an HI greater than one is an indication that further assessment may be needed to ensure exposure to multiple COPECs at a site will not lead to potential adverse impacts to a given receptor population. The HQ and HI analysis is a conservative indication of potential adverse effects and is designed to minimize the potential of overlooking possible COPECs at the site.

3.2. PROBLEM FORMULATION

Due to the site history, there is the potential for energetic compounds or their breakdown products to be present in surface soils where terrestrial animals and plants may contact surface soils and be exposed.

3.2.1. Data Summary

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- VOCs –12 samples and one duplicate
- SVOCs –12 samples
- Total Metals –12 samples and one duplicate

- Dioxins/Furans –12 samples and one duplicate
- High Explosives –12 samples and one duplicate

In addition, some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dinitrobenzenes). Figure 1-1 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment, and habitat is shown in Figure 3-1.

3.2.2. Site Visit Summary

A site visit was conducted in March 2019. The area is disturbed by human activity with buildings, roads, and maintained cleared areas to minimize fire danger. The vicinity in and around the TA-16 Burning Ground is a terrestrial ecosystem. Although the area within the fence is disturbed, approximately 50 to 100 feet away from the concrete burn pad it is vegetated with grasses, shrubs, and trees. Elk tracks were observed nearby outside of the fenced area. There are likely terrestrial birds and small mammals including deer mice or ground squirrels using the area; however, there is not enough vegetation within the fenced area to support birds or mammals.

3.2.3. Receptors and Pathways

Exposure pathways are considered complete if all of the following components are present (US EPA, 1989; NMED, 2017):

- A source and mechanism for hazardous waste/constituent release into the environment;
- An environmental transport medium or mechanism;
- A point of contact directly between the receptor and site-related contaminated media, or indirectly via dietary ingestion of prey or forage items contaminated by contact with site related contaminants; and
- An exposure route leading to interaction of the contaminant with target organs within the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site.

A CSEM was developed for the site (Figure 3-2). The primary contaminant source is the burning of munitions waste at the site. Any uncombusted material, if present, could remain in soil or be released to air as fugitive dust. Materials in surface soil could be carried by overland flow or percolate into the subsurface with rain, whereas material in air could be transported by wind. Receptors could contact contaminants within the immediate site area, up to the site boundary, or slightly beyond.

Ingestion of soil, plants, or animals are all potential exposure routes to ecological receptors. Although inhalation is recognized to occur, it is typically considered insignificant relative to ingestion and only quantified for burrowing animals where volatile organics are present in the subsurface. Respirable dust particles are likely ingested rather than inhaled by ecological receptors, and this pathway is considered negligible (EPA 1997; EPA 2003), while non-respirable dust is ingested and accounted for in incidental soil ingestion values for wildlife species (EPA 1993; EPA 2003). Therefore, the exposure pathways considered in the development of the ecological screening levels (ESLs) used in the risk-screening assessment capture the primary exposure for wildlife receptors.

Terrestrial flora (i.e., plants) and fauna (e.g., invertebrates, birds, and mammals) are the general categories of ecological receptors that could be exposed. The primary ecological exposure pathways are based on direct or indirect contact with surface soils. These include root uptake, incidental ingestion of soil, and biotic uptake leading to food-web transport. Exposure of plants and soil invertebrates is not related to dietary pathways but is the result of direct contact with, and uptake from, the surrounding medium. For terrestrial wildlife, most exposure is considered to be through the oral pathway from the diet and incidental soil ingestion (Sample et al. 1998). The dermal contact and inhalation pathways are not typically assessed quantitatively in ecological risk assessments, based on guidance indicating the ingestion route is most important to terrestrial animals (EPA 1997; EPA 2003). Dermal exposure to wildlife is mitigated by the fur or feathers covering the bodies of most vertebrates and the incidental soil consumption during grooming is included in the direct soil ingestion estimates.

3.2.4. Technical Decision Point and Recommendations

Because of the ecological habitat near the site boundaries, and because of the potential for exposure, the data were used to perform a quantitative screening level ecological evaluation.

3.3. ECOLOGICAL SCREENING EVALUATION

The summary statistics for the data were presented in Table 2-1. Maximum detected concentrations of each analyte are used as the initial EPC. The EPCs and the screening results for ecological receptors are presented in Table 3-1. Any analytes for which the measured maximum detected value exceeded the minimum ecological screening level (ESL) were considered COPECs and evaluated further by calculating UCL95s and comparing the UCL95s to the SLs. The initial ESLs were the minimum no effect (NE) and low effect (LE) SLs in the 2019 LANL database for each of the analytes.

3.3.1. Inorganics

There are eight inorganic analytes that exceed site background, most of which also result in an HQ >0.3 when the maximum EPC is divided by the minimum ESL. Some also exceed the LE ESL. The detected analytes that had maximum concentrations that exceeded background were compared to the ESLs and the results are as follows (Table 3-1):

- Antimony –HQ for NE ESL>0.3
- Barium – exceeds NE and LE ESLs resulting in HQs>0.3
- Cobalt– HQ for NE ESL>0.3
- Copper – exceeds NE ESLs and LE ESLs resulting in HQs>0.3
- Lead – exceeds NE ESLs and LE ESLs resulting in HQs>0.3
- Nickel – exceeds NE and LE ESLs resulting in HQs>0.3
- Silver– exceeds NE and LE ESLs resulting in HQs>0.3
- Zinc– exceeds NE and LE ESLs resulting in HQs>0.3

For the inorganic analytes for which the maximum exceeded the BV and also exceeded one or more risk-based SLs (as indicated by a ratio or HQ of the maximum to the SL being greater than 0.3), a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the SLs (Table 3-2) consistent with the NMED (2017) Tier II approach. Note that comparison to the UCL95s was made prior to incorporating area use factors (AUFs) into the analysis. Receptor-specific dietary composition is built into the receptor-specific ESLs. The concentrations for each of the samples in the duplicate pair 3 and 3 dup (Figure 1-1) were averaged and the UCL95 calculated with a sample size of 12.

UCL95 values for barium, nickel, silver, and zinc exceeded the BV. UCL95 values for barium, nickel, silver, and zinc also exceeded the NE ESL, but only UCL95s for barium and silver exceeded the LE ESL as well. The UCL95 for lead (14.91 mg/kg) was below background (22.3 mg/kg) and below LE ESLs. The maximum value of these five constituents was detected in the sample collected at grid point 9 (Figure 1-1). This sample also had the maximum concentration of chromium and copper. The HI for the NE ESL was 60, and the HI for the LE ESL was 10.

The analysis suggests some extremely limited potential for adverse ecological effects at TA-16-388, and therefore the COPECs for which the UCL95s exceeded the LE ESLs were evaluated in more detail by looking further at spatial distribution and toxicity as follows:

- Barium and silver are the only inorganics for which the UCL95 exceeded the LE Eco SL.
- The silver ESL is based on potential toxicity to an American robin modeled as an insectivore.
    - Only two samples had silver concentrations above both the BV and the NE ESL for the robin, and only one sample had silver concentrations above the minimum LE ESL for the robin.
    - Silver is not elevated in bird eggs from TA-16 (LANL 2018a). Egg concentrations are discussed further in Section 3.4.5.
    - This suggests that due to the limited areal extent of elevated silver concentrations that silver does not present an ecological risk.
- The minimum barium Eco SLs are based on potential toxicity to plants, however:
    - The NE ESL of 110 mg/kg is well below site background of 295 mg/kg. No toxicity to plants was noted in the field visit (i.e., chlorosis, dead plants).
    - Vegetation is controlled by removal for fire danger around the site so plant receptors are not present within or near the fenced area much of the time.
    - Nearly all of the samples (12/12) exceeded the minimum barium NE Eco SL, whereas only 7/12 (1, 2, 6, 8, 9, 10, 12 on Figure 1-1) exceeded the minimum barium LE Eco SL of 260 mg/kg. These same seven samples also exceeded the BV of 295 mg/kg.
    - For only one sample (sample grid point 9 on Figure 1-1) was the LE Eco SL HQ greater than 10.
    - The barium UCL95 concentration for the TA-16 388 data is 2223 milligrams/kilogram (2223 mg/kg). Sources of toxicity information for plants suggest that it takes concentrations of barium in soils similar to this to cause toxicity (Chaudhry et al. 1977). Chaudhry et al. (1977) found that yield depressions occurred at 2,000 mg/kg and higher barium in soil. At only one sample location (grid point 9, concentration 4060 mg/kg) was the concentration greater than 2000 mg/kg. The next highest concentration was 1550 mg/kg.
    - The data were compared first to site background values, which for barium is 295 mg/kg. However, EPA (2005) indicates barium background concentrations in the Western US range from about 350 mg/kg to about 1100 mg/kg. Only two samples had concentrations

higher than 1100 mg/kg. Thus, half the samples exceed site-specific background, and only 17% exceed the upper bound of background for the Western US. All samples above Western U.S. background fall within the fenced area (grid point samples 9 and 10).

- All samples with concentrations above 1000 mg/kg (samples 6, 8, 9, and 10) are within the fenced area where vegetation is controlled for fire suppression. The remaining three samples with concentrations above site background were not even two times higher than background.
- This analysis suggests that there may be limited toxicity to plant populations at the site due to barium concentrations in surface soils; however, it appears unlikely and very localized to areas where plants as a receptor are removed for fire suppression.

3.3.2. Dioxin and Furans

Dioxin and furans were detected in multiple samples in the Fall 2018 data set. One sample (grid point 3; Figure 1-1) had concentrations an order of magnitude higher than the other samples. The TEFs for birds and mammals were applied to calculate a TEQ for each sample (Table 3-3). Several samples had TEQs that exceeded the NE Eco SL for TCDD for mammals (Table 3-4) or birds (Table 3-5) when evaluated on a sample by sample basis. Note that dioxins and furans were not detected above the sample quantitation limits in small mammal tissue samples (Fresquez et al. 2013), discussed further in Section 3.4.4.

A UCL95 based on the sample-specific data for each congener was calculated with ProUCL (EPA 2015) using both the detected and nondetected data to obtain the EPC, and then TEQs were calculated for mammals and birds from the congener-specific UCL95s and TEFs (Table 3-6). If the UCL95 recommended by ProUCL exceeded the maximum detected value, the next recommended UCL that did not exceed the maximum TEQ was selected as the EPC. When the TEQ calculated from the UCL95s was divided by the NE Eco SL for mammals or birds for TCDD, the resulting HQ exceeded 1, as shown below.

Receptor Category	TEQ	NE Eco SL	NE HQ	LE Eco SL	LE HQ
Mammal	2.54E-05	5.80E-07	44	3.80E-06	7
Bird	1.59E-05	4.10E-06	4	4.10E-05	0.4

A box-plot of the TEQs indicates that the two highest TEQs (Table 3-4), which are for the duplicate pair collected at grid point 3, are statistical outliers (Figure 3-3). These two highest samples are the only ones for which the mammalian LE Eco SL is also exceeded.

3.3.3. Other Organics

For this risk assessment, the highest concentration found, regardless of the method used, or whether the sample was a primary sample or a duplicate, was used as the basis of the EPC in the initial screening-level assessment. This is considered conservative for the evaluation of potential risks.

Organic analytes are not compared to any background values, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based ecological SLs. Where an SL was not available, a suitable surrogate is proposed. Surrogates were obtained for the following analytes:

- TATB - Eco SLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.
- Xylenes – the toxicity values for total xylenes were used to represent each of the fractions.

Only TATB had an HQ greater than 0.3 for comparison of the maximum value to the minimum NE ESL. Although there were no individual samples that exceeded the NE ESL, the highest HQ was 0.7. The HQ for comparison to the LE ESL did not exceed 0.3. The UCL95 for TATB did not exceed the NE ESL or the LE ESL (Table 3-2). TATB was detected at grid points 6, 7, 8, and 9, all within the fenceline, and at 12.

The results of the screening evaluation for ecological receptors indicated that no detected VOCs, or SVOCs exceeded any of the ESLs (Table 3-1).

3.4. UNCERTAINTY ANALYSIS

3.4.1. Chemical Form

Inorganic analytes can speciate into different forms with varying degrees of toxicity. The assumptions used in the ESL derivations are conservative and not necessarily representative of actual conditions. These assumptions include maximum chemical bioavailability, maximum receptor ingestion rates, minimum bodyweight, and additive effects of multiple COPECs. These factors tend to result in conservative ESL estimates, which may lead to an overestimation of the potential risk. Toxicological data are typically based on the most toxic and bioavailable chemical species, which may or may not be typically found in the environment. The ESLs were calculated to ensure a conservative indication of potential risk (LANL 2012a), and the values are biased toward overestimating the potential risk to receptors.

The chemical form of the individual COPECs was not determined as part of the investigation.

3.4.2. Exposure and Risk Estimates

Exposure parameters including the EPC and the intakes are likely to bias risk estimates high since they presume no movement by receptors in and out of source areas. Sampling focused on areas of known or expected contamination which biases the EPC high. Receptors are assumed to spend 100% of their time in the contaminated area, resulting in conservative estimates of exposure. In addition, COPECs may not be 100% bioavailable to receptors in the natural environment because of interference from other natural processes, such as the adsorption of chemical constituents to matrix surfaces (e.g., soil) or rapid oxidation or reduction changes that render harmful chemical forms unavailable to biotic processes.

Another source of uncertainty is inherent in the calculation of exposure and risk estimates. Although the toxicity values are expressed to more than one significant figure, it is unlikely that the toxicity data are this accurate, especially given that the data are extrapolated from laboratory animal studies to wildlife receptors that are mobile in the environment. Likewise, given all the variables inherent in assessing exposure, exposure intakes by ecological receptors also should not be considered more accurate than one significant figure. This means that an HQ identified as 0.8 or 1.2 is actually 1, and an HQ identified as 1.5 is actually 2.

Calculating risk for dioxins is a multi-step process that involves multiplying the measured concentration by a toxicity factor (TEF) to obtain a value called the TECi that when summed adjusts the measured congener concentrations to that relative to TCDD, where the sum of all TECi is called the TEQ. Nondetected congeners were not included in the TEQ calculation, which biases the TEQ high, and biases dioxin risk estimates high for any given sample. When calculating the UCL95 as the EPC, the TEQs can be used directly but this provides a UCL95 EPC based only on detected data. ProUCL (EPA 2015) accommodates both detected and nondetected results, reducing bias and uncertainty by not ignoring the influence of nondetects on the EPC. Therefore, UCL95s were calculated for each congener, then adjusted with the TEFs, and then TECi for each congener summed to obtain the TEQ as opposed to averaging the TEQs directly. This procedure of calculating UCL95s for each congener increased the TEQ and HQs slightly for mammals, and reduced the TEQ and HQ for birds, but was considered to be slightly more accurate.

3.4.3. Mixture Toxicity

The assumption of additive effects for multiple COPECs may result in an over- or under-estimation of the potential risk to receptors. Exposure to multiple contaminants may result in other than additive effects.

3.4.4. Small-Mammal Field Investigations

Small mammal trapping and analysis of whole organisms were conducted in the area around unit TA-16-388 in 2011 and 2012. This information was considered useful for the current analysis as an additional line of evidence. Field mice and voles were collected around the open-burn site and analyzed for dioxins and furans as well as metals in 2011, and for polychlorinated biphenyls (PCBs), high explosives, and perchlorate in 2012. Small-mammal community and population parameters were also measured across the site in 2012 (Fresquez et al. 2013).

Of the analytes that exceeded SLs, historically only barium and nickel were detected in whole body samples above the regional statistical reference levels (RSRLs), which are the upper bounds of concentrations (mean plus three standard deviations) calculated from field mice collected at regional locations away from the influence of the Laboratory (over 9 miles away) (Fresquez 2009 and 2011a). The nickel concentrations were slightly above the RSRLs, while barium concentrations were 3 to 4 times the RSRL, in small mammals from TA-16-388. No high explosives were detected in any of the animals collected, and perchlorate concentrations were 1 or 2 orders of magnitude below the RSRL.

Dioxin and furan congeners were not detected above the sample quantitation limit in any of the whole-body samples analyzed. Eight congeners were detected in one deer mouse sample; one congener was detected in one long-tailed vole sample, and no congeners were detected in the other four small mammals (three voles and one deer mouse) (Fresquez et al. 2013). Concentrations in whole body samples were well below those concentrations detected in the soil, and biological samples had fewer congeners detected than in 40% of the soil samples. The dioxin and furan data are similar to other dioxin/furan field-mouse uptake studies nationally (Krouskop et al. 1991).

The data indicate dioxins and furans at the concentrations found in soil under natural field conditions are not significantly assimilated, either by ingestion and/or by surface contact, by field mice/voles possibly because of the adsorption of the chemical to soil surfaces or because of oxidation/reduction changes. In addition, the samples analyzed included the pelt and carcass so it is not clear whether the congeners detected represent uptake or adherence of soil particles to the pelt. Also, no adverse effect of burning ground operations was found on local small mammal populations based on species richness, capture rate, species diversity, sex ratios, and adult body weights (Fresquez et al. 2013).

The presence of dioxins and furans in soil does not determine exposure and risk to receptors even though HQs are above 1. Dioxins and furans are relatively unavailable for uptake by plants and animals because these compounds are tightly bound to soil particles, are immobile, and insoluble (Umbreit et al. 1986).

EPA reported that the relative bioavailability of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofuran congeners in soil is less than 100% as compared with a lipid or organic solvent vehicle as the reference material (EPA 2010a). Abiotic constituents, compound aging, and other associated soil factors may influence soil bioavailability (e.g., bioavailability appears to decrease with aging based on comparisons of laboratory spiked soil and soil contaminated in situ [Umbreit et al. 1986]). This relationship is supported by the lack of uptake and impacts to biota around the Laboratory and at the TA-16 Burn Ground where dioxin and furan congeners have been detected.

The difference between the toxicity predicted by the ESLs and the lack of adverse effects may be related to the low bioavailability of dioxins and furans in soil, or it may suggest that the ESLs are overly conservative. Because small mammal populations do not appear impacted, and because the LE Eco SL is only exceeded by soil samples identified as statistical outliers, risks to ecological receptors due to exposure to dioxins/furans are likely to be minimal.

3.4.5. Avian Studies

Avian surveys were conducted at the TA-16 Burn Ground from 2010 to 2017. Data from May to July 2014 indicated that avian abundance and diversity was greater at TA-16 than at control sites (Hathcock 2014). Data from 2017 indicated that operations were not negatively affecting local bird populations. Species richness and diversity were not different than controls (Hathcock et al. 2018). At TA-16, 17 nests were found of which 13 successfully fledged young, and some nest boxes had double clutches (Hathcock et al. 2018). There was an occupancy rate of 100% with a 76% success rate.

In 2017, nonviable avian eggs and tissue samples from nestlings that died before fledging were opportunistically collected at Los Alamos National Laboratory near open detonation sites near the TA-16 burning grounds and were evaluated for metals and other inorganics (LANL 2018a). Western bluebird (*Sialia mexicana*) and ash-throated flycatcher (*Myiarchus cinerascens*) egg samples were collected. Dioxin/furan congeners were detected in one nestling from TA-16 (Hathcock et al. 2018; Gaukler and Stanek 2020).

Most inorganics were not detected (LANL 2018a). Analyte concentrations in eggs were compared with the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval) known as the RSRL. The COPECs identified in this risk assessment for which the UCL95s for soils exceeded BVs and the NE ESLs were all below the RSRL in eggs with the exception of barium (Gaukler and Stanek 2020), suggesting inorganics will not adversely affect breeding bird populations:

- Barium – maximum and UCL95 in soil exceed NE and LE ESLs; egg>RSRL
- Nickel – maximum in soil exceeds NE and LE ESLs; not detected in eggs
- Silver– maximum and UCL95 in soil exceed NE and LE ESLs; egg<RSRL
- Zinc– maximum in soil exceeds NE and LE ESLs; egg<RSRL

The maximum and UCL95 in soil exceeds NE ESL for birds for dioxin/furans. In addition, nestling tissue exceeds the RSRL for background concentrations in tissue. However, the TEQ was less than the LOAEL for toxicity (Gaukler and Stanek 2020). This suggests that dioxin/furans will not have adverse effects on avian reproduction.

3.4.6. COPECs without ESLs

Several chemicals do not have ESLs for any receptor in release 4.1 of the ECORISK Database (LANL 2017). In the absence of a chemical-specific ESL, concentrations can be compared with the ESLs for a surrogate chemical. Comparison to surrogate ESLs provides an estimate of potential effects of a chemically related compound and a line of evidence to indicate the likelihood that ecological receptors are potentially impacted. Some chemicals without ESLs do not have chemical-specific toxicity data or surrogate chemicals to be used in the screening assessments and cannot be assessed quantitatively for potential ecological risk.

These chemicals are often infrequently detected across the site. In these cases, comparisons with human health SSLs are presented as part of a qualitative assessment. The comparison of concentrations to human health SSLs is a viable alternative for several reasons. Animal studies are used to infer effects on humans and are the basic premise of modern toxicology (EPA 1989). In addition, toxicity values derived for the calculation of human health SSLs are often based on potential effects that are more sensitive than the ones used to derive ESLs (e.g., cellular effects for humans versus survival or reproductive effects for terrestrial animals). EPA also applies uncertainty factors or modifying factors to ensure the toxicity values are protective (i.e., they are adjusted by uncertainty factors to values much lower than the study results). Concentrations compared with these values are frequently an order of magnitude or more below the SSLs, which corresponds to uncertainty factors of 10 or more. Therefore, it is assumed the differences in toxicity would not be more than an order of magnitude for any given chemical. The relative difference between values provides a weight of evidence that the potential toxicity of the chemical is likely to be low or very low to the receptor(s). Since there were no predicted adverse effects on human health, chemicals lacking ESLs are unlikely to pose an ecological risk.

There is no avian ESL for TCDD in the current (2019) LANL EcoRisk database. A value from the 2002 EcoRisk database (LANL 2003) was used as the NE ESL. The lowest ESL value is 4.1×10^{-6} mg/kg based on the robin feeding as an insectivore, which has previously been utilized in LANL risk assessments. A reported LOAEL-based ESL is 4.1×10^{-5} mg/kg. These values were used in the current risk assessment in the absence of more recent data.

3.4.7. Area Use Factors (AUFs) and Population Area Use Factors (PAUFs)

The TA-16-388 Flash Pad is a small unit. The areal extent of TA-16-388 Flash Pad is 0.2 acres within the fenceline, and only 1.18 acres (ac) or 0.478 hectares (ha) for the entire sampled area. This is about the size of the home range of an individual robin or a deer mouse (LANL 2018b). The home range (HR) is used to calculate AUFs that are used in the EcoPRG equations (LANL 2018b). Individual AUFs and population area use factors (PAUFs) may be used to modify the estimate of risk to wildlife receptors to allow estimates to be more site-specific. The application of AUFs or PAUFs reduces potential overestimation of risks for those receptors with HRs larger than the area of contamination being evaluated. The estimated ecological risk as indicated by the HQ or HI is multiplied AUF or PAUF. HQs for plants or invertebrates are not adjusted by area use.

Table 3-6 presents the area use hazard analysis. The NE ESLs for each receptor for each COPC that failed the screening evaluation are shown. The site specific AUF and PAUFs are shown for an area equivalent to the fenced area of TA-16-388 and the additional sampled area outside the fenceline. The UCL95 EPC (Appendix A) is divided by the ESL and multiplied by the PAUF to obtain revised HQs. The habitat is not suitable for Mexican Spotted Owls or other special status species, and so an AUF evaluation was not conducted.

HQs were greater than 1 for plants and invertebrates, which are taxa for which the PAUF does not affect the HQ or HI since they are not mobile in the ecosystem. Table 3-7 presents the area use hazard analysis based on LE ESLs. The HQ for plants is greater than 1.

It is appropriate to use the PAUFs for mobile receptors in order to spatially average overall exposure and obtain a more realistic estimate of potential ecological risk. Barium exceeds background as well as the LE ESL at samples 6, 8, 9, 10 (all within the fenced area) by more than a factor of 2 (Figure 1-1). Barium exceeds background at sample 12 by a factor of 2, and also exceeds the LE ESL there as well. The remainder of the samples had no elevated barium, indicating limited site-related barium contamination outside of the fenced area. The NE ESL was exceeded by other metals only at samples 9 and 10, and the LE ESL was exceeded by other metals only at sample 9 (Figure 1-1). Dioxin/furans did not follow the general pattern of metal contamination and were elevated only in sample 3.

3.5. CONCLUSIONS

For the Fall 2018 sampling data, barium, nickel, silver, and zinc were the only inorganics for which the UCL95 exceeded both the BV and the NE Eco SL. Barium and silver are the only inorganics for which the UCL95 exceeded the LE Eco SL.

Only one sample exceeded the silver LE Eco SL, suggesting that any contamination is spatially limited and unlikely to have any individual or population-level effects on ecological receptors. The minimum silver ESL is based on the exposure parameters for the American robin.

All of the samples exceeded the minimum barium NE Eco SL, whereas seven exceeded the minimum barium LE Eco SL (1, 2, 6, 8, 9, 10, 12 on Figure 1-1) of 260 mg/kg. These same seven samples also exceeded the BV of 295 mg/kg. For only one sample (sample grid point 9) was the HQ based on the LE ESL greater than 10. Note that all locations with barium concentrations above 1000 mg/kg were within the fenceline (samples 6, 8, 9, and 10). The remaining three samples were not even two times higher than background. The minimum barium Eco SLs are based on toxicity to plants, and the NE ESL is well below background.

Further evaluating the data by using the UCL95s and performing a receptor-specific hazard analysis with population area use factors indicates that plants are the only receptor likely to be affected by inorganics at TA 16-388. The barium concentrations in the sample from grid point 9 (4060 mg/kg) are producing the majority of the excess potential risk, although other samples also exceed the LE ESL for plants. No effects on plants were noted in a site visit, and vegetation is removed and controlled for prevention of fire danger, thereby eliminating plants as a receptor within the fenceline.

Dioxin/furans exceed Eco SLs in few samples, suggesting that there is elevated exposure but that this elevated exposure above the LE ESL is spatially limited to one sample for mammals. Exposure above the NE ESL is limited to the same sample for birds. The sample is the duplicate pair collected at grid point 3, which is a statistical outlier. The LE ESL HQ is 10 for mammals and 0.8 for birds for this sample location. The historical small mammal tissue study indicated little uptake of dioxins/furans by small mammals at TA 16, and no effects on population biometrics.

Because of the limited number of COPCs and the low magnitude of estimated HQs, and because risk above the LE ESL for mammals and the NE ESL for birds is limited to one sample location for dioxin/furans, it is recommended that a baseline risk assessment not be prepared. Small mammal and avian population studies have been performed and evaluated for this report and the data indicate that there are no obvious adverse effects. The ESLs are conservative, and both maximum and UCL95 EPCs were used in comparison to ESLs, and further analysis of the data would not reduce uncertainty or modify predicted ecological risk to any significant extent.

4. REFERENCES

Chaudhry, F., Wallace, A., and R.T. Mueller. 1977. Communications in Soil Science and Plant Analysis. Vol 8:795-797. (Chaudhry et al. 1977).

EPA (U.S. Environmental Protection Agency), December 1989. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final," EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989)

EPA (U.S. Environmental Protection Agency), 1993. "Wildlife Exposure Factors Handbook," U.S. Environmental Protection Agency document EPA/600/P93/187A, Office of Research and Development, Washington, D.C. (EPA 1993)

EPA (U.S. Environmental Protection Agency), June 5, 1997. "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final," U.S. Environmental Protection Agency, Environmental Response Team, Edison NJ. (EPA 1997)

EPA (U.S. Environmental Protection Agency), November 2003. "Guidance for Developing Ecological Soil Screening Levels, Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs, Attachment 1-3, U.S. Environmental Protection Agency document OSWER Directive 92857-55, Office of Solid Waste and Emergency Response. (EPA 2003)

EPA (U.S. Environmental Protection Agency), February 2005. "Ecological Soil Screening Levels for Barium". Interim Final OSWER Directive 9285.7- 63. U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response. (EPA 2005)

EPA (U.S. Environmental Protection Agency), December 2010a. "Final Report Bioavailability of Dioxins and Dioxin-Like Compounds in Soil," Office of Superfund Remediation and Technology Innovation, Environmental Response Team, West Las Vegas, Nevada (http://epa.gov/superfund/health/contaminants/dioxin/pdfs/Final_dioxin_RBA_Report_12_20_10.pdf). (EPA 2010a)

EPA (U.S. Environmental Protection Agency), December 2010b. "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8=Tetrachloro-p-dioxin and Dioxin-Like Compounds." EPA/100/R 10/005. (EPA 2010b)

EPA (U.S. Environmental Protection Agency), October 2015. "ProUCL Version 5.1.002 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations." EPA/600/R-07/041. ORD Site Characterization and Monitoring Technical Support Center. (EPA 2015)

EPA (U.S. Environmental Protection Agency), 2018. Regional Screening Levels (RSLs) - Generic Tables. November 19, 2018. https://www.epa.gov/risk/regional-screening-levels-rsls

Fresquez, P.R., 2009. "The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice collected from Regional Background Areas" Los Alamos National Laboratory document LA-UR-09-07580, Los Alamos, New Mexico. (Fresquez 2009)

Fresquez, P.R., 2011a. "The Concentration of Radionuclides, Heavy Metals, and Polychlorinated Biphenyls in Field Mice collected from Regional Background Areas: Revision 1" Los Alamos National Laboratory document LA-UR-11-11687, Los Alamos, New Mexico. (Fresquez 2011a)

Fresquez, P.R., 2013. “Chemical Concentrations in Field Mice/Voles Collected from an Open-Burn Site at Technical Area 16 at Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-11-10614, Los Alamos, New Mexico. (Fresquez 2013)

Fresquez, P.R., L. Hansen, and C. Hathcock, 2013. “Chemical Concentrations in Field Mice/Voles Collected from an Open-Burn Site at Technical Area 16 at Los Alamos National Laboratory, Revision 1,” Los Alamos National Laboratory document LA-UR-13-200040, Los Alamos, New Mexico. (Fresquez et al. 2013)

Gaukler S.M. and J.E. Stanek, 2020. 2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory. LA-UR-20-22529 (Gaukler and Stanek 2020).

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory document LA-UR-14-28161, Los Alamos, New Mexico. (Hathcock 2014).

Hathcock, C.D., A.W. Bartlow, and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory document LA-UR-18-22897, Los Alamos, New Mexico. (Hathcock 2018).

Krouskop, K.J., K.C. Ayers, and J.L. Proctor. 1991. “Multimedia Sampling for Dioxin at a Strip Mine Reclaimed with Sludge from Bleached Kraft Wastewater Treatment,” Tappi Journal, 74(4):235–240. (Krouskop et al. 1991)

LANL (Los Alamos National Laboratory), September 1998. “Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico. (LANL 1998)

LANL (Los Alamos National Laboratory), November 2003. “ECORISK Database (Version 2.0),” on CD, Los Alamos, New Mexico. (LANL 2003)

LANL (Los Alamos National Laboratory), November 2012a. “Screening-Level Ecological Risk Assessment Methods, Revision 3,” Los Alamos National Laboratory document LA-UR-12-24152, Los Alamos, New Mexico. (LANL 2012a)

LANL (Los Alamos National Laboratory), October 2012b. “ECORISK Database (Release 3.1),” LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2012b)

LANL (Los Alamos National Laboratory), September 30, 2017. ECORISK Database (Release 4.1), LA-UR-17-26376, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2017)

LANL (Los Alamos National Laboratory), June 2018a. Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory. LA-UR-19-25647. (LANL 2018a)

LANL (Los Alamos National Laboratory), February 2018b. “Development of Ecological Preliminary Remediation Goals for Los Alamos National Laboratory, Revision 1.1”. Los Alamos National Laboratory, Los Alamos, New Mexico. February 13, 2018. LA-UR-18-20670. EP2018-0017 (LANL 2018b)

NMED (New Mexico Environment Department). 2017. Risk Assessment Guidance for Site Investigations and Remediation. Volume II. Soil Screening Guidance for Ecological Risk Assessments. (NMED 2017)

NMED (New Mexico Environment Department). February 2019. Risk Assessment Guidance for Site Investigations and Remediation. Volume I. Soil Screening Guidance for Human Health Risk Assessments. February 2019. Rev. 1 (3/7/19) (NMED 2019)

Nyhan, J.W., C. W. Hacker, 7. E. Calhoun, and D. L. Young, June 1978. "Soil Survey of Los Alamos County, New Mexico," Los Alamos Scientific Laboratory Report LA-6779-MS, Los Alamos, New Mexico. ER ID 05702 (Nyhan et al. 1978)

Sample, B.E., Suter III, G.W., Efroymson, R.A., and Jones, D.A., May 1998. “A Guide to the ORNL Ecotoxicological Screening Benchmarks: Background, Development, and Application,” Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4783, ORNL/TM13615, Oak Ridge, TN. May 1998 (Sample et al. 1998)

Umbreit, T.H., Hesse, E.J., and Gallo, M.A., 1986. “Bioavailability Of Dioxin In Soil From A 2,4,5-T Manufacturing Site,” Science 232:497–499. (Umbreit et al. 1986)

Van den Berg et.al, 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency factors for Dioxin and Dioxin-like Compounds. ToxiSci Advance Access, July 7, 2006. (Van den Berg et al. 2006)

WHO (World Health Organization). September 2009. “Project For The Re-Evaluation Of Human And Mammalian Toxic Equivalency Factors (TEFS) Of Dioxins And Dioxin-Like Compounds”. International Programme on Chemical Safety. http://www.who.int/ipcs/assessment/tef_update/en/ (WHO 2009)

Tables

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
INORGANICS									
Aluminum	Al	13	5.46E+03	1.29E+04	9.06E+03	2.55E+03	6.59E+00	8.76E+00	13
Antimony	Sb	13	3.20E-01	6.61E+00	8.25E-01	1.74E+00	3.20E-01	4.25E-01	1
Arsenic	As	13	1.58E+00	5.25E+00	2.56E+00	1.14E+00	3.21E-01	4.20E-01	13
Barium	Ba	13	1.43E+02	4.06E+03	7.80E+02	1.08E+03	9.69E-02	1.03E+00	13
Beryllium	Be	13	4.07E-01	1.17E+00	7.38E-01	2.15E-01	1.90E-02	2.49E-02	13
Cadmium	Cd	13	9.69E-02	1.29E-01	1.05E-01	8.57E-03	9.69E-02	1.29E-01	1
Chromium	Cr	13	5.08E+00	1.23E+01	8.50E+00	2.23E+00	1.45E-01	1.93E-01	13
Cobalt	Co	13	2.99E+00	1.31E+01	5.90E+00	2.48E+00	1.45E-01	1.55E+00	13
Copper	Cu	13	5.22E+00	2.44E+01	8.82E+00	5.17E+00	2.91E-01	3.86E-01	13
Iron	Fe	13	9.12E+03	1.75E+04	1.19E+04	2.49E+03	7.75E+00	1.03E+01	13
Lead	Pb	13	9.22E+00	2.67E+01	1.23E+01	4.48E+00	3.20E-01	4.25E-01	13
Manganese	Mn	13	2.06E+02	3.10E+02	2.62E+02	3.15E+01	1.94E-01	2.58E-01	13
Mercury	Hg	13	5.97E-03	3.15E-02	1.33E-02	8.00E-03	3.64E-03	4.67E-03	13
Nickel	Ni	13	3.78E+00	5.53E+01	1.12E+01	1.36E+01	9.51E-02	1.24E-01	13
Perchlorate	ClO4	13	5.05E-04	6.37E-04	5.40E-04	4.67E-05	5.05E-04	6.37E-04	2
Selenium	Se	13	5.14E-01	1.09E+00	7.37E-01	1.75E-01	3.42E-01	4.47E-01	13
Silver	Ag	13	1.01E-01	8.57E+01	7.40E+00	2.36E+01	9.69E-02	1.29E-01	12
Thallium	Tl	13	1.48E-01	4.06E-01	2.34E-01	8.33E-02	1.33E-01	1.74E-01	13
Vanadium	V	13	1.37E+01	2.70E+01	2.04E+01	4.44E+00	9.69E-02	1.29E-01	13
Zinc	Zn	13	1.91E+01	3.34E+02	5.77E+01	8.42E+01	3.88E-01	5.15E-01	13
ORGANICS									
2,4-Diamino-6-nitrotoluene	6629-29-4	13	4.93E-01	5.00E-01	4.95E-01	2.64E-03	4.93E-01	5.00E-01	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	**CAS**	**Sample Size**	**Minimum (mg/kg)**	**Maximum (mg/kg)**	**Mean (mg/kg)**	**SD (mg/kg)**	**Minimum MDL (mg/kg)**	**Maximum MDL (mg/kg)**	**Number of Detected Values**
2,6-Diamino-4-nitrotoluene	59229-75-3	13	6.50E-01	6.60E-01	6.53E-01	3.73E-03	6.50E-01	6.60E-01	0
3,5-Dinitroaniline	618-87-1	13	2.96E-01	3.00E-01	2.97E-01	1.55E-03	2.96E-01	3.00E-01	0
Acenaphthene	83-32-9	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Acenaphthylene	208-96-8	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Acetone	67-64-1	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Amino-2,6-dinitrotoluene [4-]	19406-51-0	13	1.48E-01	6.55E-01	1.87E-01	1.41E-01	1.48E-01	1.50E-01	1
Amino-4,6-dinitrotoluene [2-]	35572-78-2	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0
Aniline	62-53-3	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Anthracene	120-12-7	13	1.02E-02	5.19E-02	2.10E-02	1.77E-02	1.02E-02	5.19E-02	1
Azobenzene	103-33-3	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Benzene	71-43-2	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Benzo(a)anthracene	56-55-3	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Benzo(a)pyrene	50-32-8	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Benzo(b)fluoranthene	205-99-2	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Benzo(g,h,i)perylene	191-24-2	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Benzo(k)fluoranthene	207-08-9	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Benzoic Acid	65-85-0	13	1.71E-01	8.66E-01	3.35E-01	2.99E-01	1.71E-01	8.66E-01	0
Benzyl Alcohol	100-51-6	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Bis(2-chloroethoxy)methane	111-91-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Bis(2-chloroethyl)ether	111-44-4	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Bis(2-ethylhexyl)phthalate	117-81-7	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Bromobenzene	108-86-1	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Bromochloromethane	74-97-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Bromodichloromethane	75-27-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Bromoform	75-25-2	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Bromomethane	74-83-9	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Bromophenyl-phenylether [4-]	101-55-3	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Butanone [2-]	78-93-3	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Butylbenzene [n-]	104-51-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Butylbenzene [sec-]	135-98-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Butylbenzene [tert-]	98-06-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Butylbenzylphthalate	85-68-7	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Carbon Disulfide	75-15-0	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Carbon Tetrachloride	56-23-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chloro-3-methylphenol [4-]	59-50-7	13	1.36E-01	6.93E-01	2.68E-01	2.39E-01	1.36E-01	6.93E-01	0
Chloroaniline [4-]	106-47-8	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Chlorobenzene	108-90-7	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chlorodibromomethane	124-48-1	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chloroethane	75-00-3	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chloroform	67-66-3	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chloromethane	74-87-3	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chloronaphthalene [2-]	91-58-7	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Chlorophenol [2-]	95-57-8	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Chlorophenyl-phenyl [4-] Ether	7005-72-3	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Chlorotoluene [2-]	95-49-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chlorotoluene [4-]	106-43-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Chrysene	218-01-9	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Dibenz(a,h)anthracene	53-70-3	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Dibenzofuran	132-64-9	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Dibromo-3-Chloropropane [1,2-]	96-12-8	14	4.94E-04	6.32E-04	5.21E-04	3.30E-05	4.94E-04	6.32E-04	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Dibromoethane [1,2-]	106-93-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dibromomethane	74-95-3	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichlorobenzene [1,2-]	95-50-1	27	3.29E-04	5.19E-01	9.70E-02	1.59E-01	3.29E-04	5.19E-01	0
Dichlorobenzene [1,3-]	541-73-1	27	3.29E-04	5.19E-01	9.70E-02	1.59E-01	3.29E-04	5.19E-01	0
Dichlorobenzene [1,4-]	106-46-7	27	3.29E-04	5.19E-01	9.70E-02	1.59E-01	3.29E-04	5.19E-01	0
Dichlorobenzidine [3,3'-]	91-94-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Dichlorodifluoromethane	75-71-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloroethane [1,1-]	75-34-3	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloroethane [1,2-]	107-06-2	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloroethene [1,1-]	75-35-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloroethene [cis-1,2-]	156-59-2	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloroethene [trans-1,2-]	156-60-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichlorophenol [2,4-]	120-83-2	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Dichloropropane [1,2-]	78-87-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloropropane [1,3-]	142-28-9	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloropropane [2,2-]	594-20-7	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloropropene [1,1-]	563-58-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloropropene [cis-1,3-]	10061-01-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Dichloropropene [trans-1,3-]	10061-02-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Diethylphthalate	84-66-2	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Dimethyl Phthalate	131-11-3	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Dimethylphenol [2,4-]	105-67-9	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Di-n-butylphthalate	84-74-2	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Dinitro-2-methylphenol [4,6-]	534-52-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Dinitrobenzene [1,3-]	99-65-0	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Dinitrophenol [2,4-]	51-28-5	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Dinitrotoluene [2,4-]	121-14-2	26	1.02E-01	5.19E-01	1.75E-01	1.27E-01	1.02E-01	5.19E-01	0
Dinitrotoluene [2,6-]	606-20-2	26	1.02E-01	5.19E-01	1.75E-01	1.27E-01	1.02E-01	5.19E-01	0
Di-n-octylphthalate	117-84-0	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Diphenylamine	122-39-4	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Ethylbenzene	100-41-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Fluoranthene	206-44-0	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Fluorene	86-73-7	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Heptachlorodibenzodioxin [1,2,3,4,6,7,8-]	35822-46-9	13	5.15E-07	1.05E-03	1.59E-04	3.71E-04	1.66E-06	1.68E-06	12
Heptachlorodibenzodioxins (Total)	37871-00-4	13	0.00E+00	1.80E-03	2.79E-04	6.35E-04			11
Heptachlorodibenzofuran [1,2,3,4,6,7,8-]	67562-39-4	13	4.99E-07	3.50E-04	5.39E-05	1.24E-04	1.66E-06	1.68E-06	9
Heptachlorodibenzofuran [1,2,3,4,7,8,9-]	55673-89-7	13	4.99E-07	1.61E-05	2.83E-06	5.51E-06	1.66E-06	1.68E-06	4
Heptachlorodibenzofurans (Total)	38998-75-3	13	0.00E+00	7.45E-04	1.13E-04	2.65E-04			9
Hexachlorobenzene	118-74-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Hexachlorobutadiene	87-68-3	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Hexachlorocyclopentadiene	77-47-4	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Hexachlorodibenzodioxin [1,2,3,4,7,8-]	39227-28-6	13	4.98E-07	1.90E-05	3.27E-06	6.64E-06	1.73E-06	1.75E-06	3
Hexachlorodibenzodioxin [1,2,3,6,7,8-]	57653-85-7	13	4.98E-07	3.93E-05	6.27E-06	1.37E-05	1.66E-06	1.68E-06	4
Hexachlorodibenzodioxin [1,2,3,7,8,9-]	19408-74-3	13	4.98E-07	4.96E-05	7.92E-06	1.76E-05	1.95E-06	1.97E-06	4
Hexachlorodibenzodioxins (Total)	34465-46-8	13	0.00E+00	3.56E-04	5.57E-05	1.26E-04			8
Hexachlorodibenzofuran [1,2,3,4,7,8-]	70648-26-9	13	4.98E-07	1.08E-05	2.04E-06	3.68E-06	1.66E-06	1.68E-06	4
Hexachlorodibenzofuran [1,2,3,6,7,8-]	57117-44-9	13	4.98E-07	1.47E-05	2.62E-06	5.04E-06	1.66E-06	1.68E-06	4
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	13	4.97E-07	1.30E-06	6.12E-07	2.76E-07	1.71E-06	1.74E-06	2
Hexachlorodibenzofuran [2,3,4,6,7,8-]	60851-34-5	13	4.98E-07	1.95E-05	3.35E-06	6.78E-06	1.66E-06	1.68E-06	4
Hexachlorodibenzofurans (Total)	55684-94-1	13	0.00E+00	3.79E-04	5.82E-05	1.36E-04			7

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Hexachloroethane	67-72-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Hexanone [2-]	591-78-6	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
HMX	2691-41-0	13	1.48E-01	1.84E+00	3.63E-01	4.80E-01	1.48E-01	1.50E-01	5
Indeno(1,2,3-cd)pyrene	193-39-5	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Iodomethane	74-88-4	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Isophorone	78-59-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Isopropylbenzene	98-82-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Isopropyltoluene [4-]	99-87-6	14	3.29E-04	6.68E-04	3.71E-04	8.83E-05	3.29E-04	4.21E-04	1
Methyl-2-pentanone [4-]	108-10-1	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Methylene Chloride	75-09-2	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Methylnaphthalene [2-]	91-57-6	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Methylphenol [2-]	95-48-7	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Methylphenol [3-,4-]	65794-96-9	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Naphthalene	91-20-3	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Nitroaniline [2-]	88-74-4	13	1.13E-01	5.71E-01	2.21E-01	1.97E-01	1.13E-01	5.71E-01	0
Nitroaniline [3-]	99-09-2	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitroaniline [4-]	100-01-6	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitrobenzene	98-95-3	26	1.02E-01	5.19E-01	1.75E-01	1.27E-01	1.02E-01	5.19E-01	0
Nitrophenol [2-]	88-75-5	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitrophenol [4-]	100-02-7	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitrosodimethylamine [N-]	62-75-9	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitroso-di-n-propylamine [N-]	621-64-7	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Nitrotoluene [2-]	88-72-2	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0
Nitrotoluene [3-]	99-08-1	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0
Nitrotoluene [4-]	99-99-0	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Octachlorodibenzodioxin [1,2,3,4,6,7,8,9-]	3268-87-9	13	2.78E-06	5.53E-03	8.47E-04	1.97E-03	3.32E-06	3.36E-06	13
Octachlorodibenzofuran [1,2,3,4,6,7,8,9-]	39001-02-0	13	9.97E-07	5.88E-04	9.11E-05	2.11E-04	3.32E-06	3.36E-06	9
Oxybis(1-chloropropane) [2,2'-]	108-60-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Pentachlorodibenzodioxin [1,2,3,7,8-]	40321-76-4	13	4.97E-07	7.95E-06	1.59E-06	2.67E-06	1.66E-06	1.68E-06	2
Pentachlorodibenzodioxins (Total)	36088-22-9	13	0.00E+00	4.38E-05	6.54E-06	1.54E-05			4
Pentachlorodibenzofuran [1,2,3,7,8-]	57117-41-6	13	4.97E-07	1.05E-06	5.75E-07	1.86E-07	1.66E-06	1.68E-06	2
Pentachlorodibenzofuran [2,3,4,7,8-]	57117-31-4	13	4.97E-07	1.32E-06	6.19E-07	2.92E-07	1.75E-06	1.78E-06	2
Pentachlorodibenzofurans (Totals)	30402-15-4	13	0.00E+00	7.08E-05	1.13E-05	2.59E-05			5
Pentachlorophenol	87-86-5	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
PETN	78-11-5	13	2.46E-01	2.50E-01	2.47E-01	1.57E-03	2.46E-01	2.50E-01	0
Phenanthrene	85-01-8	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Phenol	108-95-2	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Propylbenzene [1-]	103-65-1	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Pyrene	129-00-0	13	1.02E-02	5.19E-02	2.01E-02	1.79E-02	1.02E-02	5.19E-02	0
Pyridine	110-86-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
RDX	121-82-4	13	1.48E-01	2.01E-01	1.53E-01	1.46E-02	1.48E-01	1.50E-01	1
Styrene	100-42-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
TATB	3058-38-6	13	2.96E-01	7.22E+00	2.03E+00	2.46E+00	2.96E-01	7.39E-01	6
Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	13	9.97E-08	4.15E-07	1.54E-07	1.04E-07	3.32E-07	3.36E-07	3
Tetrachlorodibenzodioxins (Total)	41903-57-5	13	0.00E+00	2.34E-06	2.75E-07	6.38E-07			6
Tetrachlorodibenzofuran [2,3,7,8-]	51207-31-9	13	1.21E-07	4.07E-07	2.16E-07	8.56E-08	3.32E-07	3.36E-07	2
Tetrachlorodibenzofurans (Totals)	55722-27-5	13	0.00E+00	1.12E-05	1.96E-06	3.55E-06			8
Tetrachloroethane [1,1,1,2-]	630-20-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Tetrachloroethane [1,1,2,2-]	79-34-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Tetrachloroethene	127-18-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0

Table 2-1. Summary Statistics for the 2018 Soil Data

Analyte Name	CAS	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Tetryl	479-45-8	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0
Toluene	108-88-3	14	3.29E-04	6.99E-04	3.88E-04	9.91E-05	3.29E-04	4.21E-04	3
Trichloro-1,2,2-trifluoroethane [1,1,2-]	76-13-1	14	1.65E-03	2.11E-03	1.74E-03	1.11E-04	1.65E-03	2.11E-03	0
Trichlorobenzene [1,2,4-]	120-82-1	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Trichloroethane [1,1,1-]	71-55-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trichloroethane [1,1,2-]	79-00-5	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trichloroethene	79-01-6	14	3.29E-04	4.21E-04	3.48E-04	2.19E-05	3.29E-04	4.21E-04	0
Trichlorofluoromethane	75-69-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trichlorophenol [2,4,5-]	95-95-4	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Trichlorophenol [2,4,6-]	88-06-2	13	1.02E-01	5.19E-01	2.01E-01	1.79E-01	1.02E-01	5.19E-01	0
Trichloropropane [1,2,3-]	96-18-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trimethylbenzene [1,2,4-]	95-63-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trimethylbenzene [1,3,5-]	108-67-8	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Trinitrobenzene [1,3,5-]	99-35-4	13	1.48E-01	1.50E-01	1.48E-01	6.60E-04	1.48E-01	1.50E-01	0
Trinitrotoluene [2,4,6-]	118-96-7	13	1.48E-01	2.52E+00	3.49E-01	6.56E-01	1.48E-01	1.50E-01	2
Tris (o-cresyl) phosphate	78-30-8	13	2.96E-01	3.00E-01	2.97E-01	1.55E-03	2.96E-01	3.00E-01	0
Vinyl Chloride	75-01-4	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Xylene [1,2-]	95-47-6	14	3.29E-04	4.21E-04	3.47E-04	2.20E-05	3.29E-04	4.21E-04	0
Xylene [1,3-]+Xylene [1,4-]	Xylene [m+p]	14	6.59E-04	8.44E-04	6.95E-04	4.42E-05	6.59E-04	8.44E-04	0

Table 2-2. Human Health Screening Results for Comparison to Maximum Exposure Point Concentrations - 2018 Sampling Data

Parameter Name	**Max (mg/kg)**	**BV (mg/kg)**	**Max/ BV**	**NMSSL Res - Cancer (mg/kg)**	**NMSSL Worker- Cancer (mg/kg)**	**Res Cancer Ratio**	**Worker Cancer Ratio**	**NMSSL Res – NC (mg/kg)**	**NMSSL Worker - NC (mg/kg)**	**Res HQ**	**Worker HQ**
Aluminum	1.29E+04	29200	0.44								
Antimony	6.61E+00	0.83	7.96	NA	NA	NA	NA	3.1E+01	5.2E+02	2E-01	1E-02
Arsenic	5.25E+00	8.17	0.64								
Barium	4.06E+03	295	13.76	NA	NA	NA	NA	1.6E+04	2.5E+05	3E-01	2E-02
Beryllium	1.17E+00	1.83	0.64								
Cadmium	1.29E-01	0.4	0.32								
Calcium	3.29E+03	6120	0.54								
Chromium	1.23E+01	19.3	0.64								
Cobalt	1.31E+01	8.64	1.52	1.7E+04	8.3E+04	8E-04	2E-04	2.3E+01	3.9E+02	6E-01	3E-02
Copper	2.44E+01	14.7	1.66	NA	NA	NA	NA	3.1E+03	5.2E+04	8E-03	5E-04
Iron	1.75E+04	21500	0.81								
Lead	2.67E+01	22.3	1.20	NA	NA	NA	NA	4E+02	8E+02	7E-02	3E-02
Magnesium	2.93E+03	4610	0.64								
Manganese	3.10E+02	671	0.46								
Mercury	3.15E-02	0.1	0.32								
Nickel	5.53E+01	15.4	3.59	5.9E+05	2.9E+06	9E-05	2E-05	1.6E+03	2.6E+04	4E-02	2E-03
Perchlorate	6.37E-04	0	NA								
Potassium	2.66E+03	3460	0.77								
Selenium	1.09E+00	1.52	0.72								
Silver	8.57E+01	1	85.70	NA	NA	NA	NA	3.9E+02	6.5E+03	2E-01	1E-02
Sodium	1.87E+02	915	0.20								
Thallium	4.06E-01	0.73	0.56								
Vanadium	2.70E+01	39.6	0.68								

Table 2-2. Human Health Screening Results for Comparison to Maximum Exposure Point Concentrations - 2018 Sampling Data

Parameter Name	**Max (mg/kg)**	**BV (mg/kg)**	**Max/ BV**	**NMSSL Res - Cancer (mg/kg)**	**NMSSL Worker-Cancer (mg/kg)**	**Res Cancer Ratio**	**Worker Cancer Ratio**	**NMSSL Res – NC (mg/kg)**	**NMSSL Worker - NC (mg/kg)**	**Res HQ**	**Worker HQ**
Zinc	3.34E+02	48.8	6.84	NA	NA	NA	NA	2.3E+04	3.9E+05	1E-02	9E-04
Amino-2,6-dinitrotoluene[4-]	6.55E-01	NA	NA	NA	NA	NA	NA	1.5E+02	2.3E+03	4E-03	3E-04
Anthracene	5.19E-02	NA	NA	NA	NA	NA	NA	1.7E+04	2.5E+05	3E-06	2E-07
HMX	1.84E+00	NA	NA	NA	NA	NA	NA	3.8E+03	6.3E+04	5E-04	3E-05
Isopropyltoluene[4-]	6.68E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RDX	2.01E-01	NA	NA	8.3E+01	4.3E+02	2E-03	5E-04	3.0E+02	4.9E+03	7E-04	4E-05
TATB	7.22E+00	NA	NA	NA	NA	NA	NA	*2.2E+03*	*3.2E+04*	3E-03	2E-04
Toluene	6.99E-04	NA	NA	NA	NA	NA	NA	5.2E+03	6.1E+04	1E-07	1E-08
Trinitrotoluene[2,4,6-]	2.52E+00	NA	NA	2.1E+02	1.1E+03	1E-02	2E-03	3.6E+01	5.7E+02	7E-02	4E-03
Hazard Index						**8E-06**	**1E-06**			**1E+00**	**8E-02**

Shaded Max/BV cells indicate the maximum>BV
Shaded NMSSL cells indicate the EPA RSL for an HQ of 1 is used because a NMSSL is not available
Italics – a surrogate is applied. See Section 1.2.3
If the maximum <BV, no further evaluation is performed
Cancer ratio = Maximum/NMSSL cancer
HQ = Maximum/NMSSL Noncancer

Abbreviations:
BV – Background value
Eco SL – Ecological screening level
HQ – Noncancer hazard quotient
HI – Hazard index
Max – Maximum reported result
NA – Not available
NC – Noncancer
NMSSL – New Mexico soil screening level
Res - Residential
SL – Screening level

Table 2-3. Fall 2018 Soil Data Dioxin and Furan Human Health TEFs and Screening Results by Sample

Congener Name	CAS	Grid Point=	1	Grid Point=	2	Grid Point=	3	Grid Point=	3 dup	Grid Point=	4	Grid Point=	5
		Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	4.68E-05	1	6.83E-06	1	9.39E-04	1	1.05E-03	1	5.11E-06	1	5.24E-07	0
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	2.08E-05	1	2.15E-06	1	3.16E-04	1	3.50E-04	1	2.39E-06	1	5.00E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	6.78E-07	1	4.99E-07	0	1.43E-05	1	1.61E-05	1	7.67E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	1.11E-06	1	4.99E-07	0	1.74E-05	1	1.90E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.95E-06	1	4.99E-07	0	3.50E-05	1	3.93E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	2.74E-06	1	4.99E-07	0	4.54E-05	1	4.96E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	7.82E-07	1	4.99E-07	0	9.84E-06	1	1.08E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	1.01E-06	1	4.99E-07	0	1.32E-05	1	1.47E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.97E-07	0	4.99E-07	0	1.16E-06	1	1.30E-06	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	1.27E-06	1	4.99E-07	0	1.77E-05	1	1.95E-05	1	4.98E-07	0	5.00E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	2.62E-04	1	4.92E-05	1	5.04E-03	1	5.53E-03	1	3.34E-05	1	2.78E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	2.29E-05	1	4.29E-06	1	5.46E-04	1	5.88E-04	1	3.68E-06	1	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.97E-07	0	4.99E-07	0	7.23E-06	1	7.95E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.97E-07	0	4.99E-07	0	9.29E-07	1	1.05E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.97E-07	0	4.99E-07	0	1.23E-06	1	1.32E-06	1	4.98E-07	0	5.00E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.21E-07	1	9.99E-08	0	3.50E-07	1	4.15E-07	1	1.20E-07	0	1.52E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.79E-07	0	1.21E-07	0	2.78E-07	0	3.28E-07	0	2.15E-07	0	2.12E-07	0
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	4.68E-07	0.01	6.83E-08	0.01	9.39E-06	0.01	tyui	0.01	5.11E-08	0.01	5.24E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	2.08E-07	0.01	2.15E-08	0.01	3.16E-06	0.01	3.50E-06	0.01	2.39E-08	0.01	5.00E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	6.78E-09	0.01	4.99E-09	0.01	1.43E-07	0.01	1.61E-07	0.01	7.67E-09	0.01	5.00E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.10	1.11E-07	0.10	4.99E-08	0.10	1.74E-06	0.10	1.90E-06	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.10	1.95E-07	0.10	4.99E-08	0.10	3.50E-06	0.10	3.93E-06	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	2.74E-07	0.10	4.99E-08	0.10	4.54E-06	0.10	4.96E-06	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.10	7.82E-08	0.10	4.99E-08	0.10	9.84E-07	0.10	1.08E-06	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	1.01E-07	0.10	4.99E-08	0.10	1.32E-06	0.10	1.47E-06	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	4.97E-08	0.10	4.99E-08	0.10	1.16E-07	0.10	1.30E-07	0.10	4.98E-08	0.10	5.00E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	1.27E-07	0.10	4.99E-08	0.10	1.77E-06	0.10	1.95E-06	0.10	4.98E-08	0.10	5.00E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	7.86E-08	0.0003	1.48E-08	0.0003	1.51E-06	0.0003	1.66E-06	0.0003	1.00E-08	0.0003	8.34E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	6.87E-09	0.0003	1.29E-09	0.0003	1.64E-07	0.0003	1.76E-07	0.0003	1.10E-09	0.0003	3.00E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	4.97E-07	1.00	4.99E-07	1.00	7.23E-06	1.00	7.95E-06	1.00	4.98E-07	1.00	5.00E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	1.49E-08	0.03	1.50E-08	0.03	2.79E-08	0.03	3.15E-08	0.03	1.49E-08	0.03	1.50E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.30	1.49E-07	0.30	1.50E-07	0.30	3.69E-07	0.30	3.96E-07	0.30	1.49E-07	0.30	1.50E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	1.21E-07	1.00	9.99E-08	1.00	3.50E-07	1.00	4.15E-07	1.00	1.20E-07	1.00	1.52E-07
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.10	1.79E-08	0.10	1.21E-08	0.10	2.78E-08	0.10	3.28E-08	0.10	2.15E-08	0.10	2.12E-08
TEQ			**2.50E-06**		**1.24E-06**		**3.63E-05**		**2.97E-05**		**1.25E-06**		**1.20E-06**
NMED SSL Residential	**4.90E-05**	**Risk Ratio =**	5.11E-02		2.52E-02		7.42E-01		6.07E-01		2.54E-02		2.46E-02
NMED SSL Industrial	**8.47E-03**	**Risk Ratio =**	2.96E-04		1.46E-04		4.29E-03		3.51E-03		1.47E-04		1.42E-04

Table 2-2. Fall 2018 Soil Data Dioxin and Furan Human Health TEFs and Screening Results by Sample, cont.

Congener Name	CAS	Grid Point=	6	Grid Point=	7	Grid Point=	8	Grid Point=	9	Grid Point=	10	Grid Point=	11	Grid Point=	12
		Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	2.05E-06	1	7.45E-07	1	4.90E-06	1	9.34E-06	1	3.24E-06	1	5.15E-07	1	4.12E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	4.99E-07	0	5.00E-07	0	7.08E-07	1	4.05E-06	1	1.95E-06	1	4.99E-07	0	7.71E-07	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	9.02E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.32E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.71E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	5.97E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.09E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.27E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	6.77E-06	1	4.29E-06	1	1.43E-05	1	3.78E-05	1	1.36E-05	1	3.11E-06	1	1.70E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	9.97E-07	0	1.00E-06	0	1.07E-06	1	8.99E-06	1	3.81E-06	1	9.99E-07	0	1.08E-06	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.97E-08	0	1.00E-07	0	9.98E-08	0	1.38E-07	0	1.00E-07	0	9.99E-08	0	1.01E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	2.77E-07	0	1.33E-07	0	1.62E-07	0	4.07E-07	1	2.13E-07	0	1.34E-07	0	1.49E-07	1
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	0.01	2.05E-08	0.01	7.45E-09	0.01	4.90E-08	0.01	9.34E-08	0.01	3.24E-08	0.01	5.15E-09	0.01	4.12E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	0.01	4.99E-09	0.01	5.00E-09	0.01	7.08E-09	0.01	4.05E-08	0.01	1.95E-08	0.01	4.99E-09	0.01	7.71E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	0.01	4.99E-09	0.01	5.00E-09	0.01	4.99E-09	0.01	9.02E-09	0.01	5.02E-09	0.01	4.99E-09	0.01	5.03E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	4.99E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	7.32E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	6.71E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	5.97E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	7.09E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	4.99E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	4.99E-08	0.10	5.00E-08	0.10	4.99E-08	0.10	6.27E-08	0.10	5.02E-08	0.10	4.99E-08	0.10	5.03E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	0.0003	2.03E-09	0.0003	1.29E-09	0.0003	4.29E-09	0.0003	1.13E-08	0.0003	4.08E-09	0.0003	9.33E-10	0.0003	5.10E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	0.0003	2.99E-10	0.0003	3.00E-10	0.0003	3.21E-10	0.0003	2.70E-09	0.0003	1.14E-09	0.0003	3.00E-10	0.0003	3.24E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	4.99E-07	1.00	5.00E-07	1.00	4.99E-07	1.00	4.99E-07	1.00	5.02E-07	1.00	4.99E-07	1.00	5.03E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	1.50E-08	0.03	1.50E-08	0.03	1.50E-08	0.03	1.50E-08	0.03	1.51E-08	0.03	1.50E-08	0.03	1.51E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.30	1.50E-07	0.30	1.50E-07	0.30	1.50E-07	0.30	1.50E-07	0.30	1.51E-07	0.30	1.50E-07	0.30	1.51E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	9.97E-08	1.00	1.00E-07	1.00	9.98E-08	1.00	1.38E-07	1.00	1.00E-07	1.00	9.99E-08	1.00	1.01E-07
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.10	2.77E-08	0.10	1.33E-08	0.10	1.62E-08	0.10	4.07E-08	0.10	2.13E-08	0.10	1.34E-08	0.10	1.49E-08
TEQ			**1.17E-06**		**1.15E-06**		**1.19E-06**		**1.43E-06**		**1.20E-06**		**1.14E-06**		**1.20E-06**
NMED SSL Residential	**4.90E-05**		2.39E-02		2.34E-02		2.44E-02		2.92E-02		2.45E-02		2.33E-02		2.44E-02
NMED SSL Industrial	**8.47E-03**		1.38E-04		1.35E-04		1.41E-04		1.69E-04		1.42E-04		1.35E-04		1.41E-04

Notes: The TECi are summed in each column to obtain the TEQ. The TEQ is divided by the residential or the industrial SSLs for TCDD to obtain a risk ratio, shown directly under the TEQ. None of the TEQs exceeded the SLs. Grid point corresponds to sample locations on Figure 1-1.

Detect Code: 0= nondetect; 1=detect, ND – Not detected

Table 3-1. Ecological Screening Evaluation for the Fall 2018 Data

Parameter Name	Parameter Code	Maximum Reported Result	Number of Detected Values	Maximum BV (mg/kg)	EPC/ BV	Minimum No Effect Eco SL (mg/kg)	EPC/ Min Eco SL NE	Minimum Low Effect Eco SL (mg/kg)	EPC/ Min Eco SL LE
INORGANICS									
Aluminum	Al	1.29E+04	13	29200	4.4E-01				
Antimony	Sb	6.61E+00	1	0.83	8.0E+00	2.30E+00	3E+00	2.30E+01	3E-01
Arsenic	As	5.25E+00	13	8.17	6.4E-01				
Barium	Ba	4.06E+03	13	295	1.4E+01	1.10E+02	4E+01	2.60E+02	2E+01
Beryllium	Be	1.17E+00	13	1.83	6.4E-01				
Cadmium	Cd	1.29E-01	1	0.4	3.2E-01				
Calcium	Ca	3.29E+03	13	6120	5.4E-01				
Chromium	Cr	1.23E+01	13	19.3	6.4E-01				
Cobalt	Co	1.31E+01	13	8.64	1.5E+00	1.30E+01	1E+00	1.30E+02	1E-01
Copper	Cu	2.44E+01	13	14.7	1.7E+00	1.40E+01	2E+00	4.30E+01	6E-01
Iron	Fe	1.75E+04	13	21500	8.1E-01				
Lead	Pb	2.67E+01	13	22.3	1.2E+00	1.10E+01	2E+00	2.30E+01	1E+00
Magnesium	Mg	2.93E+03	13	4610	6.4E-01				
Manganese	Mn	3.10E+02	13	671	4.6E-01				
Mercury	Hg	3.15E-02	13	0.1	3.2E-01				
Nickel	Ni	5.53E+01	13	15.4	3.6E+00	1.00E+01	6E+00	2.10E+01	3E+00
Perchlorate	ClO4	6.37E-04	2	0	NA	1.20E-01	5E-03	2.40E-01	3E-03
Potassium	K	2.66E+03	13	3460	7.7E-01				
Selenium	Se	1.09E+00	13	1.52	7.2E-01				
Silver	Ag	8.57E+01	12	1	8.6E+01	2.60E+00	3E+01	2.60E+01	3E+00

Table 3-1. Ecological Screening Evaluation for the Fall 2018 Data

Parameter Name	**Parameter Code**	**Maximum Reported Result**	**Number of Detected Values**	**Maximum BV (mg/kg)**	**EPC/ BV**	**Minimum No Effect Eco SL (mg/kg)**	**EPC/ Min Eco SL NE**	**Minimum Low Effect Eco SL (mg/kg)**	**EPC/ Min Eco SL LE**
Sodium	Na	1.87E+02	13	915	2.0E-01				
Thallium	Tl	4.06E-01	13	0.73	5.6E-01				
Vanadium	V	2.70E+01	13	39.6	6.8E-01				
Zinc	Zn	3.34E+02	13	48.8	6.8E+00	4.70E+01	7E+00	1.20E+02	3E+00
ORGANICS									
Amino-2,6-dinitrotoluene[4-]	19406-51-0	6.55E-01	1	" "	" "	1.20E+01	6E-02	1.20E+02	6E-03
Anthracene	120-12-7	5.19E-02	1	" "	" "	6.80E+00	8E-03	9.00E+00	6E-03
HMX	2691-41-0	1.84E+00	5	" "	" "	1.60E+01	1E-01	1.60E+02	1E-02
Isopropyltoluene[4-]	99-87-6	6.68E-04	1	" "	" "	NA	NA	NA	NA
RDX	121-82-4	2.01E-01	1	" "	" "	2.30E+00	9E-02	4.30E+00	5E-02
TATB	3058-38-6	7.22E+00	6	" "	" "	*1.00E+01*	7E-01	*2.8E+01*	3E-01
Toluene	108-88-3	6.99E-04	3	" "	" "	2.30E+01	3E-05	2.30E+02	3E-06
Trinitrotoluene[2,4,6-]	118-96-7	2.52E+00	2	" "	" "	7.50E+00	3E-01	1.30E+01	2E-01

Shaded cells indicate the ratio > 1
Italics – a surrogate is used. See Section 1.2.3.

Abbreviations:
BV – Background Value
Eco SL – Ecological Screening Value
EPC – Maximum Exposure Point Concentration
Max – Maximum
mg/kg – Milligram per Kilogram
LE – Low Effect
NE – No Effect

Table 3-2. Ecological Risk Evaluation Using UCL95 EPCs.

Parameter Name	Maximum Reported Result (mg/kg)	Number of Detected Values[1]	BV (mg/kg)	UCL95 (mg/kg)	UCL Type	Distribution	UCL/BV	Minimum Eco SL NE	UCL/ Eco NE	Minimum Eco SL LE	UCL/ Eco LE
Antimony	6.61E+00	1	8.30E-01	3.39E-01	Median All Data (1 detect only)	None	4.08E-01	2.3E+00	1E-01	2.3E+01	1E-02
Barium	4.06E+03	12	2.95E+02	2.22+03	95% Chebyshev (Mean, Sd) UCL	Lognormal	7.54E+00	1.1E+02	2E+01	2.6E+02	9E+00
Cobalt	1.31E+01	12	8.64E+00	7.37E+00	95% Adjusted Gamma UCL	Gamma	8.53E-01	1.30E+01	6E-01	1.30E+02	6E-02
Copper	2.44E+01	12	1.47E+01	1.24E+01	95% Adjusted Gamma UCL	Gamma	8.40E-01	1.4E+01	9E-01	4.3E+01	3E-01
Lead	2.67E+01	12	2.23E+01	1.49E+01	95% Student's-t UCL	None	6.68E-01	1.1E+01	1E+00	2.3E+01	6E-01
Nickel	5.53E+01	12	1.54E+01	1.84E+01	95% H-UCL	Approximate Lognormal	1.20E+00	1.0E+01	2E+00	2.1E+01	9E-01
Silver	8.57E+01	12	1.00E+00	7.88E+01	99% KM (Chebyshev) UCL	Approximate Lognormal	7.88E+01	2.6E+00	3E+01	2.6E+01	3E+00
Zinc	3.34E+02	12	4.88E+01	1.70E+02	95% Chebyshev (Mean, Sd) UCL	Nonparametric	3.49E+00	4.7E+01	4E+00	1.2E+02	1E+00
TATB	7.22E+00	6	NA	5.001	95% Chebyshev (Mean, Sd) UCL	None	NA	1.00E+01	5E-01	2.80E+01	2E-01
HI									6E+01		2E+01

Shaded cells represent HQs>1

HI is the sum of all HQs > 0.3

1 – Number of detected values is based on sample count after averaging duplicates

Abbreviations:

BV – Background Value
Eco SL – Ecological Screening Level
HI – Hazard Index
LE – Low Effect
mg/kg – milligram per kilogram
NE – No Effect Sd
Sd – Standard deviation
UCL – Upper Confidence Limit

Table 3-3. Toxic Equivalency Factors (TEFs) Used for Calculating TCDD Equivalent Concentrations

Name	**CAS**	**Mammalian TEF**[a]	**Avian TEF**[b]
Chlorinated dibenzo-p-dioxins			
2,3,7,8-TCDD	1746-01-6	1	1
1,2,3,7,8-PeCDD	40321-76-4	1	1
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HpCDD	35822-46-9	0.01	0.001
OCDD	3268-87-9	0.0003	0.0001
Chlorinated dibenzofurans			
2,3,7,8-TCDF	51207-31-9	0.1	1
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1
2,3,4,7,8-PeCDF	57117-31-4	0.3	0.1
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	1
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01
OCDF	39001-02-0	0.0003	0.0001

[a] EPA (2010b); WHO (2009)

[b] Van den Berg et al. (1998).

Table 3-4. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Mammalian Risk Estimates by Sample

Congener Name	CAS	Grid Point=	1	Grid Point=	2	Grid Point=	3	Grid Point=	3 dup	Grid Point=	4	Grid Point=	5
		Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	4.68E-05	1	6.83E-06	1	9.39E-04	1	1.05E-03	1	5.11E-06	1	5.24E-07	0
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	2.08E-05	1	2.15E-06	1	3.16E-04	1	3.50E-04	1	2.39E-06	1	5.00E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	6.78E-07	1	4.99E-07	0	1.43E-05	1	1.61E-05	1	7.67E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	1.11E-06	1	4.99E-07	0	1.74E-05	1	1.90E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.95E-06	1	4.99E-07	0	3.50E-05	1	3.93E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	2.74E-06	1	4.99E-07	0	4.54E-05	1	4.96E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	7.82E-07	1	4.99E-07	0	9.84E-06	1	1.08E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	1.01E-06	1	4.99E-07	0	1.32E-05	1	1.47E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.97E-07	0	4.99E-07	0	1.16E-06	1	1.30E-06	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	1.27E-06	1	4.99E-07	0	1.77E-05	1	1.95E-05	1	4.98E-07	0	5.00E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	2.62E-04	1	4.92E-05	1	5.04E-03	1	5.53E-03	1	3.34E-05	1	2.78E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	2.29E-05	1	4.29E-06	1	5.46E-04	1	5.88E-04	1	3.68E-06	1	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.97E-07	0	4.99E-07	0	7.23E-06	1	7.95E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.97E-07	0	4.99E-07	0	9.29E-07	1	1.05E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.97E-07	0	4.99E-07	0	1.23E-06	1	1.32E-06	1	4.98E-07	0	5.00E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.21E-07	1	9.99E-08	0	3.50E-07	1	4.15E-07	1	1.20E-07	0	1.52E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.79E-07	0	1.21E-07	0	2.78E-07	0	3.28E-07	0	2.15E-07	0	2.12E-07	0
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	0.01	4.68E-07	0.01	6.83E-08	0.01	9.39E-06	0.01	1.05E-05	0.01	5.11E-08	0.01	ND
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	0.01	2.08E-07	0.01	2.15E-08	0.01	3.16E-06	0.01	3.50E-06	0.01	2.39E-08	0.01	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	0.01	6.78E-09	0.01	ND	0.01	1.43E-07	0.01	1.61E-07	0.01	ND	0.01	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.10	1.11E-07	0.10	ND	0.10	1.74E-06	0.10	1.90E-06	0.10	ND	0.10	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.10	1.95E-07	0.10	ND	0.10	3.50E-06	0.10	3.93E-06	0.10	ND	0.10	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	2.74E-07	0.10	ND	0.10	4.54E-06	0.10	4.96E-06	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.10	7.82E-08	0.10	ND	0.10	9.84E-07	0.10	1.08E-06	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	1.01E-07	0.10	ND	0.10	1.32E-06	0.10	1.47E-06	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	ND	0.10	ND	0.10	1.16E-07	0.10	1.30E-07	0.10	ND	0.10	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	1.27E-07	0.10	ND	0.10	1.77E-06	0.10	1.95E-06	0.10	ND	0.10	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	0.0003	7.86E-08	0.0003	1.48E-08	0.0003	1.51E-06	0.0003	1.66E-06	0.0003	1.00E-08	0.0003	8.34E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	0.0003	6.87E-09	0.0003	1.29E-09	0.0003	1.64E-07	0.0003	1.76E-07	0.0003	1.10E-09	0.0003	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	ND	1.00	ND	1.00	7.23E-06	1.00	7.95E-06	1.00	ND	1.00	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	0.03	ND	0.03	2.79E-08	0.03	3.15E-08	0.03	ND	0.03	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.30	ND	0.30	ND	0.30	3.69E-07	0.30	3.96E-07	0.30	ND	0.30	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	1.21E-07	1.00	ND	1.00	3.50E-07	1.00	4.15E-07	1.00	ND	1.00	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND
TEQ			**1.78E-06**		**1.06E-07**		**3.63E-05**		**4.02E-05**		**8.61E-08**		**8.34E-10**
Mammalian No Effect SSL	**5.80E-07**	**Risk Ratio=**	3E+00		2E-01		6E+01		7E+01		1E-01		1E-03
Mammalian Low Effect SSL	**3.80E-06**	**Risk Ratio=**	5E-01		3E-02		1E+01		1E+01		2E-02		2E-04

Table 3-4. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Mammalian Risk Estimates by Sample.

Congener Name	CAS	Grid Point=	6	Grid Point=	7	Grid Point=	8	Grid Point=	9	Grid Point=	10	Grid Point=	11	Grid Point=	12
		Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	2.05E-06	1	7.45E-07	1	4.90E-06	1	9.34E-06	1	3.24E-06	1	5.15E-07	1	4.12E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-	67562-39-4	4.99E-07	0	5.00E-07	0	7.08E-07	1	4.05E-06	1	1.95E-06	1	4.99E-07	0	7.71E-07	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9-	55673-89-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	9.02E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.32E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.71E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	5.97E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.09E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.27E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	6.77E-06	1	4.29E-06	1	1.43E-05	1	3.78E-05	1	1.36E-05	1	3.11E-06	1	1.70E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	9.97E-07	0	1.00E-06	0	1.07E-06	1	8.99E-06	1	3.81E-06	1	9.99E-07	0	1.08E-06	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.97E-08	0	1.00E-07	0	9.98E-08	0	1.38E-07	0	1.00E-07	0	9.99E-08	0	1.01E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	2.77E-07	0	1.33E-07	0	1.62E-07	0	4.07E-07	1	2.13E-07	0	1.34E-07	0	1.49E-07	1
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	0.01	2.05E-08	0.01	7.45E-09	0.01	4.90E-08	0.01	9.34E-08	0.01	3.24E-08	0.01	5.15E-09	0.01	4.12E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-	67562-39-4	0.01	ND	0.01	ND	0.01	7.08E-09	0.01	4.05E-08	0.01	1.95E-08	0.01	4.99E-09	0.01	7.71E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-	55673-89-7	0.01	ND	0.01	ND	0.01	ND	0.01	9.02E-09	0.01	ND	0.01	4.99E-09	0.01	5.03E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.10	ND	0.10	ND	0.10	ND	0.10	7.32E-08	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	ND	0.10	ND	0.10	ND	0.10	6.71E-08	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.10	ND	0.10	ND	0.10	ND	0.10	5.97E-08	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	ND	0.10	ND	0.10	ND	0.10	7.09E-08	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	ND	0.10	ND	0.10	ND	0.10	6.27E-08	0.10	ND	0.10	4.99E-08	0.10	5.03E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	0.0003	2.03E-09	0.0003	1.29E-09	0.0003	4.29E-09	0.0003	1.13E-08	0.0003	4.08E-09	0.0003	9.33E-10	0.0003	5.10E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	0.0003	ND	0.0003	ND	0.0003	3.21E-10	0.0003	2.70E-09	0.0003	1.14E-09	0.0003	3.00E-10	0.0003	3.24E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	4.99E-07	1.00	5.03E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.03	1.50E-08	0.03	1.51E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.30	ND	0.30	ND	0.30	ND	0.30	ND	0.30	ND	0.30	1.50E-07	0.30	1.51E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	9.99E-08	1.00	1.01E-07
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.10	ND	0.10	ND	0.10	ND	0.10	4.07E-08	0.10	ND	0.10	1.34E-08	0.10	1.49E-08
TEQ			**2.25E-08**		**8.74E-09**		**6.07E-08**		**5.31E-07**		**5.71E-08**		**1.14E-06**		**1.20E-06**
Mammalian No Effect SSL	**5.80E-07**		4E-02		2E-02		1E-01		9E-01		1E-01		2E+00		2E+00
Mammalian Low Effect SSL	**3.80E-06**		6E-03		2E-03		2E-02		1E-01		2E-02		3E-01		3E-01

Shaded cells indicate the ratio of the TEQ/SSL exceeds 1; Grid point corresponds to sample locations on Figure 1-1.
Detect Code: 0= nondetect; 1=detect
Abbreviations:
Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient, ND- Not detected

Table 3-5. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Congener Name	**CAS**	**Grid Point=**	**1**	**Grid Point=**	**2**	**Grid Point=**	**3**	**Grid Point=**	**3 dup**	**Grid Point=**	**4**	**Grid Point=**	**5**
		Ci	**Detect Code**	**Ci**	**Detect Code**	**Ci**	**Detect Code**	**Ci**	**Detect Code**	**Ci**	**Detect Code**	**Ci**	**Detect Code**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	4.68E-05	1	6.83E-06	1	9.39E-04	1	1.05E-03	1	5.11E-06	1	5.24E-07	0
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	2.08E-05	1	2.15E-06	1	3.16E-04	1	3.50E-04	1	2.39E-06	1	5.00E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	6.78E-07	1	4.99E-07	0	1.43E-05	1	1.61E-05	1	7.67E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	1.11E-06	1	4.99E-07	0	1.74E-05	1	1.90E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.95E-06	1	4.99E-07	0	3.50E-05	1	3.93E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	2.74E-06	1	4.99E-07	0	4.54E-05	1	4.96E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	7.82E-07	1	4.99E-07	0	9.84E-06	1	1.08E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	1.01E-06	1	4.99E-07	0	1.32E-05	1	1.47E-05	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.97E-07	0	4.99E-07	0	1.16E-06	1	1.30E-06	1	4.98E-07	0	5.00E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	1.27E-06	1	4.99E-07	0	1.77E-05	1	1.95E-05	1	4.98E-07	0	5.00E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	2.62E-04	1	4.92E-05	1	5.04E-03	1	5.53E-03	1	3.34E-05	1	2.78E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	2.29E-05	1	4.29E-06	1	5.46E-04	1	5.88E-04	1	3.68E-06	1	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.97E-07	0	4.99E-07	0	7.23E-06	1	7.95E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.97E-07	0	4.99E-07	0	9.29E-07	1	1.05E-06	1	4.98E-07	0	5.00E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.97E-07	0	4.99E-07	0	1.23E-06	1	1.32E-06	1	4.98E-07	0	5.00E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.21E-07	1	9.99E-08	0	3.50E-07	1	4.15E-07	1	1.20E-07	0	1.52E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.79E-07	0	1.21E-07	0	2.78E-07	0	3.28E-07	0	2.15E-07	0	2.12E-07	0
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	0.001	4.68E-08	0.001	6.83E-09	0.001	9.39E-07	0.001	1.05E-06	0.001	5.11E-09	0.001	ND
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	0.01	2.08E-07	0.01	2.15E-08	0.01	3.16E-06	0.01	3.50E-06	0.01	2.39E-08	0.01	ND
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	0.01	6.78E-09	0.01	ND	0.01	1.43E-07	0.01	1.61E-07	0.01	ND	0.01	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.05	5.55E-08	0.05	ND	0.05	8.70E-07	0.05	9.50E-07	0.05	ND	0.05	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.01	1.95E-08	0.01	ND	0.01	3.50E-07	0.01	3.93E-07	0.01	ND	0.01	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	2.74E-07	0.10	ND	0.10	4.54E-06	0.10	4.96E-06	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	1.00	7.82E-07	1.00	ND	1.00	9.84E-06	1.00	1.08E-05	1.00	ND	1.00	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	1.01E-07	0.10	ND	0.10	1.32E-06	0.10	1.47E-06	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	ND	0.10	ND	0.10	1.16E-07	0.10	1.30E-07	0.10	ND	0.10	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	1.27E-07	0.10	ND	0.10	1.77E-06	0.10	1.95E-06	0.10	ND	0.10	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	0.0001	2.62E-08	0.0001	4.92E-09	0.0001	5.04E-07	0.0001	5.53E-07	0.0001	3.34E-09	0.0001	2.78E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	0.0001	2.29E-09	0.0001	4.29E-10	0.0001	5.46E-08	0.0001	5.88E-08	0.0001	3.68E-10	0.0001	ND
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	ND	1.00	ND	1.00	7.23E-06	1.00	7.95E-06	1.00	ND	1.00	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.10	ND	0.10	ND	0.10	9.29E-08	0.10	1.05E-07	0.10	ND	0.10	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.10	ND	0.10	ND	0.10	1.23E-07	0.10	1.32E-07	0.10	ND	0.10	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	1.21E-07	1.00	ND	1.00	3.50E-07	1.00	4.15E-07	1.00	ND	1.00	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND
TEQ			**1.77E-06**		**3.37E-08**		**3.14E-05**		**3.46E-05**		**3.27E-08**		**2.78E-10**
Avian No Effect SSL	**4.10E-06**	**Risk Ratio=**	4E-01		8E-03		8E+00		8E+00		8E-03		7E-05
Avian Low Effect SSL	**4.10E-05**	**Risk Ratio=**	4E-02		8E-04		8E-01		8E-01		8E-04		7E-06

Table 3-5. Dioxin-Furan Concentrations, TEFs, TEQs, SLs, and Avian Risk Estimates by Sample

Congener Name	CAS	Grid Point=	6	Grid Point=	7	Grid Point=	8	Grid Point=	9	Grid Point=	10	Grid Point=	11	Grid Point=	12
		Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code	Ci	Detect Code
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	2.05E-06	1	7.45E-07	1	4.90E-06	1	9.34E-06	1	3.24E-06	1	5.15E-07	1	4.12E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	4.99E-07	0	5.00E-07	0	7.08E-07	1	4.05E-06	1	1.95E-06	1	4.99E-07	0	7.71E-07	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	9.02E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.32E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.71E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	5.97E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	7.09E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.99E-07	0	5.00E-07	0	4.99E-07	0	6.27E-07	1	5.02E-07	0	4.99E-07	0	5.03E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	6.77E-06	1	4.29E-06	1	1.43E-05	1	3.78E-05	1	1.36E-05	1	3.11E-06	1	1.70E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	9.97E-07	0	1.00E-06	0	1.07E-06	1	8.99E-06	1	3.81E-06	1	9.99E-07	0	1.08E-06	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.99E-07	0	5.00E-07	0	4.99E-07	0	4.99E-07	0	5.02E-07	0	4.99E-07	0	5.03E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.97E-08	0	1.00E-07	0	9.98E-08	0	1.38E-07	0	1.00E-07	0	9.99E-08	0	1.01E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	2.77E-07	0	1.33E-07	0	1.62E-07	0	4.07E-07	1	2.13E-07	0	1.34E-07	0	1.49E-07	1
Congener Name	**CAS**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**	**TEF**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	0.001	2.05E-09	0.001	7.45E-10	0.001	4.90E-09	0.001	9.34E-09	0.001	3.24E-09	0.001	5.15E-10	0.001	4.12E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8	67562-39-4	0.01	ND	0.01	ND	0.01	7.08E-09	0.01	4.05E-08	0.01	1.95E-08	0.01	ND	0.01	7.71E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9	55673-89-7	0.01	ND	0.01	ND	0.01	ND	0.01	9.02E-09	0.01	ND	0.01	ND	0.01	ND
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.01	ND	0.01	ND	0.01	ND	0.01	7.32E-09	0.01	ND	0.01	ND	0.01	ND
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.10	ND	0.10	ND	0.10	ND	0.10	6.71E-08	0.10	ND	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	1.00	ND	1.00	ND	1.00	ND	1.00	5.97E-07	1.00	ND	1.00	ND	1.00	ND
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.10	ND	0.10	ND	0.10	ND	0.10	7.09E-08	0.10	ND	0.10	ND	0.10	ND
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.10	ND	0.10	ND	0.10	ND	0.10	6.27E-08	0.10	ND	0.10	ND	0.10	ND
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	0.0001	6.77E-10	0.0001	4.29E-10	0.0001	1.43E-09	0.0001	3.78E-09	0.0001	1.36E-09	0.0001	3.11E-10	0.0001	1.70E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	0.0001	ND	0.0001	ND	0.0001	1.07E-10	0.0001	8.99E-10	0.0001	3.81E-10	0.0001	ND	0.0001	1.08E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND	0.10	ND
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND	1.00	ND
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1.00	ND	1.00	ND	1.00	ND	1.00	4.07E-07	1.00	ND	1.00	ND	1.00	1.49E-07
TEQ			**2.73E-09**		**1.17E-09**		**1.35E-08**		**1.28E-06**		**2.45E-08**		**8.26E-10**		**1.63E-07**
Avian No Effect SSL	**4.10E-06**		7E-04		3E-04		3E-03		3E-01		6E-03		2E-04		4E-02
Avian Low Effect SSL	**4.10E-05**		7E-05		3E-05		3E-04		3E-02		6E-04		2E-05		4E-03

Shaded cells indicate the ratio of the TEQ/SSL exceeds 1; Grid point corresponds to sample locations on Figure 1-1.
Detect Code: 0= nondetect; 1=detect
Abbreviations:
Ci – Measured Sample Concentration of Congener i; TECi – Toxicity Equivalent Concentration for Congener i; TEF – Toxicity Equivalency Factor; TEQ – Toxicity Equivalent Quotient; ND – Not detected

Table 3-6. UCL95 Evaluation for Dioxins/Furans for Mammals and Birds

Congener Name	Parameter Code	UCL	UCL Type	Distribution
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	9.12E-04	99% KM (Chebyshev) UCL	Lognormal
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	3.11E-04	99% KM (Chebyshev) UCL	Lognormal
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	9.02E-07	Median Detects - number detect =3	NA
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	1.82E-05	Maximum Detects - number detect = 2	NA
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	1.95E-06	Median Detects - number detect =3	NA
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	2.74E-06	Median Detects - number detect =3	NA
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	7.82E-07	Median Detects - number detect =3	NA
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	1.01E-06	Median Detects - number detect =3	NA
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	1.30E-06	Maximum Detect - 1 detect	NA
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	1.27E-06	Median Detects - number detect =3	NA
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	4.83E-03	99% Chebyshev (Mean, Sd) UCL	Lognormal
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	5.29E-04	99% KM (Chebyshev) UCL	Lognormal
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	7.95E-06	Maximum - 1 detect	NA
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	1.05E-06	Maximum - 1 detect	NA
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	1.32E-06	Maximum - 1 detect	NA
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	3.83E-07	Maximum Detects - number detect = 2	NA
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	4.07E-07	Maximum Detects - number detect = 2	NA

Congener Name	CAS	TEF	TECi	Congener Name	CAS	TEF	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8	35822-46-9	0.01	9.12E-06	Heptachlorodibenzodioxin[1,2,3,4,6,7,	35822-46-9	0.001	9.12E-07
Heptachlorodibenzofuran[1,2,3,4,6,7,8-	67562-39-4	0.01	3.11E-06	Heptachlorodibenzofuran[1,2,3,4,6,7,	67562-39-4	0.01	3.11E-06
Heptachlorodibenzofuran[1,2,3,4,7,8,9-	55673-89-7	0.01	9.02E-09	Heptachlorodibenzofuran[1,2,3,4,7,8,	55673-89-7	0.01	9.02E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	1.82E-06	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	0.1	9.10E-07
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.1	1.95E-07	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	0.01	1.95E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	2.74E-07	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	0.1	2.74E-07
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	0.1	7.82E-08	Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	1	7.82E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	1.01E-07	Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	0.1	1.01E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	1.30E-07	Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	0.1	1.30E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	1.27E-07	Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	0.1	1.27E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,	3268-87-9	0.0003	1.45E-06	Octachlorodibenzodioxin[1,2,3,4,6,7,8	3268-87-9	0.0001	4.83E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9	39001-02-0	0.0003	1.59E-07	Octachlorodibenzofuran[1,2,3,4,6,7,8,	39001-02-0	0.0001	5.29E-08
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	7.95E-06	Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	1	7.95E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.03	3.15E-08	Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	0.1	1.05E-07
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.3	3.96E-07	Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	0.1	1.32E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	3.83E-07	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	1	3.83E-07
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	0.1	4.07E-08	Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	1	4.07E-07
TEQ			**2.54E-05**	**TEQ**			**1.59E-05**
Mammalian No Effect SSL	**5.80E-07**	**Risk Ratio=**	44	**Avian No Effect SSL**	**4.10E-06**	**Risk Ratio=**	4
Mammalian Low Effect SSL	**3.80E-06**	**Risk Ratio=**	7	**Avian Low Effect SSL**	**4.10E-05**	**Risk Ratio=**	0.4

Notes: Avian SSL is ESL from ECORISK Database, Version 2.0 (LANL 2003a) as used in Attachment H Technical Area 16 Burn Ground Human Health and Ecological Risk-Screening Assessments LA-UR-13-24177, Class 3 Permit Modification Request for Addition of an Open Burning Unit at Technical Area (TA) 16 to the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit, EPA ID No. NM0890010515. September 30, 2013. Refer To: WM-D0-13-0064
LAUR: 13-27579

SSL – Soil screening level or ESL
TEF – Toxicity equivalent factor
TECi –Toxicity equivalent concentration
NA – Not applicable

Table 3-7. Hazard Analysis by Receptor and Area Use Factors for TA 16-388 Flash Pad For No Effect ESLs

COPC Name	CAS	No Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)										
		Kestrel (carnivore)	Kestrel (insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Gray fox
Antimony	SB	0	0	0	0	0	2.3	2.7	78	11	7.9	46
Barium	BA	24000	7500	720	820	770	1800	2900	330	110	2100	41000
Copper	CU	1100	80	34	14	20	63	260	80	70	42	4000
Lead	PB	540	83	18	11	14	120	310	1700	120	93	3700
Nickel	NI	2000	110	120	20	35	20	270	280	38	10	1200
Silver	AG	600	13	10	2.6	4.1	24	150	0	560	14	4400
Zinc	ZN	2600	220	330	47	83	170	1800	120	160	99	9600
TCDD	TCDD	1.40E-05	1.40E-05	2.40E-04	4.10E-06	8.10E-06	5.80E-07	4.80E-05	5.00E+00	NA	2.90E-07	1.20E-06
HR (ha)[a]		106	106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]		4240	4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]		0.0001	0.0001	0.028	0.028	0.028	0.16	0.004	NA	NA	0.031	0.00001
AUF[d]		0.0045	0.0045	1.00	1.00	1.00	1.00	0.15	NA	NA	1.00	0.0005

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted Hazard Quotients										
		Kestrel (carnivore)	Kestrel (insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Red fox
Antimony	0.34	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-02	5E-04	4E-03	3E-02	1E-03	8E-08
Barium	2223.00	1E-05	3E-05	9E-02	8E-02	8E-02	2E-01	3E-03	7E+00	2E+01	3E-02	6E-07
Copper	12.35	1E-06	2E-05	1E-02	3E-02	2E-02	3E-02	2E-04	2E-01	2E-01	9E-03	4E-08
Lead	15.11	3E-06	2E-05	2E-02	4E-02	3E-02	2E-02	2E-04	9E-03	1E-01	5E-03	5E-08
Nickel	18.41	1E-06	2E-05	4E-03	3E-02	1E-02	1E-01	3E-04	7E-02	5E-01	6E-02	2E-07
Silver	48.42	9E-06	4E-04	1E-01	5E-01	3E-01	3E-01	1E-03	NA, No ESL	9E-02	1E-01	1E-07
Zinc	159.50	7E-06	8E-05	1E-02	1E-01	5E-02	1E-01	3E-04	1E+00	1E+00	5E-02	2E-07
TCDD*	1.81E-05	1E-04	1E-04	2E-03	1E-01	6E-02	7E+00	2E-03	4E-06	NA	3E+00	2E-04

Notes:

Area of Site (ha) 0.478

NA - Not applicable

PAUF - Population area use factor

HR - Home range

ESLs - Ecological screening level

AUF - Area use factor

* The UCL95 of detected values only used for earthworm. TEQs (Table 3-6) for mammals and birds apply to these receptors.

a - Values from USEPA (1993)

b - Derived as 40*HR

c - PAUF is the area of site divided by the Population Area

d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-8. Hazard Analysis by Receptor and Area Use Factors for TA 16-388 Flash Pad For Low Effect ESLs

COPC Name	CAS	Low Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)										
		Kestrel (carnivore)	Kestrel (insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Gray fox
Antimony	SB	0	0	0	0	0	23	27	780	58	79	460
Barium	BA	44000	13000	1200	1400	1300	8700	14000	3200	260	10000	190000
Copper	CU	3500	240	100	43	60	100	430	530	490	70	6700
Lead	PB	1000	160	36	23	28	230	600	8400	570	170	7000
Nickel	NI	8100	440	500	81	130	40	540	1300	270	21	2500
Silver	AG	6000	130	100	26	41	240	1500	0	2800	140	44000
Zinc	ZN	7000	590	120	120	220	1700	18000	930	810	980	94000
TCDD	1746-01-6	1.40E-04	1.40E-04	2.40E-03	4.10E-05	8.10E-05	3.80E-06	2.70E-04	1.00E+01	NA	1.90E-06	6.80E-04
HR (ha)[a]		106	106	0.42	0.42	0.42	0.077	3.1	NA	NA	0.39	1038
Population Area[b]		4240	4240	16.8	16.8	16.8	3.08	124	NA	NA	15.6	41520
PAUF[c]		0.0001	0.0001	0.028	0.028	0.028	0.16	0.004	NA	NA	0.031	0.00001
AUF[d]		0.0045	0.0045	1.00	1.00	1.00	1.00	0.15	NA	NA	1.00	0.0005

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted Hazard Quotients										
		Kestrel (carnivore)	Kestrel (insectivore)	Robin (herbivore)	Robin (insectivore)	Robin (omnivore)	Deer mouse	Desert cottontail	Earthworm	Plant	Montane shrew	Red fox
Antimony	0.34	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-03	5E-05	4E-04	6E-03	1E-04	8E-09
Barium	2223.00	6E-06	2E-05	5E-02	5E-02	5E-02	4E-02	6E-04	7E-01	9E+00	7E-03	1E-07
Copper	12.35	4E-07	6E-06	4E-03	8E-03	6E-03	2E-02	1E-04	2E-02	3E-02	5E-03	2E-08
Lead	15.11	2E-06	1E-05	1E-02	2E-02	2E-02	1E-02	1E-04	2E-03	3E-02	3E-03	2E-08
Nickel	18.41	3E-07	5E-06	1E-03	6E-03	4E-03	7E-02	1E-04	1E-02	7E-02	3E-02	8E-08
Silver	48.42	9E-07	4E-05	1E-02	5E-02	3E-02	3E-02	1E-04	NA, No ESL	2E-02	1E-02	1E-08
Zinc	159.50	3E-06	3E-05	4E-02	4E-02	2E-02	1E-02	3E-05	2E-01	2E-01	5E-03	2E-08
TCDD*	1.81E-05	1E-05	1E-05	2E-04	1E-02	6E-03	1E+00	4E-04	2E-06	NA	4E-01	4E-07

Notes:

Area of Site (ha): 0.478

NA - Not applicable
PAUF - Population area use factor
HR - Home range
ESLs - Ecological screening level
AUF - Area use factor

* The UCL95 of detected values only used for earthworm. TEQs (Table 3-6) for mammals and birds apply to these receptors.

a - Values from USEPA (1993)

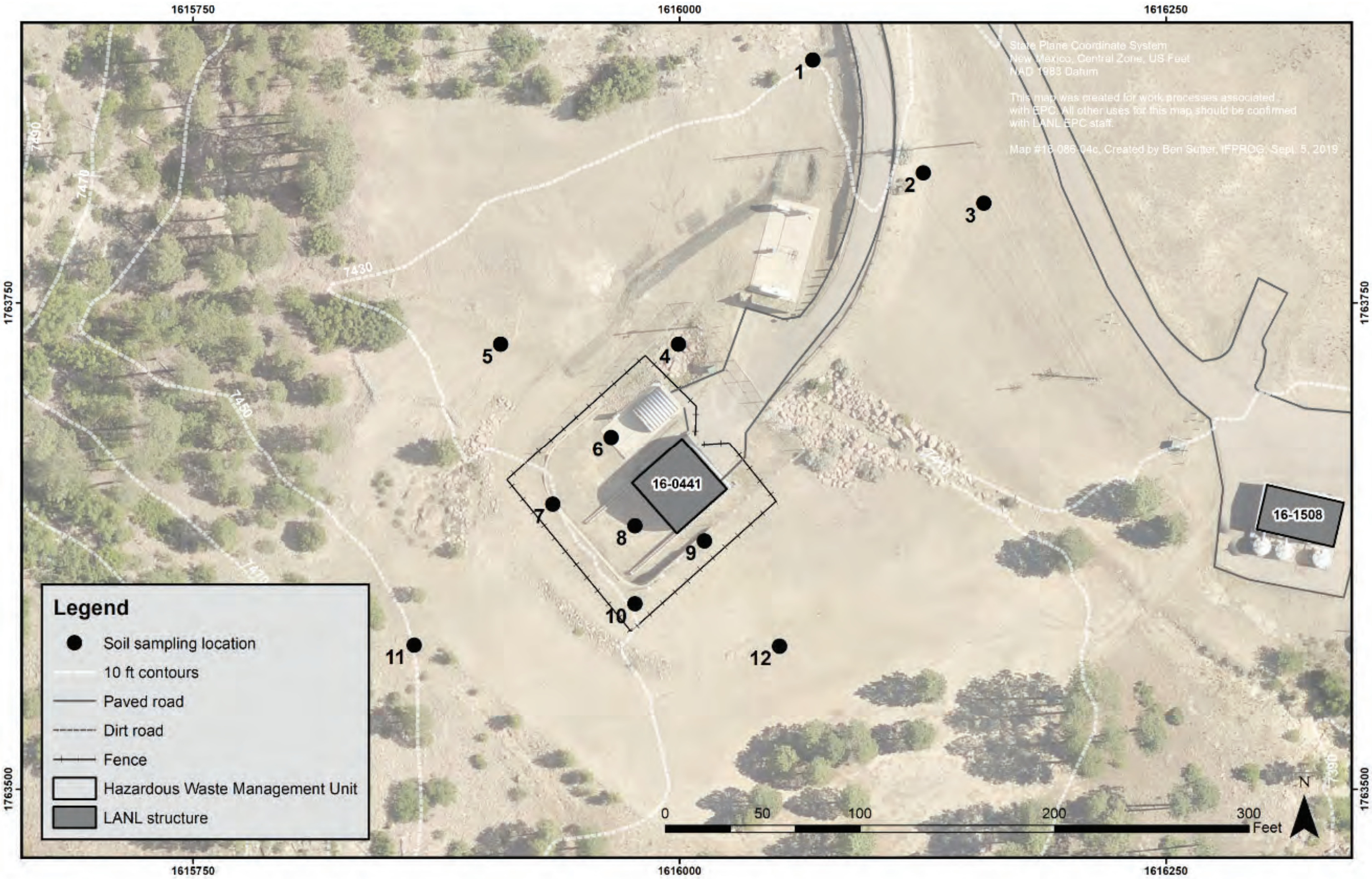
b - Derived as 40*HR

c - PAUF is the area of site divided by the Population Area

d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Figures

Figure 1-1. Map of Sampling Locations For TA-16-388 Flash Pad



State Plane Coordinate System
New Mexico, Central Zone, US Feet
NAD 1983 Datum

This map was created for work processes associated with EPC. All other uses for this map should be confirmed with LANL EPC staff.

Map #16-086-04c, Created by Ben Sutter, IFPROG, Sept. 5, 2019

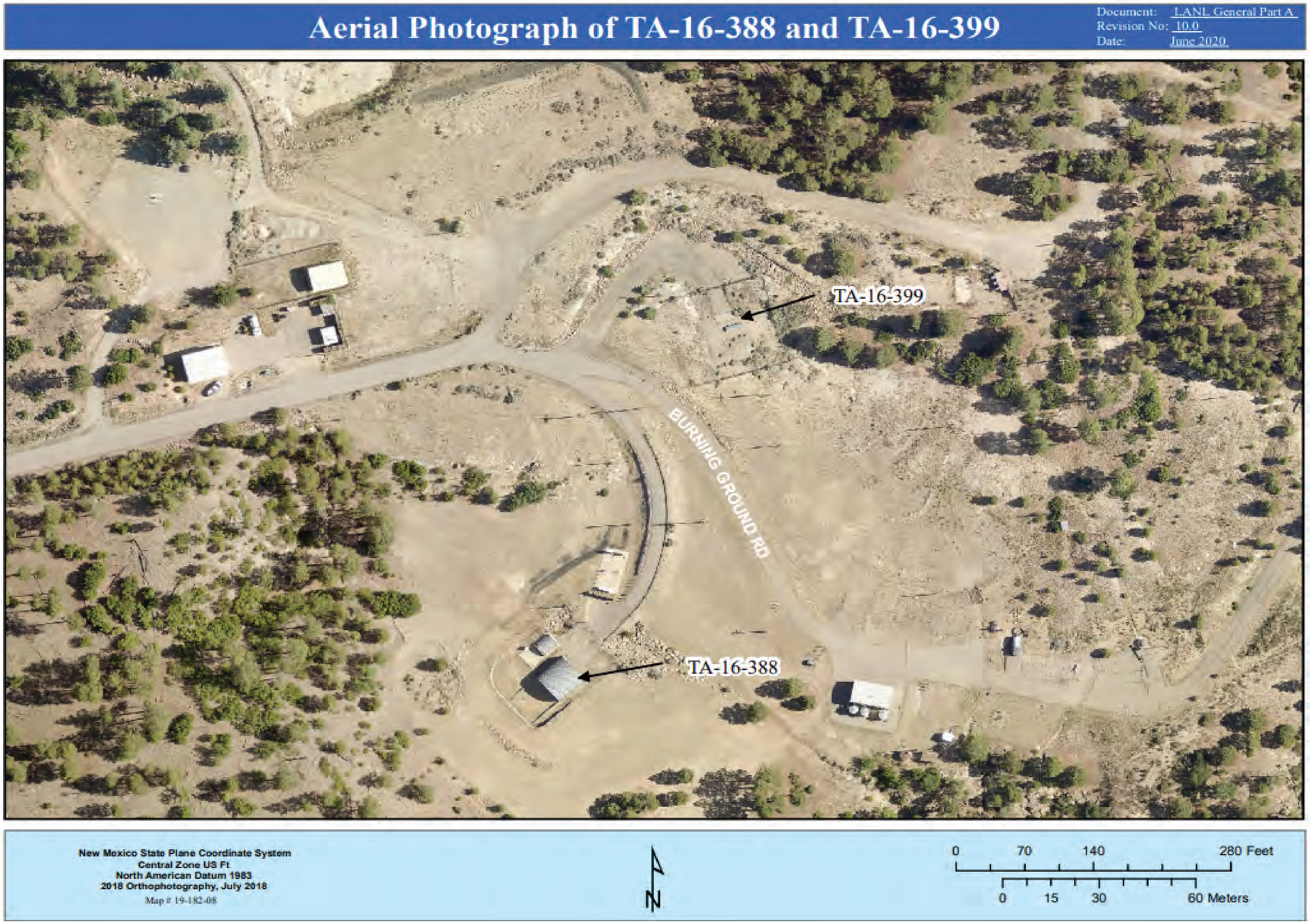
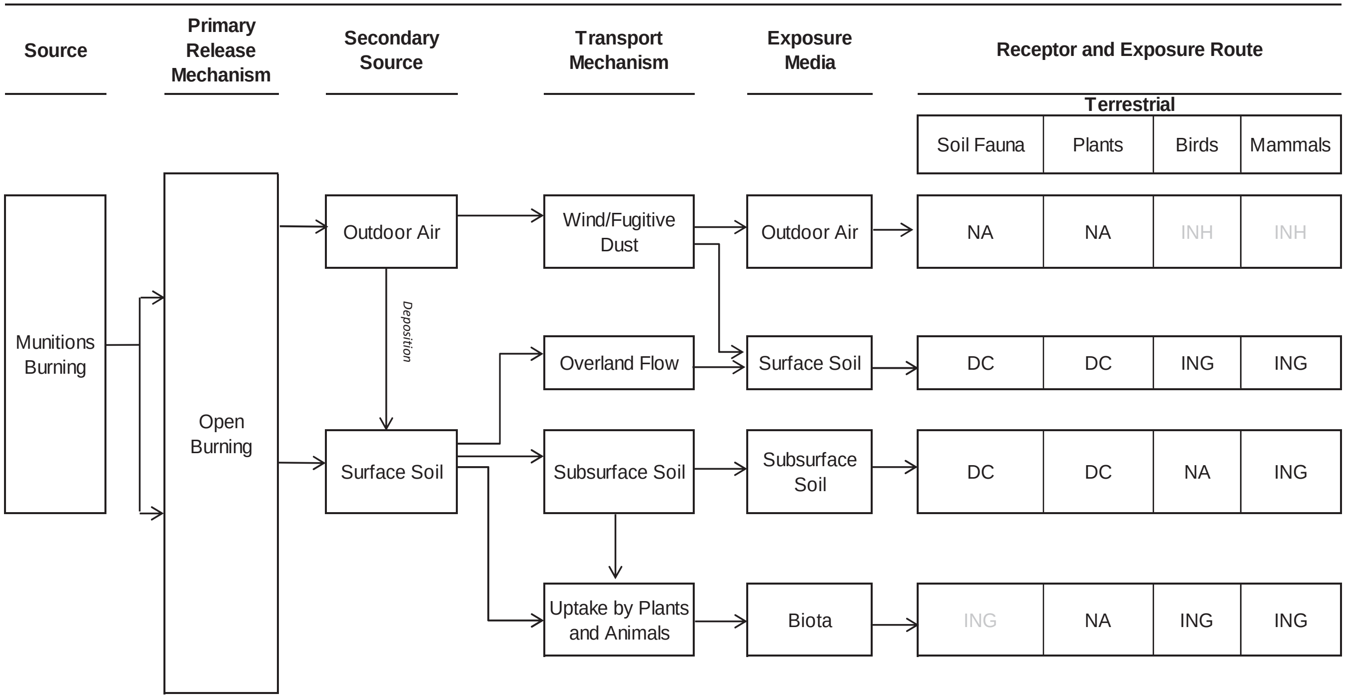


Figure 3-1. Aerial Photograph of Habitat at TA-16-388 and Vicinity

Figure 3-2. Preliminary Conceptual Site Exposure Model



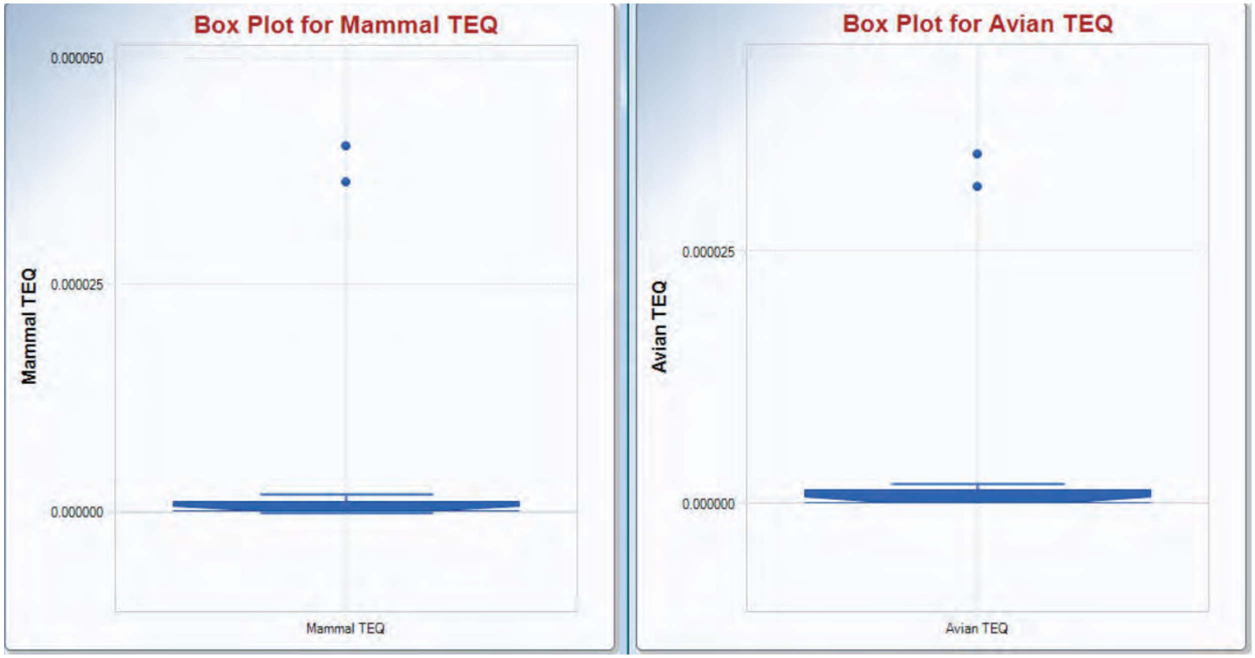
Abbreviations

DC	Direct contact; applies to receptors for which toxic effects are addressed by exposure concentration and not dose
ING	Ingestion; typically quantified as dose for birds and mammals only
INH	Inhalation; recognized to occur, but not typically quantified as standard practice with the exception of evaluating burrow air exposure by burrowing mammals
NA	Pathway considered incomplete; not applicable

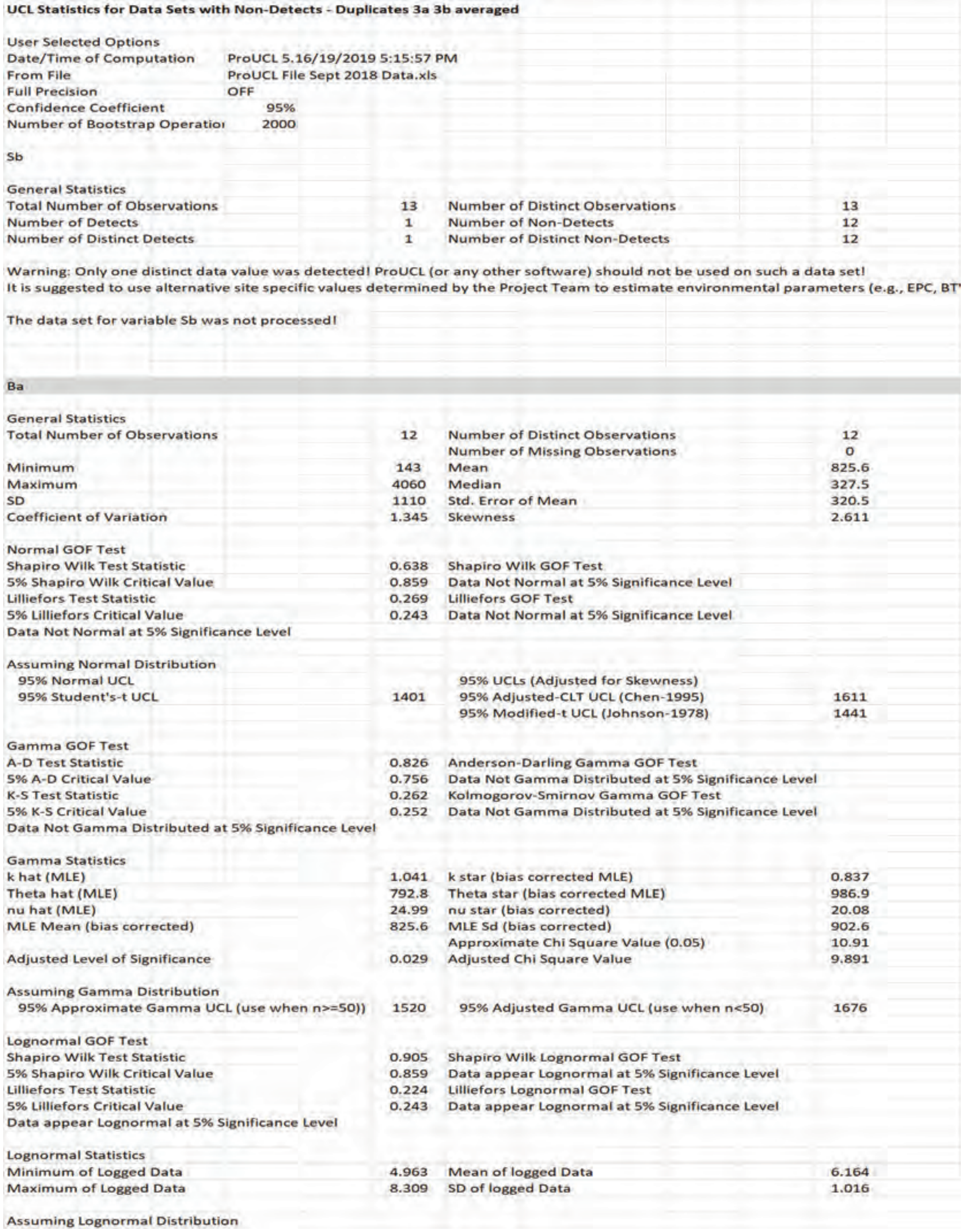
Notes:

Grayed text indicates pathways are recognized to potentially exist but are not quantified. Inhalation is considered minimal relative to dietary exposure. Ingestion by invertebrates is not typically quantified due to absence of accurate exposure parameters.

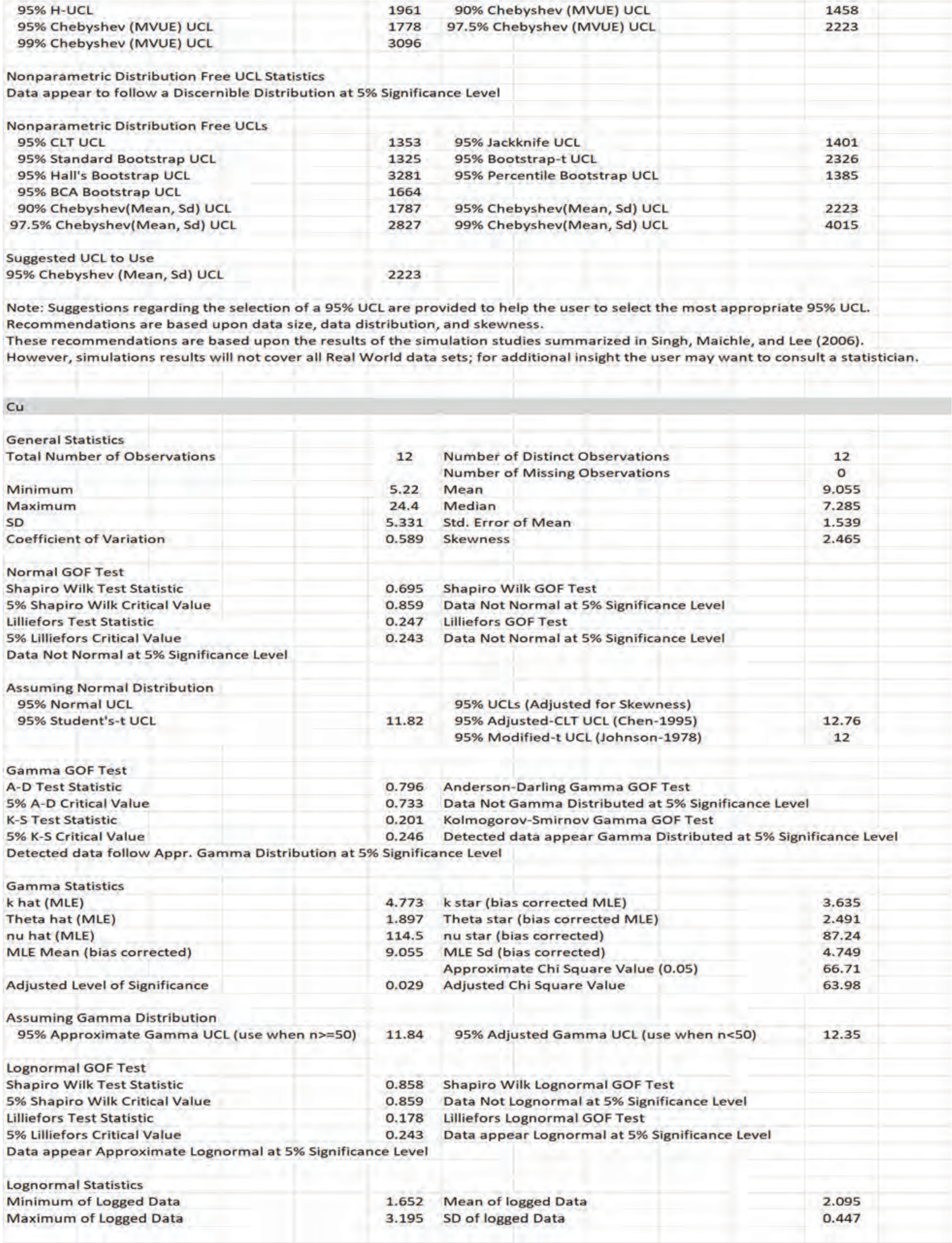
Figure 3-3. Box Plots for Mammalian and Avian Dioxin/Furan TEQs



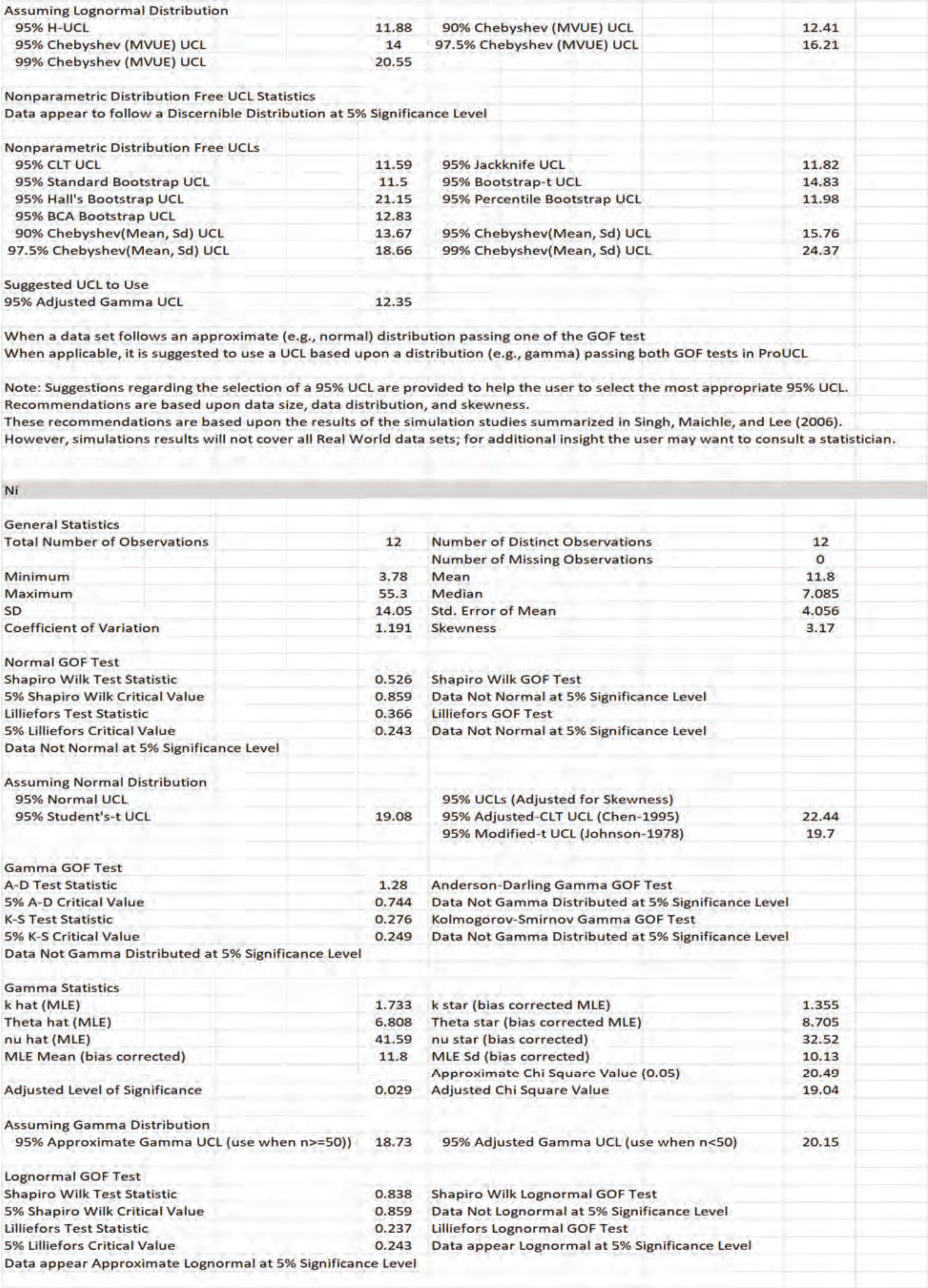
Attachment A. ProUCL Output for Upper Confidence Limit Calculations



```
UCL Statistics for Data Sets with Non-Detects - Duplicates 3a 3b averaged

User Selected Options
Date/Time of Computation      ProUCL 5.16/19/2019 5:15:57 PM
From File                     ProUCL File Sept 2018 Data.xls
Full Precision                OFF
Confidence Coefficient           95%
Number of Bootstrap Operatior    2000

Sb

General Statistics
Total Number of Observations                   13   Number of Distinct Observations           13
Number of Detects                               1   Number of Non-Detects                     12
Number of Distinct Detects                      1   Number of Distinct Non-Detects            12

Warning: Only one distinct data value was detected! ProUCL (or any other software) should not be used on such a data set!
It is suggested to use alternative site specific values determined by the Project Team to estimate environmental parameters (e.g., EPC, BT

The data set for variable Sb was not processed!


Ba

General Statistics
Total Number of Observations                   12   Number of Distinct Observations           12
                                                    Number of Missing Observations             0
Minimum                                       143   Mean                                   825.6
Maximum                                      4060   Median                                 327.5
SD                                           1110   Std. Error of Mean                     320.5
Coefficient of Variation                    1.345   Skewness                               2.611

Normal GOF Test
Shapiro Wilk Test Statistic                 0.638   Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value              0.859   Data Not Normal at 5% Significance Level
Lilliefors Test Statistic                   0.269   Lilliefors GOF Test
5% Lilliefors Critical Value                0.243   Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
  95% Normal UCL                                      95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                        1401     95% Adjusted-CLT UCL (Chen-1995)        1611
                                                      95% Modified-t UCL (Johnson-1978)       1441

Gamma GOF Test
A-D Test Statistic                          0.826   Anderson-Darling Gamma GOF Test
5% A-D Critical Value                       0.756   Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic                          0.262   Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value                       0.252   Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE)                                 1.041   k star (bias corrected MLE)            0.837
Theta hat (MLE)                             792.8   Theta star (bias corrected MLE)        986.9
nu hat (MLE)                                24.99   nu star (bias corrected)               20.08
MLE Mean (bias corrected)                   825.6   MLE Sd (bias corrected)                902.6
                                                    Approximate Chi Square Value (0.05)    10.91
Adjusted Level of Significance              0.029   Adjusted Chi Square Value              9.891

Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when n>=50))  1520   95% Adjusted Gamma UCL (use when n<50)  1676

Lognormal GOF Test
Shapiro Wilk Test Statistic                 0.905   Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value              0.859   Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic                   0.224   Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value                0.243   Data appear Lognormal at 5% Significance Level
Data appear Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data                      4.963   Mean of logged Data                    6.164
Maximum of Logged Data                      8.309   SD of logged Data                      1.016

Assuming Lognormal Distribution
```



```
  95% H-UCL                                       1961    90% Chebyshev (MVUE) UCL                          1458
  95% Chebyshev (MVUE) UCL                        1778   97.5% Chebyshev (MVUE) UCL                         2223
  99% Chebyshev (MVUE) UCL                        3096

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
  95% CLT UCL                                     1353    95% Jackknife UCL                                 1401
  95% Standard Bootstrap UCL                      1325    95% Bootstrap-t UCL                               2326
  95% Hall's Bootstrap UCL                        3281    95% Percentile Bootstrap UCL                      1385
  95% BCA Bootstrap UCL                           1664
  90% Chebyshev(Mean, Sd) UCL                     1787    95% Chebyshev(Mean, Sd) UCL                       2223
 97.5% Chebyshev(Mean, Sd) UCL                    2827    99% Chebyshev(Mean, Sd) UCL                       4015

Suggested UCL to Use
95% Chebyshev (Mean, Sd) UCL                      2223

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.


Cu

General Statistics
Total Number of Observations                        12   Number of Distinct Observations                      12
                                                         Number of Missing Observations                        0
Minimum                                           5.22   Mean                                              9.055
Maximum                                           24.4   Median                                            7.285
SD                                               5.331   Std. Error of Mean                                1.539
Coefficient of Variation                         0.589   Skewness                                          2.465

Normal GOF Test
Shapiro Wilk Test Statistic                      0.695   Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value                   0.859   Data Not Normal at 5% Significance Level
Lilliefors Test Statistic                        0.247   Lilliefors GOF Test
5% Lilliefors Critical Value                     0.243   Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
  95% Normal UCL                                          95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                            11.82    95% Adjusted-CLT UCL (Chen-1995)                 12.76
                                                          95% Modified-t UCL (Johnson-1978)                   12

Gamma GOF Test
A-D Test Statistic                               0.796   Anderson-Darling Gamma GOF Test
5% A-D Critical Value                            0.733   Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic                               0.201   Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value                            0.246   Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE)                                      4.773   k star (bias corrected MLE)                       3.635
Theta hat (MLE)                                  1.897   Theta star (bias corrected MLE)                   2.491
nu hat (MLE)                                     114.5   nu star (bias corrected)                          87.24
MLE Mean (bias corrected)                        9.055   MLE Sd (bias corrected)                           4.749
                                                         Approximate Chi Square Value (0.05)               66.71
Adjusted Level of Significance                   0.029   Adjusted Chi Square Value                         63.98

Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when n>=50)     11.84    95% Adjusted Gamma UCL (use when n<50)           12.35

Lognormal GOF Test
Shapiro Wilk Test Statistic                      0.858   Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value                   0.859   Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic                        0.178   Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value                     0.243   Data appear Lognormal at 5% Significance Level
Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data                           1.652   Mean of logged Data                               2.095
Maximum of Logged Data                           3.195   SD of logged Data                                 0.447
```



Assuming Lognormal Distribution			
95% H-UCL	11.88	90% Chebyshev (MVUE) UCL	12.41
95% Chebyshev (MVUE) UCL	14	97.5% Chebyshev (MVUE) UCL	16.21
99% Chebyshev (MVUE) UCL	20.55		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	11.59	95% Jackknife UCL	11.82
95% Standard Bootstrap UCL	11.5	95% Bootstrap-t UCL	14.83
95% Hall's Bootstrap UCL	21.15	95% Percentile Bootstrap UCL	11.98
95% BCA Bootstrap UCL	12.83		
90% Chebyshev(Mean, Sd) UCL	13.67	95% Chebyshev(Mean, Sd) UCL	15.76
97.5% Chebyshev(Mean, Sd) UCL	18.66	99% Chebyshev(Mean, Sd) UCL	24.37
Suggested UCL to Use			
95% Adjusted Gamma UCL	12.35		
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Ni			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	3.78	Mean	11.8
Maximum	55.3	Median	7.085
SD	14.05	Std. Error of Mean	4.056
Coefficient of Variation	1.191	Skewness	3.17
Normal GOF Test			
Shapiro Wilk Test Statistic	0.526	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.366	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	19.08	95% Adjusted-CLT UCL (Chen-1995)	22.44
		95% Modified-t UCL (Johnson-1978)	19.7
Gamma GOF Test			
A-D Test Statistic	1.28	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.744	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.276	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.249	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.733	k star (bias corrected MLE)	1.355
Theta hat (MLE)	6.808	Theta star (bias corrected MLE)	8.705
nu hat (MLE)	41.59	nu star (bias corrected)	32.52
MLE Mean (bias corrected)	11.8	MLE Sd (bias corrected)	10.13
		Approximate Chi Square Value (0.05)	20.49
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	19.04
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	18.73	95% Adjusted Gamma UCL (use when n<50)	20.15
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.838	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.237	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			

31. LANL (Los Alamos National Laboratory), May 2022. *Open Detonation Unit at Technical Area 36 Human Health and Ecological-Risk Screening Assessments*. (LANL WMP 2022)

OPEN DETONATION UNIT AT TECHNICAL AREA 36
HUMAN HEALTH AND ECOLOGICAL RISK-SCREENING ASSESSMENTS

May 11, 2022

Prepared by:
TerranearPMC
222 Valley Creek Blvd Exton, PA 19341

For:
Waste Management Programs
Environmental Protection and Compliance Division
Los Alamos National Laboratory
P.O. Box 1663 MS M969, Los Alamos, NM 87545

EXECUTIVE SUMMARY

The area around the open detonation (OD) area Technical Area (TA) 36 (the TA-36 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-36 OD Unit is referred to as “the Unit” in the remainder of this risk assessment. Surface soil samples were collected in September 2018 and analyzed for inorganic and organic compounds. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released into the soil at levels that pose an unacceptable risk to human health or the environment.

Screening criteria for these assessments require that residential, industrial, and construction worker exposure scenarios be evaluated, despite that the TA-36 OD Unit is not located at a residential location. For the human health risk-screening assessment, a hypothetical future resident, industrial, and construction worker exposure scenarios were evaluated by comparing the maximum exposure point concentration for each analyte to the New Mexico Environment Department (NMED) soil screening levels (NMSSLs). The following conclusions are made:

- **Detected inorganics were compared to background values (BVs) and New Mexico risk-based soil screening levels (NMSSLs).** Eight detected inorganics exceeded BVs. Of these, only one (copper) exceeded background based on hypothesis testing. Perchlorate was retained for further evaluation because there was no BV, and cadmium was retained due to low detection frequency in both site and background data sets. Mercury was retained because there were only two detects in the background dataset, and silver was retained because there was only one detect in the background dataset.
- **Detected organics were compared to risk-based NMSSLs.** There are no individual organic constituents that exceed NMSSLs.
- **Cumulative Cancer Risk (CCR) was calculated.** Cumulative cancer risk is the sum of the individual cancer risks. The resident CCR was $3x10^{-6}$, the industrial worker CCR was $4x10^{-7}$, and the construction worker CCR was $6x10^{-8}$. Therefore, there is no excess cancer risk for any human receptor evaluated in this report.
- **Screening Level Hazard Indices (HI) were calculated.** The sum of the screening level noncancer hazard quotients (HQs) is called a HI. The noncancer HI for the hypothetical future resident is 0.3, the HI for industrial workers is 0.02, and the HI for construction workers is 0.09. As all HIs were less than 1, there is no excess noncancer hazard for human receptors evaluated in this report.
- **The screening evaluation indicates that residents or workers are not at risk due to exposure to soils at the Unit.**
- **RDX exceeds groundwater protection screening levels by a factor of 20 based on the refined EPC.**

Potential risk to ecological receptors was evaluated by analyzing different lines of evidence that were weighed to draw a conclusion regarding the potential for adverse ecological effects. This included:

- **Comparing maximum exposure point concentrations (EPC) to no effect (NE) ecological screening levels (ESLs).** There were 12 analytes for which the maximum value exceeded NE ESLs resulting in hazard quotients (HQ) greater than 0.1.
- **Comparing refined EPCs based on upper 95th percentile confidence limits (UCL95) to Low Effect (LE) ESLs.** There were six analytes for which the UCL95 EPC exceeded LE ESLs.

- **Calculating HIs.** The HIs for NE ESL exceeded 1 for all receptors, and LE ESL comparisons to the EPCs exceeded 1 for several ecological receptors.
- **Application of site-specific population area use factors and NE ESLs.** The American robin, plants, and earthworms had HQs above 1 under the area use factor analysis when compared to NE ESLs due to mercury and copper. HIs based on NE ESLs exceeded 1 for robin, deer mouse, earthworm, and plants. The HIs for robins feeding as omnivores or insectivores for comparison to NE ESLs were 2 and 3, respectively, and the HIs based on NE ESLs for earthworms and plants were 20 and 3. The HI for the deer mouse was 2, but no HQs exceeded 1.
- **Application of site-specific population area use factors and LE ESLs.** There were no analytes that exceeded LE ESLs once the areal extent of the Unit was taken into consideration in conjunction with typical home range for ecological receptors and all HQs were less than 1. HIs based on LE ESLs exceeded 1 for earthworms only. A vegetative or invertebrate soil fauna community (as represented in the risk assessment by plants and earthworms) is not expected to occur in the Unit due to intended use and bare ground, and robins are not expected to feed on a daily basis totally within the Unit due to lack of food and cover, as well as human disturbance due to intended use.
- **Avian and mammalian population information does not indicate that birds or mammals are adversely affected**.
- **The ecological risk assessment concludes that there is likely no risk to ecological receptors at the Unit.**

Table of Contents

ATTACHMENT A. ProUCL Output

ATTACHMENT B. LANL ECORISK DATABASE 4.2

List of Tables

List of Figures

Acronyms and Abbreviations

AUF	Area Use Factor
BMP	Best Management Practice
BV	Background Benchmark Value
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CR	Cancer Risk
CSEM	Conceptual Site Exposure Model
DAF	Dilution Attenuation Factor
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESL	Ecological Screening Level
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Cyclotetramethylene-tetranitramine
HQ	Hazard Quotient
HR	Home Range
LANL	Los Alamos National Laboratory
LD50	Lethal Dose for Half of the Population
LE	Low Effect
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
NE	No Effect
NMED	New Mexico Environment Department
NMSSL	New Mexico Soil Screening Levels
NOAEL	No Observed Adverse Effect Level
OD	Open Detonation
PAUF	Population Area Use Factor
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RSL	Regional Screening Level
RSRL	Regional Statistical Reference Levels
SD	Standard Deviation
SF	Cancer Slope Factor
SL	Screening Level
SL-SSL	Groundwater Protection Soil Screening Level
SVOC	Semi-volatile Organic Compound
TA	Technical Area
TATB	2,4,6-Triamino-1,3,5-trinitrobenzene
TECi	Toxicity Equivalent Concentration for congener ***i***

TEF	Toxicity Equivalency Factor
TEQ	Toxicity Equivalent Quotient
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
UCL95	95% Upper Confidence Limit of the Mean
VOC	Volatile Organic Compound
WHO	World Health Organization

1. INTRODUCTION

The area around the open detonation (OD) area at Technical Area (TA) 36 (the OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The OD Unit is referred to as “the Unit” in the remainder of this risk assessment.

The Unit is a hazardous waste management unit located in the southern portion of LANL (Figure 1-1), near Building 8. The unit was established in 1959 for the testing of explosives materials and has been used for open detonation of high explosives debris potentially contaminated with depleted uranium and other metals. The Unit consists of a relatively flat area that measures approximately 1.44 acres. All waste treatment detonations are conducted above ground with the use of a predetermined amount of explosive to initiate and increase the effectiveness of the treatment. Waste treatment shots are assembled in a manner to ensure complete detonation of the waste with minimized fragmentation dispersal. There are several firing sites and support buildings. The firing pit is bounded on the east, south, and west sides by storm water best management practices (BMPs) consisting of earth berms that have been hydroseeded and mulched.

One surface soil sampling event of the top 2 inches of soil at 15 discrete locations (Figure 1-1) was conducted in and around the Unit on September 19, 2018. Sample collection included soil both in and out of potential run-off areas; however, sample collection did not include rocks, debris, or vegetation. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

The results of the risk assessments are presented in the following sections.

2. HUMAN HEALTH RISK ASSESSMENT

2.1. CONCEPTUAL SITE MODEL

The primary land use for the human health risk assessment (HHRA) is industrial because only authorized Laboratory workers currently have access to the area around the Unit. Laboratory workers are the primary human receptors, and the industrial scenario is the defining scenario for the human health risk-screening assessment (i.e., the scenario on which decisions are based).

2.1.1. Receptors

Because the site is located within the boundaries of an operational facility (i.e., the Unit), the reasonably foreseeable future land use will continue to be industrial. Both a commercial worker and a construction worker are evaluated. A Hypothetical Future Residential exposure is also assessed and provided for comparison purposes.

2.1.2. Exposure Pathways

The release of contaminants from open detonation operations has potentially occurred for many years. Releases are transported primarily by wind, which rapidly disperses the material in ambient air. Most material is likely deposited close to the source(s), and concentrations are expected to decrease with distance from the source. Exposure to a site worker may occur through various surface soil contact pathways. Potential exposure pathways are:

- Incidental ingestion of surface soil
- Inhalation of fugitive dust or volatiles emanating from surface soil
- Dermal contact with surface soil

Storm water discharges from the Unit are regulated under the Clean Water Act by the National Pollutant Discharge Elimination System permit program under the LANL Storm Water Individual Permit. The LANL Storm Water Individual Permit contains nonnumeric technology-based effluent limitations, coupled with a comprehensive, coordinated monitoring program and implementation of corrective actions where necessary, to minimize pollutants in LANL's storm water discharges. Grading for runoff and erosion control has been performed in the area of the Unit. In addition, berms and infiltration system have been installed. This, combined with the distance to the nearest surface water, makes it unlikely that impacts to surface water east of the Unit will occur.

2.1.3. Approach for Identification of Chemicals of Potential Concern

2.1.3.1. Sampling and Data Analysis

Fifteen surface soil samples and one duplicate were collected September 19, 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 to 2 inches below ground surface. The duplicate pair was WST36-18-162834 and WST36-18-162985. Each sample set was analyzed for the following:

- Volatile Organic Compounds (VOCs)
- Semi-Volatile Organic Compounds (SVOCs)
- Total Metals
- Dioxins/Furans
- Perchlorates
- High Explosives

A staged approach was used for the risk assessment. Duplicates were evaluated consistent with the New Mexico Environment Department (NMED) guidance (NMED 2019) which states that in the initial screening assessment the maximum, and not the average, of the duplicate pair must be used. Figure 1-1 shows the current sampling locations from which data were obtained for use in the risk assessment.

2.1.3.2. Comparison to Background

The background data used in this evaluation is presented in the report "Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory," (LANL, 1998). The background data are used in the RCRA corrective action process to distinguish between contaminated and uncontaminated media and have been accepted by NMED. As stated in the background report, the background dataset was collected as follows:

> Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for inorganic chemical analyses. These samples provide information about the varied soils and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, 05702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms. (LANL, 1998)

The locations sampled as part of the background study were not impacted by deposition from the historical operation of the OD units or other firing sites. Background values (BVs) were obtained from this document to use in comparison to site data.

Inorganic analytes are first compared to BVs established for the site (LANL, 1998). The inorganic data that exceeded BVs were then statistically compared to the background data with hypothesis tests. No further evaluation is necessary for analytes for which the maximum is less than the BV, and these data are not compared to NMED (2019) risk-based soil screening levels (NMSSLs). Organic analytes are not compared to background values as a matter of standard practice, although there are naturally occurring sources of organic constituents.

2.1.3.3. Comparison of Maximum EPCs to NMSSLs

The maximum concentration was used as the maximum exposure point concentration (EPC), which is the environmental concentration to which the receptors are potentially exposed. The screening approach used the maximum of all detected data, including the duplicate pair, for the initial screening evaluation. The maximum concentration of each analyte was divided by its NMSSL. For the HHRA, this meant using two screening levels (SLs) based on toxicity endpoints, (i.e., a cancer and noncancer SL were used to obtain a cancer risk and non-cancer hazard quotient (HQ).

All analytes that exceeded the initial NMSSLs were considered to have “failed” the initial screen. These are considered to be contaminants of potential concern (COPCs).

2.1.3.4. Surrogates

Where an NMSSL was not available, the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL) for residential soils was applied as an SL for residential use, and the RSL for industrial commercial soil was used as the SL for industrial and construction workers. Consistent with NMED guidance, cancer-based RSLs were adjusted to a cancer risk (CR) level of $1x10^{-5}$ by multiplying the RSL by 10; noncancer RSLs were based on a HQ of 1. If an RSL was also not available, a suitable surrogate is proposed if physicochemical data suggest identifying a suitable surrogate. Most of the surrogates are proposed for nondetected analytes in order to verify that method detection limits (MDLs) are suitable for performing risk assessment.

The NMED migration to groundwater screening levels (SL-SSL) are used to assess potential migration to groundwater risks assuming human receptors then consume groundwater. Where SL-SSLs are unavailable, surrogates based on EPA RSLs are proposed. In these cases, the EPA RSL for protection of migration to groundwater was used. The EPA RSL for protection of migration to groundwater is based on a dilution attenuation factor (DAF) of 1, whereas the NMED SL-SSL is based on a DAF of 20. For consistency with NMED, the EPA RSL migration to groundwater values were multiplied by a factor of 20.

Surrogates were obtained for the following analytes because NMSSLs were not available (Table 2-1); note that most of these are not detected, and the SL is used to verify reporting limits are adequate:

- 2,4-Diamino-6-nitrotoluene – There is no NMSSL or RSL. Use o-nitrotoluene RSLs, which has both cancer and noncancer RSL values, and the lowest of the nitrotoluene isomer cancer RSLs.
- 2,6-Diamino-4-nitrotoluene – Use o-nitrotoluene RSLs, which has both cancer and noncancer RSL values, and the lowest of the nitrotoluene isomer cancer RSLs.
- 3,5-Dinitroaniline – There is no NMSSL. Use the amino-2,6-dinitrotoluene[4-] RSL as surrogate based on structural similarity.

- Acenaphthylene – There is no NMSSL or RSL. The NMSSLs for acenaphthene were used as a surrogate based on structural similarity.
- Aniline - There is no NMSSL. The RSLs were used as a surrogate.
- Azobenzene - There is no NMSSL. The RSLs were used as a surrogate.
- Benzo(g,h,i)perylene – There is no NMSSL or RSL. The NMSSLs for benzo(a)pyrene were used as a surrogate.
- Benzoic Acid - There is no NMSSL. RSLs were used as a surrogate.
- Benzyl Alcohol- There is no NMSSL. RSLs were used as a surrogate.
- Bis(2-chloroethoxy)methane- There is no NMSSL. RSLs were used as a surrogate.
- Bromobenzene - There is no NMSSL. RSLs were used as a surrogate.
- Bromochloromethane - There is no NMSSL. RSLs were used as a surrogate.
- Bromophenyl-phenylether[4-] – There is no NMSSL or RSL. The RSL for pentabromodiphenyl ether was used.
- Butylbenzene isomers – There are no NMSSLs. The RSLs are used as surrogates.
- Butylbenzylphthalate – There are no NMSSLs. The RSLs are used as surrogates.
- Chloro-3-methylphenol[4-]– There are no NMSSLs. The RSLs are used as surrogates.
- Chloroaniline[4-] – There are no NMSSLs. The RSLs are used as surrogates.
- Chlorophenyl-phenyl[4-] Ether– There is no NMSSL or RSL. No recommendation for a surrogate is made.
- Chlorotoluene[4-] – Use the NMSSLs for the o-chlorotoluene isomer because the RSLs for the two isomers are the same.
- Dibenzofuran – There are no NMSSLs. The RSLs are used as surrogates.
- Dichlorobenzene[1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,4-dichlorobenzene were used as it may be the more toxic isomer considering it has cancer-based as well as noncancer-based endpoints.
- Dichloropropane[2,2-] – There is no NMSSL or RSL. The NMSSLs for 1,2-dichloropropane were used. The RSL is higher for 1,3 than 1,2 dichloropropane, and therefore this is considered conservative.
- Dichloropropane[1,3-] – There is no NMSSL. The NMSSLs for 1,2-dichloropropane were used.
- Dichloropropene[1,1-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.
- Dichloropropene[cis-1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.
- Dichloropropene[trans-1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.
- Dimethyl phthalate– There is no NMSSL or RSL. The NMSSLs for diethyl phthalate were used.
- Dinitrobenzene[1,3-] – There are no NMSSLs. The RSLs are used as surrogates.
- Di-n-octylphthalate – There are no NMSSLs. The RSLs are used as surrogates.
- Diphenylamine – There are no NMSSLs. The RSLs are used as surrogates.
- Hexanone[2] – There are no NMSSLs. The RSLs are used as surrogates.
- Iodomethane – There is no NMSSL or RSL. No recommendation for a surrogate is made.

- 4-Isopropyltoluene – There is no NMSSL. The NMSSL values for toluene were used as a surrogate.
- Methylphenols – There are no NMSSLs for these compounds. The RSLs were applied for 2- and 4- methylphenol. The RSLs for 3-methylphenol were used for 3,4-methylphenol as most conservative option.
- Nitroanilines – There are no NMSSLs for these compounds. The RSLs were applied for 2- and 4-nitroaniline. The RSL for 4-nitroaniline was applied to 3-nitroaniline.
- Nitrophenols – There are no NMSSLs or RSLs for these compounds. The RSLs for phenol were applied for 2- and 4-nitrophenol.
- Nitroso-di-n-propylamine[N-] – There are no NMSSLs. The RSLs were applied.
- PETN - There is no NMSSL for PETN. RSLs were used as a surrogate.
- Propylbenzene[1-] – There are no NMSSLs. The RSLs are used as surrogates.
- Pyridine– There are no NMSSLs. The RSLs are used as surrogates.
- 1,3,5-Trinitrobenzene – There is no NMSSL. RSLs for 1,3,5-trinitrobenzene were used as a surrogate.
- TATB – There is no NMSSL or RSL for TATB. RSLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.
- Trimethylbenzenes – There are no NMSSLs. The RSLs are used as surrogates.
- Tris (o-cresyl) phosphate – There is no NMSSL or RSL. The RSL for tris(2-ethylhexyl)phosphate was applied as a similar structure without halogen substitutions.

2.1.3.5. Evaluation of Refined EPCs

A refinement of the EPCs is performed if the HI or the cumulative cancer risk based on maxima exceeds target levels of 1 or $1\text{x}10^{-5}$, respectively. The maximum of each duplicate pair is used in the upper 95th percent confidence limit on the mean (UCL95). The UCL95 concentrations are compared to NMSSLs, and any analytes above the NMSSLs are considered further if necessary.

2.1.3.6. Calculation of Hazard Index or Cumulative Cancer Risk

Noncancer HQs are calculated as follows using the NMSSL based on noncancer endpoints:

$$HQ = EPC/NMSSL$$

A Hazard Index (HI) was calculated by summing all of the HQs as follows:

$$HI = \sum HQ1, HQ2, \dots$$

A CR was calculated as follows using the cancer-based NMSSL for each receptor and adjusting from a ratio to a cancer risk:

$$CR = \frac{EPC}{NMSSL} * 1 \times 10^{-5}$$

A Cumulative Cancer Risk (CCR) was calculated by summing the cancer risks for each detected analytes as follows:

$$CCR = \sum CR1, CR2, \ldots ..$$

If the HI exceeded 1, or the CCR exceeded $1x10^{-5}$, a UCL95 was calculated for all COPCs with the EPA ProUCL 5.1.002 software (EPA 2015). The refined EPCs based on UCL95 concentrations were then compared to the NMSSLs.

2.1.3.7. Dioxin/Furans

Guidance from NMED was used to evaluate the potential toxicity of the dioxin/furans. This guidance relies on the 2005 World Health Organization (WHO) toxicity equivalency factors (TEF) (Van den berg et al. 2006) approach (WHO 2009). The TEFs are multiplied by the measured concentration to obtain a congener-specific product called the toxicity equivalent concentration (TECi), and the product for each (TECi) is summed for each sample location. This sum is referred to as the toxicity equivalent quotient (TEQ). The TEQ is divided by the NMED screening level for 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) to obtain a risk ratio.

2.2. SCREENING EVALUATION

The following sections present the human health risk-screening assessment for the Unit.

2.2.1. Data Analysis

Table 2-1 presents the summary statistics. Maximum concentrations in the soil samples analyzed for inorganics were compared to the established soil BVs (LANL 1998) (Table 2-2). The exposure interval for industrial workers is 0–1 ft bgs and for hypothetical future residents and construction workers the exposure interval is 0–10 ft bgs. Since all data fall within the 0–1 ft depth interval, the available data set was used for all receptors.

Antimony was the only inorganic that was never detected. Thallium and cadmium were only detected in 3 of 16 samples. Mercury was also infrequently detected in 6 of 16 samples.

Many of the organics are not detected. Organics that were detected in the surface soil samples are indicated in Table 2-1. These include energetics or explosives (e.g., HMX [cyclotetramethylene-tetranitramine], TATB, and RDX). SVOCs including fluoranthene and pyrene were detected. Phthalates (e.g., butylbenzyl- and di-n-butylphthalate) were also detected (Table 2-1), as were some dioxin/furan congeners. Methylene chloride and toluene were the only volatile organic chemicals (VOCs) detected.

2.2.2. Comparison to Background

The maximum detected result was used as the initial EPC (Table 2-2) and compared to background. Background values for the site are from the 1998 background report (LANL 1998), and soil screening levels are the NMSSLs (Table 2-2). There were no BVs for perchlorate. The maximum concentration for the following detected inorganics exceeded BVs:

- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Silver
- Thallium

- Zinc

All other inorganics were equal to or lower than BVs. A BV for perchlorate was not available and it was retained for further evaluation.

If the maximum concentration for the an inorganic exceeded its BV, the data were statistically evaluated, and if the Wilcoxon-Mann-Whitney (or Gehan test if ProUCL identified multiple detection limits) two sample hypothesis test indicated the site exceeded background, they were carried forward, in addition to retaining perchlorate for which BVs were not available. The results are as follows:

- Cadmium – BV was exceeded; statistical test showed Site≤BKG, test concluded reject from further evaluation. Only 3 detects in the Unit and background data set, therefore retain for further evaluation due to low detection frequency.
- Chromium – BV was exceeded, statistical test showed Site≤BKG, therefore reject from further evaluation.
- Copper – BV was exceeded; statistical test showed Site>BKG, therefore retain for further evaluation.
- Lead – BV was exceeded, statistical test showed Site≤BKG, therefore reject from further evaluation.
- Mercury – BV was exceeded. All BKG data had same value. No tests could be performed. Retain for further evaluation.
- Silver – BV was exceeded; no background data available for the All H horizon. Only 1 detect in Tuff horizon. Retain for further evaluation.
- Thallium - BV was exceeded, statistical test showed Site≤BKG. Only three detects in site data (two below the residential NMSSL and one above), but 105 detects in background. Since the dataset appears robust despite the low detection frequency for site data, reject from further evaluation.
- Zinc – BV was exceeded; statistical test showed Site ≤BKG, therefore reject from further evaluation.

The maximum concentration of all other inorganics was below BVs, and statistical hypothesis testing was not performed. Only inorganics that both exceeded BVs and were above background by hypothesis testing were carried forward. The ProUCL output is reported in Attachment A.

2.2.3. Comparison of Maximum EPCs to NMSSLs

Table 2-3 presents maximum soil concentrations for the September 2018 surface soil samples compared to the NMSSLs. There were 15 samples and one duplicate included in this data set collected in September 2018. The duplicate pair is grid point 1 (WST36-18-162985 and WST36-18-162834).

The maximum EPC for each detected analyte was divided by the industrial (i.e., composite worker and construction worker) and residential NMSSLs to obtain a HQ for each of the noncarcinogens, for which the hazard index (HI) was calculated by summing the HQs (NMED 2019). The NMSSLs used in the evaluations were obtained from current NMED guidance (NMED 2021) or the most recent EPA RSLs (EPA 2021) if an NMED value was not available (Section 2.2.4). The cancer-based EPA RSLs were multiplied by 10 to adjust them to a cancer risk level of $1\text{x}10^{-5}$, consistent with the NMSSLs. The NMSSLs for carcinogens are equivalent to a 1×10^{-5} cancer risk, and for noncarcinogens the NMSSLs correlate to a ratio or HQ of 1. Any detected organic analytes that exceeded the SLs were considered

COPCs. Any inorganic analytes that exceeded both background and the NMSSL were also considered COPCs.

2.2.3.1. Results Based on Maximum EPC for Inorganics

Maximum concentrations in the soil samples analyzed for inorganics were compared to the established soil BVs (LANL 1998) as described in Section 2.4.2. The results indicate that there were no noncancer HQs above 1 for inorganics (Table 2-3). Only cadmium is also assessed as a carcinogen, and the cancer risk was below the NMED target of $1x10^{-5}$ for all receptors (Table 2-3).

2.2.3.2. Results Based on Maximum EPC for Organics

No individual constituents exceeded NMSSLs (NMED 2021).

2.2.3.3. Dioxin/Furans

The dioxin/furans are organics but are evaluated in the analysis differently than other organics. Some dioxins/furan congeners were detected in the surface soil samples, although most were not (Table 2-1). The evaluation of the dioxin/furans is summarized in Table 2-4. The measured detected concentration or the MDL for nondetects is shown for each congener in each sample. The detection status is indicated by a zero for nondetect, and a 1 for a detected value. The TEFs are shown for each congener, and multiplying the TEF by the measured concentration (or MDL for nondetects) produces the TECi. Summing the TECi yields the TEQ. Dividing the maximum TEQ by the residential or worker NMSSLs for TCDD (Tables 2-3 and 2-4) produces a HI less than 1 and a cancer risk less than $1x10^{-5}$. Therefore, the dioxins and furans do not exceed risk-based SLs.

2.2.3.4. Hazard Indices and Cumulative Cancer Risk

The HI for the evaluation of maximum detected soil concentrations of inorganics for noncancer-based health effects was 0.2 for residents, and 0.01 for industrial workers, and 0.06 for construction workers (Table 2-5). The HI for the evaluation of maximum detected soil concentrations of organics for noncancer-based health effects was 0.04 for residents, 0.002 for industrial workers, and 0.008 for construction workers (Table 2-5). The HI for the evaluation of maximum detected soil concentrations of dioxins/furans as represented by the TCDD TEQ for noncancer-based health effects was 0.1 for residents, and 0.006 for industrial workers, and 0.02 for construction workers (Table 2-5). The total HI for noncancer-based health effects was 0.3 for residents, 0.02 for industrial workers, and 0.1 for construction workers (Table 2-5).

Cancer risk due to inorganics was $5x10^{-11}$ for residents, $1x10^{-11}$ for industrial workers, and $1x10^{-9}$ for construction workers (Table 2-5). The cancer risk for maximum detected soil concentrations of organics was $2x10^{-6}$ for residents, $2x10^{-7}$ for industrial workers, and $3x10^{-8}$ for construction workers (Table 2-5). For TCDD the cancer risk was $8x10^{-7}$ for residents, $2x10^{-7}$ for industrial workers, and $2x10^{-8}$ for construction workers (Table 2-5). Total cumulative cancer risk was $3x10^{-6}$ for residents, $4x10^{-7}$ for industrial workers, and $6x10^{-8}$ for construction workers (Table 2-5).

2.2.1. Lead

Risk evaluation of lead is separate from the other inorganics. Lead was not evaluated because the hypothesis testing indicated that site concentrations were equal to or below background (Table 2-2). Maximum lead concentrations are only 35.2 mg/kg, which is below the NMSSL of 400 mg/kg protective of residential use and the NMSSL of 800 mg/kg protective of industrial use.

2.2.2. Migration to Groundwater

Maximum concentrations were compared to NMED migration to groundwater SL-SSLs based on a DAF of 20. Where SL-SSLs were unavailable, the EPA RSL (DAF of 1) was multiplied by 20 and used as a proxy value (Section 2.2.4). All maxima with the exception of RDX were below the SL-SSL indicating there is little chance of potential migration to groundwater for nearly all constituents.

The RDX maximum is 80 times higher than the SL-SSL. For this reason, RDX was carried forward for further evaluation by use of refined EPCs based on the UCL95.

2.2.3. Refined EPCs

RDX is further evaluated because it exceeds the groundwater SL-SSL. The site data for RDX follow a normal distribution. The UCL95 statistic used as the refined EPC is a 95% Kaplan Meier (KM) (t) UCL of 1.48 mg/kg. The SL-SSL is 5.93E-02 mg/kg. Dividing the refined EPC by the SL-SSL results in a ratio of 2×10^1, indicating the refined EPC is still 20 times higher than the SL-SSL.

Hydrologic information for the area north of the TA-36-8 open detonation unit is presented in the Pajarito Canyon Investigation Report, Revision 1 (LANL, 2009). Groundwater in the unit is not utilized for potable purposes. The closest water supply wells into the regional aquifer are over a mile northeast and upgradient with respect to groundwater flow direction. The depth to groundwater is approximately 1000 feet, suggesting percolation to groundwater is unlikely to occur. Furthermore, evapotranspiration exceeds precipitation, resulting in infiltration rates of less than 10 milliliters per year. The physical information combined with the low concentrations of RDX and the small spatial extent of the Unit suggests that it is unlikely that the Unit would impact groundwater significantly.

2.3. UNCERTAINTY ANALYSIS

The human health risk assessment has inherent uncertainties associated with data and data evaluation, exposure assessment, and the toxicity values on which the SLs are based. Each or all of these uncertainties may affect the assessment results, biasing the risk assessment results high or low.

2.3.1. Data and Data Analysis

Uncertainties in the data or its analysis may include errors in sampling, laboratory analysis, and data analysis. Data evaluation uncertainties are expected to have little effect on the assessment results because the data have undergone validation to minimize errors, and any errors are not expected to bias the results high or low. The J-flagged (estimated) qualification of detected concentrations of some organic COPCs does not affect the assessment. The data represent deposition from more than 60 years of operation into 2018. Therefore, the data and subsequently the screening assessment results represent current baseline conditions.

The use of a judgmental sampling design biases the risk results high since samples were targeted to locations where contamination was most likely to occur or known to occur from past sampling events.

The use of the maximum or a UCL95 as the COPC EPC for each COPC is also expected to bias risk estimates high, erring towards being conservative. Use of the maximum as the EPC overestimates exposure, as by definition all other concentrations are below this value. Use of the UCL95 may also result in an overestimation of risk since by definition true mean values are nearly always going to be less than this value.

2.3.2. Comparison of MDLs to NMSSLs

The MDLs were used for nondetects as the basis of comparing to NMSSLs to verify that detection limits were low enough to detect potential risk that might exist. Only one nondetected analyte had elevated MDLs. The maximum MDL for nitrosodimethylamine[N-] exceeds the cancer-based NMSSL for residential use resulting in a 4x10^{-5} cancer risk. NMSSLs for workers did not exceed 1x10^{-5}, and there were no HQs above 1. All the MDLs are the same indicating that the laboratory cannot achieve lower results with typical laboratory practices. N-Nitrosodimethylamine is volatile and combustible and decomposes when exposed to light (PubChem 2022). It may be formed during cooking meat or fish containing sodium nitrite as a preservative, but is also found in other foods including vegetables, cheeses, alcoholic beverages, and fruits. It is a known contaminant associated with hydrazine manufacturing. Given that volatiles are not expected to remain in surface soils over time, that it is likely to break down under UV light, that residential use is not considered likely at the site, and that there are no statistical approaches that would alter the EPC, this analyte is not addressed further. The MDLs for nondetected analytes are not expected to bias the risk assessment results high or low.

2.3.3. Exposure Assessment

The exposure assessment assumptions bias the risk results high (i.e., overestimate risk). Assumptions for the industrial SLs are that the potentially exposed individual is a Laboratory worker who is outside at the site for 8 hours per day for 225 days per year (NMED 2019), and who spends the entire 8 hours on-site within the contaminated area. Assumptions for the residential SLs are that the potentially exposed individual is a resident who is present 24 hours per day for 350 days per year (NMED 2019) and spends the entire 24 hours on-site within the contaminated area. Because it is unlikely the worker or resident would be within the contaminated area for the entire time, the screening assessments overestimate the exposure. As a result, risks may be overestimated.

Assumptions underlying the exposure parameters, routes of exposure, and intake rates for routes of exposure are consistent with NMED parameters and default values (NMED 2019). In the absence of site-specific data, several upper-bound values for the assumptions may be combined to estimate exposure for any one pathway, and the resulting risk estimate can exceed the 99th percentile. Therefore, uncertainties in the assumptions underlying the exposure pathways may contribute to risk assessments that overestimate the reasonably expected risk levels.

2.3.4. Toxicity Values

The primary uncertainty associated with the screening values is related to the derivation of toxicity values used in their calculation. Toxicity values (slope factors [SFs] and reference doses [RfDs]) were used to derive the risk-based screening values used in the screening evaluation (NMED 2019). Uncertainties were identified in four areas with respect to the toxicity values: (1) extrapolation from animals to humans, (2) variability between individuals in the human population, (3) the derivation of RfDs and SFs, and (4) the chemical form of the COPC.

The SFs and RfDs are often determined by extrapolation from animal data to humans, which may result in uncertainties in toxicity values because differences exist between animals and humans in chemical absorption, metabolism, excretion, and toxic responses. Differences in body weight, surface area, and pharmacokinetic relationships between animals and humans are taken into account to address these uncertainties in the dose-response relationship. However, conservatism is usually incorporated in each of these steps, potentially biasing the estimate high and resulting in the overestimation of potential risk.

For noncarcinogenic effects, the degree of variability in human physical characteristics is important both in determining the risks that can be expected at low exposures and in defining the no observed adverse effect level (NOAEL). The NOAEL uncertainty factor approach incorporates a 10-fold factor to reflect individual variability within the human population that can contribute to uncertainty in the risk assessment. This factor of 10 is generally considered to result in a conservative estimate of risk for noncarcinogenic COPCs.

The RfDs and SFs for different chemicals are derived from experiments conducted by different laboratories that may have different accuracy and precision that could lead to an over- or underestimation of risk. The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. For carcinogens, the weight of evidence classification indicates the likelihood that a contaminant is a human carcinogen.

COPCs may be bound to the environmental matrix and not be available for absorption into the human body following ingestion. However, the exposure scenarios typically default to the assumption that the COPCs are bioavailable. This assumption can lead to an overestimation of toxicity, total exposure, and overestimate risk.

2.3.5. Additive Approach

For noncarcinogens, the effects of exposure to multiple chemicals are generally unknown and possible interactions could be synergistic or antagonistic, resulting in either an underestimation or overestimation of the potential risk by assuming additivity. Additionally, RfDs used in the risk calculations typically are not based on the same endpoints with respect to severity, effects, or target organs. Therefore, the potential for noncarcinogenic effects may be overestimated by the HI considering individual COPCs act by different mechanisms and on different target organs but are addressed additively. Cancer risks are typically assumed to be additive.

2.4. CONCLUSIONS

Inorganics were compared to BVs and risk-based SLs. Eight inorganics exceeded background to some extent. Hypothesis testing reduced the inorganics for risk screening to cadmium, copper, mercury, and silver. Perchlorate was also retained because there was no BV.

Organics were compared to risk-based NMSSLs. There were numerous organics detected, including some energetics, some SVOCs, and dioxin/furans. However, maximum concentrations of all of the detected analytes were below cancer- and noncancer-based NMSSLs for all constituents. None of the TEQs for dioxin/furans exceeded the TCDD SL. The Unit does not present an elevated cancer risk or noncancer hazard to human health due to exposure to surficial soils. The following interpretation can be made from the analysis, where the total HI or cancer risk is the sum of the inorganics, organics, and dioxin/furan values (excluding lead):

- For the residential scenario, inorganics above background, and maximum detected concentrations for each analyte, the total noncancer HI (0.3) and cancer risk ($3x10^{-6}$) are less than the NMED target levels of 1 and $1x10^{-5}$, respectively.
- Based on an industrial scenario, inorganics above background, and maximum detected concentrations for each analyte, the total noncancer HI (0.02) and cancer risk ($4x10^{-7}$) are less than the NMED target levels of 1 and $1x10^{-5}$, respectively.

- Based on a construction worker scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer HI (0.09) and cancer risk ($6x10^{-8}$) are less than the NMED target levels of 1 and $1x10^{-5}$, respectively.
- The TEC concentration of each dioxin/furan congener was summed to obtain a TEQ which was compared to the NMED NMSSLs for each receptor for TCDD. The noncancer HI and cancer risk are less than the NMED target levels of 1 and $1x10^{-5}$, respectively.
- The maximum lead concentration of 35.2 mg/kg at the Unit is just slightly above the background value of 22.3 mg/kg, and is much less than the residential SSL (400 mg/kg). Lead is not significantly different from background based on hypothesis testing.
- RDX exceeded migration to groundwater SL-SSLs. The ratio was 80 based on the maximum RDX concentration, and 20 based on the refined EPC.
- There are no elevated human health risks for exposure to soils based on this evaluation. Risks to groundwater are considered minimal because depth to the regional aquifer is approximately 1000 ft bgs with little potential for infiltration. Runoff into surface water from the Unit is considered unlikely due to distance and existing erosion controls.

3. ECOLOGICAL RISK ASSESSMENT

3.1. INTRODUCTION

The ecological risk assessment (ERA) for the Unit is presented in the following sections. The ecological risk-screening evaluation identifies chemicals of potential ecological concern (COPECs) and is based on the comparison of EPCs with Ecological Screening Levels (ESLs) in accordance with Laboratory guidance (LANL 2012a) and NMED (2017) guidance.

Site information including ESLs, biological studies, and historical information were reviewed and a site visit was conducted. A preliminary conceptual site exposure model (CSEM) was prepared.

The ESLs obtained from the ECORISK Database, Version 4.2 (LANL 2020), updated November 11, 2020), are presented in Table 3-1. The ESLs are based on toxicity data for laboratory species similar to those expected to occur at the site, and are derived from experimentally determined NOAELs, lowest observed adverse effect levels (LOAELs), or doses determined to be lethal to 50% of the test population (LD50). Information relevant to the calculation of ESLs, including concentration equations, dose equations, bioconcentration factors, transfer factors, and toxicity reference values, are presented in the ECORISK Database, Versions 2.0, 3.1, and 4.1 (LANL 2003; LANL 2012b; LANL 2017; LANL 2020).

The screening evaluation is conducted by dividing the EPCs by the ESLs to obtain a HQ calculated for each COPEC and screening receptor. As a generalization, the higher the contaminant levels relative to the ESLs, the higher the potential risk to receptors; conversely, the higher the ESLs relative to the contaminant levels, the lower the potential risk to receptors. The analysis begins with a comparison of the No Effect (NE) ESL for each receptor and COPEC to the maximum EPC. HQs greater than 0.1 are used to identify COPECs requiring additional evaluation.

Individual HQs for a receptor are summed to derive a HI. An HI greater than 1 indicates that further assessment may be needed to ensure exposure to multiple COPECs at a site will not lead to potential adverse impacts to a given receptor population. The HQ and HI analysis is a conservative indication of potential adverse effects and is designed to minimize the potential of overlooking possible COPECs at the site.

3.2. PROBLEM FORMULATION AND CONCEPTUAL SITE EXPOSURE MODEL

The Unit is a terrestrial ecosystem. The area is disturbed with little to no vegetation present. Vegetation increases with distance from the OD area and consists of grasses and shrubs. There are likely terrestrial birds and small mammals including deer mice or ground squirrels using the area, although intermittently due to the lack of food or cover. There is not enough vegetation within the 1.44-acre Unit to support large herbivores.

Due to the site history, there is the potential for energetic compounds or their breakdown products to be present in surface soils, where terrestrial animals and plants may contact surface soils and potentially be exposed. This possibility led to the collection of data and ecological risk assessment.

3.2.1. Data Summary

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- VOCs –15 samples and one duplicate
- SVOCs –15 samples and one duplicate
- Total Metals –15 samples and one duplicate
- Dioxins/Furans –15 samples and one duplicate
- High Explosives –15 samples and one duplicate

In addition, two samples were resampled for SVOCs, and some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dinitrobenzenes) (Table 2-1). Figure 1-1 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment, and habitat in the immediate site vicinity is also shown in Figure 1-1.

3.2.2. Site Visit Summary

A site visit was conducted in March 2019. The area is disturbed by human activity with buildings, roads, and maintained cleared areas to minimize fire danger. The vicinity around the Unit is a terrestrial ecosystem, although within the Unit it is largely bare ground (Figure 1-1). There are likely terrestrial birds and small mammals including deer mice or ground squirrels using the area; however, there is not enough vegetation within the Unit to support birds or mammals or their prey items.

3.2.3. Receptors and Pathways

Exposure pathways are considered complete if all of the following components are present (EPA, 1989; NMED, 2017):

- A source and mechanism for hazardous waste/constituent release into the environment;
- An environmental transport medium or mechanism;
- A point of contact directly between the receptor and site-related contaminated media, or indirectly via dietary ingestion of prey or forage items contaminated by contact with site related contaminants; and

- An exposure route leading to interaction of the contaminant with target organs within the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site.

A CSEM was developed for the site (Figure 3-1). The primary contaminant source is the testing of explosives and detonation of explosives debris at the site. Any uncombusted material, if present, could remain in soil or be released to air as fugitive dust. Materials in surface soil could be carried by overland flow or percolate into the subsurface with rain, whereas material in air could be transported by wind. Receptors could contact contaminants within the immediate site area, up to the site boundary, or slightly beyond. The use of stormwater BMPs and earthen berms reduces the potential for migration beyond the Unit.

Ingestion of soil, plants, or animals are all potential exposure routes to ecological receptors. Although inhalation is recognized to occur, it is typically considered insignificant relative to ingestion and only quantified for burrowing animals where volatile organics are present in the subsurface. Respirable dust particles are likely ingested rather than inhaled by ecological receptors, and this pathway is considered negligible (EPA 1997; EPA 2003), while non-respirable dust is ingested and accounted for in incidental soil ingestion values for wildlife species (EPA 1993; EPA 2003). Therefore, the exposure pathways considered in the development of the ESLs used in the risk-screening assessment capture the primary exposure for wildlife receptors.

Terrestrial flora (i.e., plants) and fauna (e.g., invertebrates, birds, and mammals) are the general categories of ecological receptors that could be exposed. The primary ecological exposure pathways are based on direct or indirect contact with surface soils. These include root uptake, incidental ingestion of soil, and biotic uptake leading to food-web transport. Exposure of plants and soil invertebrates is not evaluated as related to dietary pathways but as the result of direct contact with, and uptake from, the surrounding medium. For terrestrial wildlife, most exposure is considered to be through the oral pathway from the diet and incidental soil ingestion (Sample et al. 1998). The dermal contact and inhalation pathways are not typically assessed quantitatively in ecological risk assessments, based on guidance indicating the ingestion route is most important to terrestrial animals (EPA 1997; EPA 2003). Dermal exposure to wildlife is mitigated by the fur or feathers covering the bodies of most vertebrates and the incidental soil consumption during grooming is included in the direct soil ingestion estimates. Due to lack of its preferred riparian habitat and lack of dense cover, the montane shrew (*Sorex monticolus*) is not expected to occur and is not evaluated in this analysis.

3.2.4. Technical Decision Point and Recommendations

Because of the ecological habitat near the Unit boundaries, and because of the potential for exposure, the data were used to perform a quantitative screening level ecological evaluation.

3.3. ECOLOGICAL SCREENING EVALUATION

The summary statistics for the data were presented in Table 2-1. Maximum detected concentrations of each analyte are used as the initial EPC. The EPCs and the screening results for the ecological screening assessment are presented in Table 3-2. Any analytes for which the measured maximum detected value exceeded the NE ESLs were considered COPECs and were evaluated further by calculating UCL95s and comparing the UCL95s to the Low Effect (LE) ESLs. The approach used to evaluate the data for ecological risk was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to BVs. Analytes less than BVs were eliminated from further evaluation. The remaining inorganics were tested with Wilcoxon-Mann Whitney or Gehan hypothesis tests to determine if site data exceeded or were similar to background. Analytes that exceeded background were carried forward. Cadmium, copper, mercury, perchlorate, and silver are carried forward (Section 2.1.3.4).
- The screening approach then used the maximum of all data, including the duplicate pair, for the initial screening evaluation. The maximum concentration of each analyte was divided by its NE ESL for each receptor.
- All analytes that exceeded the NE ESLs with a HQ greater than 0.1 were considered to have "failed" the initial screen. These are considered to be COPECs.
- A refinement of the EPCs was performed. The minimum of the duplicate pair was removed from the dataset prior to estimating UCL95 values to use as the refined EPC. The refined EPCs based on UCL95 concentrations were compared to LE ESLs, and any analytes above the LE ESLs with a HQ greater than 0.1 were evaluated further by comparison to population area use factors.

3.3.1. Inorganics

There are four inorganics that exceed site BVs, and perchlorate is retained because there is no BV (Section 2.2.2). The maximum concentration of each of these was compared to the NE ESL, if one was available, to determine if the resulting HQ >0.1. The inorganic analytes that exceed ecological NE SLs for one or more receptors are as follows (Table 3-2):

- Cadmium
- Copper
- Mercury
- Perchlorate
- Silver

If an inorganic analyte maximum exceeded the BV and the ratio of the maximum to the risk-based SL was greater than 0.1, a UCL95 was calculated with the EPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the LE ESLs found in Table 3-1 consistent with the NMED (2017) Tier II approach. Note that comparison to the UCL95s was made prior to incorporating population area use factors (PAUFs) into the analysis. Receptor-specific dietary composition is built into the receptor-specific ESLs. The minimum concentrations for each of the samples in the duplicate pair, site location point #1 in Figure 1-1, were removed and the UCL95 calculated with a sample size of 15. Table 3-3 presents the UCL95s used to represent refined EPCs. The ProUCL output is found in Attachment A.

UCL95 values for copper and mercury produced HQs greater than 0.1 when compared to the LE ESL with UCL95/ESL (Table 3-4). This suggests some limited potential for adverse ecological effects at the Unit, and therefore these COPECs are evaluated in more detail in the uncertainty analysis in Section 3.4.8.

3.3.2. Dioxin and Furans

Dioxin and furans were detected in multiple samples in the September 2018 data set. Dioxins and furans are evaluated in a multi-step process that takes the concentration of each congener and multiplies it by a TEF for mammals or birds (Table 3-5). The TEFs for mammals and birds were applied to calculate a TECi for each congener in a sample. The resulting TECi values are summed to obtain a TEQ specific to mammalian (Table 3-6) or avian (Table 3-7) receptors for each sample.

TEFs for plants and invertebrates are not available. Therefore, the TEFs for mammals were applied to represent these taxa in order to calculate TEQs. In general, mammalian TEFs are the same or higher than avian TEFs, and this results in a higher, more conservative, TEQ.

The maximum avian and mammalian TEQs were compared to the NE ESLs reported in Table 3-1. The results of the comparison to maximum EPCs is reported in Table 3-2. The UCL95 TEQ was used as the refined EPC and compared to the LE ESLs (Table 3-1) with the results reported in Table 3-4. There are no LE ESLs for birds for TCDD. The MDLs were used as the reported value for nondetected data.

The dioxin/furans produced HQs greater than 0.1 when compared to the NE ESL for birds. There is no LE ESL and further evaluation for avian species was not performed. The HQ based on the LE ESL for the deer mouse was 1; no other mammals or other ecological receptors are potentially negatively affected by dioxin/furans..

3.3.3. Other Organics

Maximum concentrations of six other organics produced HQs greater than 0.1 when compared to NE ESLs (Table 3-2). These were benzoic acid, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, HMX, RDX, and TATB. UCL95 values were calculated (Table 3-3) and compared to the LE ESLs (Table 3-4).

There were only two detections of benzoic acid, and four detections of di-n-butylphthalate. The low detection frequency for these two constituents means that a robust UCL95 cannot be calculated. Therefore, a median of the measured concentrations and the reported MDL values was calculated and used as the estimate of the EPC. This approach is consistent with ProUCL guidance (EPA 2015) that recommends use of alternative statistics when detection frequency is low.

Refined EPC values for bis(2-ethylhexyl)phthalate produced HQs greater than 0.1 when compared to the LE ESLs (Table 3-4) for the American kestrel and robin. RDX and TATB also produced HQs greater than 0.1 when compared to the LE ESLs (Table 3-4). These organics are further evaluated in the risk analysis in Section 3.4.8.

3.3.4. Hazard Indices

The HIs ranged from less than 1 for plants, mammalian herbivores, and top avian and mammalian carnivores to 10 for the robin modeled as an insectivore (Table 3-4). Section 3.4.8 addresses all COPECs with HQs greater than 0.1.

3.4. UNCERTAINTY ANALYSIS

3.4.1. Chemical Form

Inorganic analytes can speciate into different forms with varying degrees of toxicity. The assumptions used in the ESL derivations are conservative and not necessarily representative of actual conditions. These assumptions include maximum chemical bioavailability, maximum receptor ingestion rates, minimum bodyweight, and additive effects of multiple COPECs. These factors tend to result in conservative ESL estimates, which may lead to an overestimation of the potential risk. Toxicological data are typically based on the most toxic and bioavailable chemical species, which may or may not be found in the environment. The ESLs were calculated to ensure a conservative indication of potential risk (LANL 2012a), and the values are biased toward overestimating the potential risk to receptors.

The chemical form of the individual COPECs was not determined as part of the investigation. COPECs are generally not 100% bioavailable to receptors in the natural environment because of interference from other natural processes, such as the adsorption of chemical constituents to matrix surfaces (e.g., soil) or rapid oxidation or reduction changes that render harmful chemical forms unavailable to biotic processes.

3.4.2. Reporting Limits

Reporting limits were adequate (i.e., below NE ESLs) for ecological receptors for all analytes with few exceptions, indicating that the data were adequate for use in the risk assessment:

Thallium –

- Thallium MDLs exceeded the NE ESL for plants.
- Thallium was below background by hypothesis testing.
- Reporting limits were below the minimum LE ESL.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Dinitrobenzene[1,3-]–

- This analyte was not detected in any sample. Reporting limits were less than the non-cancer based NMSSL for residents or workers.
- The reporting limits were two times higher than the minimum NE ESL for the robin modeled as an herbivore, the deer mouse, and the mountain cottontail.
- Reporting limits were below the minimum LE ESL.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Hexachlorobenzene –

- This analyte was not detected in any sample. Reporting limits were less than the non-cancer based NMSSL for residents or workers.
- The reporting limits were slightly over 1 times higher than the minimum NE ESL for the robin modeled as an insectivore.
- Reporting limits were below the minimum LE ESL.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

3.4.3. Exposure and Risk Estimates

Exposure parameters including the EPC and the intakes likely bias risk estimates high because they presume no movement of receptors in and out of source areas. Sampling focused on areas of known or expected contamination, which biases the EPC high. Receptors are assumed to spend 100% of their time in the contaminated area which results in conservative estimates of exposure.

Another source of uncertainty is inherent in the calculation of exposure and risk estimates. Although the toxicity values are expressed to more than one significant figure, it is unlikely that the toxicity data are this accurate, especially given that the data are extrapolated from laboratory animal studies to wildlife receptors that are mobile in the environment. Likewise, given all the variables inherent in assessing exposure, exposure intakes by ecological receptors also should not be considered more accurate than one significant figure. This means that an HQ identified as 0.8 or 1.2 is actually 1, and an HQ identified as 1.5 is actually 2.

Calculating risk for dioxins is a multi-step process that involves multiplying the measured concentration by a TEF to obtain a value called the TECi that when summed adjusts the measured congener concentrations to that relative to TCDD, where the sum of all TECi is called the TEQ. TEQs were calculated for each sample to obtain a sample concentration, then a UCL95 calculated across all samples. This is consistent with how other analytes are evaluated statistically. It is not expected to bias the risk results high or low.

3.4.4. Mixture Toxicity

The assumption of additive effects for multiple COPECs may result in an over- or under-estimation of the potential risk to receptors. Exposure to multiple contaminants may result in other than additive effects. Conservative assumptions made with regards to EPCs would tend to overestimate exposure to any given constituent, and this would suggest that the toxicity of multiple constituents would not be underestimated. Therefore, mixture toxicity is not likely to bias the risk results high or low.

3.4.5. Toxicity Information

ESLs are based on toxicity information, and if toxicity data are not available an ESL is missing from the database. ESLs were not available for the cations and anions generally regarded as nutrients (i.e., calcium, magnesium, nitrate, potassium, and sodium). Human health risk was below targets for these nutrients. These inorganics were also below background. ESLs were also not available for iron, but iron was less than its BV and human health risk ratios for residents were 0.2 or lower. Lack of ESLs for these inorganics is not expected to underestimate ecological risk at the site.

Several organic chemicals (Table 3-1) do not have ESLs for any receptor in release 4.2 of the ECORISK Database (LANL 2017; LANL 2020). Predominantly, the constituents lacking ESLs are nondetected organics. In the absence of a chemical-specific ESL, concentrations can be compared with the ESLs for a surrogate chemical, if available. Comparison to surrogate ESLs provides an estimate of potential effects of a chemically related compound and a line of evidence to indicate the likelihood that ecological receptors are potentially impacted. Some chemicals without ESLs do not have chemical-specific toxicity data or surrogate chemicals to be used in the screening assessments and cannot be assessed quantitatively for potential ecological risk.

Chemicals lacking ESLs (Table 3-1) are often infrequently detected across the site. In these cases, comparisons with human health SLs are presented as part of a qualitative assessment, if human health SLs are available. The comparison of concentrations to human health SLs is a viable alternative for several reasons. Animal studies are used as the basis of toxicity values for human health risk assessments, and are the basic premise of modern toxicology (EPA 1989). In addition, toxicity values derived for the calculation of human health SLs (e.g., histopathology or biochemical changes) may be based on potential adverse effects more sensitive than the ones typically used to derive ESLs (e.g., survival, growth, or reproductive effects). EPA also applies uncertainty factors or modifying factors to ensure the toxicity values are protective (i.e., toxicity values are divided by uncertainty factors resulting in values much lower than initial study results). Since there were no predicted adverse effects on human health, chemicals lacking ESLs are unlikely to pose an ecological risk (Table 3-2). Some of the analytes for which ESLs are not available are addressed below:

- Isophorone had no ESLs. It was detected in one sample. The human health cancer risk and noncancer HQs were below targets. It is likely that this analyte will have no negative effect on ecological receptors.

- There were no ESLs for 3,5-dinitroaniline, which was not detected in any sample. The ESLs for amino-2,6-dinitrotoluene[4-] were used (Attachment B) to evaluate MDLs. HQs were less than 0.1.
- There are no avian LE ESLs for TCDD in the current (LANL 2020) LANL EcoRisk database. However, there is a NE ESL and there were no HQs greater than 1.
- There are no avian NE ESLs for most of the PAHs. However, the HQs for benzo(a)anthracene are all less than 0.1, suggesting other PAHs also might not produce adverse effects.
- There are no avian values for benzoic acid or benzyl alcohol. These did not produce adverse human health effects. There are values for mammals and so some ecological receptors are quantitatively addressed.
- There are no ESLS for isopropyltoluene[4-]. Values for toluene were used; avian values not available.
- There are no avian values for diethylphthalate. This did not produce adverse human health effects. There are values for mammals and so some ecological receptors are quantitatively addressed, and there are avian ESLs for other phthalates which are evaluated in the analysis.
- There are no NE ESLs for birds for HMX or TATB. These did not produce adverse human health effects. There are values for HMX for mammals and so some ecological receptors are quantitatively addressed, and there are avian NE ESLs for a similar compound, RDX, which is evaluated in the analysis. Values for 1,3,5-trinitrobenzene were used to represent TATB.
- There are no NE ESLs for birds for methylene chloride or toluene. These did not produce adverse human health effects. There are values for mammals and so some ecological receptors are quantitatively addressed.
- There are no NE ESLs for birds for aluminum, antimony, or beryllium. Antimony was never detected, and the other inorganics were below BVs.
- There are no avian, invertebrate, or plant NE ESLs for 2-butanone. This analyte was not detected. Mammals are evaluated and so some ecological receptors are quantitatively addressed.
- 1,3-Dintrobenzene MDL exceeded NE ESLs for robin (herbivore), deer mouse (omnivore), and cottontail (herbivore), but did not exceed any LE ESLs. This was not detected and the maximum was less than human health SLs.

TEFs reflect the toxicity of the different dioxin/furan congeners. TEFs for plants and invertebrates are not available. Therefore, the TEFs for mammals were applied to represent these taxa in order to calculate TEQs. In general, mammalian TEFs are the same or higher than avian TEFs, and this results in a higher, more conservative, TEQ. Therefore, applying mammalian TEFs for plants and earthworms is more likely to overestimate than underestimate risk.

3.4.6. Small-Mammal Field Investigations

Small mammal trapping and analysis of whole organisms were conducted in the area around the Unit in 2010. This information was considered useful for the current analysis as an additional line of evidence. Field mice were collected around the site and analyzed for dioxins and furans as well as metals, and for polychlorinated biphenyls (PCBs) (Fresquez 2011). Small-mammal community and population parameters were also measured across the site (Bennett and Robinson 2011).

Small mammals expected at the Unit are the deer mouse (*Peromyscus maniculatus*), brush mouse (*Peromyscus boylii*), pinyon mouse (*Peromyscus truei*), silky pocket mouse (*Perognathus flavescens*), western harvest mouse (*Reithrodontomys megalotis*), white-throated woodrat (*Neotoma albigula*), and the Mexican woodrat (*Neotoma mexicana*) (Bennett and Robinson 2011). The vegetation community consists of piñon (*Pinus edulis Engelm*.), juniper (*Juniperus monosperma [Englem.] Sarg*.) with scattered ponderosa pine (*Pinus ponderosa C. Lawson*) and gambel oak (*Quercus gambelii Nutt*.) (Bennett and Robinson 2011). The capture rate and species diversity were highest at the Unit relative to the control area, and five species were captured. There were no differences in deer mouse sex ratios between the Unit and the control area. Average body weight of adult male deer mice was slightly higher at the Unit than at the control area. The authors of the study concluded that there was no apparent adverse effects on small mammal populations at the Unit relative to controls.

Radionuclides and chemical concentrations in biota were compared to regional statistical reference levels (RSRLs). RSRLs represent natural and fallout levels, and are the upper-level background concentrations (mean plus three standard deviations = 99% confidence level) for radionuclides and chemicals calculated from biota that was collected from regional locations away from the influence of the Laboratory (over nine miles away) (Fresquez 2011). The only analytes that exceeded RSRLs were barium (two out of three samples) and lead (three out of three samples). Dioxins/furans and explosives were not detected. These data suggest that there are no impacts to small mammal populations at the Unit.

3.4.7. Avian Field Investigations

Two western bluebird (*Sialia mexicana*) egg samples were obtained in 2018 from the Unit and analyzed for inorganic elements (Gaukler and Stanek 2019).

Concentrations of inorganic elements were compared with the upper-level bounds of background concentrations in bird eggs. The data indicated aluminum, antimony, arsenic, beryllium, cadmium, lead, nickel, silver, or vanadium were not detected in eggs (Gaukler and Stanec 2019). Barium, calcium, chromium, cobalt, iron, magnesium, manganese, mercury, potassium, selenium, sodium, thallium, and zinc were detected but were all below the RSRL for avian eggs. Copper at 4.1 mg/kg in one egg exceeded the RSRL of 3.6 mg/kg. Copper EPCs based on the UCL95 were compared to the ESLs for birds and were all below ESLs, suggesting that there would be no impact to bird populations due to copper. One sample of mountain bluebird (*Sialia currucoides*) eggs was collected in 2019, and no analytes were above the RSRLs (Gaukler and Stanek 2020).

Avian population metrics also do not suggest that birds in the vicinity are being negatively impacted (Hathcock et al 2018). Metrics including species richness and diversity were not statistically different from the Unit than at the control area. Species diversity was higher than at the control area in 2014, and afterwards was similar. Abundance varied in the Unit and control area annually, but abundance in the Unit compared to controls were similar over time, and just slightly lower than controls in 2016 and 2017. Species composition appears more influenced by habitat type, and indicates little difference between the Unit and control sites.

Combined, the egg concentration data and population metrics suggest that adverse health effects are not expected at the observed concentrations.

3.4.8. Area Use Factors

The Unit is very small with an areal extent of 1.44 acres (0.58 hectares (ha)). This is approximately the size of the home range (HR) of an individual robin as shown in Table 3-8. The HR is used to calculate area use factors (AUFs) that are used in the EcoPRG equations (LANL 2017). Individual AUFs and population area use factors (PAUFs) may be used to modify the estimate of risk to wildlife receptors to allow estimates to be more site-specific. The application of AUFs or PAUFs reduces potential overestimation of risks for those receptors with HRs larger than the area of contamination being evaluated. The estimated ecological risk as indicated by the HQ or HI is multiplied by the AUF or PAUF. HQs for plants or invertebrates are not adjusted by area use.

Table 3-8 presents the area use hazard analysis based on NE ESLs. The NE ESLs for each COPC that failed the screening evaluation (i.e., because refined EPCs exceeded the LE ESLs with HQs greater than 0.1) are shown for each receptor. The site specific AUF and PAUFs are shown for an area equivalent to the Unit. The UCL95 EPC is divided by the ESL and multiplied by the PAUF to obtain revised HQs. The habitat is not suitable for Mexican Spotted Owls or other special status species, and so an AUF evaluation was not conducted.

The mercury HQ is above 1 for robin modeled as an insectivore based on comparison of UCL95 values as the refined EPC to the NE ESL for each receptor (Table 3-8). The HQs for copper for plants and earthworms, and the HQ for mercury for earthworms, were greater than 1. No organics produced HQs above 1 (Table 3-8).

Table 3-9 presents the area use hazard analysis based on comparison of the UCL95 values as the EPC to the LE ESLs for each receptor. There are no HQs above 1. Table 3-9 presents HIs for LE ESLs calculated by summing the HQs. HIs are above 1 only for earthworms (HI =2) for the LE ESL comparison. Summing the HQs presumes effects will be additive, when effects may occur on different target organs and not be additive.

3.5. CONCLUSIONS

The ecological risk assessment used a tiered approach for determining if the Unit would present an ecological risk. The results of the initial and highly conservative screening step indicated several inorganics occurred above background concentrations, and several detected organics, would present a potential ecological risk. Maximum concentrations of five detected inorganics (i.e., cadmium, copper, mercury, perchlorate, and silver) exceeded background. Maximum concentrations of these inorganics also exceeded NE ESLs.

Dioxin/furans, some polynuclear aromatic hydrocarbons (PAHs), phthalates, benzoic acid, benzyl alcohol, and explosives were among the organics detected in the unit. Five inorganics (cadmium copper, mercury, perchlorate, and silver) and seven detected organics (benzoic acid, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, HMX, RDX, TCDD TEQ, and TATB) exceeded NE ESLs in the initial screening level evaluation which compared maximum soil concentrations as EPCs to the NE ESLs.

Further evaluation by statistically estimating UCL95's to use as refined EPCs suggested few inorganics or organics would occur at concentrations hazardous to ecological receptors. Use of the UCL95 as the EPC provides a conservative estimate of average exposure across the Unit. Copper and mercury were the only inorganics with an HQ above 0.1 based on dividing the UCL95 by the LE ESL. UCL95's for bis(2-ethylhexyl)phthalate, RDX, TCDD TEQ, and TATB exceeded one or more LE ESLs.

Additional consideration of site ecology and receptor-specific adjustments to exposure by considering home range and site area further reduced the analytes exceeding NE ESLs. Only HQs for copper for earthworms and plants, and mercury for earthworms and robins, were above 1 based on a site-specific hazard analysis and NE ESLs. The HQs above 1 occurred for robins modeled as insectivores, and for plants and earthworms for which the area use evaluation is not relevant as they are largely immobile in the environment. However, the Unit is not vegetated because of its designated use as an OD area, and so plants and invertebrates have no habitat in the Unit. Robins would be unable to forage totally within the unit due to lack of prey and forage items. The LE ESLs are not exceeded for any receptor for any individual constituents, but the HI for earthworms is 2. This indicates that there is a very low potential for ecological risk at the Unit.

Finally, there is no suggestion of human health risk at the Unit, and the Unit is small relative to surrounding habitat, being only 1.44 acres. Due to human disturbance, ecological receptors are unlikely to remain within the Unit on a regular basis. The Unit is not likely to present an ecological risk to any receptor evaluated.

4. REFERENCES

Bennett, K., and R. Robinson. 2011. Small Mammal Sampling at Open-Detonation Firing Sites. LA-UR-11-00717. January 2011. (Bennett and Robinson 2011)

EPA (U.S. Environmental Protection Agency), December 1989. “Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final,” EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989)

EPA (U.S. Environmental Protection Agency), 1993. “Wildlife Exposure Factors Handbook,” U.S. Environmental Protection Agency document EPA/600/P93/187A, Office of Research and Development, Washington, D.C. (EPA 1993)

EPA (U.S. Environmental Protection Agency), June 5, 1997. “Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final,” U.S. Environmental Protection Agency, Environmental Response Team, Edison NJ. (EPA 1997)

EPA (U.S. Environmental Protection Agency), November 2003. “Guidance for Developing Ecological Soil Screening Levels, Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs, Attachment 1-3, U.S. Environmental Protection Agency document OSWER Directive 92857-55, Office of Solid Waste and Emergency Response. (EPA 2003)

EPA (U.S. Environmental Protection Agency), December 2010a. “Final Report Bioavailability of Dioxins and Dioxin-Like Compounds in Soil,” Office of Superfund Remediation and Technology Innovation, Environmental Response Team, West Las Vegas, Nevada (http://epa.gov/superfund/health/contaminants/dioxin/pdfs/Final_dioxin_RBA_Report_12_20_10.pdf). (EPA 2010a)

EPA (U.S. Environmental Protection Agency), December 2010b. “Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8=Tetrachloro-p-dioxin and Dioxin-Like Compounds.” EPA/100/R 10/005. (EPA 2010b)

EPA (U.S. Environmental Protection Agency), January 2014. “Technical Fact Sheet – N-Nitroso-dimethylamine (NDMA)”. https://www.epa.gov/sites/production/files/2014-03/documents/ffrrofactsheet_contaminant_ndma_january2014_final.pdf . (EPA 2014)

EPA (U.S. Environmental Protection Agency), October 2015. “ProUCL Version 5.1.002 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations.” EPA/600/R-07/041. ORD Site Characterization and Monitoring Technical Support Center. (EPA 2015)

EPA (U.S. Environmental Protection Agency), August 2021. Regional Screening Levels (RSLs) – Generic Tables Dated November 2021. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. (EPA 2019)

Fresquez, P.R. 2011. Chemical Concentrations In Field Mice Collected From Open-Detonation Firing Sites Ta-36 Minie And Ta-39 Point 6 At Los Alamos National Laboratory. LA-UR-11-10614. May 2011. (Fresquez 2011)

Gaukler, S. and J Stanek. 2019. " Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory". LA-UR-19-25647. June 2019. (Gaukler and Stanek 2019)

Gaukler, S. and J Stanek. 2020. "2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory." March 25 2020. LA-UR-20-22529. (Gaukler and Stanek 2020)

Hathcock, C. D., Bartlow, A. W., and B.E. Thompson. 2018. "2017 Results for Avian Monitoring at the Unit Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory". 2018-04-30 (rev.1) LA-UR-18-22897. (Hathcock et al. 2018)

LANL (Los Alamos National Laboratory), September 1998. "Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico. (LANL 1998)

LANL (Los Alamos National Laboratory), November 2003. "ECORISK Database (Version 2.0)," on CD, Los Alamos, New Mexico. (LANL 2003)

LANL (Los Alamos National Laboratory). 2009. Pajarito Canyon Investigation Report, Revision 1. , Los Alamos National Laboratory document LA-UR-09-04670, Los Alamos, New Mexico. August 2009.

LANL (Los Alamos National Laboratory), November 2012a. "Screening-Level Ecological Risk Assessment Methods, Revision 3," Los Alamos National Laboratory document LA-UR-12-24152, Los Alamos, New Mexico. (LANL 2012a)

LANL (Los Alamos National Laboratory), October 2012b. "ECORISK Database (Release 3.1)," LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2012b)

LANL (Los Alamos National Laboratory), 2017. "ECORISK Database User Guide, Revision 1". LA-UR-17-26376. Los Alamos National Laboratory, Los Alamos, New Mexico. September 2017. (LANL 2017)

LANL (Los Alamos National Laboratory), 2020. "ECORISK Database (Release 4.2)," Updated Database. LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. November 19, 2020. (LANL 2020)

NMED (New Mexico Environment Department). 2017. Risk Assessment Guidance for Site Investigations and Remediation. Volume II. Soil Screening Guidance for Ecological Risk Assessments.2017 Revised. (NMED 2017)

NMED (New Mexico Environment Department). February 2019. Risk Assessment Guidance for Site Investigations and Remediation. Volume I. Soil Screening Guidance for Human Health Risk Assessments. February 2019. Rev. 1 (3/7/19) (NMED 2019)

NMED (New Mexico Environment Department). 2021. New Mexico Soil Screening Levels. December 2021. (NMED 2021)

PubChem. 2022. Compound Summary. N-nitrosodimethylamine. National Library of Medicine. Accessed March 6 2022. https://pubchem.ncbi.nlm.nih.gov/compound/N-nitrosodimethylamine.

Sample, B.E., Suter III, G.W., Efroymson, R.A., and Jones, D.A., May 1998. “A Guide to the ORNL Ecotoxicological Screening Benchmarks: Background, Development, and Application,” Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4783, ORNL/TM13615, Oak Ridge, TN. May 1998 (Sample et al. 1998)

Van den Berg et.al, 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency factors for Dioxin and Dioxin-like Compounds. ToxiSci Advance Access, July 7, 2006. (Van den Berg et al. 2006)

WHO (World Health Organization). September 2009. “Project For The Re-Evaluation Of Human And Mammalian Toxic Equivalency Factors (TEFS) Of Dioxins And Dioxin-Like Compounds”. International Programme on Chemical Safety. http://www.who.int/ipcs/assessment/tef_update/en/ (WHO 2009)

Tables

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Inorganics								
Aluminum	16	1.77E+03	4.14E+03	2.89E+03	7.00E+02	6.24E+00	6.84E+00	16
Antimony	16	3.03E-01	3.32E-01	3.25E-01	2.94E-02	3.03E-01	3.32E-01	0
Arsenic	16	8.44E-01	2.28E+00	1.41E+00	3.37E-01	3.12E-01	3.42E-01	16
Barium	16	2.58E+01	1.15E+02	5.80E+01	2.53E+01	9.18E-02	1.01E-01	16
Beryllium	16	2.08E-01	5.88E-01	3.48E-01	1.19E-01	1.85E-02	2.02E-02	16
Cadmium	16	9.18E-02	4.67E-01	1.41E-01	1.05E-01	9.18E-02	1.01E-01	3
Calcium	16	1.68E+03	5.74E+03	2.99E+03	1.07E+03	7.34E+00	8.05E+00	16
Chromium	16	3.82E+00	4.92E+01	9.05E+00	1.08E+01	1.38E-01	1.51E-01	16
Cobalt	16	2.28E+00	8.44E+00	3.56E+00	1.43E+00	1.38E-01	1.51E-01	16
Copper	16	8.21E+00	5.97E+02	7.06E+01	1.43E+02	2.75E-01	3.02E-01	16
Iron	16	6.51E+03	1.29E+04	8.82E+03	1.77E+03	7.34E+00	8.05E+00	16
Lead	16	4.00E+00	3.52E+01	9.08E+00	7.56E+00	3.03E-01	3.32E-01	16
Magnesium	16	8.53E+02	2.58E+03	1.36E+03	3.90E+02	7.80E+00	8.55E+00	16
Manganese	16	1.19E+02	2.99E+02	1.70E+02	4.59E+01	1.84E-01	2.01E-01	16
Mercury	16	3.43E-03	7.75E-01	5.51E-02	1.92E-01	3.43E-03	3.44E-02	6
Nickel	16	3.35E+00	8.01E+00	6.28E+00	1.43E+00	9.24E-02	1.01E-01	16
Perchlorate	16	4.98E-04	2.96E-02	5.25E-03	8.52E-03	4.96E-04	1.01E-03	11
Potassium	16	3.58E+02	1.26E+03	6.89E+02	2.78E+02	5.87E+00	6.44E+00	16
Selenium	16	4.78E-01	9.37E-01	6.15E-01	1.29E-01	3.33E-01	3.64E-01	16
Silver	16	1.25E-01	2.19E+00	4.25E-01	5.20E-01	9.18E-02	1.01E-01	16
Sodium	16	3.73E+01	9.85E+01	5.33E+01	1.56E+01	6.43E+00	7.04E+00	16
Thallium	16	1.29E-01	2.22E+00	2.77E-01	5.19E-01	1.29E-01	1.42E-01	3
Vanadium	16	9.50E+00	2.90E+01	1.73E+01	4.96E+00	9.18E-02	1.01E-01	16
Zinc	16	1.85E+01	5.32E+01	2.89E+01	1.11E+01	3.67E-01	4.02E-01	16
Organics								
2,4-Diamino-6-nitrotoluene	16	4.93E-01	5.00E-01	4.96E-01	2.93E-03	4.93E-01	5.00E-01	0
2,6-Diamino-4-nitrotoluene	16	6.50E-01	6.60E-01	6.54E-01	4.15E-03	6.50E-01	6.60E-01	0
3,5-Dinitroaniline	16	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Acenaphthene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Acenaphthylene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Acetone	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Amino-2,6-dinitrotoluene[4-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Amino-4,6-dinitrotoluene[2-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Aniline	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Anthracene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Azobenzene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Benzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Benzo(a)anthracene	18	1.00E-02	2.95E-02	1.21E-02	5.04E-03	1.00E-02	1.02E-02	5
Benzo(a)pyrene	18	1.00E-02	2.72E-02	1.19E-02	4.75E-03	1.00E-02	1.02E-02	4
Benzo(b)fluoranthene	18	1.00E-02	3.25E-02	1.33E-02	7.20E-03	1.00E-02	1.02E-02	4
Benzo(g,h,i)perylene	18	1.00E-02	2.21E-02	1.09E-02	2.88E-03	1.00E-02	1.02E-02	2
Benzo(k)fluoranthene	18	1.00E-02	1.48E-02	1.04E-02	1.12E-03	1.00E-02	1.02E-02	2
Benzoic Acid	18	1.67E-01	4.97E-01	2.03E-01	1.00E-01	1.67E-01	1.70E-01	2
Benzyl Alcohol	18	1.00E-01	4.98E-01	1.38E-01	1.03E-01	1.00E-01	1.02E-01	4
Bis(2-chloroethoxy)methane	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Bis(2-chloroethyl)ether	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Bis(2-ethylhexyl)phthalate	18	1.00E-02	1.32E+00	2.25E-01	4.36E-01	1.00E-02	1.02E-02	6
Bromobenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromochloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromodichloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromoform	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Bromophenyl-phenylether[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Butanone[2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Butylbenzene[n-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzene[sec-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzene[tert-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Butylbenzylphthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Carbon Disulfide	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Carbon Tetrachloride	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloro-3-methylphenol[4-]	18	1.34E-01	1.36E-01	1.34E-01	6.16E-04	1.34E-01	1.36E-01	0
Chloroaniline[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorobenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chlorodibromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Chloroethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloroform	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chloronaphthalene[2-]	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Chlorophenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorophenyl-phenyl[4-] Ether	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Chlorotoluene[2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chlorotoluene[4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Chrysene	18	1.00E-02	2.95E-02	1.19E-02	4.91E-03	1.00E-02	1.02E-02	3
Dibenz(a,h)anthracene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Dibenzofuran	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dibromo-3-Chloropropane[1,2-]	16	4.66E-04	5.06E-04	4.89E-04	1.05E-05	4.66E-04	5.06E-04	0
Dibromoethane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dibromomethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichlorobenzene[1,2-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzene[1,3-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzene[1,4-]	34	3.10E-04	1.02E-01	5.36E-02	5.10E-02	3.10E-04	1.02E-01	0
Dichlorobenzidine[3,3'-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dichlorodifluoromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethane[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[cis-1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloroethene[trans-1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichlorophenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dichloropropane[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropane[1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropane[2,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[cis-1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Dichloropropene[trans-1,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Diethylphthalate	18	1.00E-02	1.44E-02	1.03E-02	1.02E-03	1.00E-02	1.02E-02	1
Dimethyl Phthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Dimethylphenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Di-n-butylphthalate	18	1.00E-02	7.44E-01	6.10E-02	1.74E-01	1.00E-02	1.02E-02	4
Dinitro-2-methylphenol[4,6-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dinitrobenzene[1,3-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Dinitrophenol[2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Dinitrotoluene[2,4-]	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Dinitrotoluene[2,6-]	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Di-n-octylphthalate	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Diphenylamine	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Ethylbenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Fluoranthene	18	1.00E-02	5.33E-02	1.50E-02	1.16E-02	1.00E-02	1.02E-02	4
Fluorene	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	16	6.82E-07	1.13E-04	1.74E-05	2.99E-05	1.66E-06	1.68E-06	16
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	16	4.97E-07	4.02E-06	1.38E-06	1.28E-06	1.66E-06	1.68E-06	8
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorobenzene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorobutadiene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorocyclopentadiene	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	16	4.97E-07	6.79E-07	5.15E-07	4.87E-08	1.73E-06	1.75E-06	2
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	16	4.97E-07	1.45E-06	6.23E-07	2.74E-07	1.66E-06	1.68E-06	4
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	16	4.97E-07	1.11E-06	5.77E-07	1.90E-07	1.95E-06	1.97E-06	3
Hexachlorodibenzofuran[1,2,3,4,7,8-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	16	1.71E-06	1.74E-06	4.99E-07	1.67E-09	1.71E-06	1.74E-06	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Hexachloroethane	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Hexanone[2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
HMX	16	1.48E-01	3.87E+00	8.78E-01	9.83E-01	1.48E-01	1.50E-01	11
Indeno(1,2,3-cd)pyrene	18	1.00E-02	2.05E-02	1.08E-02	2.51E-03	1.00E-02	1.02E-02	2
Iodomethane	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Isophorone	18	1.00E-01	3.24E-01	1.13E-01	5.26E-02	1.00E-01	1.02E-01	1
Isopropylbenzene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Isopropyltoluene[4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Methyl-2-pentanone[4-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Methylene Chloride	16	1.55E-03	5.73E-03	2.55E-03	1.46E-03	1.55E-03	1.69E-03	5
Methylnaphthalene[2-]	18	1.00E-02	1.02E-02	1.01E-02	4.16E-05	1.00E-02	1.02E-02	0
Methylphenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Methylphenol[3-,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Naphthalene	18	1.00E-02	1.51E-02	1.04E-02	1.18E-03	1.00E-02	1.02E-02	1
Nitroaniline[2-]	18	1.10E-01	1.12E-01	1.11E-01	4.16E-04	1.10E-01	1.12E-01	0
Nitroaniline[3-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitroaniline[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrobenzene	34	1.00E-01	1.50E-01	1.23E-01	2.42E-02	1.00E-01	1.50E-01	0
Nitrophenol[2-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrophenol[4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrosodimethylamine[N-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitroso-di-n-propylamine[N-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Nitrotoluene[2-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Nitrotoluene[3-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Nitrotoluene[4-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	16	4.56E-06	9.20E-04	1.39E-04	2.40E-04	3.31E-06	3.36E-06	16
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	16	9.93E-07	1.63E-05	4.50E-06	5.06E-06	3.31E-06	3.36E-06	9
Oxybis(1-chloropropane)[2,2'-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Pentachlorodibenzofuran[1,2,3,7,8-]	16	1.66E-06	1.68E-06	4.99E-07	1.67E-09	1.66E-06	1.68E-06	0
Pentachlorodibenzofuran[2,3,4,7,8-]	16	1.75E-06	1.77E-06	4.99E-07	1.67E-09	1.75E-06	1.77E-06	0
Pentachlorophenol	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
PETN	16	2.46E-01	2.50E-01	2.48E-01	1.69E-03	2.46E-01	2.50E-01	0
Phenanthrene	18	1.00E-02	2.78E-02	1.17E-02	4.34E-03	1.00E-02	1.02E-02	4
Phenol	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Propylbenzene[1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Pyrene	18	1.00E-02	5.57E-02	1.50E-02	1.18E-02	1.00E-02	1.02E-02	4
Pyridine	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
RDX	16	1.48E-01	4.76E+00	7.88E-01	1.33E+00	1.48E-01	1.50E-01	7
Styrene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
TATB	16	3.33E+00	2.22E+01	1.22E+01	4.73E+00	2.96E-01	1.50E+00	16

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	Sample Size	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detected Values
Tetrachlorodibenzodioxin[2,3,7,8-]	16	3.31E-07	3.36E-07	1.01E-07	3.28E-09	3.31E-07	3.36E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	16	1.10E-07	2.51E-07	1.83E-07	3.86E-08	3.31E-07	3.36E-07	8
Tetrachloroethane[1,1,1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetrachloroethane[1,1,2,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetrachloroethene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Tetryl	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Toluene	16	3.10E-04	2.23E-03	5.75E-04	6.22E-04	3.10E-04	3.37E-04	4
Trichloro-1,2,2-trifluoroethane[1,1,2-]	16	1.55E-03	1.69E-03	1.63E-03	3.54E-05	1.55E-03	1.69E-03	0
Trichlorobenzene[1,2,4-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichloroethane[1,1,1-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichloroethane[1,1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichloroethene	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichlorofluoromethane	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trichlorophenol[2,4,5-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichlorophenol[2,4,6-]	18	1.00E-01	1.02E-01	1.01E-01	4.16E-04	1.00E-01	1.02E-01	0
Trichloropropane[1,2,3-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trimethylbenzene[1,2,4-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trimethylbenzene[1,3,5-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Trinitrobenzene[1,3,5-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Trinitrotoluene[2,4,6-]	16	1.48E-01	1.50E-01	1.49E-01	7.75E-04	1.48E-01	1.50E-01	0
Tris (o-cresyl) phosphate	16	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Vinyl Chloride	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Xylene[1,2-]	16	3.10E-04	3.37E-04	3.26E-04	7.01E-06	3.10E-04	3.37E-04	0
Xylene[1,3-]+Xylene[1,4-]	16	6.21E-04	6.75E-04	6.53E-04	1.41E-05	6.21E-04	6.75E-04	0

Notes: Sample size (n) includes duplicate of WST39-18-162834 (WST39-18-162985) and multiple analytical methods.

Abbreviations:
MDL – Method detection limit
mg/kg – milligram per kilogram
SD – Standard deviation

Table 2-2. Comparison of Maximum Detected Exposure Point Concentrations to Background

Parameter Name	**Maximum (mg/kg)**	**Number of Detected Values**	**Background**	
			BV (mg/kg)	**Maximum /BV Ratio**
Aluminum	4.14E+03	16	29200	0.1
Antimony	4.32E-01	0	0.83	0.5
Arsenic	2.28E+00	16	8.17	0.3
Barium	1.15E+02	16	295	0.4
Beryllium	5.88E-01	16	1.83	0.3
Cadmium	4.67E-01	3	0.4	1.2
Calcium	5.74E+03	16	6120	0.9
Chromium[1]	4.92E+01	16	19.3	2.5
Cobalt	8.44E+00	16	8.64	1.0
Copper	5.97E+02	16	14.7	41
Iron	1.29E+04	16	21500	0.6
Lead[1]	3.52E+01	16	22.3	1.6
Magnesium	2.58E+03	16	4610	0.6
Manganese	2.99E+02	16	671	0.4
Mercury	7.75E-01	6	0.1	7.8
Nickel	8.01E+00	16	15.4	0.5
Perchlorate	2.96E-02	11	--	NA
Potassium	1.26E+03	16	3460	0.4
Selenium	9.37E-01	16	1.52	0.6
Silver	2.19E+00	16	1	2.2
Sodium	9.85E+01	16	915	0.1
Thallium[1]	2.22E+00	3	0.73	3.0
Vanadium	2.90E+01	16	39.6	0.7
Zinc[1]	5.32E+01	16	48.8	1.1

Notes: All data in mg/kg
[1] – Site inorganic <= background by hypothesis testing; see Section 2.2.2
-- No value
Shaded Max/BV cells indicate the inorganic is carried forward; see Section 2.2.2.
If the maximum <BV or by hypothesis testing, no further evaluation is performed
Abbreviations:
BV – Background value
HQ – Noncancer hazard quotient
NA – Not applicable

Table 2- 3. Human Health Screening Assessment for Organics and Inorganics Above Background

Parameter Name	**Maximum (mg/kg)**	Cancer						**Noncancer**					
		Res Cancer NMSSL (mg/kg)	**Ind. Worker Cancer NMSSL (mg/kg)**	**Con. Worker Cancer NMSSL (mg/kg)**	**Max/ Res Cancer Risk**	**Max/ Ind. Worker Cancer Risk**	**Max/ Con. Worker Cancer Risk**	**Res NC NMSSL (mg/kg)**	**Worker NC NMSSL (mg/kg)**	**Con. Worker NC NMSSL (mg/kg)**	**Max/ Res HQ**	**Max/ Ind. Worker HQ**	**Max/ Con. Worker HQ**
Cadmium	4.67E-01	8.59E+04	4.17E+05	3.61E+03	5E-11	1E-11	1E-09	7.05E+01	1.11E+03	7.21E+01	7E-03	4E-04	6E-03
Copper	5.97E+02	--	--	--	--	--	--	3.13E+03	5.19E+04	1.42E+04	2E-01	1E-02	4E-02
Mercury	7.75E-01	--	--	--	--	--	--	2.35E+01	3.89E+02	7.71E+01	3E-02	2E-03	1E-02
Perchlorate	2.96E-02	--	--	--	--	--	--	5.48E+01	9.08E+02	2.48E+02	5E-04	3E-05	1E-04
Silver	2.19E+00	--	--	--	--	--	--	3.91E+02	6.49E+03	1.77E+03	6E-03	3E-04	1E-03
2,3,7,8-TCDD TEQ	5.03E-06	4.90E-05	2.38E-04	1.72E-03	1E-06	2E-07	3E-08	5.06E-05	8.08E-04	2.26E-04	1E-01	6E-03	2E-02
Benzo(a)anthracene	2.95E-02	1.53E+00	3.23E+01	2.40E+02	2E-07	9E-09	1E-09	--	--	--	--	--	--
Benzo(a)pyrene	2.72E-02	1.12E+00	2.36E+01	1.73E+02	2E-07	1E-08	2E-09	1.74E+01	2.51E+02	1.50E+01	2E-03	1E-04	2E-03
Benzo(b)fluoranthene	3.25E-02	1.53E+00	3.23E+01	2.40E+02	2E-07	1E-08	1E-09	--	--	--	--	--	--
Benzo(g,h,i)perylene	2.21E-02	***1.12E+00***	***2.36E+01***	***1.73E+02***	2E-07	9E-09	1E-09	***1.74E+01***	***2.51E+02***	***1.50E+01***	1E-03	9E-05	1E-03
Benzo(k)fluoranthene	1.48E-02	1.53E+01	3.23E+02	2.31E+03	1E-08	5E-10	6E-11	--	--	--	--	--	--
Benzoic Acid	4.97E-01	--	--	--	--	--	--	**2.50E+05**	**3.30E+06**	**3.30E+06**	2E-06	2E-07	2E-07
Benzyl Alcohol	4.98E-01	--	--	--	--	--	--	**6.30E+03**	**8.20E+04**	**8.20E+04**	8E-05	6E-06	6E-06
Bis(2-ethylhexyl)phthalate	1.32E+00	3.80E+02	1.83E+03	1.34E+04	3E-08	7E-09	1E-09	1.23E+03	1.83E+04	5.38E+03	1E-03	7E-05	2E-04
Chrysene	2.95E-02	1.53E+02	3.23E+03	2.31E+04	2E-09	9E-11	1E-11	--	--	--	--	--	--
Diethylphthalate	1.44E-02	--	--	--	--	--	--	4.93E+04	7.33E+05	2.15E+05	3E-07	2E-08	7E-08
Di-n-butylphthalate	7.44E-01	--	--	--	--	--	--	6.16E+03	9.16E+04	2.69E+04	1E-04	8E-06	3E-05
Fluoranthene	5.33E-02	--	--	--	--	--	--	2.32E+03	3.37E+04	1.00E+04	2E-05	2E-06	5E-06
HMX	3.87E+00	--	--	--	--	--	--	3.85E+03	6.33E+04	1.74E+04	1E-03	6E-05	2E-04
Indeno(1,2,3-cd)pyrene	2.05E-02	1.53E+00	3.23E+01	2.40E+02	1E-07	6E-09	9E-10	--	--	--	--	--	--
Isophorone	3.24E-01	5.61E+03	2.70E+04	1.98E+05	6E-10	1E-10	2E-11	1.23E+04	1.83E+05	5.37E+04	3E-05	2E-06	6E-06
Methylene Chloride	5.73E-03	7.66E+02	1.44E+04	8.96E+04	7E-11	4E-12	6E-13	4.09E+02	5.13E+03	1.21E+03	1E-05	1E-06	5E-06
Naphthalene	1.51E-02	2.26E+01	1.34E+02	6.33E+02	7E-09	1E-09	2E-10	1.62E+02	8.43E+02	1.59E+02	9E-05	2E-05	1E-04
Phenanthrene	2.78E-02	--	--	--	--	--	--	1.74E+03	2.53E+04	7.53E+03	2E-05	1E-06	4E-06
Pyrene	5.57E-02	--	--	--	--	--	--	1.74E+03	2.53E+04	7.53E+03	3E-05	2E-06	7E-06
RDX	4.76E+00	8.31E+01	4.28E+02	2.96E+03	6E-07	1E-07	2E-08	3.01E+02	4.89E+03	1.35E+03	2E-02	1E-03	4E-03
TATB	2.22E+01	--	--	--	--	--	--	***2.20E+03***	***3.20E+04***	***3.20E+04***	1E-02	7E-04	7E-04
Toluene	2.23E-03	--	--	--	--	--	--	5.23E+03	6.13E+04	1.40E+04	4E-07	4E-08	2E-07
Cumulative Cancer Risk or Hazard Index		--	--	--	**3E-06**	**4E-07**	**6E-08**	**--**	**--**	**--**	**3E-01**	**2E-02**	**9E-02**

Notes:

All data in mg/kg

[1] – Site inorganic <= background by hypothesis testing

-- No value

Bolded NMSSL cells indicate the EPA RSL for an HQ of 1 is used. See Section 2.1.3.4.

Bold Italics – a surrogate is applied. See Section 2.1.3.4.

Cancer risk = Maximum/Cancer-based NMSSL x 1E-05

HQ = Maximum/Noncancer-based NMSSL

Abbreviations:

BV – Background value
Con – Construction
EPA – U.S. Environmental Protection Agency
HQ – Noncancer hazard quotient
Ind – Industrial
Max – Maximum
NC – Noncancer
NMSSL – New Mexico soil screening level
Res - Residential
RSL – Regional Screening level

Table 2-4. Dioxin/Furan Data, Human Health TEFs, and TEQs

Parameter Name	TEF	WST36-18-162834			WST36-18-162985			WST36-18-162986			WST36-18-162987		
		Result (mg/kg)	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	8.40E-07	1	8.40E-09	6.82E-07	1	6.82E-09	3.68E-06	1	3.68E-08	7.96E-06	1	7.96E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	5.00E-07	0	5.00E-09	4.97E-07	0	4.97E-09	8.20E-07	1	8.20E-09	1.49E-06	1	1.49E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	5.03E-07	0	1.68E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	5.03E-07	0	1.74E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	5.61E-06	1	1.68E-09	4.56E-06	1	1.37E-09	3.41E-05	1	1.02E-08	7.74E-05	1	2.32E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	9.99E-07	0	3.00E-10	9.94E-07	0	2.98E-10	2.54E-06	1	7.62E-10	5.55E-06	1	1.67E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	5.03E-07	0	1.68E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	5.00E-07	0	5.01E-08	4.97E-07	0	4.98E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.04E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	5.00E-07	0	5.28E-07	4.97E-07	0	5.25E-07	4.98E-07	0	5.28E-07	5.03E-07	0	5.31E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.99E-08	0	3.33E-07	9.94E-08	0	3.31E-07	9.95E-08	0	3.32E-07	1.01E-07	0	3.36E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.10E-07	1	1.10E-08	1.75E-07	1	1.75E-08	1.31E-07	1	1.31E-08	2.27E-07	1	2.27E-08
TEQ				**3.45E-06**			**3.43E-06**			**3.47E-06**			**3.59E-06**

Notes:
The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg
DC- Detect code (1 = detected, 0 = not detected)
WST36-18-162834 and WST36-18-162985 are the duplicate pair.

Table 2-4. Dioxin/Furan Data, Human Health TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162988			WST36-18-162989			WST36-18-162990			WST36-18-162991		
		Result (mg/kg)	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	1.74E-06	1	1.74E-08	1.06E-06	1	1.06E-08	1.11E-06	1	1.11E-08	4.67E-06	1	4.67E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	4.97E-07	0	4.97E-09	4.97E-07	0	4.97E-09	4.98E-07	0	4.98E-09	4.99E-07	0	4.99E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.97E-07	0	1.66E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.99E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.97E-07	0	1.71E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	4.99E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	1.40E-05	1	4.20E-09	1.02E-05	1	3.06E-09	1.01E-05	1	3.03E-09	4.30E-05	1	1.29E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	9.94E-07	0	2.98E-10	9.94E-07	0	2.98E-10	9.95E-07	0	2.99E-10	1.33E-06	1	3.99E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.97E-07	0	1.66E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.99E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.97E-07	0	4.98E-08	4.97E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.98E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.97E-07	0	5.25E-07	4.97E-07	0	5.25E-07	4.98E-07	0	5.28E-07	4.99E-07	0	5.28E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.94E-08	0	3.32E-07	9.94E-08	0	3.32E-07	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.79E-07	1	1.79E-08	1.87E-07	1	1.87E-08	1.71E-07	1	1.71E-08	1.44E-07	1	1.44E-08
TEQ				**3.45E-06**			**3.44E-06**			**3.44E-06**			**3.49E-06**

Notes:
The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg
DC- Detect code (1 = detected, 0 = not detected)

Table 2-4. Dioxin/Furan Data, Human Health TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162992			WST36-18-162993			WST36-18-162994			WST36-18-162995		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	2.20E-05	1	2.20E-07	8.35E-06	1	8.35E-08	4.84E-05	1	4.84E-07	1.13E-04	1	1.13E-06
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	3.44E-06	1	3.44E-08	1.29E-06	1	1.29E-08	4.02E-06	1	4.02E-08	3.66E-06	1	3.66E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	5.85E-07	1	5.85E-08	6.79E-07	1	6.79E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	6.27E-07	1	6.27E-08	4.98E-07	0	4.98E-08	1.09E-06	1	1.09E-07	1.45E-06	1	1.45E-07
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	1.11E-06	1	1.11E-07	9.91E-07	1	9.91E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	1.82E-04	1	5.46E-08	6.93E-05	1	2.08E-08	3.90E-04	1	1.17E-07	9.20E-04	1	2.76E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	1.01E-05	1	3.03E-09	3.95E-06	1	1.19E-09	1.39E-05	1	4.17E-09	1.63E-05	1	4.89E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.96E-08	0	3.32E-07	9.97E-08	0	3.32E-07	1.05E-07	0	3.32E-07	9.95E-08	0	3.32E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.73E-07	0	1.73E-08	1.67E-07	0	1.67E-08	2.19E-07	0	2.19E-08	1.59E-07	0	1.59E-08
TEQ				**3.75E-06**			**3.54E-06**			**4.20E-06**			**5.03E-06**

Notes:
Shaded cell is the maximum TEQ.
The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg
DC- Detect code (1 = detected, 0 = not detected)

Table 2-4. Dioxin/Furan Data, Human Health TEFs, and TEQs, Cont.

Parameter Name	TEFs	WST36-18-162996			WST36-18-162997			WST36-18-162998			WST36-18-162999		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	4.70E-05	1	4.70E-07	1.59E-05	1	1.59E-07	7.51E-07	1	7.51E-09	8.19E-07	1	8.19E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	2.48E-06	1	2.48E-08	9.11E-07	1	9.11E-09	4.97E-07	0	4.97E-09	5.01E-07	0	5.01E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	5.01E-07	0	1.67E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.98E-07	0	4.98E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	8.22E-07	1	8.22E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	6.55E-07	1	6.55E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	5.01E-07	0	1.73E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	3.40E-04	1	1.02E-07	1.14E-04	1	3.42E-08	5.49E-06	1	1.65E-09	8.29E-06	1	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	8.97E-06	1	2.69E-09	2.47E-06	1	7.41E-10	9.93E-07	0	2.98E-10	1.00E-06	0	3.00E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	5.01E-07	0	1.67E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.98E-07	0	4.98E-08	5.00E-07	0	5.01E-08	4.97E-07	0	4.98E-08	5.01E-07	0	5.01E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.98E-07	0	5.28E-07	5.00E-07	0	5.28E-07	4.97E-07	0	5.25E-07	5.01E-07	0	5.31E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07	1.12E-07	0	3.31E-07	1.00E-07	0	3.34E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	2.51E-07	0	2.51E-08	1.78E-07	0	1.78E-08	2.13E-07	0	2.13E-08	2.36E-07	0	2.36E-08
TEQs				**4.08E-06**			**3.64E-06**			**3.44E-06**			**3.47E-06**

Notes:
DC- Detect code (1 = detected, 0 = not detected)
Notes: The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg

Table 2-5. Screening Level Risk Assessment Cumulative Cancer Risk and Hazard Index

Category	Cancer Risk			Hazard Index		
	Resident	Industrial Worker	Construction Worker	Resident	Industrial Worker	Construction Worker
Inorganics	5E-11	1E-11	1E-09	0.2	0.01	0.06
Organics	2E-06	2E-07	3E-08	0.04	0.002	0.008
TCDD TEQ	1E-06	2E-07	3E-08	0.1	0.006	0.02
Total	3E-06	4E-07	6E-08	0.3	0.02	0.09

Notes:
Risk and HI are based on maximum soil concentrations
Cancer risk = Sum of (Maximum/Cancer-based NMSSL x 1E-05) for each detected analyte above background
Hazard Index = Sum of (Maximum/Noncancer-based NMSSL) for each detected analyte above background
NMSSL – New Mexico soil screening level

Table 2-6. Migration to Groundwater Screening Evaluation for Maximum Soil Concentrations of Inorganics above Background and Detected Organics

Parameter Name	**Parameter Code**	**Maximum Reported Result (mg/kg)**	**NMED Groundwater SSL (mg/kg)**	**Groundwater SSL Risk Ratio**
Cadmium	Cd	4.67E-01	9.39E+00	5E-02
Copper	Cu	5.97E+02	9.15E+02	7E-01
Mercury	Hg	7.75E-01	5.13E+00	2E-01
Perchlorate	ClO4	2.96E-02	1.17E-01	3E-01
Silver	Ag	2.19E+00	1.38E+01	2E-01
Benzo(a)anthracene	56-55-3	2.95E-02	6.37E-01	5E-02
Benzo(a)pyrene	50-32-8	2.72E-02	4.42E+00	6E-03
Benzo(b)fluoranthene	205-99-2	3.25E-02	6.17E+00	5E-03
Benzo(g,h,i)perylene	191-24-2	2.21E-02	***4.42E+00***	5E-03
Benzo(k)fluoranthene	207-08-9	1.48E-02	6.05E+01	2E-04
Benzoic Acid	65-85-0	4.97E-01	**3.00E+02**	2E-03
Benzyl Alcohol	100-51-6	4.98E-01	**9.60E+00**	5E-02
Bis(2-ethylhexyl)phthalate	117-81-7	1.32E+00	2.00E+02	7E-03
Chrysene	218-01-9	2.95E-02	1.86E+02	2E-04
Diethylphthalate	84-66-2	1.44E-02	9.79E+01	1E-04
Di-n-butylphthalate	84-74-2	7.44E-01	3.38E+01	2E-02
Fluoranthene	206-44-0	5.33E-02	1.34E+03	4E-05
HMX	2691-41-0	3.87E+00	1.94E+01	2E-01
Indeno(1,2,3-cd)pyrene	193-39-5	2.05E-02	2.01E+01	1E-03
Isophorone	78-59-1	3.24E-01	4.23E+00	8E-02
Methylene Chloride	75-09-2	5.73E-03	4.71E-01	1E-02
Naphthalene	91-20-3	1.51E-02	5.83E-02	3E-01
Phenanthrene	85-01-8	2.78E-02	8.59E+01	3E-04
Pyrene	129-00-0	5.57E-02	1.92E+02	3E-04
RDX	121-82-4	4.76E+00	5.93E-02	8E+01
TATB	3058-38-6	2.22E+01	***4.20E+01***	5E-01
Toluene	108-88-3	2.23E-03	1.21E+01	2E-04

Notes: Shaded cell – maximum exceeds NMSSL
Bolded values – value is the EPA RSL multiplied by a DAF of 20 for consistency with NMED (2021)
Bold italics – value is a surrogate. See Section 2.2.4.
mg/kg – milligram per kilogram
SSL – soil screening level (NMED 2021)

Table 3-1. Ecological Screening Levels (ESLs)

Analyte Group	Analyte Name	No Effect ESL									
		American kestrel (Avian top carnivore)	**American kestrel (insectivore / carnivore)**	**American robin (Avian herbivore)**	**American robin (Avian insectivore)**	**American robin (Avian omnivore)**	**Deer mouse (Mammalian omnivore)**	**Earthworm (Soil-dwelling invertebrate)**	**Generic plant (Terrestrial autotroph - producer)**	**Gray fox (Mammalian top carnivore)**	**Mountain cottontail (Mammalian herbivore)**
Inorganic Compound	Cadmium	4.30E+02	1.30E+00	4.30E+00	2.90E-01	5.40E-01	5.00E-01	1.40E+02	3.20E+01	5.50E+02	1.00E+01
	Copper	1.10E+03	8.00E+01	3.40E+01	1.40E+01	2.00E+01	6.30E+01	8.00E+01	7.00E+01	4.00E+03	2.60E+02
	Mercury (inorganic)	3.20E-01	5.80E-02	6.70E-02	1.30E-02	2.20E-02	3.00E+00	5.00E-02	3.40E+01	7.60E+01	2.30E+01
	Perchlorate	2.00E+00	3.90E+00	1.20E-01	3.10E+01	2.40E-01	2.10E-01	3.50E+00	4.00E+01	3.30E+00	2.60E-01
	Silver	6.00E+02	1.30E+01	1.00E+01	2.60E+00	4.10E+00	2.40E+01	--	5.60E+02	4.40E+03	1.50E+02
Dioxin/ Furan	2,3,7,8 TCDD	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	5.80E-07	5.00E+00	--	1.00E-04	4.00E-05
High Explosive	HMX	--	--	--	--	--	2.90E+02	1.60E+01	2.70E+03	5.90E+04	4.10E+02
	RDX	7.80E+02	1.10E+01	2.30E+00	2.40E+00	2.30E+00	1.60E+01	8.40E+00	--	7.00E+03	3.80E+01
	TATB	--	--	--	--	--	1.10E+02	1.00E+01	--	1.00E+04	1.50E+02
Polyaromatic Hydrocarbon	Benzo(a)anthracene	2.80E+01	6.40E+00	7.30E-01	8.80E-01	8.00E-01	3.40E+00	--	1.80E+01	1.10E+02	6.10E+00
	Benzo(a)pyrene	--	--	--	--	--	8.40E+01	--	--	3.40E+03	2.60E+02
	Benzo(b)fluoranthene	--	--	--	--	--	5.10E+01	--	1.80E+01	2.40E+03	1.30E+02
	Benzo(g,h,i)perylene	--	--	--	--	--	4.60E+01	--	--	3.60E+03	4.70E+02
	Benzo(k)fluoranthene	--	--	--	--	--	9.90E+01	--	--	4.30E+03	3.30E+02
	Chrysene	--	--	--	--	--	3.10E+00	--	--	1.10E+02	6.30E+00
	Fluoranthene	--	--	--	--	--	3.80E+01	1.00E+01	--	3.90E+03	2.70E+02
	Indeno(1,2,3-cd)pyrene	--	--	--	--	--	1.10E+02	--	--	4.60E+03	5.10E+02
	Naphthalene	2.10E+03	7.80E+01	3.40E+00	1.50E+01	5.70E+00	9.60E+00	--	1.00E+00	5.80E+03	1.40E+01
	Phenanthrene	--	--	--	--	--	1.50E+01	5.50E+00	--	1.90E+03	6.20E+01
	Pyrene	3.00E+03	1.60E+02	6.80E+01	3.30E+01	4.40E+01	3.10E+01	1.00E+01	--	3.10E+03	1.10E+02
Semivolatile Organic compound	Benzoic Acid	--	--	--	--	--	1.30E+00	--	--	2.00E+03	4.60E+00
	Bis(2-ethylhexyl)phthalate	9.30E+00	9.60E-02	1.60E+01	2.00E-02	4.00E-02	1.10E+00	--	--	5.00E+02	1.90E+03
	Diethyl Phthalate	--	--	--	--	--	3.60E+03	--	1.00E+02	2.50E+06	8.80E+03
	Di-n-Butyl Phthalate	2.00E+00	5.20E-02	3.80E-01	1.10E-02	2.10E-02	3.60E+02	--	1.60E+02	6.20E+04	1.70E+04
Volatile Organic Compound	Benzyl Alcohol	--	--	--	--	--	1.20E+02	--	--	1.10E+05	1.90E+02
	Isophorone	--	--	--	--	--	--	--	--	--	--
	Methylene Chloride	--	--	--	--	--	2.60E+00	--	1.60E+03	4.30E+03	3.80E+00
	Toluene	--	--	--	--	--	2.50E+01	--	2.00E+02	1.20E+04	6.60E+01

Table 3-1. Ecological Screening Levels, Cont.

Analyte Group	Analyte Name	Low Effect ESL									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph -producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganic Compound	Cadmium	2.30E+03	7.70E+00	2.30E+01	1.60E+00	3.00E+00	6.80E+00	7.60E+02	1.60E+02	7.40E+03	1.40E+02
	Copper	3.50E+03	2.40E+02	1.00E+02	4.30E+01	6.00E+01	1.00E+02	5.30E+02	4.90E+02	6.70E+03	4.30E+02
	Mercury (inorganic)	3.20E+00	5.80E-01	6.70E-01	1.30E-01	2.20E-01	3.00E+01	5.00E-01	6.40E+01	7.60E+02	2.30E+02
	Perchlorate	4.00E+00	8.00E+00	2.40E-01	6.40E+01	4.90E-01	1.00E+00	3.50E+01	8.00E+01	1.60E+01	1.30E+00
	Silver	6.00E+03	1.30E+02	1.00E+02	2.60E+01	4.10E+01	2.40E+02	--	2.80E+03	4.40E+04	1.50E+03
Dioxin/ Furan	2,3,7,8-TCDD	--	--	--	--	--	3.80E-06	1.00E+01	--	6.80E-04	2.70E-04
High Explosive	HMX	--	--	--	--	--	7.90E+02	1.60E+02	3.50E+03	1.50E+05	1.10E+03
	RDX	1.40E+03	2.20E+01	4.30E+00	4.50E+00	4.40E+00	5.10E+01	1.50E+01	--	2.20E+04	1.20E+02
	TATB	--	--	--	--	--	1.10E+03	2.80E+01	--	1.00E+05	1.50E+03
Polyaromatic Hydrocarbon	Benzo(a)anthracene	2.80E+02	6.40E+01	7.30E+00	8.80E+00	8.00E+00	3.40E+01	--	1.80E+02	1.10E+03	6.10E+01
	Benzo(a)pyrene	--	--	--	--	--	2.60E+02	--	--	1.10E+04	8.30E+02
	Benzo(b)fluoranthene	--	--	--	--	--	5.10E+02	--	1.80E+02	2.40E+04	1.30E+03
	Benzo(g,h,i)perylene	--	--	--	--	--	4.60E+02	--	--	3.60E+04	4.70E+03
	Benzo(k)fluoranthene	--	--	--	--	--	9.90E+02	--	--	4.30E+04	3.30E+03
	Chrysene	--	--	--	--	--	3.10E+01	--	--	1.10E+03	6.30E+01
	Fluoranthene	--	--	--	--	--	3.80E+02	2.30E+01	--	3.90E+04	2.70E+03
	Indeno(1,2,3-cd)pyrene	--	--	--	--	--	1.10E+03		--	4.60E+04	5.10E+03
	Naphthalene	2.10E+04	7.80E+02	3.40E+01	1.50E+02	5.70E+01	2.70E+01		1.00E+01	1.60E+04	4.00E+01
	Phenanthrene	--	--	--	--	--	1.50E+02	1.20E+01	--	1.90E+04	6.20E+02
	Pyrene	3.00E+04	1.60E+03	6.80E+02	3.30E+02	4.40E+02	3.10E+02	2.00E+01	--	3.10E+04	1.10E+03
Semivolatile Organic compound	Benzoic Acid	--	--	--	--	--	1.30E+01	--	--	2.00E+04	4.60E+01
	Bis(2-ethylhexyl)phthalate	9.30E+01	9.60E-01	1.60E+02	2.00E-01	4.00E-01	1.10E+01	--	--	5.00E+03	1.90E+04
	Diethyl Phthalate	--	--	--	--	--	3.60E+04	--	1.00E+03	2.50E+07	8.80E+04
	Di-n-Butyl Phthalate	2.00E+01	5.20E-01	3.80E+00	1.10E-01	2.10E-01	8.60E+02	--	6.00E+02	1.40E+05	4.00E+04
Volatile Organic Compound	Benzyl Alcohol	--	--	--	--	--	1.20E+03	--	--	1.10E+06	1.90E+03
	Isophorone	--	--	--	--	--	--	--	--	--	--
	Methylene Chloride	--	--	--	--	--	2.20E+01	--	1.60E+04	3.60E+04	3.20E+01
	Toluene	--	--	--	--	--	2.50E+02	--	2.00E+03	1.20E+05	6.60E+02

Notes: Source = ESL 4.2, LANL 2021.
Abbreviations:
ESL – Ecological Screening Value
Max– Maximum Exposure Point Concentration

mg/kg – Milligram per kilogram

Table 3-2. Ecological Screening Evaluation for Maximum Soil Concentrations and No Effect ESLs

Category	Parameter Name	Max Result (mg/kg)	Number of Detects	American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganic	Cadmium	0.467	3	1E-03	4E-01	1E-01	2E+00	9E-01	9E-01	3E-03	1E-02	8E-04	5E-02
	Copper	597	16	5E-01	7E+00	2E+01	4E+01	3E+01	9E+00	7E+00	9E+00	1E-01	2E+00
	Mercury	0.775	6	2E+00	1E+01	1E+01	6E+01	4E+01	3E-01	2E+01	2E-02	1E-02	3E-02
	Perchlorate	0.0296	11	1E-02	8E-03	2E-01	1E-03	1E-01	1E-01	8E-03	7E-04	9E-03	1E-01
	Silver	2.19	16	4E-03	2E-01	2E-01	8E-01	5E-01	9E-02	--	4E-03	5E-04	1E-02
Organic	2,3,7,8-TCDD TEQ mammal	5.03E-06	--	--	--	--	--	--	9E+00	1E-06	--	5E-02	1E-01
	2,3,7,8-TCDD TEQ bird	5.06E-06	--	1E+00	1E+00	1E+00	1E+00	1E+00	--	--	--	--	--
	Benzo(a)anthracene	0.0295	5	1E-03	5E-03	4E-02	3E-02	4E-02	9E-03	--	2E-03	3E-04	5E-03
	Benzo(a)pyrene	0.0272	4	--	--	--	--	--	3E-04	--	NA	8E-06	1E-04
	Benzo(b)fluoranthene	0.0325	4	--	--	--	--	--	6E-04	--	2E-03	1E-05	3E-04
	Benzo(g,h,i)perylene	0.0221	2	--	--	--	--	--	5E-04	--	--	6E-06	5E-05
	Benzo(k)fluoranthene	0.0148	2	--	--	--	--	--	1E-04	--	--	3E-06	4E-05
	Benzoic Acid	0.497	2	--	--	--	--	--	4E-01	--	--	2E-04	1E-01
	Benzyl Alcohol	0.498	4	--	--	--	--	--	4E-03	--	--	5E-06	3E-03
	Bis(2-ethylhexyl)phthalate	1.32	6	1E-01	1E+01	8E-02	7E+01	3E+01	1E+00	--	--	3E-03	7E-04
	Chrysene	0.0295	3	--	--	--	--	--	1E-02	--	--	3E-04	5E-03
	Diethylphthalate	0.0144	1	--	--	--	--	--	4E-06	--	1E-04	6E-09	2E-06
	Di-n-butylphthalate	0.744	4	4E-01	1E+01	2E+00	7E+01	4E+01	2E-03	--	5E-03	1E-05	4E-05
	Fluoranthene	0.0533	4	--	--	--	--	--	1E-03	5E-03	--	1E-05	2E-04
	HMX	3.87	11	--	--	--	--	--	1E-02	2E-01	1E-03	7E-05	9E-03
	Indeno(1,2,3-cd)pyrene	0.0205	2	--	--	--	--	--	2E-04	--	--	4E-06	4E-05
	Isophorone	0.324	1	--	--	--	--	--	--	--	--	--	--
	Methylene Chloride	0.0057	5	--	--	--	--	--	2E-03	--	4E-06	1E-06	2E-03
	Naphthalene	0.0151	1	7E-06	2E-04	4E-03	1E-03	3E-03	2E-03	--	2E-02	3E-06	1E-03
	Phenanthrene	0.0278	4	--	--	--	--	--	2E-03	5E-03	--	1E-05	4E-04
	Pyrene	0.0557	4	2E-05	3E-04	8E-04	2E-03	1E-03	2E-03	6E-03	--	2E-05	5E-04
	RDX	4.76	7	6E-03	4E-01	2E+00	2E+00	2E+00	3E-01	6E-01	--	7E-04	1E-01
	TATB	22.2	16	--	--	--	--	--	2E-01	2E+00	--	2E-03	1E-01
	Toluene	0.0022	4	--	--	--	--	--	9E-05	--	1E-05	2E-07	3E-05
Hazard Index (HI)				5E+00	5E+01	4E+01	2E+02	1E+02	2E+01	3E+01	9E+00	2E-01	3E+00

Notes:

Table 2-2 presents the comparison of maximum inorganic concentrations to BV. Only inorganics that exceeded BVs are shown in this table.
Shaded cells indicate the ratio > 0.1 for initial screening evaluation
Only detected data and inorganics above background are reported and evaluated in this table.
Abbreviations:

BV – Background Value
ESL – Ecological Screening Value
Max– Maximum Exposure Point Concentration
mg/kg – milligram per kilogram
-- - no value

Table 3-3. Refined Exposure Point Concentrations (EPCs)

COPC	UCL95 (mg/kg)	UCL Type	Distribution
Cadmium	0.096	Median all data	NA - 3 detect
Copper	240.3	95% Chebyshev (Mean, Sd) UCL	Lognormal
Mercury	0.598	99% KM (Chebyshev) UCL	NDD
Perchlorate	0.0144	Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	Gamma
Silver	0.681	95% Jackknife UCL	Lognormal
Mammalian TCDD TEQ	3.91E-06	95% Modified-t UCL	NDD
Avian TCDD TEQ	4.89E-06	95% Student's-t UCL	Normal
Benzoic Acid	0.168	Median all data	NA - 2 detects
Bis(2-ethylhexyl)phthalate	0.493	95% KM (t) UCL	Normal
Di-n-butylphthalate	0.010	Median all data	NA - 4 detects
HMX	1.736	95% Gamma Adjusted KM-UCL (use when n<50)	Gamma
Isophorone	0.101	Median all data	NA - 1 detect
RDX	1.48	95% KM (t) UCL	Normal
TATB	14.52	95% Student's-t UCL	Normal

Notes:
Maximum of the duplicate pair retained
TEQ obtained by calculating TEQs by sample, then calculating UCL95
NDD – no discernable distribution
KM – Kaplan Meier
Sd – Standard deviation
UCL – upper confidence limit

Table 3-4. Ecological Screening Evaluation for Low Effect ESLs and Refined EPCs.

Analyte Name	**Refined EPC (mg/kg)**	**Hazard Quotients for Refined EPCs and LE ESLs**									
		American kestrel (Avian top carnivore)	**American kestrel (insectivore / carnivore)**	**American robin (Avian herbivore)**	**American robin (Avian insectivore)**	**American robin (Avian omnivore)**	**Deer mouse (Mammalian omnivore)**	**Earthworm (Soil-dwelling invertebrate)**	**Generic plant (Terrestrial autotroph - producer)**	**Gray fox (Mammalian top carnivore)**	**Mountain cottontail (Mammalian herbivore)**
Cadmium	0.096	4E-05	1E-02	4E-03	6E-02	3E-02	1E-02	1E-04	6E-04	1E-05	7E-04
Copper	240.30	7E-02	1E+00	2E+00	6E+00	4E+00	2E+00	5E-01	5E-01	4E-02	6E-01
Mercury	0.598	2E-01	1E+00	9E-01	5E+00	3E+00	2E-02	1E+00	9E-03	8E-04	3E-03
Perchlorate	0.014	4E-03	2E-03	6E-02	2E-04	3E-02	1E-02	4E-04	2E-04	9E-04	1E-02
Silver	0.681	1E-04	5E-03	7E-03	3E-02	2E-02	3E-03	No ESL	2E-04	2E-05	5E-04
Mammalian TEQ	3.91E-06	--	--	--	--	--	1E+00	4E-07	No ESL	6E-03	1E-02
Avian TEQ	4.89E-06	No ESL	No ESL	No ESL	No ESL	No ESL	--	--	--	--	--
Benzoic Acid	0.168	No ESL	No ESL	No ESL	No ESL	No ESL	1E-02	No ESL	No ESL	8E-06	4E-03
Bis(2-ethylhexyl)phthalate	0.493	5E-03	5E-01	3E-03	2E+00	1E+00	4E-02	No ESL	No ESL	1E-04	3E-05
Di-n-butylphthalate	0.010	5E-04	2E-02	3E-03	9E-02	5E-02	1E-05	No ESL	2E-05	7E-08	3E-07
HMX	1.736	No ESL	No ESL	No ESL	No ESL	No ESL	2E-03	1E-02	5E-04	1E-05	2E-03
Isophorone	0.101	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL
RDX	1.476	1E-03	7E-02	3E-01	3E-01	3E-01	3E-02	1E-01	No ESL	7E-05	1E-02
TATB	14.52	No ESL	No ESL	No ESL	No ESL	No ESL	1E-02	5E-01	No ESL	1E-04	1E-02
HI		**3E-01**	**3E+00**	**4E+00**	**1E+01**	**8E+00**	**4E+00**	**2E+00**	**5E-01**	**4E-02**	**6E-01**

Notes:
Shaded cells represent HQs>0.1
HI is the sum of all HQs
-- - no value
Abbreviations:
ESL – Ecological Screening Level
HI – Hazard Index
LE – Low Effect
mg/kg – milligram per kilogram

Table 3-5. Toxic Equivalency Factors (TEFs) Used for Calculating Ecological TCDD Equivalent Concentrations

Name	CAS	Mammalian TEF[a]	Avian TEF[b]
Chlorinated dibenzo-p-dioxins			
2,3,7,8-TCDD	1746-01-6	1	1
1,2,3,7,8-PeCDD	40321-76-4	1	1
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HpCDD	35822-46-9	0.01	0.001
OCDD	3268-87-9	0.0003	0.0001
Chlorinated dibenzofurans			
2,3,7,8-TCDF	51207-31-9	0.1	1
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1
2,3,4,7,8-PeCDF	57117-31-4	0.3	0.1
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	1
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01
OCDF	39001-02-0	0.0003	0.0001

[a] EPA (2010a,b); WHO (2009)

[b] Van den Berg et al. (2006)

Table 3-6. Dioxin-Furan Concentrations, Mammalian TEFs, and TEQs,

Parameter Name	TEF	WST36-18-162834			WST36-18-162985			WST36-18-162986			WST36-18-162987		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	8.40E-07	1	8.40E-09	6.82E-07	1	6.82E-09	3.68E-06	1	3.68E-08	7.96E-06	1	7.96E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	5.00E-07	0	5.00E-09	4.97E-07	0	4.97E-09	8.20E-07	1	8.20E-09	1.49E-06	1	1.49E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	5.03E-07	0	1.68E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	5.03E-07	0	1.74E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	5.61E-06	1	1.68E-09	4.56E-06	1	1.37E-09	3.41E-05	1	1.02E-08	7.74E-05	1	2.32E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	9.99E-07	0	3.00E-10	9.94E-07	0	2.98E-10	2.54E-06	1	7.62E-10	5.55E-06	1	1.67E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	5.03E-07	0	1.68E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	5.00E-07	0	5.01E-08	4.97E-07	0	4.98E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.04E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	5.00E-07	0	5.28E-07	4.97E-07	0	5.25E-07	4.98E-07	0	5.28E-07	5.03E-07	0	5.31E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.99E-08	0	3.33E-07	9.94E-08	0	3.31E-07	9.95E-08	0	3.32E-07	1.01E-07	0	3.36E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.10E-07	1	1.10E-08	1.75E-07	1	1.75E-08	1.31E-07	1	1.31E-08	2.27E-07	1	2.27E-08
TEQ				**3.45E-06**			**3.43E-06**			**3.47E-06**			**3.59E-06**

Notes:

The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

DC- Detect code (1 = detected, 0 = not detected)

WST36-18-162834 and WST36-18-162985 are the duplicate pair.

Table 3-6. Dioxin/Furan Concentrations, Mammalian TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162988			WST36-18-162989			WST36-18-162990			WST36-18-162991		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	1.74E-06	1	1.74E-08	1.06E-06	1	1.06E-08	1.11E-06	1	1.11E-08	4.67E-06	1	4.67E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	4.97E-07	0	4.97E-09	4.97E-07	0	4.97E-09	4.98E-07	0	4.98E-09	4.99E-07	0	4.99E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.97E-07	0	1.66E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.99E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.97E-07	0	1.71E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	4.99E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	1.40E-05	1	4.20E-09	1.02E-05	1	3.06E-09	1.01E-05	1	3.03E-09	4.30E-05	1	1.29E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	9.94E-07	0	2.98E-10	9.94E-07	0	2.98E-10	9.95E-07	0	2.99E-10	1.33E-06	1	3.99E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.97E-07	0	1.66E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.99E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.97E-07	0	4.98E-08	4.97E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.98E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.97E-07	0	5.25E-07	4.97E-07	0	5.25E-07	4.98E-07	0	5.28E-07	4.99E-07	0	5.28E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.94E-08	0	3.32E-07	9.94E-08	0	3.32E-07	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.79E-07	1	1.79E-08	1.87E-07	1	1.87E-08	1.71E-07	1	1.71E-08	1.44E-07	1	1.44E-08
TEQ				**3.45E-06**			**3.44E-06**			**3.44E-06**			**3.49E-06**

Notes:

The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

DC- Detect code (1 = detected, 0 = not detected)

Table 3-6. Dioxin/Furan Concentrations, Mammalian TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162992			WST36-18-162993			WST36-18-162994			WST36-18-162995		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	2.20E-05	1	2.20E-07	8.35E-06	1	8.35E-08	4.84E-05	1	4.84E-07	1.13E-04	1	1.13E-06
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	3.44E-06	1	3.44E-08	1.29E-06	1	1.29E-08	4.02E-06	1	4.02E-08	3.66E-06	1	3.66E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	5.85E-07	1	5.85E-08	6.79E-07	1	6.79E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	6.27E-07	1	6.27E-08	4.98E-07	0	4.98E-08	1.09E-06	1	1.09E-07	1.45E-06	1	1.45E-07
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	1.11E-06	1	1.11E-07	9.91E-07	1	9.91E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	1.82E-04	1	5.46E-08	6.93E-05	1	2.08E-08	3.90E-04	1	1.17E-07	9.20E-04	1	2.76E-07
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	1.01E-05	1	3.03E-09	3.95E-06	1	1.19E-09	1.39E-05	1	4.17E-09	1.63E-05	1	4.89E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07	4.98E-07	0	5.28E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.96E-08	0	3.32E-07	9.97E-08	0	3.32E-07	1.05E-07	0	3.32E-07	9.95E-08	0	3.32E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	1.73E-07	0	1.73E-08	1.67E-07	0	1.67E-08	2.19E-07	0	2.19E-08	1.59E-07	0	1.59E-08
TEQ				**3.75E-06**			**3.54E-06**			**4.20E-06**			**5.03E-06**

Notes:
The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg
DC- Detect code (1 = detected, 0 = not detected)

Table 3-6. Dioxin/Furan Concentrations, Mammalian TEFs, and TEQs, Cont.

Parameter Name	**TEFs**	**WST36-18-162996**			**WST36-18-162997**			**WST36-18-162998**			**WST36-18-162999**		
		Result (mg/kg)	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**	**Result (mg/kg)**	**DC**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	4.70E-05	1	4.70E-07	1.59E-05	1	1.59E-07	7.51E-07	1	7.51E-09	8.19E-07	1	8.19E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	2.48E-06	1	2.48E-08	9.11E-07	1	9.11E-09	4.97E-07	0	4.97E-09	5.01E-07	0	5.01E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	5.01E-07	0	1.67E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.98E-07	0	4.98E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	8.22E-07	1	8.22E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	6.55E-07	1	6.55E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	5.01E-07	0	1.73E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	3.40E-04	1	1.02E-07	1.14E-04	1	3.42E-08	5.49E-06	1	1.65E-09	8.29E-06	1	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	8.97E-06	1	2.69E-09	2.47E-06	1	7.41E-10	9.93E-07	0	2.98E-10	1.00E-06	0	3.00E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	5.01E-07	0	1.67E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.98E-07	0	4.98E-08	5.00E-07	0	5.01E-08	4.97E-07	0	4.98E-08	5.01E-07	0	5.01E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.98E-07	0	5.28E-07	5.00E-07	0	5.28E-07	4.97E-07	0	5.25E-07	5.01E-07	0	5.31E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07	1.12E-07	0	3.31E-07	1.00E-07	0	3.34E-07
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	2.51E-07	0	2.51E-08	1.78E-07	0	1.78E-08	2.13E-07	0	2.13E-08	2.36E-07	0	2.36E-08
TEQs				**4.08E-06**			**3.64E-06**			**3.44E-06**			**3.47E-06**

Notes:

DC- Detect code (1 = detected, 0 = not detected)

Notes: The result multiplied by the TEF (Table 3-3) is the TECi. The sum of the TECi values provides the TEQ. The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

Abbreviations:
TECi – Toxicity Equivalent Concentration for Congener i
TEF – Toxicity Equivalency Factor
TEQ – Toxicity Equivalent Quotient

Table 3-7. Dioxin-Furan Concentrations, Avian TEFs, and TEQs

Parameter Name	TEF	WST36-18-162834			WST36-18-162985			WST36-18-162986			WST36-18-162987		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.001	8.40E-07	1	8.40E-10	6.82E-07	1	6.82E-10	3.68E-06	1	3.68E-09	7.96E-06	1	7.96E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	5.00E-07	0	5.00E-09	4.97E-07	0	4.97E-09	8.20E-07	1	8.20E-09	1.49E-06	1	1.49E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	5.03E-07	0	1.68E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.05	5.00E-07	0	2.50E-08	4.97E-07	0	2.49E-08	4.98E-07	0	2.49E-08	5.03E-07	0	2.52E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.01	5.00E-07	0	5.00E-09	4.97E-07	0	4.97E-09	4.98E-07	0	4.98E-09	5.03E-07	0	5.03E-09
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	5.03E-07	0	5.03E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	1	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	5.03E-07	0	1.68E-06
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	5.03E-07	0	1.74E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0001	5.61E-06	1	5.61E-10	4.56E-06	1	4.56E-10	3.41E-05	1	3.41E-09	7.74E-05	1	7.74E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0001	9.99E-07	0	9.99E-11	9.94E-07	0	9.94E-11	2.54E-06	1	2.54E-10	5.55E-06	1	5.55E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	5.03E-07	0	1.68E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.1	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	5.03E-07	0	1.68E-07
Pentachlorodibenzofuran[2,3,4,7,8-]	0.1	5.00E-07	0	1.76E-07	4.97E-07	0	1.75E-07	4.98E-07	0	1.76E-07	5.03E-07	0	1.77E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.99E-08	0	3.33E-07	9.94E-08	0	3.31E-07	9.95E-08	0	3.32E-07	1.01E-07	0	3.36E-07
Tetrachlorodibenzofuran[2,3,7,8-]	1	1.10E-07	1	1.10E-07	1.75E-07	1	1.75E-07	1.31E-07	1	1.31E-07	2.27E-07	1	2.27E-07
TEQ				**4.74E-06**			**4.77E-06**			**4.74E-06**			**4.91E-06**

Notes:

The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

DC- Detect code (1 = detected, 0 = not detected)

WST36-18-162834 and WST36-18-162985 are the duplicate pair.

Table 3-7. Dioxin/Furan Concentrations, Avian TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162988			WST36-18-162989			WST36-18-162990			WST36-18-162991		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.001	1.74E-06	1	1.74E-09	1.06E-06	1	1.06E-09	1.11E-06	1	1.11E-09	4.67E-06	1	4.67E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	4.97E-07	0	4.97E-09	4.97E-07	0	4.97E-09	4.98E-07	0	4.98E-09	4.99E-07	0	4.99E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.97E-07	0	1.66E-08	4.97E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.99E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.05	4.97E-07	0	2.49E-08	4.97E-07	0	2.49E-08	4.98E-07	0	2.49E-08	4.99E-07	0	2.50E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.01	4.97E-07	0	4.97E-09	4.97E-07	0	4.97E-09	4.98E-07	0	4.98E-09	4.99E-07	0	4.99E-09
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.97E-07	0	4.97E-08	4.97E-07	0	4.97E-08	4.98E-07	0	4.98E-08	4.99E-07	0	4.99E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	1	4.97E-07	0	1.66E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.99E-07	0	1.66E-06
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.97E-07	0	1.71E-07	4.97E-07	0	1.71E-07	4.98E-07	0	1.72E-07	4.99E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0001	1.40E-05	1	1.40E-09	1.02E-05	1	1.02E-09	1.01E-05	1	1.01E-09	4.30E-05	1	4.30E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0001	9.94E-07	0	9.94E-11	9.94E-07	0	9.94E-11	9.95E-07	0	9.95E-11	1.33E-06	1	1.33E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.97E-07	0	1.66E-06	4.97E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.99E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.1	4.97E-07	0	1.66E-07	4.97E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.99E-07	0	1.66E-07
Pentachlorodibenzofuran[2,3,4,7,8-]	0.1	4.97E-07	0	1.75E-07	4.97E-07	0	1.75E-07	4.98E-07	0	1.76E-07	4.99E-07	0	1.76E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.94E-08	0	3.32E-07	9.94E-08	0	3.32E-07	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07
Tetrachlorodibenzofuran[2,3,7,8-]	1	1.79E-07	1	1.79E-07	1.87E-07	1	1.87E-07	1.71E-07	1	1.71E-07	1.44E-07	1	1.44E-07
TEQ				**4.78E-06**			**4.79E-06**			**4.77E-06**			**4.75E-06**

Notes:

The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

DC- Detect code (1 = detected, 0 = not detected)

Table 3-7. Dioxin/Furan Concentrations, Avian TEFs, and TEQs, Cont.

Parameter Name	TEF	WST36-18-162992			WST36-18-162993			WST36-18-162994			WST36-18-162995		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.001	2.20E-05	1	2.20E-08	8.35E-06	1	8.35E-09	4.84E-05	1	4.84E-08	1.13E-04	1	1.13E-07
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	3.44E-06	1	3.44E-08	1.29E-06	1	1.29E-08	4.02E-06	1	4.02E-08	3.66E-06	1	3.66E-08
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08	4.98E-07	0	1.66E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.05	4.98E-07	0	2.49E-08	4.98E-07	0	2.49E-08	5.85E-07	1	2.93E-08	6.79E-07	1	3.40E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.01	6.27E-07	1	6.27E-09	4.98E-07	0	4.98E-09	1.09E-06	1	1.09E-08	1.45E-06	1	1.45E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.98E-07	0	4.98E-08	4.98E-07	0	4.98E-08	1.11E-06	1	1.11E-07	9.91E-07	1	9.91E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	1	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07	4.98E-07	0	1.72E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0001	1.82E-04	1	1.82E-08	6.93E-05	1	6.93E-09	3.90E-04	1	3.90E-08	9.20E-04	1	9.20E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0001	1.01E-05	1	1.01E-09	3.95E-06	1	3.95E-10	1.39E-05	1	1.39E-09	1.63E-05	1	1.63E-09
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06	4.98E-07	0	1.66E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.1	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07	4.98E-07	0	1.66E-07
Pentachlorodibenzofuran[2,3,4,7,8-]	0.1	4.98E-07	0	1.76E-07	4.98E-07	0	1.76E-07	4.98E-07	0	1.76E-07	4.98E-07	0	1.76E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.96E-08	0	3.32E-07	9.97E-08	0	3.32E-07	1.05E-07	0	3.32E-07	9.95E-08	0	3.32E-07
Tetrachlorodibenzofuran[2,3,7,8-]	1	1.73E-07	0	1.73E-07	1.67E-07	0	1.67E-07	2.19E-07	0	2.19E-07	1.59E-07	0	1.59E-07
TEQ				**4.84E-06**			**4.79E-06**			**5.01E-06**			**5.06E-06**

Notes:

The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.

All data in mg/kg

DC- Detect code (1 = detected, 0 = not detected)

Table 3-7. Dioxin/Furan Concentrations, Avian TEFs, and TEQs, Cont.

Parameter Name	TEFs	WST36-18-162996			WST36-18-162997			WST36-18-162998			WST36-18-162999		
		Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi	Result (mg/kg)	DC	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.001	4.70E-05	1	4.70E-08	1.59E-05	1	1.59E-08	7.51E-07	1	7.51E-10	8.19E-07	1	8.19E-10
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	2.48E-06	1	2.48E-08	9.11E-07	1	9.11E-09	4.97E-07	0	4.97E-09	5.01E-07	0	5.01E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	1.66E-08	5.00E-07	0	1.67E-08	4.97E-07	0	1.66E-08	5.01E-07	0	1.67E-08
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.05	4.98E-07	0	2.49E-08	5.00E-07	0	2.50E-08	4.97E-07	0	2.49E-08	5.01E-07	0	2.51E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.01	8.22E-07	1	8.22E-09	5.00E-07	0	5.00E-09	4.97E-07	0	4.97E-09	5.01E-07	0	5.01E-09
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	6.55E-07	1	6.55E-08	5.00E-07	0	5.00E-08	4.97E-07	0	4.97E-08	5.01E-07	0	5.01E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	1	4.98E-07	0	1.66E-06	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	5.01E-07	0	1.67E-06
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	1.72E-07	5.00E-07	0	1.72E-07	4.97E-07	0	1.71E-07	5.01E-07	0	1.73E-07
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0001	3.40E-04	1	3.40E-08	1.14E-04	1	1.14E-08	5.49E-06	1	5.49E-10	8.29E-06	1	8.29E-10
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0001	8.97E-06	1	8.97E-10	2.47E-06	1	2.47E-10	9.93E-07	0	9.93E-11	1.00E-06	0	1.00E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	1.66E-06	5.00E-07	0	1.67E-06	4.97E-07	0	1.66E-06	5.01E-07	0	1.67E-06
Pentachlorodibenzofuran[1,2,3,7,8-]	0.1	4.98E-07	0	1.66E-07	5.00E-07	0	1.67E-07	4.97E-07	0	1.66E-07	5.01E-07	0	1.67E-07
Pentachlorodibenzofuran[2,3,4,7,8-]	0.1	4.98E-07	0	1.76E-07	5.00E-07	0	1.76E-07	4.97E-07	0	1.75E-07	5.01E-07	0	1.77E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.95E-08	0	3.32E-07	9.99E-08	0	3.33E-07	1.12E-07	0	3.31E-07	1.00E-07	0	3.34E-07
Tetrachlorodibenzofuran[2,3,7,8-]	1	2.51E-07	0	2.51E-07	1.78E-07	0	1.78E-07	2.13E-07	0	2.13E-07	2.36E-07	0	2.36E-07
TEQs				4.97E-06			4.83E-06			4.81E-06			4.86E-06

Notes:
DC- Detect code (1 = detected, 0 = not detected)
Notes: The result multiplied by the TEF (Table 3-3) is the TECi. The sum of the TECi values provides the TEQ. The TECi are summed in each column to obtain the TEQ. The TEQs are used in ProUCL to obtain a UCL95 EPC.
All data in mg/kg

Abbreviations:
TECi – Toxicity Equivalent Concentration for Congener i
TEF – Toxicity Equivalency Factor
TEQ – Toxicity Equivalent Quotient

Table 3-8. Area Use Factor and Site-Specific Hazard Analysis for TA 36 Based on NE ESLs

COPC Name	CAS	No Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)									
		American kestrel (top carnivore)	American kestrel (insectivore / carnivore)	American robin (herbivore)	American robin (insectivore)	American robin (omnivore)	Deer mouse (omnivore)	Earthworm (invertebrate)	Generic plant (autotroph)	Gray fox (top carnivore)	Mountain cottontail (herbivore)
Inorganics											
Copper	7440-50-8	1.1E+03	8.0E+01	3.4E+01	1.4E+01	2.0E+01	6.3E+01	8.0E+01	7.0E+01	4.0E+03	2.6E+02
Mercury	7487-94-7	3.2E-01	5.8E-02	6.7E-02	1.3E-02	2.2E-02	3.0E+00	5.0E-02	3.4E+01	7.6E+01	2.3E+01
Organics											
2,3,7,8-TCDD	1746-01-6	4.1E-06	4.1E-06	4.1E-06	4.1E-06	4.1E-06	5.8E-07	5.0E+00	0.0E+00	1.0E-04	4.0E-05
Bis(2-ethylhexyl)phthalate	117-81-7	9.3E+00	9.6E-02	1.6E+01	2.0E-02	4.0E-02	1.1E+00	0.0E+00	0.0E+00	5.0E+02	1.9E+03
RDX	121-82-4	7.8E+02	1.1E+01	2.3E+00	2.4E+00	2.3E+00	1.6E+01	8.4E+00	0.0E+00	7.0E+03	3.8E+01
TATB	3058-38-6	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+02	1.0E+01	0.0E+00	1.0E+04	1.5E+02

HR (ha)[a]	106	106	0.42	0.42	0.42	0.077	NA	NA	1038	3.1
Population Area[b]	4240	4240	16.8	16.8	16.8	3.08	NA	NA	41520	124
PAUF[c]	0.00014	0.00014	0.035	0.035	0.035	0.19	NA	NA	0.000014	0.004677
AUF[d]	0.0055	0.0055	1.00	1.00	1.00	1.00	NA	NA	0.000559	0.1871

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted NE ESL Hazard Quotients									
		American kestrel (top carnivore)	American kestrel (insectivore / carnivore)	American robin (herbivore)	American robin (insectivore)	American robin (omnivore)	Deer mouse (omnivore)	Earthworm (invertebrate)	Generic plant (autotroph)	Gray fox (top carnivore)	Mountain cottontail (herbivore)
Inorganics											
Copper	240.3	3E-05	4E-04	2E-01	6E-01	4E-01	7E-01	3E+00	3E+00	8E-07	4E-03
Mercury	0.598	3E-04	1E-03	3E-01	2E+00	9E-01	4E-02	1E+01	2E-02	1E-07	1E-04
Organics											
2,3,7,8-TCDD Mammal	3.91E-06	--	--	--	--	--	1E+00	8E-07	NA, No ESL	5E-07	5E-04
2,3,7,8-TCDD Bird	4.89E-06	2E-04	2E-04	4E-02	4E-02	4E-02	--	--	--	--	--
Bis(2-ethylhexyl)phthalate	0.493	7E-06	7E-04	1E-03	9E-01	4E-01	8E-02	NA, No ESL	NA, No ESL	1E-08	1E-06
RDX	1.48	3E-07	2E-05	2E-02	2E-02	2E-02	2E-02	2E-01	NA, No ESL	3E-09	2E-04
TATB	14.52	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-02	1E+00	NA, No ESL	2E-08	5E-04
Hazard Index		5E-04	3E-03	6E-01	3E+00	2E+00	2E+00	2E+01	3E+00	2E-06	6E-03

Notes:

Area of Site (ha): 0.58

NA - Not applicable	PAUF - Population area use factor	HR - Home range
ESLs - Ecological screening level	AUF - Area use factor	

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-9. Area Use Factors and Site-Specific Hazard Analysis for TA 36 Based on LE ESLs.

COPC Name	CAS	Low Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)										
		American kestrel (top carnivore)	American kestrel (insectivore / carnivore)	American robin (herbivore)	American robin (insectivore)	American robin (omnivore)	Deer mouse (omnivore)	Earthworm (invertebrate)	Generic plant (autotroph)	Gray fox (top carnivore)	Montane shrew (insectivore)	Mountain cottontail (herbivore)
Inorganics												
Copper	7440-50-8	3.5E+03	2.4E+02	1.0E+02	4.3E+01	6.0E+01	1.0E+02	5.3E+02	4.9E+02	6.7E+03	7.0E+01	4.3E+02
Mercury	7487-94-7	3.2E+00	5.8E-01	6.7E-01	1.3E-01	2.2E-01	3.0E+01	5.0E-01	6.4E+01	7.6E+02	1.7E+01	2.3E+02
Organics												
2,3,7,8-TCDD	1746-01-6	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-06	1.0E+01	0.0E+00	6.8E-04	1.9E-06	2.7E-04
Bis(2-ethylhexyl)phthalate	117-81-7	9.3E+01	9.6E-01	1.6E+02	2.0E-01	4.0E-01	1.1E+01	0.0E+00	0.0E+00	5.0E+03	6.0E+00	1.9E+04
RDX	121-82-4	1.4E+03	2.2E+01	4.3E+00	4.5E+00	4.4E+00	5.1E+01	1.5E+01	0.0E+00	2.2E+04	5.3E+01	1.2E+02
TATB	3058-38-6	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+03	2.8E+01	0.0E+00	1.0E+05	7.2E+03	1.5E+03

HR (ha)[a]	106	106	0.42	0.42	0.42	0.077	NA	NA	1038	0.39	3.1
Population Area[b]	4240	4240	16.8	16.8	16.8	3.08	NA	NA	41520	15.6	124
PAUF[c]	0.00014	0.00014	0.035	0.035	0.035	0.19	NA	NA	0.000014	0.037	0.004677
AUF[d]	0.0055	0.0055	1.00	1.00	1.00	1.00	NA	NA	0.000559	1.00	0.1871

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted LE ESL Hazard Quotients										
		American kestrel (top carnivore)	American kestrel (insectivore / carnivore)	American robin (herbivore)	American robin (insectivore)	American robin (omnivore)	Deer mouse (omnivore)	Earthworm (invertebrate)	Generic plant (autotroph)	Gray fox (top carnivore)	Montane shrew (insectivore)	Mountain cottontail (herbivore)
Inorganics												
Copper	240.3	9E-06	1E-04	8E-02	2E-01	1E-01	5E-01	5E-01	5E-01	5E-07	1E-01	3E-03
Mercury	0.598	3E-05	1E-04	3E-02	2E-01	9E-02	4E-03	1E+00	9E-03	1E-08	1E-03	1E-05
Organics												
2,3,7,8-TCDD Mammal	3.91E-06	--	--	--	--	--	2E-01	4E-07	NA, No ESL	8E-08	8E-02	7E-05
2,3,7,8-TCDD Bird	4.89E-06	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	--	--	NA, No ESL	--	--	--
Bis(2-ethylhexyl)phthalate	0.493	7E-07	7E-05	1E-04	9E-02	4E-02	8E-03	3E-02	NA, No ESL	1E-09	3E-03	1E-07
RDX	1.48	1E-07	9E-06	1E-02	1E-02	1E-02	5E-03	5E-02	NA, No ESL	9E-10	1E-03	6E-05
TATB	14.52	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	NA, No ESL	2E-03	NA, No ESL	NA, No ESL	2E-09	7E-05	5E-05
Hazard Index		4E-05	3E-04	1E-01	4E-01	3E-01	5E-01	2E+00	5E-01	5E-07	1E-01	3E-03

Notes:

Area of Site (ha): 0.58

NA - Not applicable	PAUF - Population area use factor	HR - Home range
ESLs - Ecological screening level	AUF - Area use factor	LE - Low Effect

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Figures

Figure 1-1. Sample Location Map for the Unit OD Area

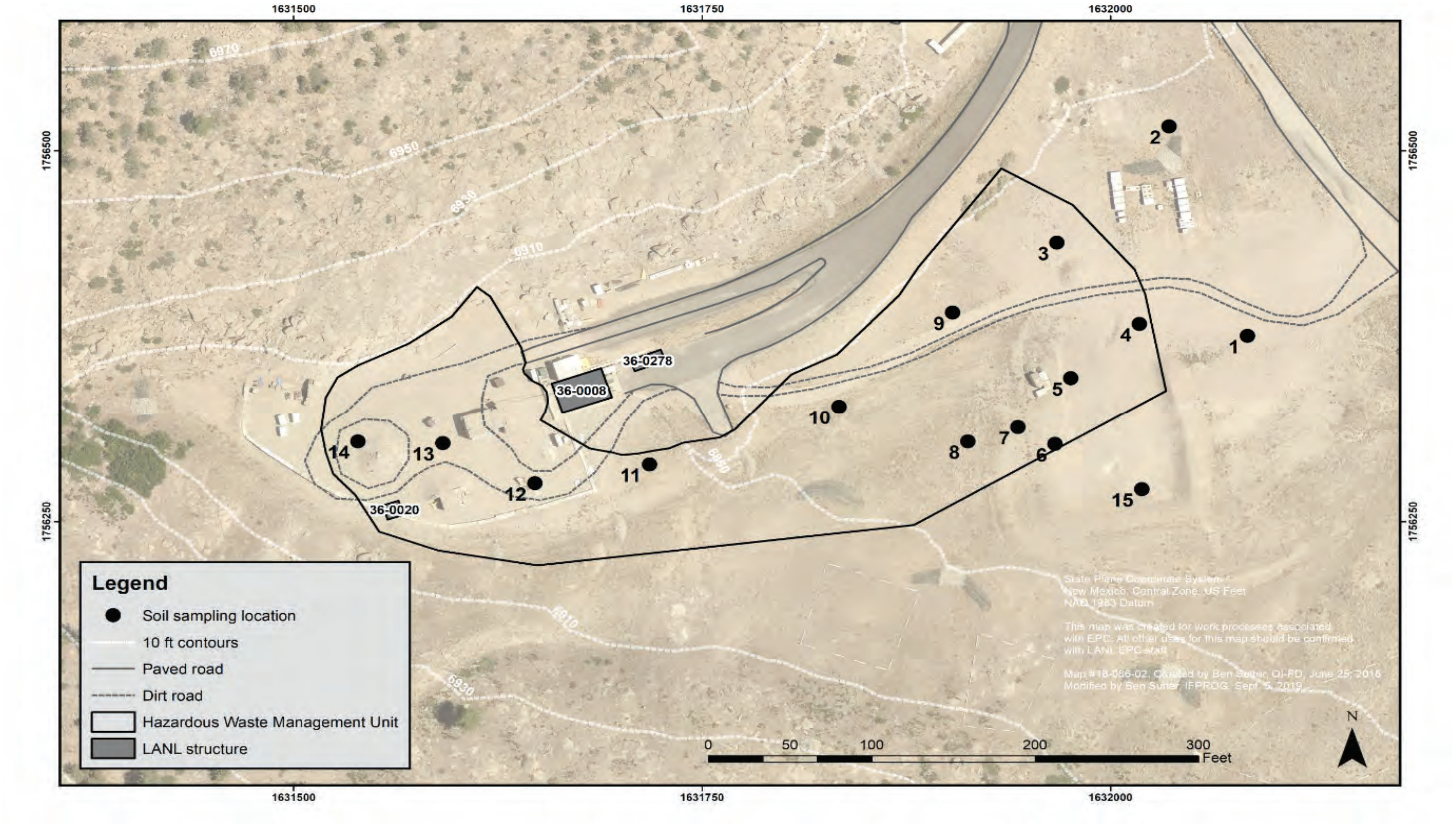
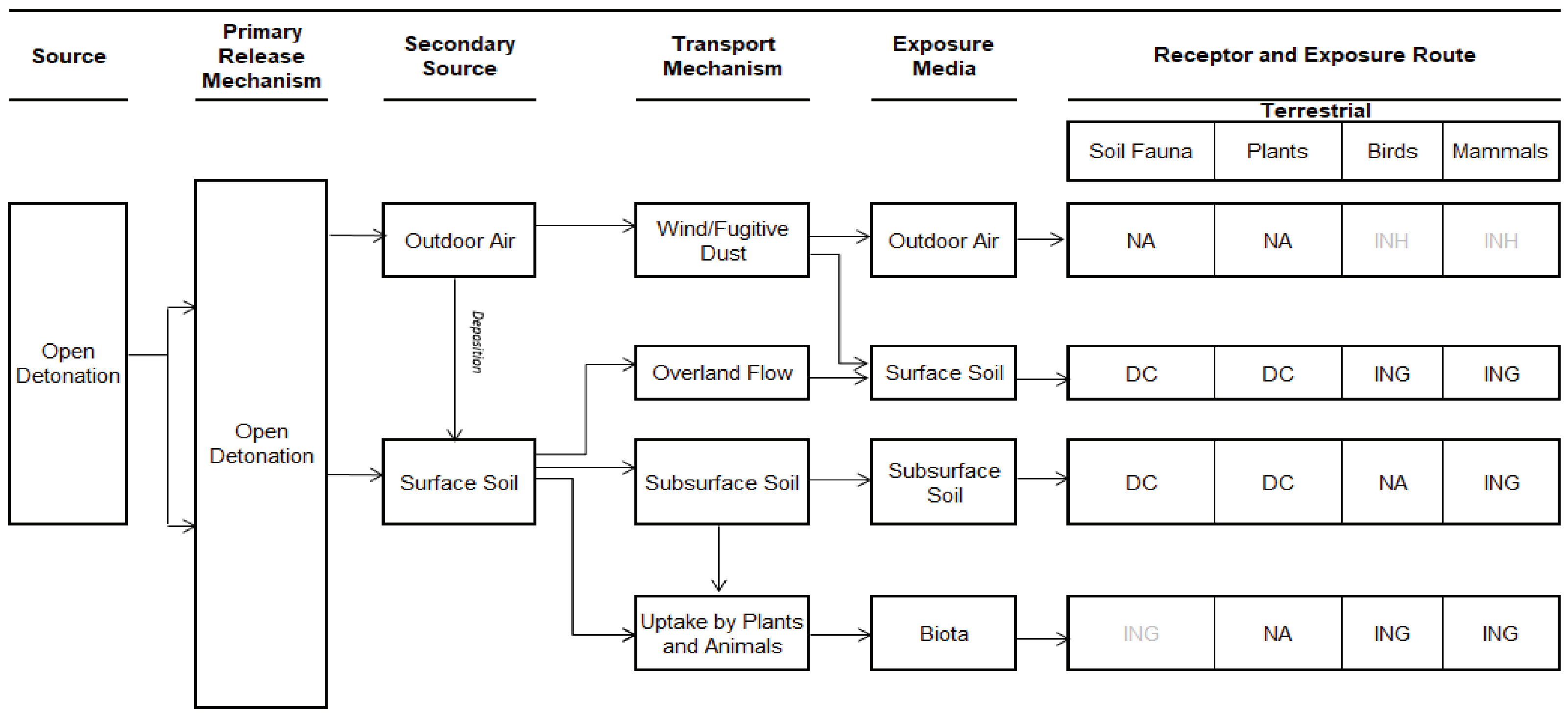


Figure 3-1. Conceptual Site Exposure Model (CSEM) for the Ecological Risk Assessment



Abbreviations

DC	Direct contact; applies to receptors for which toxic effects are addressed by exposure concentration and not dose
ING	Ingestion; typically quantified as dose for birds and mammals only
INH	Inhalation; recognized to occur, but not typically quantified as standard practice with the exception of evaluating burrow air exposure by burrowing mammals
NA	Pathway considered incomplete; not applicable

Notes:

Grayed text indicates pathways are recognized to potentially exist but are not quantified. Inhalation is considered minimal relative to dietary exposure. Ingestion by invertebrates is not typically quantified due to absence of accurate exposure parameters.

ATTACHMENT A. PROUCL OUTPUT FOR UPPER CONFIDENCE LIMITS AND HYPOTHESIS TESTS

```
UCL Statistics for Data Sets with Non-Detects
User Selected Options
Date/Time of Computation                                ProUCL 5.13/8/2022 9:53:21 AM
From File                                               UCL Data TA 36 rev 1.xls
Full Precision                                          OFF
Confidence Coefficient                                                         95%
Number of Bootstrap Operations                                                2000
Cd
General Statistics
Total Number of Observations                   15       Number of Distinct Observations             14
                                                        Number of Missing Observations               1
Number of Detects                               3       Number of Non-Detects                       12
Number of Distinct Detects                      3       Number of Distinct Non-Detects              11
Minimum Detect                              0.252       Minimum Non-Detect                      0.0918
Maximum Detect                              0.467       Maximum Non-Detect                       0.101
Variance Detects                           0.0137       Percent Non-Detects                        80%
Mean Detects                                0.333       SD Detects                               0.117
Median Detects                               0.28       CV Detects                               0.351
Skewness Detects                            1.621       Kurtosis Detects                       N/A
Mean of Logged Detects                     -1.138       SD of Logged Detects                      0.33
Warning: Data set has only 3 Detected Values.
This is not enough to compute meaningful or reliable statistics and
estimates.
Normal GOF Test on Detects Only
Shapiro Wilk Test Statistic                 0.846       Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value              0.767       Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic                   0.342       Lilliefors GOF Test
5% Lilliefors Critical Value                0.425       Detected Data appear Normal at 5% Significance Level
Detected Data appear Normal at 5% Significance Level
Kaplan-Meier (KM) Statistics using Normal Critical Values and other
Nonparametric UCLs
KM Mean                                      0.14       KM Standard Error of Mean               0.0334
KM SD                                       0.105         95% KM (BCA) UCL                     N/A
95% KM (t) UCL                              0.199       95% KM (Percentile Bootstrap) UCL      N/A
  95% KM (z) UCL                            0.195         95% KM Bootstrap t UCL               N/A
90% KM Chebyshev UCL                         0.24       95% KM Chebyshev UCL                     0.285
97.5% KM Chebyshev UCL                      0.348       99% KM Chebyshev UCL                     0.472
Gamma GOF Tests on Detected Observations Only
Not Enough Data to Perform GOF Test
Gamma Statistics on Detected Data Only
k hat (MLE)                                 13.34       k star (bias corrected MLE)            N/A
Theta hat (MLE)                             0.025       Theta star (bias corrected MLE)        N/A
nu hat (MLE)                                80.02       nu star (bias corrected)               N/A
Mean (detects)                              0.333
Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and
BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates
Minimum                                      0.01       Mean                                    0.0746
Maximum                                     0.467       Median                                    0.01
SD                                          0.141       CV                                       1.888
k hat (MLE)                                 0.485       k star (bias corrected MLE)              0.432
Theta hat (MLE)                             0.154       Theta star (bias corrected MLE)          0.173
nu hat (MLE)                                14.55       nu star (bias corrected)                 12.97
Adjusted Level of Significance (β)         0.0324
Approximate Chi Square Value (12.97, α)     5.874       Adjusted Chi Square Value (12.97, β)     5.296
95% Gamma Approximate UCL (use when n>=50)  0.165       95% Gamma Adjusted UCL (use when n<50) N/A
Estimates of Gamma Parameters using KM Estimates
Mean (KM)                                    0.14       SD (KM)                                  0.105
Variance (KM)                              0.0111       SE of Mean (KM)                         0.0334
k hat (KM)                                  1.762       k star (KM)                              1.454
```

nu hat (KM)	52.86	nu star (KM)	43.62
theta hat (KM)	0.0795	theta star (KM)	0.0963
80% gamma percentile (KM)	0.217	90% gamma percentile (KM)	0.294
95% gamma percentile (KM)	0.369	99% gamma percentile (KM)	0.537
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (43.62, α)	29.48	Adjusted Chi Square Value (43.62, β)	28.05
95% Gamma Approximate KM-UCL (use when n>=50)	0.207	95% Gamma Adjusted KM-UCL (use when n<50)	0.218
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.874	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.767	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.326	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.425	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.117	Mean in Log Scale	-2.455
SD in Original Scale	0.121	SD in Log Scale	0.707
95% t UCL (assumes normality of ROS data)	0.171	95% Percentile Bootstrap UCL	0.17
95% BCA Bootstrap UCL	0.189	95% Bootstrap t UCL	0.217
95% H-UCL (Log ROS)	0.171		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-2.138	KM Geo Mean	0.118
KM SD (logged)	0.515	95% Critical H Value (KM-Log)	2.084
KM Standard Error of Mean (logged)	0.163	95% H-UCL (KM -Log)	0.179
KM SD (logged)	0.515	95% Critical H Value (KM-Log)	2.084
KM Standard Error of Mean (logged)	0.163		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.105	Mean in Log Scale	-2.655
SD in Original Scale	0.126	SD in Log Scale	0.795
95% t UCL (Assumes normality)	0.162	95% H-Stat UCL	0.162
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.199		
Cu			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	1
Minimum	8.21	Mean	74.49
Maximum	597	Median	27.7
SD	147.3	Std. Error of Mean	38.03
Coefficient of Variation	1.977	Skewness	3.638
Normal GOF Test			
Shapiro Wilk Test Statistic	0.441	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.357	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	141.5	95% Adjusted-CLT UCL (Chen-1995)	175.2
		95% Modified-t UCL (Johnson-1978)	147.4
Gamma GOF Test			
A-D Test Statistic	1.465	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.773	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.244	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.23	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.792	k star (bias corrected MLE)	0.678
Theta hat (MLE)	94.01	Theta star (bias corrected MLE)	109.8

nu hat (MLE)	23.77	nu star (bias corrected)	20.35
MLE Mean (bias corrected)	74.49	MLE Sd (bias corrected)	90.44
		Approximate Chi Square Value (0.05)	11.11
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	10.28
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	136.4	95% Adjusted Gamma UCL (use when n<50)	147.5
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.902	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.187	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.105	Mean of logged Data	3.561
Maximum of Logged Data	6.392	SD of logged Data	1.056
Assuming Lognormal Distribution			
95% H-UCL	136.7	90% Chebyshev (MVUE) UCL	110.7
95% Chebyshev (MVUE) UCL	134.4	97.5% Chebyshev (MVUE) UCL	167.3
99% Chebyshev (MVUE) UCL	232		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	137	95% Jackknife UCL	141.5
95% Standard Bootstrap UCL	135	95% Bootstrap-t UCL	398.4
95% Hall's Bootstrap UCL	350.1	95% Percentile Bootstrap UCL	148.5
95% BCA Bootstrap UCL	192.9		
90% Chebyshev(Mean, Sd) UCL	188.6	95% Chebyshev(Mean, Sd) UCL	240.3
97.5% Chebyshev(Mean, Sd) UCL	312	99% Chebyshev(Mean, Sd) UCL	452.9
Suggested UCL to Use			
95% Chebyshev (Mean, Sd) UCL	**240.3**		
Hg			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	14
		Number of Missing Observations	1
Number of Detects	6	Number of Non-Detects	9
Number of Distinct Detects	6	Number of Distinct Non-Detects	8
Minimum Detect	0.00476	Minimum Non-Detect	0.00343
Maximum Detect	0.775	Maximum Non-Detect	0.00396
Variance Detects	0.0968	Percent Non-Detects	60%
Mean Detects	0.141	SD Detects	0.311
Median Detects	0.0062	CV Detects	2.211
Skewness Detects	2.434	Kurtosis Detects	5.94
Mean of Logged Detects	-4.006	SD of Logged Detects	2.026
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.531	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.452	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data Not Normal at 5% Significance Level	
Detected Data Not Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	0.0583	KM Standard Error of Mean	0.0543
KM SD	0.192	95% KM (BCA) UCL	0.161
95% KM (t) UCL	0.154	95% KM (Percentile Bootstrap) UCL	0.161
95% KM (z) UCL	0.148	95% KM Bootstrap t UCL	9.152
90% KM Chebyshev UCL	0.221	95% KM Chebyshev UCL	0.295
97.5% KM Chebyshev UCL	0.397	99% KM Chebyshev UCL	0.598
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	1.083	Anderson-Darling GOF Test	
5% A-D Critical Value	0.762	Detected Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.388	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.355	Detected Data Not Gamma Distributed at 5% Significance Level	

Detected Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.332	k star (bias corrected MLE)	0.277
Theta hat (MLE)	0.424	Theta star (bias corrected MLE)	0.508
nu hat (MLE)	3.98	nu star (bias corrected)	3.324
Mean (detects)	0.141		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.00476	Mean	0.0623
Maximum	0.775	Median	0.01
SD	0.197	CV	3.169
k hat (MLE)	0.412	k star (bias corrected MLE)	0.374
Theta hat (MLE)	0.151	Theta star (bias corrected MLE)	0.167
nu hat (MLE)	12.36	nu star (bias corrected)	11.22
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (11.22, α)	4.719	Adjusted Chi Square Value (11.22, β)	4.211
95% Gamma Approximate UCL (use when n>=50)	0.148	95% Gamma Adjusted UCL (use when n<50)	0.166
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.0583	SD (KM)	0.192
Variance (KM)	0.0368	SE of Mean (KM)	0.0543
k hat (KM)	0.0925	k star (KM)	0.118
nu hat (KM)	2.776	nu star (KM)	3.554
theta hat (KM)	0.631	theta star (KM)	0.493
80% gamma percentile (KM)	0.0504	90% gamma percentile (KM)	0.165
95% gamma percentile (KM)	0.333	99% gamma percentile (KM)	0.85
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (3.55, α)	0.554	Adjusted Chi Square Value (3.55, β)	0.432
95% Gamma Approximate KM-UCL (use when n>=50)	0.374	95% Gamma Adjusted KM-UCL (use when n<50)	0.48
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.735	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.361	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data Not Lognormal at 5% Significance Level	
Detected Data Not Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.0563	Mean in Log Scale	-7.708
SD in Original Scale	0.199	SD in Log Scale	3.389
95% t UCL (assumes normality of ROS data)	0.147	95% Percentile Bootstrap UCL	0.159
95% BCA Bootstrap UCL	0.211	95% Bootstrap t UCL	4.16
95% H-UCL (Log ROS)	108.7		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-5.008	KM Geo Mean	0.00669
KM SD (logged)	1.427	95% Critical H Value (KM-Log)	3.478
KM Standard Error of Mean (logged)	0.404	95% H-UCL (KM -Log)	0.0697
KM SD (logged)	1.427	95% Critical H Value (KM-Log)	3.478
KM Standard Error of Mean (logged)	0.404		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0574	Mean in Log Scale	-5.382
SD in Original Scale	0.199	SD in Log Scale	1.679
95% t UCL (Assumes normality)	0.148	95% H-Stat UCL	0.111
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution at 5% Significance Level			
Suggested UCL to Use			
99% KM (Chebyshev) UCL	0.598		
CLO4			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	1

Number of Detects	11	Number of Non-Detects	4
Number of Distinct Detects	11	Number of Distinct Non-Detects	4
Minimum Detect	5.72E-04	Minimum Non-Detect	4.99E-04
Maximum Detect	0.0296	Maximum Non-Detect	5.05E-04
Variance Detects	9.24E-05	Percent Non-Detects	26.67%
Mean Detects	0.00741	SD Detects	0.00961
Median Detects	0.00321	CV Detects	1.298
Skewness Detects	1.612	Kurtosis Detects	1.817
Mean of Logged Detects	-5.724	SD of Logged Detects	1.379

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.752	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.27	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	Detected Data Not Normal at 5% Significance Level	

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.00556	KM Standard Error of Mean	0.00228
KM SD	0.00842	95% KM (BCA) UCL	0.00975
95% KM (t) UCL	0.00958	95% KM (Percentile Bootstrap) UCL	0.00919
95% KM (z) UCL	0.00932	95% KM Bootstrap t UCL	0.0137
90% KM Chebyshev UCL	0.0124	95% KM Chebyshev UCL	0.0155
97.5% KM Chebyshev UCL	0.0198	99% KM Chebyshev UCL	0.0283

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.543	Anderson-Darling GOF Test	
5% A-D Critical Value	0.764	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.223	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.265	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.734	k star (bias corrected MLE)	0.594
Theta hat (MLE)	0.0101	Theta star (bias corrected MLE)	0.0125
nu hat (MLE)	16.14	nu star (bias corrected)	13.07
Mean (detects)	0.00741		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	5.72E-04	Mean	0.0081
Maximum	0.0296	Median	0.00637
SD	0.00821	CV	1.014
k hat (MLE)	0.953	k star (bias corrected MLE)	0.807
Theta hat (MLE)	0.0085	Theta star (bias corrected MLE)	0.01
nu hat (MLE)	28.59	nu star (bias corrected)	24.2
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (24.20, α)	14	Adjusted Chi Square Value (24.20, β)	13.05
95% Gamma Approximate UCL (use when n>=50)	0.014	95% Gamma Adjusted UCL (use when n<50)	0.015

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.00556	SD (KM)	0.00842
Variance (KM)	7.10E-05	SE of Mean (KM)	0.00228
k hat (KM)	0.436	k star (KM)	0.393
nu hat (KM)	13.09	nu star (KM)	11.8
theta hat (KM)	0.0128	theta star (KM)	0.0141
80% gamma percentile (KM)	0.00896	90% gamma percentile (KM)	0.0158
95% gamma percentile (KM)	0.0232	99% gamma percentile (KM)	0.0421

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (11.80, α)	5.099	Adjusted Chi Square Value (11.80, β)	4.567

95% Gamma Approximate KM-UCL (use when n>=50)	0.0129	95% Gamma Adjusted KM-UCL (use when n<50)	0.0144
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.924	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.201	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.00546	Mean in Log Scale	-6.608
SD in Original Scale	0.00878	SD in Log Scale	1.914
95% t UCL (assumes normality of ROS data)	0.00946	95% Percentile Bootstrap UCL	0.00938
95% BCA Bootstrap UCL	0.0105	95% Bootstrap t UCL	0.014
95% H-UCL (Log ROS)	0.0798		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-6.225	KM Geo Mean	0.00198
KM SD (logged)	1.399	95% Critical H Value (KM-Log)	3.427
KM Standard Error of Mean (logged)	0.379	95% H-UCL (KM -Log)	0.019
KM SD (logged)	1.399	95% Critical H Value (KM-Log)	3.427
KM Standard Error of Mean (logged)	0.379		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0055	Mean in Log Scale	-6.408
SD in Original Scale	0.00876	SD in Log Scale	1.654
95% t UCL (Assumes normality)	0.00948	95% H-Stat UCL	0.0363
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Gamma Distributed at 5% Significance Level			
Suggested UCL to Use			
Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	**0.0144**		
Ag			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	1
Minimum	0.125	Mean	0.437
Maximum	2.19	Median	0.27
SD	0.536	Std. Error of Mean	0.138
Coefficient of Variation	1.225	Skewness	2.922
Normal GOF Test			
Shapiro Wilk Test Statistic	0.584	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.325	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.681	95% Adjusted-CLT UCL (Chen-1995)	0.776
		95% Modified-t UCL (Johnson-1978)	0.698
Gamma GOF Test			
A-D Test Statistic	1.171	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.754	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.249	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.226	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.47	k star (bias corrected MLE)	1.221
Theta hat (MLE)	0.298	Theta star (bias corrected MLE)	0.358
nu hat (MLE)	44.11	nu star (bias corrected)	36.62
MLE Mean (bias corrected)	0.437	MLE Sd (bias corrected)	0.396
		Approximate Chi Square Value (0.05)	23.77
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	22.5
Assuming Gamma Distribution			

95% Approximate Gamma UCL (use when n>=50))	0.674	95% Adjusted Gamma UCL (use when n<50)	0.712

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.885	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.184	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-2.079	Mean of logged Data	-1.204
Maximum of Logged Data	0.784	SD of logged Data	0.788

Assuming Lognormal Distribution

95% H-UCL	0.682	90% Chebyshev (MVUE) UCL	0.658
95% Chebyshev (MVUE) UCL	0.775	97.5% Chebyshev (MVUE) UCL	0.938
99% Chebyshev (MVUE) UCL	1.258		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.665	**95% Jackknife UCL**	**0.681**
95% Standard Bootstrap UCL	0.661	95% Bootstrap-t UCL	1.352
95% Hall's Bootstrap UCL	1.72	95% Percentile Bootstrap UCL	0.681
95% BCA Bootstrap UCL	0.82		
90% Chebyshev(Mean, Sd) UCL	0.852	95% Chebyshev(Mean, Sd) UCL	1.04
97.5% Chebyshev(Mean, Sd) UCL	1.301	99% Chebyshev(Mean, Sd) UCL	1.814

Suggested UCL to Use

95% H-UCL	**0.682**

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.

H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.

It is therefore recommended to avoid the use of H-statistic based 95% UCLs.

Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

BenzAc

General Statistics

Total Number of Observations	15	Number of Distinct Observations	6
		Number of Missing Observations	1
Number of Detects	2	Number of Non-Detects	13
Number of Distinct Detects	2	Number of Distinct Non-Detects	4
Minimum Detect	0.458	Minimum Non-Detect	0.167
Maximum Detect	0.497	Maximum Non-Detect	0.17
Variance Detects	7.61E-04	Percent Non-Detects	86.67%
Mean Detects	0.478	SD Detects	0.0276
Median Detects	0.478	CV Detects	0.0578
Skewness Detects	N/A	Kurtosis Detects	N/A
Mean of Logged Detects	-0.74	SD of Logged Detects	0.0578

Warning: Data set has only 2 Detected Values.

This is not enough to compute meaningful or reliable statistics and estimates.

Normal GOF Test on Detects Only

Not Enough Data to Perform GOF Test

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.208	KM Standard Error of Mean	0.0386
KM SD	0.106	95% KM (BCA) UCL	N/A
95% KM (t) UCL	0.276	95% KM (Percentile Bootstrap) UCL	N/A
95% KM (z) UCL	0.272	95% KM Bootstrap t UCL	N/A
90% KM Chebyshev UCL	0.324	95% KM Chebyshev UCL	0.377

97.5% KM Chebyshev UCL	0.45	99% KM Chebyshev UCL	0.593
Gamma GOF Tests on Detected Observations Only			
Not Enough Data to Perform GOF Test			
Gamma Statistics on Detected Data Only			
k hat (MLE)	599.3	k star (bias corrected MLE)	N/A
Theta hat (MLE)	7.97E-04	Theta star (bias corrected MLE)	N/A
nu hat (MLE)	2397	nu star (bias corrected)	N/A
Mean (detects)	0.478		
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.208	SD (KM)	0.106
Variance (KM)	0.0112	SE of Mean (KM)	0.0386
k hat (KM)	3.881	k star (KM)	3.149
nu hat (KM)	116.4	nu star (KM)	94.47
theta hat (KM)	0.0537	theta star (KM)	0.0662
80% gamma percentile (KM)	0.296	90% gamma percentile (KM)	0.366
95% gamma percentile (KM)	0.431	99% gamma percentile (KM)	0.573
Gamma Kaplan-Meier (KM) Statistics			
		Adjusted Level of Significance (β)	0.0324
Approximate Chi Square Value (94.47, α)	73.05	Adjusted Chi Square Value (94.47, β)	70.74
95% Gamma Approximate KM-UCL (use when n>=50)	0.269	95% Gamma Adjusted KM-UCL (use when n<50)	0.278
Lognormal GOF Test on Detected Observations Only			
Not Enough Data to Perform GOF Test			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.344	Mean in Log Scale	-1.085
SD in Original Scale	0.0679	SD in Log Scale	0.189
95% t UCL (assumes normality of ROS data)	0.374	95% Percentile Bootstrap UCL	0.372
95% BCA Bootstrap UCL	0.377	95% Bootstrap t UCL	0.382
95% H-UCL (Log ROS)	0.377		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-1.65	KM Geo Mean	0.192
KM SD (logged)	0.357	95% Critical H Value (KM-Log)	1.93
KM Standard Error of Mean (logged)	0.13	95% H-UCL (KM -Log)	0.246
KM SD (logged)	0.357	95% Critical H Value (KM-Log)	1.93
KM Standard Error of Mean (logged)	0.13		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.137	Mean in Log Scale	-2.244
SD in Original Scale	0.139	SD in Log Scale	0.611
95% t UCL (Assumes normality)	0.2	95% H-Stat UCL	0.183
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.276	KM H-UCL	0.246
95% KM (BCA) UCL	N/A		
Warning: One or more Recommended UCL(s) not available!			
B2EHP			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	9
		Number of Missing Observations	1
Number of Detects	6	Number of Non-Detects	9
Number of Distinct Detects	6	Number of Distinct Non-Detects	3
Minimum Detect	0.0255	Minimum Non-Detect	0.01
Maximum Detect	1.32	Maximum Non-Detect	0.0102
Variance Detects	0.315	Percent Non-Detects	60%
Mean Detects	0.655	SD Detects	0.561
Median Detects	0.616	CV Detects	0.858
Skewness Detects	0.0747	Kurtosis Detects	-2.718
Mean of Logged Detects	-1.05	SD of Logged Detects	1.523
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.866	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.263	Lilliefors GOF Test	

5% Lilliefors Critical Value	0.325	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	0.268	KM Standard Error of Mean	0.128
KM SD	0.453	95% KM (BCA) UCL	0.483
95% KM (t) UCL	0.493	95% KM (Percentile Bootstrap) UCL	0.49
95% KM (z) UCL	0.478	95% KM Bootstrap t UCL	0.534
90% KM Chebyshev UCL	0.652	95% KM Chebyshev UCL	0.826
97.5% KM Chebyshev UCL	1.067	99% KM Chebyshev UCL	1.541
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.417	Anderson-Darling GOF Test	
5% A-D Critical Value	0.717	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.275	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.342	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.93	k star (bias corrected MLE)	0.576
Theta hat (MLE)	0.704	Theta star (bias corrected MLE)	1.136
nu hat (MLE)	11.16	nu star (bias corrected)	6.915
Mean (detects)	0.655		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	0.268
Maximum	1.32	Median	0.01
SD	0.468	CV	1.749
k hat (MLE)	0.359	k star (bias corrected MLE)	0.332
Theta hat (MLE)	0.746	Theta star (bias corrected MLE)	0.808
nu hat (MLE)	10.77	nu star (bias corrected)	9.948
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (9.95, α)	3.91	Adjusted Chi Square Value (9.95, β)	3.456
95% Gamma Approximate UCL (use when n>=50)	0.682	95% Gamma Adjusted UCL (use when n<50)	0.771
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.268	SD (KM)	0.453
Variance (KM)	0.205	SE of Mean (KM)	0.128
k hat (KM)	0.35	k star (KM)	0.325
nu hat (KM)	10.51	nu star (KM)	9.74
theta hat (KM)	0.765	theta star (KM)	0.825
80% gamma percentile (KM)	0.418	90% gamma percentile (KM)	0.782
95% gamma percentile (KM)	1.194	99% gamma percentile (KM)	2.255
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (9.74, α)	3.78	Adjusted Chi Square Value (9.74, β)	3.335
95% Gamma Approximate KM-UCL (use when n>=50)	0.69	95% Gamma Adjusted KM-UCL (use when n<50)	0.782
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.863	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.25	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.266	Mean in Log Scale	-3.773
SD in Original Scale	0.469	SD in Log Scale	2.692
95% t UCL (assumes normality of ROS data)	0.48	95% Percentile Bootstrap UCL	0.472
95% BCA Bootstrap UCL	0.495	95% Bootstrap t UCL	0.576
95% H-UCL (Log ROS)	61.91		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-3.183	KM Geo Mean	0.0415
KM SD (logged)	1.951	95% Critical H Value (KM-Log)	4.468
KM Standard Error of Mean (logged)	0.552	95% H-UCL (KM -Log)	2.859

KM SD (logged)	1.951	95% Critical H Value (KM-Log)	4.468
KM Standard Error of Mean (logged)	0.552		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.265	Mean in Log Scale	-3.593
SD in Original Scale	0.47	SD in Log Scale	2.334
95% t UCL (Assumes normality)	0.479	95% H-Stat UCL	10.91
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	**0.493**		
DNBP			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	7
		Number of Missing Observations	1
Number of Detects	4	Number of Non-Detects	11
Number of Distinct Detects	4	Number of Distinct Non-Detects	3
Minimum Detect	0.0131	Minimum Non-Detect	0.01
Maximum Detect	0.744	Maximum Non-Detect	0.0102
Variance Detects	0.118	Percent Non-Detects	73.33%
Mean Detects	0.239	SD Detects	0.343
Median Detects	0.1	CV Detects	1.435
Skewness Detects	1.776	Kurtosis Detects	3.132
Mean of Logged Detects	-2.459	SD of Logged Detects	1.785
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.779	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.333	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Normal at 5% Significance Level	
Detected Data appear Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	0.0711	KM Standard Error of Mean	0.0549
KM SD	0.184	95% KM (BCA) UCL	N/A
95% KM (t) UCL	0.168	95% KM (Percentile Bootstrap) UCL	N/A
95% KM (z) UCL	0.161	95% KM Bootstrap t UCL	N/A
90% KM Chebyshev UCL	0.236	95% KM Chebyshev UCL	0.31
97.5% KM Chebyshev UCL	0.414	99% KM Chebyshev UCL	0.617
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.292	Anderson-Darling GOF Test	
5% A-D Critical Value	0.677	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.257	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.408	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.601	k star (bias corrected MLE)	0.317
Theta hat (MLE)	0.398	Theta star (bias corrected MLE)	0.755
nu hat (MLE)	4.805	nu star (bias corrected)	2.535
Mean (detects)	0.239		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	0.0711
Maximum	0.744	Median	0.01
SD	0.19	CV	2.678
k hat (MLE)	0.463	k star (bias corrected MLE)	0.415
Theta hat (MLE)	0.154	Theta star (bias corrected MLE)	0.172
nu hat (MLE)	13.88	nu star (bias corrected)	12.44
Adjusted Level of Significance (β)	0.0324		

Approximate Chi Square Value (12.44, α)	5.517	Adjusted Chi Square Value (12.44, β)	4.96
95% Gamma Approximate UCL (use when n>=50)	0.16	95% Gamma Adjusted UCL (use when n<50)	N/A
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.0711	SD (KM)	0.184
Variance (KM)	0.0339	SE of Mean (KM)	0.0549
k hat (KM)	0.149	k star (KM)	0.164
nu hat (KM)	4.483	nu star (KM)	4.92
theta hat (KM)	0.476	theta star (KM)	0.434
80% gamma percentile (KM)	0.0829	90% gamma percentile (KM)	0.213
95% gamma percentile (KM)	0.384	99% gamma percentile (KM)	0.873
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (4.92, α)	1.115	Adjusted Chi Square Value (4.92, β)	0.912
95% Gamma Approximate KM-UCL (use when n>=50)	0.314	95% Gamma Adjusted KM-UCL (use when n<50)	0.384
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.972	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.748	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.204	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.375	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.064	Mean in Log Scale	-8.202
SD in Original Scale	0.193	SD in Log Scale	4.354
95% t UCL (assumes normality of ROS data)	0.152	95% Percentile Bootstrap UCL	0.161
95% BCA Bootstrap UCL	0.21	95% Bootstrap t UCL	1.472
95% H-UCL (Log ROS)	193999		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-4.033	KM Geo Mean	0.0177
KM SD (logged)	1.24	95% Critical H Value (KM-Log)	3.146
KM Standard Error of Mean (logged)	0.37	95% H-UCL (KM -Log)	0.109
KM SD (logged)	1.24	95% Critical H Value (KM-Log)	3.146
KM Standard Error of Mean (logged)	0.37		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0675	Mean in Log Scale	-4.534
SD in Original Scale	0.192	SD in Log Scale	1.536
95% t UCL (Assumes normality)	0.155	95% H-Stat UCL	0.158
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.168		
HMX			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	13
		Number of Missing Observations	1
Number of Detects	11	Number of Non-Detects	4
Number of Distinct Detects	11	Number of Distinct Non-Detects	2
Minimum Detect	0.158	Minimum Non-Detect	0.148
Maximum Detect	3.87	Maximum Non-Detect	0.149
Variance Detects	1.064	Percent Non-Detects	26.67%
Mean Detects	1.209	SD Detects	1.032
Median Detects	0.978	CV Detects	0.853
Skewness Detects	1.932	Kurtosis Detects	4.369
Mean of Logged Detects	-0.113	SD of Logged Detects	0.852
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.813	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	**Detected Data Not Normal at 5% Significance Level**	
Lilliefors Test Statistic	0.226	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	**Detected Data appear Normal at 5% Significance Level**	
Detected Data appear Approximate Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	0.926	KM Standard Error of Mean	0.261
KM SD	0.964	95% KM (BCA) UCL	1.41

95% KM (t) UCL	**1.386**	95% KM (Percentile Bootstrap) UCL	1.38
95% KM (z) UCL	1.356	95% KM Bootstrap t UCL	1.698
90% KM Chebyshev UCL	1.709	95% KM Chebyshev UCL	2.064
97.5% KM Chebyshev UCL	2.557	99% KM Chebyshev UCL	3.524
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.204	Anderson-Darling GOF Test	
5% A-D Critical Value	0.74	**Detected data appear Gamma Distributed at 5% Significance Level**	
K-S Test Statistic	0.128	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.259	**Detected data appear Gamma Distributed at 5% Significance Level**	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	1.799	k star (bias corrected MLE)	1.369
Theta hat (MLE)	0.672	Theta star (bias corrected MLE)	0.883
nu hat (MLE)	39.58	nu star (bias corrected)	30.12
Mean (detects)	1.209		
Gamma ROS Statistics using Imputed Non-Detects			
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
For such situations, GROS method may yield incorrect values of UCLs and BTVs			
This is especially true when the sample size is small.			
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	0.889
Maximum	3.87	Median	0.652
SD	1.03	CV	1.158
k hat (MLE)	0.528	k star (bias corrected MLE)	0.467
Theta hat (MLE)	1.685	Theta star (bias corrected MLE)	1.906
nu hat (MLE)	15.83	nu star (bias corrected)	14
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (14.00, α)	6.57	Adjusted Chi Square Value (14.00, β)	5.954
95% Gamma Approximate UCL (use when n>=50)	1.895	95% Gamma Adjusted UCL (use when n<50)	2.091
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.926	SD (KM)	0.964
Variance (KM)	0.93	SE of Mean (KM)	0.261
k hat (KM)	0.923	k star (KM)	0.783
nu hat (KM)	27.68	nu star (KM)	23.48
theta hat (KM)	1.004	theta star (KM)	1.183
80% gamma percentile (KM)	1.515	90% gamma percentile (KM)	2.264
95% gamma percentile (KM)	3.028	99% gamma percentile (KM)	4.836
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (23.48, α)	13.45	Adjusted Chi Square Value (23.48, β)	12.52
95% Gamma Approximate KM-UCL (use when n>=50)	1.616	**95% Gamma Adjusted KM-UCL (use when n<50)**	**1.736**
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.98	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.85	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.132	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.251	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.92	Mean in Log Scale	-0.651
SD in Original Scale	1.004	SD in Log Scale	1.181
95% t UCL (assumes normality of ROS data)	1.376	95% Percentile Bootstrap UCL	1.353
95% BCA Bootstrap UCL	1.498	95% Bootstrap t UCL	1.691
95% H-UCL (Log ROS)	2.733		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-0.592	KM Geo Mean	0.553
KM SD (logged)	1.056	95% Critical H Value (KM-Log)	2.835
KM Standard Error of Mean (logged)	0.286	95% H-UCL (KM -Log)	2.151
KM SD (logged)	1.056	95% Critical H Value (KM-Log)	2.835
KM Standard Error of Mean (logged)	0.286		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.906	Mean in Log Scale	-0.776
SD in Original Scale	1.015	SD in Log Scale	1.347

95% t UCL (Assumes normality)	1.368	95% H-Stat UCL	3.788

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Approximate Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	**1.386**

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Isophorone

General Statistics

Total Number of Observations	15	Number of Distinct Observations	4
		Number of Missing Observations	1
Number of Detects	1	Number of Non-Detects	14
Number of Distinct Detects	1	Number of Distinct Non-Detects	3

Warning: Only one distinct data value was detected! ProUCL (or any other software) should not be used on such a data set!

It is suggested to use alternative site specific values determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).

The data set for variable Isophorone was not processed!

RDX

General Statistics

Total Number of Observations	15	Number of Distinct Observations	10
		Number of Missing Observations	1
Number of Detects	7	Number of Non-Detects	8
Number of Distinct Detects	7	Number of Distinct Non-Detects	3
Minimum Detect	0.196	Minimum Non-Detect	0.148
Maximum Detect	4.76	Maximum Non-Detect	0.15
Variance Detects	2.991	Percent Non-Detects	53.33%
Mean Detects	1.611	SD Detects	1.729
Median Detects	0.608	CV Detects	1.074
Skewness Detects	1.112	Kurtosis Detects	0.366
Mean of Logged Detects	-0.151	SD of Logged Detects	1.281

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.824	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.29	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.831	KM Standard Error of Mean	0.367
KM SD	1.315	95% KM (BCA) UCL	1.478
95% KM (t) UCL	1.476	95% KM (Percentile Bootstrap) UCL	1.437
95% KM (z) UCL	1.434	95% KM Bootstrap t UCL	1.842
90% KM Chebyshev UCL	1.931	95% KM Chebyshev UCL	2.429
97.5% KM Chebyshev UCL	3.12	99% KM Chebyshev UCL	4.479

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.462	Anderson-Darling GOF Test	
5% A-D Critical Value	0.73	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.241	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.32	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.929	k star (bias corrected MLE)	0.626
Theta hat (MLE)	1.734	Theta star (bias corrected MLE)	2.573
nu hat (MLE)	13	nu star (bias corrected)	8.762
Mean (detects)	1.611		

Gamma ROS Statistics using Imputed Non-Detects
GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs
GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)
For such situations, GROS method may yield incorrect values of UCLs and BTVs
This is especially true when the sample size is small.
For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.757
Maximum	4.76	Median	0.01
SD	1.402	CV	1.852
k hat (MLE)	0.306	k star (bias corrected MLE)	0.289
Theta hat (MLE)	2.475	Theta star (bias corrected MLE)	2.618
nu hat (MLE)	9.174	nu star (bias corrected)	8.673
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (8.67, α)	3.13	Adjusted Chi Square Value (8.67, β)	2.734
95% Gamma Approximate UCL (use when n>=50)	2.097	95% Gamma Adjusted UCL (use when n<50)	2.401

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.831	SD (KM)	1.315
Variance (KM)	1.729	SE of Mean (KM)	0.367
k hat (KM)	0.399	k star (KM)	0.364
nu hat (KM)	11.97	nu star (KM)	10.91
theta hat (KM)	2.081	theta star (KM)	2.284
80% gamma percentile (KM)	1.323	90% gamma percentile (KM)	2.384
95% gamma percentile (KM)	3.565	99% gamma percentile (KM)	6.566

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (10.91, α)	4.518	Adjusted Chi Square Value (10.91, β)	4.023
95% Gamma Approximate KM-UCL (use when n>=50)	2.005	95% Gamma Adjusted KM-UCL (use when n<50)	2.252

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.898	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.225	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.766	Mean in Log Scale	-2.198
SD in Original Scale	1.397	SD in Log Scale	2.263
95% t UCL (assumes normality of ROS data)	1.401	95% Percentile Bootstrap UCL	1.378
95% BCA Bootstrap UCL	1.647	95% Bootstrap t UCL	1.894
95% H-UCL (Log ROS)	31.1		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-1.089	KM Geo Mean	0.336
KM SD (logged)	1.195	95% Critical H Value (KM-Log)	3.066
KM Standard Error of Mean (logged)	0.333	95% H-UCL (KM -Log)	1.828
KM SD (logged)	1.195	95% Critical H Value (KM-Log)	3.066
KM Standard Error of Mean (logged)	0.333		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.791	Mean in Log Scale	-1.457
SD in Original Scale	1.382	SD in Log Scale	1.517
95% t UCL (Assumes normality)	1.42	95% H-Stat UCL	3.229

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use
95% KM (t) UCL **1.476**

TATB

General Statistics

Total Number of Observations	15	Number of Distinct Observations	15
		Number of Missing Observations	1
Minimum	3.33	Mean	12.29
Maximum	22.2	Median	12.7
SD	4.898	Std. Error of Mean	1.265
Coefficient of Variation	0.399	Skewness	-0.203

Normal GOF Test

Shapiro Wilk Test Statistic	0.955	Shapiro Wilk GOF Test	

5% Shapiro Wilk Critical Value	0.881	**Data appear Normal at 5% Significance Level**	
Lilliefors Test Statistic	0.138	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	**Data appear Normal at 5% Significance Level**	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	14.52	95% Adjusted-CLT UCL (Chen-1995)	14.3
		95% Modified-t UCL (Johnson-1978)	14.5
Gamma GOF Test			
A-D Test Statistic	0.768	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.739	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.205	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.222	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data follow Appr. Gamma Distribution at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	4.988	k star (bias corrected MLE)	4.034
Theta hat (MLE)	2.464	Theta star (bias corrected MLE)	3.046
nu hat (MLE)	149.6	nu star (bias corrected)	121
MLE Mean (bias corrected)	12.29	MLE Sd (bias corrected)	6.118
		Approximate Chi Square Value (0.05)	96.63
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	93.95
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	15.39	95% Adjusted Gamma UCL (use when n<50)	15.83
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.843	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.235	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.203	Mean of logged Data	2.405
Maximum of Logged Data	3.1	SD of logged Data	0.523
Assuming Lognormal Distribution			
95% H-UCL	17.01	90% Chebyshev (MVUE) UCL	17.83
95% Chebyshev (MVUE) UCL	20.21	97.5% Chebyshev (MVUE) UCL	23.51
99% Chebyshev (MVUE) UCL	30.01		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	14.37	95% Jackknife UCL	14.52
95% Standard Bootstrap UCL	14.25	95% Bootstrap-t UCL	14.39
95% Hall's Bootstrap UCL	14.5	95% Percentile Bootstrap UCL	14.26
95% BCA Bootstrap UCL	14.31		
90% Chebyshev(Mean, Sd) UCL	16.08	95% Chebyshev(Mean, Sd) UCL	17.8
97.5% Chebyshev(Mean, Sd) UCL	20.19	99% Chebyshev(Mean, Sd) UCL	24.87
Suggested UCL to Use			
95% Student's-t UCL	**14.52**		

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	**ProUCL 5.1 3/7/2022 7:32:40 PM**
From File	**WorkSheet.xls**
Full Precision	**OFF**
Confidence Coefficient	**95%**
Number of Bootstrap Operations	**2000**

TEQ HH and Mammal

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	11
		Number of Missing Observations	1.00E+00
Minimum	3.44E-06	Mean	3.70E-06

Maximum	5.03E-06	Median	3.49E-06
SD	4.38E-07	Std. Error of Mean	1.13E-07
Coefficient of Variation	N/A	Skewness	2.375
Normal GOF Test			
Shapiro Wilk Test Statistic	0.654	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.287	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	3.90E-06	95% Adjusted-CLT UCL (Chen-1995)	3.96E-06
		95% Modified-t UCL (Johnson-1978)	3.91E-06
Gamma GOF Test			
A-D Test Statistic	1.939	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.734	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.279	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.221	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	8.78E+01	k star (bias corrected MLE)	7.03E+01
Theta hat (MLE)	4.21E-08	Theta star (bias corrected MLE)	5.26E-08
nu hat (MLE)	2.63E+03	nu star (bias corrected)	2.11E+03
MLE Mean (bias corrected)	3.70E-06	MLE Sd (bias corrected)	4.41E-07
		Approximate Chi Square Value (0.05)	2003
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	1990
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	3.89E-06	95% Adjusted Gamma UCL (use when n<50)	3.92E-06
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.685	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.272	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-12.58	Mean of logged Data	-12.51
Maximum of Logged Data	-12.2	SD of logged Data	0.107
Assuming Lognormal Distribution			
95% H-UCL	3.89E-06	90% Chebyshev (MVUE) UCL	4.00E-06
95% Chebyshev (MVUE) UCL	4.14E-06	97.5% Chebyshev (MVUE) UCL	4.34E-06
99% Chebyshev (MVUE) UCL	4.71E-06		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Distribution Free UCLs			
95% CLT UCL	3.88E-06	95% Jackknife UCL	3.90E-06
95% Standard Bootstrap UCL	3.88E-06	95% Bootstrap-t UCL	4.11E-06
95% Hall's Bootstrap UCL	4.43E-06	95% Percentile Bootstrap UCL	3.90E-06
95% BCA Bootstrap UCL	3.95E-06		
90% Chebyshev(Mean, Sd) UCL	4.04E-06	95% Chebyshev(Mean, Sd) UCL	4.19E-06
97.5% Chebyshev(Mean, Sd) UCL	4.40E-06	99% Chebyshev(Mean, Sd) UCL	4.82E-06

Suggested UCL to Use			
95% Student's-t UCL	3.90E-06	or 95% Modified-t UCL	3.91E-06
UCL Statistics for Uncensored Full Data Sets			
Avian TEQ			
General Statistics			
Total Number of Observations	15	Number of Distinct Observations	13
		Number of Missing Observations	1
Minimum	4.74E-06	Mean	4.85E-06
Maximum	5.06E-06	Median	4.81E-06
SD	9.88E-08	Std. Error of Mean	2.55E-08
Coefficient of Variation	N/A	Skewness	1.113
Normal GOF Test			
Shapiro Wilk Test Statistic	0.866	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.881	**Data Not Normal at 5% Significance Level**	
Lilliefors Test Statistic	0.188	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	4.89E-06	95% Adjusted-CLT UCL (Chen-1995)	4.90E-06
		95% Modified-t UCL (Johnson-1978)	4.89E-06
Gamma GOF Test			
A-D Test Statistic	0.904	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.734	**Data Not Gamma Distributed at 5% Significance Level**	
K-S Test Statistic	0.209	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.221	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data follow Appr. Gamma Distribution at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2612	k star (bias corrected MLE)	2089
Theta hat (MLE)	1.86E-09	Theta star (bias corrected MLE)	2.32E-09
nu hat (MLE)	78347	nu star (bias corrected)	62679
MLE Mean (bias corrected)	4.85E-06	MLE Sd (bias corrected)	1.06E-07
		Approximate Chi Square Value (0.05)	62098
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	62027
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	4.89E-06	95% Adjusted Gamma UCL (use when n<50)	4.90E-06
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.87	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.881	**Data Not Lognormal at 5% Significance Level**	
Lilliefors Test Statistic	0.185	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-12.26	Mean of logged Data	-12.24
Maximum of Logged Data	-12.19	SD of logged Data	0.0202
Assuming Lognormal Distribution			
95% H-UCL	N/A	90% Chebyshev (MVUE) UCL	4.92E-06
95% Chebyshev (MVUE) UCL	4.96E-06	97.5% Chebyshev (MVUE) UCL	5.00E-06
99% Chebyshev (MVUE) UCL	5.10E-06		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			

95% CLT UCL	4.89E-06	95% Jackknife UCL	4.89E-06
95% Standard Bootstrap UCL	4.89E-06	95% Bootstrap-t UCL	4.91E-06
95% Hall's Bootstrap UCL	4.89E-06	95% Percentile Bootstrap UCL	4.89E-06
95% BCA Bootstrap UCL	4.89E-06		
90% Chebyshev(Mean, Sd) UCL	4.92E-06	95% Chebyshev(Mean, Sd) UCL	4.96E-06
97.5% Chebyshev(Mean, Sd) UCL	5.00E-06	99% Chebyshev(Mean, Sd) UCL	5.10E-06

Suggested UCL to Use

95% Student's-t UCL	**4.89E-06**

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.1 3/1/2022 6:10:36 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: CD(site)
Sample 2 Data: CD(bkg)
Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	15	39
Number of Missing Observations	1	0
Number of Non-Detects	12	36
Number of Detect Data	3	3
Minimum Non-Detect	0.0918	0.4
Maximum Non-Detect	0.101	2
Percent Non-detects	80.00%	92.31%
Minimum Detect	0.252	0.6
Maximum Detect	0.467	2.6
Mean of Detects	0.333	1.533
Median of Detects	0.28	1.4
SD of Detects	0.117	1.007
KM Mean	0.14	0.49
KM SD	0.105	0.381

Sample 1 vs Sample 2 Gehan Test
H0: Mean/Median of Sample 1 <= Mean/Median of background

Gehan z Test Value	-0.262
Critical z (0.05)	1.645
P-Value	**0.603**

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Sample 1 <= Sample 2
P-Value >= alpha (0.05)
Use of Gehan or T-W test is suggested when multiple detection limits are present

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.13/1/2022 7:26:34 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cr(site)
Sample 2 Data: Cr(bkg)
Raw Statistics

```
                                                                  Sample 1    Sample 2
Number of Valid Data                                                    15         173
Number of Missing Observations                                           1           1
Number of Non-Detects                                                    0           0
Number of Detect Data                                                   15         173
Minimum Non-Detect                                                     N/A         N/A
Maximum Non-Detect                                                     N/A         N/A
Percent Non-detects                                                  0.00%       0.00%
Minimum Detect                                                        3.82         1.9
Maximum Detect                                                        49.2        36.5
Mean of Detects                                                      9.231        9.04
Median of Detects                                                     6.67         8.6
SD of Detects                                                        11.18       4.363
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                               966
Standardized WMW U-Stat                                             -2.237
Mean (U)                                                              1298
SD(U) - Adj ties                                                     202.1
Approximate U-Stat Critical Value (0.05)                             1.645
P-Value (Adjusted for Ties)                                          0.987
Conclusion with Alpha = 0.05
  Do Not Reject H0, Conclude Sample 1 <= Sample 2
  P-Value >= alpha (0.05)
Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects
Date/Time of Computation          ProUCL 5.13/1/2022 7:32:50 PM
From File                         WorkSheet.xls
Full Precision                    OFF
Confidence Coefficient               95%
Selected Null Hypothesis          Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis            Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Cu(site)
Sample 2 Data: Cu(bkg)
Raw Statistics
                                                                  Sample 1    Sample 2
Number of Valid Data                                                    15         174
Number of Missing Observations                                           1           0
Number of Non-Detects                                                    0           2
Number of Detect Data                                                   15         172
Minimum Non-Detect                                                     N/A         0.5
Maximum Non-Detect                                                     N/A         0.5
Percent Non-detects                                                  0.00%       1.15%
Minimum Detect                                                        8.21         0.6
Maximum Detect                                                         597          16
Mean of Detects                                                      74.49       6.125
Median of Detects                                                     27.7         5.8
SD of Detects                                                        147.3       2.523
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                              2699
Standardized WMW U-Stat                                              6.266
Mean (U)                                                              1305
SD(U) - Adj ties                                                     203.3
Approximate U-Stat Critical Value (0.05)                             1.645
P-Value (Adjusted for Ties)                                       1.86E-10
Conclusion with Alpha = 0.05
  Reject H0, Conclude Sample 1 > Sample 2
  P-Value < alpha (0.05)
Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects
Date/Time of Computation          ProUCL 5.13/1/2022 7:20:51 PM
From File                         WorkSheet.xls
Full Precision                    OFF
Confidence Coefficient               95%
Selected Null Hypothesis          Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis            Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Hg(site)
Sample 2 Data: Hg(bkg)
Raw Statistics
```

	Sample 1	Sample 2
Number of Valid Data	15	39
Number of Missing Observations	1	0
Number of Non-Detects	9	37
Number of Detect Data	6	2
Minimum Non-Detect	0.00343	0.1
Maximum Non-Detect	0.00396	0.1
Percent Non-detects	60.00%	94.87%
Minimum Detect	0.00476	0.1
Maximum Detect	0.775	0.1
Mean of Detects	0.141	0.1
Median of Detects	0.0062	0.1
SD of Detects	0.311	0

WMW test is meant for a Single Detection Limit Case
Use of Gehan or T-W test is suggested when multiple detection limits are present
All observations <= 0.1 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
All observations are identical in at least one group
No analysis will be performed

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.13/1/2022 7:36:25 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Pb(site)
Sample 2 Data: Pb(bkg)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	15	173
Number of Missing Observations	1	1
Number of Non-Detects	0	9
Number of Detect Data	15	164
Minimum Non-Detect	N/A	4
Maximum Non-Detect	N/A	4
Percent Non-detects	0.00%	5.20%
Minimum Detect	4.13	4
Maximum Detect	35.2	28
Mean of Detects	9.42	13.24
Median of Detects	6.52	13
SD of Detects	7.702	4.738

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	775
Standardized WMW U-Stat	-3.186
Mean (U)	1298
SD(U) - Adj ties	201.8
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.999

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Sample 1 <= Sample 2
P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.13/1/2022 7:39:29 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ag(site)
Sample 2 Data: Ag(bkg)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	15	113
Number of Missing Observations	1	0
Number of Non-Detects	0	112

Number of Detect Data	15	1
Minimum Non-Detect	N/A	0.4
Maximum Non-Detect	N/A	2
Percent Non-detects	0.00%	99.12%
Minimum Detect	0.125	1.9
Maximum Detect	2.19	1.9
Mean of Detects	0.437	1.9
Median of Detects	0.27	1.9
SD of Detects	0.536	N/A

WMW test is meant for a Single Detection Limit Case
Use of Gehan or T-W test is suggested when multiple detection limits are present
All observations <= 2 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
All observations are identical in at least one group
No analysis will be performed

Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.13/1/2022 7:44:26 PM
From File	ProUCL BKG STATS.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Tl(site)
Sample 2 Data: Tl(bkg)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	15	173
Number of Missing Observations	1	1
Number of Non-Detects	12	68
Number of Detect Data	3	105
Minimum Non-Detect	0.129	0.125
Maximum Non-Detect	0.141	1
Percent Non-detects	80.00%	39.31%
Minimum Detect	0.158	0.2
Maximum Detect	2.22	1
Mean of Detects	0.887	0.332
Median of Detects	0.282	0.2
SD of Detects	1.156	0.176
KM Mean	0.281	0.262
KM SD	0.52	0.172

Sample 1 vs Sample 2 Gehan Test

H0: Mean/Median of Sample 1 <= Mean/Median of background

Gehan z Test Value	-3.244
Critical z (0.05)	1.645
P-Value	0.999

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Sample 1 <= Sample 2
P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

Date/Time of Computation	ProUCL 5.13/1/2022 7:49:22 PM
From File	ProUCL BKG STATS.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Zn(site)
Sample 2 Data: Zn(bkg)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	15	172
Number of Missing Observations	1	0
Number of Non-Detects	0	0
Number of Detect Data	15	172
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	18.5	14

Maximum Detect	53.2	75.5
Mean of Detects	29.54	31.52
Median of Detects	25.3	30.75
SD of Detects	11.23	9.002
Wilcoxon-Mann-Whitney (WMW) Test		
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2		
Sample 1 Rank Sum W-Stat	1139	
Standardized WMW U-Stat	-1.351	
Mean (U)	1290	
SD(U) - Adj ties	200.9	
Approximate U-Stat Critical Value (0.05)	1.645	
P-Value (Adjusted for Ties)	0.912	
Conclusion with Alpha = 0.05		
Do Not Reject H0, Conclude Sample 1 <= Sample 2		
P-Value >= alpha (0.05)		

ATTACHMENT B. LANL ECORISK DATABASE FOR SOIL (MG/KG)

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	Deer mouse (Mammalian omnivore)	0.00000058	0.0000038	SOIL_DM(ip)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	Earthworm (Soil-dwelling invertebrate)	5	10	SOIL_EW_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	Gray fox (Mammalian top carnivore)	0.0001	0.00068	SOIL_RF(f)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	Montane shrew (Mammalian insectivore)	0.00000029	0.0000019	SOIL_MS(i)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	Mountain cottontail (Mammalian herbivore)	0.00004	0.00027	SOIL_DC(p)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	American kestrel (Avian top carnivore)	4.10E-06		
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	American kestrel (insectivore / carnivore)	4.10E-06		
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	American robin (Avian herbivore)	4.10E-06		
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	American robin (Avian insectivore)	4.10E-06		
Dioxin/ Furan	Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	American robin (Avian omnivore)	4.10E-06		
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Deer mouse (Mammalian omnivore)	23	230	SOIL_DM(ip)_19406-51-0
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Earthworm (Soil-dwelling invertebrate)	18	180	SOIL_EW_19406-51-0
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Generic plant (Terrestrial autotroph - producer)	33	330	SOIL_GP_19406-51-0
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Gray fox (Mammalian top carnivore)	6700	67000	SOIL_RF(f)_19406-51-0
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Montane shrew (Mammalian insectivore)	12	120	SOIL_MS(i)_19406-51-0
High Explosive	3,5-Dinitroaniline Use amino-2,6-dinitrotoluene[4-	618-87-1	Mountain cottontail (Mammalian herbivore)	320	3200	SOIL_DC(p)_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Deer mouse (Mammalian omnivore)	23	230	SOIL_DM(ip)_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Earthworm (Soil-dwelling invertebrate)	18	180	SOIL_EW_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Generic plant (Terrestrial autotroph - producer)	33	330	SOIL_GP_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Gray fox (Mammalian top carnivore)	6700	67000	SOIL_RF(f)_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Montane shrew (Mammalian insectivore)	12	120	SOIL_MS(i)_19406-51-0
High Explosive	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Mountain cottontail (Mammalian herbivore)	320	3200	SOIL_DC(p)_19406-51-0
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Deer mouse (Mammalian omnivore)	23	230	SOIL_DM(ip)_35572-78-2
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Earthworm (Soil-dwelling invertebrate)	43	430	SOIL_EW_35572-78-2
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Generic plant (Terrestrial autotroph - producer)	14	140	SOIL_GP_35572-78-2
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Gray fox (Mammalian top carnivore)	9700	97000	SOIL_RF(f)_35572-78-2
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Montane shrew (Mammalian insectivore)	16	160	SOIL_MS(i)_35572-78-2
High Explosive	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Mountain cottontail (Mammalian herbivore)	110	1100	SOIL_DC(p)_35572-78-2
High Explosive	Dinitrobenzene[1,3-]	99-65-0	American kestrel (Avian top carnivore)	120	1200	SOIL_AK(f)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	American kestrel (insectivore / carnivore)	9.3	93	SOIL_AK(fi)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian herbivore)	0.079	0.79	SOIL_AR(p)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian insectivore)	1.6	16	SOIL_AR(i)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian omnivore)	0.15	1.5	SOIL_AR(ip)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	Deer mouse (Mammalian omnivore)	0.072	0.16	SOIL_DM(ip)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	Gray fox (Mammalian top carnivore)	82	190	SOIL_RF(f)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	Montane shrew (Mammalian insectivore)	0.95	2.2	SOIL_MS(i)_99-65-0
High Explosive	Dinitrobenzene[1,3-]	99-65-0	Mountain cottontail (Mammalian herbivore)	0.091	0.21	SOIL_DC(p)_99-65-0
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Deer mouse (Mammalian omnivore)	20	200	SOIL_DM(ip)_121-14-2
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Earthworm (Soil-dwelling invertebrate)	18	180	SOIL_EW_121-14-2
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Generic plant (Terrestrial autotroph - producer)	6	60	SOIL_GP_121-14-2
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Gray fox (Mammalian top carnivore)	2000	20000	SOIL_RF(f)_121-14-2
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Montane shrew (Mammalian insectivore)	14	140	SOIL_MS(i)_121-14-2
High Explosive	Dinitrotoluene[2,4-]	121-14-2	Mountain cottontail (Mammalian herbivore)	74	740	SOIL_DC(p)_121-14-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	American kestrel (Avian top carnivore)	18000	180000	SOIL_AK(f)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	American kestrel (insectivore / carnivore)	680	6800	SOIL_AK(fi)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian herbivore)	52	520	SOIL_AR(p)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian insectivore)	130	1300	SOIL_AR(i)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian omnivore)	74	740	SOIL_AR(ip)_606-20-2

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
High Explosive	Dinitrotoluene[2,6-]	606-20-2	Deer mouse (Mammalian omnivore)	4	40	SOIL_DM(ip)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	Earthworm (Soil-dwelling invertebrate)	30	44	SOIL_EW_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	Gray fox (Mammalian top carnivore)	1300	13000	SOIL_RF(f)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	Montane shrew (Mammalian insectivore)	7.6	76	SOIL_MS(i)_606-20-2
High Explosive	Dinitrotoluene[2,6-]	606-20-2	Mountain cottontail (Mammalian herbivore)	6.7	67	SOIL_DC(p)_606-20-2
High Explosive	HMX	2691-41-0	Deer mouse (Mammalian omnivore)	290	790	SOIL_DM(ip)_2691-41-0
High Explosive	HMX	2691-41-0	Earthworm (Soil-dwelling invertebrate)	16	160	SOIL_EW_2691-41-0
High Explosive	HMX	2691-41-0	Generic plant (Terrestrial autotroph - producer)	2700	3500	SOIL_GP_2691-41-0
High Explosive	HMX	2691-41-0	Gray fox (Mammalian top carnivore)	59000	150000	SOIL_RF(f)_2691-41-0
High Explosive	HMX	2691-41-0	Montane shrew (Mammalian insectivore)	1100	2900	SOIL_MS(i)_2691-41-0
High Explosive	HMX	2691-41-0	Mountain cottontail (Mammalian herbivore)	410	1100	SOIL_DC(p)_2691-41-0
High Explosive	Nitroglycerine	55-63-0	Deer mouse (Mammalian omnivore)	70	740	SOIL_DM(ip)_55-63-0
High Explosive	Nitroglycerine	55-63-0	Earthworm (Soil-dwelling invertebrate)	13	130	SOIL_EW_55-63-0
High Explosive	Nitroglycerine	55-63-0	Generic plant (Terrestrial autotroph - producer)	21	210	SOIL_GP_55-63-0
High Explosive	Nitroglycerine	55-63-0	Gray fox (Mammalian top carnivore)	69000	730000	SOIL_RF(f)_55-63-0
High Explosive	Nitroglycerine	55-63-0	Montane shrew (Mammalian insectivore)	1200	13000	SOIL_MS(i)_55-63-0
High Explosive	Nitroglycerine	55-63-0	Mountain cottontail (Mammalian herbivore)	88	930	SOIL_DC(p)_55-63-0
High Explosive	Nitrotoluene[2-]	88-72-2	Deer mouse (Mammalian omnivore)	9.8	98	SOIL_DM(ip)_88-72-2
High Explosive	Nitrotoluene[2-]	88-72-2	Gray fox (Mammalian top carnivore)	6000	60000	SOIL_RF(f)_88-72-2
High Explosive	Nitrotoluene[2-]	88-72-2	Montane shrew (Mammalian insectivore)	22	220	SOIL_MS(i)_88-72-2
High Explosive	Nitrotoluene[2-]	88-72-2	Mountain cottontail (Mammalian herbivore)	15	150	SOIL_DC(p)_88-72-2
High Explosive	Nitrotoluene[3-]	99-08-1	Deer mouse (Mammalian omnivore)	12	120	SOIL_DM(ip)_99-08-1
High Explosive	Nitrotoluene[3-]	99-08-1	Gray fox (Mammalian top carnivore)	7000	70000	SOIL_RF(f)_99-08-1
High Explosive	Nitrotoluene[3-]	99-08-1	Montane shrew (Mammalian insectivore)	19	190	SOIL_MS(i)_99-08-1
High Explosive	Nitrotoluene[3-]	99-08-1	Mountain cottontail (Mammalian herbivore)	21	210	SOIL_DC(p)_99-08-1
High Explosive	Nitrotoluene[4-]	99-99-0	Deer mouse (Mammalian omnivore)	21	210	SOIL_DM(ip)_99-99-0
High Explosive	Nitrotoluene[4-]	99-99-0	Gray fox (Mammalian top carnivore)	13000	130000	SOIL_RF(f)_99-99-0
High Explosive	Nitrotoluene[4-]	99-99-0	Montane shrew (Mammalian insectivore)	41	410	SOIL_MS(i)_99-99-0
High Explosive	Nitrotoluene[4-]	99-99-0	Mountain cottontail (Mammalian herbivore)	36	360	SOIL_DC(p)_99-99-0
High Explosive	PETN	78-11-5	Deer mouse (Mammalian omnivore)	100	1000	SOIL_DM(ip)_78-11-5
High Explosive	PETN	78-11-5	Gray fox (Mammalian top carnivore)	47000	470000	SOIL_RF(f)_78-11-5
High Explosive	PETN	78-11-5	Montane shrew (Mammalian insectivore)	1000	10000	SOIL_MS(i)_78-11-5
High Explosive	PETN	78-11-5	Mountain cottontail (Mammalian herbivore)	120	1200	SOIL_DC(p)_78-11-5
High Explosive	RDX	121-82-4	American kestrel (Avian top carnivore)	780	1400	SOIL_AK(f)_121-82-4
High Explosive	RDX	121-82-4	American kestrel (insectivore / carnivore)	11	22	SOIL_AK(fi)_121-82-4
High Explosive	RDX	121-82-4	American robin (Avian herbivore)	2.3	4.3	SOIL_AR(p)_121-82-4
High Explosive	RDX	121-82-4	American robin (Avian insectivore)	2.4	4.5	SOIL_AR(i)_121-82-4
High Explosive	RDX	121-82-4	American robin (Avian omnivore)	2.3	4.4	SOIL_AR(ip)_121-82-4
High Explosive	RDX	121-82-4	Deer mouse (Mammalian omnivore)	16	51	SOIL_DM(ip)_121-82-4
High Explosive	RDX	121-82-4	Earthworm (Soil-dwelling invertebrate)	8.4	15	SOIL_EW_121-82-4
High Explosive	RDX	121-82-4	Gray fox (Mammalian top carnivore)	7000	22000	SOIL_RF(f)_121-82-4
High Explosive	RDX	121-82-4	Montane shrew (Mammalian insectivore)	16	53	SOIL_MS(i)_121-82-4
High Explosive	RDX	121-82-4	Mountain cottontail (Mammalian herbivore)	38	120	SOIL_DC(p)_121-82-4
High Explosive	Tetryl	479-45-8	Deer mouse (Mammalian omnivore)	1.5	7.2	SOIL_DM(ip)_479-45-8
High Explosive	Tetryl	479-45-8	Gray fox (Mammalian top carnivore)	960	4600	SOIL_RF(f)_479-45-8
High Explosive	Tetryl	479-45-8	Montane shrew (Mammalian insectivore)	60	280	SOIL_MS(i)_479-45-8
High Explosive	Tetryl	479-45-8	Mountain cottontail (Mammalian herbivore)	1.8	8.9	SOIL_DC(p)_479-45-8
High Explosive	TATB Use 1,3,5-TNB	3058-38-6	Deer mouse (Mammalian omnivore)	110	1100	SOIL_DM(ip)_99-35-4
High Explosive	TATB Use 1,3,5-TNB	3058-38-6	Earthworm (Soil-dwelling invertebrate)	10	28	SOIL_EW_99-35-4
High Explosive	TATB Use 1,3,5-TNB	3058-38-6	Gray fox (Mammalian top carnivore)	10000	100000	SOIL_RF(f)_99-35-4
High Explosive	TATB Use 1,3,5-TNB	3058-38-6	Montane shrew (Mammalian insectivore)	720	7200	SOIL_MS(i)_99-35-4
High Explosive	TATB Use 1,3,5-TNB	3058-38-6	Mountain cottontail (Mammalian herbivore)	150	1500	SOIL_DC(p)_99-35-4

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
High Explosive	Trinitrobenzene[1,3,5-]	99-35-4	Deer mouse (Mammalian omnivore)	110	1100	SOIL_DM(ip)_99-35-4
High Explosive	Trinitrobenzene[1,3,5-]	99-35-4	Earthworm (Soil-dwelling invertebrate)	10	28	SOIL_EW_99-35-4
High Explosive	Trinitrobenzene[1,3,5-]	99-35-4	Gray fox (Mammalian top carnivore)	10000	100000	SOIL_RF(f)_99-35-4
High Explosive	Trinitrobenzene[1,3,5-]	99-35-4	Montane shrew (Mammalian insectivore)	720	7200	SOIL_MS(i)_99-35-4
High Explosive	Trinitrobenzene[1,3,5-]	99-35-4	Mountain cottontail (Mammalian herbivore)	150	1500	SOIL_DC(p)_99-35-4
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	American kestrel (Avian top carnivore)	3100	5700	SOIL_AK(f)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	American kestrel (insectivore / carnivore)	1300	2400	SOIL_AK(fi)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian herbivore)	7.5	13	SOIL_AR(p)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian insectivore)	120	220	SOIL_AR(i)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian omnivore)	14	26	SOIL_AR(ip)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Deer mouse (Mammalian omnivore)	95	440	SOIL_DM(ip)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Earthworm (Soil-dwelling invertebrate)	32	58	SOIL_EW_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Generic plant (Terrestrial autotroph - producer)	62	120	SOIL_GP_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Gray fox (Mammalian top carnivore)	26000	120000	SOIL_RF(f)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Montane shrew (Mammalian insectivore)	1900	9100	SOIL_MS(i)_118-96-7
High Explosive	Trinitrotoluene[2,4,6-]	118-96-7	Mountain cottontail (Mammalian herbivore)	110	540	SOIL_DC(p)_118-96-7
Inorganic	Aluminum	7429-90-5	American kestrel (Avian top carnivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_AK(f)_AL
Inorganic	Aluminum	7429-90-5	American kestrel (insectivore / carnivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_AK(fi)_AL
Inorganic	Aluminum	7429-90-5	American robin (Avian herbivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_AR(p)_AL
Inorganic	Aluminum	7429-90-5	American robin (Avian insectivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_AR(i)_AL
Inorganic	Aluminum	7429-90-5	American robin (Avian omnivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_AR(ip)_AL
Inorganic	Aluminum	7429-90-5	Deer mouse (Mammalian omnivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_DM(ip)_AL
Inorganic	Aluminum	7429-90-5	Earthworm (Soil-dwelling invertebrate)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_EW_AL
Inorganic	Aluminum	7429-90-5	Generic plant (Terrestrial autotroph - producer)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_GP_AL
Inorganic	Aluminum	7429-90-5	Gray fox (Mammalian top carnivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_RF(f)_AL
Inorganic	Aluminum	7429-90-5	Montane shrew (Mammalian insectivore)	pH dependent. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.		SOIL_MS(i)_AL
Inorganic	Aluminum	7429-90-5	Mountain cottontail (Mammalian herbivore)	pH dependent. Aluminum is identified as a COPC only at		SOIL_DC(p)_AL

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
				sites where the soil pH is less than 5.5.		
Inorganic	Antimony	7440-36-0	Deer mouse (Mammalian omnivore)	2.3	23	SOIL_DM(ip)_SB
Inorganic	Antimony	7440-36-0	Earthworm (Soil-dwelling invertebrate)	78	780	SOIL_EW_SB
Inorganic	Antimony	7440-36-0	Generic plant (Terrestrial autotroph - producer)	11	58	SOIL_GP_SB
Inorganic	Antimony	7440-36-0	Gray fox (Mammalian top carnivore)	46	460	SOIL_RF(f)_SB
Inorganic	Antimony	7440-36-0	Montane shrew (Mammalian insectivore)	7.9	79	SOIL_MS(i)_SB
Inorganic	Antimony	7440-36-0	Mountain cottontail (Mammalian herbivore)	2.7	27	SOIL_DC(p)_SB
Inorganic	Arsenic	7440-38-2	American kestrel (Avian top carnivore)	740	7400	SOIL_AK(f)_AS
Inorganic	Arsenic	7440-38-2	American kestrel (insectivore / carnivore)	100	1000	SOIL_AK(fi)_AS
Inorganic	Arsenic	7440-38-2	American robin (Avian herbivore)	34	340	SOIL_AR(p)_AS
Inorganic	Arsenic	7440-38-2	American robin (Avian insectivore)	15	150	SOIL_AR(i)_AS
Inorganic	Arsenic	7440-38-2	American robin (Avian omnivore)	21	210	SOIL_AR(ip)_AS
Inorganic	Arsenic	7440-38-2	Deer mouse (Mammalian omnivore)	32	51	SOIL_DM(ip)_AS
Inorganic	Arsenic	7440-38-2	Earthworm (Soil-dwelling invertebrate)	6.8	68	SOIL_EW_AS
Inorganic	Arsenic	7440-38-2	Generic plant (Terrestrial autotroph - producer)	18	91	SOIL_GP_AS
Inorganic	Arsenic	7440-38-2	Gray fox (Mammalian top carnivore)	820	1300	SOIL_RF(f)_AS
Inorganic	Arsenic	7440-38-2	Montane shrew (Mammalian insectivore)	19	31	SOIL_MS(i)_AS
Inorganic	Arsenic	7440-38-2	Mountain cottontail (Mammalian herbivore)	110	180	SOIL_DC(p)_AS
Inorganic	Barium	7440-39-3	American kestrel (Avian top carnivore)	24000	44000	SOIL_AK(f)_BA
Inorganic	Barium	7440-39-3	American kestrel (insectivore / carnivore)	7500	13000	SOIL_AK(fi)_BA
Inorganic	Barium	7440-39-3	American robin (Avian herbivore)	720	1200	SOIL_AR(p)_BA
Inorganic	Barium	7440-39-3	American robin (Avian insectivore)	820	1400	SOIL_AR(i)_BA
Inorganic	Barium	7440-39-3	American robin (Avian omnivore)	770	1300	SOIL_AR(ip)_BA
Inorganic	Barium	7440-39-3	Deer mouse (Mammalian omnivore)	1800	8700	SOIL_DM(ip)_BA
Inorganic	Barium	7440-39-3	Earthworm (Soil-dwelling invertebrate)	330	3200	SOIL_EW_BA
Inorganic	Barium	7440-39-3	Generic plant (Terrestrial autotroph - producer)	110	260	SOIL_GP_BA
Inorganic	Barium	7440-39-3	Gray fox (Mammalian top carnivore)	41000	190000	SOIL_RF(f)_BA
Inorganic	Barium	7440-39-3	Montane shrew (Mammalian insectivore)	2100	10000	SOIL_MS(i)_BA
Inorganic	Barium	7440-39-3	Mountain cottontail (Mammalian herbivore)	2900	14000	SOIL_DC(p)_BA
Inorganic	Beryllium	7440-41-7	Deer mouse (Mammalian omnivore)	56	560	SOIL_DM(ip)_BE
Inorganic	Beryllium	7440-41-7	Earthworm (Soil-dwelling invertebrate)	40	400	SOIL_EW_BE
Inorganic	Beryllium	7440-41-7	Generic plant (Terrestrial autotroph - producer)	2.5	25	SOIL_GP_BE
Inorganic	Beryllium	7440-41-7	Gray fox (Mammalian top carnivore)	420	4200	SOIL_RF(f)_BE
Inorganic	Beryllium	7440-41-7	Montane shrew (Mammalian insectivore)	35	350	SOIL_MS(i)_BE
Inorganic	Beryllium	7440-41-7	Mountain cottontail (Mammalian herbivore)	89	890	SOIL_DC(p)_BE
Inorganic	Boron	#N/A	American kestrel (Avian top carnivore)	960	4700	SOIL_AK(f)_B
Inorganic	Boron	#N/A	American kestrel (insectivore / carnivore)	37	180	SOIL_AK(fi)_B
Inorganic	Boron	#N/A	American robin (Avian herbivore)	2	10	SOIL_AR(p)_B
Inorganic	Boron	#N/A	American robin (Avian insectivore)	7.1	35	SOIL_AR(i)_B
Inorganic	Boron	#N/A	American robin (Avian omnivore)	3.1	15	SOIL_AR(ip)_B
Inorganic	Boron	#N/A	Deer mouse (Mammalian omnivore)	55	550	SOIL_DM(ip)_B
Inorganic	Boron	#N/A	Generic plant (Terrestrial autotroph - producer)	36	86	SOIL_GP_B
Inorganic	Boron	#N/A	Gray fox (Mammalian top carnivore)	21000	210000	SOIL_RF(f)_B
Inorganic	Boron	#N/A	Montane shrew (Mammalian insectivore)	130	1300	SOIL_MS(i)_B
Inorganic	Boron	#N/A	Mountain cottontail (Mammalian herbivore)	84	840	SOIL_DC(p)_B
Inorganic	Cadmium	7440-43-9	American kestrel (Avian top carnivore)	430	2300	SOIL_AK(f)_CD
Inorganic	Cadmium	7440-43-9	American kestrel (insectivore / carnivore)	1.3	7.7	SOIL_AK(fi)_CD
Inorganic	Cadmium	7440-43-9	American robin (Avian herbivore)	4.3	23	SOIL_AR(p)_CD
Inorganic	Cadmium	7440-43-9	American robin (Avian insectivore)	0.29	1.6	SOIL_AR(i)_CD
Inorganic	Cadmium	7440-43-9	American robin (Avian omnivore)	0.54	3	SOIL_AR(ip)_CD
Inorganic	Cadmium	7440-43-9	Deer mouse (Mammalian omnivore)	0.5	6.8	SOIL_DM(ip)_CD
Inorganic	Cadmium	7440-43-9	Earthworm (Soil-dwelling invertebrate)	140	760	SOIL_EW_CD
Inorganic	Cadmium	7440-43-9	Generic plant (Terrestrial autotroph - producer)	32	160	SOIL_GP_CD
Inorganic	Cadmium	7440-43-9	Gray fox (Mammalian top carnivore)	550	7400	SOIL_RF(f)_CD
Inorganic	Cadmium	7440-43-9	Montane shrew (Mammalian insectivore)	0.27	3.6	SOIL_MS(i)_CD
Inorganic	Cadmium	7440-43-9	Mountain cottontail (Mammalian herbivore)	10	140	SOIL_DC(p)_CD

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
Inorganic	Chromium (total)	16065-83-1	American kestrel (Avian top carnivore)	860	2700	SOIL_AK(f)_CR
Inorganic	Chromium (total)	16065-83-1	American kestrel (insectivore / carnivore)	170	560	SOIL_AK(fi)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian herbivore)	51	160	SOIL_AR(p)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian insectivore)	23	73	SOIL_AR(i)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian omnivore)	32	100	SOIL_AR(ip)_CR
Inorganic	Chromium (total)	16065-83-1	Deer mouse (Mammalian omnivore)	110	11000	SOIL_DM(ip)_CR
Inorganic	Chromium (total)	16065-83-1	Gray fox (Mammalian top carnivore)	1800	180000	SOIL_RF(f)_CR
Inorganic	Chromium (total)	16065-83-1	Montane shrew (Mammalian insectivore)	63	6300	SOIL_MS(i)_CR
Inorganic	Chromium (total)	16065-83-1	Mountain cottontail (Mammalian herbivore)	410	41000	SOIL_DC(p)_CR
Inorganic	Chromium(+6)	#N/A	American kestrel (Avian top carnivore)	3600	36000	SOIL_AK(f)_CR(+6)
Inorganic	Chromium(+6)	#N/A	American kestrel (insectivore / carnivore)	1400	14000	SOIL_AK(fi)_CR(+6)
Inorganic	Chromium(+6)	#N/A	American robin (Avian herbivore)	210	2100	SOIL_AR(p)_CR(+6)
Inorganic	Chromium(+6)	#N/A	American robin (Avian insectivore)	140	1400	SOIL_AR(i)_CR(+6)
Inorganic	Chromium(+6)	#N/A	American robin (Avian omnivore)	160	1600	SOIL_AR(ip)_CR(+6)
Inorganic	Chromium(+6)	#N/A	Deer mouse (Mammalian omnivore)	850	5500	SOIL_DM(ip)_CR(+6)
Inorganic	Chromium(+6)	#N/A	Earthworm (Soil-dwelling invertebrate)	0.34	3.4	SOIL_EW_CR(+6)
Inorganic	Chromium(+6)	#N/A	Generic plant (Terrestrial autotroph - producer)	0.35	4	SOIL_GP_CR(+6)
Inorganic	Chromium(+6)	#N/A	Gray fox (Mammalian top carnivore)	7200	46000	SOIL_RF(f)_CR(+6)
Inorganic	Chromium(+6)	#N/A	Montane shrew (Mammalian insectivore)	510	3300	SOIL_MS(i)_CR(+6)
Inorganic	Chromium(+6)	#N/A	Mountain cottontail (Mammalian herbivore)	1600	10000	SOIL_DC(p)_CR(+6)
Inorganic	Cobalt	7440-48-4	American kestrel (Avian top carnivore)	2300	5200	SOIL_AK(f)_CO
Inorganic	Cobalt	7440-48-4	American kestrel (insectivore / carnivore)	620	1400	SOIL_AK(fi)_CO
Inorganic	Cobalt	7440-48-4	American robin (Avian herbivore)	130	300	SOIL_AR(p)_CO
Inorganic	Cobalt	7440-48-4	American robin (Avian insectivore)	76	170	SOIL_AR(i)_CO
Inorganic	Cobalt	7440-48-4	American robin (Avian omnivore)	97	210	SOIL_AR(ip)_CO
Inorganic	Cobalt	7440-48-4	Deer mouse (Mammalian omnivore)	400	1000	SOIL_DM(ip)_CO
Inorganic	Cobalt	7440-48-4	Generic plant (Terrestrial autotroph - producer)	13	130	SOIL_GP_CO
Inorganic	Cobalt	7440-48-4	Gray fox (Mammalian top carnivore)	5400	14000	SOIL_RF(f)_CO
Inorganic	Cobalt	7440-48-4	Montane shrew (Mammalian insectivore)	240	640	SOIL_MS(i)_CO
Inorganic	Cobalt	7440-48-4	Mountain cottontail (Mammalian herbivore)	1000	2800	SOIL_DC(p)_CO
Inorganic	Copper	7440-50-8	American kestrel (Avian top carnivore)	1100	3500	SOIL_AK(f)_CU
Inorganic	Copper	7440-50-8	American kestrel (insectivore / carnivore)	80	240	SOIL_AK(fi)_CU
Inorganic	Copper	7440-50-8	American robin (Avian herbivore)	34	100	SOIL_AR(p)_CU
Inorganic	Copper	7440-50-8	American robin (Avian insectivore)	14	43	SOIL_AR(i)_CU
Inorganic	Copper	7440-50-8	American robin (Avian omnivore)	20	60	SOIL_AR(ip)_CU
Inorganic	Copper	7440-50-8	Deer mouse (Mammalian omnivore)	63	100	SOIL_DM(ip)_CU
Inorganic	Copper	7440-50-8	Earthworm (Soil-dwelling invertebrate)	80	530	SOIL_EW_CU
Inorganic	Copper	7440-50-8	Generic plant (Terrestrial autotroph - producer)	70	490	SOIL_GP_CU
Inorganic	Copper	7440-50-8	Gray fox (Mammalian top carnivore)	4000	6700	SOIL_RF(f)_CU
Inorganic	Copper	7440-50-8	Montane shrew (Mammalian insectivore)	42	70	SOIL_MS(i)_CU
Inorganic	Copper	7440-50-8	Mountain cottontail (Mammalian herbivore)	260	430	SOIL_DC(p)_CU
Inorganic	Cyanide (total)	#N/A	American kestrel (Avian top carnivore)	0.59	5.9	SOIL_AK(f)_CN(-1)
Inorganic	Cyanide (total)	#N/A	American kestrel (insectivore / carnivore)	0.36	3.6	SOIL_AK(fi)_CN(-1)
Inorganic	Cyanide (total)	#N/A	American robin (Avian herbivore)	0.1	1	SOIL_AR(p)_CN(-1)
Inorganic	Cyanide (total)	#N/A	American robin (Avian insectivore)	0.098	0.98	SOIL_AR(i)_CN(-1)
Inorganic	Cyanide (total)	#N/A	American robin (Avian omnivore)	0.099	0.99	SOIL_AR(ip)_CN(-1)
Inorganic	Cyanide (total)	#N/A	Deer mouse (Mammalian omnivore)	330	3300	SOIL_DM(ip)_CN(-1)
Inorganic	Cyanide (total)	#N/A	Gray fox (Mammalian top carnivore)	3300	33000	SOIL_RF(f)_CN(-1)
Inorganic	Cyanide (total)	#N/A	Montane shrew (Mammalian insectivore)	330	3300	SOIL_MS(i)_CN(-1)
Inorganic	Cyanide (total)	#N/A	Mountain cottontail (Mammalian herbivore)	790	7900	SOIL_DC(p)_CN(-1)
Inorganic	Fluoride	#N/A	American kestrel (Avian top carnivore)	2200	22000	SOIL_AK(f)_F(-1)
Inorganic	Fluoride	#N/A	American kestrel (insectivore / carnivore)	910	9100	SOIL_AK(fi)_F(-1)
Inorganic	Fluoride	#N/A	American robin (Avian herbivore)	170	1700	SOIL_AR(p)_F(-1)
Inorganic	Fluoride	#N/A	American robin (Avian insectivore)	120	1200	SOIL_AR(i)_F(-1)
Inorganic	Fluoride	#N/A	American robin (Avian omnivore)	140	1400	SOIL_AR(ip)_F(-1)
Inorganic	Fluoride	#N/A	Deer mouse (Mammalian omnivore)	1100	2100	SOIL_DM(ip)_F(-1)
Inorganic	Fluoride	#N/A	Gray fox (Mammalian top carnivore)	13000	24000	SOIL_RF(f)_F(-1)

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
Inorganic	Fluoride	#N/A	Montane shrew (Mammalian insectivore)	870	1600	SOIL_MS(i)_F(-1)
Inorganic	Fluoride	#N/A	Mountain cottontail (Mammalian herbivore)	2600	4800	SOIL_DC(p)_F(-1)
Inorganic	Lead	7439-92-1	American kestrel (Avian top carnivore)	540	1000	SOIL_AK(f)_PB
Inorganic	Lead	7439-92-1	American kestrel (insectivore / carnivore)	83	160	SOIL_AK(fi)_PB
Inorganic	Lead	7439-92-1	American robin (Avian herbivore)	18	36	SOIL_AR(p)_PB
Inorganic	Lead	7439-92-1	American robin (Avian insectivore)	11	23	SOIL_AR(i)_PB
Inorganic	Lead	7439-92-1	American robin (Avian omnivore)	14	28	SOIL_AR(ip)_PB
Inorganic	Lead	7439-92-1	Deer mouse (Mammalian omnivore)	120	230	SOIL_DM(ip)_PB
Inorganic	Lead	7439-92-1	Earthworm (Soil-dwelling invertebrate)	1700	8400	SOIL_EW_PB
Inorganic	Lead	7439-92-1	Generic plant (Terrestrial autotroph - producer)	120	570	SOIL_GP_PB
Inorganic	Lead	7439-92-1	Gray fox (Mammalian top carnivore)	3700	7000	SOIL_RF(f)_PB
Inorganic	Lead	7439-92-1	Montane shrew (Mammalian insectivore)	93	170	SOIL_MS(i)_PB
Inorganic	Lead	7439-92-1	Mountain cottontail (Mammalian herbivore)	310	600	SOIL_DC(p)_PB
Inorganic	Lithium	#N/A	Deer mouse (Mammalian omnivore)	100	480	SOIL_DM(ip)_LI
Inorganic	Lithium	#N/A	Gray fox (Mammalian top carnivore)	870	4100	SOIL_RF(f)_LI
Inorganic	Lithium	#N/A	Montane shrew (Mammalian insectivore)	75	350	SOIL_MS(i)_LI
Inorganic	Lithium	#N/A	Mountain cottontail (Mammalian herbivore)	150	750	SOIL_DC(p)_LI
Inorganic	Manganese	7439-96-5	American kestrel (Avian top carnivore)	60000	120000	SOIL_AK(f)_MN
Inorganic	Manganese	7439-96-5	American kestrel (insectivore / carnivore)	24000	50000	SOIL_AK(fi)_MN
Inorganic	Manganese	7439-96-5	American robin (Avian herbivore)	1300	2700	SOIL_AR(p)_MN
Inorganic	Manganese	7439-96-5	American robin (Avian insectivore)	2200	4700	SOIL_AR(i)_MN
Inorganic	Manganese	7439-96-5	American robin (Avian omnivore)	1600	3500	SOIL_AR(ip)_MN
Inorganic	Manganese	7439-96-5	Deer mouse (Mammalian omnivore)	1400	5400	SOIL_DM(ip)_MN
Inorganic	Manganese	7439-96-5	Earthworm (Soil-dwelling invertebrate)	450	4500	SOIL_EW_MN
Inorganic	Manganese	7439-96-5	Generic plant (Terrestrial autotroph - producer)	220	1100	SOIL_GP_MN
Inorganic	Manganese	7439-96-5	Gray fox (Mammalian top carnivore)	40000	150000	SOIL_RF(f)_MN
Inorganic	Manganese	7439-96-5	Montane shrew (Mammalian insectivore)	2800	10000	SOIL_MS(i)_MN
Inorganic	Manganese	7439-96-5	Mountain cottontail (Mammalian herbivore)	2000	7500	SOIL_DC(p)_MN
Inorganic	Mercury (inorganic)	7487-94-7	American kestrel (Avian top carnivore)	0.32	3.2	SOIL_AK(f)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American kestrel (insectivore / carnivore)	0.058	0.58	SOIL_AK(fi)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian herbivore)	0.067	0.67	SOIL_AR(p)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian insectivore)	0.013	0.13	SOIL_AR(i)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian omnivore)	0.022	0.22	SOIL_AR(ip)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Deer mouse (Mammalian omnivore)	3	30	SOIL_DM(ip)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Earthworm (Soil-dwelling invertebrate)	0.05	0.5	SOIL_EW_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Generic plant (Terrestrial autotroph - producer)	34	64	SOIL_GP_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Gray fox (Mammalian top carnivore)	76	760	SOIL_RF(f)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Montane shrew (Mammalian insectivore)	1.7	17	SOIL_MS(i)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Mountain cottontail (Mammalian herbivore)	23	230	SOIL_DC(p)_HGI
Inorganic	Mercury (methyl)	#N/A	American kestrel (Avian top carnivore)	0.009	0.09	SOIL_AK(f)_HGM
Inorganic	Mercury (methyl)	#N/A	American kestrel (insectivore / carnivore)	0.0015	0.015	SOIL_AK(fi)_HGM
Inorganic	Mercury (methyl)	#N/A	American robin (Avian herbivore)	0.066	0.66	SOIL_AR(p)_HGM
Inorganic	Mercury (methyl)	#N/A	American robin (Avian insectivore)	0.00035	0.0035	SOIL_AR(i)_HGM
Inorganic	Mercury (methyl)	#N/A	American robin (Avian omnivore)	0.00071	0.0071	SOIL_AR(ip)_HGM
Inorganic	Mercury (methyl)	#N/A	Deer mouse (Mammalian omnivore)	0.0062	0.031	SOIL_DM(ip)_HGM
Inorganic	Mercury (methyl)	#N/A	Earthworm (Soil-dwelling invertebrate)	2.5	12	SOIL_EW_HGM
Inorganic	Mercury (methyl)	#N/A	Gray fox (Mammalian top carnivore)	0.14	0.74	SOIL_RF(f)_HGM
Inorganic	Mercury (methyl)	#N/A	Montane shrew (Mammalian insectivore)	0.0031	0.015	SOIL_MS(i)_HGM
Inorganic	Mercury (methyl)	#N/A	Mountain cottontail (Mammalian herbivore)	1.9	9.8	SOIL_DC(p)_HGM
Inorganic	Molybdenum	#N/A	American kestrel (Avian top carnivore)	1100	11000	SOIL_AK(f)_MO
Inorganic	Molybdenum	#N/A	American kestrel (insectivore / carnivore)	90	900	SOIL_AK(fi)_MO
Inorganic	Molybdenum	#N/A	American robin (Avian herbivore)	18	180	SOIL_AR(p)_MO
Inorganic	Molybdenum	#N/A	American robin (Avian insectivore)	15	150	SOIL_AR(i)_MO
Inorganic	Molybdenum	#N/A	American robin (Avian omnivore)	16	160	SOIL_AR(ip)_MO
Inorganic	Nickel	7440-02-0	American kestrel (Avian top carnivore)	2000	8100	SOIL_AK(f)_NI
Inorganic	Nickel	7440-02-0	American kestrel (insectivore / carnivore)	110	440	SOIL_AK(fi)_NI
Inorganic	Nickel	7440-02-0	American robin (Avian herbivore)	120	500	SOIL_AR(p)_NI

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
Inorganic	Nickel	7440-02-0	American robin (Avian insectivore)	20	81	SOIL_AR(i)_NI
Inorganic	Nickel	7440-02-0	American robin (Avian omnivore)	35	130	SOIL_AR(ip)_NI
Inorganic	Nickel	7440-02-0	Deer mouse (Mammalian omnivore)	20	40	SOIL_DM(ip)_NI
Inorganic	Nickel	7440-02-0	Earthworm (Soil-dwelling invertebrate)	280	1300	SOIL_EW_NI
Inorganic	Nickel	7440-02-0	Generic plant (Terrestrial autotroph - producer)	38	270	SOIL_GP_NI
Inorganic	Nickel	7440-02-0	Gray fox (Mammalian top carnivore)	1200	2500	SOIL_RF(f)_NI
Inorganic	Nickel	7440-02-0	Montane shrew (Mammalian insectivore)	10	21	SOIL_MS(i)_NI
Inorganic	Nickel	7440-02-0	Mountain cottontail (Mammalian herbivore)	270	540	SOIL_DC(p)_NI
Inorganic	Perchlorate	14797-73-0	American kestrel (Avian top carnivore)	2	4	SOIL_AK(f)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American kestrel (insectivore / carnivore)	3.9	8	SOIL_AK(fi)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian herbivore)	0.12	0.24	SOIL_AR(p)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian insectivore)	31	64	SOIL_AR(i)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian omnivore)	0.24	0.49	SOIL_AR(ip)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Deer mouse (Mammalian omnivore)	0.21	1	SOIL_DM(ip)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Earthworm (Soil-dwelling invertebrate)	3.5	35	SOIL_EW_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Generic plant (Terrestrial autotroph - producer)	40	80	SOIL_GP_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Gray fox (Mammalian top carnivore)	3.3	16	SOIL_RF(f)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Montane shrew (Mammalian insectivore)	31	150	SOIL_MS(i)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Mountain cottontail (Mammalian herbivore)	0.26	1.3	SOIL_DC(p)_ClO4(-1)
Inorganic	Selenium	7782-49-2	American kestrel (Avian top carnivore)	74	140	SOIL_AK(f)_SE
Inorganic	Selenium	7782-49-2	American kestrel (insectivore / carnivore)	3.7	7.5	SOIL_AK(fi)_SE
Inorganic	Selenium	7782-49-2	American robin (Avian herbivore)	0.98	1.9	SOIL_AR(p)_SE
Inorganic	Selenium	7782-49-2	American robin (Avian insectivore)	0.71	1.4	SOIL_AR(i)_SE
Inorganic	Selenium	7782-49-2	American robin (Avian omnivore)	0.83	1.6	SOIL_AR(ip)_SE
Inorganic	Selenium	7782-49-2	Deer mouse (Mammalian omnivore)	0.82	1.2	SOIL_DM(ip)_SE
Inorganic	Selenium	7782-49-2	Earthworm (Soil-dwelling invertebrate)	4.1	41	SOIL_EW_SE
Inorganic	Selenium	7782-49-2	Generic plant (Terrestrial autotroph - producer)	0.52	3	SOIL_GP_SE
Inorganic	Selenium	7782-49-2	Gray fox (Mammalian top carnivore)	92	130	SOIL_RF(f)_SE
Inorganic	Selenium	7782-49-2	Montane shrew (Mammalian insectivore)	0.7	1	SOIL_MS(i)_SE
Inorganic	Selenium	7782-49-2	Mountain cottontail (Mammalian herbivore)	2.2	3.4	SOIL_DC(p)_SE
Inorganic	Silver	7440-22-4	American kestrel (Avian top carnivore)	600	6000	SOIL_AK(f)_AG
Inorganic	Silver	7440-22-4	American kestrel (insectivore / carnivore)	13	130	SOIL_AK(fi)_AG
Inorganic	Silver	7440-22-4	American robin (Avian herbivore)	10	100	SOIL_AR(p)_AG
Inorganic	Silver	7440-22-4	American robin (Avian insectivore)	2.6	26	SOIL_AR(i)_AG
Inorganic	Silver	7440-22-4	American robin (Avian omnivore)	4.1	41	SOIL_AR(ip)_AG
Inorganic	Silver	7440-22-4	Deer mouse (Mammalian omnivore)	24	240	SOIL_DM(ip)_AG
Inorganic	Silver	7440-22-4	Generic plant (Terrestrial autotroph - producer)	560	2800	SOIL_GP_AG
Inorganic	Silver	7440-22-4	Gray fox (Mammalian top carnivore)	4400	44000	SOIL_RF(f)_AG
Inorganic	Silver	7440-22-4	Montane shrew (Mammalian insectivore)	14	140	SOIL_MS(i)_AG
Inorganic	Silver	7440-22-4	Mountain cottontail (Mammalian herbivore)	150	1500	SOIL_DC(p)_AG
Inorganic	Strontium (stable)	#N/A	Deer mouse (Mammalian omnivore)	95	950	SOIL_DM(ip)_SR
Inorganic	Strontium (stable)	#N/A	Gray fox (Mammalian top carnivore)	19000	190000	SOIL_RF(f)_SR
Inorganic	Strontium (stable)	#N/A	Montane shrew (Mammalian insectivore)	1000	10000	SOIL_MS(i)_SR
Inorganic	Strontium (stable)	#N/A	Mountain cottontail (Mammalian herbivore)	110	1100	SOIL_DC(p)_SR
Inorganic	Thallium	7440-28-0	American kestrel (Avian top carnivore)	100	1000	SOIL_AK(f)_TL
Inorganic	Thallium	7440-28-0	American kestrel (insectivore / carnivore)	48	480	SOIL_AK(fi)_TL
Inorganic	Thallium	7440-28-0	American robin (Avian herbivore)	6.9	69	SOIL_AR(p)_TL
Inorganic	Thallium	7440-28-0	American robin (Avian insectivore)	4.5	45	SOIL_AR(i)_TL
Inorganic	Thallium	7440-28-0	American robin (Avian omnivore)	5.5	55	SOIL_AR(ip)_TL
Inorganic	Thallium	7440-28-0	Deer mouse (Mammalian omnivore)	0.72	7.2	SOIL_DM(ip)_TL
Inorganic	Thallium	7440-28-0	Generic plant (Terrestrial autotroph - producer)	0.05	0.5	SOIL_GP_TL
Inorganic	Thallium	7440-28-0	Gray fox (Mammalian top carnivore)	5	50	SOIL_RF(f)_TL
Inorganic	Thallium	7440-28-0	Montane shrew (Mammalian insectivore)	0.42	4.2	SOIL_MS(i)_TL
Inorganic	Thallium	7440-28-0	Mountain cottontail (Mammalian herbivore)	1.2	12	SOIL_DC(p)_TL
Inorganic	Titanium	#N/A	Deer mouse (Mammalian omnivore)	150	1500	SOIL_DM(ip)_TI
Inorganic	Titanium	#N/A	Gray fox (Mammalian top carnivore)	8600	86000	SOIL_RF(f)_TI
Inorganic	Titanium	#N/A	Montane shrew (Mammalian insectivore)	77	770	SOIL_MS(i)_TI

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
Inorganic	Titanium	#N/A	Mountain cottontail (Mammalian herbivore)	2800	28000	SOIL_DC(p)_TI
Inorganic	Uranium	#N/A	American kestrel (Avian top carnivore)	26000	260000	SOIL_AK(f)_U
Inorganic	Uranium	#N/A	American kestrel (insectivore / carnivore)	14000	140000	SOIL_AK(fi)_U
Inorganic	Uranium	#N/A	American robin (Avian herbivore)	1500	15000	SOIL_AR(p)_U
Inorganic	Uranium	#N/A	American robin (Avian insectivore)	1100	11000	SOIL_AR(i)_U
Inorganic	Uranium	#N/A	American robin (Avian omnivore)	1200	12000	SOIL_AR(ip)_U
Inorganic	Uranium	#N/A	Deer mouse (Mammalian omnivore)	740	1800	SOIL_DM(ip)_U
Inorganic	Uranium	#N/A	Generic plant (Terrestrial autotroph - producer)	25	250	SOIL_GP_U
Inorganic	Uranium	#N/A	Gray fox (Mammalian top carnivore)	4800	12000	SOIL_RF(f)_U
Inorganic	Uranium	#N/A	Montane shrew (Mammalian insectivore)	480	1200	SOIL_MS(i)_U
Inorganic	Uranium	#N/A	Mountain cottontail (Mammalian herbivore)	1000	2600	SOIL_DC(p)_U
Inorganic	Vanadium	7440-62-2	American kestrel (Avian top carnivore)	110	230	SOIL_AK(f)_V
Inorganic	Vanadium	7440-62-2	American kestrel (insectivore / carnivore)	56	110	SOIL_AK(fi)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian herbivore)	6.8	13	SOIL_AR(p)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian insectivore)	4.7	9.5	SOIL_AR(i)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian omnivore)	5.5	11	SOIL_AR(ip)_V
Inorganic	Vanadium	7440-62-2	Deer mouse (Mammalian omnivore)	470	1000	SOIL_DM(ip)_V
Inorganic	Vanadium	7440-62-2	Generic plant (Terrestrial autotroph - producer)	60	80	SOIL_GP_V
Inorganic	Vanadium	7440-62-2	Gray fox (Mammalian top carnivore)	3200	6900	SOIL_RF(f)_V
Inorganic	Vanadium	7440-62-2	Montane shrew (Mammalian insectivore)	290	610	SOIL_MS(i)_V
Inorganic	Vanadium	7440-62-2	Mountain cottontail (Mammalian herbivore)	740	1500	SOIL_DC(p)_V
Inorganic	Zinc	7440-66-6	American kestrel (Avian top carnivore)	2600	7000	SOIL_AK(f)_ZN
Inorganic	Zinc	7440-66-6	American kestrel (insectivore / carnivore)	220	590	SOIL_AK(fi)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian herbivore)	330	120	SOIL_AR(p)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian insectivore)	47	120	SOIL_AR(i)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian omnivore)	83	220	SOIL_AR(ip)_ZN
Inorganic	Zinc	7440-66-6	Deer mouse (Mammalian omnivore)	170	1700	SOIL_DM(ip)_ZN
Inorganic	Zinc	7440-66-6	Earthworm (Soil-dwelling invertebrate)	120	930	SOIL_EW_ZN
Inorganic	Zinc	7440-66-6	Generic plant (Terrestrial autotroph - producer)	160	810	SOIL_GP_ZN
Inorganic	Zinc	7440-66-6	Gray fox (Mammalian top carnivore)	9600	94000	SOIL_RF(f)_ZN
Inorganic	Zinc	7440-66-6	Montane shrew (Mammalian insectivore)	99	980	SOIL_MS(i)_ZN
Inorganic	Zinc	7440-66-6	Mountain cottontail (Mammalian herbivore)	1800	18000	SOIL_DC(p)_ZN
Organic	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	Earthworm (Soil-dwelling invertebrate)	1.8	81.5	SOIL_EW_1763-23-1
Organic	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	Generic plant (Terrestrial autotroph - producer)	62.2	80.8	SOIL_GP_1763-23-1
Organic	Perfluorooctanoic acid (PFOA)	335-67-1	Earthworm (Soil-dwelling invertebrate)	12.2	101.1	SOIL_EW_335-67-1
Organic	Perfluorooctanoic acid (PFOA)	335-67-1	Generic plant (Terrestrial autotroph - producer)	41.1	62.1	SOIL_GP_335-67-1
Organic	Total Petroleum Hydrocarbon (Fraction 2, Fraction 3)	TPH F2F3	Earthworm (Soil-dwelling invertebrate)	198	1977	SOIL_EW_TPH F2F3
Organic	Total Petroleum Hydrocarbon (Fraction 2, Fraction 3)	TPH F2F3	Generic plant (Terrestrial autotroph - producer)	81.2	419	SOIL_GP_TPH F2F3
Organic	Total Petroleum Hydrocarbon DRO	TPH-DRO	Earthworm (Soil-dwelling invertebrate)	198	1977	SOIL_EW_TPH F2F3
Organic	Total Petroleum Hydrocarbon DRO	TPH-DRO	Generic plant (Terrestrial autotroph - producer)	81.2	419	SOIL_GP_TPH F2F3
PAH	Acenaphthene	83-32-9	Deer mouse (Mammalian omnivore)	160	1600	SOIL_DM(ip)_83-32-9
PAH	Acenaphthene	83-32-9	Generic plant (Terrestrial autotroph - producer)	0.25	2	SOIL_GP_83-32-9
PAH	Acenaphthene	83-32-9	Gray fox (Mammalian top carnivore)	29000	290000	SOIL_RF(f)_83-32-9
PAH	Acenaphthene	83-32-9	Montane shrew (Mammalian insectivore)	130	1300	SOIL_MS(i)_83-32-9
PAH	Acenaphthene	83-32-9	Mountain cottontail (Mammalian herbivore)	530	5300	SOIL_DC(p)_83-32-9
PAH	Acenaphthylene	208-96-8	Deer mouse (Mammalian omnivore)	160	1600	SOIL_DM(ip)_208-96-8
PAH	Acenaphthylene	208-96-8	Gray fox (Mammalian top carnivore)	28000	280000	SOIL_RF(f)_208-96-8
PAH	Acenaphthylene	208-96-8	Montane shrew (Mammalian insectivore)	120	1200	SOIL_MS(i)_208-96-8
PAH	Acenaphthylene	208-96-8	Mountain cottontail (Mammalian herbivore)	540	5400	SOIL_DC(p)_208-96-8
PAH	Anthracene	120-12-7	Deer mouse (Mammalian omnivore)	300	3000	SOIL_DM(ip)_120-12-7
PAH	Anthracene	120-12-7	Generic plant (Terrestrial autotroph - producer)	6.8	9	SOIL_GP_120-12-7
PAH	Anthracene	120-12-7	Gray fox (Mammalian top carnivore)	38000	380000	SOIL_RF(f)_120-12-7

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
PAH	Anthracene	120-12-7	Montane shrew (Mammalian insectivore)	210	2100	SOIL_MS(i)_120-12-7
PAH	Anthracene	120-12-7	Mountain cottontail (Mammalian herbivore)	1200	12000	SOIL_DC(p)_120-12-7
PAH	Benzo(a)anthracene	56-55-3	American kestrel (Avian top carnivore)	28	280	SOIL_AK(f)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American kestrel (insectivore / carnivore)	6.4	64	SOIL_AK(fi)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian herbivore)	0.73	7.3	SOIL_AR(p)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian insectivore)	0.88	8.8	SOIL_AR(i)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian omnivore)	0.8	8	SOIL_AR(ip)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Deer mouse (Mammalian omnivore)	3.4	34	SOIL_DM(ip)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Generic plant (Terrestrial autotroph - producer)	18	180	SOIL_GP_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Gray fox (Mammalian top carnivore)	110	1100	SOIL_RF(f)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Montane shrew (Mammalian insectivore)	4	40	SOIL_MS(i)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Mountain cottontail (Mammalian herbivore)	6.1	61	SOIL_DC(p)_56-55-3
PAH	Benzo(a)pyrene	50-32-8	Deer mouse (Mammalian omnivore)	84	260	SOIL_DM(ip)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Gray fox (Mammalian top carnivore)	3400	11000	SOIL_RF(f)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Montane shrew (Mammalian insectivore)	62	190	SOIL_MS(i)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Mountain cottontail (Mammalian herbivore)	260	830	SOIL_DC(p)_50-32-8
PAH	Benzo(b)fluoranthene	205-99-2	Deer mouse (Mammalian omnivore)	51	510	SOIL_DM(ip)_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Generic plant (Terrestrial autotroph - producer)	18	180	SOIL_GP_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Gray fox (Mammalian top carnivore)	2400	24000	SOIL_RF(f)_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Montane shrew (Mammalian insectivore)	44	440	SOIL_MS(i)_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Mountain cottontail (Mammalian herbivore)	130	1300	SOIL_DC(p)_205-99-2
PAH	Benzo(g,h,i)perylene	191-24-2	Deer mouse (Mammalian omnivore)	46	460	SOIL_DM(ip)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Gray fox (Mammalian top carnivore)	3600	36000	SOIL_RF(f)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Montane shrew (Mammalian insectivore)	25	250	SOIL_MS(i)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Mountain cottontail (Mammalian herbivore)	470	4700	SOIL_DC(p)_191-24-2
PAH	Benzo(k)fluoranthene	207-08-9	Deer mouse (Mammalian omnivore)	99	990	SOIL_DM(ip)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Gray fox (Mammalian top carnivore)	4300	43000	SOIL_RF(f)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Montane shrew (Mammalian insectivore)	71	710	SOIL_MS(i)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Mountain cottontail (Mammalian herbivore)	330	3300	SOIL_DC(p)_207-08-9
PAH	Chrysene	218-01-9	Deer mouse (Mammalian omnivore)	3.1	31	SOIL_DM(ip)_218-01-9
PAH	Chrysene	218-01-9	Gray fox (Mammalian top carnivore)	110	1100	SOIL_RF(f)_218-01-9
PAH	Chrysene	218-01-9	Montane shrew (Mammalian insectivore)	3.1	31	SOIL_MS(i)_218-01-9
PAH	Chrysene	218-01-9	Mountain cottontail (Mammalian herbivore)	6.3	63	SOIL_DC(p)_218-01-9
PAH	Dibenzo(a,h)anthracene	53-70-3	Deer mouse (Mammalian omnivore)	22	220	SOIL_DM(ip)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Gray fox (Mammalian top carnivore)	850	8500	SOIL_RF(f)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Montane shrew (Mammalian insectivore)	14	140	SOIL_MS(i)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Mountain cottontail (Mammalian herbivore)	84	840	SOIL_DC(p)_53-70-3
PAH	Fluoranthene	206-44-0	Deer mouse (Mammalian omnivore)	38	380	SOIL_DM(ip)_206-44-0
PAH	Fluoranthene	206-44-0	Earthworm (Soil-dwelling invertebrate)	10	23	SOIL_EW_206-44-0
PAH	Fluoranthene	206-44-0	Gray fox (Mammalian top carnivore)	3900	39000	SOIL_RF(f)_206-44-0
PAH	Fluoranthene	206-44-0	Montane shrew (Mammalian insectivore)	22	220	SOIL_MS(i)_206-44-0
PAH	Fluoranthene	206-44-0	Mountain cottontail (Mammalian herbivore)	270	2700	SOIL_DC(p)_206-44-0
PAH	Fluorene	86-73-7	Deer mouse (Mammalian omnivore)	340	680	SOIL_DM(ip)_86-73-7
PAH	Fluorene	86-73-7	Earthworm (Soil-dwelling invertebrate)	3.7	19	SOIL_EW_86-73-7
PAH	Fluorene	86-73-7	Gray fox (Mammalian top carnivore)	50000	100000	SOIL_RF(f)_86-73-7
PAH	Fluorene	86-73-7	Montane shrew (Mammalian insectivore)	250	510	SOIL_MS(i)_86-73-7
PAH	Fluorene	86-73-7	Mountain cottontail (Mammalian herbivore)	1100	2300	SOIL_DC(p)_86-73-7
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Deer mouse (Mammalian omnivore)	110	1100	SOIL_DM(ip)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Gray fox (Mammalian top carnivore)	4600	46000	SOIL_RF(f)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Montane shrew (Mammalian insectivore)	71	710	SOIL_MS(i)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Mountain cottontail (Mammalian herbivore)	510	5100	SOIL_DC(p)_193-39-5
PAH	Methylnaphthalene[2-]	91-57-6	Deer mouse (Mammalian omnivore)	24	240	SOIL_DM(ip)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Gray fox (Mammalian top carnivore)	4900	49000	SOIL_RF(f)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Montane shrew (Mammalian insectivore)	16	160	SOIL_MS(i)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Mountain cottontail (Mammalian herbivore)	110	1100	SOIL_DC(p)_91-57-6
PAH	Naphthalene	91-20-3	American kestrel (Avian top carnivore)	2100	21000	SOIL_AK(f)_91-20-3
PAH	Naphthalene	91-20-3	American kestrel (insectivore / carnivore)	78	780	SOIL_AK(fi)_91-20-3

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
PAH	Naphthalene	91-20-3	American robin (Avian herbivore)	3.4	34	SOIL_AR(p)_91-20-3
PAH	Naphthalene	91-20-3	American robin (Avian insectivore)	15	150	SOIL_AR(i)_91-20-3
PAH	Naphthalene	91-20-3	American robin (Avian omnivore)	5.7	57	SOIL_AR(ip)_91-20-3
PAH	Naphthalene	91-20-3	Deer mouse (Mammalian omnivore)	9.6	27	SOIL_DM(ip)_91-20-3
PAH	Naphthalene	91-20-3	Generic plant (Terrestrial autotroph - producer)	1	10	SOIL_GP_91-20-3
PAH	Naphthalene	91-20-3	Gray fox (Mammalian top carnivore)	5800	16000	SOIL_RF(f)_91-20-3
PAH	Naphthalene	91-20-3	Montane shrew (Mammalian insectivore)	28	79	SOIL_MS(i)_91-20-3
PAH	Naphthalene	91-20-3	Mountain cottontail (Mammalian herbivore)	14	40	SOIL_DC(p)_91-20-3
PAH	Phenanthrene	85-01-8	Deer mouse (Mammalian omnivore)	15	150	SOIL_DM(ip)_85-01-8
PAH	Phenanthrene	85-01-8	Earthworm (Soil-dwelling invertebrate)	5.5	12	SOIL_EW_85-01-8
PAH	Phenanthrene	85-01-8	Gray fox (Mammalian top carnivore)	1900	19000	SOIL_RF(f)_85-01-8
PAH	Phenanthrene	85-01-8	Montane shrew (Mammalian insectivore)	11	110	SOIL_MS(i)_85-01-8
PAH	Phenanthrene	85-01-8	Mountain cottontail (Mammalian herbivore)	62	620	SOIL_DC(p)_85-01-8
PAH	Pyrene	129-00-0	American kestrel (Avian top carnivore)	3000	30000	SOIL_AK(f)_129-00-0
PAH	Pyrene	129-00-0	American kestrel (insectivore / carnivore)	160	1600	SOIL_AK(fi)_129-00-0
PAH	Pyrene	129-00-0	American robin (Avian herbivore)	68	680	SOIL_AR(p)_129-00-0
PAH	Pyrene	129-00-0	American robin (Avian insectivore)	33	330	SOIL_AR(i)_129-00-0
PAH	Pyrene	129-00-0	American robin (Avian omnivore)	44	440	SOIL_AR(ip)_129-00-0
PAH	Pyrene	129-00-0	Deer mouse (Mammalian omnivore)	31	310	SOIL_DM(ip)_129-00-0
PAH	Pyrene	129-00-0	Earthworm (Soil-dwelling invertebrate)	10	20	SOIL_EW_129-00-0
PAH	Pyrene	129-00-0	Gray fox (Mammalian top carnivore)	3100	31000	SOIL_RF(f)_129-00-0
PAH	Pyrene	129-00-0	Montane shrew (Mammalian insectivore)	23	230	SOIL_MS(i)_129-00-0
PAH	Pyrene	129-00-0	Mountain cottontail (Mammalian herbivore)	110	1100	SOIL_DC(p)_129-00-0
SVOC	Benzoic Acid	65-85-0	Deer mouse (Mammalian omnivore)	1.3	13	SOIL_DM(ip)_65-85-0
SVOC	Benzoic Acid	65-85-0	Gray fox (Mammalian top carnivore)	2000	20000	SOIL_RF(f)_65-85-0
SVOC	Benzoic Acid	65-85-0	Montane shrew (Mammalian insectivore)	1	10	SOIL_MS(i)_65-85-0
SVOC	Benzoic Acid	65-85-0	Mountain cottontail (Mammalian herbivore)	4.6	46	SOIL_DC(p)_65-85-0
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American kestrel (Avian top carnivore)	9.3	93	SOIL_AK(f)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American kestrel (insectivore / carnivore)	0.096	0.96	SOIL_AK(fi)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian herbivore)	16	160	SOIL_AR(p)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian insectivore)	0.02	0.2	SOIL_AR(i)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian omnivore)	0.04	0.4	SOIL_AR(ip)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Deer mouse (Mammalian omnivore)	1.1	11	SOIL_DM(ip)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Gray fox (Mammalian top carnivore)	500	5000	SOIL_RF(f)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Montane shrew (Mammalian insectivore)	0.6	6	SOIL_MS(i)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Mountain cottontail (Mammalian herbivore)	1900	19000	SOIL_DC(p)_117-81-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Deer mouse (Mammalian omnivore)	160	1600	SOIL_DM(ip)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Gray fox (Mammalian top carnivore)	23000	230000	SOIL_RF(f)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Montane shrew (Mammalian insectivore)	90	900	SOIL_MS(i)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Mountain cottontail (Mammalian herbivore)	2400	24000	SOIL_DC(p)_85-68-7
SVOC	Carbazole	86-74-8	Deer mouse (Mammalian omnivore)	79	790	SOIL_DM(ip)_86-74-8
SVOC	Carbazole	86-74-8	Gray fox (Mammalian top carnivore)	13000	130000	SOIL_RF(f)_86-74-8
SVOC	Carbazole	86-74-8	Montane shrew (Mammalian insectivore)	110	1100	SOIL_MS(i)_86-74-8
SVOC	Carbazole	86-74-8	Mountain cottontail (Mammalian herbivore)	140	1400	SOIL_DC(p)_86-74-8
SVOC	Chlorobenzene	108-90-7	Deer mouse (Mammalian omnivore)	53	530	SOIL_DM(ip)_108-90-7
SVOC	Chlorobenzene	108-90-7	Earthworm (Soil-dwelling invertebrate)	2.4	24	SOIL_EW_108-90-7
SVOC	Chlorobenzene	108-90-7	Gray fox (Mammalian top carnivore)	25000	250000	SOIL_RF(f)_108-90-7
SVOC	Chlorobenzene	108-90-7	Montane shrew (Mammalian insectivore)	43	430	SOIL_MS(i)_108-90-7
SVOC	Chlorobenzene	108-90-7	Mountain cottontail (Mammalian herbivore)	170	1700	SOIL_DC(p)_108-90-7
SVOC	Chlorophenol[2-]	95-57-8	American kestrel (Avian top carnivore)	310	3100	SOIL_AK(f)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American kestrel (insectivore / carnivore)	14	140	SOIL_AK(fi)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian herbivore)	0.39	3.9	SOIL_AR(p)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian insectivore)	2.6	26	SOIL_AR(i)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian omnivore)	0.68	6.8	SOIL_AR(ip)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Deer mouse (Mammalian omnivore)	0.54	5.4	SOIL_DM(ip)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Gray fox (Mammalian top carnivore)	340	3400	SOIL_RF(f)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Montane shrew (Mammalian insectivore)	2.3	23	SOIL_MS(i)_95-57-8

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
SVOC	Chlorophenol[2-]	95-57-8	Mountain cottontail (Mammalian herbivore)	0.74	7.4	SOIL_DC(p)_95-57-8
SVOC	Dibenzofuran	132-64-9	Generic plant (Terrestrial autotroph - producer)	6.1	61	SOIL_GP_132-64-9
SVOC	Diethyl Phthalate	84-66-2	Deer mouse (Mammalian omnivore)	3600	36000	SOIL_DM(ip)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Generic plant (Terrestrial autotroph - producer)	100	1000	SOIL_GP_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Gray fox (Mammalian top carnivore)	2500000	25000000	SOIL_RF(f)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Montane shrew (Mammalian insectivore)	3600	36000	SOIL_MS(i)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Mountain cottontail (Mammalian herbivore)	8800	88000	SOIL_DC(p)_84-66-2
SVOC	Dimethyl Phthalate	131-11-3	Deer mouse (Mammalian omnivore)	38	460	SOIL_DM(ip)_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Earthworm (Soil-dwelling invertebrate)	10	100	SOIL_EW_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Gray fox (Mammalian top carnivore)	48000	590000	SOIL_RF(f)_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Montane shrew (Mammalian insectivore)	80	980	SOIL_MS(i)_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Mountain cottontail (Mammalian herbivore)	60	740	SOIL_DC(p)_131-11-3
SVOC	Di-n-Butyl Phthalate	84-74-2	American kestrel (Avian top carnivore)	2	20	SOIL_AK(f)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American kestrel (insectivore / carnivore)	0.052	0.52	SOIL_AK(fi)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian herbivore)	0.38	3.8	SOIL_AR(p)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian insectivore)	0.011	0.11	SOIL_AR(i)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian omnivore)	0.021	0.21	SOIL_AR(ip)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Deer mouse (Mammalian omnivore)	360	860	SOIL_DM(ip)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Generic plant (Terrestrial autotroph - producer)	160	600	SOIL_GP_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Gray fox (Mammalian top carnivore)	62000	140000	SOIL_RF(f)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Montane shrew (Mammalian insectivore)	180	450	SOIL_MS(i)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Mountain cottontail (Mammalian herbivore)	17000	40000	SOIL_DC(p)_84-74-2
SVOC	Di-n-octylphthalate	117-84-0	Deer mouse (Mammalian omnivore)	1.8	18	SOIL_DM(ip)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Gray fox (Mammalian top carnivore)	1300	13000	SOIL_RF(f)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Montane shrew (Mammalian insectivore)	0.91	9.1	SOIL_MS(i)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Mountain cottontail (Mammalian herbivore)	8400	84000	SOIL_DC(p)_117-84-0
SVOC	Methylphenol[2-]	95-48-7	Deer mouse (Mammalian omnivore)	580	5800	SOIL_DM(ip)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Generic plant (Terrestrial autotroph - producer)	0.67	7	SOIL_GP_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Gray fox (Mammalian top carnivore)	160000	1600000	SOIL_RF(f)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Montane shrew (Mammalian insectivore)	1500	15000	SOIL_MS(i)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Mountain cottontail (Mammalian herbivore)	880	8800	SOIL_DC(p)_95-48-7
SVOC	Methylphenol[3-]	108-39-4	Generic plant (Terrestrial autotroph - producer)	0.69	7	SOIL_GP_108-39-4
SVOC	Nitroaniline[2-]	88-74-4	Deer mouse (Mammalian omnivore)	5.3	10	SOIL_DM(ip)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Gray fox (Mammalian top carnivore)	2200	4400	SOIL_RF(f)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Montane shrew (Mammalian insectivore)	6.5	13	SOIL_MS(i)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Mountain cottontail (Mammalian herbivore)	11	22	SOIL_DC(p)_88-74-4
SVOC	Nitrobenzene	98-95-3	Deer mouse (Mammalian omnivore)	4.8	48	SOIL_DM(ip)_98-95-3
SVOC	Nitrobenzene	98-95-3	Earthworm (Soil-dwelling invertebrate)	2.2	22	SOIL_EW_98-95-3
SVOC	Nitrobenzene	98-95-3	Gray fox (Mammalian top carnivore)	4100	41000	SOIL_RF(f)_98-95-3
SVOC	Nitrobenzene	98-95-3	Montane shrew (Mammalian insectivore)	21	210	SOIL_MS(i)_98-95-3
SVOC	Nitrobenzene	98-95-3	Mountain cottontail (Mammalian herbivore)	6.7	67	SOIL_DC(p)_98-95-3
SVOC	Pentachloronitrobenzene	82-68-8	American kestrel (Avian top carnivore)	110	1100	SOIL_AK(f)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American kestrel (insectivore / carnivore)	3.3	33	SOIL_AK(fi)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian herbivore)	21	210	SOIL_AR(p)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian insectivore)	0.7	7	SOIL_AR(i)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian omnivore)	1.3	13	SOIL_AR(ip)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Deer mouse (Mammalian omnivore)	22	220	SOIL_DM(ip)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Gray fox (Mammalian top carnivore)	3500	35000	SOIL_RF(f)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Montane shrew (Mammalian insectivore)	11	110	SOIL_MS(i)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Mountain cottontail (Mammalian herbivore)	930	9300	SOIL_DC(p)_82-68-8
SVOC	Pentachlorophenol	87-86-5	American kestrel (Avian top carnivore)	57	570	SOIL_AK(f)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American kestrel (insectivore / carnivore)	1.7	17	SOIL_AK(fi)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian herbivore)	29	290	SOIL_AR(p)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian insectivore)	0.36	3.6	SOIL_AR(i)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian omnivore)	0.72	7.2	SOIL_AR(ip)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Deer mouse (Mammalian omnivore)	1.5	15	SOIL_DM(ip)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Earthworm (Soil-dwelling invertebrate)	31	150	SOIL_EW_87-86-5

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
SVOC	Pentachlorophenol	87-86-5	Generic plant (Terrestrial autotroph - producer)	5	50	SOIL_GP_87-86-5
SVOC	Pentachlorophenol	87-86-5	Gray fox (Mammalian top carnivore)	230	2300	SOIL_RF(f)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Montane shrew (Mammalian insectivore)	0.81	8.1	SOIL_MS(i)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Mountain cottontail (Mammalian herbivore)	180	1800	SOIL_DC(p)_87-86-5
SVOC	Phenol	108-95-2	Deer mouse (Mammalian omnivore)	37	370	SOIL_DM(ip)_108-95-2
SVOC	Phenol	108-95-2	Earthworm (Soil-dwelling invertebrate)	1.8	18	SOIL_EW_108-95-2
SVOC	Phenol	108-95-2	Generic plant (Terrestrial autotroph - producer)	0.79	8	SOIL_GP_108-95-2
SVOC	Phenol	108-95-2	Gray fox (Mammalian top carnivore)	43000	430000	SOIL_RF(f)_108-95-2
SVOC	Phenol	108-95-2	Montane shrew (Mammalian insectivore)	640	6400	SOIL_MS(i)_108-95-2
SVOC	Phenol	108-95-2	Mountain cottontail (Mammalian herbivore)	47	470	SOIL_DC(p)_108-95-2
VOC	Acetone	67-64-1	American kestrel (Avian top carnivore)	66000	660000	SOIL_AK(f)_67-64-1
VOC	Acetone	67-64-1	American kestrel (insectivore / carnivore)	840	8400	SOIL_AK(fi)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian herbivore)	7.5	75	SOIL_AR(p)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian insectivore)	170	1700	SOIL_AR(i)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian omnivore)	14	140	SOIL_AR(ip)_67-64-1
VOC	Acetone	67-64-1	Deer mouse (Mammalian omnivore)	1.2	6.3	SOIL_DM(ip)_67-64-1
VOC	Acetone	67-64-1	Gray fox (Mammalian top carnivore)	7800	39000	SOIL_RF(f)_67-64-1
VOC	Acetone	67-64-1	Montane shrew (Mammalian insectivore)	15	79	SOIL_MS(i)_67-64-1
VOC	Acetone	67-64-1	Mountain cottontail (Mammalian herbivore)	1.6	8	SOIL_DC(p)_67-64-1
VOC	Benzene	71-43-2	Deer mouse (Mammalian omnivore)	24	240	SOIL_DM(ip)_71-43-2
VOC	Benzene	71-43-2	Gray fox (Mammalian top carnivore)	18000	180000	SOIL_RF(f)_71-43-2
VOC	Benzene	71-43-2	Montane shrew (Mammalian insectivore)	49	490	SOIL_MS(i)_71-43-2
VOC	Benzene	71-43-2	Mountain cottontail (Mammalian herbivore)	38	380	SOIL_DC(p)_71-43-2
VOC	Benzyl Alcohol	100-51-6	Deer mouse (Mammalian omnivore)	120	1200	SOIL_DM(ip)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Gray fox (Mammalian top carnivore)	110000	1100000	SOIL_RF(f)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Montane shrew (Mammalian insectivore)	270	2700	SOIL_MS(i)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Mountain cottontail (Mammalian herbivore)	190	1900	SOIL_DC(p)_100-51-6
VOC	Butanone[2-]	78-93-3	Deer mouse (Mammalian omnivore)	350	920	SOIL_DM(ip)_78-93-3
VOC	Butanone[2-]	78-93-3	Gray fox (Mammalian top carnivore)	1300000	3500000	SOIL_RF(f)_78-93-3
VOC	Butanone[2-]	78-93-3	Montane shrew (Mammalian insectivore)	2700	6900	SOIL_MS(i)_78-93-3
VOC	Butanone[2-]	78-93-3	Mountain cottontail (Mammalian herbivore)	470	1200	SOIL_DC(p)_78-93-3
VOC	Carbon Disulfide	75-15-0	Deer mouse (Mammalian omnivore)	0.81	8.1	SOIL_DM(ip)_75-15-0
VOC	Carbon Disulfide	75-15-0	Gray fox (Mammalian top carnivore)	190	1900	SOIL_RF(f)_75-15-0
VOC	Carbon Disulfide	75-15-0	Montane shrew (Mammalian insectivore)	1.2	12	SOIL_MS(i)_75-15-0
VOC	Carbon Disulfide	75-15-0	Mountain cottontail (Mammalian herbivore)	1.4	14	SOIL_DC(p)_75-15-0
VOC	Chloroaniline[4-]	106-47-8	Earthworm (Soil-dwelling invertebrate)	1.8	18	SOIL_EW_106-47-8
VOC	Chloroaniline[4-]	106-47-8	Generic plant (Terrestrial autotroph - producer)	1	10	SOIL_GP_106-47-8
VOC	Chloroform	67-66-3	Deer mouse (Mammalian omnivore)	8	21	SOIL_DM(ip)_67-66-3
VOC	Chloroform	67-66-3	Gray fox (Mammalian top carnivore)	8900	24000	SOIL_RF(f)_67-66-3
VOC	Chloroform	67-66-3	Montane shrew (Mammalian insectivore)	8.2	22	SOIL_MS(i)_67-66-3
VOC	Chloroform	67-66-3	Mountain cottontail (Mammalian herbivore)	19	52	SOIL_DC(p)_67-66-3
VOC	Dichlorobenzene[1,2-]	95-50-1	Deer mouse (Mammalian omnivore)	1.5	15	SOIL_DM(ip)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Gray fox (Mammalian top carnivore)	480	4800	SOIL_RF(f)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Montane shrew (Mammalian insectivore)	0.92	9.2	SOIL_MS(i)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Mountain cottontail (Mammalian herbivore)	12	120	SOIL_DC(p)_95-50-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Deer mouse (Mammalian omnivore)	1.2	12	SOIL_DM(ip)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Gray fox (Mammalian top carnivore)	380	3800	SOIL_RF(f)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Montane shrew (Mammalian insectivore)	0.74	7.4	SOIL_MS(i)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Mountain cottontail (Mammalian herbivore)	13	130	SOIL_DC(p)_541-73-1
VOC	Dichlorobenzene[1,4-]	106-46-7	Deer mouse (Mammalian omnivore)	1.5	6	SOIL_DM(ip)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Earthworm (Soil-dwelling invertebrate)	1.2	12	SOIL_EW_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Gray fox (Mammalian top carnivore)	470	1800	SOIL_RF(f)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Montane shrew (Mammalian insectivore)	0.89	3.5	SOIL_MS(i)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Mountain cottontail (Mammalian herbivore)	12	49	SOIL_DC(p)_106-46-7
VOC	Dichloroethane[1,1-]	75-34-3	Deer mouse (Mammalian omnivore)	210	2100	SOIL_DM(ip)_75-34-3
VOC	Dichloroethane[1,1-]	75-34-3	Gray fox (Mammalian top carnivore)	250000	2500000	SOIL_RF(f)_75-34-3
VOC	Dichloroethane[1,1-]	75-34-3	Montane shrew (Mammalian insectivore)	290	2900	SOIL_MS(i)_75-34-3

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
VOC	Dichloroethane[1,1-]	75-34-3	Mountain cottontail (Mammalian herbivore)	410	4100	SOIL_DC(p)_75-34-3
VOC	Dichloroethane[1,2-]	107-06-2	American kestrel (Avian top carnivore)	1300	2700	SOIL_AK(f)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American kestrel (insectivore / carnivore)	22	44	SOIL_AK(fi)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian herbivore)	0.85	1.6	SOIL_AR(p)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian insectivore)	4.5	9	SOIL_AR(i)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian omnivore)	1.4	2.8	SOIL_AR(ip)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Deer mouse (Mammalian omnivore)	27	270	SOIL_DM(ip)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Gray fox (Mammalian top carnivore)	36000	360000	SOIL_RF(f)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Montane shrew (Mammalian insectivore)	91	910	SOIL_MS(i)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Mountain cottontail (Mammalian herbivore)	39	390	SOIL_DC(p)_107-06-2
VOC	Dichloroethene[1,1-]	75-35-4	Deer mouse (Mammalian omnivore)	14	140	SOIL_DM(ip)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Gray fox (Mammalian top carnivore)	14000	140000	SOIL_RF(f)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Montane shrew (Mammalian insectivore)	11	110	SOIL_MS(i)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Mountain cottontail (Mammalian herbivore)	44	440	SOIL_DC(p)_75-35-4
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Deer mouse (Mammalian omnivore)	25	250	SOIL_DM(ip)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Gray fox (Mammalian top carnivore)	25000	250000	SOIL_RF(f)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Montane shrew (Mammalian insectivore)	24	240	SOIL_MS(i)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Mountain cottontail (Mammalian herbivore)	64	640	SOIL_DC(p)_540-59-0
VOC	Diphenylamine	122-39-4	American kestrel (Avian top carnivore)	3900	6500	SOIL_AK(f)_122-39-4
VOC	Diphenylamine	122-39-4	American kestrel (insectivore / carnivore)	49	81	SOIL_AK(fi)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian herbivore)	78	130	SOIL_AR(p)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian insectivore)	10	16	SOIL_AR(i)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian omnivore)	17	29	SOIL_AR(ip)_122-39-4
VOC	Hexachlorobenzene	118-74-1	American kestrel (Avian top carnivore)	12	120	SOIL_AK(f)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American kestrel (insectivore / carnivore)	0.37	3.7	SOIL_AK(fi)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian herbivore)	83	830	SOIL_AR(p)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian insectivore)	0.079	0.79	SOIL_AR(i)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian omnivore)	0.15	1.5	SOIL_AR(ip)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Deer mouse (Mammalian omnivore)	0.39	3.9	SOIL_DM(ip)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Earthworm (Soil-dwelling invertebrate)	10	100	SOIL_EW_118-74-1
VOC	Hexachlorobenzene	118-74-1	Generic plant (Terrestrial autotroph - producer)	10	100	SOIL_GP_118-74-1
VOC	Hexachlorobenzene	118-74-1	Gray fox (Mammalian top carnivore)	59	590	SOIL_RF(f)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Montane shrew (Mammalian insectivore)	0.2	2	SOIL_MS(i)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Mountain cottontail (Mammalian herbivore)	910	9100	SOIL_DC(p)_118-74-1
VOC	Hexanone[2-]	591-78-6	American kestrel (Avian top carnivore)	290	2900	SOIL_AK(f)_591-78-6
VOC	Hexanone[2-]	591-78-6	American kestrel (insectivore / carnivore)	1.7	17	SOIL_AK(fi)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian herbivore)	0.47	4.7	SOIL_AR(p)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian insectivore)	0.36	3.6	SOIL_AR(i)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian omnivore)	0.41	4.1	SOIL_AR(ip)_591-78-6
VOC	Hexanone[2-]	591-78-6	Deer mouse (Mammalian omnivore)	6.1	23	SOIL_DM(ip)_591-78-6
VOC	Hexanone[2-]	591-78-6	Gray fox (Mammalian top carnivore)	5900	22000	SOIL_RF(f)_591-78-6
VOC	Hexanone[2-]	591-78-6	Montane shrew (Mammalian insectivore)	5.4	20	SOIL_MS(i)_591-78-6
VOC	Hexanone[2-]	591-78-6	Mountain cottontail (Mammalian herbivore)	17	65	SOIL_DC(p)_591-78-6
VOC	Iodomethane	74-88-4	American kestrel (Avian top carnivore)	46	92	SOIL_AK(f)_74-88-4
VOC	Iodomethane	74-88-4	American kestrel (insectivore / carnivore)	0.29	0.59	SOIL_AK(fi)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian herbivore)	0.038	0.076	SOIL_AR(p)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian insectivore)	0.062	0.12	SOIL_AR(i)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian omnivore)	0.047	0.095	SOIL_AR(ip)_74-88-4
VOC	Methyl-2-pentanone[4-]	108-10-1	Deer mouse (Mammalian omnivore)	9.7	97	SOIL_DM(ip)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Gray fox (Mammalian top carnivore)	18000	180000	SOIL_RF(f)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Montane shrew (Mammalian insectivore)	15	150	SOIL_MS(i)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Mountain cottontail (Mammalian herbivore)	17	170	SOIL_DC(p)_108-10-1
VOC	Methylene Chloride	75-09-2	Deer mouse (Mammalian omnivore)	2.6	22	SOIL_DM(ip)_75-09-2
VOC	Methylene Chloride	75-09-2	Generic plant (Terrestrial autotroph - producer)	1600	16000	SOIL_GP_75-09-2
VOC	Methylene Chloride	75-09-2	Gray fox (Mammalian top carnivore)	4300	36000	SOIL_RF(f)_75-09-2
VOC	Methylene Chloride	75-09-2	Montane shrew (Mammalian insectivore)	9.2	79	SOIL_MS(i)_75-09-2
VOC	Methylene Chloride	75-09-2	Mountain cottontail (Mammalian herbivore)	3.8	32	SOIL_DC(p)_75-09-2

Group	Name	CAS	Receptor	NE ESL	LE ESL	ESL ID
VOC	Styrene	100-42-5	Earthworm (Soil-dwelling invertebrate)	1.2	12	SOIL_EW_100-42-5
VOC	Styrene	100-42-5	Generic plant (Terrestrial autotroph - producer)	3.2	32	SOIL_GP_100-42-5
VOC	Tetrachloroethene	127-18-4	Deer mouse (Mammalian omnivore)	0.35	1.7	SOIL_DM(ip)_127-18-4
VOC	Tetrachloroethene	127-18-4	Generic plant (Terrestrial autotroph - producer)	10	100	SOIL_GP_127-18-4
VOC	Tetrachloroethene	127-18-4	Gray fox (Mammalian top carnivore)	120	630	SOIL_RF(f)_127-18-4
VOC	Tetrachloroethene	127-18-4	Montane shrew (Mammalian insectivore)	0.18	0.94	SOIL_MS(i)_127-18-4
VOC	Tetrachloroethene	127-18-4	Mountain cottontail (Mammalian herbivore)	9.5	47	SOIL_DC(p)_127-18-4
VOC	**Isopropyltoluene[4-].** Use toluene	99-87-6	Deer mouse (Mammalian omnivore)	25	250	SOIL_DM(ip)_108-88-3
VOC	**Isopropyltoluene[4-].** Use toluene	99-87-6	Generic plant (Terrestrial autotroph - producer)	200	2000	SOIL_GP_108-88-3
VOC	**Isopropyltoluene[4-].** Use toluene	99-87-6	Gray fox (Mammalian top carnivore)	12000	120000	SOIL_RF(f)_108-88-3
VOC	**Isopropyltoluene[4-].** Use toluene	99-87-6	Montane shrew (Mammalian insectivore)	23	230	SOIL_MS(i)_108-88-3
VOC	**Isopropyltoluene[4-].** Use toluene	99-87-6	Mountain cottontail (Mammalian herbivore)	66	660	SOIL_DC(p)_108-88-3
VOC	Toluene	108-88-3	Deer mouse (Mammalian omnivore)	25	250	SOIL_DM(ip)_108-88-3
VOC	Toluene	108-88-3	Generic plant (Terrestrial autotroph - producer)	200	2000	SOIL_GP_108-88-3
VOC	Toluene	108-88-3	Gray fox (Mammalian top carnivore)	12000	120000	SOIL_RF(f)_108-88-3
VOC	Toluene	108-88-3	Montane shrew (Mammalian insectivore)	23	230	SOIL_MS(i)_108-88-3
VOC	Toluene	108-88-3	Mountain cottontail (Mammalian herbivore)	66	660	SOIL_DC(p)_108-88-3
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Deer mouse (Mammalian omnivore)	0.51	5.1	SOIL_DM(ip)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Earthworm (Soil-dwelling invertebrate)	1.2	12	SOIL_EW_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Gray fox (Mammalian top carnivore)	110	1100	SOIL_RF(f)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Montane shrew (Mammalian insectivore)	0.27	2.7	SOIL_MS(i)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Mountain cottontail (Mammalian herbivore)	12	120	SOIL_DC(p)_120-82-1
VOC	Trichloroethane[1,1,1-]	71-55-6	Deer mouse (Mammalian omnivore)	400	4000	SOIL_DM(ip)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Gray fox (Mammalian top carnivore)	310000	3100000	SOIL_RF(f)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Montane shrew (Mammalian insectivore)	260	2600	SOIL_MS(i)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Mountain cottontail (Mammalian herbivore)	2000	20000	SOIL_DC(p)_71-55-6
VOC	Trichloroethene	79-01-6	Deer mouse (Mammalian omnivore)	54	540	SOIL_DM(ip)_79-01-6
VOC	Trichloroethene	79-01-6	Gray fox (Mammalian top carnivore)	42000	420000	SOIL_RF(f)_79-01-6
VOC	Trichloroethene	79-01-6	Montane shrew (Mammalian insectivore)	42	420	SOIL_MS(i)_79-01-6
VOC	Trichloroethene	79-01-6	Mountain cottontail (Mammalian herbivore)	190	1900	SOIL_DC(p)_79-01-6
VOC	Trichlorofluoromethane	75-69-4	Deer mouse (Mammalian omnivore)	97	650	SOIL_DM(ip)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Gray fox (Mammalian top carnivore)	62000	420000	SOIL_RF(f)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Montane shrew (Mammalian insectivore)	52	350	SOIL_MS(i)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Mountain cottontail (Mammalian herbivore)	1800	12000	SOIL_DC(p)_75-69-4
VOC	Vinyl Chloride	75-01-4	Deer mouse (Mammalian omnivore)	0.13	1.3	SOIL_DM(ip)_75-01-4
VOC	Vinyl Chloride	75-01-4	Gray fox (Mammalian top carnivore)	110	1100	SOIL_RF(f)_75-01-4
VOC	Vinyl Chloride	75-01-4	Montane shrew (Mammalian insectivore)	0.12	1.2	SOIL_MS(i)_75-01-4
VOC	Vinyl Chloride	75-01-4	Mountain cottontail (Mammalian herbivore)	0.34	3.4	SOIL_DC(p)_75-01-4
VOC	Xylene (Total)	1330-20-7	American kestrel (Avian top carnivore)	13000	130000	SOIL_AK(f)_1330-20-7
VOC	Xylene (Total)	1330-20-7	American kestrel (insectivore / carnivore)	190	1900	SOIL_AK(fi)_1330-20-7
VOC	Xylene (Total)	1330-20-7	American robin (Avian herbivore)	89	890	SOIL_AR(p)_1330-20-7
VOC	Xylene (Total)	1330-20-7	American robin (Avian insectivore)	41	410	SOIL_AR(i)_1330-20-7
VOC	Xylene (Total)	1330-20-7	American robin (Avian omnivore)	56	560	SOIL_AR(ip)_1330-20-7
VOC	Xylene (Total)	1330-20-7	Deer mouse (Mammalian omnivore)	1.9	2.4	SOIL_DM(ip)_1330-20-7
VOC	Xylene (Total)	1330-20-7	Generic plant (Terrestrial autotroph - producer)	100	1000	SOIL_GP_1330-20-7
VOC	Xylene (Total)	1330-20-7	Gray fox (Mammalian top carnivore)	750	930	SOIL_RF(f)_1330-20-7
VOC	Xylene (Total)	1330-20-7	Montane shrew (Mammalian insectivore)	1.4	1.8	SOIL_MS(i)_1330-20-7
VOC	Xylene (Total)	1330-20-7	Mountain cottontail (Mammalian herbivore)	7.6	9.5	SOIL_DC(p)_1330-20-7

32. LANL (Los Alamos National Laboratory), May 2022. *Open Detonation Unit at Technical Area 39 Human Health and Ecological-Risk Screening Assessments*. (LANL 2022)

OPEN DETONATION UNIT AT TECHNICAL AREA 39
HUMAN HEALTH AND ECOLOGICAL
RISK-SCREENING ASSESSMENTS

May 16, 2022

EXECUTIVE SUMMARY

The area around the open detonation (OD) area near Building 6 at Technical Area (TA) 39 (the TA-39-6 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-39-6 OD Unit is referred to as “the Unit” in the remainder of this risk assessment. Surface soil and tuff samples were collected in September 2018 and analyzed for inorganic and organic compounds. Data from these samples were used to conduct human health and ecological risk-screening assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

Screening criteria for these assessments require that residential, industrial, and construction worker exposure scenarios be evaluated, despite that the TA-39-6 OD Unit is not located at a residential location. For the human health risk assessment, a hypothetical future resident and industrial exposure scenarios were evaluated by comparing the maximum exposure point concentration for each analyte to the New Mexico Environment Department (NMED) soil screening levels (NMSSLs) (NMED 2021). The following conclusions are made:

- **Detected inorganics were compared to background values (BVs) and risk-based screening levels (NMSSLs).** Six detected inorganics exceeded background, although four of those were only 1.2 to 1.3 times higher than background. No inorganics exceeded risk-based screening levels (SLs).

- **Detected organics were compared to risk-based NMSSLs.** Maximum concentrations of detected analytes were compared to the NMSSLs. There are no individual constituents that exceed NMSSLs.

- **Cumulative Cancer Risks (CCR) and Hazard Indices (HI) were calculated.** The sum of the cancer risks (CR) is called a CCR, and the sum of the noncancer hazard quotients (HQs) is called an HI. The CCRs are less than the NMED target cancer risk of $1x10^{-5}$. The HIs do not exceed the target value of one.

- The screening evaluation indicates that hypothetical future residents, general workers, or construction workers are not at risk due to exposure to soils at the Unit.

Potential risk to ecological receptors was evaluated by analyzing different lines of evidence that were weighed to draw a conclusion regarding the potential for adverse ecological effects. This included:

- **Comparing maximum exposure point concentrations (EPC) to no effect (NE) ecological screening levels (ESLs).** There were 10 analytes that exceeded NE ESLs to produce HQs greater than 0.1. There were no ESLs for calcium, which was detected and slightly elevated above background.

- **Comparing upper 95th percentile confidence limits (UCL95) as the refined EPC to low effect (LE) ESLs.** There were six analytes that exceeded LE ESLs.

- **Calculating HIs.** The HIs for NE ESL and LE ESL comparisons exceeded 1.

- **Application of site-specific area use factors.** Only plants had HQs above 1 for the area use factor analysis. There were no analytes that exceeded LE ESLs once the areal extent of the Unit was taken into consideration in conjunction with typical home range for ecological receptors. The HIs for plants and earthworms were 2 and 3 respectively for NE ESLs, and less than 1 for LE ESLs. Plants and earthworms are not expected to occur in the Unit due to intended use and presence of bare ground.

- **Avian and mammalian population and tissue data.** There was no indication that bird or mammal populations are being affected. Tissue concentrations were not elevated relative to regional statistical reference levels (RSRLs).

- There is no apparent risk to ecological receptors at the Unit.

TABLE OF CONTENTS

LIST OF ATTACHMENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AUF	Area Use Factor
BMP	Best Management Practice
BV	Background Value
COPC	Contaminant of Potential Concern
COPEC	Contaminant of Potential Ecological Concern
CCR	Cumulative Cancer Risk
CR	Cancer Risk
CSEM	Conceptual Site Exposure Model
DAF	Dilution Attenuation Factor
EPA	Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESL	Ecological Screening Level
ha	Hectare
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Cyclotetramethylene-tetranitramine
HQ	Hazard Quotient
HR	Home Range
LANL	Los Alamos National Laboratory
LD50	Lethal Dose for Half of the Population
LE	Low Effect
LOAEL	Lowest Observed Adverse Effect Level
MDL	Method Detection Limit
MTGW	Migration to Groundwater
NE	No Effect
NMED	New Mexico Environment Department
NMSSL	New Mexico Soil Screening Levels
NOAEL	No Observed Adverse Effect Level
OD	Open Detonation
PAHs	Polynuclear Aromatic Hydrocarbons
PAUF	Population Area Use Factor
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RSL	Regional Screening Level
RSRL	Regional Statistical Reference Levels
SF	Cancer Slope Factor
SL	Screening Level
SVOC	Semi-volatile Organic Compounds
TA	Technical Area
TATB	2,4,6-Triamino-1,3,5-trinitrobenzene
TECi	Toxicity Equivalent Concentration for congener ***i***
TEF	Toxicity Equivalency Factor
TEQ	Toxicity Equivalent Quotient

TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
UCL95	95% Upper Confidence Limit of The Mean
VOC	Volatile Organic Compound
WHO	World Health Organization

1. INTRODUCTION

The area around the open detonation (OD) area near Building 6 at Technical Area (TA) 39 (the TA-39-6 OD Unit) within the Los Alamos National Laboratory (LANL) was sampled as part of the application process for a Resource Conservation and Recovery Act (RCRA) permit to perform hazardous waste treatment operations. The TA-39-6 OD Unit is referred to as “the Unit” in the remainder of this risk assessment.

The Unit is a hazardous waste management unit located in the southern portion of LANL (Figure 1-1). The Unit consists of a relatively flat, sand covered area that measures approximately 40 feet by 40 feet and is located directly to the west of Building 6 (the control building) (Figure 1-2). The Unit has historically been used for experimental, sanitization, and waste treatment OD activities.

Steep canyon walls that rise to heights of 100 feet or higher form a semicircle around the Unit and act to attenuate the force of the detonations. Although the Unit is used to treat both solid and liquid explosive hazardous waste, the primary use of the unit is for nontreatment-related experimental test detonations. The last hazardous waste treatment shot at the site occurred on December 9, 2014. Upgrades to the firing pad at the Unit in recent years include a concrete retaining wall and storm water best management practices (BMPs) that improve fragment capture and minimize runoff from the firing site to the surrounding areas, respectively.

One surface soil sampling event of the top 2 inches of soil and tuff at 12 discrete locations and one duplicate (Figure 1-2) was conducted in and around the Unit on September 27, 2018. Sample collection included soil both in and out of potential run-off areas; however, sample collection did not include rocks, debris, or vegetation. Data from these samples were used to conduct human health and ecological risk assessments to determine whether hazardous contaminants from ongoing treatment operations are being released to soil at levels that pose an unacceptable risk to human health or the environment.

The results of the risk assessments are presented in the following sections.

2. HUMAN HEALTH RISK ASSESSMENT

2.1. CONCEPTUAL SITE MODEL

The primary land use is industrial because only authorized Laboratory workers currently have access to the area around the Unit. Laboratory workers are the primary human receptors, and the industrial scenario is the defining scenario for the human health risk-screening assessment (i.e., the scenario on which decisions are based).

2.1.1. Receptors

Because the site is located within the boundaries of an operational facility (TA-39), the reasonably foreseeable future land use will continue to be industrial. An industrial worker and a construction worker exposure scenario are evaluated. A Hypothetical Future Residential exposure is also assessed and provided for comparison purposes.

2.1.2. Exposure Pathways

The release of contaminants from open detonation operations has potentially occurred for many years. Releases are transported primarily by wind, which rapidly disperses the material in ambient air. Most material is likely deposited close to the source(s), and concentrations are expected to decrease with distance from the source. Exposure to a site worker may occur through various surface soil contact pathways. Potential exposure pathways are:

- Incidental ingestion of surface soil
- Inhalation of fugitive dust or volatiles emanating from surface soil
- Dermal contact with surface soil

Surface water is not considered an exposure pathway. Storm water discharges from the Unit are regulated under the Clean Water Act by the National Pollutant Discharge Elimination System permit program under the LANL Storm Water Individual Permit. The LANL Storm Water Individual Permit contains nonnumeric technology-based effluent limitations, coupled with a comprehensive, coordinated monitoring program and implementation of corrective actions where necessary, to minimize pollutants in LANL's storm water discharges. Grading for runoff and erosion control has been performed in the area of the Unit. In addition, berms and infiltration systems have been installed. In addition, berms and infiltration systems have been installed. This, combined with the distance to the nearest surface water, makes it unlikely that impacts to surface water east of the Unit will occur.

Published precipitation data for TA-39 do not exist; however, TA-49, located west of TA39-6, has an annual precipitation of 22.27 inches per year, as summarized in LANL (2009). The evaporation rate of freestanding water exceeds the average annual precipitation. Hydrologic information for the area north of the Unit is presented in the Pajarito Canyon Investigation Report, Revision 1 (LANL, 2009). Generally, on the Pajarito Plateau, dry canyons have relatively small catchment areas (less than 13 square kilometers), experience infrequent surface flows, and have limited or no saturated alluvial systems. The hydrologic conditions yield little down canyon, near-surface contaminant migration and are characterized by very slow unsaturated water flow from the surface to the regional aquifer. Because surface-water flow is infrequent and shallow alluvial groundwater is not common, contaminants largely remain near their original sources, predominantly in soil and sediment. Net infiltration beneath dry canyons is low, with rates generally believed to be less than tens of mm/yr. and commonly on the order of 1 mm/yr. or less. Finally, transport times to the regional aquifer beneath dry canyons are expected to exceed hundreds of years.

Groundwater in the unit is not utilized for potable purposes. The closest water supply wells into the regional aquifer are over a mile northeast and upgradient with respect to groundwater flow direction. The depth to groundwater is approximately 1000 feet, suggesting percolation to groundwater is unlikely to occur. Furthermore, evapotranspiration exceeds precipitation, resulting in infiltration rates of less than 10 milliliters per year. Migration to groundwater is not indicated as a viable exposure pathway.

2.2. APPROACH FOR IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

2.2.1. Sampling and Data Analysis

Twelve surface soil samples and one duplicate were collected September 27, 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 to 2 inches below ground surface. The duplicate pair was point 1 and 1 dup (field sample identification WST39-18-162832 and WST39-18-162973). Each sample set was analyzed for the following:

- Semi-Volatile Organic Compounds (SVOCs)
- Volatile Organic Compounds (VOCs)
- Total Metals
- Dioxins/Furans
- High Explosives

A staged approach was used for the risk assessment. Duplicates were evaluated consistent with the New Mexico Environment Department (NMED) guidance (NMED 2019) which states that in the initial screening assessment the maximum, and not the average, of the duplicate pair must be used. Figure 1-1 shows a map of the site location, and Figure 1-2 shows site features and the current sampling locations from which data were obtained for use in the risk assessment.

2.2.2. Comparison to Background

The background data used in this evaluation is presented in the report "Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory," (LANL, 1998). The background data are used in the RCRA corrective action process to distinguish between contaminated and uncontaminated media and have been accepted by NMED. As stated in the background report, the background dataset was collected as follows:

> "Twenty-one soil profiles distributed across the Pajarito Plateau were described in the field and were sampled for inorganic chemical analyses. These samples provide information about the varied soils and geomorphic settings that occur on the Pajarito Plateau, allowing for an evaluation of the variability in soil characteristics and chemistry within several of the soil series previously described by Nyhan et al. (1978, 05702). Most sampled soils were collected from mesa tops. Other geomorphic settings sampled include hillslopes and canyon bottoms." (LANL, 1998)

The locations sampled as part of the background study were not impacted by deposition from the historical operation of the OD units or other firing sites. Background values (BVs) were obtained from this document to use in comparison to site data.

An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data BVs. Analytes less than BVs were eliminated from further evaluation. Analytes greater than BVs were evaluated with statistical hypothesis tests to determine whether or not the site data were significantly different from background. No further evaluation is necessary for analytes for which the maximum is less than the BV, and these data are not compared to NMED (2021) risk-based soil screening levels (NMSSLs). Organic analytes are not compared to background values as a matter of standard practice, although there are naturally occurring sources of organic constituents.

2.2.3. Comparison of Maximum Exposure Point Concentrations to NMSSLs

The maximum concentration was used as the maximum exposure point concentration (EPC), which is the environmental concentration to which the receptors are potentially exposed. The screening approach used the maximum of all detected data, including the duplicate pair, for the initial screening evaluation. The maximum concentration of each analyte was divided by its NMED (2021) NMSSL. For the HHRA, this meant using two screening levels (SLs) based on toxicity endpoints, i.e., a cancer and noncancer SL were used to obtain a cancer risk (CR) and noncancer hazard quotient (HQ), respectively.

All analytes that exceeded the NMSSLs were considered to have "failed" the initial screen. These are considered to be contaminants of potential concern (COPCs).

2.2.4. NMSSLs and Surrogates

Where an NMSSL (NMED 2021) was not available, the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL) for residential soils was applied as an SL for residential use, and the RSL for industrial commercial soil was used as the SL for industrial and construction workers. Consistent with NMED guidance, EPA cancer-based RSLs were adjusted to a CR level of $1x10^{-5}$ by multiplying the RSL by 10; noncancer RSLs were based on a HQ of 1. If an RSL was also not available, a suitable surrogate is proposed if physicochemical data suggest identifying a suitable surrogate. Most of the surrogates are proposed for nondetected analytes in order to verify that method detection limits (MDLs) are suitable for performing risk assessment.

NMSSLs were available for all inorganics. The toxicity values for NMED mercuric salts were used for the SL as this is the form expected in arid soils. Per NMED (2019), lead is evaluated with the EPA toxicity values of 400 mg/kg in soil for residents and 800 mg/kg for workers.

The NMED protection from migration to groundwater (MTGW) SLs are used to assess potential migration to groundwater risks assuming human receptors then consume groundwater. Where MTGW SLs are unavailable, surrogates based on EPA RSLs are proposed. In these cases, the EPA RSL for protection of migration to groundwater was used. The EPA RSL for protection of migration to groundwater is based on a dilution attenuation factor (DAF) of 1, whereas the NMED SL-SSL is based on a DAF of 20. For consistency with NMED, the EPA RSL migration to groundwater values were multiplied by a factor of 20.

Surrogates were obtained for the following analytes because NMSSLs were not available; and although most are not detected, the SL is needed to verify that the MDL is adequate for use in the risk assessment:

- 2,4-Diamino-6-nitrotoluene – There is no NMSSL or RSL. Use o-nitrotoluene RSLs, which has both cancer and noncancer RSL values, and the lowest of the nitrotoluene isomer cancer RSLs.
- 2,6-Diamino-4-nitrotoluene – Use o-nitrotoluene RSLs, which has both cancer and noncancer RSL values, and the lowest of the nitrotoluene isomer cancer RSLs.
- 3,5-Dinitroaniline – There is no NMSSL. Use the amino-2,6-dinitrotoluene[4-] RSL as surrogate based on structural similarity.
- Acenaphthylene – There is no NMSSL or RSL. The NMSSLs for acenaphthene were used as a surrogate based on structural similarity.
- Aniline - There is no NMSSL. The RSLs were used as a surrogate.
- Azobenzene - There is no NMSSL. The RSLs were used as a surrogate.
- Benzo(g,h,i)perylene – There is no NMSSL or RSL. The NMSSLs for benzo(a)pyrene were used as a surrogate.
- Benzoic Acid - There is no NMSSL. RSLs were used as a surrogate.
- Benzyl Alcohol- There is no NMSSL. RSLs were used as a surrogate.
- Bis(2-chloroethoxy)methane- There is no NMSSL. RSLs were used as a surrogate.
- Bromobenzene - There is no NMSSL. RSLs were used as a surrogate.
- Bromochloromethane - There is no NMSSL. RSLs were used as a surrogate.
- Bromophenyl-phenylether[4-] – There is no NMSSL or RSL. The RSL for pentabromodiphenyl ether was used.
- Butylbenzene isomers – There are no NMSSLs. The RSLs are used as surrogates.
- Butylbenzylphthalate – There are no NMSSLs. The RSLs are used as surrogates.
- Chloro-3-methylphenol[4-]– There are no NMSSLs. The RSLs are used as surrogates.
- Chloroaniline[4-] – There are no NMSSLs. The RSLs are used as surrogates.
- Chlorophenyl-phenyl[4-] Ether– There is no NMSSL or RSL. No recommendation for a surrogate is made.
- Chlorotoluene[4-] – Use the NMSSLs for the o-chlorotoluene isomer because the RSLs for the two isomers are the same.
- Dibenzofuran – There are no NMSSLs. The RSLs are used as surrogates.

- Dichlorobenzene[1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,4-dichlorobenzene were used as it may be the more toxic isomer considering it has cancer-based as well as noncancer-based endpoints.

- Dichloropropane[2,2-] – There is no NMSSL or RSL. The NMSSLs for 1,2-dichloropropane were used. The RSL is higher for 1,3 than 1,2 dichloropropane, and therefore this is considered conservative.

- Dichloropropane[1,3-] – There is no NMSSL. The NMSSLs for 1,2-dichloropropane were used.

- Dichloropropene[1,1-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.

- Dichloropropene[cis-1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.

- Dichloropropene[trans-1,3-] – There is no NMSSL or RSL. The NMSSLs for 1,3-dichloropropene were used.

- Dimethyl phthalate– There is no NMSSL or RSL. The NMSSLs for diethyl phthalate were used.

- Dinitrobenzene[1,3-] – There are no NMSSLs. The RSLs are used as surrogates.

- Di-n-octylphthalate – There are no NMSSLs. The RSLs are used as surrogates.

- Diphenylamine – There are no NMSSLs. The RSLs are used as surrogates.

- Hexanone[2] – There are no NMSSLs. The RSLs are used as surrogates.

- Iodomethane – There is no NMSSL or RSL. No recommendation for a surrogate is made.

- 4-Isopropyltoluene – There is no NMSSL. The NMSSL values for toluene were used as a surrogate.

- Methylphenols – There are no NMSSLs for these compounds. The RSLs were applied for 2- and 4-methylphenol. The RSLs for 3-methylphenol were used for 3,4-methylphenol as most conservative option.

- Nitroanilines – There are no NMSSLs for these compounds. The RSLs were applied for 2- and 4-nitroaniline. The RSL for 4-nitroaniline was applied to 3-nitroaniline.

- Nitrophenols – There are no NMSSLs or RSLs for these compounds. The RSLs for phenol were applied for 2- and 4-nitrophenol.

- Nitroso-di-n-propylamine[N-] – There are no NMSSLs. The RSLs were applied.

- PETN - There is no NMSSL for PETN. RSLs were used as a surrogate.

- Propylbenzene[1-] – There are no NMSSLs. The RSLs are used as surrogates.

- Pyridine– There are no NMSSLs. The RSLs are used as surrogates.

- 1,3,5-Trinitrobenzene – There is no NMSSL. RSLs for 1,3,5-trinitrobenzene were used as a surrogate.

- TATB – There is no NMSSL or RSL for TATB. RSLs for 1,3,5-trinitrobenzene were used as a surrogate because of structural similarity.

- Trimethylbenzenes – There are no NMSSLs. The RSLs are used as surrogates.

- Tris (o-cresyl) phosphate – There is no NMSSL or RSL. The RSL for tris(2-ethylhexyl)phosphate was applied as a similar structure without halogen substitutions.

2.2.5. Evaluation of Refined EPCs

A refinement of the EPCs was performed if the HI or the CCR based on maxima exceeded target levels of 1 or $1x10^{-5}$, respectively. The maximum of each duplicate pair was retained prior to calculating an upper 95th percent confidence limit on the mean (UCL95). The UCL95 concentrations were compared to SLs, and any analytes above the SLs are evaluated further.

2.3. SCREENING EVALUATION

The following sections present the human health risk-screening assessment for the Unit.

2.3.1. Data Analysis

The summary statistics and maximum values used as EPCs are presented in Table 2-1.

The EPC based on the maximum concentration for each detected analyte was compared with the industrial and residential soil SLs to obtain a HQ or CR, and the HI was calculated by summing the HQs and the CCR was calculated by summing the CRs (NMED 2019). The chemical SLs used in the evaluations were obtained from current NMED guidance (NMED 2020) or from the most recent RSLs (EPA 2021) if an NMED value was not available.

The NMSSLs for carcinogens are equivalent to a 1×10^{-5} cancer risk, and for noncarcinogens the NMSSLs correlate to a ratio or HQ of 1. The cancer-based EPA RSLs as surrogates were multiplied by 10 to adjust them to a cancer risk level of $1x10^{-5}$, consistent with the NMSSLs. Any detected organic analytes that exceeded the SLs were considered COPCs. Any inorganic analytes that exceeded both background and the SL were also considered COPCs.

The exposure interval for industrial workers is 0–1 ft bgs and for hypothetical future residents and construction workers the exposure interval is 0–10 ft bgs. Since all data fall within the 0–1 ft depth interval, the available data set was used for all receptors.

Antimony, cadmium, selenium, silver, and thallium were not detected in any of the 12 samples and one duplicate. Mercury was detected in 7 samples, and the remaining inorganics were detected in all samples (Table 2-1).

Many of the organics are not detected. Organics that were detected are the energetics or explosives HMX [cyclotetramethylene-tetranitramine] and TATB. SVOCs detected include the polynuclear aromatic hydrocarbons (PAHs) fluoranthene and pyrene, two phthalates (butylbenzyl- and di-n-butylphthalate) and benzoic acid, and the volatile benzyl alcohol was detected (Table 2-1). Five dioxin/furan congeners were detected.

2.3.2. Comparison to Background

The maximum detected result was used as the initial EPC (Table 2-2) and compared to background. Background values for the site are from the 1998 background report (LANL 1998). There were no BVs for perchlorate; however, perchlorate was not detected in any samples. The maximum concentration of the following inorganics exceeded BVs:

- Calcium
- Chromium
- Copper
- Mercury
- Vanadium
- Zinc

Wilcoxon-Mann-Whitney two sample hypothesis tests were performed on these inorganics, with the exception of mercury, for which Gehan's test was considered more appropriate due to differing detection limits in the site data. The minimum of the duplicate pair was removed from the data prior to statistical analysis. Each inorganic, with the exception of mercury, was statistically significantly higher in the site samples than in the all horizon soils (All H) background dataset. Mercury was not statistically higher in site samples than in background soils; however, due to the low number of detections and because all values for background data were the same, the statistical tests are not robust. Therefore, mercury was also retained for further evaluation. The ProUCL (EPA 2015) output is presented in Attachment A. All six inorganics listed above carry forward for comparison to NMSSLs.

2.3.3. Comparison of Maximum EPCs to NMSSLs

None of the inorganics exceeded the residential, general worker, or construction worker NMSSLs (NMED 2021). There was therefore no elevated cancer risk or noncancer hazard indicated for the Unit for any inorganic. All reporting limits were adequate when compared to risk-based NMSSLs for nondetected inorganics or organics with the exception of nitrosodimethylamine[N-] (Table 2-3), as determined by cancer risks and HQs less than the targets of $1x10^{-5}$ and 1, respectively. There were no rejected (R-qualified) inorganic data in the dataset.

A few organics were detected in the surface soil samples (Table 2-1). These include energetics or explosives (e.g., HMX [cyclotetramethylene-tetranitramine] and TATB). The SVOCs fluoranthene and pyrene were detected in one sample. Phthalates (e.g., butylbenzyl- and di-n-butylphthalate) were also detected (Table 2-1), as were benzyl alcohol and benzoic acid.

No individual detected constituents exceeded NMSSLs (NMED 2020) (Table 2-4). The CCR for the evaluation of maximum detected soil concentrations for cancer-based health effects was $3x10^{-7}$ for hypothetical future residents, $6x10^{-8}$ for general workers, and $8x10^{-9}$ for construction workers (Table 2-4). The noncancer-based sum of the screening level HQs for maximum detected soil concentrations was 0.2 for residents, 0.01 for general workers, and 0.1 for construction workers (Table 2-4).

2.3.4. Lead

Maximum lead concentrations were less than BVs. Lead was not evaluated further.

2.3.5. Dioxin/Furans

The dioxin/furans are organics but are evaluated in the analysis differently than other organics. Dioxins/furans were detected in the surface soil samples (Table 2-5). The detection status is indicated by a zero for nondetect, and a 1 for a detected value.

The evaluation of the dioxin/furans is summarized in Table 2-6. The measured detected concentration or the MDL for nondetects for each congener in each sample is multiplied by the toxicity equivalency factor (TEF) (Table 2-5) to produce the toxicity equivalent concentration (TECi) (Table 2-6). Summing the TECi yields the toxicity equivalent quotient (TEQ). Dividing the maximum TEQ by the residential or industrial NMSSLs (Table 2-7) produces a CR or HQ which for all samples was less than target levels of $1x10^{-5}$ or 1, respectively. Therefore, the dioxins and furans do not exceed risk-based SLs. This maximum TEQ was also used to calculate the HI reported in Table 2-4.

2.3.6. Migration to Groundwater

The maximum concentrations were compared to the groundwater protection MTGW SLs (NMED 2020) (Table 2-8). None of the detected analytes and inorganics greater than background exceeded the groundwater protection SLs. There is no potential impact to groundwater due to analytes detected at the Unit. There are some reporting limits that exceed MTGW SL values.

Given that there is no human health risk due to direct contact exposure pathways, and that groundwater is very deep, groundwater impacts are not indicated.

2.3.7. Data Analysis Conclusions

The risk analysis for all inorganic and organic analytes was based on comparison of the maximum detected value as the EPC. There are no individual constituents that exceed NMED residential, commercial/industrial, or construction worker NMSSLs. The CCR does not exceed 1×10^{-5} for any receptor, and the HIs do not exceed a value of one. The screening evaluation indicates that hypothetical future residents, general workers, or construction workers are not at risk due to exposure to soils at the Unit.

2.4. UNCERTAINTY ANALYSIS

The human health risk assessment has inherent uncertainties associated with data and data evaluation, exposure assessment, and the toxicity values on which the SLs are based. Each or all of these uncertainties may affect the assessment results, biasing the risk assessment results high or low.

2.4.1. Data and Data Analysis

Uncertainties in the data or its analysis may include errors in sampling, laboratory analysis, and data analysis. Data evaluation uncertainties are expected to have little effect on the assessment results because the data have undergone validation to minimize errors, and any errors are not expected to bias the results high or low. The J-flagged (estimated) qualification of detected concentrations of some organic COPCs does not affect the assessment. The data represent deposition from more than 60 years of operation into 2019. Therefore, the data and subsequently the screening assessment results represent current baseline conditions.

The use of a judgmental sampling design biases the risk results high since samples were targeted to locations where contamination was most likely to occur or known to occur from past sampling events.

The use of the maximum as the EPC is also expected to bias risk estimates high, erring towards being conservative. Use of the maximum as the EPC overestimates exposure, as by definition all other concentrations are below this value.

2.4.2. Exposure Assessment

The exposure assessment assumptions bias the risk results high (i.e., overestimate risk). The assumptions for the industrial SLs are that the potentially exposed individual is a Laboratory worker who is outside at the Unit for 8 hours per day for 225 days per year (NMED 2019), and who spends the entire 8 hours on-site within the contaminated area. Assumptions for the residential SLs are that the potentially exposed individual is a hypothetical future resident who is present 24 hours per day for 350 days per year (NMED 2019) and spends the entire 24 hours on-site within the contaminated area. Because it is unlikely the worker or resident would be within the Unit for the entire time, the screening assessments overestimate the exposure. As a result, risks may be overestimated.

Assumptions underlying the exposure parameters, routes of exposure, and intake rates for routes of exposure are consistent with NMED parameters and default values (NMED 2019). In the absence of site-specific data, several upper-bound values for the assumptions may be combined to estimate exposure for any one pathway, and the resulting risk estimate can exceed the 99th percentile. Therefore, uncertainties in the assumptions underlying the exposure pathways may contribute to risk assessments that overestimate the reasonably expected risk levels.

2.4.3. Toxicity Values

The primary uncertainty associated with the screening values is related to the derivation of toxicity values used in their calculation. Toxicity values (slope factors [SFs] and reference doses [RfDs]) were used to derive the risk-based screening values used in the screening evaluation (NMED 2019). Uncertainties were identified in four areas with respect to the toxicity values: (1) extrapolation from animals to humans, (2) variability between individuals in the human population, (3) the derivation of RfDs and SFs, and (4) the chemical form of the COPC.

The SFs and RfDs are often determined by extrapolation from animal data to humans, which may result in uncertainties in toxicity values because differences exist between animals and humans in chemical absorption, metabolism, excretion, and toxic responses. Differences in body weight, surface area, and pharmacokinetic relationships between animals and humans are taken into account to address these uncertainties in the dose-response relationship. However, conservatism is usually incorporated in each of these steps, potentially biasing the estimate high and resulting in the overestimation of potential risk.

For noncarcinogenic effects, the degree of variability in human physical characteristics is important both in determining the risks that can be expected at low exposures and in defining the no observed adverse effect level (NOAEL). The NOAEL uncertainty factor approach incorporates a 10-fold factor to reflect individual variability within the human population that can contribute to uncertainty in the risk assessment. This factor of 10 is generally considered to result in a conservative estimate of risk for noncarcinogenic COPCs.

The RfDs and SFs for different chemicals are derived from experiments conducted by different laboratories that may have different accuracy and precision that could lead to an over- or underestimation of risk. The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. For carcinogens, the weight of evidence classification indicates the likelihood that a contaminant is a human carcinogen.

COPCs may be bound to the environmental matrix and not be available for absorption into the human body following ingestion. However, the exposure scenarios typically default to the assumption that the COPCs are bioavailable. This assumption can lead to an overestimation of the total exposure and overestimate risk.

2.4.4. Additive Approach

For noncarcinogens, the effects of exposure to multiple chemicals are generally unknown and possible interactions could be synergistic or antagonistic, resulting in either an underestimation or overestimation of the potential risk by assuming additivity. Additionally, RfDs used in the risk calculations typically are not based on the same endpoints with respect to severity, effects, or target organs. Therefore, the potential for noncarcinogenic effects may be overestimated by the HI considering individual COPCs act by different mechanisms and on different target organs but are addressed additively. Cancer risks are typically assumed to be additive.

2.5. CONCLUSIONS

Inorganics were compared to BVs and risk-based SLs. Six inorganics equaled or exceeded background. No inorganics exceeded risk-based SLs. The cancer risks were less than 1×10^{-5} and noncancer screening level HQs than 1 for inorganics for workers or hypothetical residents.

Organics were compared to risk-based SLs. There were a few organics detected, including some energetics, some SVOCs, and dioxin/furans. However, maximum concentrations of any of the detected analytes were below SLs for all constituents. The maximum TEQ for dioxin/furans did not exceed the TCDD SL. The Unit does not present an elevated cancer risk or noncancer hazard to human health due to exposure to soils. The following interpretation can be made from the analysis:

- For the hypothetical future residential scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer HI (0.2) is less than the NMED target level of 1. The CCR of 3×10^{-7} is also below the NMED target level of 1×10^{-5}.

- Based on an industrial scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer HIs (0.01) and CCRs ($6x10^{-8}$) are less than the NMED target levels of 1 and $1x10^{-5}$, respectively.

- For the construction worker scenario, inorganics above background, and maximum detected concentrations for each analyte, the noncancer HI (0.1) is less than the NMED target level of 1. The CCR of $8x10^{-9}$ is also below the NMED target level of $1x10^{-5}$.

- The concentration of each dioxin/furan congener was summed to obtain a TEQ which was compared to the NMED NMSSL for TCDD. Cancer risk and HQs for each receptor were below target levels.

- Summing the maximum dioxin/furan ratio with the other cancer risks and HIs provides a CCR of $3x10^{-7}$ and a total HI of 0.2 for residential use, a CCR of $6x10^{-8}$ and a total HI of 0.01 for commercial/industrial use, and a CCR of $8x10^{-9}$ and a total HI of 0.1 for construction workers.

- The maximum lead concentration of 15.6 mg/kg is less than the background value of 22.3 mg/kg and is much less than the residential SL (400 mg/kg).

- There are no elevated human health risks for exposure to soils based on this evaluation.

- There are no potential impacts to groundwater based on comparison of maximum concentrations of detected analytes including those inorganics above background to NMED MTGW SLs.

3. ECOLOGICAL SCREENING ASSESSMENT

3.1. INTRODUCTION

The ecological risk assessment (ERA) for the Unit is presented in the following sections. The ecological risk-screening evaluation identifies chemicals of potential ecological concern (COPECs) and is based on the comparison of EPCs with Ecological Screening Levels (ESLs) in accordance with Laboratory guidance (LANL 2012a) and NMED (2017) guidance. Site information including ESLs, biological studies, and historical information were reviewed and a site visit was conducted. A preliminary conceptual site exposure model (CSEM) was prepared.

The ESLs obtained from the ECORISK Database, Version 4.2 (LANL 2017; LANL 2020) for detected chemicals and inorganics above background are presented in Table 3-1. The ESLs are based on toxicity data for laboratory species similar to those expected to occur at the site, and are derived from experimentally determined NOAELs, lowest observed adverse effect levels (LOAELs), or doses determined to be lethal to 50% of the test population (LD50s). Information relevant to the calculation of ESLs, including concentration equations, dose equations, bioconcentration factors, transfer factors, and toxicity reference values, are presented in the ECORISK Database, Versions 2.0, 3.1, 4.1, and 4.2 (LANL 2003; LANL 2012b; LANL 2017; LANL 2019; LANL 2020).

The screening evaluation is conducted by dividing the EPCs by the ESLs to obtain a HQ calculated for each COPEC and screening receptor. As a generalization, the higher the contaminant levels relative to the ESLs, the higher the potential risk to receptors; conversely, the higher the ESLs relative to the contaminant levels, the lower the potential risk to receptors. HQs greater than 0.1 are used to identify COPECs requiring additional evaluation.

Individual HQs for a receptor are summed to derive a HI. An HI greater than 1 indicates that further assessment may be needed to ensure exposure to multiple COPECs at a site will not lead to potential adverse impacts to a given receptor population. The HQ and HI analyses provide a conservative indication of potential adverse effects and are designed to minimize the potential of overlooking possible COPECs at the site.

3.2. PROBLEM FORMULATION AND CONCEPTUAL SITE EXPOSURE MODEL

The Unit is a terrestrial ecosystem. The area is disturbed with little to no vegetation present. Vegetation increases with distance from the OD area and consists of grasses and shrubs. There are likely terrestrial birds and small mammals including deer mice (*Peromyscus maniculatus*) or ground squirrels using the area, although intermittently due to the lack of food or cover. There is not enough vegetation within the Unit to support large herbivores.

Due to the site history, there is the potential for energetic compounds or their breakdown products to be present in surface soils. Terrestrial animals and plants may contact surface soils and be exposed. This possibility led to the collection of data and ecological risk assessment.

3.2.1. Data Summary

Soil samples used in this analysis were collected in September 2018. Surface soil samples were collected as grab samples (independent, discrete samples) from a depth of 0 - 2 inches below ground surface. Each sample set was analyzed for the following:

- VOCs –12 samples and one duplicate
- SVOCs –12 samples and one duplicate
- Total Metals –12 samples and one duplicate
- Dioxins/Furans –12 samples and one duplicate
- High Explosives –12 samples and one duplicate

Some organics were analyzed by more than one method, resulting in an apparently higher sample count (i.e., 2,4 and 2,6 dinitrotoluene, nitrobenzene, dichlorobenzenes). Figure 1-2 shows a map of the site including the current sampling locations from which data were obtained for use in the risk assessment, and habitat in the immediate site vicinity is also shown in Figure 1-2.

3.2.2. Receptors and Pathways

Exposure pathways are considered complete if all of the following components are present (EPA, 1989; NMED, 2017):

- A source and mechanism for hazardous waste/constituent release into the environment;
- An environmental transport medium or mechanism;
- A point of contact directly between the receptor and site-related contaminated media, or indirectly via dietary ingestion of prey or forage items contaminated by contact with site related contaminants; and
- An exposure route leading to interaction of the contaminant with target organs within the receptor.

If any of the above components are missing from the exposure pathway, it is not a complete pathway for the site.

The primary potentially complete ecological exposure pathways are based on direct or indirect contact with surface soils. These include root uptake, incidental ingestion of soil, and biotic uptake leading to food-web transport. Exposure of plants and soil invertebrates is not related to dietary pathways but is the result of direct contact with, and uptake from, the surrounding medium. For terrestrial wildlife, most exposure is through the oral pathway from the diet and incidental ingestion of soil (Sample et al. 1998). The dermal contact and inhalation pathways are not typically assessed quantitatively in ecological risk assessments, based on guidance indicating the ingestion route is most important to terrestrial animals (EPA 1997; EPA 2003). Dermal exposure to wildlife is mitigated by the fur or feathers covering the bodies of most vertebrates and the incidental consumption of soil during grooming is included in the direct soil ingestion estimates.

Although inhalation is recognized to occur, it is typically considered insignificant relative to ingestion and only quantified for burrowing animals where volatile organics are present in the subsurface. Respirable dust particles are most likely ingested rather than inhaled, and this pathway is considered negligible (EPA 1997; EPA 2003), while non-respirable dust is ingested and accounted for in incidental soil ingestion values for wildlife species (EPA 1993; EPA 2003). Therefore, the exposure pathways considered in the development of the ESLs used in the risk-screening assessment capture the primary exposure for wildlife receptors.

A CSEM was developed for the site (Figure 3-1) showing the major receptor categories. The primary contaminant source is the testing of explosives and detonation of explosives for waste management at the site. Any uncombusted material, if present, could remain in soil or be released to air as fugitive dust. Materials in surface soil could potentially be carried by overland flow or percolate into the subsurface with rain, whereas material in air could be transported by wind. Receptors could contact contaminants within the immediate site area, up to the site boundary, or slightly beyond. The use of stormwater BMPs reduces the potential for migration beyond the Unit.

Terrestrial flora (i.e., plants) and fauna (e.g., invertebrates, birds, and mammals) are the general categories of ecological receptors that could be exposed. There are multiple avian and mammalian receptors evaluated in this ERA (Table 3-1). All receptors are evaluated if habitat is suitable. Habitat for the montane shrew (i.e., riparian areas) is not present, and this receptor is not evaluated.

3.2.3. Technical Decision Point and Recommendations

Because of the ecological habitat near the Unit boundaries, and because of the potential for exposure, the data were used to perform a quantitative screening level ecological evaluation.

3.3. SCREENING EVALUATION

The summary statistics for the data were presented in Table 2-1. Maximum detected concentrations of each analyte are used as the initial EPC. The EPCs and the screening results for the ecological screening assessment are presented in Table 3-2. Any analytes for which the measured maximum detected value exceeded the no effect (NE) ESL were considered COPECs and were evaluated further by calculating UCL95s and comparing the UCL95s to the LE ESLs (Table 3-3). The approach was as follows:

- An attribution analysis (NMED 2019) was conducted by comparing the inorganic site data to BVs. Analytes less than BVs were eliminated from further evaluation.

- The screening approach then used the maximum of all detected data for the initial screening evaluation. The maximum concentration of each analyte was divided by the NE ESL for each of the receptors.

- All analytes that exceeded the NE ESLs were considered to have “failed” the initial screen. These are considered to be COPECs.

- A refinement of the EPCs was performed. The maximum of each duplicate pair was retained prior to calculating a UCL95. The UCL95 concentrations were compared to LE ESLs, and any analytes above the LE ESLs are evaluated further with population area use factors (PAUFs).

3.3.1. Inorganics

There are two inorganics that exceed site BVs by a factor of 2 or more, and four that are slightly above background. All six inorganics exceeded background based on hypothesis tests. The maximum concentration of each of these was compared to the minimum no effect (NE) ESL, if one was available, to determine if the resulting HQ >0.1. The analytes that exceed ecological SLs are as follows (Table 3-1):

- Calcium – no ESLs, and only 1.2 times above BV. There were no adverse human health effects. Not evaluated further due to lack of ESLs and likelihood of low toxicity.
- Chromium – exceeds NE ESLs
- Copper – exceeds NE ESLs
- Mercury – exceeds NE ESLs
- Vanadium - exceeds NE ESLs
- Zinc– exceeds NE ESLs

If the maximum exceeded the BV and the ratio of the maximum to the risk-based SL was greater than 0.1, a UCL95 was calculated with the USEPA ProUCL 5.1.002 software (EPA 2015). This UCL95 was then compared to the LE ESLs (Table 3-3) consistent with the NMED (2017) Tier II approach. Note that comparison to the UCL95s was made prior to incorporating area use factors (AUFs) or PAUFs into the analysis. Receptor-specific dietary composition is built into the receptor-specific ESLs. The maximum concentration for each of the samples in the duplicate pair 1 and 1 dup (Figure 1-2) were retained and the minimum removed from the analysis, and the UCL95 calculated with a sample size of 12.

UCL95 values for chromium, copper, mercury, vanadium, and zinc exceeded the LE ESL with UCL95/ESL ratios above 0.1. This suggests some limited potential for adverse ecological effects at the Unit, and therefore the COPECs producing HQs above 1 are evaluated in more detail in the uncertainty analysis.

3.3.2. Dioxin and Furans

Dioxins and furans are evaluated in a multi-step process that takes the concentration of each congener in each sample and multiplies it by a TEF for mammals or birds (Table 3-4). The resulting TECi values (Table 3-5, Table 3-6) are summed to obtain TEQs for mammals and birds.

The maximum TEQ is divided by the mammalian and other receptor NE ESLs for species that could occur in the Unit (Table 3-2). Due to lack of its preferred riparian habitat and lack of dense cover, the montane shrew is not expected to occur. All other terrestrial receptors were retained for evaluation.

Dioxin and furans were detected in multiple samples in the September 2018 data set. The TEFs for birds and mammals were applied to calculate a mammal and bird TEQ for each sample. The HQ for the maximum TCDD TEQ exceeded 0.1 for avian species, deer mouse, and mountain cottontail. There was no ESL for plants. The TEQs were used to estimate a refined EPC with ProUCL (EPA 2015) based on the UCL95 statistic.

The potential for risk was then investigated further. There is no LE ESL for birds, and further ecological risk to avian species cannot be quantified. The HQ for deer mouse exceeds 0.1 (Table 3-3). The dioxin/furans are further evaluated in the Uncertainty Analysis (Section 3.4.3).

3.3.3. Other Organics

For this risk assessment, the highest concentration found, regardless of the method used, or whether the sample was a primary sample or a duplicate, was used as the basis of the EPC in the initial screening-level assessment. This is considered conservative for the evaluation of potential risks.

Organic analytes are not compared to any background values, although there are naturally occurring sources of organic constituents. Organics are compared to risk-based ESLs.

Maximum concentrations of four organics exceeded one or more ESLs (Table 3-2). These were benzoic acid, di-n-butylphthalate, HMX, and TATB. UCL95 values were calculated and compared to the LE ESLs (Table 3-3), and the refined EPCs were less than ESLs. The other organics do not contribute significantly to the HI.

There was only one detection of benzoic acid, fluoranthene, and pyrene, two detections of butylbenzylphthalate, and four detections of di-n-butylphthalate once duplicates are removed. The low detection frequency means that a robust UCL95 cannot be calculated for these organics. Therefore, a median of the detected concentrations and the reported detection limit values was calculated and used as the estimate of the EPC. This approach is consistent with ProUCL guidance (EPA 2015) that recommends use of alternative statistics when detection frequency is low.

3.4. UNCERTAINTY ANALYSIS

3.4.1. Chemical Form

Inorganic analytes can speciate into different forms with varying degrees of toxicity. The assumptions used in the ESL derivations are conservative and not necessarily representative of actual conditions. These assumptions include maximum chemical bioavailability, maximum receptor ingestion rates, minimum bodyweight, and additive effects of multiple COPECs. These factors tend to result in conservative ESL estimates, which may lead to an overestimation of the potential risk. Toxicological data are typically based on the most toxic and bioavailable chemical species, which may or may not be found in the environment. The ESLs were calculated to ensure a conservative indication of potential risk (LANL 2012a), and the values are biased toward overestimating the potential risk to receptors.

The chemical form of the individual COPECs was not determined as part of the investigation. COPECs may undergo natural processes, such as the adsorption of chemical constituents to matrix surfaces (e.g., soil) or rapid oxidation or reduction changes that render harmful chemical forms less available to biotic processes.

3.4.2. Reporting Limits

The evaluation was focused on detected values. Reporting limits were adequate (i.e., below ESLs) for all nondetected analytes with several exceptions, indicating that the data were adequate for use in the risk assessment:

Bis(2-ethylhexyl)phthalate –

- This analyte was not detected in any sample. Reporting limits were less than the cancer or noncancer based NMSSL for residents or workers.
- The maximum MDL (0.0101 mg/kg) produced an HQ of 2 for robin modeled as an insectivore.
- The maximum nondetected value was flagged as having blank contamination and may be biased high.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Dinitrobenzene[1,3-] –

- This analyte was not detected in any sample. Reporting limits were less than the cancer or noncancer based NMSSL for residents or workers.
- The maximum reporting limit (0.15 mg/kg) was two times higher than the minimum NE ESL. All reporting limits were similar. The maximum HQ was 2 for robin modeled as an herbivore.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

Thallium -

- This analyte was not detected in any sample. Reporting limits were less than the cancer or noncancer based NMSSL for residents or workers.
- The highest HQ was 2. This was for plants.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.
- This analyte is not considered further. This is not expected to bias the risk assessment results high or low.

3.4.3. Exposure Parameters and Risk Estimates

Exposure parameters including the EPC and the intakes likely bias risk estimates high because they presume no movement of receptors in and out of source areas. Sampling focused on areas of known or expected contamination, which biases the EPC high. Receptors are assumed to spend 100% of their time in the contaminated area which results in conservative estimates of exposure.

Another source of uncertainty is inherent in the calculation of exposure and risk estimates. Although the toxicity values are expressed to more than one significant figure, it is unlikely that the toxicity data are this accurate, especially given that the data are extrapolated from laboratory animal studies to wildlife receptors that are mobile in the environment. Likewise, given all the variables inherent in assessing exposure, exposure intakes by ecological receptors also should not be considered more accurate than one significant figure. This means that an HQ identified as 0.95 or 1.2 is actually 1, and an HQ identified as 1.5 is actually 2.

Calculating risk for dioxins is a multi-step process that involves multiplying the measured concentration by a TEF to obtain a value called the TECi that when summed adjusts the measured congener concentrations to that relative to TCDD, where the sum of all TECi is called the TEQ. ProUCL (EPA 2015) accommodates both detected and nondetected results, reducing bias and uncertainty by not ignoring the influence of nondetects on the EPC. Therefore, TEQs were calculated for each sample, then UCL95 was calculated from all the TEQs. This procedure of calculating UCL95s was considered to be slightly more accurate and similar to how sample data are used to estimate UCL95 values for other analytes.

3.4.4. Mixture Toxicity

The assumption of additive effects for multiple COPECs may result in an over- or under-estimation of the potential risk to receptors. Calculating the HI assumes additivity with respect to toxicity. Exposure to multiple contaminants may result in other than additive effects. Conservative assumptions made with regards to EPCs would tend to overestimate exposure to any given constituent, and this would suggest that the toxicity of multiple constituents would not be underestimated. Therefore, mixture toxicity is not likely to bias the risk results high or low.

3.4.5. COPECs without ESLs

ESLs were not available for the cations and anions generally regarded as nutrients such as calcium, magnesium, nitrate, potassium, and sodium. ESLs were also not available for iron, but human health risk ratios for residents were 0.4 or lower. Only calcium was above background levels established for the site with a ratio of site maximum to background of 1.2. There is no human health risk or hazard for calcium. Lack of ESLs for these inorganics is not expected to underestimate risk at the site.

Several organic chemicals do not have ESLs for any receptor in release 4.2 of the ECORISK Database (LANL 2020). Predominantly, the constituents lacking ESLs are nondetected organics. In the absence of a chemical-specific ESL, concentrations can be compared with the ESLs for a surrogate chemical, if available. Comparison to surrogate ESLs can provide an estimate of potential effects of a chemically related compound and a line of evidence to indicate the likelihood that ecological receptors are potentially impacted. Some chemicals without ESLs do not have chemical-specific toxicity data or surrogate chemicals to be used in the screening assessments and cannot be assessed quantitatively for potential ecological risk.

The chemical TATB was detected in six samples. TATB did not have any ESLs for use in the evaluation. The toxicity values for 1,3,5-trinitrobenzene for mammals and invertebrates were used as a surrogate based on structural similarity. There were no avian surrogates available.

Chemicals lacking ESLs are often infrequently detected across the site. In these cases, comparisons with human health SLs are presented as part of a qualitative assessment, if human health SLs are available. The comparison of concentrations to human health SLs is a viable alternative for several reasons. Animal studies are used as the basis of toxicity values for human health risk assessments and are the basic premise of modern toxicology (EPA 1989). In addition, toxicity values derived for the calculation of human health SLs (e.g., histopathology or biochemical changes) may be based on potential adverse effects more sensitive than the ones typically used to derive ESLs (e.g., survival, growth, or reproductive effects). EPA also applies uncertainty factors or modifying factors to ensure the toxicity values are protective (i.e., toxicity values are divided by uncertainty factors resulting in values much lower than initial study results).

Since there were no predicted adverse effects on human health, chemicals lacking ESLs are unlikely to pose an ecological risk.

3.4.6. Small-Mammal Field Investigations

Small mammal trapping and analysis of whole organisms were conducted in the area around the Unit in August and September 2010 to evaluate small mammal abundance and occurrence relative to background. Small-mammal community and population parameters were also measured across the site (Bennett and Robinson 2011). This information was considered useful for the current analysis as an additional line of evidence. Field mice were collected around the site and analyzed for dioxins and furans as well as metals, and for polychlorinated biphenyls (PCBs) (Fresquez 2011).

Small mammals that could occur at the Unit are the deer mouse (*Peromyscus maniculatus*), brush mouse (*Peromyscus boylii*), pinyon mouse (*Peromyscus truei*), silky pocket mouse (*Perognathus flavescens*), western harvest mouse (*Reithrodontomys megalotis*), white-throated woodrat (*Neotoma albigula*), and the Mexican woodrat (*Neotoma 16exicana*) (Bennett and Robinson 2011). The Unit is located at the bottom of Ancho Canyon. The vegetation community consists of piñon (*Pinus edulis Engelm.*)-juniper (*Juniperus monosperma [Englem.] Sarg.*) with scattered ponderosa pine (*Pinus ponderosa C. Lawson*) and gambel oak (*Quercus gambelii Nutt.*) (Bennett and Robinson 2011).

The capture rate was higher at the Unit relative to the control area, but the Unit exhibited lower diversity and lower eveness. There were five species captured, including the rock pocket mouse (*Chaetodipus intermedius*) which had never been caught at LANL before. In addition, Mexican woodrats, deer mice, harvest mice, and brush mice were collected. There were no differences in deer mouse sex ratios or body weight between the Unit and the control area. The authors of the study concluded that there was no apparent adverse effects on small mammal populations at the Unit relative to controls.

Radionuclides and chemical concentrations in biota were compared to regional statistical reference levels (RSRLs). RSRLs represent natural and fallout levels and are the upper-level background concentrations (mean plus three standard deviations = 99% confidence level) for radionuclides and chemicals calculated from biota that was collected from regional locations away from the influence of the Laboratory (over nine miles away) (Fresquez 2011). The only analytes that exceeded RSRLs were barium (two out of three samples) and lead (three out of three samples). Barium and lead soil concentrations were below BVs in the current data set. Dioxins/furans and explosives were not detected. These data suggest that there are no impacts to small mammal populations at the Unit.

3.4.7. Avian Field Investigations

One western bluebird (*Sialia 17exicana*) and one ash-throated flycatcher (*Myiarchus cinerascens*) egg sample were obtained in 2018 from the Unit and analyzed for inorganic elements (Gaukler and Stanek 2019). Concentrations of inorganic elements were compared with the upper-level bounds of background concentrations in bird eggs as represented by the RSRL. The data indicated aluminum, antimony, arsenic, beryllium, cadmium, chromium, lead, nickel, silver, thallium, or vanadium were not detected in eggs (Gaukler and Stanec 2019). Barium, cobalt, and zinc were detected, but were below the RSRL.

Calcium, copper, iron, magnesium, manganese, mercury, potassium, selenium and sodium, were detected in bluebird eggs above the RSRL for avian eggs. Whereas mercury and selenium egg concentrations were below LOAELs, no benchmarks were available for copper, iron, or manganese (Gaukler and Stanek 2019). The other inorganics are considered macronutrients. Most of these inorganics above RSRLs in eggs were either not detected in soils or were detected with maximum soil concentrations below soil BVs. Only copper, mercury, and vanadium soil UCL95 EPCs exceeded NE ESLs, and copper and vanadium soil UCL95s exceeded LE ESLs. In the current data set analyzed for this report, none of the UCL95 EPCs for soil for the detected inorganics above BVs were above NE ESLs once area use factors were incorporated into the analysis. One sample consisting of four western bluebird eggs was collected in 2019, and no detected analytes were above the RSRLs (Gaukler and Stanek 2020).

Avian population metrics also do not suggest that birds in the vicinity are being negatively impacted (Hathcock et al. 2018). The avian population transect at the Unit was in a canyon bottom, whereas the control areas were on mesa tops. This could lead to differences in species identified and population metrics between the Unit and control areas. Species diversity was significantly higher at the Unit in 2013, 2014, and 2016 than at the control areas. Abundance varied in the Unit and control areas annually, but abundance in the Unit compared to controls was similar over time. Combined, the egg concentration data and population metrics suggest that adverse health effects are not expected at the observed concentrations.

3.4.8. Area Use Factors

The Unit is very small with an aerial extent of 40 by 40 feet (0.037 acres or 0.015 hectares (ha)). This is less than the size of the home range (HR) of an individual robin or a deer mouse as shown in Table 3-7. The HR is used to calculate AUFs that are used in the EcoPRG equations (LANL 2017). Individual AUFs and PAUFs may be used to modify the estimate of risk to wildlife receptors to allow estimates to be more site-specific. The application of AUFs or PAUFs reduces potential overestimation of risks for those receptors with HRs larger than the area of contamination being evaluated. The estimated ecological risk as indicated by the HQ or HI is multiplied by the AUF or PAUF. HQs for plants or invertebrates are not adjusted by AUFs or PAUFs.

Table 3-7 presents the area use hazard analysis based on NE ESLs. The NE ESLs for each COPC that failed the screening evaluation (i.e., because EPCs exceeded the SLs) are shown for each receptor. The site specific AUF and PAUFs are shown for an area equivalent to the Unit. The UCL95 EPC is divided by the ESL and multiplied by the PAUF to obtain revised HQs. The habitat is not suitable for Mexican Spotted Owls or other special status species, and so an AUF evaluation was not conducted.

There were no HQs above 1, or even above 0.1, for birds or mammals based on comparison of UCL95 values as the EPC to the NE ESLs for each receptor (Table 3-7) when PAUFs were accounted for. The HQ for copper for plants was 2. The HI for earthworms and plants are 3 and 2, respectively.

Table 3-8 presents the area use hazard analysis based on comparison of the UCL95 values as the EPC to the LE ESLs for each receptor. There are no HQs or HIs above 1.

3.5. CONCLUSIONS

The ecological risk assessment used a tiered approach for determining if the Unit would present an ecological risk. The results of the initial and highly conservative screening step indicated several inorganics occurring above background concentrations, and several detected organics, would present an ecological risk. Maximum concentrations of six detected inorganics exceeded background (calcium, chromium, copper, mercury, vanadium, and zinc). There is no ESL for calcium, but there was no human health risk. Maximum concentrations of other inorganics exceeded NE ESLs.

Dioxin/furans, some polynuclear aromatic hydrocarbons (PAHs), phthalates, benzoic acid, benzyl alcohol, volatile organics, and two explosives were detected in the unit. Of the detected organics, only four (benzoic acid, di-n-butylphthalate, HMX, and TATB) exceeded ESLs in the initial screening level evaluation which compared maximum detected values to the NE ESLs. There were HQs above 1 for TCDD.

Further evaluation by statistically estimating UCL95’s to use as EPCs in soil suggested organics would occur at concentrations hazardous to ecological receptors. Use of the UCL95 as the EPC provides a conservative estimate of average exposure across the Unit. Inorganics exceeded the LE ESLs. None of the UCL95’s for organics exceeded ESLs.

Additional consideration of site ecology and receptor-specific adjustments to exposure by considering home range and site area further reduced the analytes exceeding NE ESLs. Only HQs for copper exceeded 1. This was for plants for which the area use evaluation is not relevant as they are immobile in the environment. However, the Unit is not vegetated because of its designated use as an OD area, and so plants have marginal habitat in the Unit. The LE ESLs are not exceeded for any receptor based on a LE ESL hazard analysis.

The results of the ERA indicate that the Unit does not present a significant ecological risk to any receptor evaluated.

4. REFERENCES

ATSDR. 2012. *Toxicological Profile for Chromium*. September 2012. Pg 374. https://www.atsdr.cdc.gov/toxprofiles/tp7.pdf

Bennett, K., and R. Robinson. 2011. *Small Mammal Sampling at Open-Detonation Firing Sites*. LA-UR-11-00717. January 2011. (Bennett and Robinson 2011)

EPA (U.S. Environmental Protection Agency), December 1989. *“Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final,”* EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989)

EPA (U.S. Environmental Protection Agency), 1993. *“Wildlife Exposure Factors Handbook,”* U.S. Environmental Protection Agency document EPA/600/P93/187A, Office of Research and Development, Washington, D.C. (EPA 1993)

EPA (U.S. Environmental Protection Agency), June 5, 1997. *"Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final,"* U.S. Environmental Protection Agency, Environmental Response Team, Edison NJ. (EPA 1997)

EPA (U.S. Environmental Protection Agency), November 2003. *"Guidance for Developing Ecological Soil Screening Levels, Evaluation of Dermal Contact and Inhalation Exposure Pathways for the Purpose of Setting Eco-SSLs, Attachment 1-3,* U.S. Environmental Protection Agency document OSWER Directive 92857-55, Office of Solid Waste and Emergency Response. (EPA 2003)

EPA (U.S. Environmental Protection Agency), December 2010a. *"Final Report Bioavailability of Dioxins and Dioxin-Like Compounds in Soil,"* Office of Superfund Remediation and Technology Innovation, Environmental Response Team, West Las Vegas, Nevada (http://epa.gov/superfund/health/contaminants/dioxin/pdfs/Final_dioxin_RBA_Report_12_20_10.p df). (EPA 2010a)

EPA (U.S. Environmental Protection Agency), December 2010b. *"Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8=Tetrachloro-p-dioxin and Dioxin-Like Compounds."* EPA/100/R 10/005. (EPA 2010b)

EPA (U.S. Environmental Protection Agency), January 2014. *"Technical Fact Sheet – N-Nitroso-dimethylamine (NDMA)"*. https://www.epa.gov/sites/production/files/2014-03/documents/ffrrofactsheet_contaminant_ndma_january2014_final.pdf . (EPA 2014)

EPA (U.S. Environmental Protection Agency), October 2015. *"ProUCL Version 5.1.002 User Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations."* EPA/600/R-07/041. ORD Site Characterization and Monitoring Technical Support Center. (EPA 2015)

EPA (U.S. Environmental Protection Agency), November 2021. *Regional Screening Levels (RSLs) – Generic Tables* Dated November 2021. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables. (EPA 2021)

Fresquez, P.R. 2011. *Chemical Concentrations In Field Mice Collected From Open-Detonation Firing Sites Ta-36 Minie And Ta-39 Point 6 At Los Alamos National Laboratory*. LA-UR-11-10614. May 2011. (Fresquez 2011)

Gaukler, S. and J Stanek. 2019. *" Inorganic Element Concentrations in Passerine Eggs Collected at Technical Areas 36, 39, and 16 at Los Alamos National Laboratory"*. LA-UR-19-25647. June 2019. (Gaukler and Stanek 2019)

Gaukler, S. and J Stanek. 2020. *"2019 Results for Avian Monitoring of Inorganic and Organic Element Concentrations in Passerine Eggs and a Nestling Collected from Technical Area 16 Burn Grounds, Technical Area 36 Minie, and Technical Area 39 Point 6 at Los Alamos National Laboratory."* March 25, 2020. LA-UR-20-22529. (Gaukler and Stanek 2020)

Hathcock, C. D., Bartlow, A. W., and B.E. Thompson. 2018. *"2017 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory"*. 2018-04-30 (rev.1) LA-UR-18-22897. (Hathcock et al. 2018)

LANL (Los Alamos National Laboratory), September 1998. *"Inorganic and Radionuclide Background Data for Soils, Sediments, and Bandelier Tuff at Los Alamos National Laboratory,"* Los Alamos National Laboratory document LA-UR-98-4847, Los Alamos, New Mexico. (LANL 1998)

LANL (Los Alamos National Laboratory), November 2003. *"ECORISK Database (Version 2.0),"* on CD, Los Alamos, New Mexico. (LANL 2003)

LANL (Los Alamos National Laboratory). 2009. *"Pajarito Canyon Investigation Report, Revision 1."* Los Alamos National Laboratory document LA-UR-09-04670, Los Alamos, New Mexico. August 2009.

LANL (Los Alamos National Laboratory), November 2012. *"Screening-Level Ecological Risk Assessment Methods, Revision 3,"* Los Alamos National Laboratory document LA-UR-12-24152, Los Alamos, New Mexico. (LANL 2012a)

LANL (Los Alamos National Laboratory), October 2012. *"ECORISK Database (Release 3.1),"* LA-UR-12-24548, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2012b)

LANL (Los Alamos National Laboratory), 2017. *"ECORISK Database User Guide, Revision 1"*. LA-UR-17-26376. Los Alamos National Laboratory, Los Alamos, New Mexico. September 2017. (LANL 2017)

LANL (Los Alamos National Laboratory), 2019. *"ECORISK Database (Release 4.1),"* March 2019 Release. (LANL 2019)

LANL (Los Alamos National Laboratory), 2020. *"ECORISK Database (Release 4.2),"* Updated Database. LA-UR-12- 24548, Los Alamos National Laboratory, Los Alamos, New Mexico. November 19, 2020. (LANL 2020)

NMED (New Mexico Environment Department). 2021. *New Mexico Soil Screening Levels.* December 2021. (NMED 2021)

NMED (New Mexico Environment Department). 2017. *Risk Assessment Guidance for Site Investigations and Remediation. Volume II. Soil Screening Guidance for Ecological Risk Assessments.* 2017 Revised. (NMED 2017)

NMED (New Mexico Environment Department). February 2019. *Risk Assessment Guidance for Site Investigations and Remediation. Volume I. Soil Screening Guidance for Human Health Risk Assessments.* February 2019. Rev. 1 (3/7/19) (NMED 2019)

NMED (New Mexico Environment Department). 2021. *New Mexico Soil Screening Levels*. December 2021. (NMED 2021)

Sample, B.E., Suter III, G.W., Efroymson, R.A., and Jones, D.A., May 1998. *"A Guide to the ORNL Ecotoxicological Screening Benchmarks: Background, Development, and Application,"* Oak Ridge National Laboratory, Environmental Sciences Division, Publication No. 4783, ORNL/TM13615, Oak Ridge, TN. May 1998 (Sample et al. 1998)

Van den Berg et.al, 2006. *The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency factors for Dioxin and Dioxin-like Compounds.* ToxiSci Advance Access, July 7, 2006. (Van den Berg et al. 2006)

WHO (World Health Organization). September 2009. *"Project For The Re-Evaluation Of Human And Mammalian Toxic Equivalency Factors (TEFS) Of Dioxins And Dioxin-Like Compounds"*. International Programme on Chemical Safety. http://www.who.int/ipcs/assessment/tef_update/en/ (WHO 2009)

TABLES

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
INORGANICS								
Aluminum	13	1.76E+03	5.28E+03	3.90E+03	8.48E+02	6.24E+00	6.82E+00	13
Antimony	13	3.07E-01	3.24E+00	1.82E+00	1.45E+00	3.07E-01	3.24E+00	0
Arsenic	13	3.65E-01	1.28E+00	8.13E-01	2.07E-01	3.10E-01	3.36E-01	13
Barium	13	1.68E+01	8.86E+01	4.29E+01	1.75E+01	9.17E-02	1.00E-01	13
Beryllium	13	1.43E-01	2.32E-01	1.90E-01	2.68E-02	1.83E-02	1.99E-02	13
Cadmium	13	9.17E-02	1.00E-01	9.52E-02	2.23E-03	9.17E-02	1.00E-01	0
Calcium	13	5.88E+02	7.16E+03	4.67E+03	1.76E+03	7.34E+00	8.02E+00	13
Chromium	13	3.22E+00	4.79E+01	1.64E+01	1.18E+01	1.38E-01	1.50E-01	13
Cobalt	13	2.25E+00	8.95E+00	5.59E+00	1.85E+00	1.38E-01	1.50E-01	13
Copper	13	4.92E+00	1.74E+02	5.78E+01	5.23E+01	2.75E-01	3.01E-01	13
Iron	13	9.03E+03	2.14E+04	1.49E+04	3.77E+03	7.34E+00	8.02E+00	13
Lead	13	5.83E+00	1.56E+01	8.98E+00	2.88E+00	3.03E-01	3.31E-01	13
Magnesium	13	3.75E+02	3.74E+03	2.40E+03	8.21E+02	7.80E+00	8.52E+00	13
Manganese	13	1.47E+02	2.81E+02	2.14E+02	3.80E+01	1.83E-01	2.01E-01	13
Mercury	13	3.55E-03	1.31E-01	3.37E-02	4.50E-02	3.48E-03	3.93E-03	7
Nickel	13	1.27E+00	1.38E+01	8.19E+00	2.94E+00	9.17E-02	9.95E-02	13
Perchlorate	13	4.86E-04	5.04E-04	4.94E-04	5.39E-06	4.86E-04	5.04E-04	0
Potassium	13	3.74E+02	8.12E+02	6.21E+02	1.18E+02	5.87E+00	6.42E+00	13
Selenium	13	3.30E-01	3.58E-01	3.46E-01	9.48E-03	3.30E-01	3.58E-01	0
Silver	13	1.67E-01	6.85E-01	3.77E-01	1.65E-01	9.17E-02	1.00E-01	0
Sodium	13	1.28E+02	3.99E+02	2.76E+02	6.65E+01	6.42E+00	7.02E+00	13
Thallium	13	1.28E-01	1.39E-01	1.34E-01	3.84E-03	1.28E-01	1.39E-01	0
Vanadium	13	1.14E+01	4.83E+01	3.17E+01	1.10E+01	9.17E-02	1.00E-01	13
Zinc	13	2.44E+01	6.25E+01	3.89E+01	1.15E+01	3.67E-01	4.01E-01	13
ORGANICS								
2,4-Diamino-6-nitrotoluene	13	4.93E-01	5.00E-01	4.97E-01	2.94E-03	4.93E-01	5.00E-01	0
2,6-Diamino-4-nitrotoluene	13	6.50E-01	6.60E-01	6.56E-01	4.17E-03	6.50E-01	6.60E-01	0
3,5-Dinitroaniline	13	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Acenaphthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Acenaphthylene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Acetone	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Amino-2,6-dinitrotoluene[4-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Amino-4,6-dinitrotoluene[2-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Aniline	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Azobenzene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Benzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Benzo(a)anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(a)pyrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Benzo(b)fluoranthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(g,h,i)perylene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzo(k)fluoranthene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Benzoic Acid	13	1.67E-01	4.83E-01	1.92E-01	8.75E-02	1.67E-01	1.68E-01	1
Benzyl Alcohol	13	1.00E-01	1.65E+00	3.93E-01	4.81E-01	1.00E-01	1.01E-01	7
Bis(2-chloroethoxy)methane	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Bis(2-chloroethyl)ether	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Bis(2-ethylhexyl)phthalate	13	1.00E-02	3.05E-02	1.23E-02	5.70E-03	1.00E-02	1.01E-02	0
Bromobenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromochloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromodichloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromoform	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Bromophenyl-phenylether[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Butanone[2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Butylbenzene[n-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzene[sec-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzene[tert-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Butylbenzylphthalate	13	1.00E-02	6.35E-02	1.59E-02	1.56E-02	1.00E-02	1.01E-02	2
Carbon Disulfide	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Carbon Tetrachloride	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloro-3-methylphenol[4-]	13	1.34E-01	1.34E-01	1.34E-01	3.73E-09	1.34E-01	1.34E-01	0
Chloroaniline[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorobenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chlorodibromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloroethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloroform	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chloronaphthalene[2-]	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Chlorophenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorophenyl-phenyl[4-] Ether	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Chlorotoluene[2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chlorotoluene[4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Chrysene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dibenz(a,h)anthracene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dibenzofuran	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dibromo-3-Chloropropane[1,2-]	13	4.93E-04	5.04E-04	4.99E-04	4.97E-06	4.93E-04	5.04E-04	0
Dibromoethane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dibromomethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichlorobenzene[1,2-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Dichlorobenzene[1,3-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0
Dichlorobenzene[1,4-]	26	3.28E-04	1.01E-01	5.05E-02	5.11E-02	3.28E-04	1.01E-01	0
Dichlorobenzidine[3,3'-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dichlorodifluoromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethane[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[cis-1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloroethene[trans-1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichlorophenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dichloropropane[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropane[1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropane[2,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[cis-1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Dichloropropene[trans-1,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Diethylphthalate	13	1.00E-02	1.28E-02	1.03E-02	7.62E-04	1.00E-02	1.01E-02	0
Dimethyl Phthalate	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Dimethylphenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Di-n-butylphthalate	13	1.00E-02	1.00E-01	2.30E-02	2.63E-02	1.00E-02	1.01E-02	5
Dinitro-2-methylphenol[4,6-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dinitrobenzene[1,3-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Dinitrophenol[2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Dinitrotoluene[2,4-]	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Dinitrotoluene[2,6-]	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Di-n-octylphthalate	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Diphenylamine	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Ethylbenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Fluoranthene	13	1.00E-02	1.87E-02	1.07E-02	2.39E-03	1.00E-02	1.01E-02	1
Fluorene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	13	5.01E-07	1.17E-05	4.91E-06	3.79E-06	1.65E-06	1.67E-06	12
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	13	4.96E-07	2.21E-06	7.84E-07	4.81E-07	1.65E-06	1.67E-06	6
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Heptachlorodibenzofurans (Total)	13	0.00E+00	1.22E-05	1.82E-06	3.35E-06			7
Hexachlorobenzene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorobutadiene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorocyclopentadiene	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.73E-06	1.75E-06	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.94E-06	1.97E-06	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Hexachlorodibenzofuran[1,2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.71E-06	1.73E-06	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Hexachloroethane	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Hexanone[2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
HMX	13	1.48E-01	6.66E+00	9.80E-01	1.80E+00	1.48E-01	1.50E-01	7
Indeno(1,2,3-cd)pyrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Iodomethane	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Isophorone	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Isopropylbenzene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Isopropyltoluene[4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Methyl-2-pentanone[4-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Methylene Chloride	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Methylnaphthalene[2-]	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Methylphenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Methylphenol[3-,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Naphthalene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Nitroaniline[2-]	13	1.10E-01	1.11E-01	1.11E-01	4.39E-04	1.10E-01	1.11E-01	0
Nitroaniline[3-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitroaniline[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrobenzene	26	1.00E-01	1.50E-01	1.25E-01	2.48E-02	1.00E-01	1.50E-01	0
Nitrophenol[2-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrophenol[4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrosodimethylamine[N-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitroso-di-n-propylamine[N-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Nitrotoluene[2-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Nitrotoluene[3-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Nitrotoluene[4-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	13	1.96E-06	9.57E-05	4.10E-05	3.26E-05	3.31E-06	3.35E-06	13
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	13	9.93E-07	1.92E-05	2.99E-06	4.94E-06	3.31E-06	3.35E-06	7
Oxybis(1-chloropropane)[2,2'-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Pentachlorodibenzofuran[1,2,3,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.65E-06	1.67E-06	0
Pentachlorodibenzofuran[2,3,4,7,8-]	13	4.96E-07	5.02E-07	4.99E-07	2.02E-09	1.75E-06	1.77E-06	0
Pentachlorophenol	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
PETN	13	2.46E-01	2.50E-01	2.49E-01	1.61E-03	2.46E-01	2.50E-01	0
Phenanthrene	13	1.00E-02	1.01E-02	1.01E-02	5.06E-05	1.00E-02	1.01E-02	0
Phenol	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Propylbenzene[1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0

Table 2-1. Summary Statistics for Fall 2018 Data

Analyte Name	n	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	SD (mg/kg)	Minimum MDL (mg/kg)	Maximum MDL (mg/kg)	Number of Detects
Pyrene	13	1.00E-02	1.61E-02	1.05E-02	1.67E-03	1.00E-02	1.01E-02	1
Pyridine	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
RDX	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Styrene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
TATB	13	2.96E-01	6.76E+00	1.37E+00	1.97E+00	2.96E-01	3.00E-01	6
Tetrachlorodibenzodioxin[2,3,7,8-]	13	9.93E-08	1.00E-07	9.98E-08	2.18E-10	3.31E-07	3.35E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	13	1.05E-07	5.60E-07	2.67E-07	1.62E-07	3.31E-07	3.35E-07	11
Tetrachloroethane[1,1,1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetrachloroethane[1,1,2,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetrachloroethene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Tetryl	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Toluene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloro-1,2,2-trifluoroethane[1,1,2-]	13	1.64E-03	1.68E-03	1.66E-03	1.80E-05	1.64E-03	1.68E-03	0
Trichlorobenzene[1,2,4-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichloroethane[1,1,1-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloroethane[1,1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichloroethene	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichlorofluoromethane	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trichlorophenol[2,4,5-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichlorophenol[2,4,6-]	13	1.00E-01	1.01E-01	1.01E-01	5.06E-04	1.00E-01	1.01E-01	0
Trichloropropane[1,2,3-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trimethylbenzene[1,2,4-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trimethylbenzene[1,3,5-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Trinitrobenzene[1,3,5-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Trinitrotoluene[2,4,6-]	13	1.48E-01	1.50E-01	1.49E-01	8.01E-04	1.48E-01	1.50E-01	0
Tris (o-cresyl) phosphate	13	2.96E-01	3.00E-01	2.98E-01	1.71E-03	2.96E-01	3.00E-01	0
Vinyl Chloride	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Xylene[1,2-]	13	3.28E-04	3.36E-04	3.32E-04	3.33E-06	3.28E-04	3.36E-04	0
Xylene[1,3-]+Xylene[1,4-]	13	6.57E-04	6.73E-04	6.65E-04	6.86E-06	6.57E-04	6.73E-04	0

Notes: Sample size (n) includes duplicate of WST39-18-162832 (WST39-18-162973) and multiple analytical methods.

Abbreviations:
MDL – method detection limit
mg/kg – milligram per kilogram
n – sample size
SD - standard deviation

Table 2-2. Comparison of Maximum Detected Exposure Point Concentrations To Background

Parameter Name	Maximum Result (mg/kg)	Number of Detected Values	Background Threshold Value (BV) (mg/kg)	Ratio of Maximum/ BV
Aluminum	5280.00	13	29200	0.2
Arsenic	1.28	13	8.17	0.2
Barium	88.60	13	295	0.3
Beryllium	0.23	13	1.83	0.1
Calcium	7160.00	13	6120	1.2
Chromium	47.90	13	19.3	2
Cobalt	8.95	13	8.64	1.0
Copper	174.00	13	14.7	12
Iron	21400.00	13	21500	1
Lead	15.60	13	22.3	0.7
Magnesium	3740.00	13	4610	0.8
Manganese	281.00	13	671	0.4
Mercury	0.13	7	0.1	1.3
Nickel	13.80	13	15.4	0.9
Potassium	812.00	13	3460	0.2
Sodium	399.00	13	915	0.4
Vanadium	48.30	13	39.6	1.2
Zinc	62.50	13	48.8	1.3

Notes:
All data in mg/kg. Shaded Max/BV cells indicate the maximum>BV
All inorganics above BVs carry forward on the basis of hypothesis testing. See Section 2.3.2.

Table 2-3. Verification of MDLs for Nondetects for Data Useability

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Antimony	3.24	NV	NA	NV	NA	NV	NA	3.13E+01	1E-01	5.19E+02	6E-03	1.42E+02	2E-02
Cadmium	0.10	8.59E+04	1E-11	4.17E+05	2E-12	3.61E+03	3E-10	7.05E+01	1E-03	1.11E+03	9E-05	7.21E+01	1E-03
Mercury	0.004	NV	NA	NV	NA	NV	NA	2.35E+01	2E-04	3.89E+02	1E-05	7.71E+01	5E-05
Perchlorate	0.0005	NV	NA	NV	NA	NV	NA	5.48E+01	9E-06	9.08E+02	6E-07	2.48E+02	2E-06
Selenium	0.36	NV	NA	NV	NA	NV	NA	3.91E+02	9E-04	6.49E+03	6E-05	1.75E+03	2E-04
Silver	0.69	NV	NA	NV	NA	NV	NA	3.91E+02	2E-03	6.49E+03	1E-04	1.77E+03	4E-04
Thallium	0.14	NV	NA	NV	NA	NV	NA	7.82E-01	2E-01	1.30E+01	1E-02	3.54E+00	4E-02
2,4-Diamino-6-nitrotoluene	5.00E-01	3.16E+01	2E-07	1.65E+02	3E-08	1.13E+03	4E-09	6.16E+00	8E-02	9.16E+01	5E-03	2.69E+01	2E-02
2,6-Diamino-4-nitrotoluene	6.60E-01	3.16E+01	2E-07	1.65E+02	4E-08	1.13E+03	6E-09	6.16E+00	1E-01	9.16E+01	7E-03	2.69E+01	2E-02
3,5-Dinitroaniline	3.00E-01	NV	NA	NV	NA	NV	NA	7.64E+00	4E-02	1.25E+02	2E-03	1.73E+01	2E-02
Acenaphthene	1.01E-02	NV	NA	NV	NA	NV	NA	3.48E+03	3E-06	5.05E+04	2E-07	1.51E+04	7E-07
Acenaphthylene	1.01E-02	NV	NA	NV	NA	NV	NA	3.48E+03	3E-06	5.05E+04	2E-07	1.51E+04	7E-07
Acetone	1.68E-03	NV	NA	NV	NA	NV	NA	6.63E+04	3E-08	9.60E+05	2E-09	2.42E+05	7E-09
Amino-2,6-dinitrotoluene[4-]	1.50E-01	NV	NA	NV	NA	NV	NA	7.64E+00	2E-02	1.25E+02	1E-03	1.73E+01	9E-03
Amino-4,6-dinitrotoluene[2-]	1.50E-01	NV	NA	NV	NA	NV	NA	7.70E+00	2E-02	1.27E+02	1E-03	1.73E+01	9E-03
Aniline	1.01E-01	9.50E+02	1E-09	4.00E+03	3E-10	4.00E+03	3E-10	4.40E+02	2E-04	5.70E+03	2E-05	5.70E+03	2E-05
Anthracene	1.01E-02	NV	NA	NV	NA	NV	NA	1.74E+04	6E-07	2.53E+05	4E-08	7.53E+04	1E-07
Azobenzene	1.01E-01	5.60E+01	2E-08	2.60E+02	4E-09	2.60E+02	4E-09	NV	NA	NV	NA	NV	NA
Benzene	3.36E-04	1.78E+01	2E-10	8.72E+01	4E-11	4.23E+02	8E-12	1.14E+02	3E-06	7.29E+02	5E-07	1.42E+02	2E-06
Benzo(a)anthracene	1.01E-02	1.53E+00	7E-08	3.23E+01	3E-09	2.40E+02	4E-10	NV	NA	NV	NA	NV	NA
Benzo(a)pyrene	1.01E-02	1.12E+00	9E-08	2.36E+01	4E-09	1.73E+02	6E-10	1.74E+01	6E-04	2.51E+02	4E-05	1.50E+01	7E-04
Benzo(g,h,i)perylene	1.01E-02	1.12E+00	9E-08	2.36E+01	4E-09	1.73E+02	6E-10	1.74E+01	6E-04	2.51E+02	4E-05	1.50E+01	7E-04
Benzo(k)fluoranthene	1.01E-02	1.53E+01	7E-09	3.23E+02	3E-10	2.31E+03	4E-11	NV	NA	NV	NA	NV	NA
Benzoic Acid	1.68E-01	NV	NA	NV	NA	NV	NA	2.50E+05	7E-07	3.30E+06	5E-08	3.30E+06	5E-08
Benzyl Alcohol	1.01E-01	NV	NA	NV	NA	NV	NA	6.30E+03	2E-05	8.20E+04	1E-06	8.20E+04	1E-06
Bis(2-chloroethoxy)methane	1.01E-01	NV	NA	NV	NA	NV	NA	1.90E+02	5E-04	2.50E+03	4E-05	2.50E+03	4E-05
Bis(2-chloroethyl)ether	1.01E-01	3.11E+00	3E-07	1.57E+01	6E-08	1.95E+00	5E-07	NV	NA	NV	NA	NV	NA

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Bis(2-ethylhexyl)phthalate	3.05E-02	3.80E+02	8E-10	1.83E+03	2E-10	1.34E+04	2E-11	1.23E+03	2E-05	1.83E+04	2E-06	5.38E+03	6E-06
Bromobenzene	3.36E-04	NV	NA	NV	NA	NV	NA	2.90E+02	1E-06	1.80E+03	2E-07	1.80E+03	2E-07
Bromochloromethane	3.36E-04	NV	NA	NV	NA	NV	NA	1.50E+02	2E-06	6.30E+02	5E-07	6.30E+02	5E-07
Bromodichloromethane	3.36E-04	6.19E+00	5E-10	3.02E+01	1E-10	1.43E+02	2E-11	1.56E+03	2E-07	2.60E+04	1E-08	7.08E+03	5E-08
Bromoform	3.36E-04	6.74E+02	5E-12	1.76E+03	2E-12	2.37E+04	1E-13	1.23E+03	3E-07	1.83E+04	2E-08	5.38E+03	6E-08
Bromomethane	3.36E-04	NV	NA	NV	NA	NV	NA	1.77E+01	2E-05	9.45E+01	4E-06	1.79E+01	2E-05
Bromophenyl-phenylether[4-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.60E+02	6E-04	2.30E+03	4E-05	2.30E+03	4E-05
Butanone[2-]	1.68E-03	NV	NA	NV	NA	NV	NA	3.74E+04	4E-08	4.11E+05	4E-09	9.17E+04	2E-08
Butylbenzene[n-]	3.36E-04	NV	NA	NV	NA	NV	NA	3.90E+03	9E-08	5.80E+04	6E-09	5.80E+04	6E-09
Butylbenzene[sec-]	3.36E-04	NV	NA	NV	NA	NV	NA	7.80E+03	4E-08	1.20E+05	3E-09	1.20E+05	3E-09
Butylbenzene[tert-]	3.36E-04	NV	NA	NV	NA	NV	NA	7.80E+03	4E-08	1.20E+05	3E-09	1.20E+05	3E-09
Butylbenzylphthalate	1.01E-02	2.90E+03	3E-11	1.20E+04	8E-12	1.20E+04	8E-12	1.30E+04	8E-07	1.60E+05	6E-08	1.60E+05	6E-08
Carbon Disulfide	1.68E-03	NV	NA	NV	NA	NV	NA	1.55E+03	1E-06	8.54E+03	2E-07	1.62E+03	1E-06
Carbon Tetrachloride	3.36E-04	1.07E+01	3E-10	5.25E+01	6E-11	2.52E+02	1E-11	1.44E+02	2E-06	1.02E+03	3E-07	2.02E+02	2E-06
Chloro-3-methylphenol[4-]	1.34E-01	NV	NA	NV	NA	NV	NA	6.30E+03	2E-05	8.20E+04	2E-06	8.20E+04	2E-06
Chloroaniline[4-]	1.01E-01	2.70E+01	4E-08	1.10E+02	9E-09	1.10E+02	9E-09	3.20E+01	3E-03	4.10E+02	2E-04	4.10E+02	2E-04
Chlorobenzene	3.36E-04	NV	NA	NV	NA	NV	NA	3.78E+02	9E-07	2.16E+03	2E-07	4.12E+02	8E-07
Chlorodibromomethane	3.36E-04	1.39E+01	2E-10	6.74E+01	5E-11	3.40E+02	1E-11	1.23E+03	3E-07	1.83E+04	2E-08	5.38E+03	6E-08
Chloroethane	3.36E-04	NV	NA	NV	NA	NV	NA	1.90E+04	2E-08	8.95E+04	4E-09	1.66E+04	2E-08
Chloroform	3.36E-04	5.90E+00	6E-10	2.87E+01	1E-10	1.34E+02	3E-11	3.06E+02	1E-06	2.00E+03	2E-07	3.91E+02	9E-07
Chloromethane	3.36E-04	4.11E+01	8E-11	2.01E+02	2E-11	9.56E+02	4E-12	2.68E+02	1E-06	1.26E+03	3E-07	2.35E+02	1E-06
Chloronaphthalene[2-]	1.01E-02	NV	NA	NV	NA	NV	NA	6.26E+03	2E-06	1.04E+05	1E-07	2.83E+04	4E-07
Chlorophenol[2-]	1.01E-01	NV	NA	NV	NA	NV	NA	3.91E+02	3E-04	6.49E+03	2E-05	1.77E+03	6E-05
Chlorophenyl-phenyl[4-] Ether	1.01E-01	NV	NA	NV	NA	NV	NA	NV	NA	NV	NA	NV	NA
Chlorotoluene[2-]	3.36E-04	NV	NA	NV	NA	NV	NA	1.56E+03	2E-07	2.60E+04	1E-08	7.08E+03	5E-08
Chlorotoluene[4-]	3.36E-04	NV	NA	NV	NA	NV	NA	1.56E+03	2E-07	2.60E+04	1E-08	7.08E+03	5E-08
Chrysene	1.01E-02	1.53E+02	7E-10	3.23E+03	3E-11	2.31E+04	4E-12	NV	NA	NV	NA	NV	NA

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Dibenz(a,h)anthracene	1.01E-02	1.53E-01	7E-07	3.23E+00	3E-08	2.40E+01	4E-09	NV	NA	NV	NA	NV	NA
Dibenzofuran	1.01E-01	NV	NA	NV	NA	NV	NA	7.80E+01	1E-03	1.20E+03	8E-05	1.20E+03	8E-05
Dibromo-3-Chloropropane[1,2-]	5.04E-04	8.58E-02	6E-08	1.18E+00	4E-09	5.53E+00	9E-10	5.88E+00	9E-05	4.11E+01	1E-05	8.29E+00	6E-05
Dibromoethane[1,2-]	3.36E-04	6.72E-01	5E-09	3.31E+00	1E-09	1.63E+01	2E-10	1.35E+02	2E-06	7.38E+02	5E-07	1.40E+02	2E-06
Dibromomethane	3.36E-04	NV	NA	NV	NA	NV	NA	5.79E+01	6E-06	2.88E+02	1E-06	5.39E+01	6E-06
Dichlorobenzene[1,2-]	1.01E-01	NV	NA	NV	NA	NV	NA	2.15E+03	5E-05	1.30E+04	8E-06	2.50E+03	4E-05
Dichlorobenzene[1,3-]	1.01E-01	1.29E+03	8E-10	6.73E+03	2E-10	4.59E+04	2E-11	5.48E+03	2E-05	9.08E+04	1E-06	2.48E+04	4E-06
Dichlorobenzene[1,4-]	1.01E-01	1.29E+03	8E-10	6.73E+03	2E-10	4.59E+04	2E-11	5.48E+03	2E-05	9.08E+04	1E-06	2.48E+04	4E-06
Dichlorobenzidine[3,3'-]	1.01E-01	1.18E+01	9E-08	5.70E+01	2E-08	4.10E+02	2E-09	NV	NA	NV	NA	NV	NA
Dichlorodifluoromethane	3.36E-04	NV	NA	NV	NA	NV	NA	1.82E+02	2E-06	8.65E+02	4E-07	1.61E+02	2E-06
Dichloroethane[1,1-]	3.36E-04	7.86E+01	4E-11	3.83E+02	9E-12	1.82E+03	2E-12	1.56E+04	2E-08	2.60E+05	1E-09	7.08E+04	5E-09
Dichloroethane[1,2-]	3.36E-04	8.32E+00	4E-10	4.07E+01	8E-11	1.95E+02	2E-11	5.56E+01	6E-06	2.86E+02	1E-06	5.38E+01	6E-06
Dichloroethene[1,1-]	3.36E-04	NV	NA	NV	NA	NV	NA	4.40E+02	8E-07	2.26E+03	1E-07	4.24E+02	8E-07
Dichloroethene[cis-1,2-]	3.36E-04	NV	NA	NV	NA	NV	NA	1.56E+02	2E-06	2.60E+03	1E-07	7.08E+02	5E-07
Dichloroethene[trans-1,2-]	3.36E-04	NV	NA	NV	NA	NV	NA	2.10E+02	2E-06	1.10E+03	3E-07	2.06E+02	2E-06
Dichlorophenol[2,4-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.85E+02	5E-04	2.75E+03	4E-05	8.07E+02	1E-04
Dichloropropane[1,2-]	3.36E-04	1.78E+01	2E-10	8.68E+01	4E-11	4.15E+02	8E-12	2.90E+01	1E-05	1.37E+02	2E-06	2.54E+01	1E-05
Dichloropropane[1,3-]	3.36E-04	1.78E+01	2E-10	8.68E+01	4E-11	4.15E+02	8E-12	2.90E+01	1E-05	1.37E+02	2E-06	2.54E+01	1E-05
Dichloropropane[2,2-]	3.36E-04	1.78E+01	2E-10	8.68E+01	4E-11	4.15E+02	8E-12	2.90E+01	1E-05	1.37E+02	2E-06	2.54E+01	1E-05
Dichloropropene[1,1-]	3.36E-04	2.93E+01	1E-10	1.46E+02	2E-11	7.81E+02	4E-12	1.41E+02	2E-06	6.95E+02	5E-07	1.30E+02	3E-06
Dichloropropene[cis-1,3-]	3.36E-04	2.93E+01	1E-10	1.46E+02	2E-11	7.81E+02	4E-12	1.41E+02	2E-06	6.95E+02	5E-07	1.30E+02	3E-06

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Dichloropropene[trans-1,3-]	3.36E-04	2.93E+01	1E-10	1.46E+02	2E-11	7.81E+02	4E-12	1.41E+02	2E-06	6.95E+02	5E-07	1.30E+02	3E-06
Diethylphthalate	1.28E-02	NV	NA	NV	NA	NV	NA	4.93E+04	3E-07	7.33E+05	2E-08	2.15E+05	6E-08
Dimethyl Phthalate	1.01E-02	NV	NA	NV	NA	NV	NA	4.93E+04	2E-07	7.33E+05	1E-08	2.15E+05	5E-08
Dimethylphenol[2,4-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.23E+03	8E-05	1.83E+04	6E-06	5.38E+03	2E-05
Di-n-butylphthalate	1.01E-02	NV	NA	NV	NA	NV	NA	6.16E+03	2E-06	9.16E+04	1E-07	2.69E+04	4E-07
Dinitro-2-methylphenol[4,6-]	1.01E-01	NV	NA	NV	NA	NV	NA	4.93E+00	2E-02	7.33E+01	1E-03	2.15E+01	5E-03
Dinitrobenzene[1,3-]	1.50E-01	NV	NA	NV	NA	NV	NA	6.30E+00	2E-02	8.20E+01	2E-03	8.20E+01	2E-03
Dinitrophenol[2,4-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.23E+02	8E-04	1.83E+03	6E-05	5.38E+02	2E-04
Dinitrotoluene[2,4-]	1.50E-01	1.71E+01	9E-08	8.23E+01	2E-08	6.00E+02	3E-09	1.23E+02	1E-03	1.82E+03	8E-05	5.36E+02	3E-04
Dinitrotoluene[2,6-]	1.50E-01	3.56E+00	4E-07	1.72E+01	9E-08	1.65E+02	9E-09	1.85E+01	8E-03	2.76E+02	5E-04	8.09E+01	2E-03
Di-n-octylphthalate	1.01E-02	NV	NA	NV	NA	NV	NA	6.30E+02	2E-05	8.20E+03	1E-06	8.20E+03	1E-06
Diphenylamine	1.01E-01	NV	NA	NV	NA	NV	NA	6.30E+03	2E-05	8.20E+04	1E-06	8.20E+04	1E-06
Ethylbenzene	3.36E-04	7.51E+01	4E-11	3.68E+02	9E-12	1.77E+03	2E-12	3.93E+03	9E-08	2.90E+04	1E-08	5.80E+03	6E-08
Fluoranthene	1.01E-02	NV	NA	NV	NA	NV	NA	2.32E+03	4E-06	3.37E+04	3E-07	1.00E+04	1E-06
Fluorene	1.01E-02	NV	NA	NV	NA	NV	NA	2.32E+03	4E-06	3.37E+04	3E-07	1.00E+04	1E-06
Hexachlorobenzene	1.01E-01	3.33E+00	3E-07	1.60E+01	6E-08	1.17E+02	9E-09	4.93E+01	2E-03	7.33E+02	1E-04	2.15E+02	5E-04
Hexachlorobutadiene	1.01E-01	6.83E+01	1E-08	5.21E+01	2E-08	2.40E+03	4E-10	6.16E+01	2E-03	9.16E+02	1E-04	2.69E+02	4E-04
Hexachlorocyclopentadiene	1.01E-01	NV	NA	NV	NA	NV	NA	2.30E+00	4E-02	5.49E+03	2E-05	8.67E+02	1E-04
Hexachloroethane	1.01E-01	1.33E+02	8E-09	6.41E+02	2E-09	4.67E+03	2E-10	4.31E+01	2E-03	6.41E+02	2E-04	1.88E+02	5E-04
Isopropylbenzene	3.36E-04	NV	NA	NV	NA	NV	NA	2.36E+03	1E-07	1.42E+04	2E-08	2.74E+03	1E-07
Isopropyltoluene[4-]	3.36E-04	NV	NA	NV	NA	NV	NA	5.23E+03	6E-08	6.13E+04	5E-09	1.40E+04	2E-08
Methyl-2-pentanone[4-]	1.68E-03	NV	NA	NV	NA	NV	NA	5.81E+03	3E-07	8.16E+04	2E-08	2.02E+04	8E-08
Nitrophenol[2-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.85E+04	5E-06	2.75E+05	4E-07	7.74E+04	1E-06
Nitrophenol[4-]	1.01E-01	NV	NA	NV	NA	NV	NA	1.85E+04	5E-06	2.75E+05	4E-07	7.74E+04	1E-06
Nitrosodimethylamine[N-]	1.01E-01	2.34E-02	4E-05	5.03E-01	2E-06	3.66E+00	3E-07	4.93E-01	2E-01	7.33E+00	1E-02	2.14E+00	5E-02
Nitroso-di-n-propylamine[N-]	1.01E-01	7.80E-01	1E-06	3.30E+00	3E-07	3.30E+00	3E-07	NV	NA	NV	NA	NV	NA

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Nitrotoluene[2-]	1.50E-01	3.16E+01	5E-08	1.65E+02	9E-09	1.13E+03	1E-09	7.04E+01	2E-03	1.17E+03	1E-04	3.19E+02	5E-04
Nitrotoluene[3-]	1.50E-01	NV	NA	NV	NA	NV	NA	6.16E+00	2E-02	9.16E+01	2E-03	2.69E+01	6E-03
Nitrotoluene[4-]	1.50E-01	3.33E+02	5E-09	1.60E+03	9E-10	1.18E+04	1E-10	2.47E+02	6E-04	3.67E+03	4E-05	1.08E+03	1E-04
Oxybis(1-chloropropane)[2,2'-]	1.01E-01	9.93E+01	1E-08	5.19E+02	2E-09	3.54E+03	3E-10	NV	NA	NV	NA	NV	NA
Pentachlorophenol	1.01E-01	9.85E+00	1E-07	4.45E+01	2E-08	3.46E+02	3E-09	2.34E+02	4E-04	3.18E+03	3E-05	9.89E+02	1E-04
PETN	2.50E-01	1.30E+03	2E-09	5.30E+03	5E-10	5.30E+03	5E-10	NV	NA	NV	NA	NV	NA
Phenanthrene	1.01E-02	NV	NA	NV	NA	NV	NA	1.74E+03	6E-06	2.53E+04	4E-07	7.53E+03	1E-06
Phenol	1.01E-01	NV	NA	NV	NA	NV	NA	1.85E+04	5E-06	2.75E+05	4E-07	7.74E+04	1E-06
Propylbenzene[1-]	3.36E-04	NV	NA	NV	NA	NV	NA	3.80E+03	9E-08	2.40E+04	1E-08	2.40E+04	1E-08
Pyrene	1.01E-02	NV	NA	NV	NA	NV	NA	1.74E+03	6E-06	2.53E+04	4E-07	7.53E+03	1E-06
Pyridine	1.01E-01	NV	NA	NV	NA	NV	NA	7.80E+01	1E-03	1.20E+03	8E-05	1.20E+03	8E-05
RDX	1.50E-01	8.31E+01	2E-08	4.28E+02	4E-09	2.96E+03	5E-10	3.01E+02	5E-04	4.89E+03	3E-05	1.35E+03	1E-04
Styrene	3.36E-04	NV	NA	NV	NA	NV	NA	7.26E+03	5E-08	5.13E+04	7E-09	1.02E+04	3E-08
TATB	3.00E-01	NV	NA	NV	NA	NV	NA	2.20E+03	1E-04	3.20E+04	9E-06	3.20E+04	9E-06
Tetrachlorodibenzodioxin[2,3,7,8-]	1.00E-07	4.90E-05	2E-08	2.38E-04	4E-09	1.72E-03	6E-10	5.06E-05	2E-03	8.08E-04	1E-04	2.26E-04	4E-04
Trichloro-1,2,2-trifluoroethane[1,1,2-]	1.68E-03	NV	NA	NV	NA	NV	NA	5.08E+04	3E-08	2.43E+05	7E-09	4.53E+04	4E-08
Trichlorobenzene[1,2,4-]	1.01E-01	2.40E+02	4E-09	1.25E+03	8E-10	8.54E+03	1E-10	8.29E+01	1E-03	4.23E+02	2E-04	7.91E+01	1E-03
Trichloroethane[1,1,1-]	3.36E-04	NV	NA	NV	NA	NV	NA	1.44E+04	2E-08	7.25E+04	5E-09	1.36E+04	2E-08
Trichloroethane[1,1,2-]	3.36E-04	1.88E+01	2E-10	9.21E+01	4E-11	4.30E+03	8E-13	2.61E+00	1E-04	1.24E+01	3E-05	2.30E+00	1E-04
Trichloroethene	3.36E-04	1.55E+01	2E-10	1.12E+02	3E-11	5.37E+03	6E-13	6.77E+00	5E-05	3.65E+01	9E-06	6.90E+00	5E-05
Trichlorofluoromethane	3.36E-04	NV	NA	NV	NA	NV	NA	1.23E+03	3E-07	6.03E+03	6E-08	1.13E+03	3E-07
Trichlorophenol[2,4,5-]	1.01E-01	NV	NA	NV	NA	NV	NA	6.16E+03	2E-05	9.16E+04	1E-06	2.69E+04	4E-06
Trichlorophenol[2,4,6-]	1.01E-01	4.84E+02	2E-09	2.33E+03	4E-10	1.70E+04	6E-11	6.16E+01	2E-03	9.16E+02	1E-04	2.69E+02	4E-04
Trichloropropane[1,2,3-]	3.36E-04	5.10E-02	7E-08	1.21E+00	3E-09	8.26E+00	4E-10	7.09E+00	5E-05	3.40E+01	1E-05	6.31E+00	5E-05
Trimethylbenzene[1,2,4-]	3.36E-04	NV	NA	NV	NA	NV	NA	3.00E+02	1E-06	1.80E+03	2E-07	1.80E+03	2E-07
Trimethylbenzene[1,3,5-]	3.36E-04	NV	NA	NV	NA	NV	NA	2.70E+02	1E-06	1.50E+03	2E-07	1.50E+03	2E-07

Name	Max. MDL (mg/kg)	Res. Cancer NMSSL (mg/kg)	Res. Cancer Risk	CI Cancer NMSSL (mg/kg)	CI Cancer Risk	Con Cancer NMSSL (mg/kg)	Con Cancer Risk	Res. NC NMSSL (mg/kg)	Res. HQ	CI NC NMSSL	CI HQ	Con NC NMSSL	Con HQ
Vinyl Chloride	3.36E-04	7.42E-01	5E-09	2.84E+01	1E-10	1.61E+02	2E-11	1.13E+02	3E-06	8.16E+02	4E-07	1.62E+02	2E-06
Xylene[1,2-]	3.36E-04	NV	NA	NV	NA	NV	NA	8.05E+02	4E-07	3.94E+03	9E-08	7.36E+02	5E-07
Xylene[1,3-]+Xylene[1,4-]	6.73E-04	NV	NA	NV	NA	NV	NA	8.71E+02	8E-07	4.28E+03	2E-07	7.98E+02	8E-07

Notes: All cancer risks and HQs were below the target levels of $1x10^{-5}$ and 1, respectively
The maximum result is the highest method detection limit (MDL) reported

CI – Commercial/industrial worker
Con – Construction worker
HQ – Hazard quotient
Max – Maximum
mg/kg – Milligram per kilogram
NC - Noncancer
NMSSL – New Mexico soil screening level (NMED 2021)
NA – not applicable
NV – no value
Res - residential

Table 2-4. Human Health Risk Screening For Detected Analytes Above Background

Category	Name	Max Result (mg/kg)	Cancer						Noncancer					
			Res Cancer NMSSL (mg/kg)	**Res Cancer Risk**	**CI Worker Cancer NMSSL (mg/kg)**	**CI Worker Cancer Risk**	**Con Worker Cancer NMSSL (mg/kg)**	**Con Worker Cancer Risk**	**Res Noncancer NMSSL (mg/kg)**	**Res HQ**	**CI NC NMSSL**	**CI HQ**	**Con NC NMSSL**	**Con HQ**
Inorganic	Calcium	7160.00	NV	NA	NV	NA	NV	NA	1.30E+07	5E-04	3.24E+07	2E-04	8.85E+06	8E-04
	Chromium	47.90	NV	NA	NV	NA	NV	NA	1.17E+05	4E-04	1.95E+06	2E-05	5.31E+05	9E-05
	Copper	174.00	NV	NA	NV	NA	NV	NA	3.13E+03	6E-02	5.19E+04	3E-03	1.42E+04	1E-02
	Mercury	0.13	NV	NA	NV	NA	NV	NA	2.35E+01	6E-03	3.89E+02	3E-04	7.71E+01	2E-03
	Vanadium	48.30	NV	NA	NV	NA	NV	NA	3.94E+02	1E-01	6.53E+03	7E-03	6.14E+02	8E-02
	Zinc	62.50	NV	NA	NV	NA	NV	NA	2.35E+04	3E-03	3.89E+05	2E-04	1.06E+05	6E-04
Organic	Benzoic Acid	0.483	NV	NA	NV	NA	NV	NA	2.50E+05	2E-06	3.30E+06	1E-07	3.30E+06	1E-07
	Benzyl Alcohol	1.65	NV	NA	NV	NA	NV	NA	6.30E+03	3E-04	8.20E+04	2E-05	8.20E+04	2E-05
	Butylbenzyl-phthalate	0.0635	2.90E+03	2E-10	1.20E+04	5E-11	1.2E+04	5E-11	1.30E+04	5E-06	1.60E+05	4E-07	1.60E+05	4E-07
	Di-n-butylphthalate	0.1	NV	NA	NV	NA	NV	NA	6.16E+03	2E-05	9.16E+04	1E-06	2.69E+04	4E-06
	Fluoranthene	0.0187	NV	NA	NV	NA	NV	NA	2.32E+03	8E-06	3.37E+04	6E-07	1.00E+04	2E-06
	HMX	6.66	NV	NA	NV	NA	NV	NA	3.85E+03	2E-03	6.33E+04	1E-04	1.74E+04	4E-04
	Pyrene	0.0161	NV	NA	NV	NA	NV	NA	1.74E+03	9E-06	2.53E+04	6E-07	7.53E+03	2E-06
	TATB	6.76	NV	NA	NV	NA	NV	NA	2.20E+03	3E-03	3.20E+04	2E-04	3.20E+04	2E-04
	2,3,6,8 TCDD TEQ	1.33E-06	4.90E-05	3E-07	2.38E-04	6E-08	1.72E-03	8E-09	5.06E-05	3E-02	8.08E-04	2E-03	2.26E-4	6E-03
Cumulative Cancer Risk or Hazard Index				3E-07		6E-08		8E-09		2E-01		1E-02		1E-01

Notes: All cancer risks and HQs were below the target levels of 1x10^{-5} and 1, respectively
CI – Commercial/industrial worker
Con – Construction worker
HQ – Hazard quotient
Max – Maximum
mg/kg – Milligram per kilogram
NC – Noncancer
NMSSL – New Mexico soil screening level (NMED 2021)
NA – Not applicable
NV – No value
Res - Resident

Table 2-5. Dioxin/Furan Data and Human Health TEFs

Parameter Name	TEFs	Point 1 WST39-18-162832		Point 1 Dup WST39-18-162973		Point 2 WST39-18-162974		Point 3 WST39-18-162975		Point 4 WST39-18-162976		Point 5 WST39-18-162977	
		Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	0.01	8.52E-06	1	9.83E-06	1	4.57E-06	1	3.49E-06	1	5.01E-07	0	8.28E-07	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	0.01	9.01E-07	1	1.00E-06	1	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	0.01	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	0.1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	0.0003	7.21E-05	1	8.89E-05	1	3.58E-05	1	2.99E-05	1	1.96E-06	1	5.50E-06	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	0.0003	2.49E-06	1	2.73E-06	1	1.38E-06	1	9.97E-07	0	1.00E-06	0	1.00E-06	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	1	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	0.03	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	0.3	4.98E-07	0	5.02E-07	0	5.02E-07	0	4.98E-07	0	5.01E-07	0	5.01E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1	9.97E-08	0	1.00E-07	0	1.00E-07	0	9.97E-08	0	1.00E-07	0	1.00E-07	0
Tetrachlorodibenzofuran[2,3,7,8-]	0.1	3.65E-07	1	3.63E-07	1	2.01E-07	1	2.57E-07	1	1.05E-07	0	1.36E-07	1

Table 2-5., Dioxin/Furan Data and Human Health TEFs, cont.

Name	Point 6 WST39-18-162978		Point 7 WST39-18-162979		Point 8 WST39-18-162980		Point 9 WST39-18-162981		Point 10 WST39-18-162982	
	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.60E-06	1	5.86E-06	1	1.13E-06	1	6.07E-07	1	5.21E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	7.97E-07	1	2.21E-06	1	4.98E-07	0	4.98E-07	0	6.88E-07	1
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	5.49E-05	1	6.84E-05	1	9.66E-06	1	3.91E-06	1	4.10E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	2.51E-06	1	1.92E-05	1	9.97E-07	0	9.96E-07	0	1.18E-06	1
Pentachlorodibenzodioxin[1,2,3,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	5.02E-07	0	4.98E-07	0	4.98E-07	0	4.98E-07	0	4.99E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1.00E-07	0	9.97E-08	0	9.97E-08	0	9.96E-08	0	9.97E-08	0
Tetrachlorodibenzofuran[2,3,7,8-]	1.87E-07	1	1.16E-07	0	1.44E-07	1	1.06E-07	1	5.50E-07	1

Table 2-5., Dioxin/Furan Data and Human Health TEFs, cont.

Parameter Name	CAS	Point 11 WST39-18-162983		Point 12 WST39-18-162984	
		Result (mg/kg)	DC	Result (mg/kg)	DC
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	35822-46-9	1.17E-05	1	3.01E-06	1
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	67562-39-4	1.10E-06	1	4.96E-07	0
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	55673-89-7	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	39227-28-6	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	57653-85-7	4.98E-07	0	4.96E-07	0
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	19408-74-3	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,4,7,8-]	70648-26-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,6,7,8-]	57117-44-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[1,2,3,7,8,9-]	72918-21-9	4.98E-07	0	4.96E-07	0
Hexachlorodibenzofuran[2,3,4,6,7,8-]	60851-34-5	4.98E-07	0	4.96E-07	0
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	3268-87-9	9.57E-05	1	2.49E-05	1
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	39001-02-0	3.40E-06	1	9.93E-07	0
Pentachlorodibenzodioxin[1,2,3,7,8-]	40321-76-4	4.98E-07	0	4.96E-07	0
Pentachlorodibenzofuran[1,2,3,7,8-]	57117-41-6	4.98E-07	0	4.96E-07	0
Pentachlorodibenzofuran[2,3,4,7,8-]	57117-31-4	4.98E-07	0	4.96E-07	0
Tetrachlorodibenzodioxin[2,3,7,8-]	1746-01-6	9.96E-08	0	9.93E-08	0
Tetrachlorodibenzofuran[2,3,7,8-]	51207-31-9	5.60E-07	1	3.75E-07	1

Notes:
DC- Detect code (1 = detected, 0 = not detected)
mg/kg – milligram per kilogram
TEF – toxicity equivalent factor

Table 2-6. Human Health TECs and TEQs for Dioxin Furan Samples

	Point 1 WST39-18-162832	**Point 1-Dup WST39-18-162973**	**Point 2 WST39-18-162974**	**Point 3 WST39-18-162975**	**Point 4 WST39-18-162976**	**Point 5 WST39-18-162977**	**Point 6 WST39-18-162978**
Congener Name	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.52E-08	9.83E-08	4.57E-08	3.49E-08	5.01E-09	8.28E-09	8.60E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	9.01E-09	1.00E-08	5.02E-09	4.98E-09	5.01E-09	5.01E-09	7.97E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	5.02E-09	5.02E-09	4.98E-09	5.01E-09	5.01E-09	5.02E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.16E-08	2.667E-08	1.074E-08	8.97E-09	5.88E-10	1.65E-09	1.65E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	7.47E-10	8.19E-10	4.14E-10	2.99E-10	3.00E-10	3.00E-10	7.53E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	5.02E-07	5.02E-07	4.98E-07	5.01E-07	5.01E-07	5.02E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	1.49E-08	1.506E-08	1.506E-08	1.49E-08	1.50E-08	1.50E-08	1.51E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	1.49E-07	1.506E-07	1.506E-07	1.49E-07	1.50E-07	1.50E-07	1.51E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	1.00E-07	1.00E-07	9.97E-08	1.00E-07	1.00E-07	1.00E-07
Tetrachlorodibenzofuran[2,3,7,8-]	3.65E-08	3.63E-08	2.01E-08	2.57E-08	1.05E-08	1.36E-08	1.87E-08
TEQ	1.27E-06	1.30 E-06	1.21E-06	1.19E-06	1.14E-06	1.15E-06	1.25E-06

Notes: The TECi are summed in each column to obtain the TEQ.

Table 2-6. Human Health TECs and TEQs for Dioxin Furan Samples, cont.

Congener Name	Point 7 WST39-18-162979	Point 8 WST39-18-162980	Point 9 WST39-18-162981	Point 10 WST39-18-162982	Point 11 WST39-18-162983	Point 12 WST39-18-162984
	TECi	TECi	TECi	TECi	TECi	TECi
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	5.86E-08	1.13E-08	6.07E-09	5.21E-08	1.17E-07	3.01E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	2.21E-08	4.98E-09	4.98E-09	6.88E-09	1.10E-08	4.96E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	4.98E-09	4.98E-09	4.99E-09	4.98E-09	4.96E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.05E-08	2.90E-09	1.17E-09	1.23E-08	2.87E-08	7.47E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	5.76E-09	2.99E-10	2.99E-10	3.54E-10	1.02E-09	2.98E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	4.98E-07	4.98E-07	4.99E-07	4.98E-07	4.96E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	1.49E-08	1.49E-08	1.49E-08	1.50E-08	1.49E-08	1.49E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	1.49E-07	1.49E-07	1.49E-07	1.50E-07	1.49E-07	1.49E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	9.97E-08	9.96E-08	9.97E-08	9.96E-08	9.93E-08
Tetrachlorodibenzofuran[2,3,7,8-]	1.16E-08	1.44E-08	1.06E-08	5.50E-08	5.60E-08	3.75E-08
TEQ	1.23E-06	1.15E-06	1.14E-06	1.24E-06	1.33E-06	1.19E-06

Notes: Shaded cell indicates the maximum TEQ
TECi – toxicity equivalent concentration for each congener (product of measured concentration or MDL for nondetects and the TEF)
TEF – toxicity equivalent factor
TEQ – toxicity equivalent quotient (sum of the TECi values)

Table 2-7. Maximum 2,3,7,8 TCDD TEQ Cancer Risk and Hazard by Receptor

Receptor	Maximum TCDD TEQ (mg/kg)	NMSSL TCDD-Cancer (mg/kg)	Cancer Risk	NMSSL – TCDD Noncancer (mg/kg)	HQ
Residential	1.33E-06	4.90E-05	3E-07	5.06E-05	3E-02
Commercial/Industrial	1.33E-06	2.38E-04	6E-08	8.08E-04	2E-03
Construction Worker	1.33E-06	1.72E-03	8E-09	2.26E-04	6E-03

Table 2-8. Comparison of Maximum EPCs to Groundwater Protection Screening Levels

Category	Name	Maximum Result (mg/kg)	MTGW SL (mg/kg)	Maximum/ MTGW Ratio
Inorganics	Calcium	7160.00	NV	NA
	Chromium	47.90	4.91E+08	1E-07
	Copper	174.00	9.15E+02	2E-01
	Mercury	0.13	5.13E+00	3E-02
	Vanadium	48.30	1.26E+03	4E-02
	Zinc	62.50	7.41E+03	8E-03
Organics	Benzoic Acid	0.483	3.00E+02	2E-03
	Benzyl Alcohol	1.65	9.60E+00	2E-01
	Butylbenzylphthalate	0.0635	4.80E+01	1E-03
	Di-n-butylphthalate	0.1	3.38E+01	3E-03
	Fluoranthene	0.0187	1.34E+03	1E-05
	HMX	6.66	1.94E+01	3E-01
	Pyrene	0.0161	1.92E+02	8E-05
	TATB	6.76	4.20E+01	2E-01
Dioxin/Furans	2,3,7,8 TCDD TEQ	1.33E-06	2.24E-04	6E-03

Notes: Ratios are less than 1 indicating maximum values are below MTGW SLs
mg/kg- milligram per kilogram
MTGW SL – NMED (2021) groundwater protection screening level

Table 3-1. Ecological Screening Levels

Group	Name	No Effect ESL									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganics	Chromium (total)	8.60E+02	1.70E+02	5.10E+01	2.30E+01	3.20E+01	1.10E+02			1.80E+03	4.10E+02
	Copper	1.10E+03	8.00E+01	3.40E+01	1.40E+01	2.00E+01	6.30E+01	8.00E+01	7.00E+01	4.00E+03	2.60E+02
	Mercury (inorganic)	3.20E-01	5.80E-02	6.70E-02	1.30E-02	2.20E-02	3.00E+00	5.00E-02	3.40E+01	7.60E+01	2.30E+01
	Vanadium	1.10E+02	5.60E+01	6.80E+00	4.70E+00	5.50E+00	4.70E+02		6.00E+01	3.20E+03	7.40E+02
	Zinc	2.60E+03	2.20E+02	3.30E+02	4.70E+01	8.30E+01	1.70E+02	1.20E+02	1.60E+02	9.60E+03	1.80E+03
Dioxin/ Furan	Tetrachlorodibenzo dioxin[2,3,7,8-]	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	5.80E-07	5.00E+00		1.00E-04	4.00E-05
Explosive	HMX						2.90E+02	1.60E+01	2.70E+03	5.90E+04	4.10E+02
	TATB						1.10E+02	1.00E+01		1.00E+04	1.50E+02
PA Hs	Fluoranthene						3.80E+01	1.00E+01		3.90E+03	2.70E+02
	Pyrene	3.00E+03	1.60E+02	6.80E+01	3.30E+01	4.40E+01	3.10E+01	1.00E+01		3.10E+03	1.10E+02
SVOCs	Benzoic Acid						1.30E+00			2.00E+03	4.60E+00
	Butyl Benzyl Phthalate						1.60E+02			2.30E+04	2.40E+03
	Di-n-Butyl Phthalate	2.00E+00	5.20E-02	3.80E-01	1.10E-02	2.10E-02	3.60E+02		1.60E+02	6.20E+04	1.70E+04
VOC	Benzyl Alcohol						1.20E+02			1.10E+05	1.90E+02

Group	Analyte Name	Low Effect ESL									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganics	Chromium (total)	2.70E+03	5.60E+02	1.60E+02	7.30E+01	1.00E+02	1.10E+04			1.80E+05	4.10E+04
	Copper	3.50E+03	2.40E+02	1.00E+02	4.30E+01	6.00E+01	1.00E+02	5.30E+02	4.90E+02	6.70E+03	4.30E+02
	Mercury (inorganic)	3.20E+00	5.80E-01	6.70E-01	1.30E-01	2.20E-01	3.00E+01	5.00E-01	6.40E+01	7.60E+02	2.30E+02
	Vanadium	2.30E+02	1.10E+02	1.30E+01	9.50E+00	1.10E+01	1.00E+03		8.00E+01	6.90E+03	1.50E+03
	Zinc	7.00E+03	5.90E+02	1.20E+02	1.20E+02	2.20E+02	1.70E+03	9.30E+02	8.10E+02	9.40E+04	1.80E+04
Dioxin/ Furan	2,3,7,8 TCDD						3.80E-06	1.00E+01		6.80E-04	2.70E-04
Explosive	HMX						7.90E+02	1.60E+02	3.50E+03	1.50E+05	1.10E+03
	TATB						1.10E+03	2.80E+01		1.00E+05	1.50E+03
PAH	Fluoranthene						3.80E+02	2.30E+01		3.90E+04	2.70E+03
	Pyrene	3.00E+04	1.60E+03	6.80E+02	3.30E+02	4.40E+02	3.10E+02	2.00E+01		3.10E+04	1.10E+03
SVOC	Benzoic Acid						1.30E+01			2.00E+04	4.60E+01
	Butyl Benzyl Phthalate						1.60E+03			2.30E+05	2.40E+04
	Di-n-Butyl Phthalate	2.00E+01	5.20E-01	3.80E+00	1.10E-01	2.10E-01	8.60E+02		6.00E+02	1.40E+05	4.00E+04
VOC	Benzyl Alcohol						1.20E+03			1.10E+06	1.90E+03

Notes: ESL source LANL (2020)
Only detected analytes and inorganics above background are reported.

Abbreviations:
BV – Background Value
ESL – Ecological Screening Value
Max– Maximum Exposure Point Concentration
mg/kg – Milligram per Kilogram
LE – Low Effect
NE – No Effect

Table 3-2. Ecological Risk Evaluation For Maximum EPCs and NE ESLs

Category	Parameter Name	Maximum EPC (mg/kg)	Number of Detects	American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganic	Calcium	7160	13	NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
	Chromium	47.9	13	6E-02	3E-01	9E-01	2E+00	1E+00	4E-01	NV	NV	3E-02	1E-01
	Copper	174	13	2E-01	2E+00	5E+00	1E+01	9E+00	3E+00	2E+00	2E+00	4E-02	7E-01
	Mercury	0.131	7	4E-01	2E+00	2E+00	1E+01	6E+00	4E-02	3E+00	4E-03	2E-03	6E-03
	Vanadium	48.3	13	4E-01	9E-01	7E+00	1E+01	9E+00	1E-01	NV	8E-01	2E-02	7E-02
	Zinc	62.5	13	2E-02	3E-01	2E-01	1E+00	8E-01	4E-01	5E-01	4E-01	7E-03	3E-02
Organic	Benzoic Acid	0.483	1	NV	NV	NV	NV	NV	4E-01	NV	NV	2E-04	1E-01
	Benzyl Alcohol	1.65	7	NV	NV	NV	NV	NV	1E-02	NV	NV	2E-05	9E-03
	Butylbenzylphthalate	0.0635	2	NV	NV	NV	NV	NV	4E-04	NV	NV	3E-06	3E-05
	Di-n-butylphthalate	0.1	5	5E-02	2E+00	3E-01	9E+00	5E+00	3E-04	NV	6E-04	2E-06	6E-06
	Fluoranthene	0.0187	1	NV	NV	NV	NV	NV	5E-04	2E-03	NV	5E-06	7E-05
	HMX	6.66	7	NV	NV	NV	NV	NV	2E-02	4E-01	2E-03	1E-04	2E-02
	Pyrene	0.0161	1	5E-06	1E-04	2E-04	5E-04	4E-04	5E-04	2E-03	NV	5E-06	1E-04
	TATB	6.76	6	NV	NV	NV	NV	NV	6E-02	7E-01	NV	7E-04	5E-02
	2,3,7,8 TCDD TEQ [Bird]	2.02E-06	NA	5E-01	5E-01	5E-01	5E-01	5E-01	NV	NV	NV	NV	NV
	2,3,7,8 TCDD TEQ [Mammal]	1.33E-06	NA	NV	NV	NV	NV	NV	2E+00	3E-07	NV	1E-02	5E+00
	Hazard Index (HI)			2E+00	8E+00	2E+01	5E+01	3E+01	6E+00	6E+00	4E+00	1E-01	6E+00

Notes:
Shaded cells indicate the ratio > 0.1 for initial screening evaluation
HI is the sum of all HQs

Abbreviations:
EPC – exposure point concentration
ESL – ecological screening level
HI – hazard Index
mg/kg – milligram per kilogram
NE – no effect
NV – No value

Table 3-3. Ecological Risk Evaluation For Refined EPCs and LE ESLs

Analyte Name	Refined EPC (mg/kg)	Hazard Quotients (HQs) for Refined EPCs and LE ESLs									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Calcium	5624	NV	NV	NV	NV	NV	NV	NV	NV	NV	NV
Chromium (total)	23.27	9E-03	4E-02	1E-01	3E-01	2E-01	2E-03	NV	NV	1E-04	6E-04
Copper	109.4	3E-02	5E-01	1E+00	3E+00	2E+00	1E+00	2E-01	2E-01	2E-02	3E-01
Mercury (inorganic)	0.054	2E-02	9E-02	8E-02	4E-01	2E-01	2E-03	1E-01	8E-04	7E-05	2E-04
Vanadium	38.2	2E-01	3E-01	3E+00	4E+00	3E+00	4E-02	NV	5E-01	6E-03	3E-02
Zinc	45.51	7E-03	8E-02	4E-01	4E-01	2E-01	3E-02	5E-02	6E-02	5E-04	3E-03
Benzoic Acid	0.168	NV	NV	NV	NV	NV	1E-02	NV	NV	8E-06	4E-03
Benzyl Alcohol	0.683	NV	NV	NV	NV	NV	6E-04	NV	NV	6E-07	4E-04
Butyl Benzyl Phthalate	0.010	NV	NV	NV	NV	NV	6E-06	NV	NV	4E-08	4E-07
Di-n-Butyl Phthalate	0.010	5E-04	2E-02	3E-03	9E-02	5E-02	1E-05	NV	2E-05	7E-08	3E-07
Fluoranthene	0.010	NV	NV	NV	NV	NV	3E-05	4E-04	NV	3E-07	4E-06
HMX	3.874	NV	NV	NV	NV	NV	5E-03	2E-02	1E-03	3E-05	4E-03
Pyrene	0.010	3E-07	6E-06	1E-05	3E-05	2E-05	3E-05	5E-04	NV	3E-07	9E-06
TATB	2.938	NV	NV	NV	NV	NV	3E-03	1E-01	NV	3E-05	2E-03
2,3,7,8 TCDD TEQ	1.8E-06 (bird) 1.24-06 (mammal)	NV	NV	NV	NV	NV	3E-01	1E-07	NV	2E-03	5E-03
Hazard Index		2E-01	1E+00	5E+00	8E+00	6E+00	1E+00	5E-01	8E-01	2E-02	3E-01

Notes:Shaded cells indicate the ratio > 0.1
Hazard Index is the sum of all HQs

Abbreviations:
EPC – Exposure point concentration
ESL – Ecological Screening Level
HQ – Hazard quotient
LE – Low Effect
mg/kg – milligram per kilogram
NV – No value

Table 3-4. Toxic Equivalency Factors (TEFs) Used for Calculating Ecological TCDD Equivalent Concentrations

Name	CAS	Mammalian TEF[a]	Avian TEF[b]
Chlorinated dibenzo-p-dioxins			
2,3,7,8-TCDD	1746-01-6	1	1
1,2,3,7,8-PeCDD	40321-76-4	1	1
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HpCDD	35822-46-9	0.01	0.001
OCDD	3268-87-9	0.0003	0.0001
Chlorinated dibenzofurans			
2,3,7,8-TCDF	51207-31-9	0.1	1
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1
2,3,4,7,8-PeCDF	57117-31-4	0.3	0.1
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	1
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01
OCDF	39001-02-0	0.0003	0.0001

[a] EPA (2010a,b); WHO (2009)
[b] Van den Berg et al. (1998)

Table 3-5. Dioxin-Furan Mammal TECi, and TEQs by Sample

	Point 1 WST39-18-162832	**Point 1-Dup WST39-18-162973**	**Point 2 WST39-18-162974**	**Point 3 WST39-18-162975**	**Point 4 WST39-18-162976**	**Point 5 WST39-18-162977**	**Point 6 WST39-18-162978**
Congener Name	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.52E-08	9.83E-08	4.57E-08	3.49E-08	5.01E-09	8.28E-09	8.60E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	9.01E-09	1.00E-08	5.02E-09	4.98E-09	5.01E-09	5.01E-09	7.97E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	5.02E-09	5.02E-09	4.98E-09	5.01E-09	5.01E-09	5.02E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.16E-08	2.67E-08	1.07E-08	8.97E-09	5.88E-10	1.65E-09	1.65E-08
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	7.47E-10	8.19E-10	4.14E-10	2.99E-10	3.00E-10	3.00E-10	7.53E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	5.02E-07	5.02E-07	4.98E-07	5.01E-07	5.01E-07	5.02E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	1.49E-08	1.51E-08	1.51E-08	1.49E-08	1.50E-08	1.50E-08	1.51E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	1.49E-07	1.51E-07	1.51E-07	1.49E-07	1.50E-07	1.50E-07	1.51E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	1.00E-07	1.00E-07	9.97E-08	1.00E-07	1.00E-07	1.00E-07
Tetrachlorodibenzofuran[2,3,7,8-]	3.65E-08	3.63E-08	2.01E-08	2.57E-08	1.05E-08	1.36E-08	1.87E-08
TEQ	**1.27E-06**	**1.30E-06**	**1.21E-06**	**1.19E-06**	**1.14E-06**	**1.15E-06**	**1.25E-06**

Table 3-5. Dioxin-Furan Mammal TECi, and TEQs by Sample, cont.

	Point 7 WST39-18-162979	**Point 8 WST39-18-162980**	**Point 9 WST39-18-162981**	**Point 10 WST39-18-162982**	**Point 11 WST39-18-162983**	**Point 12 WST39-18-162984**
Congener Name	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	5.86E-08	1.13E-08	6.07E-09	5.21E-08	1.17E-07	3.01E-08
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	2.21E-08	4.98E-09	4.98E-09	6.88E-09	1.10E-08	4.96E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	4.98E-09	4.98E-09	4.99E-09	4.98E-09	4.96E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	2.05E-08	2.90E-09	1.17E-09	1.23E-08	2.87E-08	7.47E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	5.76E-09	2.99E-10	2.99E-10	3.54E-10	1.02E-09	2.98E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	4.98E-07	4.98E-07	4.99E-07	4.98E-07	4.96E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	1.49E-08	1.49E-08	1.49E-08	1.50E-08	1.49E-08	1.49E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	1.49E-07	1.49E-07	1.49E-07	1.50E-07	1.49E-07	1.49E-07
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	9.97E-08	9.96E-08	9.97E-08	9.96E-08	9.93E-08
Tetrachlorodibenzofuran[2,3,7,8-]	1.16E-08	1.44E-08	1.06E-08	5.50E-08	5.60E-08	3.75E-08
TEQ	**1.23E-06**	**1.15E-06**	**1.14E-06**	**1.24E-06**	**1.33E-06**	**1.19E-06**

Notes: The data and detection status were reported in Table 2-5. The TEFs for mammals are reported in Table 3-4.
All data in mg/kg.

Abbreviations:
TECi – Toxicity Equivalent Concentration for Congener i;
TEF – Toxicity Equivalency Factor;
TEQ – Toxicity Equivalent Quotient

Table 3-6. Dioxin-Furan Avian TECs and TEQs by Sample	**Point 1 WST39-18-162832**	**Point 1-Dup WST39-18-162973**	**Point 2 WST39-18-162974**	**Point 3 WST39-18-162975**	**Point 4 WST39-18-162976**	**Point 5 WST39-18-162977**	**Point 6 WST39-18-162978**
Congener Name	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	8.52E-09	9.83E-09	4.57E-09	3.49E-09	5.01E-10	8.28E-10	8.60E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	9.01E-09	1.00E-08	5.02E-09	4.98E-09	5.01E-09	5.01E-09	7.97E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	5.02E-09	5.02E-09	4.98E-09	5.01E-09	5.01E-09	5.02E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	2.49E-08	2.51E-08	2.51E-08	2.49E-08	2.51E-08	2.51E-08	2.51E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-09	5.02E-09	5.02E-09	4.98E-09	5.01E-09	5.01E-09	5.02E-09
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-07	5.02E-07	5.02E-07	4.98E-07	5.01E-07	5.01E-07	5.02E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	7.21E-09	8.89E-09	3.58E-09	2.99E-09	1.96E-10	5.50E-10	5.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	2.49E-10	2.73E-10	1.38E-10	9.97E-11	1.00E-10	1.00E-10	2.51E-10
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	5.02E-07	5.02E-07	4.98E-07	5.01E-07	5.01E-07	5.02E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	4.98E-08	5.02E-08	5.02E-08	4.98E-08	5.01E-08	5.01E-08	5.02E-08
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	1.00E-07	1.00E-07	9.97E-08	1.00E-07	1.00E-07	1.00E-07
Tetrachlorodibenzofuran[2,3,7,8-]	3.65E-07	3.63E-07	2.01E-07	2.57E-07	1.05E-07	1.36E-07	1.87E-07
TEQ	**1.82E-06**	**1.83E-06**	**1.65E-06**	**1.70E-06**	**1.55E-06**	**1.58E-06**	**1.65E-06**

Table 3-6. Dioxin-Furan Avian TECs and TEQs by Sample, cont.

Congener Name	Point 7 WST39-18-162979	Point 8 WST39-18-162980	Point 9 WST39-18-162981	Point 10 WST39-18-162982	Point 11 WST39-18-162983	Point 12 WST39-18-162984
	TECi	**TECi**	**TECi**	**TECi**	**TECi**	**TECi**
Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	5.86E-09	1.13E-09	6.07E-10	5.21E-09	1.17E-08	3.01E-09
Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	2.21E-08	4.98E-09	4.98E-09	6.88E-09	1.10E-08	4.96E-09
Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	4.98E-09	4.98E-09	4.98E-09	4.99E-09	4.98E-09	4.96E-09
Hexachlorodibenzodioxin[1,2,3,4,7,8-]	2.49E-08	2.49E-08	2.49E-08	2.50E-08	2.49E-08	2.48E-08
Hexachlorodibenzodioxin[1,2,3,6,7,8-]	4.98E-09	4.98E-09	4.98E-09	4.99E-09	4.98E-09	4.96E-09
Hexachlorodibenzodioxin[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,4,7,8-]	4.98E-07	4.98E-07	4.98E-07	4.99E-07	4.98E-07	4.96E-07
Hexachlorodibenzofuran[1,2,3,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[1,2,3,7,8,9-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Hexachlorodibenzofuran[2,3,4,6,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	6.84E-09	9.66E-10	3.91E-10	4.10E-09	9.57E-09	2.49E-09
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	1.92E-09	9.97E-11	9.96E-11	1.18E-10	3.40E-10	9.93E-11
Pentachlorodibenzodioxin[1,2,3,7,8-]	4.98E-07	4.98E-07	4.98E-07	4.99E-07	4.98E-07	4.96E-07
Pentachlorodibenzofuran[1,2,3,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Pentachlorodibenzofuran[2,3,4,7,8-]	4.98E-08	4.98E-08	4.98E-08	4.99E-08	4.98E-08	4.96E-08
Tetrachlorodibenzodioxin[2,3,7,8-]	9.97E-08	9.97E-08	9.96E-08	9.97E-08	9.96E-08	9.93E-08
Tetrachlorodibenzofuran[2,3,7,8-]	1.16E-07	1.44E-07	1.06E-07	5.50E-07	5.60E-07	3.75E-07
TEQ	**1.58E-06**	**1.58E-06**	**1.54E-06**	**2.00E-06**	**2.02E-06**	**1.81E-06**

Notes: The data and detection status were reported in Table 2-5. The TEFs for birds are reported in Table 3-4.
All data in mg/kg.

Abbreviations:
TECi – Toxicity Equivalent Concentration for Congener i;
TEF – Toxicity Equivalency Factor;
TEQ – Toxicity Equivalent Quotient

Table 3-7. Area Use Factors for TA 39-6 and Risks based on the NE ESL

COPC Name	CAS	No Effect Ecological Screening Levels (ESLs) for Terrestrial Receptors (mg/kg)									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Calcium	Ca	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL
Chromium (total)	16065-83-1	860	170	51	23	32	110	No ESL	No ESL	1800	410
Copper	7440-50-8	1100	80	34	14	20	63	80	70	4000	260
Mercury (inorganic)	7487-94-7	0.32	0.058	0.067	0.013	0.022	3	0.05	34	76	23
Vanadium	7440-62-2	110	56	6.8	4.7	5.5	470	No ESL	60	3200	740
Zinc	7440-66-6	2600	220	330	47	83	170	120	160	9600	1800
Benzoic Acid	65-85-0	No ESL	No ESL	No ESL	No ESL	No ESL	1.3	No ESL	No ESL	2000	4.6
Benzyl Alcohol	100-51-6	No ESL	No ESL	No ESL	No ESL	No ESL	120	No ESL	No ESL	110000	190
Butylbenzylphthalate	85-68-7	No ESL	No ESL	No ESL	No ESL	No ESL	160	No ESL	No ESL	23000	2400
Di-n-butylphthalate	84-74-2	2	0.052	0.38	0.011	0.021	360	No ESL	160	62000	17000
Fluoranthene	206-44-0	No ESL	No ESL	No ESL	No ESL	No ESL	38	10	No ESL	3900	270
HMX	2691-41-0	No ESL	No ESL	No ESL	No ESL	No ESL	290	16	2700	59000	410
Pyrene	129-00-0	3000	160	68	33	44	31	10	No ESL	3100	110
TATB	3058-38-6	No ESL	No ESL	No ESL	No ESL	No ESL	110	10	No ESL	10000	150
2,3,7,8 TCDD	1746-01-6	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	5.80E-07	5.00E+00	No ESL	1.00E-04	4.00E-05

HR (ha)[a]	106	106	0.42	0.42	0.42	0.077	NA	NA	1038	3.1
Population Area[b]	4240	4240	16.8	16.8	16.8	3.08	NA	NA	41520	124
PAUF[c]	0.000004	0.000004	0.001	0.001	0.001	0.005	NA	NA	2.41E-07	0.0001
AUF[d]	0.0001	0.0001	0.04	0.04	0.04	0.19	NA	NA	9.63E-06	0.005

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted NE ESL Hazard Quotients									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganics											
Calcium	5624.00	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL
Chromium	23.27	1E-07	5E-07	4E-04	9E-04	6E-04	1E-03	No ESL	No ESL	3E-09	7E-06
Copper	109.40	4E-07	5E-06	3E-03	7E-03	5E-03	8E-03	1E+00	2E+00	7E-09	5E-05
Mercury	0.0536	6E-07	3E-06	7E-04	4E-03	2E-03	9E-05	1E+00	2E-03	2E-10	3E-07
Vanadium	38.20	1E-06	2E-06	5E-03	7E-03	6E-03	4E-04	No ESL	6E-01	3E-09	6E-06
Zinc	45.51	6E-08	7E-07	1E-04	9E-04	5E-04	1E-03	4E-01	3E-01	1E-09	3E-06
Organics											
Benzoic Acid	0.168	No ESL	No ESL	No ESL	No ESL	No ESL	6E-04	No ESL	No ESL	2E-11	4E-06
Benzyl Alcohol	0.683	No ESL	No ESL	No ESL	No ESL	No ESL	3E-05	No ESL	No ESL	1E-12	4E-07
Butylbenzylphthalate	0.01	No ESL	No ESL	No ESL	No ESL	No ESL	3E-07	No ESL	No ESL	1E-13	5E-10
Di-n-butylphthalate	0.01	2E-08	7E-07	2E-05	8E-04	4E-04	1E-07	No ESL	6E-05	4E-14	7E-11
Fluoranthene	0.01	No ESL	No ESL	No ESL	No ESL	No ESL	1E-06	1E-03	No ESL	6E-13	4E-09
HMX	3.874	No ESL	No ESL	No ESL	No ESL	No ESL	7E-05	2E-01	1E-03	2E-11	1E-06
Pyrene	0.01	1E-11	2E-10	1E-07	3E-07	2E-07	2E-06	1E-03	No ESL	8E-13	1E-08
TATB	2.938	No ESL	No ESL	No ESL	No ESL	No ESL	1E-04	3E-01	No ESL	7E-11	2E-06
2,3,7,8 TCDD (bird)	1.80E-06	2E-06	2E-06	4E-04	4E-04	4E-04	NA	NA	NA	NA	NA
2,3,7,8 TCDD (mammal)	1.24E-06	NA	NA	NA	NA	NA	1E-02	2E-07	No ESL	3E-09	4E-06
Hazard Index		4E-06	1E-05	1E-02	2E-02	2E-02	2E-02	3E+00	2E+00	2E-08	8E-05

Notes: the mammal TCDD TEQ is used for earthworms

Area of Site (ha): 0.015

NA - Not applicable	PAUF - Population area use factor	HR - Home range
ESLs - Ecological screening level	AUF - Area use factor	

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

Table 3-8. Area Use Factors for TA 39-6 and Risks based on the LE ESL.

COPC Name	CAS	Low Effect Ecological Screening Levels (LE ESLs) for Terrestrial Receptors (mg/kg)									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Calcium	Ca	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL
Chromium (total)	16065-83-1	2700	560	160	73	100	11000	No ESL	No ESL	180000	41000
Copper	7440-50-8	3500	240	100	43	60	100	530	490	6700	430
Mercury (inorganic)	7487-94-7	3.2	0.58	0.67	0.13	0.22	30	0.5	64	760	230
Vanadium	7440-62-2	230	110	13	9.5	11	1000	No ESL	80	6900	1500
Zinc	7440-66-6	7000	590	120	120	220	1700	930	810	94000	18000
Benzoic Acid	65-85-0	No ESL	No ESL	No ESL	No ESL	No ESL	13	No ESL	No ESL	20000	46
Benzyl Alcohol	100-51-6	No ESL	No ESL	No ESL	No ESL	No ESL	1200	No ESL	No ESL	1100000	1900
Butylbenzylphthalate	85-68-7	No ESL	No ESL	No ESL	No ESL	No ESL	1600	No ESL	No ESL	230000	24000
Di-n-butylphthalate	84-74-2	20	0.52	3.8	0.11	0.21	860	No ESL	600	140000	40000
Fluoranthene	206-44-0	No ESL	No ESL	No ESL	No ESL	No ESL	380	23	No ESL	39000	2700
HMX	2691-41-0	No ESL	No ESL	No ESL	No ESL	No ESL	790	160	3500	150000	1100
Pyrene	129-00-0	30000	1600	680	330	440	310	20	No ESL	31000	1100
TATB	3058-38-6	No ESL	No ESL	No ESL	No ESL	No ESL	1100	28	No ESL	100000	1500
2,3,7,8 TCDD	1746-01-6	No ESL	No ESL	No ESL	No ESL	No ESL	0.0000038	10	No ESL	0.00068	0.00027

HR (ha)[a]	106	106	0.42	0.42	0.42	0.077	NA	NA	1038	3.1
Population Area[b]	4240	4240	16.8	16.8	16.8	3.08	NA	NA	41520	124
PAUF[c]	0.000004	0.000004	0.001	0.001	0.001	0.005	NA	NA	2.41E-07	0.0001
AUF[d]	0.0001	0.0001	0.04	0.04	0.04	0.19	NA	NA	9.63E-06	0.005

COPC Name	UCL95 EPC (mg/kg)	Population Area Use Adjusted LE ESL Hazard Quotients									
		American kestrel (Avian top carnivore)	American kestrel (insectivore / carnivore)	American robin (Avian herbivore)	American robin (Avian insectivore)	American robin (Avian omnivore)	Deer mouse (Mammalian omnivore)	Earthworm (Soil-dwelling invertebrate)	Generic plant (Terrestrial autotroph - producer)	Gray fox (Mammalian top carnivore)	Mountain cottontail (Mammalian herbivore)
Inorganics											
Calcium	5624.00	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL	No ESL
Chromium	23.27	3E-08	1E-07	1E-04	3E-04	2E-04	1E-05	No ESL	No ESL	3E-11	7E-08
Copper	109.40	1E-07	2E-06	1E-03	2E-03	2E-03	5E-03	2E-01	2E-01	4E-09	3E-05
Mercury	0.0536	6E-08	3E-07	7E-05	4E-04	2E-04	9E-06	1E-01	8E-04	2E-11	3E-08
Vanadium	38.20	6E-07	1E-06	3E-03	4E-03	3E-03	2E-04	No ESL	5E-01	1E-09	3E-06
Zinc	45.51	2E-08	3E-07	3E-04	3E-04	2E-04	1E-04	5E-02	6E-02	1E-10	3E-07
Organics											
Benzoic Acid	0.168	No ESL	No ESL	No ESL	No ESL	No ESL	6E-05	No ESL	No ESL	2E-12	4E-07
Benzyl Alcohol	0.683	No ESL	No ESL	No ESL	No ESL	No ESL	3E-06	No ESL	No ESL	1E-13	4E-08
Butylbenzylphthalate	0.01	No ESL	No ESL	No ESL	No ESL	No ESL	3E-08	No ESL	No ESL	1E-14	5E-11
Di-n-butylphthalate	0.01	2E-09	7E-08	2E-06	8E-05	4E-05	6E-08	No ESL	2E-05	2E-14	3E-11
Fluoranthene	0.01	No ESL	No ESL	No ESL	No ESL	No ESL	1E-07	4E-04	No ESL	6E-14	4E-10
HMX	3.874	No ESL	No ESL	No ESL	No ESL	No ESL	2E-05	2E-02	1E-03	6E-12	4E-07
Pyrene	0.01	1E-12	2E-11	1E-08	3E-08	2E-08	2E-07	5E-04	No ESL	8E-14	1E-09
TATB	2.938	No ESL	No ESL	No ESL	No ESL	No ESL	1E-05	1E-01	No ESL	7E-12	2E-07
2,3,7,8 TCDD TEQ (mammal)	1.24E-06	No ESL	No ESL	No ESL	No ESL	No ESL	2E-03	1E-07	No ESL	4E-10	6E-07
Hazard Index		8E-07	4E-06	4E-03	7E-03	5E-03	7E-03	5E-01	8E-01	6E-09	4E-05

Notes: the mammal TCDD TEQ is used for earthworms

Area of Site (ha): 0.015

NA - Not applicable	PAUF - Population area use factor
ESLs - Ecological screening level	AUF - Area use factor

HR - Home range

a - Values from USEPA (1993)
b - Derived as 40*HR
c - PAUF is the area of site divided by the Population Area
d - AUF is the area of the site divided by the HR; AUF cannot exceed 1 and value is set to 1 if calculation results in a higher value

FIGURES

Figure 1-1. Location of TA-39 at the Los Alamos National Laboratory

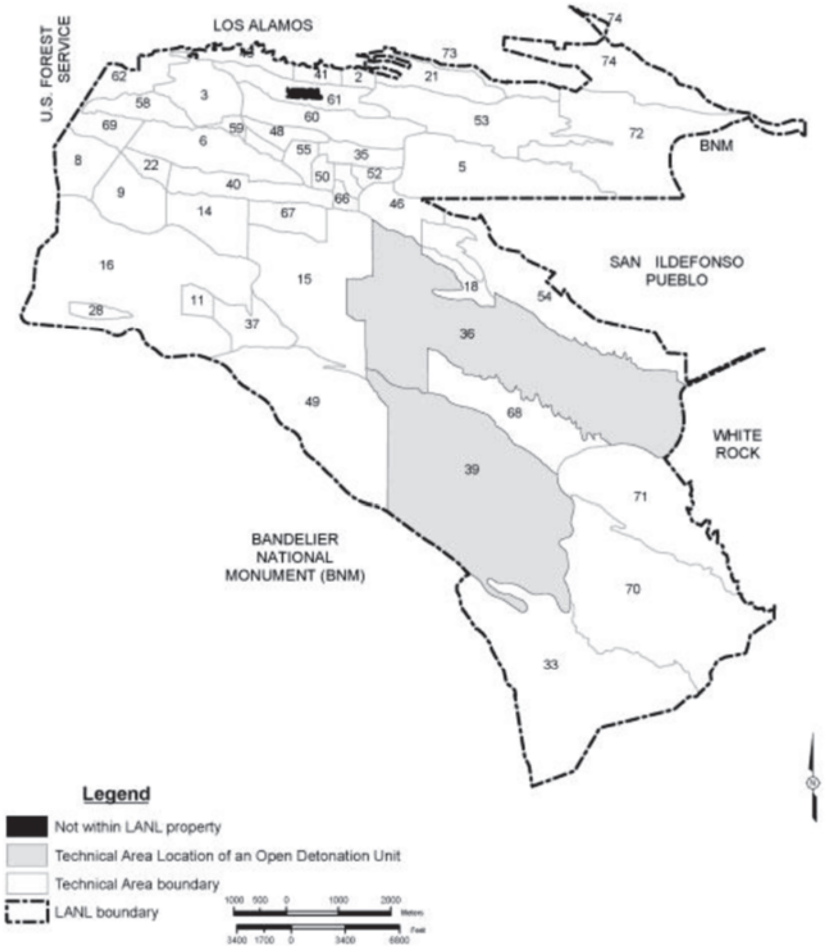


Figure 1-2. Sample Location Map for TA-39-6 OD Area

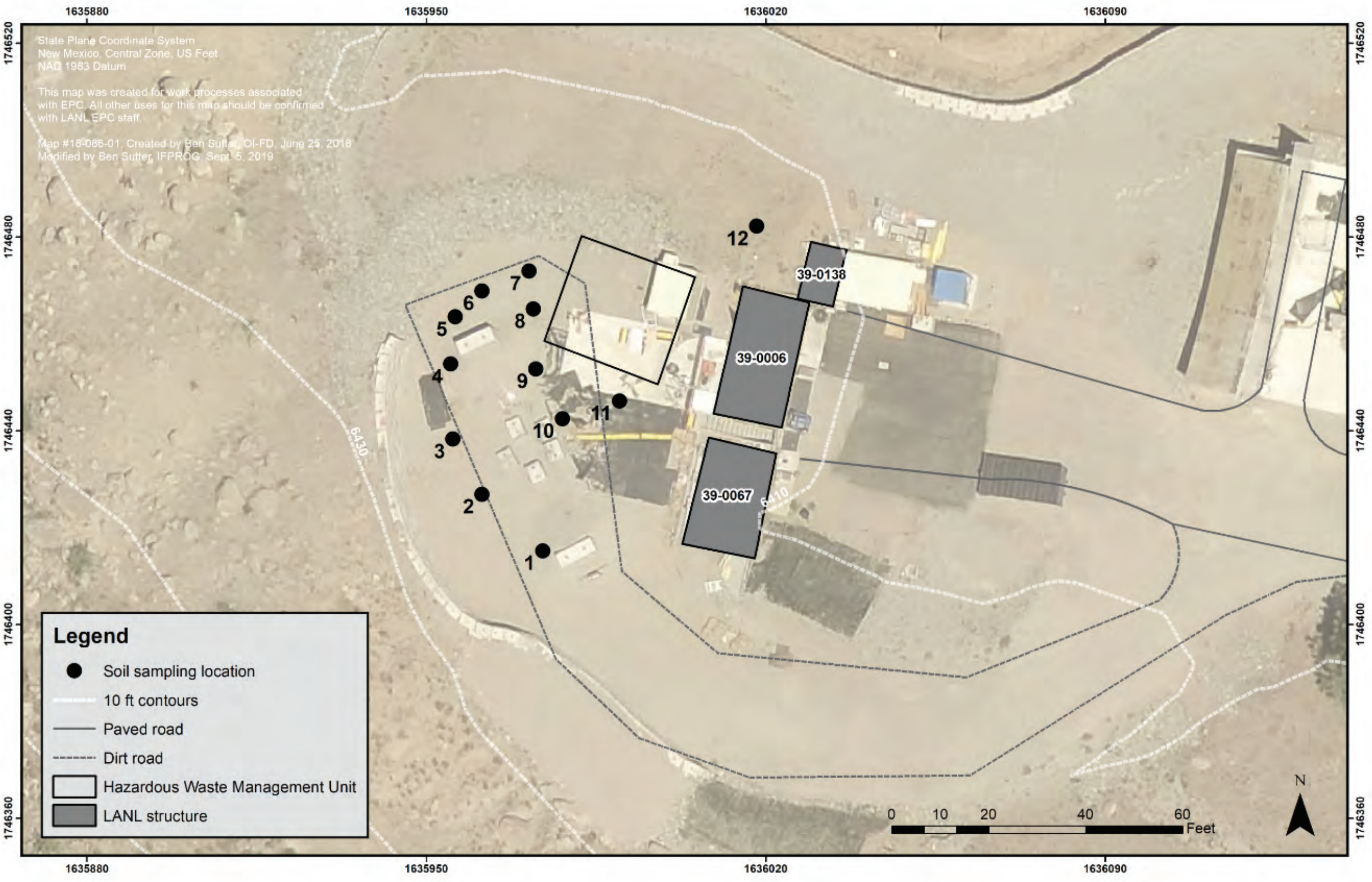
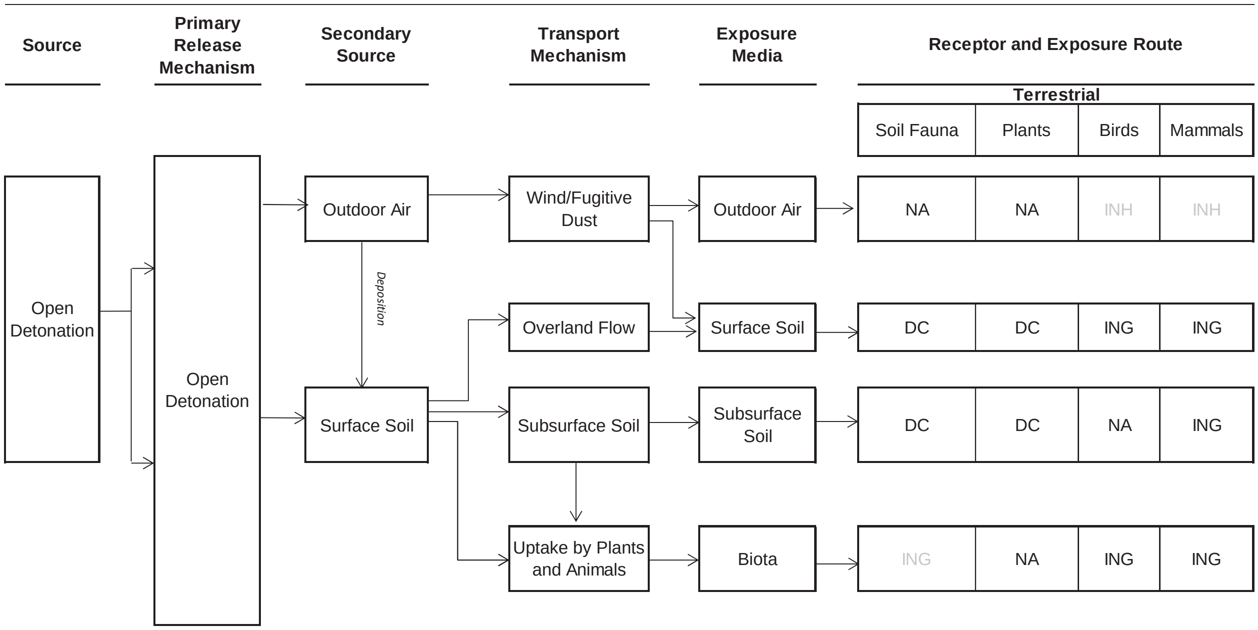


Figure 3-1. Conceptual Site Exposure Model for the ERA



Abbreviations

DC	Direct contact; applies to receptors for which toxic effects are addressed by exposure concentration and not dose
ING	Ingestion; typically quantified as dose for birds and mammals only
INH	Inhalation; recognized to occur, but not typically quantified as standard practice with the exception of evaluating burrow air exposure by burrowing mammals
NA	Pathway considered incomplete; not applicable

Notes:

Grayed text indicates pathways are recognized to potentially exist but are not quantified. Inhalation is considered minimal relative to dietary exposure. Ingestion by invertebrates is not typically quantified due to absence of accurate exposure parameters.

ATTACHMENT A. PROUCL OUTPUT FOR UPPER CONFIDENCE LIMIT CALCULATIONS

Summary of UCL95s Used in ERA. ProUCL output is reported below.

ERA	UCL95 (mg/kg)	UCL Type	Distribution
Calcium	5624.00	95% Student's-t UCL	Normal
Chromium	23.27	95% Student's-t UCL	Normal
Copper	109.40	95% Adjusted Gamma UCL (use when n<50)	Gamma
Mercury	0.0536	95% KM (t) UCL	Normal
Vanadium	38.20	95% Student's-t UCL	Normal
Zinc	45.51	95% Student's-t UCL	Normal
Benzoic Acid	0.168	Median all	1 detect
Benzyl Alcohol	0.683	95% KM (t) UCL	Normal
Butyl Benzyl Phthalate	0.01	Median all	2 detects
Di-n-Butyl Phthalate	0.01	Median all	4 detects
Fluoranthene	0.01	Median all	1 detect
HMX	3.874	Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	Gamma
Pyrene	0.01	Median all	1 detect
TATB	2.938	95% Gamma Adjusted KM-UCL (use when n<50)	Gamma
Tetrachlorodibenzofuran[2,3,7,8-] (mammal)	1.24E-06	95% Student's-t UCL	Normal

```
Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-
Detects - Max of Duplicate pair
User Selected Options
Date/Time of Computation          ProUCL 5.14/27/2022 12:50:06 PM
From File                         BKG data for ProUCL tests.xls
Full Precision                    OFF
Confidence Coefficient                  95%
                                  Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis          (Form 1)
Alternative Hypothesis            Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Ca(ta39 6)
Sample 2 Data: Ca(bkg)
Raw Statistics
                                            Sample 1             Sample 2
Number of Valid Data                                        12        173
Number of Non-Detects                                        0          0
Number of Detect Data                                       12        173
Minimum Non-Detect                            N/A                 N/A
Maximum Non-Detect                            N/A                 N/A
Percent Non-detects                                      0.00%      0.00%
Minimum Detect                                             588        500
Maximum Detect                                            7160      14000
Mean of Detects                                           4669       2644
Median of Detects                                         4925       2100
SD of Detects                                             1841       1771
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                  1782
Standardized WMW U-Stat                                  3.712
Mean (U)                                                  1038
SD(U) - Adj ties                                         179.3
Approximate U-Stat Critical Value (0.05)                 1.645
P-Value (Adjusted for Ties)                           1.03E-04
Conclusion with Alpha = 0.05
   Reject H0, Conclude Sample 1 > Sample 2
   P-Value < alpha (0.05)
Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-
Detects
User Selected Options
Date/Time of Computation          ProUCL 5.14/27/2022 12:53:54 PM
From File                         BKG data for ProUCL tests.xls
Full Precision                    OFF
Confidence Coefficient                  95%
```

```
                                        Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis                (Form 1)
Alternative Hypothesis                  Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Cr(ta39 6)
Sample 2 Data: Cr(bkg)
Raw Statistics
                                                   Sample 1          Sample 2
Number of Valid Data                                          12         173
Number of Non-Detects                                          0           0
Number of Detect Data                                         12         173
Minimum Non-Detect                                   N/A              N/A
Maximum Non-Detect                                   N/A              N/A
Percent Non-detects                                        0.00%       0.00%
Minimum Detect                                              3.22         1.9
Maximum Detect                                              47.9        36.5
Mean of Detects                                            16.95        9.04
Median of Detects                                          12.25         8.6
SD of Detects                                              12.19       4.363
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                    1687
Standardized WMW U-Stat                                    3.182
Mean (U)                                                    1038
SD(U) - Adj ties                                           179.3
Approximate U-Stat Critical Value (0.05)                   1.645
P-Value (Adjusted for Ties)                             7.31E-04
Conclusion with Alpha = 0.05
  Reject H0, Conclude Sample 1 > Sample 2
  P-Value < alpha (0.05)
```

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

```
User Selected Options
Date/Time of Computation                ProUCL 5.14/27/2022 12:55:29 PM
From File                               BKG data for ProUCL tests.xls
Full Precision                          OFF
Confidence Coefficient                        95%
                                        Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis                (Form 1)
Alternative Hypothesis                  Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Cu(ta39 6)
Sample 2 Data: Cu(bkg)
Raw Statistics
                                                   Sample 1          Sample 2
Number of Valid Data                                          12         174
Number of Non-Detects                                          0           2
Number of Detect Data                                         12         172
Minimum Non-Detect                                   N/A                 0.5
Maximum Non-Detect                                   N/A                 0.5
Percent Non-detects                                        0.00%       1.15%
Minimum Detect                                              4.92         0.6
Maximum Detect                                               174          16
Mean of Detects                                            60.27       6.125
Median of Detects                                           52.1         5.8
SD of Detects                                              53.77       2.523
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                    2046
Standardized WMW U-Stat                                     5.12
Mean (U)                                                    1044
SD(U) - Adj ties                                           180.4
Approximate U-Stat Critical Value (0.05)                   1.645
P-Value (Adjusted for Ties)                             1.52E-07
Conclusion with Alpha = 0.05
  Reject H0, Conclude Sample 1 > Sample 2
  P-Value < alpha (0.05)
```

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

```
User Selected Options
Date/Time of Computation                ProUCL 5.14/27/2022 12:57:44 PM
From File                               BKG data for ProUCL tests.xls
```

```
Full Precision                    OFF
Confidence Coefficient                  95%
                                  Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis          (Form 1)
Alternative Hypothesis            Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: V(ta39 6)
Sample 2 Data: V(bkg)
Raw Statistics
                                           Sample 1            Sample 2
Number of Valid Data                                    12          174
Number of Non-Detects                                    0            0
Number of Detect Data                                   12          174
Minimum Non-Detect                           N/A                N/A
Maximum Non-Detect                           N/A                N/A
Percent Non-detects                                  0.00%        0.00%
Minimum Detect                                        11.4            4
Maximum Detect                                        48.3         56.5
Mean of Detects                                      32.33        21.26
Median of Detects                                    30.05           21
SD of Detects                                        11.21        8.925
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                              1740
Standardized WMW U-Stat                              3.423
Mean (U)                                              1044
SD(U) - Adj ties                                     180.3
Approximate U-Stat Critical Value (0.05)             1.645
P-Value (Adjusted for Ties)                       3.10E-04
Conclusion with Alpha = 0.05
  Reject H0, Conclude Sample 1 > Sample 2
  P-Value < alpha (0.05)
Gehan Sample 1 vs Sample 2 Comparison Hypothesis Test for Data Sets with Non-Detects
User Selected Options
Date/Time of Computation          ProUCL 5.14/27/2022 1:01:09 PM
From File                         BKG data for ProUCL tests.xls
Full Precision                    OFF
Confidence Coefficient                  95%
                                  Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis          (Form 1)
Alternative Hypothesis            Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Hg(ta39 6)
Sample 2 Data: Hg(bkg)
Raw Statistics
                                           Sample 1            Sample 2
Number of Valid Data                                    12           39
Number of Non-Detects                                    6           37
Number of Detect Data                                    6            2
Minimum Non-Detect                                 0.00355          0.1
Maximum Non-Detect                                  0.0039          0.1
Percent Non-detects                                 50.00%       94.87%
Minimum Detect                                     0.00507          0.1
Maximum Detect                                       0.131          0.1
Mean of Detects                                     0.0554          0.1
Median of Detects                                    0.038          0.1
SD of Detects                                       0.0522            0
KM Mean                                             0.0295          0.1
KM SD                                               0.0425            0
Sample 1 vs Sample 2 Gehan Test
H0: Mean/Median of Sample 1 <= Mean/Median of background
Gehan z Test Value                                   1.363
Critical z (0.05)                                    1.645
P-Value                                             0.0865
Conclusion with Alpha = 0.05
  Do Not Reject H0, Conclude Sample 1 <= Sample 2
  P-Value >= alpha (0.05)
```

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

```
User Selected Options
Date/Time of Computation          ProUCL 5.14/27/2022 1:02:44 PM
From File                         BKG data for ProUCL tests.xls
```

```
Full Precision                          OFF
Confidence Coefficient                        95%
                                        Sample 1 Mean/Median <= Sample 2 Mean/Median
Selected Null Hypothesis                (Form 1)
Alternative Hypothesis                  Sample 1 Mean/Median > Sample 2 Mean/Median
Sample 1 Data: Zn(ta39 6)
Sample 2 Data: Zn(bkg)
Raw Statistics
                                                        Sample 1        Sample 2
Number of Valid Data                                       12              172
Number of Non-Detects                                       0               0
Number of Detect Data                                      12              172
Minimum Non-Detect                                        N/A             N/A
Maximum Non-Detect                                        N/A             N/A
Percent Non-detects                                      0.00%           0.00%
Minimum Detect                                            24.4             14
Maximum Detect                                            62.5            75.5
Mean of Detects                                          39.34           31.52
Median of Detects                                        37.95           30.75
SD of Detects                                             11.9           9.002
Wilcoxon-Mann-Whitney (WMW) Test
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2
Sample 1 Rank Sum W-Stat                                         1540
Standardized WMW U-Stat                                          2.41
Mean (U)                                                         1032
SD(U) - Adj ties                                                178.2
Approximate U-Stat Critical Value (0.05)                        1.645
P-Value (Adjusted for Ties)                                   0.00798
Conclusion with Alpha = 0.05
  Reject H0, Conclude Sample 1 > Sample 2
  P-Value < alpha (0.05)
```

```
UCL Statistics for Data Sets with Non-Detects        Maximum of duplicate pair used in analysis
User Selected Options
Date/Time of Computation                             ProUCL 5.1 5/11/2022 9:03:53 PM
From File                                            WorkSheet.xls
Full Precision                                       OFF
Confidence Coefficient                               95%
Number of Bootstrap Operations                       2000
Ca
General Statistics
Total Number of Observations                12      Number of Distinct Observations              12
                                                    Number of Missing Observations                1
Minimum                                    588      Mean                                       4669
Maximum                                   7160      Median                                     4925
SD                                        1841      Std. Error of Mean                        531.6
Coefficient of Variation                 0.394      Skewness                                 -0.813
Normal GOF Test
Shapiro Wilk Test Statistic              0.952      Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value           0.859      Data appear Normal at 5% Significance Level
Lilliefors Test Statistic                0.118      Lilliefors GOF Test
5% Lilliefors Critical Value             0.243      Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level
Assuming Normal Distribution
  95% Normal UCL                                      95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                     5624        95% Adjusted-CLT UCL (Chen-1995)         5410
                                                      95% Modified-t UCL (Johnson-1978)        5603
Gamma GOF Test
A-D Test Statistic                        0.79      Anderson-Darling Gamma GOF Test
                                                    Data Not Gamma Distributed at 5%
5% A-D Critical Value                    0.736      Significance Level
K-S Test Statistic                        0.19      Kolmogorov-Smirnov Gamma GOF Test
                                                    Detected data appear Gamma Distributed at
5% K-S Critical Value                    0.247      5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level
Gamma Statistics
k hat (MLE)                              3.829      k star (bias corrected MLE)               2.927
Theta hat (MLE)                           1219      Theta star (bias corrected MLE)            1595
nu hat (MLE)                             91.89      nu star (bias corrected)                  70.25
MLE Mean (bias corrected)                 4669      MLE Sd (bias corrected)                    2729
                                                    Approximate Chi Square Value (0.05)       51.96
Adjusted Level of Significance           0.029      Adjusted Chi Square Value                 49.56
```

```
Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when n>=50))            6313     95% Adjusted Gamma UCL (use when n<50)        6618
Lognormal GOF Test
Shapiro Wilk Test Statistic                             0.717    Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value                          0.859    Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic                               0.242    Lilliefors Lognormal GOF Test
                                                                 Data appear Lognormal at 5% Significance
5% Lilliefors Critical Value                            0.243    Level
Data appear Approximate Lognormal at 5% Significance Level
Lognormal Statistics
Minimum of Logged Data                                  6.377    Mean of logged Data                          8.312
Maximum of Logged Data                                  8.876    SD of logged Data                            0.669
Assuming Lognormal Distribution
  95% H-UCL                                              8222      90% Chebyshev (MVUE) UCL                    7991
  95% Chebyshev (MVUE) UCL                               9352     97.5% Chebyshev (MVUE) UCL                  11240
  99% Chebyshev (MVUE) UCL                              14950
Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level
Nonparametric Distribution Free UCLs
  95% CLT UCL                                            5543      95% Jackknife UCL                           5624
  95% Standard Bootstrap UCL                             5502      95% Bootstrap-t UCL                         5488
  95% Hall's Bootstrap UCL                               5458      95% Percentile Bootstrap UCL                5499
  95% BCA Bootstrap UCL                                  5389
  90% Chebyshev(Mean, Sd) UCL                            6264      95% Chebyshev(Mean, Sd) UCL                 6986
 97.5% Chebyshev(Mean, Sd) UCL                           7989      99% Chebyshev(Mean, Sd) UCL                 9958
Suggested UCL to Use
95% Student's-t UCL                                      5624
Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable.  Chen's and Johnson's methods provide adjustments for positvely skewed data sets.
Cr
General Statistics
Total Number of Observations                               12    Number of Distinct Observations                12
                                                                 Number of Missing Observations                  1
Minimum                                                  3.22    Mean                                        16.95
Maximum                                                  47.9    Median                                      12.25
SD                                                      12.19    Std. Error of Mean                          3.519
Coefficient of Variation                                0.719    Skewness                                    1.748
Normal GOF Test
Shapiro Wilk Test Statistic                             0.818    Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value                          0.859    Data Not Normal at 5% Significance Level
Lilliefors Test Statistic                               0.233    Lilliefors GOF Test
5% Lilliefors Critical Value                            0.243    Data appear Normal at 5% Significance Level
Data appear Approximate Normal at 5% Significance Level
Assuming Normal Distribution
  95% Normal UCL                                                   95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                                   23.27      95% Adjusted-CLT UCL (Chen-1995)           24.63
                                                                   95% Modified-t UCL (Johnson-1978)          23.56
Gamma GOF Test
A-D Test Statistic                                      0.431    Anderson-Darling Gamma GOF Test
                                                                 Detected data appear Gamma Distributed at
5% A-D Critical Value                                    0.74    5% Significance Level
K-S Test Statistic                                      0.186    Kolmogorov-Smirnov Gamma GOF Test
                                                                 Detected data appear Gamma Distributed at
5% K-S Critical Value                                   0.248    5% Significance Level
Detected data appear Gamma Distributed at 5% Significance Level
Gamma Statistics
k hat (MLE)                                             2.558    k star (bias corrected MLE)                 1.974
Theta hat (MLE)                                         6.624    Theta star (bias corrected MLE)             8.584
nu hat (MLE)                                             61.4    nu star (bias corrected)                    47.38
MLE Mean (bias corrected)                               16.95    MLE Sd (bias corrected)                     12.06
                                                                 Approximate Chi Square Value (0.05)         32.58
Adjusted Level of Significance                          0.029    Adjusted Chi Square Value                   30.72
Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when n>=50))           24.64      95% Adjusted Gamma UCL (use when n<50)     26.14
Lognormal GOF Test
Shapiro Wilk Test Statistic                             0.951    Shapiro Wilk Lognormal GOF Test
                                                                 Data appear Lognormal at 5% Significance
5% Shapiro Wilk Critical Value                          0.859    Level
Lilliefors Test Statistic                               0.181    Lilliefors Lognormal GOF Test
                                                                 Data appear Lognormal at 5% Significance
5% Lilliefors Critical Value                            0.243    Level
```

Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.169	Mean of logged Data	2.622
Maximum of Logged Data	3.869	SD of logged Data	0.683
Assuming Lognormal Distribution			
95% H-UCL	28.41	90% Chebyshev (MVUE) UCL	27.43
95% Chebyshev (MVUE) UCL	32.17	97.5% Chebyshev (MVUE) UCL	38.73
99% Chebyshev (MVUE) UCL	51.64		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	22.73	95% Jackknife UCL	23.27
95% Standard Bootstrap UCL	22.49	95% Bootstrap-t UCL	28.51
95% Hall's Bootstrap UCL	53.81	95% Percentile Bootstrap UCL	22.75
95% BCA Bootstrap UCL	23.77		
90% Chebyshev(Mean, Sd) UCL	27.5	95% Chebyshev(Mean, Sd) UCL	32.28
97.5% Chebyshev(Mean, Sd) UCL	38.92	99% Chebyshev(Mean, Sd) UCL	51.96
Suggested UCL to Use			
95% Student's-t UCL	23.27		
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
Cu			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	1
Minimum	4.92	Mean	60.27
Maximum	174	Median	52.1
SD	53.77	Std. Error of Mean	15.52
Coefficient of Variation	0.892	Skewness	1.407
Normal GOF Test			
Shapiro Wilk Test Statistic	0.818	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.234	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	88.14	95% Adjusted-CLT UCL (Chen-1995)	92.54
		95% Modified-t UCL (Johnson-1978)	89.19
Gamma GOF Test			
A-D Test Statistic	0.29	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.747	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.132	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.25	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	1.425	k star (bias corrected MLE)	1.124
Theta hat (MLE)	42.3	Theta star (bias corrected MLE)	53.61
nu hat (MLE)	34.2	nu star (bias corrected)	26.98
MLE Mean (bias corrected)	60.27	MLE Sd (bias corrected)	56.84
		Approximate Chi Square Value (0.05)	16.14
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	14.87
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	100.8	95% Adjusted Gamma UCL (use when n<50)	109.4
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.955	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.176	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	1.593	Mean of logged Data	3.709
Maximum of Logged Data	5.159	SD of logged Data	0.999
Assuming Lognormal Distribution			
95% H-UCL	161.4	90% Chebyshev (MVUE) UCL	122.2
95% Chebyshev (MVUE) UCL	148.8	97.5% Chebyshev (MVUE) UCL	185.7
99% Chebyshev (MVUE) UCL	258.2		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	85.8	95% Jackknife UCL	88.14
95% Standard Bootstrap UCL	84.61	95% Bootstrap-t UCL	108.3
95% Hall's Bootstrap UCL	254.5	95% Percentile Bootstrap UCL	86.16
95% BCA Bootstrap UCL	91.64		
90% Chebyshev(Mean, Sd) UCL	106.8	95% Chebyshev(Mean, Sd) UCL	127.9
97.5% Chebyshev(Mean, Sd) UCL	157.2	99% Chebyshev(Mean, Sd) UCL	214.7

Suggested UCL to Use

95% Student's-t UCL	88.14

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test

When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Hg

General Statistics

Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	1
Number of Detects	6	Number of Non-Detects	6
Number of Distinct Detects	6	Number of Distinct Non-Detects	5
Minimum Detect	0.00507	Minimum Non-Detect	0.00355
Maximum Detect	0.131	Maximum Non-Detect	0.0039
Variance Detects	0.00273	Percent Non-Detects	50%
Mean Detects	0.0554	SD Detects	0.0522
Median Detects	0.038	CV Detects	0.944
Skewness Detects	0.663	Kurtosis Detects	-1.594
Mean of Logged Detects	-3.431	SD of Logged Detects	1.261

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.879	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.256	Lilliefors GOF Test
5% Lilliefors Critical Value	0.325	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0295	KM Standard Error of Mean	0.0134
KM SD	0.0425	95% KM (BCA) UCL	0.0501
95% KM (t) UCL	0.0536	95% KM (Percentile Bootstrap) UCL	0.052
95% KM (z) UCL	0.0516	95% KM Bootstrap t UCL	0.079
90% KM Chebyshev UCL	0.0698	95% KM Chebyshev UCL	0.0881
97.5% KM Chebyshev UCL	0.113	99% KM Chebyshev UCL	0.163

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.29	Anderson-Darling GOF Test
5% A-D Critical Value	0.714	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.221	Kolmogorov-Smirnov GOF
5% K-S Critical Value	0.34	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.067	k star (bias corrected MLE)	0.645
Theta hat (MLE)	0.0519	Theta star (bias corrected MLE)	0.0859
nu hat (MLE)	12.8	nu star (bias corrected)	7.735
Mean (detects)	0.0554		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.00507	Mean	0.0327
Maximum	0.131	Median	0.01
SD	0.0424	CV	1.299
k hat (MLE)	0.97	k star (bias corrected MLE)	0.783
Theta hat (MLE)	0.0337	Theta star (bias corrected MLE)	0.0417
nu hat (MLE)	23.29	nu star (bias corrected)	18.8
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (18.80, α)	9.97	Adjusted Chi Square Value (18.80, β)	9.004
95% Gamma Approximate UCL (use when n>=50)	0.0616	95% Gamma Adjusted UCL (use when n<50)	0.0682

Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.0295	SD (KM)	0.0425
Variance (KM)	0.00181	SE of Mean (KM)	0.0134
k hat (KM)	0.48	k star (KM)	0.415
nu hat (KM)	11.52	nu star (KM)	9.97
theta hat (KM)	0.0614	theta star (KM)	0.0709
80% gamma percentile (KM)	0.0477	90% gamma percentile (KM)	0.0826
95% gamma percentile (KM)	0.121	99% gamma percentile (KM)	0.216
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (9.97, α)	3.923	Adjusted Chi Square Value (9.97, β)	3.365
95% Gamma Approximate KM-UCL (use when n>=50)	0.0749	95% Gamma Adjusted KM-UCL (use when n<50)	0.0873
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.938	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.788	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.172	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.325	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.0282	Mean in Log Scale	-5.236
SD in Original Scale	0.0453	SD in Log Scale	2.089
95% t UCL (assumes normality of ROS data)	0.0516	95% Percentile Bootstrap UCL	0.0507
95% BCA Bootstrap UCL	0.057	95% Bootstrap t UCL	0.0848
95% H-UCL (Log ROS)	1.212		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-4.536	KM Geo Mean	0.0107
KM SD (logged)	1.372	95% Critical H Value (KM-Log)	3.633
KM Standard Error of Mean (logged)	0.434	95% H-UCL (KM -Log)	0.124
KM SD (logged)	1.372	95% Critical H Value (KM-Log)	3.633
KM Standard Error of Mean (logged)	0.434		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.0286	Mean in Log Scale	-4.857
SD in Original Scale	0.045	SD in Log Scale	1.715
95% t UCL (Assumes normality)	0.0519	95% H-Stat UCL	0.32
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.0536		
V			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	11
		Number of Missing Observations	1
Minimum	11	Mean	32.31
Maximum	48	Median	30
SD	11.37	Std. Error of Mean	3.281
Coefficient of Variation	0.352	Skewness	-0.147
Normal GOF Test			
Shapiro Wilk Test Statistic	0.942	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.16	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	38.2	95% Adjusted-CLT UCL (Chen-1995)	37.56
		95% Modified-t UCL (Johnson-1978)	38.18
Gamma GOF Test			
A-D Test Statistic	0.376	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.158	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.246	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	7.35	k star (bias corrected MLE)	5.568
Theta hat (MLE)	4.396	Theta star (bias corrected MLE)	5.802

nu hat (MLE)	176.4	nu star (bias corrected)	133.6
MLE Mean (bias corrected)	32.31	MLE Sd (bias corrected)	13.69
		Approximate Chi Square Value (0.05)	107.9
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	104.4
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	40	95% Adjusted Gamma UCL (use when n<50)	41.35
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.89	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.17	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.398	Mean of logged Data	3.406
Maximum of Logged Data	3.871	SD of logged Data	0.416
Assuming Lognormal Distribution			
95% H-UCL	42.48	90% Chebyshev (MVUE) UCL	44.58
95% Chebyshev (MVUE) UCL	50	97.5% Chebyshev (MVUE) UCL	57.52
99% Chebyshev (MVUE) UCL	72.29		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	37.71	95% Jackknife UCL	38.2
95% Standard Bootstrap UCL	37.4	95% Bootstrap-t UCL	38.39
95% Hall's Bootstrap UCL	37.55	95% Percentile Bootstrap UCL	37.08
95% BCA Bootstrap UCL	37.14		
90% Chebyshev(Mean, Sd) UCL	42.15	95% Chebyshev(Mean, Sd) UCL	46.61
97.5% Chebyshev(Mean, Sd) UCL	52.8	99% Chebyshev(Mean, Sd) UCL	64.96
Suggested UCL to Use			
95% Student's-t UCL	38.2		

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

Zn

General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	1
Minimum	24.4	Mean	39.34
Maximum	62.5	Median	37.95
SD	11.9	Std. Error of Mean	3.435
Coefficient of Variation	0.302	Skewness	0.686
Normal GOF Test			
Shapiro Wilk Test Statistic	0.933	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.161	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	45.51	95% Adjusted-CLT UCL (Chen-1995)	45.72
		95% Modified-t UCL (Johnson-1978)	45.62
Gamma GOF Test			
A-D Test Statistic	0.253	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.123	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.245	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	12.41	k star (bias corrected MLE)	9.36
Theta hat (MLE)	3.171	Theta star (bias corrected MLE)	4.203
nu hat (MLE)	297.7	nu star (bias corrected)	224.6
MLE Mean (bias corrected)	39.34	MLE Sd (bias corrected)	12.86
		Approximate Chi Square Value (0.05)	191
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	186.2
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	46.28	95% Adjusted Gamma UCL (use when n<50)	47.46
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.958	Shapiro Wilk Lognormal GOF Test	

5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.121	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	3.195	Mean of logged Data	3.631
Maximum of Logged Data	4.135	SD of logged Data	0.298

Assuming Lognormal Distribution

95% H-UCL	46.93	90% Chebyshev (MVUE) UCL	49.57
95% Chebyshev (MVUE) UCL	54.2	97.5% Chebyshev (MVUE) UCL	60.64
99% Chebyshev (MVUE) UCL	73.28		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	44.99	95% Jackknife UCL	45.51
95% Standard Bootstrap UCL	44.88	95% Bootstrap-t UCL	47.07
95% Hall's Bootstrap UCL	47.53	95% Percentile Bootstrap UCL	45.31
95% BCA Bootstrap UCL	45.88		
90% Chebyshev(Mean, Sd) UCL	49.65	95% Chebyshev(Mean, Sd) UCL	54.31
97.5% Chebyshev(Mean, Sd) UCL	60.79	99% Chebyshev(Mean, Sd) UCL	73.52

Suggested UCL to Use

95% Student's-t UCL	45.51		

Benzyl Alchohol

General Statistics

Total Number of Observations	12	Number of Distinct Observations	9
		Number of Missing Observations	1
Number of Detects	7	Number of Non-Detects	5
Number of Distinct Detects	7	Number of Distinct Non-Detects	2
Minimum Detect	0.127	Minimum Non-Detect	0.1
Maximum Detect	1.65	Maximum Non-Detect	0.101
Variance Detects	0.304	Percent Non-Detects	41.67%
Mean Detects	0.644	SD Detects	0.552
Median Detects	0.434	CV Detects	0.856
Skewness Detects	1.097	Kurtosis Detects	0.574
Mean of Logged Detects	-0.794	SD of Logged Detects	0.952

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.893	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.22	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.418	KM Standard Error of Mean	0.148
KM SD	0.473	95% KM (BCA) UCL	0.669
95% KM (t) UCL	0.683	95% KM (Percentile Bootstrap) UCL	0.674
95% KM (z) UCL	0.66	95% KM Bootstrap t UCL	0.863
90% KM Chebyshev UCL	0.86	95% KM Chebyshev UCL	1.061
97.5% KM Chebyshev UCL	1.339	99% KM Chebyshev UCL	1.886

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.212	Anderson-Darling GOF Test	
5% A-D Critical Value	0.721	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.155	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.317	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.557	k star (bias corrected MLE)	0.985
Theta hat (MLE)	0.414	Theta star (bias corrected MLE)	0.654
nu hat (MLE)	21.8	nu star (bias corrected)	13.79
Mean (detects)	0.644		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
Minimum	0.01	Mean	0.38
Maximum	1.65	Median	0.144
SD	0.522	CV	1.374
k hat (MLE)	0.456	k star (bias corrected MLE)	0.397
Theta hat (MLE)	0.834	Theta star (bias corrected MLE)	0.956
nu hat (MLE)	10.94	nu star (bias corrected)	9.536
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (9.54, α)	3.654	Adjusted Chi Square Value (9.54, β)	3.119
95% Gamma Approximate UCL (use when n>=50)	0.992	95% Gamma Adjusted UCL (use when n<50)	1.162
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.418	SD (KM)	0.473
Variance (KM)	0.224	SE of Mean (KM)	0.148
k hat (KM)	0.778	k star (KM)	0.639
nu hat (KM)	18.66	nu star (KM)	15.33
theta hat (KM)	0.537	theta star (KM)	0.654
80% gamma percentile (KM)	0.688	90% gamma percentile (KM)	1.071
95% gamma percentile (KM)	1.469	99% gamma percentile (KM)	2.427
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (15.33, α)	7.491	Adjusted Chi Square Value (15.33, β)	6.671
95% Gamma Approximate KM-UCL (use when n>=50)	0.854	95% Gamma Adjusted KM-UCL (use when n<50)	0.959
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.959	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.148	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.391	Mean in Log Scale	-1.889
SD in Original Scale	0.514	SD in Log Scale	1.565
95% t UCL (assumes normality of ROS data)	0.658	95% Percentile Bootstrap UCL	0.628
95% BCA Bootstrap UCL	0.702	95% Bootstrap t UCL	0.909
95% H-UCL (Log ROS)	3.447		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-1.422	KM Geo Mean	0.241
KM SD (logged)	1.003	95% Critical H Value (KM-Log)	2.921
KM Standard Error of Mean (logged)	0.313	95% H-UCL (KM -Log)	0.964
KM SD (logged)	1.003	95% Critical H Value (KM-Log)	2.921
KM Standard Error of Mean (logged)	0.313		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.397	Mean in Log Scale	-1.709
SD in Original Scale	0.509	SD in Log Scale	1.331
95% t UCL (Assumes normality)	0.661	95% H-Stat UCL	1.827
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	0.683		
HMX			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	9
		Number of Missing Observations	1
Number of Detects	7	Number of Non-Detects	5
Number of Distinct Detects	7	Number of Distinct Non-Detects	2
Minimum Detect	0.172	Minimum Non-Detect	0.149
Maximum Detect	6.66	Maximum Non-Detect	0.15
Variance Detects	5.265	Percent Non-Detects	41.67%
Mean Detects	1.683	SD Detects	2.295
Median Detects	1.14	CV Detects	1.363
Skewness Detects	2.198	Kurtosis Detects	5.159
Mean of Logged Detects	-0.217	SD of Logged Detects	1.34
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.704	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data Not Normal at 5% Significance Level	

Lilliefors Test Statistic	0.314	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data Not Normal at 5% Significance Level	

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	1.044	KM Standard Error of Mean	0.558
KM SD	1.79	95% KM (BCA) UCL	2.103
95% KM (t) UCL	2.046	95% KM (Percentile Bootstrap) UCL	1.964
95% KM (z) UCL	1.962	95% KM Bootstrap t UCL	3.731
90% KM Chebyshev UCL	2.718	95% KM Chebyshev UCL	3.477
97.5% KM Chebyshev UCL	4.53	99% KM Chebyshev UCL	6.598

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.394	Anderson-Darling GOF Test	
5% A-D Critical Value	0.734	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.22	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.322	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.804	k star (bias corrected MLE)	0.555
Theta hat (MLE)	2.093	Theta star (bias corrected MLE)	3.034
nu hat (MLE)	11.26	nu star (bias corrected)	7.766
Mean (detects)	1.683		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.986
Maximum	6.66	Median	0.194
SD	1.901	CV	1.928
k hat (MLE)	0.334	k star (bias corrected MLE)	0.306
Theta hat (MLE)	2.955	Theta star (bias corrected MLE)	3.225
nu hat (MLE)	8.007	nu star (bias corrected)	7.339
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (7.34, α)	2.358	Adjusted Chi Square Value (7.34, β)	1.951
95% Gamma Approximate UCL (use when n>=50)	3.068	95% Gamma Adjusted UCL (use when n<50)	3.709

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.044	SD (KM)	1.79
Variance (KM)	3.204	SE of Mean (KM)	0.558
k hat (KM)	0.34	k star (KM)	0.311
nu hat (KM)	8.162	nu star (KM)	7.455
theta hat (KM)	3.07	theta star (KM)	3.361
80% gamma percentile (KM)	1.614	90% gamma percentile (KM)	3.066
95% gamma percentile (KM)	4.722	99% gamma percentile (KM)	9.009

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (7.45, α)	2.423	Adjusted Chi Square Value (7.45, β)	2.009
95% Gamma Approximate KM-UCL (use when n>=50)	3.211	95% Gamma Adjusted KM-UCL (use when n<50)	3.874

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.927	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.202	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.304	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.993	Mean in Log Scale	-1.753
SD in Original Scale	1.897	SD in Log Scale	2.196
95% t UCL (assumes normality of ROS data)	1.976	95% Percentile Bootstrap UCL	1.953
95% BCA Bootstrap UCL	2.558	95% Bootstrap t UCL	3.902
95% H-UCL (Log ROS)	68.69		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-0.92	KM Geo Mean	0.399
KM SD (logged)	1.26	95% Critical H Value (KM-Log)	3.41
KM Standard Error of Mean (logged)	0.393	95% H-UCL (KM -Log)	3.223
KM SD (logged)	1.26	95% Critical H Value (KM-Log)	3.41
KM Standard Error of Mean (logged)	0.393		

DL/2 Statistics

DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	1.013	Mean in Log Scale	-1.207
SD in Original Scale	1.886	SD in Log Scale	1.573
95% t UCL (Assumes normality)	1.991	95% H-Stat UCL	7.039

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics

Detected Data appear Gamma Distributed at 5% Significance Level

Suggested UCL to Use

95% KM Bootstrap t UCL	3.731	Gamma Adjusted KM-UCL (use when k<=1 and 15 < n < 50 but k<=1)	3.874

TATB

General Statistics

Total Number of Observations	12	Number of Distinct Observations	8
		Number of Missing Observations	1
Number of Detects	5	Number of Non-Detects	7
Number of Distinct Detects	5	Number of Distinct Non-Detects	3
Minimum Detect	0.791	Minimum Non-Detect	0.296
Maximum Detect	5.535	Maximum Non-Detect	0.3
Variance Detects	3.981	Percent Non-Detects	58.33%
Mean Detects	2.042	SD Detects	1.995
Median Detects	1.06	CV Detects	0.977
Skewness Detects	2.017	Kurtosis Detects	4.113
Mean of Logged Detects	0.424	SD of Logged Detects	0.786

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.713	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.336	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Normal at 5% Significance Level	

Detected Data appear Approximate Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	1.024	KM Standard Error of Mean	0.464
KM SD	1.438	95% KM (BCA) UCL	1.863
95% KM (t) UCL	1.857	95% KM (Percentile Bootstrap) UCL	1.789
95% KM (z) UCL	1.787	95% KM Bootstrap t UCL	2.976
90% KM Chebyshev UCL	2.416	95% KM Chebyshev UCL	3.047
97.5% KM Chebyshev UCL	3.922	99% KM Chebyshev UCL	5.642

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.595	Anderson-Darling GOF Test	
5% A-D Critical Value	0.685	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.31	Kolmogorov-Smirnov GOF	
5% K-S Critical Value	0.361	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.873	k star (bias corrected MLE)	0.883
Theta hat (MLE)	1.09	Theta star (bias corrected MLE)	2.314
nu hat (MLE)	18.73	nu star (bias corrected)	8.826
Mean (detects)	2.042		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.857
Maximum	5.535	Median	0.01
SD	1.595	CV	1.861
k hat (MLE)	0.294	k star (bias corrected MLE)	0.276
Theta hat (MLE)	2.916	Theta star (bias corrected MLE)	3.105
nu hat (MLE)	7.051	nu star (bias corrected)	6.622
Adjusted Level of Significance (β)	0.029		
Approximate Chi Square Value (6.62, α)	1.965	Adjusted Chi Square Value (6.62, β)	1.603
95% Gamma Approximate UCL (use when n>=50)	2.887	95% Gamma Adjusted UCL (use when n<50)	3.539

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.024	SD (KM)	1.438
Variance (KM)	2.068	SE of Mean (KM)	0.464
k hat (KM)	0.507	k star (KM)	0.436
nu hat (KM)	12.16	nu star (KM)	10.45

theta hat (KM)	2.02	theta star (KM)	2.35
80% gamma percentile (KM)	1.666	90% gamma percentile (KM)	2.846
95% gamma percentile (KM)	4.129	99% gamma percentile (KM)	7.325
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (10.45, α)	4.226	Adjusted Chi Square Value (10.45, β)	3.642
95% Gamma Approximate KM-UCL (use when n>=50)	2.531	95% Gamma Adjusted KM-UCL (use when n<50)	2.938
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.851	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.762	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.279	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.343	Detected Data appear Lognormal at 5% Significance Level	
Detected Data appear Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.93	Mean in Log Scale	-1.077
SD in Original Scale	1.554	SD in Log Scale	1.48
95% t UCL (assumes normality of ROS data)	1.736	95% Percentile Bootstrap UCL	1.733
95% BCA Bootstrap UCL	2.079	95% Bootstrap t UCL	3.229
95% H-UCL (Log ROS)	5.697		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-0.533	KM Geo Mean	0.587
KM SD (logged)	0.928	95% Critical H Value (KM-Log)	2.786
KM Standard Error of Mean (logged)	0.299	95% H-UCL (KM -Log)	1.967
KM SD (logged)	0.928	95% Critical H Value (KM-Log)	2.786
KM Standard Error of Mean (logged)	0.299		
DL/2 Statistics			
DL/2 Normal		DL/2 Log-Transformed	
Mean in Original Scale	0.938	Mean in Log Scale	-0.933
SD in Original Scale	1.548	SD in Log Scale	1.288
95% t UCL (Assumes normality)	1.741	95% H-Stat UCL	3.464
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Detected Data appear Approximate Normal Distributed at 5% Significance Level			
Suggested UCL to Use			
95% KM (t) UCL	1.857		
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
UCL Statistics for Uncensored Full Data Sets	Dioxin/Furan TEQ		
User Selected Options			
Date/Time of Computation	ProUCL 5.15/12/2022 4:38:07 PM		
From File	WorkSheet.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
Bird TEQ			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	0
Minimum	1.54E-06	Mean	1.71E-06
Maximum	2.02E-06	Median	1.65E-06
SD	1.70E-07	Std. Error of Mean	4.90E-08
Coefficient of Variation	N/A	Skewness	0.964
Normal GOF Test			
Shapiro Wilk Test Statistic	0.851	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.207	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	1.80E-06	95% Adjusted-CLT UCL (Chen-1995)	1.80E-06
		95% Modified-t UCL (Johnson-1978)	1.80E-06
Gamma GOF Test			
A-D Test Statistic	0.714	Anderson-Darling Gamma GOF Test	

```
                                                                   Detected data appear Gamma Distributed at
5% A-D Critical Value                                       0.731  5% Significance Level
K-S Test Statistic                                          0.205  Kolmogorov-Smirnov Gamma GOF Test
                                                                   Detected data appear Gamma Distributed at
5% K-S Critical Value                                       0.245  5% Significance Level
Detected data appear Gamma Distributed at 5% Significance Level
Gamma Statistics
k hat (MLE)                                              1.16E+02  k star (bias corrected MLE)                   8.69E+01
Theta hat (MLE)                                          1.47E-08  Theta star (bias corrected MLE)               1.96E-08
nu hat (MLE)                                             2.78E+03  nu star (bias corrected)                      2.09E+03
MLE Mean (bias corrected)                                1.71E-06  MLE Sd (bias corrected)                       1.83E-07
                                                                   Approximate Chi Square Value (0.05)               1981
Adjusted Level of Significance                              0.029  Adjusted Chi Square Value                         1965
Assuming Gamma Distribution
  95% Approximate Gamma UCL (use when n>=50))            1.80E-06    95% Adjusted Gamma UCL (use when n<50)      1.81E-06
Lognormal GOF Test
Shapiro Wilk Test Statistic                                 0.864  Shapiro Wilk Lognormal GOF Test
                                                                   Data appear Lognormal at 5% Significance
5% Shapiro Wilk Critical Value                              0.859  Level
Lilliefors Test Statistic                                   0.196  Lilliefors Lognormal GOF Test
                                                                   Data appear Lognormal at 5% Significance
5% Lilliefors Critical Value                                0.243  Level
Data appear Lognormal at 5% Significance Level
Lognormal Statistics
Minimum of Logged Data                                     -13.38  Mean of logged Data                             -13.28
Maximum of Logged Data                                     -13.11  SD of logged Data                                0.096
Assuming Lognormal Distribution
  95% H-UCL                                                   N/A    90% Chebyshev (MVUE) UCL                    1.85E-06
  95% Chebyshev (MVUE) UCL                               1.91E-06   97.5% Chebyshev (MVUE) UCL                   2.00E-06
  99% Chebyshev (MVUE) UCL                               2.18E-06
Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level
Nonparametric Distribution Free UCLs
  95% CLT UCL                                            1.79E-06    95% Jackknife UCL                           1.80E-06
  95% Standard Bootstrap UCL                             1.78E-06    95% Bootstrap-t UCL                         1.82E-06
  95% Hall's Bootstrap UCL                               1.81E-06    95% Percentile Bootstrap UCL                1.79E-06
  95% BCA Bootstrap UCL                                  1.80E-06
  90% Chebyshev(Mean, Sd) UCL                            1.86E-06    95% Chebyshev(Mean, Sd) UCL                 1.92E-06
 97.5% Chebyshev(Mean, Sd) UCL                           2.01E-06    99% Chebyshev(Mean, Sd) UCL                 2.20E-06
Suggested UCL to Use
95% Student's-t UCL                                      1.80E-06
When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.
Mammal TEQ
General Statistics
Total Number of Observations                                   12  Number of Distinct Observations                     12
                                                                   Number of Missing Observations                       0
Minimum                                                  1.14E-06  Mean                                          1.21E-06
Maximum                                                  1.33E-06  Median                                        1.20E-06
SD                                                       6.23E-08  Std. Error of Mean                            1.80E-08
Coefficient of Variation                                      N/A  Skewness                                         0.579
Normal GOF Test
Shapiro Wilk Test Statistic                                 0.926  Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value                              0.859  Data appear Normal at 5% Significance Level
Lilliefors Test Statistic                                   0.165  Lilliefors GOF Test
5% Lilliefors Critical Value                                0.243  Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level
Assuming Normal Distribution
  95% Normal UCL                                                     95% UCLs (Adjusted for Skewness)
  95% Student's-t UCL                                    1.24E-06    95% Adjusted-CLT UCL (Chen-1995)            1.24E-06
                                                                     95% Modified-t UCL (Johnson-1978)           1.24E-06

Gamma GOF Test
A-D Test Statistic                                          0.358  Anderson-Darling Gamma GOF Test
                                                                   Detected data appear Gamma Distributed at
5% A-D Critical Value                                       0.731  5% Significance Level
K-S Test Statistic                                          0.177  Kolmogorov-Smirnov Gamma GOF Test
```

5% K-S Critical Value	0.245	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	417.5	k star (bias corrected MLE)	313.1
Theta hat (MLE)	2.90E-09	Theta star (bias corrected MLE)	3.87E-09
nu hat (MLE)	10019	nu star (bias corrected)	7516
MLE Mean (bias corrected)	1.21E-06	MLE Sd (bias corrected)	6.84E-08
		Approximate Chi Square Value (0.05)	7315
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	7285
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	1.24E-06	95% Adjusted Gamma UCL (use when n<50)	1.25E-06
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.929	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.168	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-13.69	Mean of logged Data	-13.63
Maximum of Logged Data	-13.53	SD of logged Data	0.051
Assuming Lognormal Distribution			
95% H-UCL	N/A	90% Chebyshev (MVUE) UCL	1.26E-06
95% Chebyshev (MVUE) UCL	1.29E-06	97.5% Chebyshev (MVUE) UCL	1.32E-06
99% Chebyshev (MVUE) UCL	1.39E-06		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	1.24E-06	95% Jackknife UCL	1.24E-06
95% Standard Bootstrap UCL	1.24E-06	95% Bootstrap-t UCL	1.24E-06
95% Hall's Bootstrap UCL	1.25E-06	95% Percentile Bootstrap UCL	1.24E-06
95% BCA Bootstrap UCL	1.24E-06		
90% Chebyshev(Mean, Sd) UCL	1.26E-06	95% Chebyshev(Mean, Sd) UCL	1.29E-06
97.5% Chebyshev(Mean, Sd) UCL	1.32E-06	99% Chebyshev(Mean, Sd) UCL	1.39E-06
Suggested UCL to Use			
95% Student's-t UCL	1.24E-06		

ATTACHMENT B. LANL ECORISK 4.2 DATABASE (MG/KG) FOR ORGANICS AND INORGANICS ABOVE BACKGROUND- SOIL

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	Deer mouse (Mammalian omnivore)	0.00000058	0.0000038		SOIL_DM(ip)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	Earthworm (Soil-dwelling invertebrate)	5	10		SOIL_EW_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	Gray fox (Mammalian top carnivore)	0.0001	0.00068		SOIL_RF(f)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	Montane shrew (Mammalian insectivore)	0.00000029	0.0000019		SOIL_MS(i)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	Mountain cottontail (Mammalian herbivore)	0.00004	0.00027		SOIL_DC(p)_1746-01-6
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	American kestrel (Avian top carnivore)	4.10E-06			
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	American kestrel (insectivore / carnivore)	4.10E-06			
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	American robin (Avian herbivore)	4.10E-06			
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	American robin (Avian insectivore)	4.10E-06			
Dioxin/ Furan	Tetrachlorodibenzodioxin [2,3,7,8-]	1746-01-6	American robin (Avian omnivore)	4.10E-06			
HE	3,5-Dinitroaniline	618-87-1	Deer mouse (Mammalian omnivore)	23	230	Use amino-2,6-dinitrotoluene [4-	SOIL_DM(ip)_19406-51-0
HE	3,5-Dinitroaniline	618-87-1	Earthworm (Soil-dwelling invertebrate)	18	180	Use amino-2,6-dinitrotoluene [4-	SOIL_EW_19406-51-0
HE	3,5-Dinitroaniline	618-87-1	Generic plant (Terrestrial autotroph - producer)	33	330	Use amino-2,6-dinitrotoluene [4-	SOIL_GP_19406-51-0
HE	3,5-Dinitroaniline	618-87-1	Gray fox (Mammalian top carnivore)	6700	67000	Use amino-2,6-dinitrotoluene [4-	SOIL_RF(f)_19406-51-0
HE	3,5-Dinitroaniline	618-87-1	Montane shrew (Mammalian insectivore)	12	120	Use amino-2,6-dinitrotoluene [4-	SOIL_MS(i)_19406-51-0
HE	3,5-Dinitroaniline	618-87-1	Mountain cottontail (Mammalian herbivore)	320	3200	Use amino-2,6-dinitrotoluene [4-	SOIL_DC(p)_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Deer mouse (Mammalian omnivore)	23	230		SOIL_DM(ip)_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Earthworm (Soil-dwelling invertebrate)	18	180		SOIL_EW_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Generic plant (Terrestrial autotroph - producer)	33	330		SOIL_GP_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Gray fox (Mammalian top carnivore)	6700	67000		SOIL_RF(f)_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Montane shrew (Mammalian insectivore)	12	120		SOIL_MS(i)_19406-51-0
HE	Amino-2,6-dinitrotoluene[4-]	19406-51-0	Mountain cottontail (Mammalian herbivore)	320	3200		SOIL_DC(p)_19406-51-0

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Deer mouse (Mammalian omnivore)	23	230		SOIL_DM(ip)_35572-78-2
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Earthworm (Soil-dwelling invertebrate)	43	430		SOIL_EW_35572-78-2
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Generic plant (Terrestrial autotroph - producer)	14	140		SOIL_GP_35572-78-2
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Gray fox (Mammalian top carnivore)	9700	97000		SOIL_RF(f)_35572-78-2
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Montane shrew (Mammalian insectivore)	16	160		SOIL_MS(i)_35572-78-2
HE	Amino-4,6-dinitrotoluene[2-]	35572-78-2	Mountain cottontail (Mammalian herbivore)	110	1100		SOIL_DC(p)_35572-78-2
HE	Dinitrobenzene[1,3-]	99-65-0	American kestrel (Avian top carnivore)	120	1200		SOIL_AK(f)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	American kestrel (insectivore / carnivore)	9.3	93		SOIL_AK(fi)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian herbivore)	0.079	0.79		SOIL_AR(p)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian insectivore)	1.6	16		SOIL_AR(i)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	American robin (Avian omnivore)	0.15	1.5		SOIL_AR(ip)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	Deer mouse (Mammalian omnivore)	0.072	0.16		SOIL_DM(ip)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	Gray fox (Mammalian top carnivore)	82	190		SOIL_RF(f)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	Montane shrew (Mammalian insectivore)	0.95	2.2		SOIL_MS(i)_99-65-0
HE	Dinitrobenzene[1,3-]	99-65-0	Mountain cottontail (Mammalian herbivore)	0.091	0.21		SOIL_DC(p)_99-65-0
HE	Dinitrotoluene[2,4-]	121-14-2	Deer mouse (Mammalian omnivore)	20	200		SOIL_DM(ip)_121-14-2
HE	Dinitrotoluene[2,4-]	121-14-2	Earthworm (Soil-dwelling invertebrate)	18	180		SOIL_EW_121-14-2
HE	Dinitrotoluene[2,4-]	121-14-2	Generic plant (Terrestrial autotroph - producer)	6	60		SOIL_GP_121-14-2
HE	Dinitrotoluene[2,4-]	121-14-2	Gray fox (Mammalian top carnivore)	2000	20000		SOIL_RF(f)_121-14-2
HE	Dinitrotoluene[2,4-]	121-14-2	Montane shrew (Mammalian insectivore)	14	140		SOIL_MS(i)_121-14-2
HE	Dinitrotoluene[2,4-]	121-14-2	Mountain cottontail (Mammalian herbivore)	74	740		SOIL_DC(p)_121-14-2
HE	Dinitrotoluene[2,6-]	606-20-2	American kestrel (Avian top carnivore)	18000	180000		SOIL_AK(f)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	American kestrel (insectivore / carnivore)	680	6800		SOIL_AK(fi)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian herbivore)	52	520		SOIL_AR(p)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian insectivore)	130	1300		SOIL_AR(i)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	American robin (Avian omnivore)	74	740		SOIL_AR(ip)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	Deer mouse (Mammalian omnivore)	4	40		SOIL_DM(ip)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	Earthworm (Soil-dwelling invertebrate)	30	44		SOIL_EW_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	Gray fox (Mammalian top carnivore)	1300	13000		SOIL_RF(f)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	Montane shrew (Mammalian insectivore)	7.6	76		SOIL_MS(i)_606-20-2
HE	Dinitrotoluene[2,6-]	606-20-2	Mountain cottontail (Mammalian herbivore)	6.7	67		SOIL_DC(p)_606-20-2
HE	HMX	2691-41-0	Deer mouse (Mammalian omnivore)	290	790		SOIL_DM(ip)_2691-41-0
HE	HMX	2691-41-0	Earthworm (Soil-dwelling invertebrate)	16	160		SOIL_EW_2691-41-0
HE	HMX	2691-41-0	Generic plant (Terrestrial autotroph - producer)	2700	3500		SOIL_GP_2691-41-0
HE	HMX	2691-41-0	Gray fox (Mammalian top carnivore)	59000	150000		SOIL_RF(f)_2691-41-0
HE	HMX	2691-41-0	Montane shrew (Mammalian insectivore)	1100	2900		SOIL_MS(i)_2691-41-0
HE	HMX	2691-41-0	Mountain cottontail (Mammalian herbivore)	410	1100		SOIL_DC(p)_2691-41-0
HE	Nitroglycerine	55-63-0	Deer mouse (Mammalian omnivore)	70	740		SOIL_DM(ip)_55-63-0
HE	Nitroglycerine	55-63-0	Earthworm (Soil-dwelling invertebrate)	13	130		SOIL_EW_55-63-0
HE	Nitroglycerine	55-63-0	Generic plant (Terrestrial autotroph - producer)	21	210		SOIL_GP_55-63-0
HE	Nitroglycerine	55-63-0	Gray fox (Mammalian top carnivore)	69000	730000		SOIL_RF(f)_55-63-0
HE	Nitroglycerine	55-63-0	Montane shrew (Mammalian insectivore)	1200	13000		SOIL_MS(i)_55-63-0
HE	Nitroglycerine	55-63-0	Mountain cottontail (Mammalian herbivore)	88	930		SOIL_DC(p)_55-63-0
HE	Nitrotoluene[2-]	88-72-2	Deer mouse (Mammalian omnivore)	9.8	98		SOIL_DM(ip)_88-72-2
HE	Nitrotoluene[2-]	88-72-2	Gray fox (Mammalian top carnivore)	6000	60000		SOIL_RF(f)_88-72-2
HE	Nitrotoluene[2-]	88-72-2	Montane shrew (Mammalian insectivore)	22	220		SOIL_MS(i)_88-72-2
HE	Nitrotoluene[2-]	88-72-2	Mountain cottontail (Mammalian herbivore)	15	150		SOIL_DC(p)_88-72-2
HE	Nitrotoluene[3-]	99-08-1	Deer mouse (Mammalian omnivore)	12	120		SOIL_DM(ip)_99-08-1
HE	Nitrotoluene[3-]	99-08-1	Gray fox (Mammalian top carnivore)	7000	70000		SOIL_RF(f)_99-08-1
HE	Nitrotoluene[3-]	99-08-1	Montane shrew (Mammalian insectivore)	19	190		SOIL_MS(i)_99-08-1

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
HE	Nitrotoluene[3-]	99-08-1	Mountain cottontail (Mammalian herbivore)	21	210		SOIL_DC(p)_99-08-1
HE	Nitrotoluene[4-]	99-99-0	Deer mouse (Mammalian omnivore)	21	210		SOIL_DM(ip)_99-99-0
HE	Nitrotoluene[4-]	99-99-0	Gray fox (Mammalian top carnivore)	13000	130000		SOIL_RF(f)_99-99-0
HE	Nitrotoluene[4-]	99-99-0	Montane shrew (Mammalian insectivore)	41	410		SOIL_MS(i)_99-99-0
HE	Nitrotoluene[4-]	99-99-0	Mountain cottontail (Mammalian herbivore)	36	360		SOIL_DC(p)_99-99-0
HE	PETN	78-11-5	Deer mouse (Mammalian omnivore)	100	1000		SOIL_DM(ip)_78-11-5
HE	PETN	78-11-5	Gray fox (Mammalian top carnivore)	47000	470000		SOIL_RF(f)_78-11-5
HE	PETN	78-11-5	Montane shrew (Mammalian insectivore)	1000	10000		SOIL_MS(i)_78-11-5
HE	PETN	78-11-5	Mountain cottontail (Mammalian herbivore)	120	1200		SOIL_DC(p)_78-11-5
HE	RDX	121-82-4	American kestrel (Avian top carnivore)	780	1400		SOIL_AK(f)_121-82-4
HE	RDX	121-82-4	American kestrel (insectivore / carnivore)	11	22		SOIL_AK(fi)_121-82-4
HE	RDX	121-82-4	American robin (Avian herbivore)	2.3	4.3		SOIL_AR(p)_121-82-4
HE	RDX	121-82-4	American robin (Avian insectivore)	2.4	4.5		SOIL_AR(i)_121-82-4
HE	RDX	121-82-4	American robin (Avian omnivore)	2.3	4.4		SOIL_AR(ip)_121-82-4
HE	RDX	121-82-4	Deer mouse (Mammalian omnivore)	16	51		SOIL_DM(ip)_121-82-4
HE	RDX	121-82-4	Earthworm (Soil-dwelling invertebrate)	8.4	15		SOIL_EW_121-82-4
HE	RDX	121-82-4	Gray fox (Mammalian top carnivore)	7000	22000		SOIL_RF(f)_121-82-4
HE	RDX	121-82-4	Montane shrew (Mammalian insectivore)	16	53		SOIL_MS(i)_121-82-4
HE	RDX	121-82-4	Mountain cottontail (Mammalian herbivore)	38	120		SOIL_DC(p)_121-82-4
HE	Tetryl	479-45-8	Deer mouse (Mammalian omnivore)	1.5	7.2		SOIL_DM(ip)_479-45-8
HE	Tetryl	479-45-8	Gray fox (Mammalian top carnivore)	960	4600		SOIL_RF(f)_479-45-8
HE	Tetryl	479-45-8	Montane shrew (Mammalian insectivore)	60	280		SOIL_MS(i)_479-45-8
HE	Tetryl	479-45-8	Mountain cottontail (Mammalian herbivore)	1.8	8.9		SOIL_DC(p)_479-45-8
HE	TATB	3058-38-6	Deer mouse (Mammalian omnivore)	110	1100	Use 1,3,5-TNB for all	SOIL_DM(ip)_99-35-4
HE	TATB	3058-38-6	Earthworm (Soil-dwelling invertebrate)	10	28	Use 1,3,5-TNB for all	SOIL_EW_99-35-4
HE	TATB	3058-38-6	Gray fox (Mammalian top carnivore)	10000	100000	Use 1,3,5-TNB for all	SOIL_RF(f)_99-35-4
HE	TATB	3058-38-6	Montane shrew (Mammalian insectivore)	720	7200	Use 1,3,5-TNB for all	SOIL_MS(i)_99-35-4
HE	TATB	3058-38-6	Mountain cottontail (Mammalian herbivore)	150	1500	Use 1,3,5-TNB for all	SOIL_DC(p)_99-35-4
HE	Trinitrobenzene[1,3,5-]	99-35-4	Deer mouse (Mammalian omnivore)	110	1100		SOIL_DM(ip)_99-35-4
HE	Trinitrobenzene[1,3,5-]	99-35-4	Earthworm (Soil-dwelling invertebrate)	10	28		SOIL_EW_99-35-4
HE	Trinitrobenzene[1,3,5-]	99-35-4	Gray fox (Mammalian top carnivore)	10000	100000		SOIL_RF(f)_99-35-4
HE	Trinitrobenzene[1,3,5-]	99-35-4	Montane shrew (Mammalian insectivore)	720	7200		SOIL_MS(i)_99-35-4
HE	Trinitrobenzene[1,3,5-]	99-35-4	Mountain cottontail (Mammalian herbivore)	150	1500		SOIL_DC(p)_99-35-4
HE	Trinitrotoluene[2,4,6-]	118-96-7	American kestrel (Avian top carnivore)	3100	5700		SOIL_AK(f)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	American kestrel (insectivore / carnivore)	1300	2400		SOIL_AK(fi)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian herbivore)	7.5	13		SOIL_AR(p)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian insectivore)	120	220		SOIL_AR(i)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	American robin (Avian omnivore)	14	26		SOIL_AR(ip)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Deer mouse (Mammalian omnivore)	95	440		SOIL_DM(ip)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Earthworm (Soil-dwelling invertebrate)	32	58		SOIL_EW_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Generic plant (Terrestrial autotroph - producer)	62	120		SOIL_GP_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Gray fox (Mammalian top carnivore)	26000	120000		SOIL_RF(f)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Montane shrew (Mammalian insectivore)	1900	9100		SOIL_MS(i)_118-96-7
HE	Trinitrotoluene[2,4,6-]	118-96-7	Mountain cottontail (Mammalian herbivore)	110	540		SOIL_DC(p)_118-96-7

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
Inorganic	Chromium (total)	16065-83-1	American kestrel (Avian top carnivore)	860	2700		SOIL_AK(f)_CR
Inorganic	Chromium (total)	16065-83-1	American kestrel (insectivore / carnivore)	170	560		SOIL_AK(fi)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian herbivore)	51	160		SOIL_AR(p)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian insectivore)	23	73		SOIL_AR(i)_CR
Inorganic	Chromium (total)	16065-83-1	American robin (Avian omnivore)	32	100		SOIL_AR(ip)_CR
Inorganic	Chromium (total)	16065-83-1	Deer mouse (Mammalian omnivore)	110	11000		SOIL_DM(ip)_CR
Inorganic	Chromium (total)	16065-83-1	Gray fox (Mammalian top carnivore)	1800	180000		SOIL_RF(f)_CR
Inorganic	Chromium (total)	16065-83-1	Montane shrew (Mammalian insectivore)	63	6300		SOIL_MS(i)_CR
Inorganic	Chromium (total)	16065-83-1	Mountain cottontail (Mammalian herbivore)	410	41000		SOIL_DC(p)_CR
Inorganic	Copper	7440-50-8	American kestrel (Avian top carnivore)	1100	3500		SOIL_AK(f)_CU
Inorganic	Copper	7440-50-8	American kestrel (insectivore / carnivore)	80	240		SOIL_AK(fi)_CU
Inorganic	Copper	7440-50-8	American robin (Avian herbivore)	34	100		SOIL_AR(p)_CU
Inorganic	Copper	7440-50-8	American robin (Avian insectivore)	14	43		SOIL_AR(i)_CU
Inorganic	Copper	7440-50-8	American robin (Avian omnivore)	20	60		SOIL_AR(ip)_CU
Inorganic	Copper	7440-50-8	Deer mouse (Mammalian omnivore)	63	100		SOIL_DM(ip)_CU
Inorganic	Copper	7440-50-8	Earthworm (Soil-dwelling invertebrate)	80	530		SOIL_EW_CU
Inorganic	Copper	7440-50-8	Generic plant (Terrestrial autotroph - producer)	70	490		SOIL_GP_CU
Inorganic	Copper	7440-50-8	Gray fox (Mammalian top carnivore)	4000	6700		SOIL_RF(f)_CU
Inorganic	Copper	7440-50-8	Montane shrew (Mammalian insectivore)	42	70		SOIL_MS(i)_CU
Inorganic	Copper	7440-50-8	Mountain cottontail (Mammalian herbivore)	260	430		SOIL_DC(p)_CU
Inorganic	Mercury (inorganic)	7487-94-7	American kestrel (Avian top carnivore)	0.32	3.2		SOIL_AK(f)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American kestrel (insectivore / carnivore)	0.058	0.58		SOIL_AK(fi)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian herbivore)	0.067	0.67		SOIL_AR(p)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian insectivore)	0.013	0.13		SOIL_AR(i)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	American robin (Avian omnivore)	0.022	0.22		SOIL_AR(ip)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Deer mouse (Mammalian omnivore)	3	30		SOIL_DM(ip)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Earthworm (Soil-dwelling invertebrate)	0.05	0.5		SOIL_EW_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Generic plant (Terrestrial autotroph - producer)	34	64		SOIL_GP_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Gray fox (Mammalian top carnivore)	76	760		SOIL_RF(f)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Montane shrew (Mammalian insectivore)	1.7	17		SOIL_MS(i)_HGI
Inorganic	Mercury (inorganic)	7487-94-7	Mountain cottontail (Mammalian herbivore)	23	230		SOIL_DC(p)_HGI
Inorganic	Perchlorate	14797-73-0	American kestrel (Avian top carnivore)	2	4		SOIL_AK(f)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American kestrel (insectivore / carnivore)	3.9	8		SOIL_AK(fi)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian herbivore)	0.12	0.24		SOIL_AR(p)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian insectivore)	31	64		SOIL_AR(i)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	American robin (Avian omnivore)	0.24	0.49		SOIL_AR(ip)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Deer mouse (Mammalian omnivore)	0.21	1		SOIL_DM(ip)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Earthworm (Soil-dwelling invertebrate)	3.5	35		SOIL_EW_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Generic plant (Terrestrial autotroph - producer)	40	80		SOIL_GP_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Gray fox (Mammalian top carnivore)	3.3	16		SOIL_RF(f)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Montane shrew (Mammalian insectivore)	31	150		SOIL_MS(i)_ClO4(-1)
Inorganic	Perchlorate	14797-73-0	Mountain cottontail (Mammalian herbivore)	0.26	1.3		SOIL_DC(p)_ClO4(-1)
Inorganic	Vanadium	7440-62-2	American kestrel (Avian top carnivore)	110	230		SOIL_AK(f)_V
Inorganic	Vanadium	7440-62-2	American kestrel (insectivore / carnivore)	56	110		SOIL_AK(fi)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian herbivore)	6.8	13		SOIL_AR(p)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian insectivore)	4.7	9.5		SOIL_AR(i)_V
Inorganic	Vanadium	7440-62-2	American robin (Avian omnivore)	5.5	11		SOIL_AR(ip)_V
Inorganic	Vanadium	7440-62-2	Deer mouse (Mammalian omnivore)	470	1000		SOIL_DM(ip)_V
Inorganic	Vanadium	7440-62-2	Generic plant (Terrestrial autotroph - producer)	60	80		SOIL_GP_V
Inorganic	Vanadium	7440-62-2	Gray fox (Mammalian top carnivore)	3200	6900		SOIL_RF(f)_V
Inorganic	Vanadium	7440-62-2	Montane shrew (Mammalian insectivore)	290	610		SOIL_MS(i)_V
Inorganic	Vanadium	7440-62-2	Mountain cottontail (Mammalian herbivore)	740	1500		SOIL_DC(p)_V
Inorganic	Zinc	7440-66-6	American kestrel (Avian top carnivore)	2600	7000		SOIL_AK(f)_ZN
Inorganic	Zinc	7440-66-6	American kestrel (insectivore / carnivore)	220	590		SOIL_AK(fi)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian herbivore)	330	120		SOIL_AR(p)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian insectivore)	47	120		SOIL_AR(i)_ZN
Inorganic	Zinc	7440-66-6	American robin (Avian omnivore)	83	220		SOIL_AR(ip)_ZN

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
Inorganic	Zinc	7440-66-6	Deer mouse (Mammalian omnivore)	170	1700		SOIL_DM(ip)_ZN
Inorganic	Zinc	7440-66-6	Earthworm (Soil-dwelling invertebrate)	120	930		SOIL_EW_ZN
Inorganic	Zinc	7440-66-6	Generic plant (Terrestrial autotroph - producer)	160	810		SOIL_GP_ZN
Inorganic	Zinc	7440-66-6	Gray fox (Mammalian top carnivore)	9600	94000		SOIL_RF(f)_ZN
Inorganic	Zinc	7440-66-6	Montane shrew (Mammalian insectivore)	99	980		SOIL_MS(i)_ZN
Inorganic	Zinc	7440-66-6	Mountain cottontail (Mammalian herbivore)	1800	18000		SOIL_DC(p)_ZN
Organic	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	Earthworm (Soil-dwelling invertebrate)	1.8	81.5		SOIL_EW_1763-23-1
Organic	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	Generic plant (Terrestrial autotroph - producer)	62.2	80.8		SOIL_GP_1763-23-1
Organic	Perfluorooctanoic acid (PFOA)	335-67-1	Earthworm (Soil-dwelling invertebrate)	12.2	101.1		SOIL_EW_335-67-1
Organic	Perfluorooctanoic acid (PFOA)	335-67-1	Generic plant (Terrestrial autotroph - producer)	41.1	62.1		SOIL_GP_335-67-1
Organic	Total Petroleum Hydrocarbon (Fraction 2, Fraction 3)	TPH F2F3	Earthworm (Soil-dwelling invertebrate)	198	1977		SOIL_EW_TPH F2F3
Organic	Total Petroleum Hydrocarbon (Fraction 2, Fraction 3)	TPH F2F3	Generic plant (Terrestrial autotroph - producer)	81.2	419		SOIL_GP_TPH F2F3
Organic	Total Petroleum Hydrocarbon DRO	TPH-DRO	Earthworm (Soil-dwelling invertebrate)	198	1977		SOIL_EW_TPH F2F3
Organic	Total Petroleum Hydrocarbon DRO	TPH-DRO	Generic plant (Terrestrial autotroph - producer)	81.2	419		SOIL_GP_TPH F2F3
PAH	Acenaphthene	83-32-9	Deer mouse (Mammalian omnivore)	160	1600		SOIL_DM(ip)_83-32-9
PAH	Acenaphthene	83-32-9	Generic plant (Terrestrial autotroph - producer)	0.25	2		SOIL_GP_83-32-9
PAH	Acenaphthene	83-32-9	Gray fox (Mammalian top carnivore)	29000	290000		SOIL_RF(f)_83-32-9
PAH	Acenaphthene	83-32-9	Montane shrew (Mammalian insectivore)	130	1300		SOIL_MS(i)_83-32-9
PAH	Acenaphthene	83-32-9	Mountain cottontail (Mammalian herbivore)	530	5300		SOIL_DC(p)_83-32-9
PAH	Acenaphthylene	208-96-8	Deer mouse (Mammalian omnivore)	160	1600		SOIL_DM(ip)_208-96-8
PAH	Acenaphthylene	208-96-8	Gray fox (Mammalian top carnivore)	28000	280000		SOIL_RF(f)_208-96-8
PAH	Acenaphthylene	208-96-8	Montane shrew (Mammalian insectivore)	120	1200		SOIL_MS(i)_208-96-8
PAH	Acenaphthylene	208-96-8	Mountain cottontail (Mammalian herbivore)	540	5400		SOIL_DC(p)_208-96-8
PAH	Anthracene	120-12-7	Deer mouse (Mammalian omnivore)	300	3000		SOIL_DM(ip)_120-12-7
PAH	Anthracene	120-12-7	Generic plant (Terrestrial autotroph - producer)	6.8	9		SOIL_GP_120-12-7
PAH	Anthracene	120-12-7	Gray fox (Mammalian top carnivore)	38000	380000		SOIL_RF(f)_120-12-7
PAH	Anthracene	120-12-7	Montane shrew (Mammalian insectivore)	210	2100		SOIL_MS(i)_120-12-7
PAH	Anthracene	120-12-7	Mountain cottontail (Mammalian herbivore)	1200	12000		SOIL_DC(p)_120-12-7
PAH	Benzo(a)anthracene	56-55-3	American kestrel (Avian top carnivore)	28	280		SOIL_AK(f)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American kestrel (insectivore / carnivore)	6.4	64		SOIL_AK(fi)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian herbivore)	0.73	7.3		SOIL_AR(p)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian insectivore)	0.88	8.8		SOIL_AR(i)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	American robin (Avian omnivore)	0.8	8		SOIL_AR(ip)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Deer mouse (Mammalian omnivore)	3.4	34		SOIL_DM(ip)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Generic plant (Terrestrial autotroph - producer)	18	180		SOIL_GP_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Gray fox (Mammalian top carnivore)	110	1100		SOIL_RF(f)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Montane shrew (Mammalian insectivore)	4	40		SOIL_MS(i)_56-55-3
PAH	Benzo(a)anthracene	56-55-3	Mountain cottontail (Mammalian herbivore)	6.1	61		SOIL_DC(p)_56-55-3
PAH	Benzo(a)pyrene	50-32-8	Deer mouse (Mammalian omnivore)	84	260		SOIL_DM(ip)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Gray fox (Mammalian top carnivore)	3400	11000		SOIL_RF(f)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Montane shrew (Mammalian insectivore)	62	190		SOIL_MS(i)_50-32-8
PAH	Benzo(a)pyrene	50-32-8	Mountain cottontail (Mammalian herbivore)	260	830		SOIL_DC(p)_50-32-8
PAH	Benzo(b)fluoranthene	205-99-2	Deer mouse (Mammalian omnivore)	51	510		SOIL_DM(ip)_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Generic plant (Terrestrial autotroph - producer)	18	180		SOIL_GP_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Gray fox (Mammalian top carnivore)	2400	24000		SOIL_RF(f)_205-99-2
PAH	Benzo(b)fluoranthene	205-99-2	Montane shrew (Mammalian insectivore)	44	440		SOIL_MS(i)_205-99-2

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
PAH	Benzo(b)fluoranthene	205-99-2	Mountain cottontail (Mammalian herbivore)	130	1300		SOIL_DC(p)_205-99-2
PAH	Benzo(g,h,i)perylene	191-24-2	Deer mouse (Mammalian omnivore)	46	460		SOIL_DM(ip)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Gray fox (Mammalian top carnivore)	3600	36000		SOIL_RF(f)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Montane shrew (Mammalian insectivore)	25	250		SOIL_MS(i)_191-24-2
PAH	Benzo(g,h,i)perylene	191-24-2	Mountain cottontail (Mammalian herbivore)	470	4700		SOIL_DC(p)_191-24-2
PAH	Benzo(k)fluoranthene	207-08-9	Deer mouse (Mammalian omnivore)	99	990		SOIL_DM(ip)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Gray fox (Mammalian top carnivore)	4300	43000		SOIL_RF(f)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Montane shrew (Mammalian insectivore)	71	710		SOIL_MS(i)_207-08-9
PAH	Benzo(k)fluoranthene	207-08-9	Mountain cottontail (Mammalian herbivore)	330	3300		SOIL_DC(p)_207-08-9
PAH	Chrysene	218-01-9	Deer mouse (Mammalian omnivore)	3.1	31		SOIL_DM(ip)_218-01-9
PAH	Chrysene	218-01-9	Gray fox (Mammalian top carnivore)	110	1100		SOIL_RF(f)_218-01-9
PAH	Chrysene	218-01-9	Montane shrew (Mammalian insectivore)	3.1	31		SOIL_MS(i)_218-01-9
PAH	Chrysene	218-01-9	Mountain cottontail (Mammalian herbivore)	6.3	63		SOIL_DC(p)_218-01-9
PAH	Dibenzo(a,h)anthracene	53-70-3	Deer mouse (Mammalian omnivore)	22	220		SOIL_DM(ip)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Gray fox (Mammalian top carnivore)	850	8500		SOIL_RF(f)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Montane shrew (Mammalian insectivore)	14	140		SOIL_MS(i)_53-70-3
PAH	Dibenzo(a,h)anthracene	53-70-3	Mountain cottontail (Mammalian herbivore)	84	840		SOIL_DC(p)_53-70-3
PAH	Fluoranthene	206-44-0	Deer mouse (Mammalian omnivore)	38	380		SOIL_DM(ip)_206-44-0
PAH	Fluoranthene	206-44-0	Earthworm (Soil-dwelling invertebrate)	10	23		SOIL_EW_206-44-0
PAH	Fluoranthene	206-44-0	Gray fox (Mammalian top carnivore)	3900	39000		SOIL_RF(f)_206-44-0
PAH	Fluoranthene	206-44-0	Montane shrew (Mammalian insectivore)	22	220		SOIL_MS(i)_206-44-0
PAH	Fluoranthene	206-44-0	Mountain cottontail (Mammalian herbivore)	270	2700		SOIL_DC(p)_206-44-0
PAH	Fluorene	86-73-7	Deer mouse (Mammalian omnivore)	340	680		SOIL_DM(ip)_86-73-7
PAH	Fluorene	86-73-7	Earthworm (Soil-dwelling invertebrate)	3.7	19		SOIL_EW_86-73-7
PAH	Fluorene	86-73-7	Gray fox (Mammalian top carnivore)	50000	100000		SOIL_RF(f)_86-73-7
PAH	Fluorene	86-73-7	Montane shrew (Mammalian insectivore)	250	510		SOIL_MS(i)_86-73-7
PAH	Fluorene	86-73-7	Mountain cottontail (Mammalian herbivore)	1100	2300		SOIL_DC(p)_86-73-7
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Deer mouse (Mammalian omnivore)	110	1100		SOIL_DM(ip)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Gray fox (Mammalian top carnivore)	4600	46000		SOIL_RF(f)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Montane shrew (Mammalian insectivore)	71	710		SOIL_MS(i)_193-39-5
PAH	Indeno(1,2,3-cd)pyrene	193-39-5	Mountain cottontail (Mammalian herbivore)	510	5100		SOIL_DC(p)_193-39-5
PAH	Methylnaphthalene[2-]	91-57-6	Deer mouse (Mammalian omnivore)	24	240		SOIL_DM(ip)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Gray fox (Mammalian top carnivore)	4900	49000		SOIL_RF(f)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Montane shrew (Mammalian insectivore)	16	160		SOIL_MS(i)_91-57-6
PAH	Methylnaphthalene[2-]	91-57-6	Mountain cottontail (Mammalian herbivore)	110	1100		SOIL_DC(p)_91-57-6
PAH	Naphthalene	91-20-3	American kestrel (Avian top carnivore)	2100	21000		SOIL_AK(f)_91-20-3
PAH	Naphthalene	91-20-3	American kestrel (insectivore / carnivore)	78	780		SOIL_AK(fi)_91-20-3
PAH	Naphthalene	91-20-3	American robin (Avian herbivore)	3.4	34		SOIL_AR(p)_91-20-3
PAH	Naphthalene	91-20-3	American robin (Avian insectivore)	15	150		SOIL_AR(i)_91-20-3
PAH	Naphthalene	91-20-3	American robin (Avian omnivore)	5.7	57		SOIL_AR(ip)_91-20-3
PAH	Naphthalene	91-20-3	Deer mouse (Mammalian omnivore)	9.6	27		SOIL_DM(ip)_91-20-3
PAH	Naphthalene	91-20-3	Generic plant (Terrestrial autotroph - producer)	1	10		SOIL_GP_91-20-3
PAH	Naphthalene	91-20-3	Gray fox (Mammalian top carnivore)	5800	16000		SOIL_RF(f)_91-20-3
PAH	Naphthalene	91-20-3	Montane shrew (Mammalian insectivore)	28	79		SOIL_MS(i)_91-20-3
PAH	Naphthalene	91-20-3	Mountain cottontail (Mammalian herbivore)	14	40		SOIL_DC(p)_91-20-3
PAH	Phenanthrene	85-01-8	Deer mouse (Mammalian omnivore)	15	150		SOIL_DM(ip)_85-01-8
PAH	Phenanthrene	85-01-8	Earthworm (Soil-dwelling invertebrate)	5.5	12		SOIL_EW_85-01-8
PAH	Phenanthrene	85-01-8	Gray fox (Mammalian top carnivore)	1900	19000		SOIL_RF(f)_85-01-8
PAH	Phenanthrene	85-01-8	Montane shrew (Mammalian insectivore)	11	110		SOIL_MS(i)_85-01-8
PAH	Phenanthrene	85-01-8	Mountain cottontail (Mammalian herbivore)	62	620		SOIL_DC(p)_85-01-8
PAH	Pyrene	129-00-0	American kestrel (Avian top carnivore)	3000	30000		SOIL_AK(f)_129-00-0
PAH	Pyrene	129-00-0	American kestrel (insectivore / carnivore)	160	1600		SOIL_AK(fi)_129-00-0
PAH	Pyrene	129-00-0	American robin (Avian herbivore)	68	680		SOIL_AR(p)_129-00-0
PAH	Pyrene	129-00-0	American robin (Avian insectivore)	33	330		SOIL_AR(i)_129-00-0

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
PAH	Pyrene	129-00-0	American robin (Avian omnivore)	44	440		SOIL_AR(ip)_129-00-0
PAH	Pyrene	129-00-0	Deer mouse (Mammalian omnivore)	31	310		SOIL_DM(ip)_129-00-0
PAH	Pyrene	129-00-0	Earthworm (Soil-dwelling invertebrate)	10	20		SOIL_EW_129-00-0
PAH	Pyrene	129-00-0	Gray fox (Mammalian top carnivore)	3100	31000		SOIL_RF(f)_129-00-0
PAH	Pyrene	129-00-0	Montane shrew (Mammalian insectivore)	23	230		SOIL_MS(i)_129-00-0
PAH	Pyrene	129-00-0	Mountain cottontail (Mammalian herbivore)	110	1100		SOIL_DC(p)_129-00-0
SVOC	Benzoic Acid	65-85-0	Deer mouse (Mammalian omnivore)	1.3	13		SOIL_DM(ip)_65-85-0
SVOC	Benzoic Acid	65-85-0	Gray fox (Mammalian top carnivore)	2000	20000		SOIL_RF(f)_65-85-0
SVOC	Benzoic Acid	65-85-0	Montane shrew (Mammalian insectivore)	1	10		SOIL_MS(i)_65-85-0
SVOC	Benzoic Acid	65-85-0	Mountain cottontail (Mammalian herbivore)	4.6	46		SOIL_DC(p)_65-85-0
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American kestrel (Avian top carnivore)	9.3	93		SOIL_AK(f)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American kestrel (insectivore / carnivore)	0.096	0.96		SOIL_AK(fi)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian herbivore)	16	160		SOIL_AR(p)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian insectivore)	0.02	0.2		SOIL_AR(i)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	American robin (Avian omnivore)	0.04	0.4		SOIL_AR(ip)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Deer mouse (Mammalian omnivore)	1.1	11		SOIL_DM(ip)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Gray fox (Mammalian top carnivore)	500	5000		SOIL_RF(f)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Montane shrew (Mammalian insectivore)	0.6	6		SOIL_MS(i)_117-81-7
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	Mountain cottontail (Mammalian herbivore)	1900	19000		SOIL_DC(p)_117-81-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Deer mouse (Mammalian omnivore)	160	1600		SOIL_DM(ip)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Gray fox (Mammalian top carnivore)	23000	230000		SOIL_RF(f)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Montane shrew (Mammalian insectivore)	90	900		SOIL_MS(i)_85-68-7
SVOC	Butyl Benzyl Phthalate	85-68-7	Mountain cottontail (Mammalian herbivore)	2400	24000		SOIL_DC(p)_85-68-7
SVOC	Carbazole	86-74-8	Deer mouse (Mammalian omnivore)	79	790		SOIL_DM(ip)_86-74-8
SVOC	Carbazole	86-74-8	Gray fox (Mammalian top carnivore)	13000	130000		SOIL_RF(f)_86-74-8
SVOC	Carbazole	86-74-8	Montane shrew (Mammalian insectivore)	110	1100		SOIL_MS(i)_86-74-8
SVOC	Carbazole	86-74-8	Mountain cottontail (Mammalian herbivore)	140	1400		SOIL_DC(p)_86-74-8
SVOC	Chlorobenzene	108-90-7	Deer mouse (Mammalian omnivore)	53	530		SOIL_DM(ip)_108-90-7
SVOC	Chlorobenzene	108-90-7	Earthworm (Soil-dwelling invertebrate)	2.4	24		SOIL_EW_108-90-7
SVOC	Chlorobenzene	108-90-7	Gray fox (Mammalian top carnivore)	25000	250000		SOIL_RF(f)_108-90-7
SVOC	Chlorobenzene	108-90-7	Montane shrew (Mammalian insectivore)	43	430		SOIL_MS(i)_108-90-7
SVOC	Chlorobenzene	108-90-7	Mountain cottontail (Mammalian herbivore)	170	1700		SOIL_DC(p)_108-90-7
SVOC	Chlorophenol[2-]	95-57-8	American kestrel (Avian top carnivore)	310	3100		SOIL_AK(f)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American kestrel (insectivore / carnivore)	14	140		SOIL_AK(fi)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian herbivore)	0.39	3.9		SOIL_AR(p)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian insectivore)	2.6	26		SOIL_AR(i)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	American robin (Avian omnivore)	0.68	6.8		SOIL_AR(ip)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Deer mouse (Mammalian omnivore)	0.54	5.4		SOIL_DM(ip)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Gray fox (Mammalian top carnivore)	340	3400		SOIL_RF(f)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Montane shrew (Mammalian insectivore)	2.3	23		SOIL_MS(i)_95-57-8
SVOC	Chlorophenol[2-]	95-57-8	Mountain cottontail (Mammalian herbivore)	0.74	7.4		SOIL_DC(p)_95-57-8
SVOC	Dibenzofuran	132-64-9	Generic plant (Terrestrial autotroph - producer)	6.1	61		SOIL_GP_132-64-9
SVOC	Diethyl Phthalate	84-66-2	Deer mouse (Mammalian omnivore)	3600	36000		SOIL_DM(ip)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Generic plant (Terrestrial autotroph - producer)	100	1000		SOIL_GP_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Gray fox (Mammalian top carnivore)	2500000	25000000		SOIL_RF(f)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Montane shrew (Mammalian insectivore)	3600	36000		SOIL_MS(i)_84-66-2
SVOC	Diethyl Phthalate	84-66-2	Mountain cottontail (Mammalian herbivore)	8800	88000		SOIL_DC(p)_84-66-2
SVOC	Dimethyl Phthalate	131-11-3	Deer mouse (Mammalian omnivore)	38	460		SOIL_DM(ip)_131-11-3

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
SVOC	Dimethyl Phthalate	131-11-3	Earthworm (Soil-dwelling invertebrate)	10	100		SOIL_EW_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Gray fox (Mammalian top carnivore)	48000	590000		SOIL_RF(f)_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Montane shrew (Mammalian insectivore)	80	980		SOIL_MS(i)_131-11-3
SVOC	Dimethyl Phthalate	131-11-3	Mountain cottontail (Mammalian herbivore)	60	740		SOIL_DC(p)_131-11-3
SVOC	Di-n-Butyl Phthalate	84-74-2	American kestrel (Avian top carnivore)	2	20		SOIL_AK(f)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American kestrel (insectivore / carnivore)	0.052	0.52		SOIL_AK(fi)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian herbivore)	0.38	3.8		SOIL_AR(p)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian insectivore)	0.011	0.11		SOIL_AR(i)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	American robin (Avian omnivore)	0.021	0.21		SOIL_AR(ip)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Deer mouse (Mammalian omnivore)	360	860		SOIL_DM(ip)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Generic plant (Terrestrial autotroph - producer)	160	600		SOIL_GP_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Gray fox (Mammalian top carnivore)	62000	140000		SOIL_RF(f)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Montane shrew (Mammalian insectivore)	180	450		SOIL_MS(i)_84-74-2
SVOC	Di-n-Butyl Phthalate	84-74-2	Mountain cottontail (Mammalian herbivore)	17000	40000		SOIL_DC(p)_84-74-2
SVOC	Di-n-octylphthalate	117-84-0	Deer mouse (Mammalian omnivore)	1.8	18		SOIL_DM(ip)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Gray fox (Mammalian top carnivore)	1300	13000		SOIL_RF(f)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Montane shrew (Mammalian insectivore)	0.91	9.1		SOIL_MS(i)_117-84-0
SVOC	Di-n-octylphthalate	117-84-0	Mountain cottontail (Mammalian herbivore)	8400	84000		SOIL_DC(p)_117-84-0
SVOC	Methylphenol[2-]	95-48-7	Deer mouse (Mammalian omnivore)	580	5800		SOIL_DM(ip)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Generic plant (Terrestrial autotroph - producer)	0.67	7		SOIL_GP_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Gray fox (Mammalian top carnivore)	160000	1600000		SOIL_RF(f)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Montane shrew (Mammalian insectivore)	1500	15000		SOIL_MS(i)_95-48-7
SVOC	Methylphenol[2-]	95-48-7	Mountain cottontail (Mammalian herbivore)	880	8800		SOIL_DC(p)_95-48-7
SVOC	Methylphenol[3-]	108-39-4	Generic plant (Terrestrial autotroph - producer)	0.69	7		SOIL_GP_108-39-4
SVOC	Nitroaniline[2-]	88-74-4	Deer mouse (Mammalian omnivore)	5.3	10		SOIL_DM(ip)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Gray fox (Mammalian top carnivore)	2200	4400		SOIL_RF(f)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Montane shrew (Mammalian insectivore)	6.5	13		SOIL_MS(i)_88-74-4
SVOC	Nitroaniline[2-]	88-74-4	Mountain cottontail (Mammalian herbivore)	11	22		SOIL_DC(p)_88-74-4
SVOC	Nitrobenzene	98-95-3	Deer mouse (Mammalian omnivore)	4.8	48		SOIL_DM(ip)_98-95-3
SVOC	Nitrobenzene	98-95-3	Earthworm (Soil-dwelling invertebrate)	2.2	22		SOIL_EW_98-95-3
SVOC	Nitrobenzene	98-95-3	Gray fox (Mammalian top carnivore)	4100	41000		SOIL_RF(f)_98-95-3
SVOC	Nitrobenzene	98-95-3	Montane shrew (Mammalian insectivore)	21	210		SOIL_MS(i)_98-95-3
SVOC	Nitrobenzene	98-95-3	Mountain cottontail (Mammalian herbivore)	6.7	67		SOIL_DC(p)_98-95-3
SVOC	Pentachloronitrobenzene	82-68-8	American kestrel (Avian top carnivore)	110	1100		SOIL_AK(f)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American kestrel (insectivore / carnivore)	3.3	33		SOIL_AK(fi)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian herbivore)	21	210		SOIL_AR(p)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian insectivore)	0.7	7		SOIL_AR(i)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	American robin (Avian omnivore)	1.3	13		SOIL_AR(ip)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Deer mouse (Mammalian omnivore)	22	220		SOIL_DM(ip)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Gray fox (Mammalian top carnivore)	3500	35000		SOIL_RF(f)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Montane shrew (Mammalian insectivore)	11	110		SOIL_MS(i)_82-68-8
SVOC	Pentachloronitrobenzene	82-68-8	Mountain cottontail (Mammalian herbivore)	930	9300		SOIL_DC(p)_82-68-8
SVOC	Pentachlorophenol	87-86-5	American kestrel (Avian top carnivore)	57	570		SOIL_AK(f)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American kestrel (insectivore / carnivore)	1.7	17		SOIL_AK(fi)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian herbivore)	29	290		SOIL_AR(p)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian insectivore)	0.36	3.6		SOIL_AR(i)_87-86-5
SVOC	Pentachlorophenol	87-86-5	American robin (Avian omnivore)	0.72	7.2		SOIL_AR(ip)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Deer mouse (Mammalian omnivore)	1.5	15		SOIL_DM(ip)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Earthworm (Soil-dwelling invertebrate)	31	150		SOIL_EW_87-86-5
SVOC	Pentachlorophenol	87-86-5	Generic plant (Terrestrial autotroph - producer)	5	50		SOIL_GP_87-86-5
SVOC	Pentachlorophenol	87-86-5	Gray fox (Mammalian top carnivore)	230	2300		SOIL_RF(f)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Montane shrew (Mammalian insectivore)	0.81	8.1		SOIL_MS(i)_87-86-5
SVOC	Pentachlorophenol	87-86-5	Mountain cottontail (Mammalian herbivore)	180	1800		SOIL_DC(p)_87-86-5

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
SVOC	Phenol	108-95-2	Deer mouse (Mammalian omnivore)	37	370		SOIL_DM(ip)_108-95-2
SVOC	Phenol	108-95-2	Earthworm (Soil-dwelling invertebrate)	1.8	18		SOIL_EW_108-95-2
SVOC	Phenol	108-95-2	Generic plant (Terrestrial autotroph - producer)	0.79	8		SOIL_GP_108-95-2
SVOC	Phenol	108-95-2	Gray fox (Mammalian top carnivore)	43000	430000		SOIL_RF(f)_108-95-2
SVOC	Phenol	108-95-2	Montane shrew (Mammalian insectivore)	640	6400		SOIL_MS(i)_108-95-2
SVOC	Phenol	108-95-2	Mountain cottontail (Mammalian herbivore)	47	470		SOIL_DC(p)_108-95-2
VOC	Acetone	67-64-1	American kestrel (Avian top carnivore)	66000	660000		SOIL_AK(f)_67-64-1
VOC	Acetone	67-64-1	American kestrel (insectivore / carnivore)	840	8400		SOIL_AK(fi)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian herbivore)	7.5	75		SOIL_AR(p)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian insectivore)	170	1700		SOIL_AR(i)_67-64-1
VOC	Acetone	67-64-1	American robin (Avian omnivore)	14	140		SOIL_AR(ip)_67-64-1
VOC	Acetone	67-64-1	Deer mouse (Mammalian omnivore)	1.2	6.3		SOIL_DM(ip)_67-64-1
VOC	Acetone	67-64-1	Gray fox (Mammalian top carnivore)	7800	39000		SOIL_RF(f)_67-64-1
VOC	Acetone	67-64-1	Montane shrew (Mammalian insectivore)	15	79		SOIL_MS(i)_67-64-1
VOC	Acetone	67-64-1	Mountain cottontail (Mammalian herbivore)	1.6	8		SOIL_DC(p)_67-64-1
VOC	Benzene	71-43-2	Deer mouse (Mammalian omnivore)	24	240		SOIL_DM(ip)_71-43-2
VOC	Benzene	71-43-2	Gray fox (Mammalian top carnivore)	18000	180000		SOIL_RF(f)_71-43-2
VOC	Benzene	71-43-2	Montane shrew (Mammalian insectivore)	49	490		SOIL_MS(i)_71-43-2
VOC	Benzene	71-43-2	Mountain cottontail (Mammalian herbivore)	38	380		SOIL_DC(p)_71-43-2
VOC	Benzyl Alcohol	100-51-6	Deer mouse (Mammalian omnivore)	120	1200		SOIL_DM(ip)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Gray fox (Mammalian top carnivore)	110000	1100000		SOIL_RF(f)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Montane shrew (Mammalian insectivore)	270	2700		SOIL_MS(i)_100-51-6
VOC	Benzyl Alcohol	100-51-6	Mountain cottontail (Mammalian herbivore)	190	1900		SOIL_DC(p)_100-51-6
VOC	Butanone[2-]	78-93-3	Deer mouse (Mammalian omnivore)	350	920		SOIL_DM(ip)_78-93-3
VOC	Butanone[2-]	78-93-3	Gray fox (Mammalian top carnivore)	1300000	3500000		SOIL_RF(f)_78-93-3
VOC	Butanone[2-]	78-93-3	Montane shrew (Mammalian insectivore)	2700	6900		SOIL_MS(i)_78-93-3
VOC	Butanone[2-]	78-93-3	Mountain cottontail (Mammalian herbivore)	470	1200		SOIL_DC(p)_78-93-3
VOC	Carbon Disulfide	75-15-0	Deer mouse (Mammalian omnivore)	0.81	8.1		SOIL_DM(ip)_75-15-0
VOC	Carbon Disulfide	75-15-0	Gray fox (Mammalian top carnivore)	190	1900		SOIL_RF(f)_75-15-0
VOC	Carbon Disulfide	75-15-0	Montane shrew (Mammalian insectivore)	1.2	12		SOIL_MS(i)_75-15-0
VOC	Carbon Disulfide	75-15-0	Mountain cottontail (Mammalian herbivore)	1.4	14		SOIL_DC(p)_75-15-0
VOC	Chloroaniline[4-]	106-47-8	Earthworm (Soil-dwelling invertebrate)	1.8	18		SOIL_EW_106-47-8
VOC	Chloroaniline[4-]	106-47-8	Generic plant (Terrestrial autotroph - producer)	1	10		SOIL_GP_106-47-8
VOC	Chloroform	67-66-3	Deer mouse (Mammalian omnivore)	8	21		SOIL_DM(ip)_67-66-3
VOC	Chloroform	67-66-3	Gray fox (Mammalian top carnivore)	8900	24000		SOIL_RF(f)_67-66-3
VOC	Chloroform	67-66-3	Montane shrew (Mammalian insectivore)	8.2	22		SOIL_MS(i)_67-66-3
VOC	Chloroform	67-66-3	Mountain cottontail (Mammalian herbivore)	19	52		SOIL_DC(p)_67-66-3
VOC	Dichlorobenzene[1,2-]	95-50-1	Deer mouse (Mammalian omnivore)	1.5	15		SOIL_DM(ip)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Gray fox (Mammalian top carnivore)	480	4800		SOIL_RF(f)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Montane shrew (Mammalian insectivore)	0.92	9.2		SOIL_MS(i)_95-50-1
VOC	Dichlorobenzene[1,2-]	95-50-1	Mountain cottontail (Mammalian herbivore)	12	120		SOIL_DC(p)_95-50-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Deer mouse (Mammalian omnivore)	1.2	12		SOIL_DM(ip)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Gray fox (Mammalian top carnivore)	380	3800		SOIL_RF(f)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Montane shrew (Mammalian insectivore)	0.74	7.4		SOIL_MS(i)_541-73-1
VOC	Dichlorobenzene[1,3-]	541-73-1	Mountain cottontail (Mammalian herbivore)	13	130		SOIL_DC(p)_541-73-1
VOC	Dichlorobenzene[1,4-]	106-46-7	Deer mouse (Mammalian omnivore)	1.5	6		SOIL_DM(ip)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Earthworm (Soil-dwelling invertebrate)	1.2	12		SOIL_EW_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Gray fox (Mammalian top carnivore)	470	1800		SOIL_RF(f)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Montane shrew (Mammalian insectivore)	0.89	3.5		SOIL_MS(i)_106-46-7
VOC	Dichlorobenzene[1,4-]	106-46-7	Mountain cottontail (Mammalian herbivore)	12	49		SOIL_DC(p)_106-46-7
VOC	Dichloroethane[1,1-]	75-34-3	Deer mouse (Mammalian omnivore)	210	2100		SOIL_DM(ip)_75-34-3
VOC	Dichloroethane[1,1-]	75-34-3	Gray fox (Mammalian top carnivore)	250000	2500000		SOIL_RF(f)_75-34-3

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
VOC	Dichloroethane[1,1-]	75-34-3	Montane shrew (Mammalian insectivore)	290	2900		SOIL_MS(i)_75-34-3
VOC	Dichloroethane[1,1-]	75-34-3	Mountain cottontail (Mammalian herbivore)	410	4100		SOIL_DC(p)_75-34-3
VOC	Dichloroethane[1,2-]	107-06-2	American kestrel (Avian top carnivore)	1300	2700		SOIL_AK(f)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American kestrel (insectivore / carnivore)	22	44		SOIL_AK(fi)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian herbivore)	0.85	1.6		SOIL_AR(p)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian insectivore)	4.5	9		SOIL_AR(i)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	American robin (Avian omnivore)	1.4	2.8		SOIL_AR(ip)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Deer mouse (Mammalian omnivore)	27	270		SOIL_DM(ip)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Gray fox (Mammalian top carnivore)	36000	360000		SOIL_RF(f)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Montane shrew (Mammalian insectivore)	91	910		SOIL_MS(i)_107-06-2
VOC	Dichloroethane[1,2-]	107-06-2	Mountain cottontail (Mammalian herbivore)	39	390		SOIL_DC(p)_107-06-2
VOC	Dichloroethene[1,1-]	75-35-4	Deer mouse (Mammalian omnivore)	14	140		SOIL_DM(ip)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Gray fox (Mammalian top carnivore)	14000	140000		SOIL_RF(f)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Montane shrew (Mammalian insectivore)	11	110		SOIL_MS(i)_75-35-4
VOC	Dichloroethene[1,1-]	75-35-4	Mountain cottontail (Mammalian herbivore)	44	440		SOIL_DC(p)_75-35-4
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Deer mouse (Mammalian omnivore)	25	250		SOIL_DM(ip)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Gray fox (Mammalian top carnivore)	25000	250000		SOIL_RF(f)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Montane shrew (Mammalian insectivore)	24	240		SOIL_MS(i)_540-59-0
VOC	Dichloroethene[cis/trans-1,2-]	540-59-0	Mountain cottontail (Mammalian herbivore)	64	640		SOIL_DC(p)_540-59-0
VOC	Diphenylamine	122-39-4	American kestrel (Avian top carnivore)	3900	6500		SOIL_AK(f)_122-39-4
VOC	Diphenylamine	122-39-4	American kestrel (insectivore / carnivore)	49	81		SOIL_AK(fi)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian herbivore)	78	130		SOIL_AR(p)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian insectivore)	10	16		SOIL_AR(i)_122-39-4
VOC	Diphenylamine	122-39-4	American robin (Avian omnivore)	17	29		SOIL_AR(ip)_122-39-4
VOC	Hexachlorobenzene	118-74-1	American kestrel (Avian top carnivore)	12	120		SOIL_AK(f)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American kestrel (insectivore / carnivore)	0.37	3.7		SOIL_AK(fi)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian herbivore)	83	830		SOIL_AR(p)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian insectivore)	0.079	0.79		SOIL_AR(i)_118-74-1
VOC	Hexachlorobenzene	118-74-1	American robin (Avian omnivore)	0.15	1.5		SOIL_AR(ip)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Deer mouse (Mammalian omnivore)	0.39	3.9		SOIL_DM(ip)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Earthworm (Soil-dwelling invertebrate)	10	100		SOIL_EW_118-74-1
VOC	Hexachlorobenzene	118-74-1	Generic plant (Terrestrial autotroph - producer)	10	100		SOIL_GP_118-74-1
VOC	Hexachlorobenzene	118-74-1	Gray fox (Mammalian top carnivore)	59	590		SOIL_RF(f)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Montane shrew (Mammalian insectivore)	0.2	2		SOIL_MS(i)_118-74-1
VOC	Hexachlorobenzene	118-74-1	Mountain cottontail (Mammalian herbivore)	910	9100		SOIL_DC(p)_118-74-1
VOC	Hexanone[2-]	591-78-6	American kestrel (Avian top carnivore)	290	2900		SOIL_AK(f)_591-78-6
VOC	Hexanone[2-]	591-78-6	American kestrel (insectivore / carnivore)	1.7	17		SOIL_AK(fi)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian herbivore)	0.47	4.7		SOIL_AR(p)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian insectivore)	0.36	3.6		SOIL_AR(i)_591-78-6
VOC	Hexanone[2-]	591-78-6	American robin (Avian omnivore)	0.41	4.1		SOIL_AR(ip)_591-78-6
VOC	Hexanone[2-]	591-78-6	Deer mouse (Mammalian omnivore)	6.1	23		SOIL_DM(ip)_591-78-6
VOC	Hexanone[2-]	591-78-6	Gray fox (Mammalian top carnivore)	5900	22000		SOIL_RF(f)_591-78-6
VOC	Hexanone[2-]	591-78-6	Montane shrew (Mammalian insectivore)	5.4	20		SOIL_MS(i)_591-78-6
VOC	Hexanone[2-]	591-78-6	Mountain cottontail (Mammalian herbivore)	17	65		SOIL_DC(p)_591-78-6
VOC	Iodomethane	74-88-4	American kestrel (Avian top carnivore)	46	92		SOIL_AK(f)_74-88-4
VOC	Iodomethane	74-88-4	American kestrel (insectivore / carnivore)	0.29	0.59		SOIL_AK(fi)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian herbivore)	0.038	0.076		SOIL_AR(p)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian insectivore)	0.062	0.12		SOIL_AR(i)_74-88-4
VOC	Iodomethane	74-88-4	American robin (Avian omnivore)	0.047	0.095		SOIL_AR(ip)_74-88-4
VOC	Methyl-2-pentanone[4-]	108-10-1	Deer mouse (Mammalian omnivore)	9.7	97		SOIL_DM(ip)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Gray fox (Mammalian top carnivore)	18000	180000		SOIL_RF(f)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Montane shrew (Mammalian insectivore)	15	150		SOIL_MS(i)_108-10-1
VOC	Methyl-2-pentanone[4-]	108-10-1	Mountain cottontail (Mammalian herbivore)	17	170		SOIL_DC(p)_108-10-1
VOC	Methylene Chloride	75-09-2	Deer mouse (Mammalian omnivore)	2.6	22		SOIL_DM(ip)_75-09-2

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
VOC	Methylene Chloride	75-09-2	Generic plant (Terrestrial autotroph - producer)	1600	16000		SOIL_GP_75-09-2
VOC	Methylene Chloride	75-09-2	Gray fox (Mammalian top carnivore)	4300	36000		SOIL_RF(f)_75-09-2
VOC	Methylene Chloride	75-09-2	Montane shrew (Mammalian insectivore)	9.2	79		SOIL_MS(i)_75-09-2
VOC	Methylene Chloride	75-09-2	Mountain cottontail (Mammalian herbivore)	3.8	32		SOIL_DC(p)_75-09-2
VOC	Styrene	100-42-5	Earthworm (Soil-dwelling invertebrate)	1.2	12		SOIL_EW_100-42-5
VOC	Styrene	100-42-5	Generic plant (Terrestrial autotroph - producer)	3.2	32		SOIL_GP_100-42-5
VOC	Tetrachloroethene	127-18-4	Deer mouse (Mammalian omnivore)	0.35	1.7		SOIL_DM(ip)_127-18-4
VOC	Tetrachloroethene	127-18-4	Generic plant (Terrestrial autotroph - producer)	10	100		SOIL_GP_127-18-4
VOC	Tetrachloroethene	127-18-4	Gray fox (Mammalian top carnivore)	120	630		SOIL_RF(f)_127-18-4
VOC	Tetrachloroethene	127-18-4	Montane shrew (Mammalian insectivore)	0.18	0.94		SOIL_MS(i)_127-18-4
VOC	Tetrachloroethene	127-18-4	Mountain cottontail (Mammalian herbivore)	9.5	47		SOIL_DC(p)_127-18-4
VOC	Isopropyltoluene[4-]	99-87-6	Deer mouse (Mammalian omnivore)	25	250	Use toluene	SOIL_DM(ip)_108-88-3
VOC	Isopropyltoluene[4-]	99-87-6	Generic plant (Terrestrial autotroph - producer)	200	2000	Use toluene	SOIL_GP_108-88-3
VOC	Isopropyltoluene[4-]	99-87-6	Gray fox (Mammalian top carnivore)	12000	120000	Use toluene	SOIL_RF(f)_108-88-3
VOC	Isopropyltoluene[4-]	99-87-6	Montane shrew (Mammalian insectivore)	23	230	Use toluene	SOIL_MS(i)_108-88-3
VOC	Isopropyltoluene[4-]	99-87-6	Mountain cottontail (Mammalian herbivore)	66	660	Use toluene	SOIL_DC(p)_108-88-3
VOC	Toluene	108-88-3	Deer mouse (Mammalian omnivore)	25	250		SOIL_DM(ip)_108-88-3
VOC	Toluene	108-88-3	Generic plant (Terrestrial autotroph - producer)	200	2000		SOIL_GP_108-88-3
VOC	Toluene	108-88-3	Gray fox (Mammalian top carnivore)	12000	120000		SOIL_RF(f)_108-88-3
VOC	Toluene	108-88-3	Montane shrew (Mammalian insectivore)	23	230		SOIL_MS(i)_108-88-3
VOC	Toluene	108-88-3	Mountain cottontail (Mammalian herbivore)	66	660		SOIL_DC(p)_108-88-3
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Deer mouse (Mammalian omnivore)	0.51	5.1		SOIL_DM(ip)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Earthworm (Soil-dwelling invertebrate)	1.2	12		SOIL_EW_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Gray fox (Mammalian top carnivore)	110	1100		SOIL_RF(f)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Montane shrew (Mammalian insectivore)	0.27	2.7		SOIL_MS(i)_120-82-1
VOC	Trichlorobenzene[1,2,4-]	120-82-1	Mountain cottontail (Mammalian herbivore)	12	120		SOIL_DC(p)_120-82-1
VOC	Trichloroethane[1,1,1-]	71-55-6	Deer mouse (Mammalian omnivore)	400	4000		SOIL_DM(ip)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Gray fox (Mammalian top carnivore)	310000	3100000		SOIL_RF(f)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Montane shrew (Mammalian insectivore)	260	2600		SOIL_MS(i)_71-55-6
VOC	Trichloroethane[1,1,1-]	71-55-6	Mountain cottontail (Mammalian herbivore)	2000	20000		SOIL_DC(p)_71-55-6
VOC	Trichloroethene	79-01-6	Deer mouse (Mammalian omnivore)	54	540		SOIL_DM(ip)_79-01-6
VOC	Trichloroethene	79-01-6	Gray fox (Mammalian top carnivore)	42000	420000		SOIL_RF(f)_79-01-6
VOC	Trichloroethene	79-01-6	Montane shrew (Mammalian insectivore)	42	420		SOIL_MS(i)_79-01-6
VOC	Trichloroethene	79-01-6	Mountain cottontail (Mammalian herbivore)	190	1900		SOIL_DC(p)_79-01-6
VOC	Trichlorofluoromethane	75-69-4	Deer mouse (Mammalian omnivore)	97	650		SOIL_DM(ip)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Gray fox (Mammalian top carnivore)	62000	420000		SOIL_RF(f)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Montane shrew (Mammalian insectivore)	52	350		SOIL_MS(i)_75-69-4
VOC	Trichlorofluoromethane	75-69-4	Mountain cottontail (Mammalian herbivore)	1800	12000		SOIL_DC(p)_75-69-4
VOC	Vinyl Chloride	75-01-4	Deer mouse (Mammalian omnivore)	0.13	1.3		SOIL_DM(ip)_75-01-4
VOC	Vinyl Chloride	75-01-4	Gray fox (Mammalian top carnivore)	110	1100		SOIL_RF(f)_75-01-4
VOC	Vinyl Chloride	75-01-4	Montane shrew (Mammalian insectivore)	0.12	1.2		SOIL_MS(i)_75-01-4
VOC	Vinyl Chloride	75-01-4	Mountain cottontail (Mammalian herbivore)	0.34	3.4		SOIL_DC(p)_75-01-4

Analyte Group	Analyte Name	Analyte Code	ESL Receptor	No Effect ESL	Low Effect ESL	Note	ESL ID
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	American kestrel (Avian top carnivore)	13000	130000	Use Xylene total	SOIL_AK(f)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	American kestrel (insectivore / carnivore)	190	1900	Use Xylene total	SOIL_AK(fi)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	American robin (Avian herbivore)	89	890	Use Xylene total	SOIL_AR(p)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	American robin (Avian insectivore)	41	410	Use Xylene total	SOIL_AR(i)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	American robin (Avian omnivore)	56	560	Use Xylene total	SOIL_AR(ip)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	Deer mouse (Mammalian omnivore)	1.9	2.4	Use Xylene total	SOIL_DM(ip)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	Generic plant (Terrestrial autotroph - producer)	100	1000	Use Xylene total	SOIL_GP_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	Gray fox (Mammalian top carnivore)	750	930	Use Xylene total	SOIL_RF(f)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	Montane shrew (Mammalian insectivore)	1.4	1.8	Use Xylene total	SOIL_MS(i)_1330-20-7
VOC	Xylene[1,3-]+Xylene[1,4-]	Xylene[m+p]	Mountain cottontail (Mammalian herbivore)	7.6	9.5	Use Xylene total	SOIL_DC(p)_1330-20-7

33. Leininger, L.D., *et al*., May 2020. *IHE Material and IHE Subassembly Qualification Test Description and Criteria*, Vol. 14.7. LLNL-TR-679331-REV-1. LA-UR-15-29238. OSTI Identifier 1635762. (Leininger *et al*. 2020)

May 14, 2020
Version 14.7
LLNL-TR-679331-REV-1
LA-UR-15-29238

IHE Material and IHE Subassembly Qualification Test Description and Criteria

May 14, 2020
Version 14.7

Editor:
Lara D. Leininger[1]

Authors:
Peter Dickson[2], Micha Gresshoff[1], Matt Holmes[2], Daniel E. Hooks[2], Jon L. Maienschein[1], Gary Parker[2]

Contributors: Bill Andrews[1], Eric N. Brown[2], Alan J. DeHope[1], Anthony Dutton[3], Laurence E. Fried[1], Alex Gash[1], Barry G. Hill[3], Maximillian Hobson-Dupont[1], Constantine A. Hrousis[1], Evan Kahl[1], Michael J. Kaneshige[4], Matt McClelland[1], Tommy J. Morris[2], George E. Overturf[1], Paul D. Peterson[1], Philip J. Rae[2], Chris L. Robbins[1], Jonathan A. Simpson[1], Harry K. Springer[1], Craig M. Tarver[1], Daniel Trujillo[2], Kevin Vandersall[1]

[1] Lawrence Livermore National Laboratory
[2] Los Alamos National Laboratory
[3] Pantex Plant
[4] Sandia National Laboratories

Unlimited Unclassified Release

Disclaimer

Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

Publication Record

Revision	Date	Notes
LLNL-TR-679331 LA-UR-15-29238 (version 13.5)	November 17, 2015 (Updated June 7, 2016)	Initial Release
LLNL-TR-679331-REV-1 LA-UR-15-29238 (version 14.7)	May 14, 2020	• Test details of the Deflagration to Detonation Transition (DDT) experiment specified. • High temperature Shock to Detonation (SDT) experiment temperature setpoint from DDT high temperature experiment, instead of from an additional cookoff test. • No substantive changes to the Skid Test • Number of Bullet Tests reduced from 6 to 3 for each of 2 bullet types. • No substantive changes to IHE Subassembly Definitions

Table of Contents

Insensitive High Explosive (IHE) Materials and Subassemblies

As defined in Chapter 16 of the DOE Explosive Safety Standard (DOE-STD-1212), IHE Materials are mass-detonable explosives that are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. The test series to qualify an IHE material contains the following elements:

1. Deflagration-to-Detonation Transition (DDT)
2. Shock-to-Detonation Transition (SDT)
3. Skid Test
4. Bullet Test

For explosives that do not meet the qualification criteria of an IHE material, there is a test series to qualify as an IHE subassembly in a smaller, weapon-system relevant, configuration. The IHE Subassembly Qualification Test Series contains the following elements:

1. DDT of individual subassembly materials in relevant, conservative, scales to application
2. SDT material test of the main charge only
3. Skid Test
4. Multiple Bullet Impact Test

The first section of this document defines the DDT, SDT, Skid, and Bullet tests that comprise the IHE Material Qualification Test Series.

The second section of this document describes the tests that are required for the IHE Subassembly Qualification Test Series. These tests are described in more general terms, as some details will depend on the configuration and materials of the specific IHE subassembly being tested.

The qualification and approval process described herein is limited to the Department of Energy (DOE) and nuclear weapons applications.

These definitions were approved by vote of the DOE/NNSA Explosive Safety Committee in May 2016 and are required for any new material or subassembly proposed that is not already noted as approved in DOE-STD-1212.

May 14, 2020
Version 14.7
LLNL-TR-679331-REV-1
LA-UR-15-29238

Section 1

IHE Material Qualification Test Series

2.1 Deflagration-to-Detonation Experiment

1.1.1 Introduction

The purpose of the deflagration-to-detonation test is to demonstrate that an IHE material will not undergo deflagration-to-detonation transition (DDT) under stockpile relevant conditions of scale, confinement, and material condition. Inherent in this test design is the assumption that ignition does occur, with onset of deflagration. The test design will incorporate large margins and replicates to account for the stochastic nature of DDT events.

1.1.2 Underlying Physics

DDT in condensed-phase, inhomogeneous, explosives is a significantly more complex process than shock-to-detonation transition (SDT), comprising a number of distinct steps:

1. Ignition of reaction.
2. Conductive burning, in which the ignition front advances by thermal conduction.
3. Convective burning, in which the ignition front advances by penetration of hot, gaseous, products.
4. Compaction of the unreacted explosive ahead of the ignition front by pressurization due to the reaction products, choking off the convective process.
5. Downstream plug formation.
6. Shock formation at the downstream plug boundary.
7. SDT

This process is dependent on:

1. Decomposition chemistry and kinetics: intrinsic properties that control pre-ignition decomposition, which affect the degree of porosity developed at elevated temperature prior to ignition and, consequently, the compaction characteristics of the material. They also determine deflagration rate as a function of pressure; faster favors reaction build up and shorter run-to-detonation distances.

2. Mechanical properties: rate-dependent intensive intrinsic properties that control deflagration rate as a function of accessible surface area via strain-rate-dependent fracture properties, and also determine compaction and plug formation.

This combination of complex factors puts a quantitative understanding of the phenomenon beyond our current modeling capabilities but, since we understand the trends arising from each factor, we can bound the problem by experimental exploration of worst-case scenarios with a limited number of replicates.

Accordingly, the proposed DDT test is highly conservative in terms of the external (to the explosive) parameters of importance, specifically confinement and charge size. The metric is the absence of transition to detonation in a charge size and geometry that permits a significantly longer run distance, and which is subject to much stronger and more massive confinement, than any configuration of relevance to a nuclear weapon.

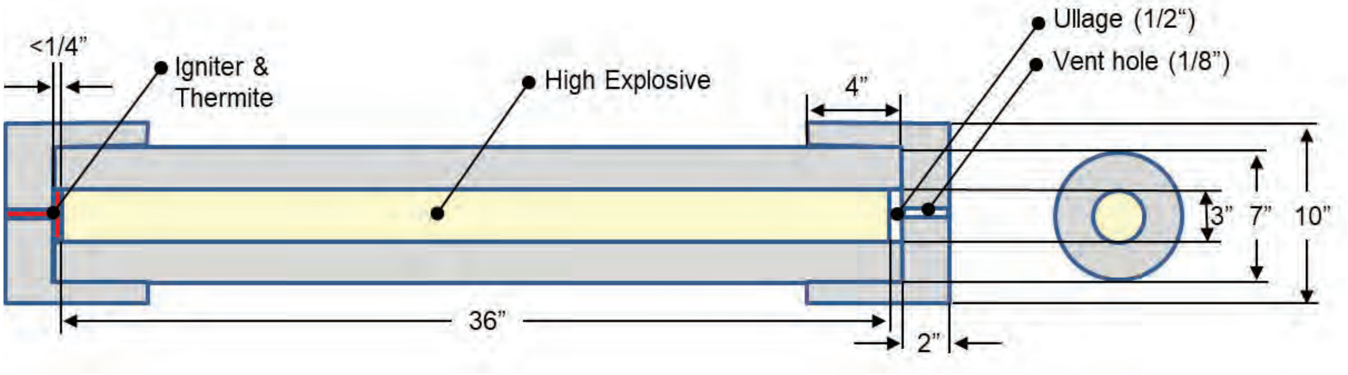
1.1.3 DDT Test Configuration and Diagnostics

A representative apparatus is shown in Figure 1, and described as follows:

- Heavily confined explosive samples with long run length.
    - Confinement is provided by a thick-walled steel cylinder (yield strength of the steel to be ~36 ksi (or larger); should be widely-available commercially:
        - 3 inch nominal internal diameter,
        - 2 inch wall thickness, and
        - ~40 inches long to accommodate explosive column, head space, and end caps
    - Both ends are sealed with threaded end caps. End cap shall be 2 inches thick in the axial direction and 1.5 inch thick in the radial direction. Length of thread engagement shall be 4 inches. If threaded end caps are undesirable, alternate closure hardware may be used instead, provided confinement is demonstrated to be equivalent (if alternate end cap design is employed, justification demonstrating confinement equivalence must be approved by the DOE/NNSA IHE Qualification Update Group).
    - One end cap possesses an igniter system, typically comprised of a hot-wire embedded in pyrotechnic. The gap between the ignitor and the explosive column should not exceed ¼ inch to ensure the system can reliably ignite deflagration in the explosive; failure to ignite the explosive does not constitute a “passing”. In the event that the igniter fails to ignite deflagration in the explosive, re-ignition may be attempted on the assembly.
    - The other end cap possesses a vent hole; ~1/8 inch diameter. This vent hole permits slow gas products to escape, avoiding quasi-static pre-pressurization of the tube, but is too small of a diameter to provide significant venting when cookoff occurs (a choked flow condition is attained when the explosive deflagrates).
    - Length of the explosive column is 36 inches and shorter than the bore length, to leave an initial axial ullage of ~1/2 ± 0.1 inch. This ullage allows for thermal expansion of the explosive column, permitting porosity to develop that might increase the likelihood of DDT. Alternate ullage lengths are permissible if they meet the intent.

  - Additional penetrations of the tube are permissible (e.g. for internal thermocouple or pressure diagnostics) provided they do not compromise the mechanical confinement of the tube. If postmortem analysis reveals failure of confinement at the feedthrough location, the validity of the test confinement must be justified.

- Externally heated tube with external temperatures recorded during the long-duration thermal heating of the assembly, at a rate ≥ 0.25 Hz (the temperature rise during dynamic event does not need to be resolved).
- Test may be executed with tube in any orientation (horizontal, igniter on top, igniter on bottom). If the test is oriented with the igniter on top, care must be taken that explosive successfully ignites even if internal slumping takes place during the thermal conditioning and there is a gap between the ignitor system and the explosive column.
- Two material states examined are (1) typical charge density and (2) surrogate damaged material utilizing pressing prills (molding powder) of the candidate material.
  1. Consolidated explosive can be in the form of multiple stacked uniaxially pressed pellets, provided the pellet density is within ±1% of production density material. The diametral clearance between explosive pellets and bore at ambient temperature shall be small enough so that thermal expansion during heating develops an interference fit once the explosive reaches 10°C below the critical temperature for the experiment, with consideration given to the Coefficient of Thermal Expansion (CTE) of the explosive being tested. This interference fit prevents gas flow between the explosive and the wall of the tube, so burning will progress through the bulk explosive and not at the edges.
  2. Pressing prills (molding powder) shall be loaded into the bore via “pouring” with no additional packing pressure applied. This assembly method will achieve a “pour density” test configuration, which constitutes the lowest handling density of material and a worse-case scenario with regards to surface area available for deflagration. Pour density attained shall be reported as part of the test record and will be calculated from the mass of the material used and the nominal volume of the bore.
- The IHE candidate material is evaluated in two configurations:
  1. In one configuration, the explosive self-ignites from heating, similar to a cookoff test. (Although the igniter system is not required for this test configuration, any through holes in the non-vented cap end of the tube shall be plugged.). This configuration is used to establish a “critical temperature”, T_c.
  2. In a second configuration, after reaching a set elevated temperature, which is slightly below the established critical temperature, deflagration is ignited by a donor pyrotechnic.
- Diagnostics:
  - External tube temperatures (e.g. thermocouples).
  - Post-reaction examination of the confinement tube, particularly fragment size distribution.
  - Velocimetry (e.g. PDV) on the tube wall close to the vented end to quantify the presence (or lack of) detonation at the end of the tube. PDV diagnostics may be optional if the occurrence of DDT can be successfully ascertained by comparison with deliberately-detonated tubes (e.g. postmortem analysis of fragments).



o

Figure 1: Conceptual configuration of IHE Deflagration-to-Detonation Transition (DDT) IHE experiment.

1.1.3.1 *Test Conditions*

First test series (slow cook-off ensures ignition at the center of the charge):

- Production density explosive is heated ~20˚C/hr until self-ignition occurs. Intent of heating rate is to achieve no more than 10˚C radial temperature difference.
- The control location for temperature shall be a measurement of the external surface of the central tube, at the midpoint of the long dimension of the tube. The temperature measurement will not be in contact with a heating element, shall be adequately insulated from ambient air conditions, and adhered to the metal to ensure that the measurement accurately represents the surface temperature of the tube.
- The temperature of this control thermocouple when explosion occurs will be designated Tc (critical temperature) for the purpose of this experiment. It is understood that this critical temperature is not directly indicative of the explosive temperature necessary to induce self-ignition, but rather as a fiducial reference for conducting subsequent experiments. Designating a critical temperature using exterior thermocouples provides a test method that avoids the challenge of diagnosing internal temperatures without compromising the confinement of the assembly.
- This test configuration is identically repeated twice more for a total of three tests. The lowest Tc obtained of the three tests is used as the Tc for subsequent testing.
- External temperature difference is measured along the length of the central tube and shall not exceed 10 ˚C during heating.

Second test series:

- Production density explosive is heated at the same ramp rate of ~20˚C/hr to 10˚C below Tc, then promptly ignited with a pyrotechnic composition.
- If the final recorded temperature is higher than 10˚C below Tc, the test remains valid; the final recorded temperature must be ≥ [Tc-10˚C].

Third test series:

- Pour density molding powder is tested identically (heated at ~20˚C/hr to 10˚C below Tc, then promptly ignited with a pyrotechnic composition).
- If the final recorded temperature is higher than 10˚C below Tc, the test remains valid; the final recorded temperature must be ≥ [Tc-10˚C].

1.1.3.2 Number of Tests

Three tests at each test series (9 total). As mentioned above, all three repeats of the first configuration are performed first in order to determine the lowest Tc; that Tc is used for the remaining two series. The purpose of the triplicate execution of the second and third configurations is to establish a measure of statistical repeatability. If substantive variations in test outcome are observed—even if no test exhibits DDT—the validity of the test series must be reviewed by the DOE/NNSA IHE Qualification Update Group.

1.1.3.3 Quantity of Explosive Required

- ~8 kg per production density explosive test.
- ~5 kg per molding powder explosive test.
- ~63 kg for nine tests.

1.1.3.4 Criteria for Qualifying as IHE

No development of a detonation wave within the tube length in any test as confirmed by post-test examination of the tube and/or by fielding velocimetry.

- If velocimetry diagnostics are not fielded, two additional deliberate detonation tests must be performed to provide a baseline against which to compare the qualification test results. One tube is deliberately detonated with production-density explosive, the other with the pour density molding powder. For both tests, a section of central tube ≥ 1 ft long (otherwise with the same bore diameter and wall thickness) will be filled at one end with 6 inches of explosive material. A detonator and booster will be placed in contact with the inside surface of the explosive fill and deliberately detonated. No end caps are required. The failure morphology of the tube obtained from these deliberate detonation baseline tests can be used in comparison with the qualification testing to establish whether detonation occurred.

OR

- ▪ Absence of DDT may be diagnosed with velocimetry data.

2.2 Shock-to-Detonation Experiment

1.2.1 Introduction

The purpose of the shock-to-detonation experiment is to demonstrate that the IHE will not undergo shock-to-detonation transition (SDT) under a defined shock stimulus at ambient temperature, which differentiates the SDT behavior of IHEs from the SDT behavior of Conventional High Explosives (CHEs). Note that any explosive, IHE or CHE, must undergo SDT at some shock stimulus for a nuclear weapon to function as designed.

In addition to the defined ambient-temperature shock stimulus, an additional SDT experiment is required at high temperature, to show that the explosive is not excessively sensitized by exposure to high-temperature conditions.

The ambient-temperature threshold shock stimulus was developed based on consideration of the shock sensitivity of a set of CHEs and currently recognized IHEs (Gresshoff, 2018). Figure 2 shows the shock sensitivity of CHEs and IHEs represented as a threshold SDT pressure as a function of shock duration.

Figure 2 is based on run-to-detonation, or Pop-Plot, data for TATB-based (LX-17, PBX 9502, and UF-TATB) and HMX-based (LX-04, PBX 9501, LX-07-2, and LX-10) high explosives scaled to the shock initiation threshold based on short-pulse initiation data for LX-17 and LX-04 (Gresshoff, 2018). There is some uncertainty in this scaling; however, the shock duration for the SDT threshold was chosen with this in mind and was necessary as the run-to-detonation distance is unknown for a future candidate IHE. As pressure is decreased, the shock duration required for SDT increases until a pressure is reached where there is no SDT regardless of the shock duration. HMX and TATB cut-offs are estimated at ~1.5 and ~7.5 GPa respectively for the HEs evaluated in this study and published in the literature. It is expected that SDT does not occur below these pressures, even for very long shocks. The figure indicates the SDT criterion for a sustained shockwave (3 μs duration) is 3.5 GPa.

Previous work on IHE Qualification of TATB (PBX 9502, LX-17, and UF-TATB) show data from Pantex Plant (Slape, 1984) which suggest that IHE qualification with the No. 8 Blasting Cap detonator was performed on both molding powder and “compacted” parts at nominal density. Although it was never written in DOE-STD-1212 (which prescribes TB 700-2 protocol for transportation and storage with molding powder), this history suggests a precedence for short-duration, high pressure, Taylor wave-type, loading of pressed parts as a component of the material definition. Hydrocode calculations of the Pantex Modified NOL Card Gap test showed that the upper limit of output for a Taylor wave into Explosive D is approximately 5.3 GPa. The lower limit of duration available for a gas gun flyer plate design is approximately 0.5 μs duration (cap duration is expected to be longer, but a Taylor wave). Therefore, the criterion for short pulse shockwave is prescribed to be 5.3 GPa at 0.5 μs and noted on Figure 2.

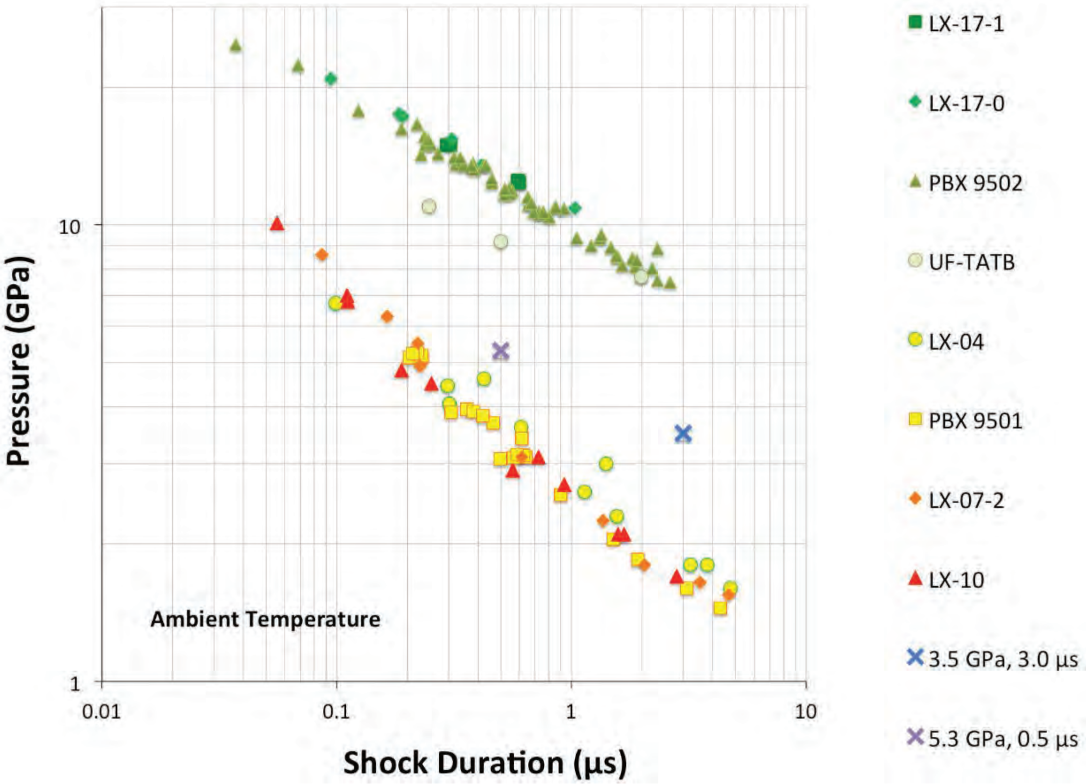


Figure 2. Shock sensitivity of several DOE explosives scaled from Pop-Plot data, showing the separation in behavior between IHEs and CHEs. The TATB-based IHEs (LX-17, PBX 9502, and UF-TATB) form a family with significantly lower shock sensitivity than the HMX-based CHEs (LX-04, PBX 9501, LX-07, and LX-10). The SDT criterion for IHEs is no evidence of detonation for a log-pulse (3 µs duration) of 3.5 GPa and a short-pulse (0.5 µs duration) of 5.3 GPa.

A second experimental series is required to evaluate SDT at high temperature. Virtually all known explosives are sensitized to SDT at high temperatures. It is important that the degree of sensitization to shock not be so high that the heated explosive represents a severe SDT hazard. The hazard is likely worse at the highest temperature where the explosive will survive, and the risk is that the explosive is extremely shock sensitive (e.g. an explosive that passes that SDT criteria at ambient, but recovers primary-like shock sensitivity at high temperatures is undesirable). The shock criterion for a heated test is substantially lower than criterion for the ambient temperature test. High-temperature shock sensitivity data for some IHEs and CHEs are shown in Figure 3 (Gresshoff, 2018). Because short-pulse data is not widely known for HEs at temperature, the data in the graph is still in the standard "Pop-Plot" format revealing pressure and run distance to detonation.

Also shown in Figure 3 is the new IHE criterion for high-temperature shock sensitivity – absence of shock-to-detonation transition with a 1.5 GPa shock sustained for at least 3 µs. The high-temperature testing must be done at a temperature that involves the effect of phase changes or other physical changes. For this reason, the test temperature is defined as the temperature 10°C below that which the explosive is expected to thermally explode, which will be a worst-case test for thermal sensitization.

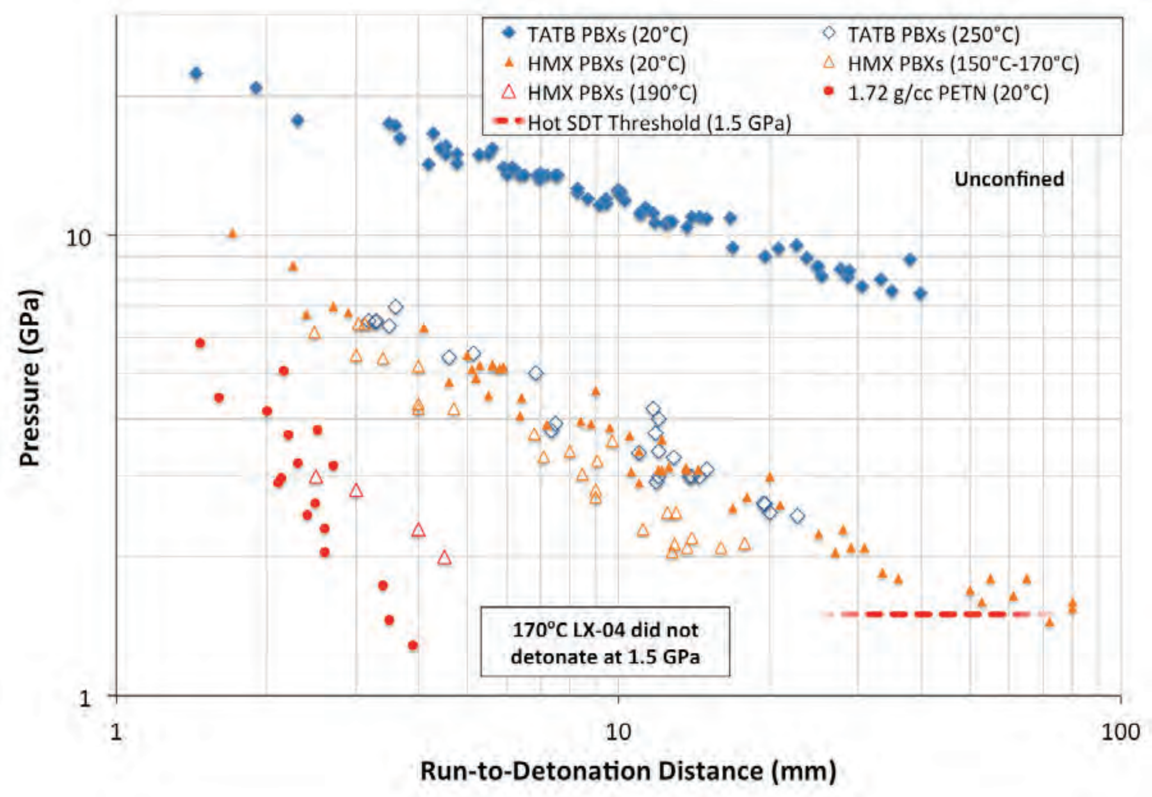


Figure 3. Shock sensitivity of several DOE explosives at high temperatures. The elevated-temperature SDT criterion of 1.5 GPa is shown as a dotted line as run-to-detonation distance is unknown in future candidate IHEs.

1.2.2 Underlying Physics

In the accepted understanding of shock-to-detonation transition (SDT) in composite solid explosives, interaction of the shock front with voids, interfaces, or other irregularities in the solid results in development of localized hot spots. If the shock is sufficiently strong and long-lasting, these hot spots react, coalesce, and release chemical energy fast enough to accelerate the shock wave until it forms a detonation. If the shock is too low in magnitude or duration, the hot spots may not react, or may quench before coalescing, and transition to detonation does not occur.

In addition to shock magnitude and duration, other factors are very important in SDT. The shock duration determines the time until a rarefaction from the rear of the sample reduces the shock pressure and may quench the reaction. Rarefaction waves from the side of explosive samples will have a similar effect, with the rarefaction penetrating farther from the edge as the shock travels from the impact surface. Shocks driven by small-diameter impactors similarly have rarefaction waves from the side that will quench the reaction. Therefore, size of explosive sample and diameter of the impactor driving the shock wave are important. If the shock is not planar or is not parallel to the explosive surface, these interactions are even more complex. If the shock wave at a surface is reflected back into the sample by a higher-impedance material, this also may have a strong effect on the SDT response.

To make the IHE test for SDT as unambiguous and reproducible as possible, it is specified as a 1-dimensional planar shock input with long duration. The explosive sample diameter and length are specified to avoid the effect of rarefactions from the side, while also allowing enough distance for the shock to run before side rarefactions come into play.

The propagation rate of the shock or reaction front provides a clear delineation between an unreacted shock and a detonation wave. Diagnostics are embedded in the explosive sample to measure either pressure or particle velocity, *in situ*, and measure if the shock wave is building to a detonation or is failing. The use of such diagnostics is an important element of these tests, as a reacting shock wave that may not have reached detonation conditions is a quite different response than an unreacted, or failing, shock front.

Sensitization of explosives at high temperature is driven by physical transformations in the explosive. For TATB plastic-bonded explosives, the shock sensitivity at 250°C is caused by the irreversible ratchet growth with formation of additional voids that sensitize the explosive to shock; when TATB explosives are physically confined, the shock sensitivity is significantly reduced. For HMX plastic-bonded explosives, the shock sensitivity is only slightly increased by heating to 150°C; the large increase in sensitivity at 190°C is caused by the beta-to-delta phase transition in HMX with the resultant formation of additional voids. To evaluate a candidate IHE, testing must be done at a sufficiently high temperature to include the effect of phase changes or other physical changes. The worst-case conditions are those in which the explosive is heated just below the temperature at which it will thermally decompose. This temperature is dependent on the thermal stability of the explosive, and on the configuration (e.g., size) of the explosive sample, and therefore the test temperature cannot be defined *a priori*. Instead, it is defined as the temperature 10°C below that at which the explosive will thermally explode in a relevant configuration.

1.2.3 SDT Test Configuration and Diagnostics

- Use gun to achieve reproducible 1-D planar shock into sample.
- Ambient temperature test:
  - 3.5 GPa, >3.0 μs
  - 5.3 GPa, >0.5 μs
- High temperature test:
  - Explosive is heated at a ramp rate of ~20˚C/hr to a set point of [Tc-10 ˚C], where Tc is the temperature determined in the DDT cook-off test as measured on the boundary of the sample.
  - 1.5 GPa, >3.0 μs
- Explosive sample diameter and length sufficient to ensure 1-D shock:
  - diameter: ~60-90 mm (~2.5-4 inches).
  - length: ~30-45 mm (~1-1.5 inches).
- Explosive density: within the production range for the application.

- Diagnostics:
    - Embedded gauges (pressure or particle velocity) at several distances from the shock front.
    - Other standard diagnostics to measure impact velocity.
- To achieve shock pressures and durations for the 1D collision of a teflon impactor (2.15 g/cc, C_o=2.08 mm/μs, S_1=1.62) on an LX-17 IHE sample (1.9 g/cc, C_o=2.5 mm/μs, S_1=2.1) at room temperature (configuration shown in Figure 4):
    - 3.5 GPa for 3 μs:

    6 mm thick flyer at 1 km/s

    - 5.3 GPa for 0.5 μs:

    1 mm thick flyer at 1.5 km/s

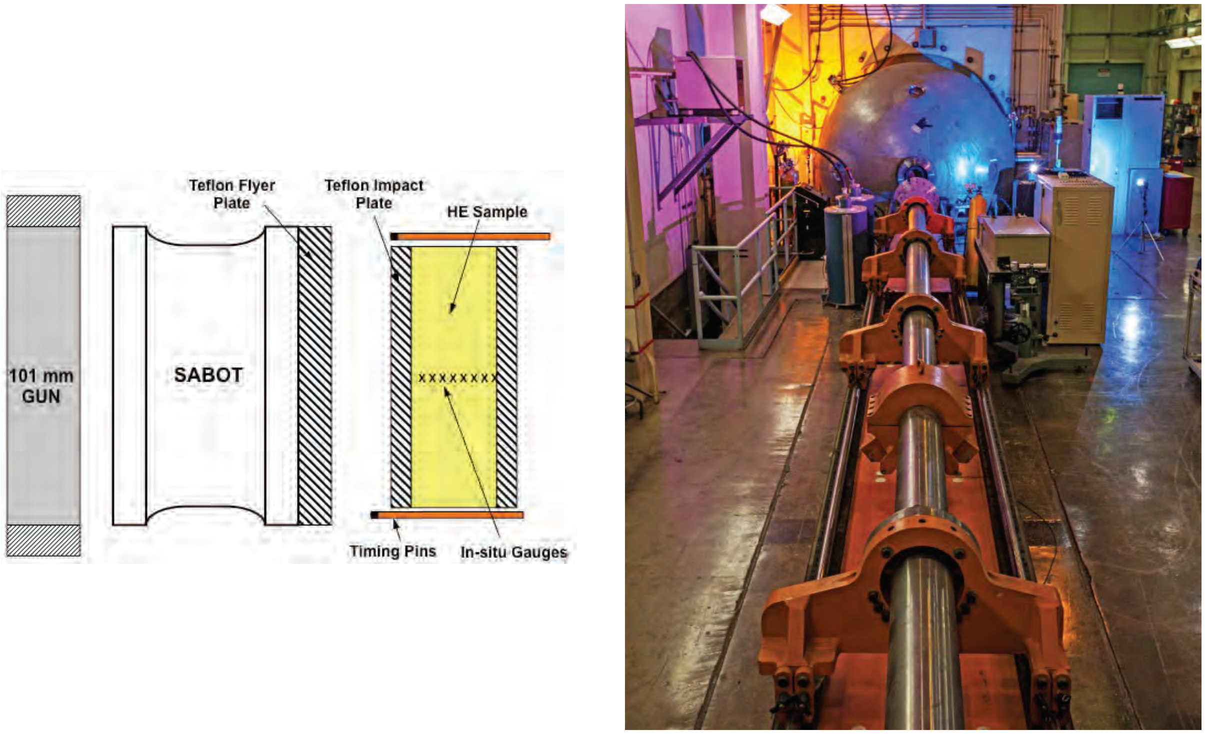


Figure 4. Example of SDT test configuration in the 100 mm gun at LLNL's High Explosive Application Facility (HEAF). Other similar configurations will give the same type of data and are equally acceptable. Elevated-temperature shock tests require heaters and thermocouples integrated into the target assembly.

1.2.3.1 Test Conditions

- Temperature
    - Ambient temperature: ~ 25°C.

  - High temperature: 10°C below the thermal explosion temperature for the explosive from the DDT cook-off experiment.
- Shock input to explosive with symmetric flyer/impact surface.
- Embedded diagnostics.

1.2.3.2 Number of Tests

- Three replicate tests at each temperature.

1.2.3.3 Quantity of Explosive Required

- ~600 g per test.
- ~1,800 g for three tests at each temperature.
- ~3.6 kg total.

1.2.3.4 Criteria for Qualifying as IHE

- No development of detonation wave in the explosive as shock progresses through the sample.
- Reaction wave, if any, is failing as the end of the sample is approached, as shown by the pressure or particle velocity gauges.

2.3 Skid Test

1.3.1 Introduction

The purpose of the skid test is to show that bare billets of explosive will not react with significant violence when subjected to a very severe drop environment, far worse than is anticipated in any actual handling accident.

For this test, which is a worker safety test, the acceptance criteria are based on worker safety concerns rather than detonation. As described below, the worst-case response for an explosive that has passed the skid test is non-violent explosive reaction.

The pendulum apparatus used in this skid test was first developed by Los Alamos National Laboratory in 2013 (Parker et al., 2020) and was conceived and designed to capture the underlying physics of reaction which had only previously been observed in "outlier data" as reported from the standard skid tests (Slape, 1984; Garrow, 2015). The new pendulum configuration allows exquisite control of the strike surface location, angle, and drop height such that potential reaction can be imaged to quantify the hazard and the experiment is highly repeatable. The apparatus has been designed to provide equivalent loading to the previously used vertical free-fall apparatus, with improved diagnostics.

1.3.2 Underlying Physics

The physical mechanisms governing explosive response in the skid test are very complex. Impacts such as those encountered from any conceivable drop height are incapable of driving a shock-to-detonation response. Ignition and deflagration is the worst possible outcome. The initial impact of an explosive causes compression and/or fracture with simultaneous conversion of mechanical energy to heat by frictional heating, which is generally grit-mediated. If the thermal energy is sufficient to ignite the explosive, and depending on the surface area that is produced by the fracture that may then become incorporated into the reaction, the ensuing response may range from a few points of light, to a rapid deflagration, to a detonation. If the DDT test described previously has been successfully completed before the skid test is executed, then the most violent response of a detonation is not possible, and the worst case is a rapid deflagration.

1.3.3 Skid Test Configuration and Diagnostics

- Pendulum skid impact test based on the new LANL Skid Test apparatus (Parker et al., 2020) shown in Figure 5
- Hemispherical sample, 28 cm diameter, of production density explosive
- Target surface will be gritty glass or steel.
    - Grit particles must be loose or weakly bonded such that they break free during impact.
    - Level of grit (silica sand, mean diameter ~600 μm) should be sufficient to cover the strike surface, while still providing space between grit (typical coverage: areal density ~2x10^5 particles/m^2) (Heatwole et al, 2015)
- Diagnostics: High-speed video side-on to impact plane and through target plate if transparent

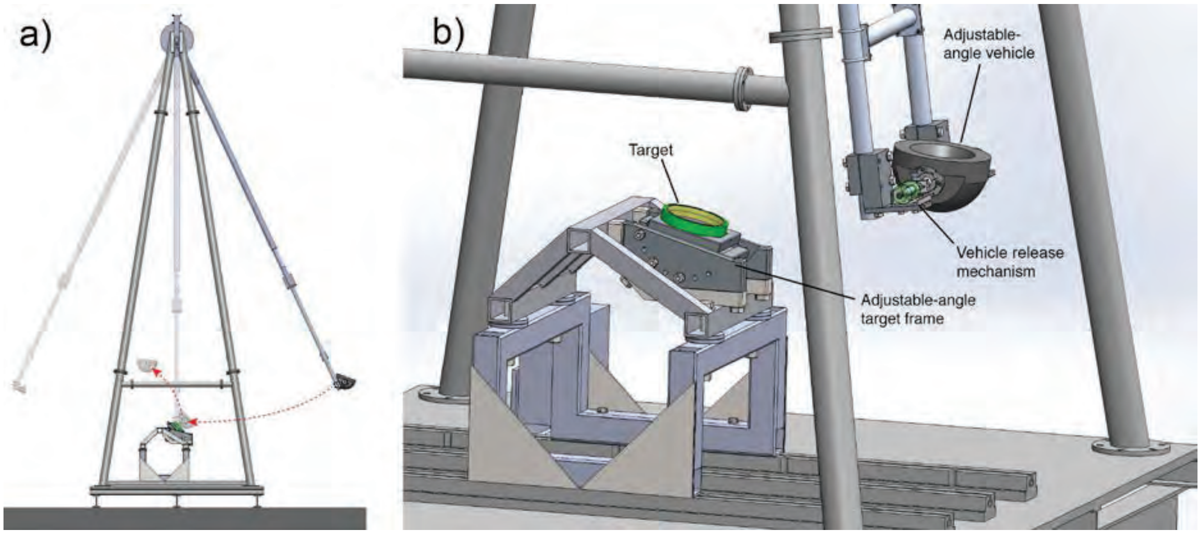


Figure 5. Pendulum skid impact test based on the new LANL Skid Test apparatus. (a) arm length = 15 ft (b) hemispherical charge rests in cradle, free to escape (bounce) upon contact with target.

1.3.3.1 Test Conditions

- Initial test configuration: Production machined hemisphere at ambient temperature
- Impact angle of 45°
- Initial equivalent drop height of 12 ft. “Equivalent drop height” is the height at which the pendulum must be released in order to achieve an impact velocity that is equal to the impact velocity attained during vertical free-fall, i.e. $v = \sqrt{(2gh)}$. A 12 ft drop is a representative yet conservative worse-case height for handling accident scenarios involving workers manipulating a bare charge.

1.3.3.2 Number of Tests

- Three at 12 foot-equivalent drop height.

1.3.3.3 Quantity of Explosive Required

- ~10 kg per hemispherical charge.
- ~30 kg for three tests.

1.3.3.4 Criteria for Qualifying as IHE in the Skid Test

Reaction criteria (Note: These levels have been modified from levels in the original skid test which ranged from "0" for “no reaction” to "6" for “full detonation” (Garrow, 2015)). Image panels of the various reactions are shown in Figure 10 from Parker, et al. (2020):

- Reaction 0 is acceptable:
    - No visible smoke. No scorching of explosive surface. Video may show glowing abrasive particles from target surface.
- Reaction 1 is acceptable:
    - Visible smoke. Non-propagating, luminous ignition sites may be visible. Scorching of the explosive surface. No luminous flames are visible in high-speed videography from a side view.
- Reaction 2 is not acceptable:
    - Propagating, luminous flames are visible from high-speed videography. Postmortem examination reveals partial or complete disintegration of the explosive contact surface due to cracking induced by explosive reaction.

- The above criteria apply regardless of fracture of the explosive test object.
    - Occurrence of Reaction 2, or reaction violence exceeding Reaction 2, in any of the tests performed in the series, including tests where the charge fractured, disqualify the material as an IHE.

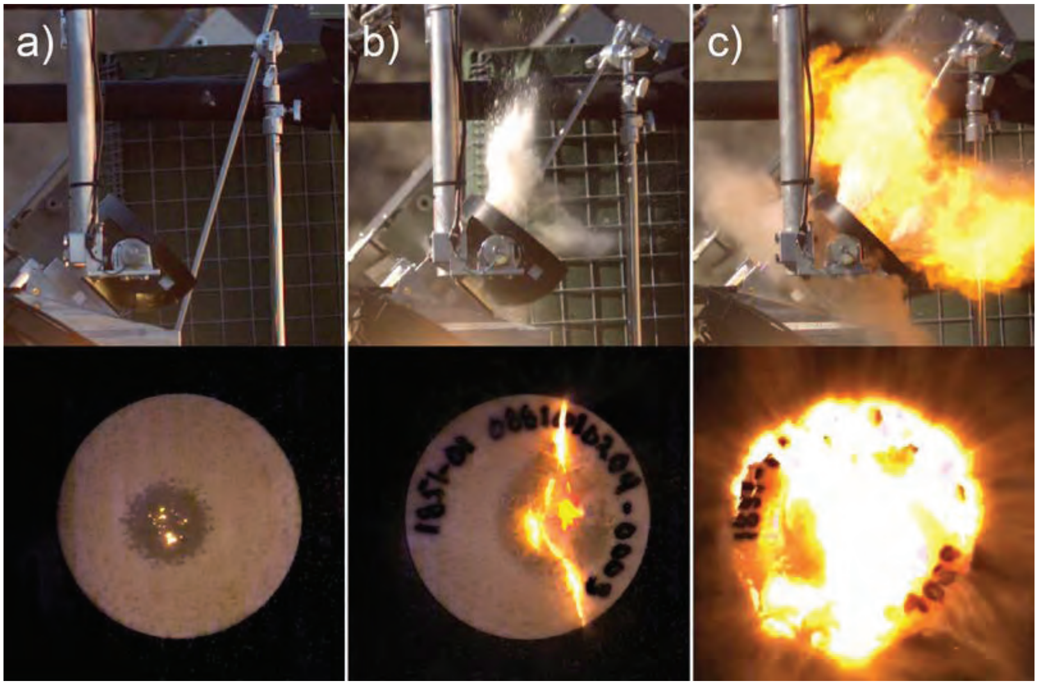


Figure 6. Examples of skid test reaction levels with a smaller, scaled, explosive charge. Three image pairs showing synchronous views from the side and through transparent impact surfaces: (a) Reaction 1, non-propagating luminous ignition sites, (b) Reaction 2, flame propagation into cracks, no fireball, and (c) Reaction 2, flame propagation and fireball.

2.4 Bullet Test

1.4.1 Introduction

The purpose of the bullet test is to show that an IHE does not react violently when impacted by a bullet under the conditions described below. This is a demonstration that the IHE is relatively unreactive to this type of stimulus and is not intended to prove that the IHE will not react to any sort of bullet or related stimulus. The ammunition selected is representative of threats to which the IHE will be exposed during its lifecycle but does not represent the worst possible case. The configuration represents the likely worst-case path of least resistance. Figure 10 shows an example of the response from this test for both HMX-based and TATB-based explosives.

1.4.2 Underlying Physics

Explosive response to the impact from a bullet is very complex. Typically, the bullet does not impart a shock to the explosive in such a way to cause shock-to-detonation transition, but instead provides input of mechanical and thermal energy to the explosive. The mechanical energy of the bullet impacting and tearing through the explosive is converted to thermal energy by the thermomechanical response of the explosive, and thermal energy from the hot bullet is deposited as the bullet travels through. This thermal energy may cause the explosive to ignite, and then may eventually lead to an explosion.

The mechanical response of the explosive is dependent on its configuration and confinement. The experimental configuration shown in Figure 7 offers a geometry somewhat representative of IHEs in their intended applications.

1.4.3 Bullet Test Configuration and Diagnostics

The test configuration is shown in Figure 7.

- Explosive sample is contained in a steel fixture with steel front and back plates.
- Bullets are shown in Figure 8 and Figure 9, and are 50 caliber, armor piercing, and military ball rounds.
- Bullet enters the sample through the front plate and exits through a plate-foam-plate stack-up.
- Diagnostics:
    - Include a method to measure the bullet velocity.
    - High-speed imaging to observe the target response for at least 10 seconds.

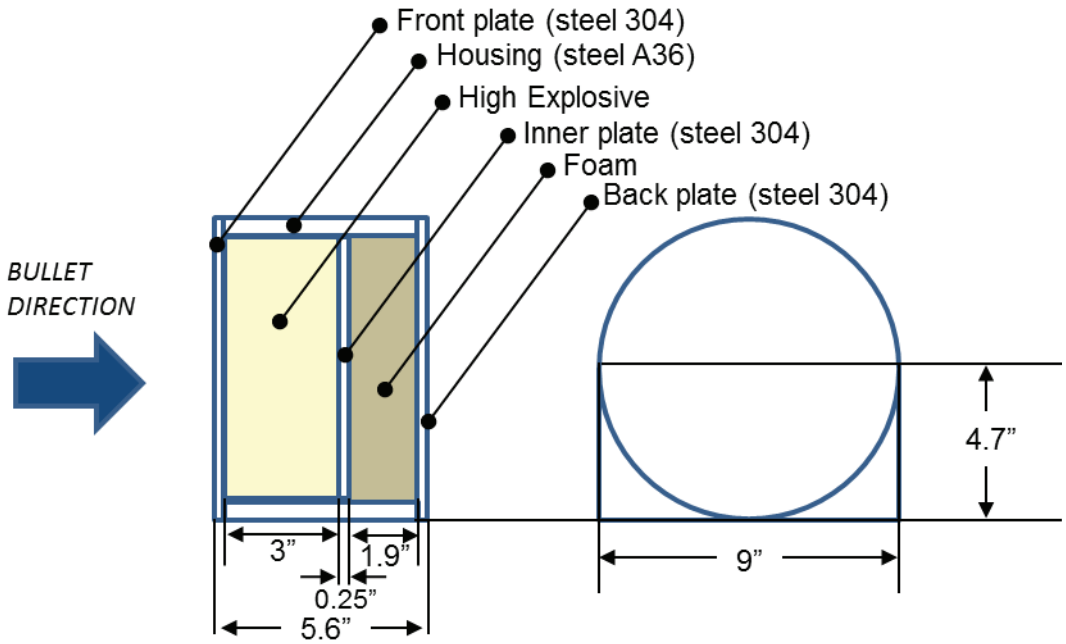
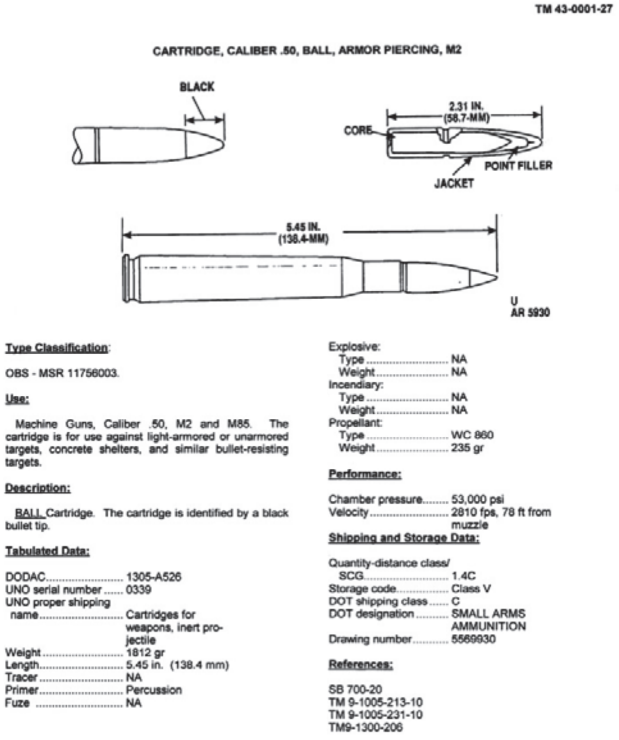


Figure 7. Conceptual configuration of IHE Qualification Bullet Test



TM 43-0001-27

CARTRIDGE, CALIBER .50, BALL, ARMOR PIERCING, M2

Type Classification:

OBS - MSR 11756003.

Use:

Machine Guns, Caliber .50, M2 and M85. The cartridge is for use against light-armored or unarmored targets, concrete shelters, and similar bullet-resisting targets.

Description:

BALL Cartridge. The cartridge is identified by a black bullet tip.

Tabulated Data:

DODAC	1305-A526
UNO serial number	0339
UNO proper shipping name	Cartridges for weapons, inert projectile
Weight	1812 gr
Length	5.45 in. (138.4 mm)
Tracer	NA
Primer	Percussion
Fuze	NA

Explosive:	
Type	NA
Weight	NA
Incendiary:	
Type	NA
Weight	NA
Propellant:	
Type	WC 860
Weight	235 gr

Performance:

Chamber pressure	53,000 psi
Velocity	2810 fps, 78 ft from muzzle

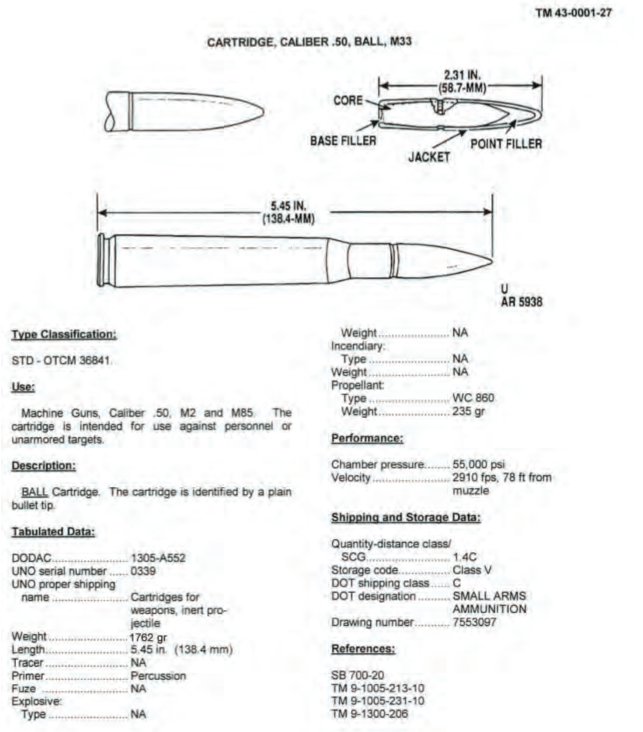
Shipping and Storage Data:

Quantity-distance class/ SCG	1.4C
Storage code	Class V
DOT shipping class	C
DOT designation	SMALL ARMS AMMUNITION
Drawing number	5569930

References:

SB 700-20
TM 9-1005-213-10
TM 9-1005-231-10
TM9-1300-206

Figure 8. 50-caliber armor piercing round.



TM 43-0001-27

CARTRIDGE, CALIBER .50, BALL, M33

Type Classification:

STD - OTCM 36841.

Use:

Machine Guns, Caliber .50, M2 and M85. The cartridge is intended for use against personnel or unarmored targets.

Description:

BALL Cartridge. The cartridge is identified by a plain bullet tip.

Tabulated Data:

DODAC	1305-A552
UNO serial number	0339
UNO proper shipping name	Cartridges for weapons, inert projectile
Weight	1762 gr
Length	5.45 in. (138.4 mm)
Tracer	NA
Primer	Percussion
Fuze	NA
Explosive:	
Type	NA
Weight	NA
Incendiary:	
Type	NA
Weight	NA
Propellant:	
Type	WC 860
Weight	235 gr

Performance:

Chamber pressure	55,000 psi
Velocity	2910 fps, 78 ft from muzzle

Shipping and Storage Data:

Quantity-distance class/ SCG	1.4C
Storage code	Class V
DOT shipping class	C
DOT designation	SMALL ARMS AMMUNITION
Drawing number	7553097

References:

SB 700-20
TM 9-1005-213-10
TM 9-1005-231-10
TM 9-1300-206

Figure 9. 50-caliber ball round.

1.4.3.1 *Test Conditions*

- Ammunition: 50 caliber armor piercing and 50 caliber military ball round.
- Muzzle velocity: standard for each type.
- One bullet per test.
- Explosive sample:
    - Diameter: ~8 inches (200 mm).
    - Thickness: ~ 3inches (75 mm).
    - Density: within the specified range for the application.
        - Main charges are generally 96-98% TMD.
        - Boosters are generally 92-95% TMD.

1.4.3.2 *Number of Tests*

- Three replicates with each bullet type (six tests total).

1.4.3.3 Quantity of Explosive Required

- ~ 4500 g per test.
- ~ 27 kg total.

1.4.3.4 Criteria for Qualifying as IHE

- Burn: smoke and/ or visible light is acceptable, burning reaction can completely consume material. Assembly may be distorted, and surfaces blackened. Any level of damage beyond that is a failure. If the assembly is fragmented, that is a failure.
- Panels of pass and fail are in Figure 10.

FAIL: HMX-based target response PASS: TATB-based target response

Bullet just prior to impact

At bullet impact

5 seconds after bullet impact

Figure 10. The bullet impact test distinguishes between the reaction violence of an HMX-based explosive and TATB-based explosive to the impact with a 50 caliber armor-piercing round. In this case, the HMX-based explosive fails to meet the IHE criteria. The visible light/reaction at impact is acceptable, however the violent disassembly of the undetonated HE constitutes a failure.

Section 2

IHE Subassembly Qualification Test Series

This section outlines a general plan to qualify IHE subassemblies that contain explosives that are not qualified as IHE materials. In general, this will occur when it is desired to have an IHE subassembly that consists of a main charge of IHE qualified materials with CHE boosters and/or detonators. However, it is also possible that the main charge be a material that has not passed the IHE material qualification tests outlined in Section 1, provided it qualifies to the same criteria at a system-relevant scale (as described herein), and it passes the SDT criterion for an IHE material at both ambient and heated conditions.

While this document provides an outline of the expectations for IHE subassembly qualification, this is an outline to aid in the development of a test plan for approval by the DOE/NNSA Explosives Safety Committee in consultation with the DOE/NNSA IHE Qualification Update Group. DOE-STD-1212, Chapter 16, Section 16.6 “IHE Subassembly Qualification Process” outlines the procedure for submitting a test plan, committee review procedures, and submission requirements. The test plan must consider worst-case configurations for testing.

2.1 Deflagration-to-Detonation Transition Experiment

For cases where the main charge is composed of IHE qualified materials, using booster, detonator, or other materials that are not IHE, it is a requirement to demonstrate that the materials that are not IHE cannot undergo DDT on a scale that is conservative to its relevant application in the subassembly.

For cases where it is desired to use a main charge that is not an IHE qualified material, but is smaller than was imagined in the material definition from the previous section, the main charge material must also be subjected to and pass a DDT test at the scale of use plus a conservative margin of scale and confinement consistent with the IHE materials test scale outlined in Section 1.1.

Each non-IHE material to be used shall be qualified by testing it in a scaled version of the DDT test. Each material will be tested in this configuration in a scale that is the actual scale of use plus a conservative margin in dimensions and confinement. All materials in the subassembly must pass this test individually for the subassembly to qualify as an IHE subassembly. No evidence of DDT may be observed in any test. Three replications of each test are required.

2.2 Shock-to-Detonation Transition Experiment – Main charge only

In order for the subassembly to qualify as an IHE subassembly, the main charge material must pass the identical SDT test as described in Section 1.2, for both ambient and heated configurations, with the same criteria for a passing result. Booster and detonator materials are not subjected to the SDT criteria to be consistent with previous test requirements.

2.3 Skid Test

Skid testing will be performed as above in Section 2.3, except that the assembly will be dropped for impact in the worst possible configuration - on the booster surrounded by main charge material consistent with the actual weapon configuration, with or without detonators. Three tests are required with drops at 45 degrees from 12 ft, with no observation of violent reaction (based on criteria described in Section1.3.3).

2.4 Multiple Bullet Impact Test

Bullet testing will be performed on the assembly, and in this case, the configuration of the target material will be designed to present a worst-case, path of attack, for the weapon subassembly. The test specimen geometry may or may not be the same as described in Section 2.4. If the path of attack includes a booster, then that booster must be included in the test. Threat is a three-round burst of NATO-7.62 mm (0.3 inches) ammunition. The passing criterion is to exhibit no violent reaction (based on criteria described in Section 1.4.3.4) when subjected to the threat. Three replicate tests are required.

References

Cheung, H., et al., “Explosive Initiation,” LLNL Report UCRL-76578, June 18, 1975.

Chidester, S.K., et al., “Shock Initiation Experiments on PBX 9501 Explosive at Pressures Below 3 GPa with Associated Ignition and Growth Modeling,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 955, 2007, pp. 903-906.

Christensen, J.S., et al., “Probabilistic Shock Threshold Development for LX-17,” *15th International Detonation Symposium*, Office of Naval Research ONR 43-280-15, San Francisco, CA, 2014, p. 639.

Dallman, J.C., and J. Wackerle, "Temperature-Dependent Shock Initiation of TATB-based High Explosives," *10th International Detonation Symposium*, Office of Naval Research Report 3395-12, Boston, MA, 1993, pp. 130-138.

Dick, J.J., et al., "The Hugoniot and Shock Sensitivity of a Plastic-Bonded TATB Explosive PBX 9502," *Journal of Applied Physics* 63(10), 1988, pp. 4881-4888.

Forbes, J.W., et al., “The Effects of Confinement and Temperature on the Shock Sensitivity of Solid Explosives,” *11th International Detonation Symposium*, Office of Naval Research ONR 33300-5, Snowmass, CO, 1998, p. 145.

Garrow, M.T., “Skid Testing of Modified As-Pressed Universal Hemispheres,” Pantex Report PXRPT 16-03 Revision 0, October 19, 2015.

Gibbs, T.R. and A. Popolato (ed.), *LASL Explosive Property Data*, University of California Press, 1980, p. 370.

Green, L.G., et al., “Shock Initiation of LX-07-2 and LX-10-0,” LLNL Report UCRL-50851, 1970.

Gresshoff, M., “Insensitive High Explosive Shock-to-Detonation Transition Criteria,” *16th International Detonation Symposium*, Cambridge, MD, 2018.

Gustavsen, R.L., et al., “Embedded Electromagnetic Gauge Measurements and Modeling Shock Initiation in the TATB Based Explosives LX-17 and PBX 9502,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 620, Atlanta, GA, 2001, pp. 1019-1022.

Gustavsen, R.L., et al., “Shock initiation of new and aged PBX 9501,” *12th International Detonation Symposium*, San Diego, CA, 2002, pp. 530-537.

Gustavsen, R.L., et al., “Measurement of Shock Initiation in the Tri-amino-tri-nitro-benzene Based Explosive PBX 9502: Wave Forms from Embedded Gauges and Comparison of Four Different Material Lots,” *Journal of Applied Physics* 99, 2006, pp. 114907-1.

Gustavsen, R.L., et al., “Extended Run Distance Measurements of Shock Initiation in PBX 9502,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 955, 2007, pp. 915-918.

E. Heatwole, G. Parker, M. Holmes, P. Dickson, “Grit-mediated frictional ignition of a polymer-bonded explosive during oblique impacts: Probability calculations for safety engineering), Reliability Engineering and System Safety 134 (2015) 10–18.

Jackson, R.K., et al., “Initiation and Detonation Characteristics of TATB,” *6th International Symposium on Detonation*, Office of Naval Research Report ACR-221, Coronado, CA, 1976, pp. 755-765.

James, H.R., “Links Between Macroscopic Behaviour and Explosive Morphology in Shock to Detonation Transitions," *13th International Detonation Symposium*, Office of Naval Research ONR 351-07-01, Norfolk, VA, 2006, p. 952.

Mulford, R.N., et al., "Shock Initiation of PBX-9502 at Elevated Temperature." *Shock Compression of Condensed Matter,* AIP Conference Proceedings 370, 1995, p. 855.

Parker, G.R. et al., “Direct Observation of Frictional Ignition in Dropped HMX-based Polymer-bonded Explosives (*submitted*), 2020.

Slape, R.J., “Insensitive High Explosive (IHE) Qualification Test Plant”, Mason & Hanger – Silas Mason Co., Inc. Pantex Plant, February 8, 1984.

Tarver, C.M., et al., “Manganin Gauge and Reactive Flow Modeling Study of the Shock Initiation of PBX 9501,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 620, Atlanta, GA, 2001, pp. 1043-1046.

Urtiew, P.A., et al., “Shock Sensitivity of IHE at Elevated Temperatures,” *10th International Detonation Symposium*, Office of Naval Research Report ONR 33395-12, Boston, MA, 1993, p. 139.

Urtiew, P.A., et al., “Effects of Confinement and Thermal Cycling on the Shock Initiation of LX- 17,” *Combustion and Flame* 105, 1996, p. 43.

Urtiew, P.A., et al., “Shock Sensitivity of LX-04 at Elevated Temperatures,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 429, Amherst, MA, 1997, pp. 727-730.

Urtiew, P.A., et al., “Shock Initiation of UF-TATB at 250°C,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 620, Atlanta, GA, 2001, pp.1039-1042.

Urtiew, P.A., C.M. Tarver, “Shock Initiation of Energetic Materials at Different Initial Temperatures (Review),” *Combustion, Explosion and Shock Waves* 41, 2005, p. 766.

Urtiew, P.A., et al., “Initiation of Heated PBX-9501 Explosive When Exposed to Dynamic Loading,” presented at Zababakhin Scientific Talks, Snezhinsk, Russia, September 5-10, 2005, LLNL report UCRL-CONF-214667, August 17, 2005.

Vandersall, K.S., et al., “Low Amplitude Single and Multiple Shock Initiation Experiments and Modeling of LX-04,” *13th International Detonation Symposium*, Norfolk, VA, 2006, pp. 904-913.

Vandersall, K.S., et al., “Shock Initiation Experiments on PBX9501 Explosive at 150ºC for Ignition and Growth Modeling,” *Shock Compression of Condensed Matter*, AIP Conference Proceedings 845, Baltimore, MD, 2006, p. 1127.

Vandersall, K.S., "LX-10 Summary Sheet," LLNL Explosives Reference Guide, UCRL-WEB-207690, 2006.

Vandersall, K.S., et al., “On The Low Pressure Shock Initiation of Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine Based Plastid Bonded Explosives,” *Journal of Applied Physics* 107, 2010, p. 094906-1.

Vandersall, K.S., et al., “Shock Initiation Experiments on the HMX Based Explosive LX-10 with Associated Ignition and Growth Modeling,” *Shock Compression of Condensed Matter,* AIP Conference Proceedings 955, 2007, pp. 1010-1013.

Walker, F.E. and R.J. Wasley, “Critical Energy for Shock Initiation of Heterogeneous Explosives,” LLNL Report UCRL-70891 Revision 1, June 7, 1972.

34. Mason, N.M. *et al*., May 2024. *2023 Results for Avian Monitoring at the Technical Area 36 Minie Site*, *Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory*. LA-UR-24-21036. (Mason *et al*. 2024)

LA-UR-24-21036

Approved for public release; distribution is unlimited.

Title:	2023 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory
Author(s):	Mason, Noelle Maryann Gadek, Chauncey Ryland Abeyta, Elisa Janelle Stanek, Jenna Elizabeth Gaukler, Shannon Marie
Intended for:	Report Environmental Regulatory Document
Issued:	2024-05-31 (rev.2)

2023 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory

LA-UR-24-21036
February 2024

Los Alamos
NATIONAL LABORATORY

Prepared for: U.S. Department of Energy/National Nuclear Security Administration,
LosAlamos Field Office

Prepared by: Noelle Mason, Chauncey Gadek, Elisa Abeyta, Jenna Stanek, and Shannon Gaukler
Environmental Protection and Compliance Division
Environmental Stewardship Group (EPC-ES)
Los Alamos National Laboratory

Editing and Layout by: Tamara Hawman, Communications Specialist
Communications and External Affairs Division
Technical Editing and Communications (CEA-TEC)
Los Alamos National Laboratory

*Cover photo: Western bluebird (*Sialia mexicana*) nestlings observed during nest box monitoring at Bandelier National Monument in 2023. Photo taken by Noelle Mason.*

Los Alamos
NATIONAL LABORATORY

Contents

Figures

Tables

EXECUTIVE SUMMARY

Los Alamos National Laboratory (LANL) biological subject matter experts in the Environmental Protection and Compliance Division initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. Additional monitoring began in 2017 at a third firing site, the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT). In this annual report, we compare monitoring results from these efforts among years to identify and evaluate firing and open burn site impacts on the local bird community. The objectives of this study are:

- to determine whether LANL operations impact bird abundance, species richness, or diversity;
- to examine occupancy and nest success of secondary-cavity nesting birds that use nest boxes; and
- to examine chemical concentrations (e.g., radionuclides, inorganic elements, and/or organic compounds) in nonviable eggs and deceased nestlings that are collected opportunistically with the upper-level bounds of background concentrations, when available.

During May through July 2023, LANL biologists completed multiple avian point count surveys at each of the following treatment sites except TA-36 Minie site, where only two surveys were completed due to heightened activity there. Additionally, avian nest boxes were monitored at control sites (at Bandelier National Monument) as well as the treatment sites:

- Technical Area (TA) 36 Minie Site,
- TA-39 Point 6,
- TA-16 Burn Ground, and
- DARHT.

LANL biologists completed the tenth year of this effort in 2023. We recorded a total of 849 birds representing 62 species at the four treatment sites and compared these results with data from their associated control sites. We also compared occupancy and nest success data from nest boxes at treatment sites with the overall avian nest box monitoring network and against a subset of relevant control sites.

In 2023, abundance and species richness at treatment and control sites continued to trend similarly from year to year, with minor random deviations indicative of a stable avian community. Though richness remained stable across all sites, three new bird species were observed at the treatment sites—Brewer's blackbird (*Euphagus cyanocephalus*), merlin (*Falco columbarius*), and yellow-breasted chat (*Icteria virens)*. The species diversity at the TA-36 Minie site, TA-39, and DARHT was statistically higher than their associated controls. The species diversity at all three treatment sites has been consistently lower at the control sites relative to treatment sites, likely due to subtle habitat differences. Annual diversity at treatment sites in 2023 remains stable relative to past years, and overall diversity remains high across all sites relative to similar habitats.

Nest box occupancy and success continue to fluctuate annually; however, a long-term discrepancy between occupancy and nest success at treatment sites in ponderosa pine habitat warrants further data collection and analyses.

In 2023, nonviable avian eggs were opportunistically collected at TA-16 Burn Ground, TA-36 Minie, and DARHT. All egg samples were evaluated for per- and polyfluoroalkyl substances, which were detected in eggs from TA-16 Burn Ground and from DARHT.

Overall results from 2023 continue to suggest that operations at the four treatment sites are not negatively impacting bird populations. This long-term project will continue to monitor for any changes over time.

1 INTRODUCTION

As part of the Resource Conservation and Recovery Act permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites—Technical Area (TA)-36 Minie Site and TA-39 Point 6; and one open burn site—TA-16 Burn Ground (hereafter referred to as TA-36 Minie, TA-39, and TA-16, respectively; or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock, Thompson, and Berryhill 2017; Hathcock, Bartlow, and Thompson 2018; Hathcock et al. 2019; Sanchez, Hathcock, and Thompson 2020; Rodriguez and Abeyta 2021). LANL biologists have been conducting point counts and monitoring nest boxes near an additional firing site, the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT), since 2017. Results for DARHT are included in this report. The objectives of this long-term monitoring program are:

- to determine whether LANL operations impact bird abundance, species richness, or diversity;
- to examine occupancy and nest success of secondary cavity-nesting birds that use nest boxes; and
- to document chemical concentrations (e.g., radionuclides, inorganic elements, and/or organic compounds) in nonviable eggs and deceased nestlings that are collected opportunistically and to compare them with the upper-level bounds of background concentrations, when available.

This effort involves comparing community and nest box data from treatment sites with control sites of similar habitat type that have been surveyed since 2011 (Hathcock, Zemlick, and Norris 2011).

Standard point count methodology to record avian abundance, richness, and diversity were used along transects at the three treatment sites and their associated control sites during the summer of 2023. Summer surveys provide information about which bird species could be breeding at each site. These surveys are most valuable when they are conducted over multiple years because they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

Although point counts are a reliable way to assess community level metrics, their utility in detecting fine-scale landscape differences may be limited (Ralph, Sauer, and Droege 1995). Point counts cannot reliably distinguish between birds that use the local habitat to breed versus itinerant individuals that migrate through or are temporarily foraging. Assessing the success of birds known to nest near firing (treatment) sites and those that nest in similar habitats away from firing (control) sites provides increased power to connect local environmental disturbances with local biology. To perform this assessment, we monitored nest boxes around all four treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared with the overall avian nest box monitoring network—established in 1997 (Fair and Myers 2002)—and a subset of sites of similar habitat type and nest box label number.

Another objective of this ongoing study is to document chemical concentrations in nonviable eggs and deceased nestlings that are collected opportunistically near TA-16 Burn Ground, TA-36 Minie, TA-39 Point 6, and DARHT. We compare concentrations of radionuclides, inorganic elements, and/or organic compounds (e.g. per- and polyfluoroalkyl substances [PFAS], polychlorinated biphenyls, dioxin, furans) observed in this study with the upper-level bounds of background concentrations, when available.

Radionuclides, inorganic elements, dioxins, and furans are of interest at open-detonation firing sites (TA-36 Minie and TA-39) and at DARHT (which performs detonations within steel vessels) as well as the burn ground at TA-16 (Fresquez 2011). PFAS compounds are being monitored to contribute to site-wide characterization at LANL. PFAS are a class of manufactured compounds that are used in many consumer and industrial products, such as cookware, food packaging, stain repellents, paints, and fire-fighting foams. PFAS compounds have useful properties, including repelling oil, stains, grease, and water, which contribute to their widespread use. Several thousand known PFAS compounds exist, some of which have been more widely used and studied than others, and these compounds have been manufactured since the 1940s. PFAS compounds have been detected in the environment around the globe. PFAS have been detected in avian tissues in remote areas such as oceanic environments or the Arctic region, where global deposition, or *fallout*, is the primary source of PFAS in the environment (Kannan et al. 2002; Martin et al. 2004). Toxicity data for PFAS compounds on avian ecological receptors are sparse (Dennis et al. 2021).

Biomonitoring is an important tool for assessing environmental contamination by analyzing chemicals or their metabolites from biological tissues (Becker 2003). Avian eggs and nestlings are useful as bioindicators because different species occupy many trophic levels. Additionally, the collection of nonviable eggs and/or nestlings that die of natural causes is noninvasive and is nondestructive to populations. Inorganic elements (i.e., mostly metals) and organic chemicals can pose risks of adverse effects to birds if exposed at high enough concentrations (Jones and de Voogt 1999). Birds can be exposed to chemicals through multiple routes, including diet, ingestion of soil, drinking water, and inhalation. Levels of some constituents in biological tissues can also indicate whether adverse effects could be expected (Gochfeld and Burger 1998). Examining population parameters along with tissue concentrations provides a more comprehensive and robust assessment of potential impacts caused by environmental pollution.

2 METHODS

2.1 Field Methods for Point Count Surveys

LANL biologists conducted the point count surveys along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1 through 5). The habitat types included in this monitoring are piñon pine (*Pinus edulis*) and juniper (*Juniperus monosperma*) woodland (PJ), present at TA-36 Minie (Figure 1) and TA-39 (Figure 2); and ponderosa pine (*Pinus ponderosa*) forest (PIPO), present at TA-16 (Figure 3) and DARHT (Figure 4). The habitat types are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites are monitored annually. The control sites were originally established in 2011 (Hathcock, Zemlick, and Norris 2011). Each habitat type control contained two replicate transects that LANL biologists monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects are surveyed in random order.

The treatment sites at TA-36 Minie and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 is located in the canyon bottom, whereas the controls are located on mesa tops. The treatment sites at TA-16 and DARHT are similar in elevation and overstory vegetation to the PIPO control sites, and all are located on mesa tops. One of the PIPO control transects is located adjacent to development, and the other transect is located in an undeveloped area.

Transects are approximately 2.0 to 2.5 km in length, with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The timeframe for breeding bird surveys is May 11 through July 9. Ideally, the breeding bird surveys should take place during the second week of May, June, and July. Sites are surveyed three times, and surveys are conducted between 0.5 hours before sunrise and within 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for 5 minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected are point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an “unlimited-distance circular plot”; however, surveyors record the distance to each bird out to an estimated 100 m. A range finder should be used if available. Surveyors avoid re-counting individuals between points.
- While walking between points, surveyors record any obvious species not recorded at the previous point that also would not be counted at the next point. Surveyors do not spend excess time looking for birds between points.
- Surveyors do not conduct surveys during rain events or during winds greater than 24 kph.

Surveyors use the “NOTES” section to document additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Surveyors also record other wildlife or unusual sightings that could be useful for other projects.

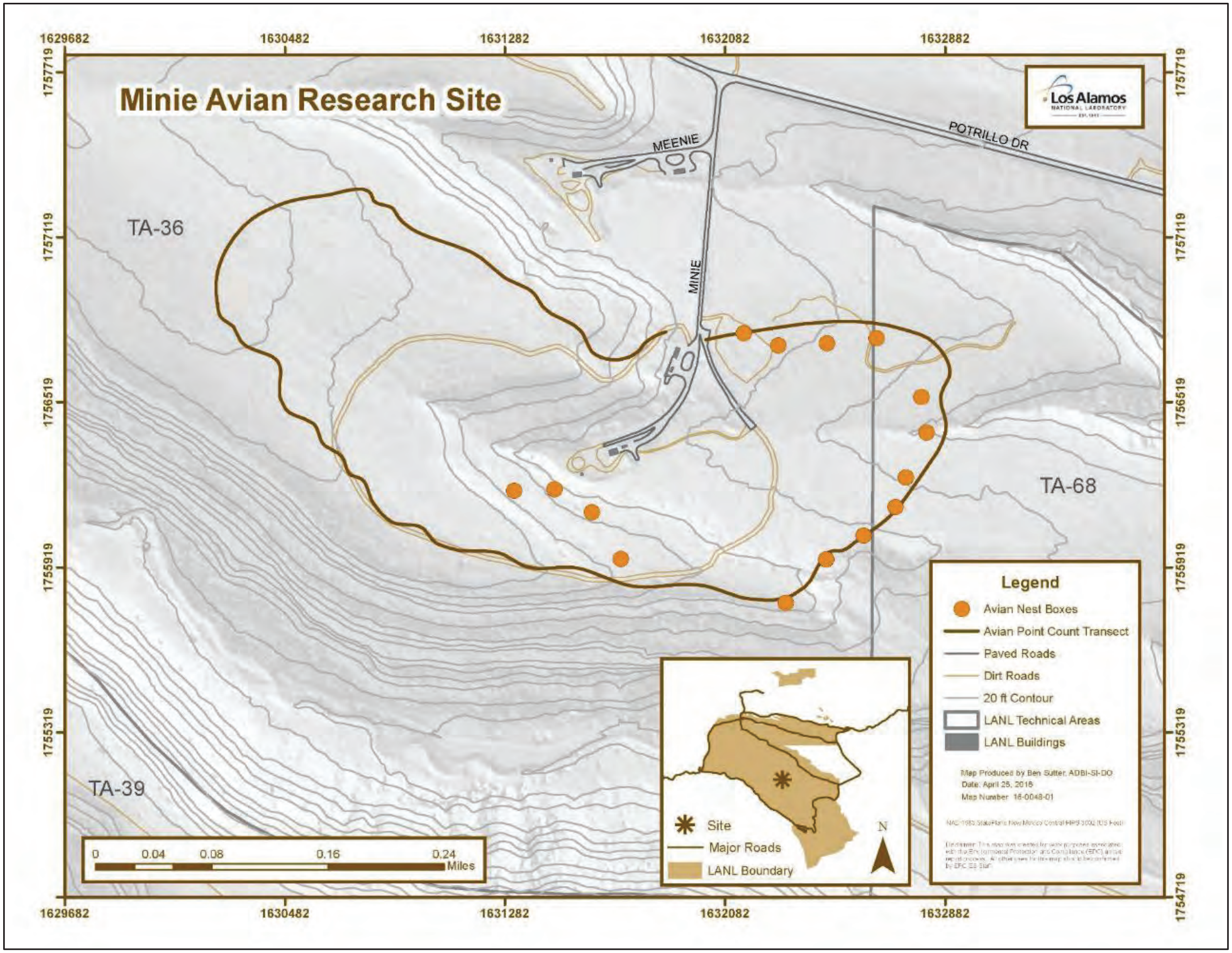


Figure 1. Breeding bird survey transect and nest box locations around TA-36 Minie Site.

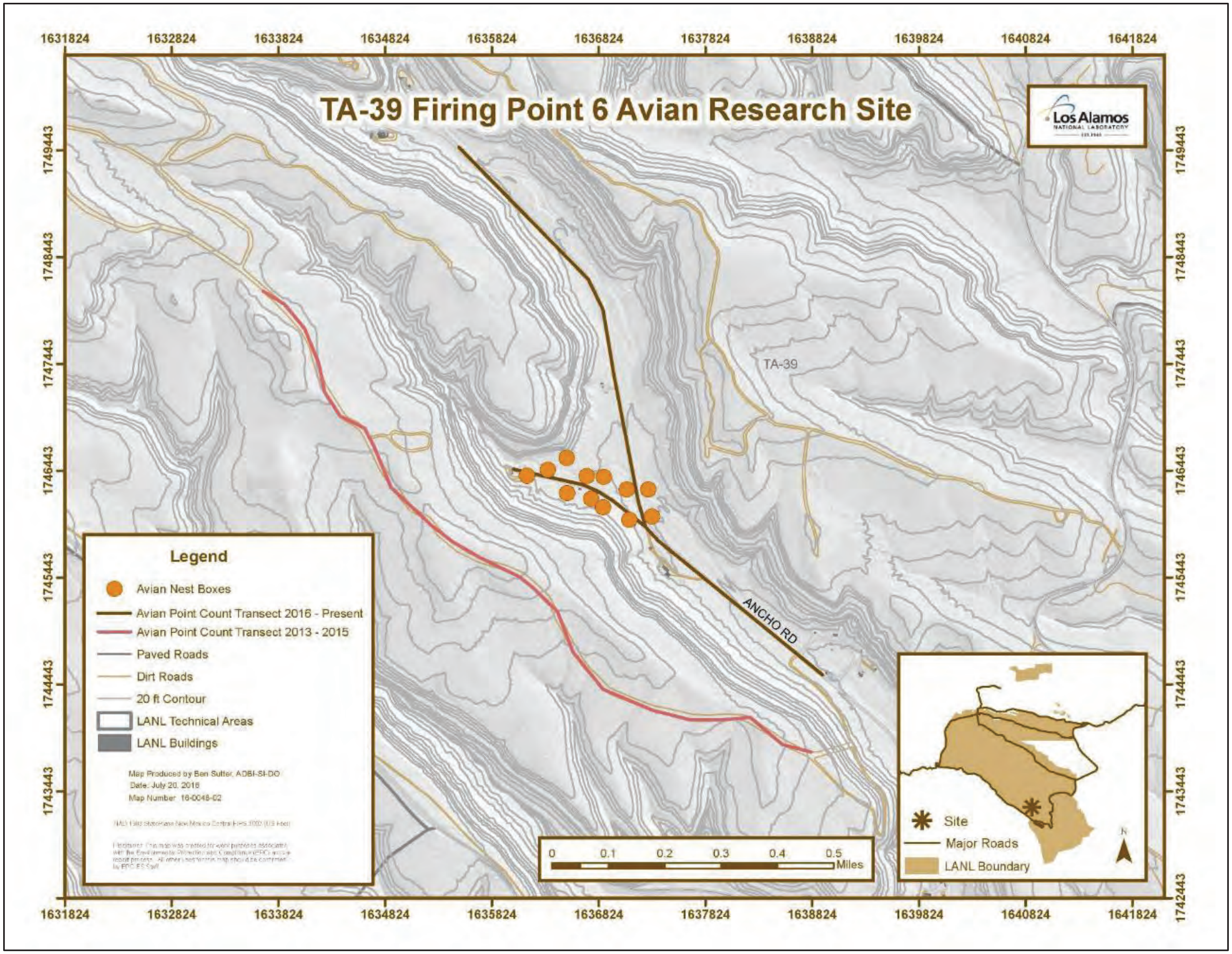


Figure 2. Breeding bird survey transect and nest box locations around TA-39 Point 6.

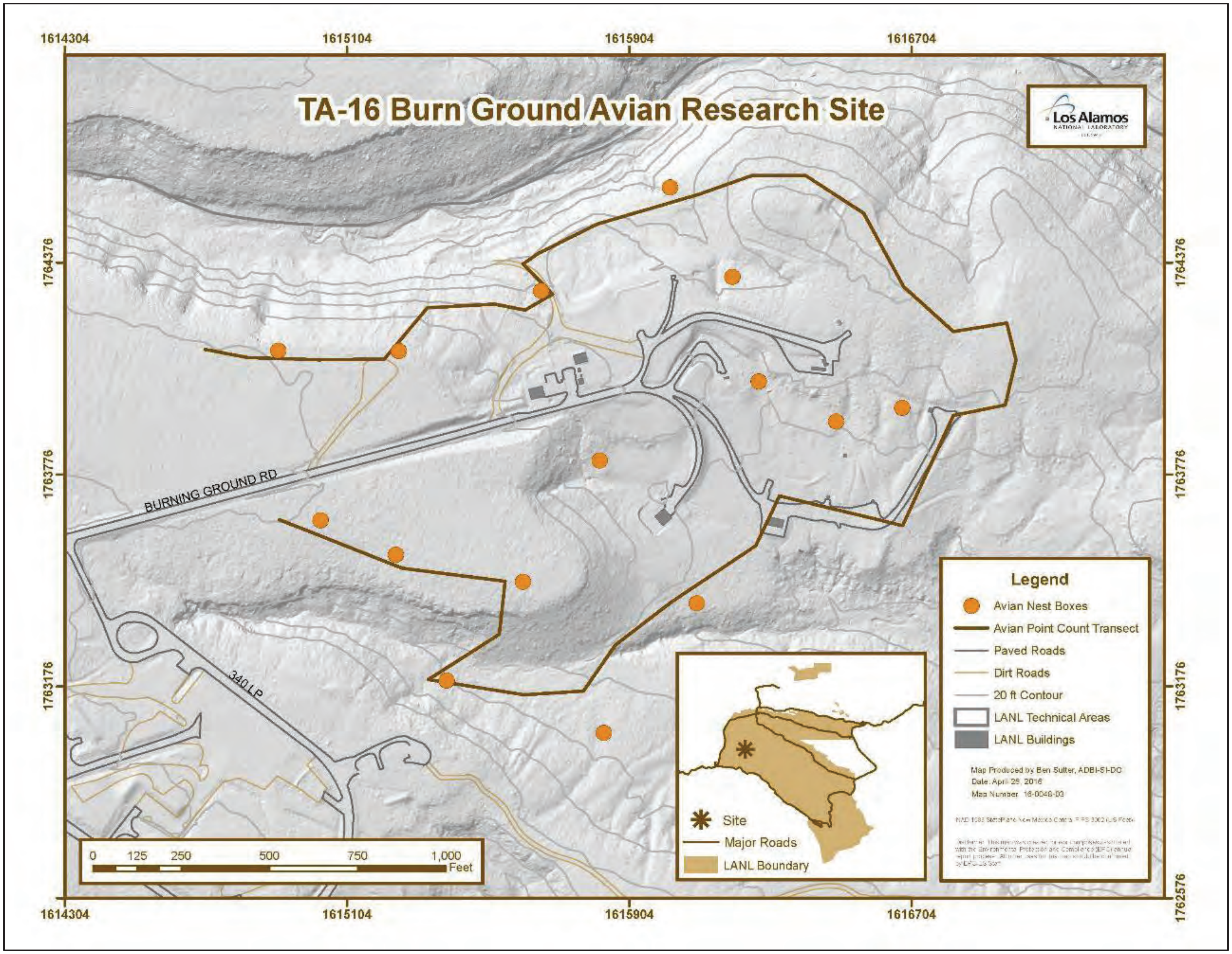


Figure 3. Breeding bird survey transect and nest box locations around TA-16 Burn Ground.

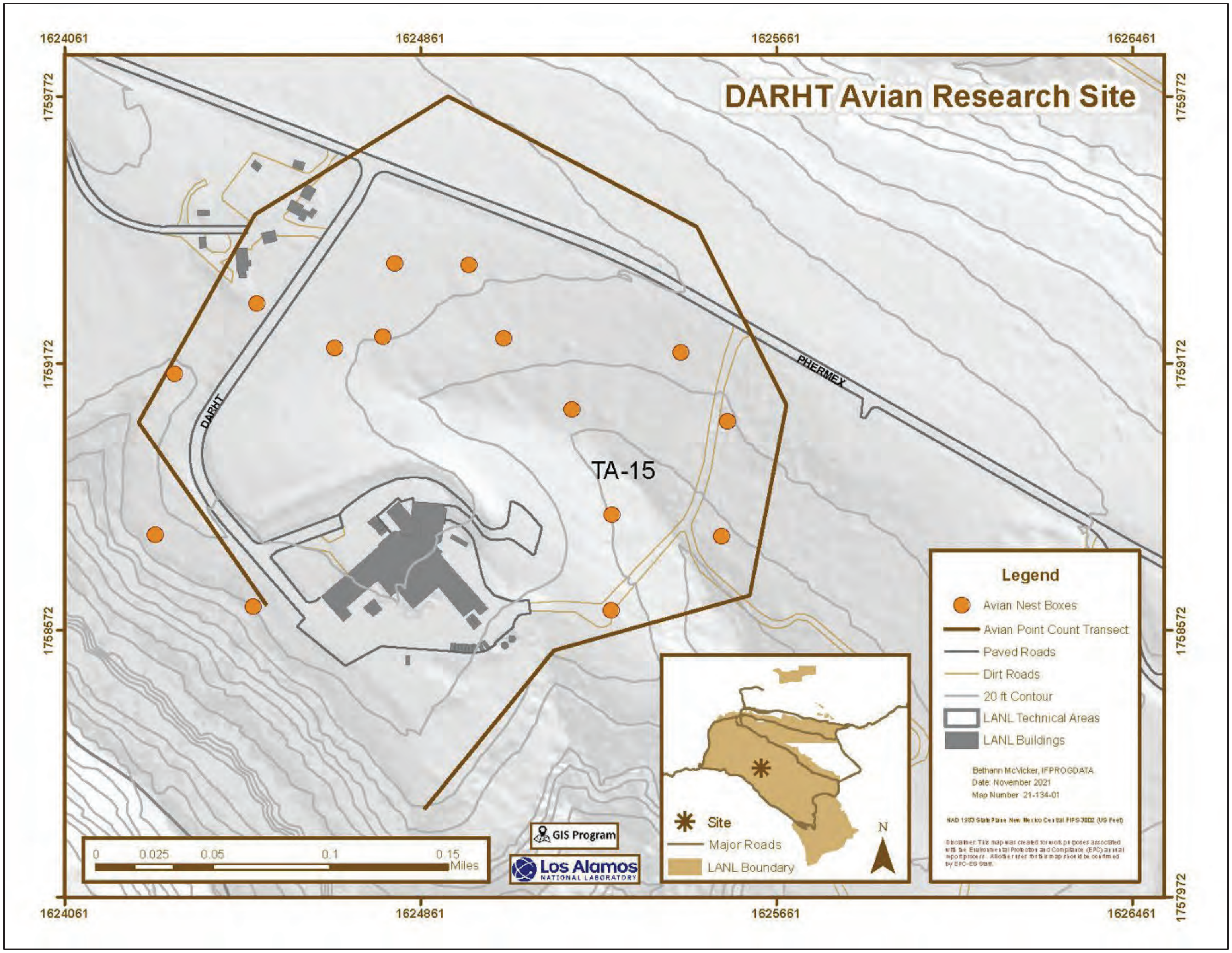


Figure 4. Breeding bird survey transect and nest box locations around the Dual-Axis Radiographic Hydrodynamic Test Facility.

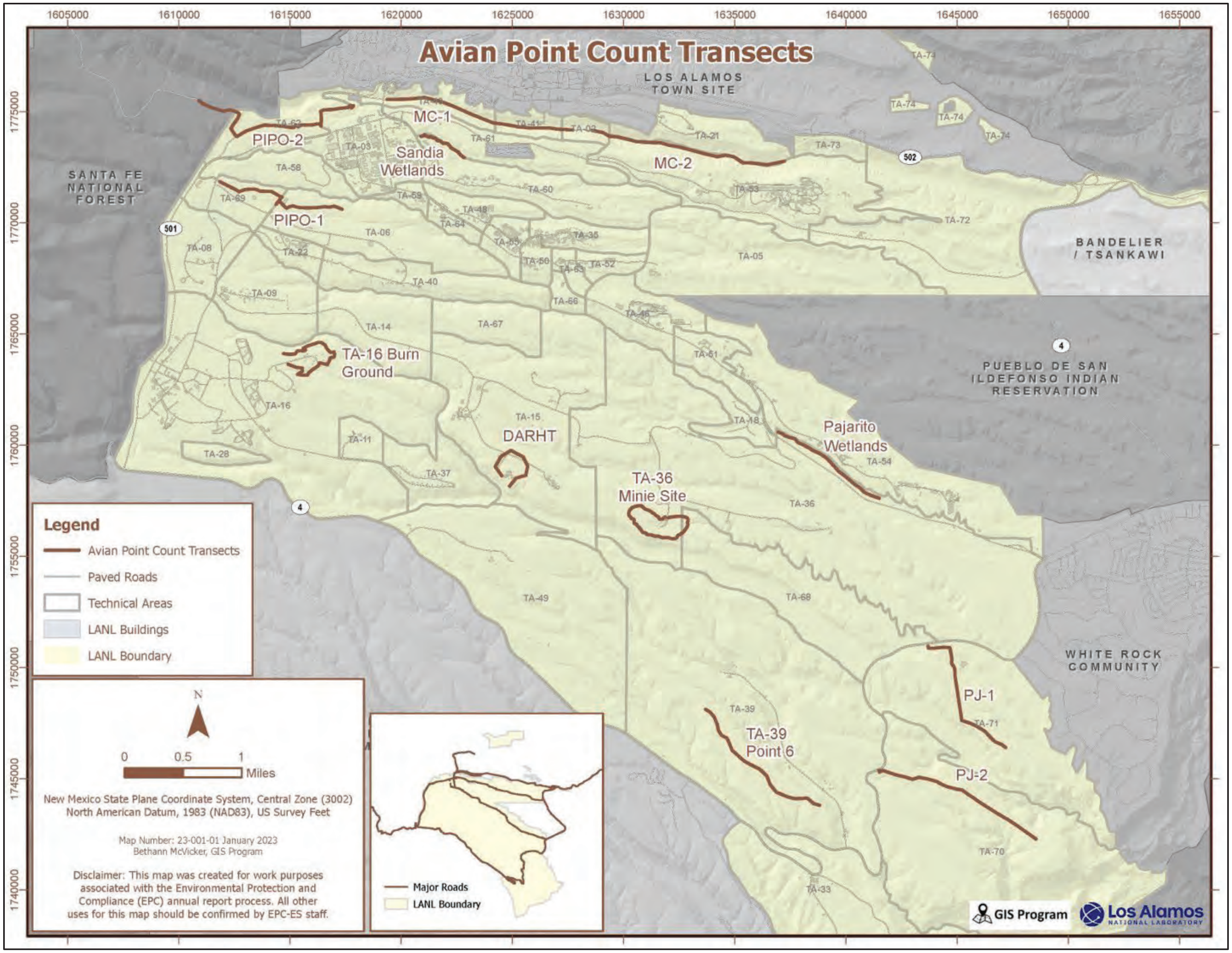


Figure 5. All avian point count transects around LANL ponderosa pine forest (PIPO) and piñon-juniper woodland (PJ). MC = mixed conifer.

2.2 Statistical Methods for Point Counts

We summarized breeding bird survey data to compare abundance, species richness, and diversity between treatment and control sites and over time. We considered each treatment site and control to be an individual community and compared averaged metrics by combining treatment and control sites within the same habitat class.

Abundance is the total number of individuals recorded of a given species (Gotelli and Colwell 2011). Species richness is the number of different species represented in an ecological community and is simply a count of species (Boulinier et al. 1998). Species diversity is a measure that considers species richness and the overall abundance to compare evenness across a community (Tramer 1969). As a species diversity metric, we used Shannon's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species (Shannon and Weaver 1949; Clarke et al. 2014). We used the diversity index to compare diversity between treatment and control sites. Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5 and are rarely greater than 4.5, where high values indicate high diversity.

We calculated all community metrics using the statistical software R (version 4.2.2; R Core Team 2023) and the package *vegan* (Dixon 2003) and used simple linear models to estimate coarse trends across the study period. We used Hutcheson's t-tests in the R package *ecolTest* (Salinas and Ramirez-Delgado 2021) to test for differences between treatment and combined (averaged species abundances) control site diversity for each year from 2013 through 2023.

2.3 Field Methods for Nest Box Monitoring

In 2011, we added nest boxes to TA-36 Minie and TA-39 (Figure 1 and Figure 2). In 2015, we added nest boxes to TA-16 (Figure 3). In 2017, we added 15 nest boxes to DARHT (Figure 4). Beginning in May, we monitored nest boxes every 1 to 2 weeks for active nests. When an active nest was found, we monitored it more frequently to determine whether the nest failed or successfully fledged young. We also banded nestlings and determined the sex after the age of 10 days.

2.4 Statistical Methods for Nest Boxes

We calculated occupancy and nest success rates of the nest boxes at the four treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nest boxes divided by the total number of nest boxes. Similarly, the nest success rate was the number of nest boxes that successfully fledged young divided by the number of active nest boxes. We compared the 2023 data from the four treatment sites with the overall avian nest box network at LANL, which was established in 1997 (Fair and Myers 2002). Because the overall nest box network comprises habitats and conditions not present at treatment sites, we also selected control sites that closely matched habitat type and nest box number of comparable treatment sites to examine nesting success metrics in a more balanced design. We calculated and plotted mean nest occupancy and success estimates by treatment and control sites between habitats across all study years.

2.5 Field Methods for Egg and Nestling Sample Collection

Eggs and nestlings are collected from nest boxes when they were determined to be nonviable based on documented timing of known incubation periods for the species. In 2023, we collected a total of five nonviable egg samples at LANL near the TA-16 Burn Ground (Figure 3), near open detonation site TA-36 Minie (Figure 1), and DARHT (Figure 4). At TA-16 Burn Ground, two nonviable western bluebird eggs were collected from one nest and were submitted as one composite sample. At TA-36 Minie, one western bluebird egg sample was collected and submitted as an individual sample. At DARHT, two nonviable western bluebird egg samples collected from two separate nests were submitted as individual samples. Additionally, we collected three samples from Bandelier National Monument; one western bluebird egg sample was collected and submitted as an individual sample, and two composite samples of nonviable western bluebird eggs were collected from two separate nests. All samples were collected during May through August 2023. Concentrations of PFAS chemicals in eggs have been monitored at these locations since 2022.

2.6 Chemical Analyses for Egg and Nestling Samples

Due to limited sample mass, nonviable eggs were analyzed for PFAS only and were analyzed at GEL Laboratories in Charleston, South Carolina. PFAS compounds were analyzed by liquid chromatograph triple quadrupole mass spectrometry (EPA:537M) and were reported on a ng/g (nanogram per gram) wet weight basis.

2.7 Statistical Methods for Egg and Nestling Samples

The 2023 results were compared with the regional statistical reference levels (RSRLs), which represent natural and fallout levels of chemicals and are the upper-level bounds of background concentrations (mean + three standard deviations = 99% confidence interval). The RSRLs were calculated from nonviable eggs of western bluebirds and ash-throated flycatchers collected from Bandelier National Monument in 2022 and 2023 (n = 4 samples). Nonviable egg results are also compared with the levels associated with adverse effects from peer-reviewed literature, when available.

3 RESULTS

3.1 Point Count Surveys

LANL biologists completed three surveys at each of the three treatment sites and PIPO control sites between May and July 2023 except for TA-36 Minie site, where only two surveys were completed due to shot activity. Table 1 summarizes the species richness, diversity, and abundance for 2023 for each treatment and control site. A total of 849 birds representing 62 species were recorded at the treatment sites. A full account of the 2013–2023 data is detailed in Appendix A.

Table 1. Species Richness, Diversity, and Abundance Recorded during 2023 at All Treatment and Control Sites

	Minie	TA-39	PJ Control 1	PJ Control 2	TA-16	DARHT	PIPO Control 1	PIPO Control 2
Richness	34	34	38	34	38	39	37	36
Diversity	3.15	3.06	2.74	2.81	2.82	3.01	3.18	3.18
Abundance	134	251	260	212	294	170	250	232

Overall bird abundance has trended similarly for both treatment and control. Figure 1 and Table B-1 detail abundance measured across all years for all sites. Overall abundance has tended to increase since 2013, with minor fluctuations and no clear pattern that indicates bird numbers are reduced at treatment sites (Figure 6, Table 1, and Table B-1). Mean annual abundance estimates trended higher at PIPO control sites than at comparable firing sites since 2016, with years of substantial overlap in site-specific abundances (Figure 6). Surveys began at DARHT in 2017 and increased raw abundance at combined PIPO treatment sites; however, mean estimates were calculated using survey-specific abundance values and account for the number of sites.

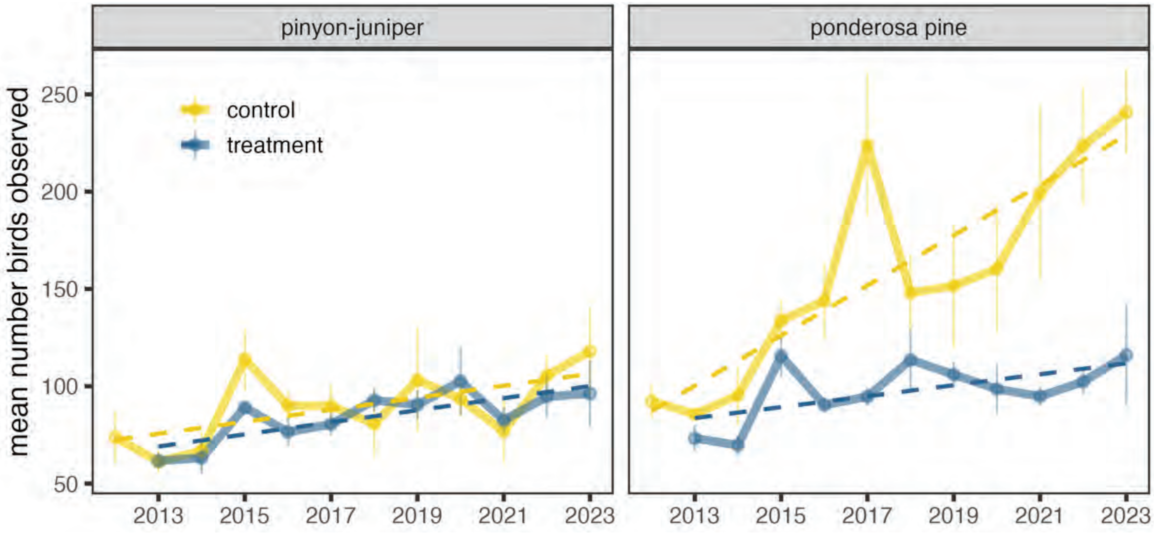


Figure 6. Mean bird abundances across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean abundance from all annual surveys per treatment and control site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

Figure 7 and Table B-2 illustrate changes in species richness over time at the treatment and control sites. Overall, the mean richness at treatment sites has marginally increased with annual fluctuations since monitoring began (Figure 7 and Table B-2). The only significant increase across all years occurred at PJ treatment sites ($t = 3.72$, $p < 0.01$). Species richness at both treatment and control sites has partially trended together, with average richness slightly higher at treatment sites than at control sites for most years. Though slight increasing trends seem promising, it cannot be ruled out that survey effort and detectability has changed across the study period, leading to increased identification ability. Future data collection should include surveyors' names to control surveyor variability in ongoing analyses.

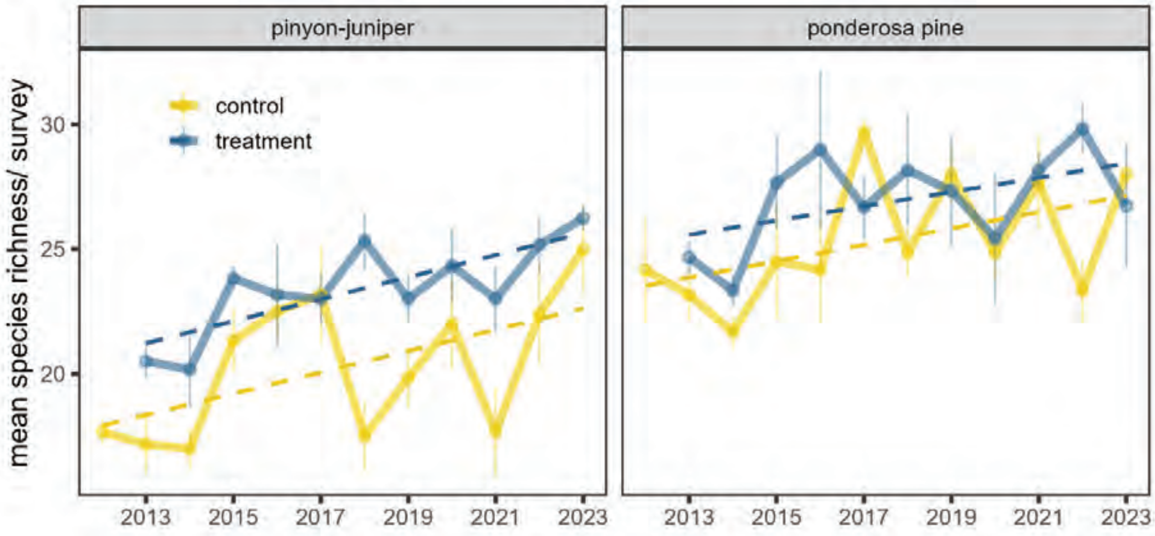


Figure 7. Mean bird species richness across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean richness from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

Figure 8 and Table B-3 through Table B-10 illustrate variation in species diversity over time between the treatment and control sites. Both treatment sites in PJ habitat and DARHT in PIPO habitat have historically had substantially higher total diversity than the comparable control sites; however, TA-36 Minie's diversity dropped relatively substantially in 2023 (Table B-3 through Table B-10). Across the entire study window in all significantly different comparisons, the diversity was higher at the treatment site than the combined controls (Table B-3 through Table B-10). Though we see substantial differences between treatment and control diversity in certain years, the total bird diversity at all sites has remained similar between treatment and controls, including in 2023. Per-survey diversity indices between treatment and control sites in PIPO habitat marginally diverge in 2017, likely driven by the addition of DARHT surveys (Figure 8). The generally lower disturbance conditions at Weapons Facilities Operations relative to control sites could be driving the higher diversity we observed at treatment sites.

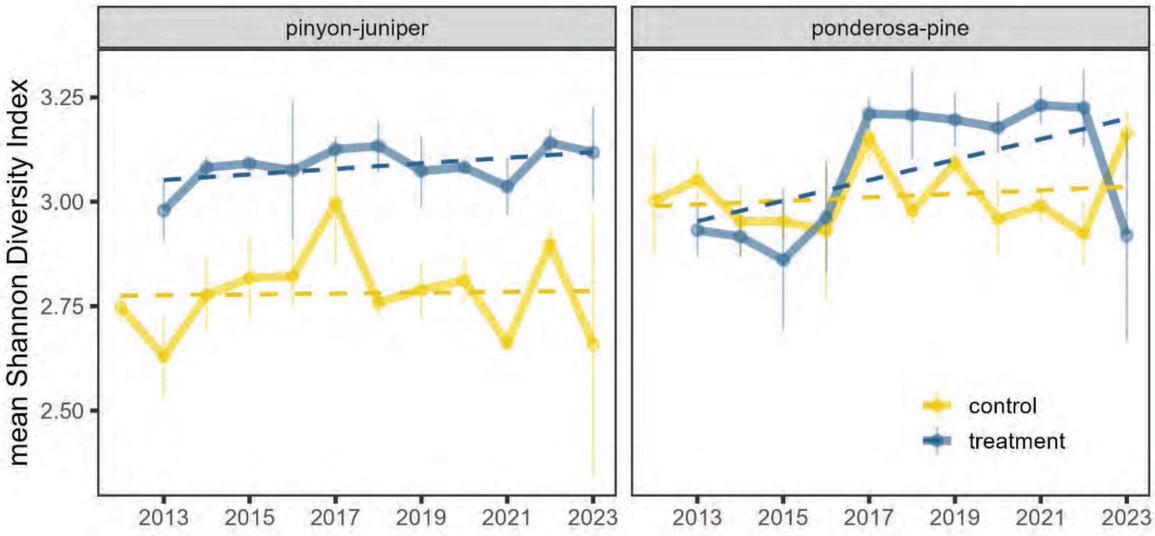


Figure 8. Mean Shannon Diversity Index across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean diversity from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.2 Nest Box Occupancy and Success

During the 2023 nesting season, LANL biologists actively monitored 15 nest boxes at each treatment site and a total of 356 nest boxes throughout the overall avian nest box network. Of those, 144 contained active nests, and 71 of those nests fledged young successfully, for an overall occupancy rate of 43 percent and a success rate of 49 percent. Occupancy rate continued to increase from a historic low in 2021, and nesting success rate increased from another record low in 2022. Figure 9, Figure 10, Table B-11, and Table B-12 compare the occupancy and nest success rates for each treatment site and the overall nest box network from 2014 through 2023.

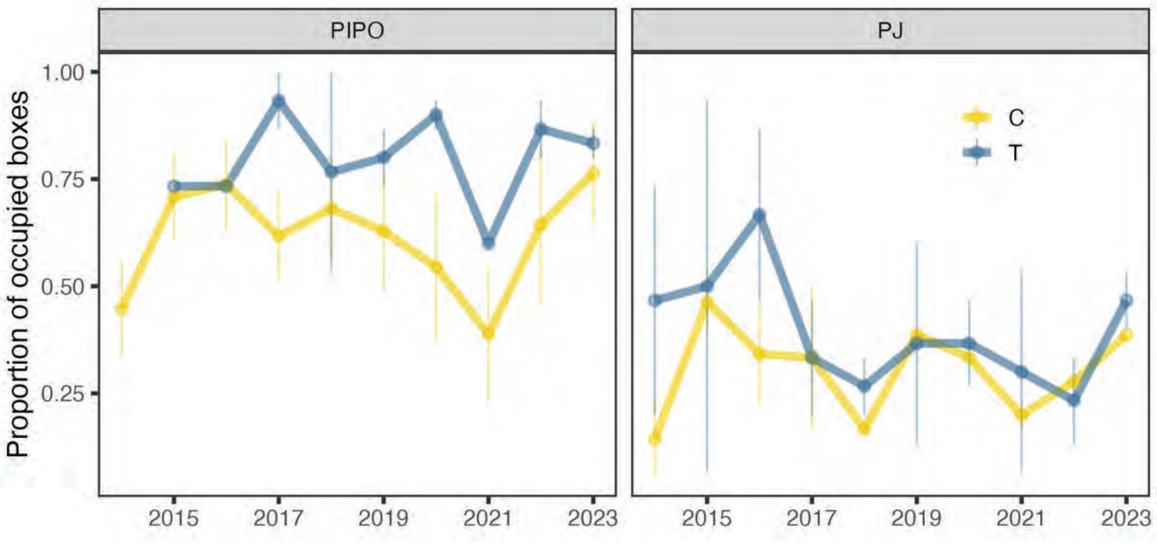


Figure 9. Mean proportion occupancy across study period for treatment sites (blue) and control sites (yellow) in ponderosa pine habitat (left panels) and piñon-juniper habitat (right panels). Lines connecting sequential year's values to illustrate trends. Vertical lines represent standard error of mean values.

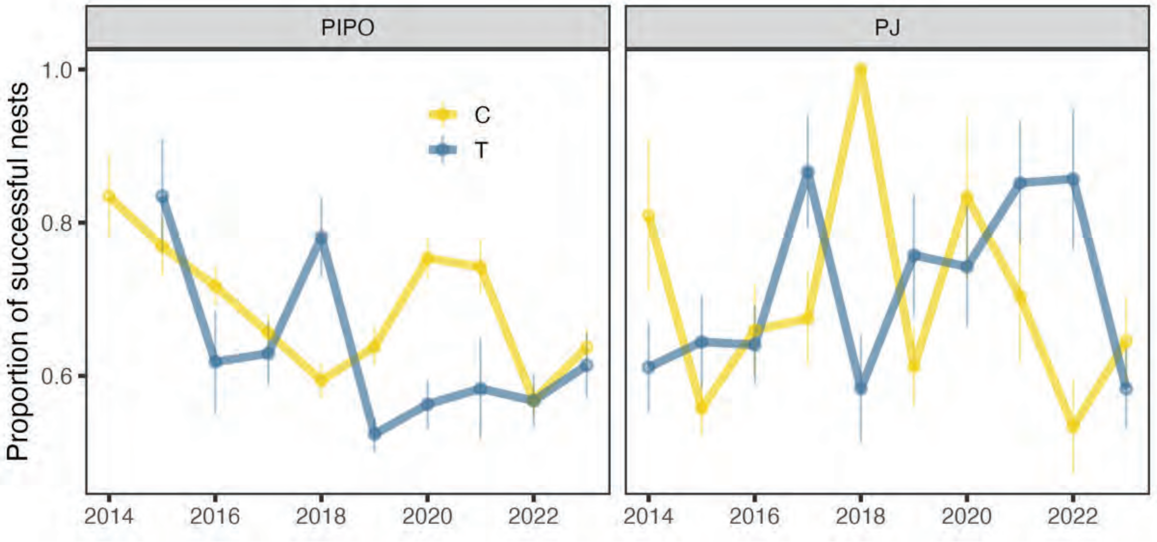


Figure 10. Mean proportion occupancy and success across study period for treatment sites (blue) and control sites (yellow) in ponderosa pine habitat (left panels) and piñon-juniper habitat (right panels). Lines connecting sequential year's values to illustrate trends. Vertical lines represent standard error around mean values.

In 2023, three nests fledged young at TA-36 Minie, six at TA-16, and four at TA-39. Occupancy at TA-39 continues to be low relative to the other treatment sites and the overall network. The nest success rate at TA-39 has been highly variable since monitoring began in 2015, ranging between 0 percent and 100 percent. TA-39 is the lowest elevation treatment site, and occupancy has been decreasing over time at this site and surrounding areas of the avian nest box network (Table B-11). Wysner et al. (2019) found that western bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. This shift in elevation is likely not due to individual nesting site preferences and more likely due to immigration of birds to the population (Abeyta et al. 2021). Western bluebirds have the highest occupancy rates throughout the nest box network, and shifts in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the TA-36 Minie treatment site have fluctuated annually and have not displayed a decreasing trend over time. The success rate at TA-16 has climbed from a large decrease in 2021 (Table B-12), likely driven by extremely low precipitation levels in winter 2020 (NOAA 2023). Decreases in precipitation have been linked to declines in body mass, which could indirectly impact reproductive success (Smith, Reitsma, and Marra 2010). Drought has been shown to shift avian community dynamics, including decreases in abundance and richness of neotropical migrants in dry regions (Albright et al. 2010).

Overall occupancy patterns varied between habitat types (Figure 9). Proportion of site occupancy across all years was substantially higher in PIPO treatment sites than controls ($t = 3.1$, $df = 45.5$, $p <0.001$) Conversely, PJ habitat showed no difference in occupancy combined across all years $t = 1.31$, $df = 29.8$, $p = 0.20$ (Figure 9).

Overall nest success also varied between habitat types but contradicted the within-habitat-type nest success patterns (Figure 9). In PIPO habitat, the proportion of nest success across all years was significantly lower at treatment sites relative to control sites (TA-16 and DARHT; $t = -2.76df = 317.1$, $p < 0.01$). There was no discernable difference across all years between treatment and control sites in PJ habitat ($t = 1.16$, $df = 233.8$, $p = 0.249$).

3.3 Chemical Analyses

In 2023, we submitted nonviable eggs collected from nest boxes at the treatment and control sites for chemical analyses. A total of 10 nonviable egg samples and no nestlings were collected from treatment (n = 5) and control (n = 5) sites in 2023.

Detectable concentrations of PFAS were compared with RSRLs, which—for PFAS in eggs—were calculated from nonviable eggs of western bluebirds (n = 3) and ash-throated flycatchers (n = 1) at background locations from Bandelier National Monument collected in 2022 and 2023 (n = 4).

The one western bluebird composite egg sample (n = 2) collected from a nest box at TA-16 Burn Ground was tested for 37 PFAS compounds; one compound—perfluorotridecanoic acid—was detected at a very low level of 0.439 ng/g. The level detected for perfluorotridecanoic acid is below the RSRL in passerine eggs at 0.568 ng/g. No PFAS compounds were observed in the western bluebird egg sample collected from a nest box at TA-36 Minie.

The two separate nonviable western bluebird egg samples collected from nest boxes at DARHT were tested for 37 PFAS compounds. One egg sample did not contain any detectable PFAS compounds. In the other western bluebird egg sample, most of the PFAS compounds that were detected were below the RSRLs (Table 2). Perfluoroundecanoic acid, perfluorotridecanoic acid, perfluorododecanoic acid, 3-Perfluoroheptyl propanoic acid, 1H, 1H, 2H, 2H-Perfluorododecanesulphonic acid, and 1H, 1H, 2H, 2H-Perfluorodecane sulfonic acid were all detected and slightly above the RSRLs (Table 2).

Table 2. Detectable PFAS concentrations (ng/g wet weight) detected in one single egg sample collected near DARHT compared with RSRL. The RSRL is the upper limit background concentrations (mean + three standard deviations) for passerine eggs.

Element	Western Bluebird (n = 1) SFB-23-297569	RSRL
Perfluoroundecanoic acid	0.929	0.568
Perfluorotridecanoic acid	0.996	0.568
Perfluorotetradecanoic acid	0.657	0.689
Perfluorononanoic acid	0.369	0.568
Perfluorododecanoic acid	0.821	0.568
Perfluorodecanoic acid	0.898	1.27
3-Perfluoroheptyl propanoic acid	1.42	1.14
1H, 1H, 2H, 2H-Perfluorododecanesulphonic acid	2.76	1.14
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid	6.51	1.32

Although these PFAS compounds are not as well-studied as other PFAS compounds such as perfluorooctanesulfonic acid (PFOS), an adverse effect from PFOS in avian eggs was determined at 92.4 ng/g (Dennis et al. 2021). The concentrations observed here are at least one order of magnitude below the levels associated with adverse effects. Additionally, the PFAS concentrations observed here are within the ranges observed in avian tissues from published studies, including studies that occurred away from point-source pollution and in the Arctic, where global deposition (or fallout) is the primary source of PFAS in the environment (Kannan et al. 2002; Martin et al. 2004). We are exploring other potential sources for some of the PFAS chemicals detected at LANL. Anticipated sources are atmospheric deposition and historical use of PFAS-containing materials.

4 DISCUSSION

In addition to supporting federally protected bird species such as the Mexican spotted owl (*Strix occidentalis lucida*) and the southwestern willow flycatcher (*Empidonax traillii extimus*), LANL lands are important for migratory bird conservation. During the 10-year study period, LANL biologists have documented sensitive species from the “Sensitive Species Best Management Practices Source Document” (Berryhill et al. 2020) and the “Birds of Conservation Concern 2021” (USFWS 2021) at the treatment sites. Those species are Cassin’s finch (*Haemorhous cassinii*), juniper titmouse (*Baeolophus ridgwayi*), Grace’s warbler (*Setophaga graciae*), Virginia’s warbler (*Leiothlypis virginiae*), black-throated gray warbler (*Setophaga nigrescens*), evening grosbeak (*Coccothraustes vespertinus*), peregrine falcon (*Falco peregrinus*), and mourning dove (*Zenaida macroura*). The gray vireo (*Vireo vicinior*) and pinyon jay (*Gymnorhinus cyanocephalus*) are the only sensitive species documented in only control sites. Of the 81 species detected at the three treatment sites, the Migratory Bird Treaty Act protects all but one species; the Eurasian collared-dove (*Streptopelia decaocto*) is not native and is therefore not protected under the Migratory Bird Treaty Act.

Overall comparisons provide mixed evidence for and against firing sites’ potential negative impact on birds. Through further data collection and refining analyses to appropriately control for uneven sampling and site-specific variation, we gain to sharpen our understanding of differences between bird communities and productivity at treatment and control sites. It is likely that a complex interaction of local habitat, climate trends, and disturbance levels interact in ways that might obscure signals in the absence of large, long-term datasets. Continuing to document migratory bird occurrences and nest success among treatment and control sites will only increase our ability to detect such signals should they exist, allowing LANL biologists to assess the ecological health of bird communities at the three firing sites and one open burn site at LANL.

Anthropogenic noise variation has been documented to affect bird behavior (Derryberry et al. 2020; Bernat-Ponce, Gil-Delgado, and López-Iborra 2021). Because a primary disturbance of concern at the open firing sites is intermittent noise, we suggest measuring sound levels within the local bird communities using passive acoustic recording devices between and during firing operations and comparing those levels against appropriate controls.

The overall chemical analysis results indicate that the levels of constituents detected in eggs are not likely to cause adverse effects in breeding bird populations from these study sites. The majority of PFAS results were either not detected or were below RSRLs. These results suggest that the detectable concentrations observed here are not of ecological concern. More data from nonviable eggs and nestlings are needed to make a robust assessment and to examine trends over time. Evaluating avian nestling samples for high explosives is also of interest for future work as those samples become available.

This research contributes to meeting the Department of Energy’s commitments under the Migratory Bird Treaty Act and the associated memorandum of understanding with the U.S. Fish and Wildlife Service. It also allows LANL to contribute to national goals in avian conservation monitoring and research.

5 ACKNOWLEDGMENTS

Thanks to the following individuals for technical, field, and lab support work in 2023: Jesse Berryhill, Jessica Celmer, Justin Clements, Jacob Martinez, Hanna Mora, Maria Musgrave, Audrey Sanchez, Brent Thompson, Makenzie Quintana, Milu Velardi, and former staff and interns who helped in previous years.

6 LITERATURE CITED

Abeyta, E. J., A. W. Bartlow, C. D. Hathcock, J. M. Fair. 2021. “Individual Nest Site Preferences Do Not Explain Upslope Population Shifts of a Secondary Cavity-Nesting Species.” *Animals* 11(8):2457. https://doi.org/10.3390/ani11082457

Albright, T. P., A. M. Pidgeon, C. D. Rittenhouse, M. K. Clayton, C. H. Flather, P. D. Culbert, B. D. Wardlow, and V. C. Radeloff. 2010. “Effects of Drought on Avian Community Structure.” *Global Change Biology* 16:2158–2170. https://doi.org/10.1111/j.1365-2486.2009.02120.x

Becker, P. H. 2003. “Chapter 19: Biomonitoring with Birds.” *Trace Metals and other Contaminants in the Environment* 6:677–736. https://doi.org/10.1016/S0927-5215(03)80149-2

Bernat-Ponce, E., J. A. Gil-Delgado, and G. M. López-Iborra. 2021. “Recreational Noise Pollution of Traditional Festivals Reduces the Juvenile Productivity of an Avian Urban Bioindicator.” *Environmental Pollution* 286:117247. https://doi.org/10.1016/j.envpol.2021.117247

Berryhill, J. T., J. E. Stanek, E. J. Abeyta, and C. D. Hathcock. 2020. “Sensitive Species Best Management Practices Source Document, Revision 5.” Los Alamos National Laboratory report LA-UR-20-24514, Los Alamos, New Mexico.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Polluck. 1998. “Estimating Species Richness: The Importance of Heterogeneity in Species Detectability.” *Ecology* 79(3):1018–1028.

Clarke, K. R., R. N. Gorley, P. J. Somerfield, and R. Warwick. 2014. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262 pp.

Dennis, N. M., S. Subbiah, A. Karnjanapiboonwong, M. L. Dennis, C. McCarthy, C. J. Salice, and T. A. Anderson. 2021. “Species- and Tissue-Specific Avian Chronic Toxicity Values for Perfluorooctane Sulfonate (PFOS) and a Binary Mixture of PFOS and Perfluorohexane Sulfonate.” *Environmental Toxicology and Chemistry* 40(3):899–909.

Derryberry, E. P., J. N. Phillips, G. E. Derryberry, M. J. Blum, and D. Luther. 2020. “Singing in a Silent Spring: Birds Respond to a Half-Century Soundscape Reversion during the COVID-19 Shutdown.” *Science* 370(6516):575–79. https://doi.org/10.1126/science.abd5777

Dixon, P. 2003. “Vegan, a Package of R Functions for Community Ecology.” *Journal of Vegetation Science* 14(6):927–930.

Fair, J. M., and O. B. Myers. 2002. “Early Reproductive Success of Western Bluebirds and Ash-Throated Flycatchers: A Landscape-Contaminant Perspective.” *Environmental Pollution* 118(3):321–330.

Fresquez, P. R. 2011. “Chemical Concentrations in Field Mice Collected from Open-Detonation Firing Sites TA-36 Minie and TA-39 Point 6 at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-11-10614, Los Alamos, New Mexico.

Gochfeld, M. and J. Burger. 1998. “Temporal Trends in Metal Levels in Eggs of the Endangered Roseate Tern (*Sterna dougallii*) in New York.” *Environmental Research* 77(1):36–42. doi:10.1006/enrs.1997.3802

Gotelli, N. J. and R. K. Colwell. 2011. “Estimating Species Richness.” In *Biological Diversity: Frontiers in Measurement and Assessment*. Oxford University Press, United Kingdom pp. 39–54.

Hathcock, C. D., K. Zemlick, and B. Norris. 2011. “Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011.” Los Alamos National Laboratory report LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C. D. and J. M. Fair. 2013. “Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds.” Los Alamos National Laboratory report LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C. D. 2014. “Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C. D. 2015. “Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C. D., B. E. Thompson, and J. T. Berryhill. 2017. “2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C. D., A. W. Bartlow, and B. E. Thompson. 2018. “2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-18-22897, Los Alamos, New Mexico.

Hathcock, C. D., A. W. Bartlow, A. A. Sanchez, J. Stanek, and B. E. Thompson. 2019. “2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-19-24156, Los Alamos, New Mexico.

Jones, K. C. and P. de Voogt. 1999. Persistent Organic Pollutants (POPs): State of the Science. *Environmental Pollution* 100(1–3):209–221.

Kannan, K., S. Corsolini, J. Falandysz, G. Oehme, S. Focardi, and J. Giesy. 2002. “Perfluorooctanesulfonate and Related Fluorinated Hydrocarbons in Marine Mammals, Fishes, and Birds from Coasts of the Baltic and the Mediterranean Seas.” *Environmental Science and Technology* 36(15):3210–3216.

Martin, J. W., M. M. Smithwick, B. M. Braune, P. F. Hoekstra, D. C. G. Muir, and S. A. Mabury. 2004. “Identification of Long-Chain Perfluorinated Acids in Biota from the Canadian Arctic.” *Environmental Science and Technology* 38(2):373–380.

McKown, B., S. W. Koch, R. G. Balice, and P. Neville. 2003. “Land Cover Classification Map for the Eastern Jemez Region.” Los Alamos National Laboratory report LA-14029, Los Alamos, New Mexico.

NOAA (National Oceanic and Atmospheric Administration). 2022. Climate at a Glance: Global Mapping. https://www.ncdc.noaa.gov/cag/

Ralph, C. J., J. R. Sauer, and S. Droege. 1995. Monitoring Bird Populations by Point Counts. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 187 pp. https://doi.org/10.2737/PSW-GTR-149

R Core Team. 2023. “R: A Language and Environment for Statistical Computing.” R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Rodriguez, J. M. and E. J. Abeyta. 2021. “2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-21-22304, Los Alamos, New Mexico.

Salinas, H. and D. Ramirez-Delgado. 2021. “ecolTest: Community Ecology Tests.” https://cran.r-project.org/web/packages/ecolTest/index.html

Sanchez, A. A., C. D. Hathcock, and B. E. Thompson. 2020. “2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory.” Los Alamos National Laboratory report LA-UR-20-20436, Los Alamos, New Mexico.

Shannon, C. E. and W. Weaver. 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois, USA. 127 pp.

Smith, J. A. M., L. R. Reitsma, and P. P. Marra. 2010. “Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird.” *Ecology* 91(10):2874–2882.

Tramer, E. J. 1969. “Bird Species Diversity: Components of Shannon’s Formula,” *Ecology* 50(5):927–929.

USFWS (U.S. Fish and Wildlife Service). 2021. *Birds of Conservation Concern 2021*. United States Department of Interior, Fish and Wildlife Service, Migratory Bird Program, Arlington, Virginia. 48 pp.

Wysner, T. E., A. W. Bartlow, C. D. Hathcock, and J. M. Fair. 2019. “Long-Term Phenology of Two North American Secondary Cavity-Nesters in Response to Changing Climate Conditions.” *The Science of Nature* 106:54. https://link.springer.com/article/10.1007/s00114-019-1650-9.

7 ACRONYMS AND ABBREVIATIONS

Acronym	Definition
DARHT	Dual-Axis Radiographic Hydrodynamic Test Facility
LANL	Los Alamos National Laboratory
ng/g	nanograms per gram
PFAS	per- and polyfluoroalkyl substances
PFOS	perfluorooctanesulfonic acid
PIPO	ponderosa pine forest
PJ	piñon-juniper woodland
RSRL	regional statistical reference level
TA	technical area

Appendix A Tables of 2013–2023 Species Abundances among Firing Sites

Table A-1. Detected Species Abundances at TA-36 Minie Site (Piñon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Acorn woodpecker											
American crow											
American kestrel				1				1	1		
American robin	1	1	2		2					5	1
Ash-throated flycatcher	11	5	14	13	13	10	17	12	12	7	5
Audubon’s warbler		2				5				1	2
Bewick’s wren	4	8	9	9	14	14	5	10	4	5	6
Black-chinned hummingbird		1	1				1	2	1	2	1
Black-headed grosbeak	1	3				1	1	2	1		
Black-throated gray warbler			1		2			2			1
Blue-gray gnatcatcher	3	14	16	8	10	9	8	11	8	14	9
Blue grosbeak											
Broad-tailed hummingbird	2	1	3		1		3	2		5	
Brown creeper											
Brown-headed cowbird	1								1		
Bullock’s oriole											
Bushtit		2		2		11				12	1
Canada goose											
Canyon towhee	2		5	3	6	2	3	5	3		
Canyon wren					1						
Cassin’s finch						4					
Cassin’s kingbird	6	13	13	5	2	5	6	5	4		6
Chipping sparrow	3	16	17	29	6	22	10	10	10		18
Clark’s nutcracker											
Common nighthawk	6		5	2	4	4	1	5			
Common raven	2	5	1		1	2	3			12	2

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Cooper’s hawk					1						
Cordilleran flycatcher											
Dark-eyed junco											
Downy woodpecker				1							
Dusky flycatcher				1							
Eurasian collared-dove	3										
Evening grosbeak	3		4						1		
Grace’s warbler							1				1
Gray flycatcher	12	6	5	7	3	6	3	2	4	8	3
Great horned owl		3									
Green-tailed towhee	3	1								1	
Hairy woodpecker			2	1		1		1	1	1	
Hammond’s flycatcher											
Hepatic tanager									2		1
Hermit thrush						1					
House finch	16	17	26	17	12	18	17	11	11	17	7
House wren											
Juniper titmouse	12		7	6	9	3	26	8	20	3	5
Lark sparrow										2	2
Lesser goldfinch	2	6	7	4	9	12	8	4	4	8	1
MacGillivray’s warbler										0	
Merlin											1
Mountain bluebird		2	20	10	11	1	9	3	2	5	5
Mountain chickadee	5	2	1	2						5	
Mourning dove	17	17	13	5	8	8	11	9	7	9	9
Northern mockingbird					2		1	4		8	
Northern rough-winged swallow						3					
Olive-sided flycatcher											
Orange-crowned warbler											
Painted redstart											

Appendix A: Tables of 2013–2023 Species Abundances among Firing Sites

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Peregrine falcon									1		
Pine siskin	10	2		5	1			1			
Plumbeous vireo	10	10	7	3	9	9	15	3	3	7	6
Pygmy nuthatch				2		2	3		1		
Red crossbill					1						
Red-shafted flicker	3	1	3	2	5	2	1		1	1	2
Red-tailed hawk							1	2	1		
Rock wren	3	3	4		2	10	11	10	4	5	5
Ruby-crowned kinglet											
Savannah sparrow											
Say’s phoebe	2	1	2		2	5	1	1	2	2	1
Scaled quail			1								
Spotted towhee	17	8	19	27	32	24	19	20	17	18	12
Steller’s jay							1				
Townsend’s solitaire	1									1	
Turkey vulture					1			2		2	
Vesper sparrow											
Violet-green swallow		5	7	1	3	2	1	6		3	3
Virginia’s warbler					1	3	1				
Warbling vireo						2					
Western bluebird	15	11	18	17	16	19	21	23	8	11	5
Western tanager		2	3		1						
Western wood-pewee	10	8	18	11	10	7	18	14	10	13	3
White-breasted nuthatch	1	4	9	10	13	5	2	1	2	1	
White-crowned sparrow											1
White-throated swift											
White-winged dove	1	5	9	2		3	2	1	1		1
Willow flycatcher											
Wilson’s warbler											
Woodhouse’s scrub-jay	5	1	3	4	8	7	14	10	10	7	6

Table A-2. Detected Species Abundances at TA-39 Point 6 (Piñon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Acorn woodpecker											4
American crow											
American kestrel	1			2					2		
American robin	1	1		2		4	2				1
Ash-throated flycatcher	19	11	30	12	8	8	6	11	4	7	10
Audubon’s warbler				2				5		3	7
Bewick’s wren	3	10	15	9	2	8	1	2		1	
Black-chinned hummingbird	3	2				1	2	3			2
Black-headed grosbeak		2	4	1		3	2	1	1	1	
Black-throated gray warbler	5	6	4								3
Blue-gray gnatcatcher	2		7	5	4	2	13	5	2	13	11
Blue grosbeak									1		
Broad-tailed hummingbird	3	1	2		3	1	2	9	3	2	
Brown creeper											
Brown-headed cowbird			2			3	2	10	3	12	5
Bullock’s oriole										1	2
Bushtit	2	14			1	12		2			
Canada goose			16				2				
Canyon towhee	1	1	2	10	13	19	6	3	9	5	2
Canyon wren			2	3	8	6	2	4			3
Cassin’s finch											
Cassin’s kingbird	7	6	2	21	21	32	37	49	14	41	35
Chipping sparrow	6	6	5	8	15	25	27	24	16	20	19
Clark’s nutcracker											
Common nighthawk	5	1	3	2	7	5	7	3	1	6	
Common raven	1		2	1		1	2	5		2	4
Cooper’s hawk											
Cordilleran flycatcher											
Dark-eyed junco						1	1				

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Downy woodpecker				1	2		1	2	1		
Dusky flycatcher			1		1					1	
Eurasian collared-dove					4			2			
Evening grosbeak			8								
Grace’s warbler						2	4	1	6	3	6
Gray flycatcher	10	10	11	10	5	8	3	14	5	6	13
Great horned owl	1										
Green-tailed towhee	1										
Hairy woodpecker			5	3			1	1	4		
Hammond’s flycatcher											
Hepatic tanager			1	2	1	2			1		
Hermit thrush											
House finch	21	4	23	9	30	44	50	53	22	41	31
House wren							1				
Juniper titmouse	11	13	18	6	1			3	2	3	
Lark sparrow											
Lesser goldfinch	4	12	9	10	14	19	15	27	8	31	13
MacGillivray’s warbler											
Mountain bluebird		4						2	1		
Mountain chickadee				1	1		1				
Mourning dove	13	22	10	3	15	11	8	10	9	16	7
Northern mockingbird		1							2	19	1
Northern rough-winged swallow											
Olive-sided flycatcher											
Orange-crowned warbler											2
Painted redstart											
Peregrine falcon			1						1		
Pine siskin	6		3	3						1	2
Plumbeous vireo	1		1	6	6	5	5	12	4	9	6
Pygmy nuthatch			2	4	12	9	11	10	1	8	

Appendix A: Tables of 2013–2023 Species Abundances among Firing Sites

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Red crossbill		2						1			
Red-shafted flicker	3	2	4	8		3	2	2		4	3
Red-tailed hawk			1	1	1	1					1
Rock wren	7	10	4	12	14	14	12	20	15	14	12
Ruby-crowned kinglet											
Savannah sparrow											
Say’s phoebe	2	1		5	2	4		6	5		2
Scaled quail											
Spotted towhee	12	6	33	16	12	16	15	20	14	20	18
Steller’s jay											
Townsend’s solitaire											
Turkey vulture								1			
Vesper sparrow											
Violet-green swallow	6	4	1	9	6	6	9	47	5		8
Virginia’s warbler			1	2	4		5		2	3	
Warbling vireo											
Western bluebird	5	19	12	21	13	6	7	17	3	4	10
Western tanager		2	1	1	2	2	6	1	2	4	
Western wood-pewee		4	2	10	8	11	12	18	12	16	3
White-breasted nuthatch			2	4	4	2	6	3	2	3	3
White-crowned sparrow									1		
White-throated swift		1						2			
White-winged dove	7	5	6	16	15	15	5	2	5	7	1
Willow flycatcher									1		
Wilson’s warbler											
Woodhouse’s scrub-jay	8	10	4	8	6	4	5		2	3	
Yellow-breasted chat											1

Table A-3. Detected Species Abundances at TA-16 Burn Ground (Ponderosa Pine Forest Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Acorn woodpecker	5		3	2	3	5	3	5	1		2
American crow					1	1		1	1	5	2
American kestrel											
American robin	7		9	4	4	6	12	6	14		4
Ash-throated flycatcher	3	5	6	2	3	8	4	6	6	11	4
Audubon’s warbler	6	5	1	6		1	11	14	9	5	10
Bewick’s wren											
Black-chinned hummingbird	1		1		1		1	12	1		
Black-headed grosbeak			1	2		2		1	1	1	2
Black-throated gray warbler											
Blue-gray gnatcatcher		6	2	1	3	6	4	9	3	9	4
Blue grosbeak											
Broad-tailed hummingbird	5	11	11	5	7	10	8			11	6
Brown creeper	1										
Brown-headed cowbird	4	1			4	2	8	4	4	3	3
Bullock’s oriole											
Bushtit											
Canada goose											
Canyon towhee	1			1		1					
Canyon wren			2								
Cassin’s finch									1		
Cassin’s kingbird				1				2		1	
Chipping sparrow	1	5	3	10	5	21	8	32	6	19	12
Clark’s nutcracker		4		1							
Common nighthawk			1	2	2			1			
Common raven	5	6	2	2	5	5	7	4	2	9	5
Cooper’s hawk	1			1			1				
Cordilleran flycatcher	5	10	6	3	3	1	2	4		2	2
Dark-eyed junco	6	2	4		5	2		2	3	3	1

Appendix A: Tables of 2013–2023 Species Abundances among Firing Sites

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Downy woodpecker		1		1	1	1					
Dusky flycatcher								2	1	1	2
Eurasian collared-dove						1					
Evening grosbeak	5		29			1					
Grace’s warbler	6	4	4	8	5	8	22	12	17	11	12
Gray flycatcher											1
Great horned owl											
Green-tailed towhee								1			
Hairy woodpecker	1	1		1	1	2	1	1			
Hammond’s flycatcher	8	9	12	5	7	5	10	5	7	1	
Hepatic tanager				1							
Hermit thrush		4	6	1	2	2	5	5	2	2	2
House finch	16	2	5	5	12	7	12	18	11	20	15
House wren	1	1		2	2	6	8	2	1	2	
Juniper titmouse											
Lark sparrow											
Lesser goldfinch	3		8	9	4	8	5	6	2	9	1
MacGillivray’s warbler				1	3			1		1	
Merlin											
Mountain bluebird			4	4	4	7	4	5			
Mountain chickadee	5	8	9	6	8	9	1	4	6	6	
Mourning dove	4		1	3	17	3	5	17	5	2	1
Northern mockingbird											
Northern rough-winged swallow											
Olive-sided flycatcher											
Orange-crowned warbler								1		1	1
Painted redstart										1	
Peregrine falcon											
Pine siskin	12	4	5		4	2		6		1	5
Plumbeous vireo	11	16	15	14	11	18	16	24	17	19	7

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Pygmy nuthatch	11	13	26	29	41	20	16	23	5	21	6
Red crossbill		2	9	13	9		6	26	1		
Red-shafted flicker	3	4	11	11	5	5	2	7	5	7	5
Red-tailed hawk										1	
Rock wren	1	2	2	6			4	1			4
Ruby-crowned kinglet						2			1		
Savannah sparrow								1			
Say’s phoebe	1		1	3	3	4	1	1	4		1
Scaled quail											
Spotted towhee	11	18	16	14	21	22	34	24	16	23	16
Steller’s jay	3	2	5	6	3	4	4	2	1		
Townsend’s solitaire					1						
Turkey vulture	1					1					1
Vesper sparrow							1				
Violet-green swallow		2	19	2	2	4	2	7	6	7	97
Virginia’s warbler	17	11	21	13	7	5	5	8	3	4	9
Warbling vireo	2	9	7	6	5	4	6	3	7	7	4
Western bluebird	20	20	49	37	32	27	20	27	8	32	16
Western tanager	2	3	7	2	4	6	16	10	7		8
Western wood-pewee	15	10	16	14	22	20	24	28	25	47	16
White-breasted nuthatch	9	8	7	9	20	10	10	8	10	9	4
White-crowned sparrow											
White-throated swift											
White-winged dove			1	2			1				
Willow flycatcher											
Wilson’s warbler											
Woodhouse’s scrub-jay	1										1

Table A-4. Detected Species Abundances at Dual-Axis Radiographic Hydrodynamic Test Facility (Ponderosa Pine Forest Habitat)

Species	2017	2018	2019	2020	2021	2022	2023
Acorn woodpecker		1	1	1		2	
American crow							
American kestrel						1	1
American robin	1		9	2	6	3	
Ash-throated flycatcher	7	2	2	5	4	2	
Audubon’s warbler		4	12	2	3	2	5
Bewick’s wren							
Black-chinned hummingbird		1				1	1
Black-headed grosbeak		3	1			3	1
Black-throated gray warbler							
Blue-gray gnatcatcher	5	8	16	17	4	9	4
Blue grosbeak							
Brewer’s blackbird							1
Broad-tailed hummingbird	3	4	5	10	1	7	5
Brown creeper							
Brown-headed cowbird		5	2	7	6	8	1
Bullock’s oriole							
Bushtit							1
Canada goose							
Canyon towhee							
Canyon wren							
Cassin’s finch							
Cassin’s kingbird	9	14	13	1	15	10	9
Chipping sparrow	16	31	21	17	30	18	34
Clark’s nutcracker		1					
Common nighthawk							
Common raven	10	1	5	5	6	4	
Cooper’s hawk							
Cordilleran flycatcher		1	1			3	

Species	2017	2018	2019	2020	2021	2022	2023
Dark-eyed junco							
Downy woodpecker							
Dusky flycatcher						2	
Eurasian collared-dove							
Evening grosbeak							2
Grace’s warbler	6	8	12	4	7	6	1
Gray flycatcher			1		3		1
Great horned owl			2		2		
Green-tailed towhee							
Hairy woodpecker		1					
Hammond’s flycatcher	1					1	
Hepatic tanager	1		1			2	1
Hermit thrush	1	1				1	
House finch	30	20	25	27	23	17	10
House wren							
Juniper titmouse						2	
Lark sparrow	1	2			1		2
Lesser goldfinch	19	12	20	25	5	9	
Macgillivray’s warbler							
Mountain bluebird	7	8	7	7	4	1	2
Mountain chickadee	3		7	7	4	1	
Mourning dove	1	1	5	5	7	6	5
Northern mockingbird		1		1	2	5	2
Northern rough-winged swallow			1				
Olive-sided flycatcher		1	1		3		
Orange-crowned warbler							1
Painted redstart							
Peregrine falcon							
Pine siskin	1				3		2
Plumbeous vireo	11	14	19	14	9	12	2

Species	2017	2018	2019	2020	2021	2022	2023
Pygmy nuthatch	9	13	13	3	4	6	6
Red crossbill	4					4	
Red-shafted flicker	8	10	3	1	3	2	
Red-tailed hawk	1		1			1	1
Rock wren	2	1		1	2		3
Ruby-crowned kinglet							
Savannah sparrow							
Say’s phoebe	8	1	5	2	2	1	
Scaled quail							
Spotted towhee	28	22	22	27	31	27	17
Steller’s jay	1						
Townsend’s solitaire		1				1	
Turkey vulture	2	1		1			1
Vesper sparrow							1
Violet-green swallow	9	12	32	20	28	15	19
Virginia’s warbler	12	8	4	1	8	2	
Warbling vireo							
Western bluebird	15	24	25	32	12	26	12
Western tanager	2	1	4	6	6	3	2
Western wood-pewee	14	19	22	14	17	25	4
White-breasted nuthatch	5	7	7	4	6	3	2
White-crowned sparrow							
White-throated swift	8					3	1
White-winged dove		4	1	2		1	2
Willow flycatcher							
Wilson’s warbler		2					2
Woodhouse’s scrub-jay	3					7	1

Appendix B Supplemental Statistics Tables

Table B-1. Yearly Species Abundance over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Minie	193	186	275	210	222	242	245	203	209	229	134
TA-39	177	193	260	249	261	315	298	413	286	339	251
PJ Control 1	187	157	269	312	240	235	226	292	225	209	260
PJ Control 2	181	177	301	228	300	168	187	269	159	142	212
TA-16	220	209	347	271	302	285	310	389	283	340	294
PIPO Control 1	258	223	432	323	447	374	364	373	349	337	250
PIPO Control 2	256	254	371	396	449	366	394	429	448	334	232

Table B-2. Yearly Species Richness over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Minie	33	33	34	30	35	35	34	33	33	37	34
TA-39	31	31	39	38	34	36	38	40	38	36	34
PJ Control 1	29	30	33	36	37	30	30	37	33	40	38
PJ Control 2	30	29	37	33	39	23	33	32	25	30	34
TA-16	39	33	40	44	41	43	39	46	37	40	39
PIPO Control 1	34	34	30	40	46	40	41	33	36	37	38
PIPO Control 2	33	36	43	43	44	39	40	40	44	39	37

Table B-3. T-tests Comparing Yearly Shannon Diversity between Minie Site with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Minie		3.14	3.14	3.19	2.97	3.13	3.21	3.06	3.13	3.00	3.31	2.74
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98	3.15
Hutcheson’s t-test	t	−3.93	−3.06	−2.10	−0.68	−1.73	−4.38	−3.31	−2.99	−1.87	−3.59	−3.73
	df	327	272	534	511	450	458	392	493	419	331	388
	p-value	<0.01	<0.01	0.04	0.50	0.08	<0.01	<0.01	<0.01	0.06	<0.01	2.21

Table B-4. T-tests Comparing Yearly Shannon Diversity between Minie Site with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Minie		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69	2.81
PJ Control 2		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98	3.15
Hutcheson’s t-test	t	−3.64	−2.94	−2.06	0.81	0.88	−7.20	−1.81	−3.42	−4.46	−7.49	−3.22
	df	337	328	563	436	490	312	346	471	299	252	345
	p-value	<0.01	<0.01	<0.01	0.42	0.38	<0.01	0.07	<0.01	<0.01	<0.01	<0.01

Table B-5. T-tests Comparing Yearly Shannon Diversity between TA-39 with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11	2.74
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98	3.07
Hutcheson’s t-test	t	−3.36	−2.42	−1.12	−5.34	−2.40	−3.27	−3.37	−2.52	−2.15	−1.31	−3.17
	df	330	268	509	540	425	497	444	561	462	361	447
	p-value	<0.01	0.02	0.26	0.00	0.02	<0.01	<0.01	0.01	0.03	0.19	<0.01

Table B-6. T-tests Comparing Yearly Shannon Diversity between TA-39 with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11	2.80
PJ Control 2		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69	3.07
Hutcheson’s t-test	t	−3.04	−2.22	−1.13	−3.89	0.31	−6.21	−1.94	−2.92	−4.70	−4.90	−2.60
	df	337	325	542	440	561	325	396	578	319	279	385
	p-value	<0.01	0.03	0.26	<0.01	0.76	<0.01	0.05	<0.01	<0.01	<0.01	<0.01

Table B-7. T-tests Comparing Yearly Shannon Diversity between TA-16 with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18	3.19
PIPO Control 1		3.14	3.12	2.91	3.14	3.13	3.04	3.13	2.90	3.01	2.96	2.84
Hutcheson’s t-test	t	−2.42	−1.21	−5.22	−2.01	−1.41	−4.55	−2.38	−6.95	−2.85	−3.12	3.60
	df	470	424	742	574	706	644	668	725	632	668	511
	p-value	0.02	0.23	<0.01	0.04	0.16	<0.01	0.02	<0.01	<0.01	<0.01	<0.01

Table B-8. T-tests Comparing Yearly Shannon Diversity between TA-16 with PIPO Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18	3.20
PIPO Control 2		3.20	3.16	3.26	3.11	3.23	3.10	3.29	3.18	3.22	3.05	2.84
Hutcheson’s t-test	t	−1.58	−0.67	0.43	−2.40	−0.11	−3.85	−0.08	−3.15	0.18	−1.98	3.77
	df	445	463	714	621	630	634	661	817	664	667	409
	p-value	0.11	0.50	0.67	0.02	0.91	<0.01	0.94	<0.01	0.86	0.05	<0.01

Table B-9. T-tests Comparing Yearly Shannon Diversity between DARHT with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33	3.01
PIPO Control 1		-	-	-	-	3.13	3.04	3.13	2.90	3.01	2.96	3.19
Hutcheson’s t-test	t	-	-	-	-	−0.72	−2.73	−0.24	−3.59	−3.40	−4.85	1.77
	df	-	-	-	-	687	621	679	665	613	599	308
	p-value	-	-	-	-	0.47	0.01	0.81	0.00	0.00	0.00	0.07

Appendix B: Supplemental Statistics Tables

Table B-10. T-tests Comparing Yearly Shannon Diversity between DARHT with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33	3.01
PIPO Control 2		-	-	-	-	3.23	3.10	3.29	3.18	3.22	3.05	3.20
Hutcheson's t-test	t	-	-	-	-	−2.05	2.43	0.16	−0.70	−3.86	−2.05	1.90
	df	-	-	-	-	609	686	640	593	572	609	293
	p-value	-	-	-	-	0.04	0.02	0.87	0.49	<0.01	0.04	0.06

Table B-11. Comparison of Yearly Percent Occupancy for Treatment Sites and Overall Nest Box Network

	2015	2016	2017	2018	2019	2020	2021	2022	2023
Overall Network	40%	45%	48%	53%	44%	58%	30%	41%	65%
Minie	66%	73%	46%	20%	60%	47%	53%	33%	53%
TA-39	8%	58%	20%	33%	13%	27%	7%	13%	40%
TA-16	-	73%	100%	53%	87%	87%	80%	93%	80%
DARHT	-	-	87%	99%	73%	93%	64%	80%	86%

Table B-12. Comparison of Yearly Percent Nest Success for Treatment Sites and Overall Nest Box Network

	2015	2016	2017	2018	2019	2020	2021	2022	2023
Overall Network	66%	69%	57%	49%	51%	59%	45%	42%	60%
Minie	64%	23%	29%	33%	44%	86%	38%	40%	56%
TA-39	100%	57%	0%	40%	0%	75%	0%	0%	61%
TA-16	-	63%	76%	63%	54%	54%	33%	36%	55%
DARHT	-	-	62%	6.3%	45%	31%	56%	58%	68%

35. Mitchell, W.J. and J.C. Suggs, August 1998.
Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD). EPA/600/R-98/103.
(Mitchell *et al*. 1998)

EPA/600/R-98/103

Emission Factors for the Disposal of Energetic Materials by Open Burning and Open Detonation (OB/OD)

By

William J. Mitchell and Jack C. Suggs
US Environmental Protection Agency, MD-46
Research Triangle Park, NC 27711

AUGUST 1998

This emission factor database
was created using data collected
by the U.S. Department of Defense

Contents

Appendices

Disclaimer

The U.S. Environmental Protection Agency through its Office of research and development funded the data analysis and validation study described in this report. It has been subjected to the agency's peer and administrative review and has been approved for publication as an EPA document.

Abstract

This report contains a validated database of pollutant emission factors applicable to the disposal of energetic-containing materials through open-air burning (in burn pans) and unconfined detonation processes (OB/OD). The emission factors in the database were compiled using data from studies, which measured the quantities of particles, semivolatile organic compounds, polychlorinated dibenzo-p-dioxins and furans, toxic metals, volatile organic compounds, and inorganic gases released when 0.22 kg of energetic materials were detonated and 2.2 kg of these materials were burned in 930 m^3 chambers, called BangBoxes. Air samples from the chamber were analyzed for over 275 analytes. The actions taken in validating the database are also described along with the minimum quantification limits for each pollutant measurement system. Summary statistics were calculated and compared to the results from smaller (0.02 kg)and larger (250-3,200 kg) scale detonations and burns of energetic materials. These comparisons confirm and expand upon results from earlier studies which determined that emission factors derived from chamber-based results can be used to predict the emission products that would be released from much larger scale detonations and burns, that is, the results are scalable. These comparisons also indicate that OB- and OD-based processes can be environmentally friendly ways to dispose of many of the energetic materials in the demil inventories of the world.

Tables

List Of Abbreviations And Terms

Abbreviations

DPG: Dugway Proving Ground, UT

LLNL: Lawrence Livermore National Laboratories

SNL: Sandia National laboratories

Definition of Terms

Blast effect: the high pressure generated by the explosion.

Brisance: the ability of an explosive to provide shock waves to shatter the target. After shattering the target, the shock wave can continue moving through the target. In this respect, brisance differs from blast effect. The blast itself can not transmit the energy through solid material without moving the target, but shock waves can.

Composite Explosive: A solid propellant comprised of an oxidizer (e.g., ammonium perchlorate) and a metallic fuel (e.g., aluminum powder) held together by a polymeric substance (e.g., polybutadiene).

Double-base Propellant: A solid propellant comprised of nitrocellulose (NC) and nitroglycerin (NG).

Emission Factor: The mass of an analyte released by a detonation or burn normalized to the energetic mass of the material (MEM) detonated. In the database, the emission factors are in terms of Kg analyte/kg MEM.

Encapsulated Energetic: An assembled energetic-containing material, such as a mine or a fuze.

Energetic: A substance, either a pure compound or a mixture of compounds, capable of undergoing a very rapid chemical change, releasing large quantities of heat and large volumes of hot gases. Includes high explosives, low explosives (propellants and pyrotechnics), incendiaries, fuse powders and thermites.

Explosive: A chemical compound or mixture which, when subjected to heat, impact, friction, shock or other suitable stimulous, undergoes a very rapidchemical reaction with the evolution of large volumes of heated gases that exert high pressures in the surrounding medium. Explosives are a subset of energetics, excluding those which do not produce large volumes of hot gases (e.g., incendiaries, fuse powders and thermites).

High Explosive: An energetic material in which the decomposition process (detonation) proceeds through the entire material at supersonic speed. The rate at which the decomposition process passes through the explosive is determined by the velocity of the shock wave. TNT, RDX and PETN are examples of high explosives.

Low Explosive: An energetic material in which the decomposition process (deflagration) occurs at subsonic speed. The decomposition occurs on the surface of the explosive only; there is no shock wave. Propellants and pyrotechnics are examples of low explosives.

Single -base Propellant: A solid propellant containing only nitrocellulose (NC) as the primary energetic material.

Target Analytes: The chemical species sought in the emissions from the detonations and burns, e.g., Pb, Al, acetylene. The target analytes are identified in Appendix C.

Triple-base Propellants: A solid propellant comprised of nitrocellulose (NC), nitroglycerin (NG) and nitroguanidine (NQ).

Acknowledgments

This database of emission factors was constructed from seven studies funded by the U.S. Department of Defense (DOD). The authors wish to acknowledge the support, cooperation and encouragement they received from Mr. MacDonald Johnson (retired) and Mr. Casey Wilcox (retired), the project officers at Dugway proving ground, UT for the seven studies. We want to particularly acknowledge the substantial contribution of Mr. Johnson, the project officer for the first five studies. It was Mr. Johnson's vision, personal integrity and personal sacrifice which brought about the DOD emission factor development program and which established its credibility with the regulatory community. It is regrettable that his health prevented him from completing the program and receiving the recognition he deserves for his significant contributions towards solving the demilitarization problem.

The authors also wish to acknowledge the contributions of the following individuals for their suggestions on ways to improve the readability of the document; Mr. R. J. Black of Dugway Proving Ground, UT: Mr Thomas E. Ward and Mr Jeff Gaines of the U.S. Environmental Protection Agency, Research Triangle Park, NC and Washington DC, respectively; Mr. Robert O'Brien of Brooks AFB; Dr. Charles Lind of the U.S. Naval Research Laboratory, Washington DC and Mr. Ed Patterson of the Department of Energy's Pantex Plant, Amarillo, TX.

Executive Summary

A database of emission factors applicable to the open burning (in burn pans, OB) and open detonation (OD) practices routinely used to destroy surplus or unserviceable energetic materials has been constructed and validated using emissions data from 16 energetic materials which were burned and 23 materials which were detonated in a 930 m^3 chamber called a BangBox. Both high and low explosives in bulk and assembled (encapsulated) form were detonated, but only low explosives in bulk and encapsulated forms were burned.

The database also contains emission factors from the burning of two surrogate materials, dunnage and an energetic-containing waste. The waste simulated one that would result from cleaning the processing equipment after an aluminized ammonium perchlorate (Al-AP) waste had been manufactured. The burns of these surrogate materials were initiated with diesel fuel.

A comparison of the emission factors in the database to those generated in other chamber studies and in large scale, unconfined field tests showed that all test results conformed to detonation theory. This finding indicates strongly that it should be possible to classify energetic materials into broad categories for the purpose of predicting the emission products and confirmed that chambers can be used to derive emission factors for use in predicting the emissions from unconfined detonations and burns.

Significant findings from these comparisons follow.

Findings Applicable To Both OB and OD

(1) Unconfined detonations, lightly-confined detonations and burns yield similar emission products, but the mix of products is different. If the energetic materials do not contain toxic metals, chlorine, plastic, wood or diesel fuel, the emission products will be CO_2, H_2O and N_2 along with small quantities of NOx and light hydrocarbons. Consistent with detonation theory, molecules larger than the starting molecules are not formed, even when the detonation is partially confined.

(2) The following four parameters are statistically the same across all the items detonated and burned in an unconfined state: %C as COx, %CO/COx, %N as NOx, and %NO/NOx.

(3) The emission products from most energetic materials destroyed by OB and OD processes will be adequately represented by the following analytes: CO_2, CO, NO, NO_2, total saturated hydrocarbons (e.g., ethane, propane, butane), acetylene, ethylene, propene, benzene, toluene, and particulate.

(4) Low recoveries of aluminum, lead, sulfur and chlorine were common across all detonation and burn studies used in these comparisons. In all studies 98 to 99% of the chlorine recovered was

determined to be HCl. The high reactivity of chlorine is a likely explanation for the low recoveries. The reasons for the low recoveries for sulfur and the metals still need to be determined to more fully characterize the environmental safety of OB and OD practices.

(5) Because most of the emission products from OB and OD operations are all species commonly found in the environment, it is particularly difficult to correct for contamination of metals and semi-volatile organic compounds (SVOCs)released from the walls of the chamber or the soil by the blast wave or the rapid movement of heated air. To compensate for the sample contamination from these sources when measuring the emission products from OB and OD activities, background samples should be collected by sampling the emissions from burning or detonating a material that would not be expected to release SVOC's or metals, e.g., detonation cord and nitrocellulose.

Findings Applicable to OD Only

(1) For the unconfined detonations, the median % recovery of carbon as carbon oxides (CO_2 + CO) was 98.5%; only 1.6% of the carbon was recovered as CO. The median % recovery of nitrogen as NOx was 1.2%. The remaining nitrogen was likely converted to N_2 in conformance with detonation theory and the results from large scale detonations conducted in the tunnels at the Nevada Test Site.

(2) Detonation-based processes can be an environmentally-safe way to dispose of bulk energetic materials, particularly for those which have been recovered from assembled munitions and for which there is no commercial or military use. This is especially applicable when: (1) the detonation occurs in an unconfined or lightly-confined state; (2) the detonation goes high order; (3) the soil particles released to the atmosphere are not hazardous in their own right; and (4) the toxic metals in the energetic materials are either at concentrations low enough not to endanger the health of humans or ecosystems or, their release to the environment can be kept below these levels. Coupling OB with phytoremediation techniques could be particularly rewarding in terms of protecting human health and the environment in both the short term and long term.

(3) It is also possible that many assembled munitions could be destroyed in an environmentally safe manner using detonation-based processes, provided research can provide a better understanding on how the following variables affect the emission products: donor charge placement, stacking geometry, mass of energetic material, degree of blast confinement and the type of casing.

(4) Compared to an unconfined detonation of the same material, detonating an energetic under a soil cover (buried detonation), or under other conditions which inhibit the formation of a fireball, will cause a decrease in CO_2 and an increase in soot (free carbon), CO, light saturated hydrocarbons, acetylene, ethylene, propene, benzene and toluene. It will very likely also increase the quantities of

undegraded or partially degraded energetic starting materials. Placing an oxygen source next to a buried energetic material will not automatically ensure that detonation will convert all the carbon in the energetic to carbon oxides.

(5) Buried detonations should be avoided whenever possible. For those situations where OB is not acceptable and blast noise control is needed, numerous, small scale detonations in chambers should be considered as an alternate to buried detonations.

Findings Applicable to OB Only

(1) The median % recovery of carbon as carbon oxides (CO_2 + CO) from the materials burned was 98.5%; only 0.2% of the carbon was recovered as CO. The median % recovery of nitrogen as NOx was 0.9%. The remaining nitrogen was likely converted to N_2 in conformance with detonation theory and the results from large scale detonations conducted in the tunnels at the Nevada Test Site.

(2) Open burning is an environmentally-safe means to dispose of single, double and triple base (organic-based) propellants when the propellants do not contain significant amounts of other combustible materials, such as diesel fuel, wood and chlorinated plastics or toxic metals. OB may be particularly appropriate for destroying energetic materials which result from steamout, water jet cutting and other demilitarization processes. Coupling OB with phytoremediation techniques could be particularly rewarding in terms of protecting human health and the environment in both the short term and long term.

(3) Open burning may also be appropriate for energetic materials containing AP, if the HCl and any metals in the energetic released could be prevented from entering the environment in quantities which could endanger the health of humans or ecosystems. Pollution control technologies that could accomplish this are available, although their suitability for this application needs to be established.

(4) Burning energetics containing plastics and chlorine in the presence of diesel fuel and wood may produce dioxins and furans.

Chapter 1
Introduction

U.S. EPA Regulations For the Disposal of Energetic Materials

During the Cold War, the United States of America, its allies and the former Soviet Union accumulated over 9,000,000 tons of energetic materials. With the ending of the Cold War, the United States, as well as these other countries, are now faced with disposing of large inventories of these materials in an environmentally sound manner. For example, in 1997, the U.S. Department of Defense (DoD) had 450,000 tons in its "demil inventory" and the inventory has been increasing by 40,000 to 50,000 tons per year.

The four methods commonly used to dispose of unneeded energetic materials are: (1) incineration; (2) disassembly, recovery and recycling (DRC); (3) burning in pans in an open area (OB); and (4) detonating either at ground level (OD) or under a soil cover (buried OD).

Although incineration and DRC are the environmentally-preferred methods of disposal, for the following reasons, they are not suitable for disposing of many of the items already in the demil inventory or likely to enter the inventory in the near future. First, the composition of many of the materials is either unknown, unstable, obsolete or has degraded. Second, the materials cannot be safely disassembled. Third, the financial and environmental expense of developing a recovery and reuse technology for them cannot be justified based on the quantity in the demil inventory or the commercial value of the material that would be recovered. For these materials, OB and OD are the only disposal techniques currently available and, thus, they continue to be an integral part of this nation's demil programs.

In the U.S., as elsewhere, there are concerns about the impact of OB and OD-based practices on human health and the environment. In the U.S., the disposal of energetic materials by OB and OD has been regulated under the Resource Conservation and Recovery Act (Subpart X of 40CFR264)[1], since 1984. One of the major concerns is the degree to which the energetic and its associated packing or containment materials are converted to innocuous chemicals. Other concerns relate to the toxicities and dispersion in the environment of the ash, soil and chemical pollutants released and the impact of the blast waves and sound waves released.

Because of these concerns the Subpart X permits that have been issued are very restrictive in terms of the conditions under which OB and OD can be carried out and the quantities that can be destroyed at one time, and over selected periods. To obtain a Subpart X permit, a facility must, at a minimum, provide the following information to the regulatory agency. First, the identity and quantities of pollutants and debris that will be released per event and over time. Second, the intensity of the blast waves and sound waves that will be generated. Third, a description of how these pollutants, debris, blast waves and sound waves will be distributed in the environment. Fourth, the degree to which the health of humans and the environment may be endangered in the short term (event basis) and over the lifetime of the OB and OD program.

The Detonation Process

Explosives are the class of energetic materials normally disposed of by OB and OD procedures. Explosives fall into two general classes: high and low[2]. High explosives are energetic materials in which the decomposition process (detonation) proceeds through the entire material at supersonic speed. The rate at which the decomposition process passes through the explosive is determined by the velocity of the shock wave and not by the rate of heat transfer. Low explosives (propellants and pyrotechnics) are energetic materials in which the decomposition process (deflagration) occurs at subsonic speed. The decomposition occurs on the surface of the explosive only and there is no shock wave. The rate determining factors in the deflagration process are the rate of heat transfer into the propellant itself from the burning surface and the rate of decomposition of the propellant formulation. The rate of the heat transfer is affected by the pressure of the combustion products.

The amount of energy released by propellant burning is comparable to that released when a high explosive of that same mass is detonated; the difference is in the rate at which the energy is released. In high explosives, a fast reaction produces a very high pressure shock in the surrounding medium. This shock is capable of shattering objects. In propellants (low explosives), a lower pressure is produced that extends over a longer period of time. High explosives produce peak pressure of 36,000 to 360,000 atmospheres in less than 4 microseconds; this pressure wave radiates through the material at a velocity (detonation velocity) between 2,500 and 10,200 m/s. The detonation also produces a 2-10 second fireball (afterburn) which has initial dimensions 1.2 to 1.5 times the dimensions of the material detonated. Propellants on the other hand, seldom produce peak pressures in excess of 3,500 atmospheres. TNT, RDX, Comp B are examples of high explosives and nitrocellulose (NC) and nitroguanidine (NQ) are examples of low explosives. Nitroglycerin (NG) by itself is a high explosive, but when added to NC, it becomes part of a low explosive. For both types of explosives, the initial release of energy results from adiabatic, oxidation reduction processes, which involve oxidant (e.g., $-ONO_2$, $-NO_2$, $-NHNO_2$) and reductant (e.g., C_xH_y) radicals within the energetic material.

Cook[3] and Ornellas[4,5] have published extensively regarding the mechanisms involved when explosives are detonated and burned. The information presented in this section was taken primarily from their publications.

Cook's publication provides a very lucid, comprehensive description of how explosives are made and how their performance is modified by the addition of accelerators and retardants. Ornellas's publications, on the other hand, describe results from experiments conducted to derive thermodynamic codes for use in predicting the explosive performance of C,H,N,O,Al-based explosives. These studies primarily assessed the effect the following factors had on the efficiency and effectiveness of the detonation process: explosive density, purity, and particle size; degree of confinement; and type of initiating charge. One of his reports[4] presents a comprehensive summary of the results obtained from detonating 25g cylindrical pellets (6.4 to 12.7 mm diameter, 114 mm long) of 43 energetic materials in a 5.3L bomb calorimeter at Lawrence Livermore National Laboratories (LLNL). Most of the detonations were done with the calorimeter evacuated, but a few were done when the calorimeter was pressurized with either CO_2 or O_2. Some of the detonations were done with the energetic simply suspended by a string (unconfined detonation), others were done with the energetic encased in glass or metal cylinders; sometimes the ends of the cylinders were open (partially-confined detonation), but at other times they were closed (fully-confined detonation). Approximately 90 minutes after the detonation, gas samples were taken from the bomb calorimeter and analyzed for N_2, CO, CO_2, H_2, H_2O, CH_4, NO, NO_2, HCN, HCl, HF, C_2H_2, C_2H_4 C_2H_6, and CH_2O, as appropriate. The calorimeter itself was also rinsed out and the rinse analyzed for solid carbon (C_S), HCl, HF Al_2O_3, and Zr_2O_3, as appropriate.

Ornellas's studies determined the following:

(1) The major reaction products from an unconfined detonation are primarily the fully oxidized, thermodynamically-stable compounds: N_2, CO_2, and H_2O. The detonation also produces small quantities of incompletely-oxidized, combustible products such as elemental carbon (C_S or soot), CO, H_2, CH_4, NO, NO_2, HCN, HCl, HF, C_2H_2, C_2H_4, C_2H_6 and CH_2O, but, as the fireball expands all or most all of these latter products react with O_2 in the air or with each other to form CO_2, N_2, and H_2O. The oxidation (afterburn) of these initial products releases energy which helps support additional combustion. After the burning gaseous mass cools to about 1800^0 K, the reaction rates fall to a point where further chemical change takes hours or longer to occur.

(2) The actual composition of initial detonation products depends on a variety of factors; one of the most important of these is the amount and form of oxygen in the energetic molecule. If the energetic is oxygen-balanced or only slightly oxygen-deficient, most of the carbon is converted to CO_2 and most of the hydrogen is converted to H_2O at the instant of detonation. As the oxygen-balance becomes more negative, the amount of soot, CO and other incompletely oxidized products formed increases and the fireball must occur if the incompletely oxidized products formed by the detonation are to converted to CO_2, N_2, and H_2O.

(3) Generally, at least 97% of the nitrogen in the energetic is released as N_2; almost all the rest is released as NO and NO_2.

(4) As noted above, the initial release of energy by an explosive results from an adiabatic oxidation reduction mechanism. This was dramatically demonstrated by Ornellas using a 20:80 blend (by weight) of ammonium nitrate (AN) and TNT. In his experiments, Ornellas used unlabeled AN (contains 99.8% $_{14}N$), labeled AN (contains 99.1% $_{15}N$ isotope) and unlabeled TNT (contains 99.8% $_{14}N$). In one of the experiments he made a slurry of TNT and AN in toluene, dried the slurry, blended it, sieved it through a 30-mesh screen and pressed the resulting powder into 12.7 mm diameter pellets, which he then detonated in the calorimeter. In the other experiment he detonated a 12.7 mm diameter AN pellet containing a 6.4 mm diameter core of labeled AN and an annulus of unlabeled AN. After each detonation, Ornellas measured the isotopic content of the N_2 formed, i.e., $_{14}N_{14}N$, $_{14}N_{15}N$, and $_{15}N_{15}N$. The two experiments yielded similar results, i.e., only about 13% of the nitrogen in the TNT and the AN mixed.

(5) If the oxygen in the energetic is bonded with nitrogen, the energy released upon detonation is much greater than that which is released when the oxygen is bonded to hydrogen.

(6) The composition of the initial detonation products is not greatly affected by the degree of confinement, but, the composition of the final products is affected. The more oxygen-deficient the energetic, the more the degree of confinement affects the final product mix.

(7) If an oxygen-deficient energetic is detonated in an oxygen-enriched environment, the final products will be CO_2, N_2 and H_2O. On the other hand, the products formed by detonating an energetic in an inert atmosphere (e.g., CO_2) will be essentially the same as those formed when the energetic is detonated in a vacuum, regardless of the degree the energetic is oxygen-balanced (Table 1-1). The oxygen-rich atmosphere will also yield a much higher total energy release (Table 1-1), because of the heat released when the incompletely oxidized radicals are oxidized by the oxygen.

(8) Generally, less than 20% of the Cl and F in the energetics detonated in the bomb calorimeter was recovered, but all of the Cl and F recovered was in the form of HCl and HF. The missing Cl and F were assumed to have reacted with the steel walls of the calorimeter, because they were not found in the rinse of the calorimeter.

(9) Al and Zr in the energetic were usually not quantitatively recovered, but the portion recovered was all in the oxide form.

(10) The packing density has a profound influence on the ratios of initial products formed from a detonation. For example, free-flowing loose granules do not explode as efficiently as cast explosives.

(11) As the density of a high explosive is increased, the detonation pressure and temperature also increases. On the other hand,

when the density of a propellant is increased the detonation pressure decreases, even though the reaction (deflagration) temperature increases.

(12) A trace impurity can substantially increase or decrease the efficiency with which the detonation will occur.

(13) The manner in which the charges are placed, the priming method, and the placement of the initiating charge can influence the effectiveness of the detonation in destroying all of the energetic. The most desirable circumstance would be to assure that the explosive detonates ideally. An explosive stack with an irregular shape will usually impact much more force in the direction of the longest dimension.

The studies described above were conducted to improve the in-use performance of energetic materials. The nature of the emissions and the impact of these emission products on the health of humans and ecosystems when surplus or unserviceable energetic materials are destroyed by OB and OD processes were not addressed. These latter energetic materials frequently contain degraded or below specification grade energetics and other materials, such as asphalt, resinous shell linings, binders, cardboard, wood, metal foil, etc., which could adversely impact the efficiency of the detonation and burning processes.

Also, real world OD processes are usually not truly adiabatic, because the fireball and plume encounter a myriad of heat sinks which prematurely quench the fireball or cool the plume and therefore can hinder the oxidation of the incompletely oxidized products released by the detonation. For example, even in a truly spherical fireball having the lowest possible ratio of surface to mass of any geometrical form, the outermost layer of the expanding fireball will be in direct contact with the ambient air. Also, the expanding gases penetrate the earth under the cloud, where they are both cooled by conduction and denied access to air for further oxidation until below equilibrium maintaining temperature. Further, for noise control purposes, at many facilities the detonations are conducted under a soil cover.

Studies To Assess The Environmentally Important Emissions From OB and OD Activities

In response to public concerns about the ability of OB and OD processes to convert degraded energetics into innocuous products, the Department of Defense (DOD) began its first comprehensive study to characterize the emissions from OB and OD activities in 1984. The DOD hoped to demonstrate that OB and OD would yield emission products which were similar to those from energetics when used for their intended purpose.

In this study, helicopters equipped with commonly-used air pollutant sampling equipment measured the pollutants in the plumes released when

900 to 5000 kg quantities of energetic materials were open burned and open detonated at DPG, UT. The results were inconclusive.[6] Few of the target compounds (analytes) were detected, but it wasn't clear if this was because they weren't present or because they were present at concentrations which were below the detection limits of the sampling equipment. Also, it was subsequently established that the helicopter frequently sampled only the outer portion of the plume and that the plume volume measurement technique was not reliable.

In 1988, the United States Army initiated a second study which had two major objectives: (1) to determine if toxic or hazardous pollutants were released when energetic materials were detonated or burned; and (2) to determine if emission factors produced by detonating and burning small quantities of energetic materials in large chambers containing ambient air would provide emission factors equivalent to those determined when large quantities of energetic materials were open-detonated and open-burned in the ambient air in the unconfined state.

Detonating and burning the energetic materials in large chambers provided DOD the opportunity to: (1) characterize ten or more energetic materials at a cost comparable to conducting field tests on one energetic material; (2) collect sufficient sample to meet the minimum quantification limits of the pollution measurement systems; (3) study the decay rates of the primary and secondary products released from detonations and burns; (4) minimize testing delays due to adverse weather conditions; and (5) obtain the minimum number of detonations and burns required to calculate statistically valid emission factors on each type of PEP material under repeatable and controlled conditions.

In this second study, 225 g quantities of flaked TNT were detonated and 2 kg quantities of two types of propellants were burned in a 930 m^3 hemispherical chamber (BangBox) at Sandia National Laboratories (SNL) in Albuquerque, NM and the emission products were measured with state-of-the-art air sampling equipment. This sampling equipment was then installed in a twin-engine, turboprop aircraft and used to sample the plumes released when 900 kg quantities of four explosives (reclaimed TNT, PBXN, Explosive D and Composition B) contained in treated wood boxes were detonated on the ground and 2,000-3100 kg quantities of four bulk propellants (M1, M6, M30 and a composite propellant) were burned in steel pans in the open at Dugway Proving Ground (DPG), UT.[7,8] Three, 2000-kg TNT detonations were also conducted with the TNT in iron cages suspended 10 m above the ground.

Based on their review of the test results, the U.S. Army concluded that the emission factors derived from the BangBox tests were: (1) more reliable and reproducible than those from the field tests; (2) were statistically equivalent to those determined from the field tests; and (3) supported the original assumption that the detonations and burns were producing emission products consistent with detonation theory. For example, the CO_2 and CO emission factors derived from the

TNT-BangBox detonations (TNT block suspended 1 m above the floor) were the same as those from the 2000-kg, suspended, reclaimed-TNT detonation, but both were substantially higher than those from the 2000-kg surface reclaimed-TNT detonatio.n[8] In this latter detonation, the expanding gases likely penetrated the earth under the detonating TNT and some of the energy released by the detonation was lost (transferred) to the soil. The resultant "cooling" of the fireball in combination with the reduced access to O_2 prevented the complete oxidation of the incompletely-oxidized products which were released by the detonation of the severely oxygen-deficient TNT molecules.

In their test reports the Army also noted the similarity of the emission products from the BangBox and field tests across all the materials tested, i.e., the emission products were primarily: N_2 (assumed), H_2O and CO_2; particles and metals; and small quantities of CO, NO, NO_2, low molecular weight volatile organic compounds (VOCs)and a few semivolatile organic compounds (SVOCs) commonly found in the ambient air. The report also noted: (1) that the soil at DPG had a high organic content and that the soil could have been the primary source for the SVOC's associated with the detonations; and (2) that the % C Recovered as CO_2 followed detonation theory, i.e., 99% for the 900 kg suspended field detonations (no detonation energy losses to soil), 97.5% for the 0.2 kg detonation in the BangBox and 95% for the 900 kg surface field detonations.[8]

In 1992, the U.S. EPA concurred with the Army's conclusion and agreed to accept BangBox derived emission factors for energetic materials as representative of those that would be derived through ground level, open-air tests. The Army then installed a BangBox at DPG identical to the one at SNL and initiated a program to characterize the compounds released when a wide variety of bulk and assembled munitions representative of those in the demil inventory were destroyed by OB and OD.

BangBox Study Results Used To Construct Database

Seven studies to characterize the emissions from the detonation and burning of energetic materials have now been conducted in BangBoxes. In these studies, 16 energetic materials have been burned and 23 have been detonated under conditions representing standard, unconfined OB and OD disposal practices. Since the seven studies used similar sampling and analysis procedures and had extensive documentation on what was done, it was possible to develop and validate the database of emission factors described in this report.

The database also includes the results from two special experiments. One experiment involved burning a surrogate dunnage to determine the contribution the burning dunnage makes to the emissions when it is used to initiate or support burning of an energetic material.

The other experiment involved using bags of water to suppress the detonations of two, TNT-based energetic materials, amatol and tritonal. These suppressed detonations were done primarily to assess how detonating an energetic under a soil cover could change the emission products compared to detonating the same weight of the energetic material on the ground. (As mentioned above, buried detonations are frequently used in the U.S. to mitigate the sound and blast waves released by the detonation.) Amatol and tritonal were selected for this experiment because they represent two extremes in the oxygen content of commonly used explosives. When detonated, amatol, an oxygen-balanced explosive, contains sufficient oxygen to convert its C and H to CO_2 and H_2O, whereas tritonal contains only 20% of the oxygen required to convert all its carbon to CO2 and H_2O.

These suppressed detonation experiments were also done to provide some robust emission factors for a blast and noise suppression technology developed in the U.S.[9], but refined in Europe[10,11] and South Africa [12]. The technology involves detonating munitions in contact with plastic bags containing water. This technology reduces the blast noise by more than 90% when compared to an equivalent unrestricted detonation[10]. However, the water also quenches the fireball which, based on the amount of sooty particulate found after the detonation, reduces the overall destruction efficiency of the detonation process.

Table 1-1. Distribution of Carbon in Emission Products from Detonating TNT in Different Atmospheres in Bomb Calorimeter[a].

	Calorimeter Atmosphere		
	Vacuum	CO_2 (1.66 Atm.)	O_2 (2.46 Atm.)
Total Energy Released (kcal/mol)	1093	1116	3575
% C Recovered as CO_2	18	17	97
% C Recovered as CO	28	29	5
% C Recovered as(soot)	52	52	Not Detected
Total % Carbon Recovered	98	98	102

a.) Data taken from Table 44 on page 77 of Reference 4.

Table 1-2.Heats of Reaction (kcal/mol) for Selected Gas Phase Reactions at 1 Atmosphere and 298° K

REACTANTS		PRODUCTS	HEATS OF REACTION
$C + ½ O_2$	=	CO	-26
$C + O_2$	=	CO_2	-94
$CO + ½ O_2$	=	CO_2	-68
$2 CO$	=	$CO_2 + C$	-41
$CH_4 + ½ O_2$	=	$CO_2 + H_2O$ (gas)	-192
$H_2 + ½ O_2$	=	H_2O (gas)	-58
$H_2 + CO$	=	$C + H_2O$ (gas)	-31
$½ N_2 + ½ O_2$	=	NO	+22
$NO + ½ O_2$	=	NO_2	-14
$3/2\ H_2 + ½\ N_2$	=	NH_3	-11
$NH_3 + 3/4\ O_2$	=	$½ N_2 + 3/2\ H_2O$ (gas)	-78
$NH_3 + 3/2\ NO$	=	$5/4\ N_2 + 3/2\ H_2O$ (gas)	-108
$4/3\ NH_3 + NO_2$	=	$7/6\ N_2 + 2\ H_2O$ (gas)	-108
$CH_4 + 2\ NO_2$	=	$N_2 + 2\ H_2O$ (gas) $+ CO_2$	-208
$S + O_2$	=	SO_2	-71
$SO_2 + ½ O_2$	=	SO_3	-23
$H_2 + S$	=	H_2S	-5

Chapter 2
Methods and Materials

Composition of the Energetic Materials Characterized

Table 2-1 identifies the materials detonated and burned in the seven studies. Table 2-1 also presents: the abbreviation used for each material in the other tables in this paper; the total weight (mass) of each energetic material (MEM) tested; and the number of times (trials) each material was detonated or burned. MEM includes the weight of all supplemental energetic materials such as blasting caps, donor charge, smokeless powder, etc. used in initiating the detonation or burn.

Tables 2-2 and 2-3 present the weights of the energetic components and Pb and Al in each material detonated and burned to the extent information is available. The abbreviations used in these tables represent the following compounds: TNT (2,4,6 trinitrotoluene); RDX (1,3,5-trinitro-1,3,5-triazacyclohexane); PETN (pentaeyrthritol tetranitrate); TETRYL (2,4,6, N-tetranitro-N-methylaniline); NC (nitrocellulose); NG (nitroglycerin); NQ (nitroguanidine); HMX (1,3,5,7-tetranitro-1,3,5,7-tetraazacyclooctane); AP (ammonium perchlorate); and AN (ammonium nitrate), KN (potassium nitrate); zinc powder (Zn) and aluminum powder (Al).

Appendix A contains detailed descriptions of the compositions of each energetic material.

Description of the BangBoxes

Each BangBox sits on a concrete pad and is divided into two sections: an inflatable, 930 m^3, 16.5 m diameter hemispherical test chamber made from a flexible polyvinyl-coated polyester fabric and a 5.5 x 2.1 x 2.5 m building (airlock) with a plywood front and a wood frame covered with the same material as the BangBox. The test chamber is kept inflated by two high-capacity blowers; six fans spaced 60^0 apart circulate the air in the test chamber to produce a homogeneous pollutant mix that is sampled with instruments in the chamber and the attached air lock. The energetic materials are burned in stainless steel burn pans placed on a steel pad located in the center of the test chamber and detonated in a 1 m^3 steel-lined pit after the steel cover is removed. The test chamber is purged with air for at least 60 minutes (two air volume exchanges) between trials.

When detonations and burns are initiated, a known quantity of SF_6 is released in the chamber. The concentration of the SF_6 is then measured over the time air pollutant samples are taken and used to establish the actual volume of the chamber and the dilution of the emission products which occurred (due to the chamber blowers) between initiation of the burn/detonation and completion of sample collection. This information is used to calculate the initial concentrations of the compounds released by the burn/detonation. (The SF_6 was collected in 0.85 L Summa canisters and analyzed by a gas chromatograph equipped with a flame photometric detector (GC/FPD).

Sampling and Analysis Procedures Used in the DPG BangBox

The following sampling equipment was located in the test chamber: (1) high volume samplers (Hi-Vol) for measuring particle mass, metals, and EPA SW846 Method 8270 semivolatile organic compounds (SVOCs); (2) Hi-Vol-based PM-10 sampler for measuring particles and metals in the respirable range; (3) EPA PS-1 samplers for measuring Method 8270 SVOCs and chlorinated dioxins and furans; (4) EPA Method 26 samplers for HCl and Cl_2.

The following sampling equipment for gases was located in the airlock attached to the chamber: (1) continuous emission monitors (CEMs) for CO_2, CO, NO, NO_2, O_3, and HCl; and (2) canisters for measuring volatile organic compounds (VOCs), CO_2, and CO.

Background samples were collected in the test chamber at the beginning of every test day, analyzed in a manner identical to the test samples, and the results used to correct the emission factors for any contribution background levels of the target compounds (analytes) made to the measured (uncorrected) emission factors.

The sampling equipment used in each study was selected based on the composition of the materials being tested and the objective(s) of the study. Table 2-4 identifies the sampling systems used in each study.

Appendix B contains a more detailed description of the actual sampling systems used and Appendix C delineates the target analytes used in the seven studies.

Sampling and Analysis Procedures Used in the SNL BangBox

The procedures used at SNL were similar to those used at DPG. The differences are: (1) particle mass was determined from the PS-1 filter; (2) the extract from the PS-1 sampler was analyzed by selective-ion SFC/MS as well as by the full scan GC/MS procedure used for the DPG BangBox samples; (3) the PS-1 samplers for dioxins and furans contained polyurethane foam rather than XAD-2; (4) samples for metals were collected on Teflon filters and analyzed using x-ray fluorescence; (5) individual VOC compounds from the canister analysis were not reported except for acetylene and benzene; and (6) two, [illegible] SVOC, two PS-1 dioxins/furans samples, two metals samples and five [illegible] canister samples were collected during each detonation or burn.

Table 2-1. Energetic Materials Burned and Detonated in the BangBoxes

Study	Item	Abbreviation	MEM (g)	OB Trials	OD Trials
1	TNT (block)	TNT-SNL	230		1
	TNT (block)	TNT-SNL	230		1
	TNT (block)	TNT-SNL	230		1
	Foam-suppressed TNT OD	TNT-foam	225		1
	Double-based Propellant	Dbl-base-SNL	471	1	
	MK-6 Propellant	MK-6	448	1	
2	PBXN-110	PBXN	1064	1	
	MK-23	MK-23	1030	1	
	M-43-LOVA	M-43	1060	1	
	Smokeless Powder	Smkles-pwdr	454	1	
	Smokey Sam	Smky-sam	273	1	
3	TNT (flake)	TNT-ACC1	230		3
	20 mm HEI cartridge	20 mm	189		3
	40 mm HEI cartridge	40 mm	158		3
	M18A1 Claymore mine	Claymore	229		3
	T45E7 Adapter Booster	T45E7	193		3
4	M-9 Propellant in Bags	M-9	2406	3	
	M-1 Propellant in M-3 Bag	M-1	2273	3	
5	TNT (block)	TNT-ACC2	230		1
	Detonation Train	Det. train	178		3
	M187 Impulse Cartridge	ARD-446	215		3
	BBU-36B Impulse Cartridge	BBU-36	144		3
	Gas Generator GCU-2A	GGU-2A.	139		3
	MK-107 Impulse Cartridge	MK-107	208		3
	Signal, Red Star, M-158	M-158	239		3
	Fuze, Tail Bomb, FMU-54	FMU-54	210		3

Table 2-1. Continued.

Study	Item	Abbreviation	MEM (g)	OB Trials	OD Trials
5	IR Flare, M-206	M-206	241		3
	Fuze, Tail Bomb, FMU-139	FMU-139	172		3
	Signal, Red Star, M43A2	M43A2	260		3
6	M31A1E1 Propellant	M31A1E1	2276	3	
	Double-based Propellant	Dbl-base-DPG	2227	2	
	Ammonium Perchlorate	AP	2270	2	
	Aluminized AP Propellant	Al-AP	1183	2	
7	Detonation Cord	Det cord	205		3
	Tritonal	Tritonal	235		3
	Tritonal With Wax	Tritonal-wax	235		3
	Amatol	Amatol	235		3
	Composition B	Comp B	235		3
	Composition B With Alum.	HBX	220		3
	H_2O-Suppressed Tritonal	Tritonal-H_2O	235		3
	Manufacturing Waste	AP-waste	1139	3	
	H_2O-Suppressed Amatol	Amatol-H_2O	235		3
	Diesel Fuel/Dunnage	Dunnage	913	3	

Table 2-2. Weights (grams) of Energetic Materials in Items Detonated

Item	TNT	RDX	TETRYL	PETN	Al	KNO_3	AN	NC	NG
TNT	227	2							
Tritonal	182	8			46				
Tritonal-wax	173	8			43				
Amatol	114	8					113		
Comp B	86	136							
HBX	72	111			39				
FMU-139		28	126	17					
FMU-54		28	163	18					
T45E7		28	177						
ARD-446		54		32		50		53	15
BBU-36		54		32		45		28	8
MK-107		54		32		6		87	25
Det train		108		65					
M43A2		54		32					
M-158		54		32		44			
M-206		54		32					
Claymore		229							
20 mm		79						100	10
40 mm		145						7	2
Det cord				203					
GCU-2A[a]		26		15					

[a] Energetic composition and weight classified.

Table 2-3. Weights (grams) of Energetic Materials in Items Burned

Item	RDX	AP	Al	Zn	KNO_3	NC	NG	NQ	HMX
Dbl-base-SNL						240	184		
M-1						1815			
M-9					36	1387	960		
Dbl-base-DPG						(a)	(a)		
M31A1E1						493	410	1245	
PBXN						16	1		924
M-43	775					38	2		
Smkles pwdr						435	23		
MK-6		381	1						
AP[b]		1946							
Al-AP[b]		821	226			4	0.2		
MK-23		800	20			28	2		
Smky-sam[b]		110		100		22	1		
AP-waste		738	140			4			

a Actual weights classified

b. Identity and weights of other energetic materials either classified or not available

Table 2-4. Sampling Systems Used in Each Study[a]

System	Analyte	Study 1	Study 2	Study 3	Study 4	Study 5	Study 6	Study 7
CEM	CO2	S	S	NA	NS	S	S	S
	CO	S	S	NA	NS	S	S	S
	NO/NO2	S	S	NA	NS	S	S	S
	SO2	S	S	NA	NS	S	S	S
	O3	S	S	NA	NS	S	S	S
	HCl	S	NS	S	NS	NS	S	S
Bubbler	HCl/Cl2	S	NS	NS	NS	NS	S	S
Canister	VOC	S	S	S	S	S	S	S
	CO/CO2	S	S	S	S	S	S	S
Hi-Vol	Mass	NS	NA	S	S	S	S	S
	SVOC/GCMS	NS	NA	S	S	S	S	S
	SVOC/SFCMS	S	NA	S	S	S	NA	NA
	Metals	S	NA	S	S	S	S	S
PM-10	Mass	NS	S	S	S	S	S	S
	Metals	NS	NS	S	S	S	S	S
PS-1	Mass	S	NS	NS	NS	NS	NS	NS
	SVOC/GCMS	S	NA	S	S	S	S	S
	SVOC/SFCMS	S	NS	NS	NS	NS	NS	NS
	Dioxins/Furans	S	NS	NS	NS	S	S	S
Teflon filter	Metals	S	NS	NS	NS	NS	NS	NS

a. S = sample taken; NS = no sample taken; NA = sample taken, results not valid or not available.

Chapter 3

Construction and Validation of the Database

Construction of the Raw Database

A matrix was developed to accommodate all the emission factors that could exist if every study had used the complete suite of sampling systems available. This matrix was then completed using data from each study's documentation file, e.g., test design plans, final reports, field notes, calibration data, laboratory reports, QA and QC reports, etc. Instances where data were missing were identified and the reason(s) determined. Some of these reasons were: (1) no sample collected; (2) sample collected, but no emission factor calculated because the sample was determined to be invalid; and (3) only those target compounds (analytes) actually detected were specifically identified in the final report. In this latter case, the Experimental Section of that final report listed all the target analytes and, if a target analyte was not mentioned in the Results Section of that report, then the reader was to assume that it was not detected. This latter situation was common for the VOC and SVOC analytes.

In addition to the previously reported results, previously unreported results were converted to emission factors and placed in the database, except when the analyte had not been detected in any study. There were a large number of analytes in the not detected category, e.g., 103 of the 108 Method 8270 analytes and 65% of the VOCs. **Thus, if an analyte is listed in Appendix C, but is not in the database, the user of the database can safely assume that it was never detected, or if it was detected, it was not above the concentration in the associated background sample.**

After all quantitative values had been put into the database, the matrix was filled in using the following codes: (1) NS (no sample collected); (2) ND (sample collected, but analyte either not detected or not detected above background concentration); and (3) NA (sample was supposed to have been collected, but either no results were found or result had been invalidated). The emission factors were then examined to assure that the total mass of the energetic material (MEM) detonated/burned had been used in calculating each emission factor. When this was not the case, the emission factors were recalculated using the correct MEM and the corrected emission factors were then entered into the database.

The emission factors from the seven studies had been adjusted to compensate for the concentrations of the analyte in the background sample(s) taken the day of the test, hereafter designated as (EF_{BC}). The uncorrected emission factors were not reported. Since it is helpful to know the extent to which an emission factor has been adjusted for the background concentration, the concentration of each analyte measured in each background sample was converted to the equivalent emission factor for that test (EF_B) and entered in the database. In Studies 1, 5, 6, and 7 (Table 2-1), the actual volume of gas sampled was used for this calculation. Because the original sampling volumes were not available for the other three studies, the average volume of gas collected by the sampling systems used in Studies 5, 6 and 7 was used instead.

Two additional types of emission factors were also calculated, the minimum quantitation limit (MQL) emission factors (EF_{MQL}), which are shown in Table 3-1, and the "uncorrected (for background)" emission factors (EF_{UC}). Each EF_{MQL} was calculated by entering the laboratory-determined MQL for the analyte (expressed in units of mass/m^3) into the pollutant concentration term of the emission factor equation. Each EF_{UC} was calculated by adding the average background-corrected emission factor (EF_{BC})to the associated background emission factor (EF_B).

After these additional types of emission factors were added to the database, statistical outlier tests were done to identify anomalous values. The records associated with these values were examined to determine if there was an explanation for them being identified as an anomalous value, e.g., transcription error, misspelled word, etc. Values that could not be rejected for scientifically-defendable reasons were left in the database.

After these outlier tests were completed, it was clear that most of the uncorrected Method 8270 SVOC emission factors were considerably less than the corresponding MQL emission factors. A subsequent investigation showed that in the actual test report, these SVOC emission factors were identified as qualitative or tentative in nature; thus, they were not useful in calculating quantitative emission factors. To address this situation, it was decided to change the uncorrected emission factor (EF_{UC}) and the associated background-corrected emission factor (EF_{BC}) to ND if the EF_{BC} was less than 30% of the associated MQL emission factor.

Because Hg, As, Ni and Be were never detected above background levels, they were not included in the validated database. It was also apparent that the PM-10 mass emission factors for metals were less reproducible and sometimes were larger than the corresponding Hi-Vol values. Much of this variation likely occurred because each PM-10 mass emission factor represented a single measurement whereas each Hi-Vol value represented the average of three measurements. Also, most of the uncorrected PM-10 mass emission factors were at or below the EF_{MQL}. For the above reasons, the PM-10 mass emission factors for metals were not included in the "raw database". The PM-10 emission factors themselves, however, were included, because there wasn't an alternative source for these emission factors.

At this point, the raw database contained approximately 100,000 values. However, 80% of these values were identified as either ND, NS or NA. To facilitate the validation and statistical analysis of the database using SAS , all NS and NA values were changed to "." and all ND values were changed to "0.0E+00".

Validation of the Database

Adjustment of the Emission Factors for Metals from the Floor

Bulk explosives which did not contain any metals still yielded emission factors above the MQL emission factors for: Al, Ba, Cu, Pb, Ti and Zn. These "emission factors" likely came from metals in or on the concrete floor of the BangBox, since dust from the floor was commonly found on Hi-Vol filters collected after detonations. Thus, it was decided to use the emission factors from the bulk explosives to derive the detonation-related, background emission factors for these six metals rather than use the pre-test background samples. These detonation-related, background emission factors were calculated by averaging the emission factors for the following five bulk explosives : TNT-DPG1; TNT-DPG2; Amatol; Comp B; and Det. train. These calculations yielded the following background emission factors (g analyte/g MEM): Al (7.2E-04); Ba (3.7E-04); Cu (4.8E-04); Zn (3.8E-04) and Pb (5.9E-04). The averages were then subtracted from the individual and average trial emission factors and the uncorrected emission factors to obtain the corrected emission factors.

Comparisons Between Sampling Systems

As part of the validation effort and to remove redundant data from the database, the following comparisons were done using the average emission factor for each analyte: (1) CO/CO_2 (CEM vs canister); (2) VOC (GC/FID vs GC/MS); and (3) PS-1/GCMS vs Hi-Vol GCMS vs Hi-Vol/SFCMS. These comparisons yielded the following results.

Canister vs CEM for CO and CO_2: The CEM CO emission factors are statistically equivalent to the corresponding canister values at the 95% confidence level (based on a comparison of 53 paired values). In contrast, the CEM CO_2 emission factors are on the average 5% higher than the corresponding canister emission factors (based on a comparison of 48 paired values) and the CEM mean difference is statistically different from the canister mean value at the 95% confidence level. Because the canisters were also used to measure the VOC emissions, it was decided to include the canister-derived CO and CO_2 emission factors in the validated database and to include the CEM-derived values if the canister-derived values were not available.

GC/FID vs GC/MS for VOCs: The GC/FID emission factors for (o,m,p)-xylene, are statistically equivalent to the corresponding GC/MS values, but for the seven other VOCs (measured by GC/FID and GC/MS) the emission factors are statistically different at the 95% confidence level. For 1,3-butadiene, the GC/FID mean emission factor is 66% of the GC/MS value (based on a comparison of 12 paired values), but for the other six VOCs, the GC/FID mean values are larger than the GC/MS values. The magnitudes of these mean differences are: benzene (34% larger, 51 paired values); ethylbenzene (21% larger, 38 paired values); styrene (102% larger, 19 paired values); toluene (39% larger, 38 paired values); and 1,3,5-trimethylbenzene (130% larger, 9 paired values). On an absolute basis, however, the mean differences are small, i.e., benzene (0.00002);

ethylbenzene (0.0000006); styrene (0.000002); toluene (0.000004); and 1,3,5-trimethylbenzene (0.000001). Since the GC/FID emission factors were larger than the GC/MS values for most compounds and GC/FID was also used for all the other VOC compounds, it was decided to include the GC/FID-derived emission factors in the validated database and to include the GC/MS-derived values only when the GC/FID values were not available.

PS-1/GCMS vs Hi-Vol/GCMS vs Hi-Vol/SFCMS: The PS-1 sampling system yielded non-zero emission factors for 5 of the 108 Method 8270 (non-energetic SVOC) target compounds. These compounds and the energetic materials they were associated with are: acenaphthalene (AP-waste); fluoranthene (AP-waste); phenol AP-waste); 2-chlorophenol (AP-waste) and diethylphthalate (BBU-36, FMU-139, MK-107, GGU and M-9).

(1) Phenol: The PS-1 sampler detected phenol only in the first of the two AP-waste burns; it also detected phenol in the background sample (at a concentration only slightly less than that measured in the burn sample) taken in the BangBox before this burn. The Hi-Vol/SFCMS system also detected phenol for only the first burn and the emission factor (3.8E-05) is essentially the same as that from the PS-1 sampling system (3.4E-05). The phenol emission factors for the AP-waste burn were excluded from the validated database for three reasons. First, it was a common component of background samples in the concentration levels equivalent to the emission factors calculated from the burn. Second, it was in the background sample for the surrogate waste burn. Third, phenol was not found in the samples from the second burn. The Hi-Vol/SFCMS sampling system did detect phenol in the detonation products from the following four energetic-containing items: ARD-446 (1.9E-06); MK-107 (8.4E-07); FMU-54 (4.7E-06); and 40mm (1.5E-06). These emission factors are very close to the MQL emission factor (2.9E-06), and, as noted above, phenol was a common constituent of the ambient air in the BangBox. Also, the PS-1 sampling system detected phenol in the background samples associated with these four items at levels which would have yielded emission factors of the same magnitude reported for these four items. Therefore, these latter phenol emission factors were not included in the validated database.

(2) Acenaphthalene and Fluoranthene: The Hi-Vol GC/MS sampling system yielded emission factors for only two of the 108 EPA-8270 compounds (acenaphthalene and fluoranthene) and both compounds were associated only with the AP-waste burn. These two compounds are normally released when diesel fuel and wood, two of the materials in the AP-waste material, are burned. These two compounds were also found by the corresponding PS-1 sampler. For acenaphthalene the average PS-1 emission factor was 1.0E-04 and the corresponding Hi-vol emission factor was 1.6E-04. Similarly, for fluoranthene the PS-1 emission factor was 2.0E-04 and the Hi-Vol value was 1.0E-04. Since it is highly likely that these are valid emission factors, the PS-1 derived emission factors were included in the validated database.

(3) 2-Chlorophenol: This compound was detected only by the PS-1

sampler during the two AP propellant burns conducted July 31, 1995. Both trials yielded the same emission factor (1.0E-05), a value approximately 30% of the MQL. Since 2-chlorophenol was not found in the associated background samples and it was not a common background contaminant, the 2-chlorophenol emission factors were included in the validated database.

(4) Diethylphthalate: Non-zero emission factors for diethylphthalate came only from the PS-1 sampler. They were associated with the four items which were detonated (BBU-36,MK-107,FMU-139 and GGU-2A) and one item which was burned (M-9). For the following reasons the emission factors associated with the four items detonated (BBU-36, MK-107; FMU-139, and GGU-2A) were included in the validated database. First, diethylphthalate was not detected in the background samples associated with these energetic materials. Second, the MQL emission factor (2.1E-04) associated with the four materials is less than the average emission factors reported for these materials. Third, it was found in almost all samples.

The emission factor from the single M-9 propellant burn was excluded from the validated database for the following reasons. First, the MQL for diethylphthalate is higher than the emission factor from the M-9 propellant burn. Second, although diethylphthalate was not found in the background sample associated with this burn, it was frequently found in background samples at levels tenfold greater than the M-9 emission factor.

Mass Balance Assessments for C, N, S, Cl, Al and Pb

Carbon Mass Balance

The carbon mass balance was conducted by calculating the total mass (weight) of carbon in the material (MEM) detonated or burned and comparing it to the mass of carbon found using the sum of the average emission factors for CO_2 and CO (expressed as their carbon equivalent values). Sufficient composition data was available to conduct the mass balance calculation for 23 of the materials detonated and burned. Only the detonation cord gave a % Conversion (210%) which differed by more than 18% from the value of 100% that was expected if all the carbon had been converted to CO and CO_2. The extremely high % Conversion value for the det. cord was unexpected because each of the three trials involved detonating 203 g of PETN with an electric blasting cap and because the emission factors for the three trials agreed so closely. A subsequent review of the raw data also showed that this material had an usually large difference between the CEM and canister values for both CO_2 and CO. It also showed that PETN was not detected in the emission from any of the three detonations. This was particularly unusual, because, when much lower quantities of PETN had been detonated (as part of donor charges), measurable quantities of PETN had been detected. For the above reasons all emission factors for the det. cord were excluded from the validated database.

Nitrogen Mass Balance

Although N was not measured directly in the BangBox studies, there is solid scientific evidence from detonation and burn experiments on explosives where the N_2 emissions were measured directly.[4,5,13,14] The experiments described in references 13 and 14 are particularly relevant here because they involved detonating M107, 155 mm artillery rounds (965 - 2260 kg) and burning NIKE rocket motors in a 4,100 m^3 chamber. More than 99.8% of the N in the Comp B in the M107 rounds and 99.7% of the N in the NIKE's double base propellant were converted to N_2. These low %N Conversion are particularly striking when compared to those for other CHNO-based materials. For example, the percentages of N (in the fuel) converted to NOx in utility boilers firing residual fuel oil, distillate oil and coal are: 50-60%, 60-80% and 20-25%, respectively[15,16].

The N mass balance calculations used the NO and NO_2 emission factors (expressed as N) to determine how much of the N in the energetic material was converted to nitrogen oxides. Sufficient chemical composition data was available to conduct the assessment on 25 of the materials detonated and burned. The AP-waste burn, which had a % Conversion of N to nitrogen oxides of 17%, was the only material with a % Conversion of N value greater than 6%. Since all the % Conversion of N values are reasonable based on the work of Cook[3] and Ornellas[4], all the NO and NO_2 emission factors were included in the validated database.

Chlorine Mass Balance

Percent recoveries for Cl could be calculated for five energetic materials. These materials and the associated % recoveries are: AP (85%), Al-AP (102%), MK-23 (99%), MK-6 (37%) and AP-waste (60%). Since these % Recoveries are reasonable based on the work of Ornellas[4], all HCl and Cl_2 emission factors were included in the validated database.

Sulfur Mass Balance

Four of the materials detonated contained known quantities of S. These materials and their associated % Conversion to SO_2 are: M31A1E1 (28%), HBX (5%), M43A2 (5%), and M158(1%). Because no literature references on recovery of S from detonations was found, the SO_2 emission factors were included in the validated database.

Lead Mass Balance

The two materials known to contain Pb (Dbl-SNL and Dbl-DPG) yielded % Recoveries of 37% ((Dbl-DPG) and 128% (Dbl-SNL). The reason for the low % Recovery for Dbl-DPG burn is not known. (Pb was found in the residue from this latter burn, but, the quantity in the residue was not reported.) Because Pb is one of the most likely toxic compounds potentially released from OB and OD activities, the Pb emission factors were included in the validated database.

Aluminum Mass Balance

The six materials known to contain measurable quantities of Al yielded a wide range of % Recoveries. These materials and the associated % Recoveries are: tritonal (6%), tritonal-wax (9%), HBX (5%), Al-AP (7%), AP-waste (29%) and MK-6 (60%). Although Al was found in the residue from the three burns and observed on the floor of the BangBox for the three detonations, the actual amount was never determined. Because Ornellas[4] also reported low recoveries for Al, all the Al emission factors were included in the validated database.

Energetic Material Mass Balance

The database contained non-zero emission factors for only four of the original energetic compounds: NG, HMX, RDX and PETN; all were associated with detonations. The other target energetics (including TETRYL and TNT) were never detected. However, it should be noted that sampling results for energetics were only available for the energetic materials detonated and burned in Studies 1,3,4 and 5. Air samples for energetics were also taken in Studies 6 and 7, but the samples were not analyzed because the SFC/MS unit was broken and it was not repaired until six months after the samples had been extracted. (The analytical method specified that the extract must be analyzed within 60 days after extraction). Thus, it is possible that additional energetic emission factors would have resulted had these latter samples been analyzed.

NG was associated only with detonations of energetic materials which did not contain NG and it was found in the background samples associated with these detonations. Therefore, the NG emission factors were not included in the validated database.

The PETN and RDX emission factors were included in the validated database, because they were associated only with detonations in which materials containing these energetics were used to initiate the detonation.

The emission factors for HMX were included in the validated database because: (1) the HMX was consistently detected only when RDX was also detected in the emission products; (2) military grades of RDX contain between 4 to 15% HMX by weight; and (3) with one exception, the HMX emission factors were 3 to 24% of the corresponding RDX emission factor.

Validation of Chlorinated Dioxins and Furans Results

The validation of the dioxin and furan data was difficult because of the excellent MQL_{EF} (E-10 to E-11) and the ubiquitous nature of these compounds in all environmental media[17]. Dioxin and furan samples were collected during four burns (AP propellant, aluminized AP propellant, AP-waste and diesel fuel and dunnage) and after the detonations of the M-158, M43A2 and M-206 flares.

Furans were detected only in the emissions from the AP waste burn. The five isomers (octochlorinated dibenzo-p-furan (OCDF), 1234678 HpCDF, 1234789 HpCDF, 123478 HxCDF and 123678 HxCDF) were detected at levels 100 to 1,000 times larger than the MQL emission factor (2.6E-11) and therefore, were included in the validated database. No total furan values (e.g., total HxCDF) were reported.

Octochlorinated dibenzo-p-dioxin (OCDD) was detected in the emissions from the detonation of the M43A2 flare and the burning of the diesel fuel and dunnage surrogate. The OCDD emission factor for the M43A2 was included in the validated database, because: (1) it was not found in the background sample; and (2) was found at levels 4 to 10 times larger than the EF_{MQL} (2.1E-10) for the three trials (detonations).

The OCDD emission factor for the dunnage burn was not included because: (1) it was found for only one of the three trials; (2) the background emission factor accounted for 70% of the corrected emission factor; and (3) the uncorrected emission factor was only 30% larger than the MQL emission factor (2.1E-10). A total HpCDD emission factor was also reported for the M43A2 detonation. It was included in the validated database, because it was found in each of the three trials (detonations) at levels which were 1.3, 2.5 and 5 times the EF_{MQL} (2.1E-10). No other dioxins were reported for any of the items tested.

Table 3-1. Representative MQL Emission Factors (kg.analyte/kg MEM)

Analyte	MQL for Detonations	MQL for Burns
HCl	9.2E-05	1.2E-05
Cl_2	4.6E-05	6.0E-06
CO_2	4.3E-07	5.5E-08
CO	4.3E-07	5.5E-08
NO	3.1E-05	3.9E-06
NO_2	4.7E-05	6.0E-06
SO_2	2.2E-05	2.8E-06
SVOCs	2.0E-04	2.6E-05
Dioxins & Furans	2.0E-10	2.6E-11
RDX, PETN & HMX	2.9E-07	3.7E-08
VOCs	4.3E-07	5.5E-08
Al	2.7E-04	3.5E-05
Sb & Ba	6.7E-04	8.6E-05
Cd	3.9E-05	4.9E-06
Cu	8.7E-05	1.1E-05
Pb	3.6E-04	4.6E-05
Ti	1.1E-05	1.4E-06
Zn	9.0E-04	1.2E-05

Chapter 4
Overview of the Validated Database

Appendices D and E contain printouts of the BangBox-derived emission factor databases for burns and detonations, respectively. These emission factors apply to the disposal of energetic materials through OB in a pan and through unconfined, surface detonations (OD) with the following exceptions: dunnage burn; AP-manufacturing waste burn; gas generator detonation; and water-suppressed tritonal and amatol detonations. The reasons these latter materials were designated as exceptions is discussed below.

The validated database contains emission factors for 83 analytes: 7 inorganic gases; total nonmethane hydrocarbons (TNMHC); total unidentified hydrocarbons; 22 unsaturated hydrocarbons (including a total unsaturated hydrocarbons); 16 saturated hydrocarbons (including total unsaturated hydrocarbons); 10 aromatics (including total aromatics); 8 chlorinated hydrocarbons; 8 metals; 5 chlorinated furans; 1 chlorinated dioxin; 4 non-energetics SVOCs; and 3 energetic SVOCs. Most of the analytes are nonhazardous compounds commonly found in ambient air. If an analyte is listed in Appendix C, but is not in the database, the user of the database can safely assume that it was never detected, or if it was detected, it was not above the concentration in the associated background sample.

The many similarities between the emission products from detonations and burns reported earlier[7,8] are also present in the expanded database. For example, ethane, propane and isobutane were associated with almost every energetic material tested and their emission factors were usually much greater than those for the other saturated hydrocarbons. Also, almost every energetic material tested released ethylene, propene and acetylene and these three compounds represented a very substantial part of the emission factor for total unsaturated compounds.

Chapter 5
Discussion of Results from Unsuppressed Detonations

The materials detonated in the BangBoxes without water suppression, were placed into two categories: BangBox bulk explosives and BangBox assembled (encapsulated) explosives, e.g., fuzes, flares and impulse cartridges. A third category (DPG field bulk explosives) was also created using the emission factors from the 900-kg surface detonations (TNT-Phase A, TNT-Phase B, TNT-Phase C, Comp B, Explosive D and PBXN) and the 900-kg suspended detonations conducted at DPG in 1989 and 1990.[8] The mean emission factors and associated standard deviations were then calculated for the following analytes within each category (if the data were available): total saturated hydrocarbons; ethylene, propene, acetylene, and (total of) other unsaturated hydrocarbons; benzene, toluene and (total of)other aromatics; and PM-10 (Table 5.1). The mean %C and %N converted to the corresponding oxides (COx, NOx) and the ratios $\%CO/CO_2$ and $\%NO/NO_2$ and the associated standard deviations were also calculated (Table 5.2).

These analytes were selected because they are found in the emissions from most of the materials detonated. Emission factors for individual saturated hydrocarbon compounds, such as ethane, propane and butane, were excluded for two reasons. First, these compounds are environmentally benign. Second, the background concentrations of these saturated hydrocarbons averaged approximately 50 percent of the concentrations found in the samples collected after the detonations (compared to average values of 10% and 30% for the unsaturated hydrocarbons and aromatic hydrocarbons, respectively.

The means were then subjected to a Student's t-test to determine if the means for the same ratio or analyte were statistically the same across at least two of the three categories. These t-tests determined that the means were statistically equivalent across all three categories for %C Converted to COx; %CO/COx and PM-10 mass and therefore the individual values could be combined to create larger data sets (Table 5.3).

No other means were equivalent. However, because the absolute differences between the mean values for the %N Converted to NOx were small across the three categories, the individual values were ranked from highest to lowest to see if they were sufficiently intermixed across the three data sets to justify combining them into one large data set. For this exercise, the BangBox bulk detonations, the DPG field detonations, and the BangBox encapsulated detonations were designated by the numbers 1, 2 and 3, respectively.

This ranking exercise, which is shown below, demonstrated that for all practical purposes, there is sufficient overlap of values across the three categories to rationalize combining them (Table 5.3).

%N as NOx: 3, 1, 3, 3, 3, 1, 1, 3, 1, 3, 3, 3, 1, 2, 1, 1, 2, 2, 1, 2, 2, 2, 2, 2

As shown below, a similar ranking exercise performed on the %NO/NOx ratios also yielded results which justified combining the three data sets into one large data set (Table 5.3).

%NO/NOx: 1, 1, 1, 1, 1, 3, 1, 3, 3, 3, 3, 3, 2, 2, 3, 3, 2, 2, 2, 2, 1, 2, 2, 3, 3.

Users of the database who are estimating the emissions from a variety of energetic materials should consider using the data in Table 5.3 rather than the average CO_2, CO, NO and NO_2 emission factors in the validated database. Users should also assume that BangBox-derived PM-10 mass emission factors will likely underestimate the PM-10 emissions from detonations, since they do not include the soil particles that are entrained in the plume by the surface detonations.

On the other hand, the differences between the means for the organic analytes were too large to rationalize combining them into larger data sets. The means in Table 5.1 are normalized to the mass of the energetic material (MEM) detonated, but for some applications, having the emission factors normalized to the carbon content of the material detonated might be more appropriate. Users who need the organic analytes normalized to the carbon content of the material detonated will find this information in Table 5.4.

Other VOC Compounds

Other than benzene and toluene, styrene, a common air pollutant, was the only other aromatic found at high levels. It was found after the detonation of the Claymore mines (average emission factor of 1.7E-03) and the T-45E7 adapter boosters (average emission factor of 1.2E-04). These emission factors are likely valid, because both materials contained polystyrene (the casing of the Claymore mine contained 150g and the T45E7 contained a 31g polystyrene plug).

Sulfur and Aluminum

The low and variable recoveries for S and Al should be investigated further. It is possible that the S was converted to compounds, such as SO_3, H_2SO_4, H_2S, metallic sulfates or even free $S(S_8)$; none of which were target analytes. The low recovery of Al may be completely, or at least partly, explained by the silvery-gray residue observed on the floor after each detonation of an Al-containing material. Unfortunately, the identity and mass of this residue was never determined. However, Ornellas[4] also reported low recoveries of Al for some materials. Until the reasons for the low recoveries are determined, it would be prudent to assume that all the Al (and any other metal in the explosive detonated) is released to the environment.

Method 8270 Compounds (SVOCs)

Diethylphthalate was the only Method 8270 compound found in the detonation samples and it was associated with items which were either known to contain phthalates or were likely to contain them. Consistent with detonation theory, no SVOC's attributable to molecular rearrangement reactions of the energetic molecule were found.

Dioxins and Furans

Furans were not detected, despite the extremely sensitive sampling and analysis method employed (MQL emission factor of 2.0E-10). One dioxin, OCDD (octochlorinated dibenzo-p-dioxin) was found (average emission factor of 1.8E-09) in the samples from the detonation of the M43A2 flare and likely resulted from the reaction of the chloride-containing compound(s) and the plastic materials in the flare.

Residual Energetics

The presence of HMX, RDX and PETN in some of the air samples collected after detonations is expected, because detonations are usually not 100.0% efficient. However, it must be noted that for most of these detonations, the ratio of the donor charge mass to the total mass (MEM) detonated was two to four times greater than that used in a routine OD activities. The emission factors in the validated database are calculated based on the total MEM detonated, rather than the actual mass of PETN and RDX used. Table 5.5 compares these original emission factors to those which result when the actual mass of PETN and RDX detonated is used to calculate the emission factors.

As noted in Chapter 3, HMX is an accepted contaminant in RDX; military-grade RDX contains between 4 to 15% HMX by weight. If the percentage of HMX in the RDX being used is known, one should consider using an emission factor for HMX derived by multiplying the RDX emission factor by the percentage of HMX in the RDX rather than using the values in the database.

Table 5.1 Mean Emission Factors (kg Analyte/kg MEM) for Selected Analytes for Detonations

Analyte	Category	MEM (kg)	No. Of Values	Mean	Std. Dev.
PM-10	BB, Encapsulated	0.2	12	0.30	0.26
	BB, Bulk	0.2	8	0.13	0.13
Total Saturated HC	BB, Encapsulated	0.2	11	55E-06	59E-06
	BB, Bulk	0.2	7	11E-06	11E-06
Ethylene	BB, Encapsulated	0.2	11	256E-06	132E-06
	BB, Bulk	0.2	8	69E-06	130E-06
Propene	BB, Encapsulated	0.2	11	50E-06	40E-06
	BB, Bulk	0.2	8	14E-06	24E-06
Acetylene	BB, Encapsulated	0.2	11	300E-06	171E-06
	BB, Bulk	0.2	8	56E-06	70E-06
Other Unsaturated HC	BB, Encapsulated	0.2	11	61E-06	NM
	BB, Bulk	0.2	8	11E-06	NM
Benzene	BB, Encapsulated	0.2	11	69E-06	41E-06
	BB, Bulk	0.2	8	9E-06	9E-06
	Field, Bulk	900	6	69E-06	37E-06
Toluene	BB, Encapsulated	0.2	11	26E-06	12E-06
	BB, Bulk	0.2	8	4E-06	2E-06
Other Aromatics	BB, Encapsulated	0.2	11	42E-06	NM
	BB, Bulk	0.2	8	10E-06	NM

Table 5.2 % Recoveries of C and N as the Oxides for Detonations

Parameter	Category	MEM (kg)	No. Of Values	Mean	Std. Dev.
%C as COx	BB, Encapsulated	0.2	5	100%	10%
	BB, Bulk	0.2	9	102%	10%
	Field, Bulk	900	8	96%	2%
%CO/COx	BB, Encapsulated	0.2	13	6.6%	16%
	BB, Bulk	0.2	9	0.6%	4%
	Field, Bulk	900	8	3.4%	2.0%
%N as NOx	BB, Encapsulated	0.2	8	2.9%	2.0%
	BB, Bulk	0.2	8	1.9%	1.4%
	Field, Bulk	900	8	0.6%	0.3%
%NO/NOx	BB, Encapsulated	0.2	9	69%	20%
	BB, Bulk	0.2	8	92%	18%
	Field, Bulk	900	8	55%	8.1%

Table 5.3 Emission Factor Averages Across Categories for Detonations

Parameter	No. Of Values	Median	Mean	Std. Dev.
%C as COx	22	98.55	99.6%	8.4%
%CO/COx	30	1.60%	3.96%	11.1%
%N as NOx	24	1.20%	1.78%	1.57%
%NO / NOx	25	66.0%	71.0%	22.3%
PM-10	20	0.21	0.230	0.180

Table 5.4 Mean Emission Factors (kg Analyte/kg C in Energetic) for Selected Analytes for Detonations

Analyte	Category	No. Of Values	Mean
Total Saturated HC	BB, Encapsulated	5	117E-06
	BB, Bulk	8	14E-06
Ethylene	BB, Encapsulated	5	1302E-06
	BB, Bulk	8	239E-06
Propene	BB, Encapsulated	5	209E-06
	BB, Bulk	8	47E-06
Acetylene	BB, Encapsulated	5	1267E-06
	BB, Bulk	8	187E-06
Other Unsaturated HC	BB, Encapsulated	5	6700E-06
	BB, Bulk	8	38E-06
Benzene	BB, Encapsulated	5	231E-06
	BB, Bulk	8	32E-06
	Field, Bulk	6	244E-06
Toluene	BB, Encapsulated	5	95E-06
	BB, Bulk	8	12E-06
Other Aromatics	BB, Encapsulated	5	137E-06
	BB, Bulk	8	33E-06

Table 5.5 Original and Adjusted Emission Factors for PETN and RDX

	PETN Emission Factors		RDX Emission Factors	
	Original	Adjusted	Original	Adjusted
FMU-139	1.7E-05	1.7E-04	3.4E-04	2.1E-03
FMU-54	9.6E-06	1.1E-04	9.0E-05	6.4E-04
T45E7	PETN Not Used	PETN Not Used	2.4E-04	1.6E-03
ARD-446	0	0	8.4E-04	3.3E-03
BBU-36	5.8E-04	2.6E-03	0	0
MK-107	5.1E-05	3.4E-03	0	0
Det. Train	5.6E-04	1.5E-03	7.4E-03	1.2E-02
M43A2	1.2E-05	1.5E-03	1.9E-04	9.1E-04
M-158	8.4E-06	6.2E-05	5.5E-05	2.4E-04
M-206	1.6E-06	1.0E-05	6.0E-05	2.5E-04
GGU-2A	4.9E-05	4.5E-04	1.4E-04	7.4E-04
Claymore	PETN Not Used	PETN Not Used	9.9E-06	1.0E-05
20-mm	PETN Not Used	PETN Not Used	1.2E-05	2.7E-05
40-mm	PETN Not Used	PETN Not Used	3.7E-05	4.0E-05
Number of Values	10	10	14	14
Median	1.45E-05	2.55E-04	1.7E-04	7.4E-04
Mean	1.28E-04	6.74E-04	6.84E-04	1.61E-03
Standard dev.	2.33E-04	8.87E-04	1.94E-03	3.14E-03

Chapter 6
Results for Water-Suppressed Detonations

Tables 6.1 and 6.2 compare the emission factors derived from the water-suppressed detonations of amatol and tritonal to those derived from the unsuppressed detonations of these materials. The suppressed detonations were done primarily to assess in a robust manner the impact that detonating oxygen balanced (amatol) and severely oxygen-deficient (tritonal) explosives under a soil or water-blanket cover might have on the emissions. Amatol, an oxygen balanced explosive comprised of a mixture of TNT and AN, contains sufficient oxygen to convert its C and H to CO_2 and H_2O, whereas tritonal contains only 20% of the oxygen required. The water quenched the fireball (afterburn) required by the tritonal to convert its C, N and H to COx, NOx, and H_2O.

These experiments were also done to provide some robust emission factors for a blast and noise suppression technology developed in the U.S.[9], but refined in Europe[10,11] and South Africa[12]. This technology involves detonating munitions in contact with plastic bags containing water. This technology reduces the blast noise by more than 90% when compared to an equivalent unrestricted detonation[11]. However, the water also quenches the fireball which, based on the amount of sooty particulate found after the detonation, reduces the overall destruction efficiency of the detonation process.

The data in Tables 6.1 and 6.2 are consistent with the results from Ornellas.[4,5] That is, quenching the afterburn significantly increases the emissions of incompletely-oxidized species such as soot and the hydrocarbons, and sharply decreases the emissions of CO_2. The results also are in general agreement with detonation theory.[3,4,5] For example, the increase in hydrocarbons is limited to molecules which are smaller than the starting energetic molecules (Table 6.2), i.e., rearrangement into larger molecules did not occur.

The decrease in the CO_2 and increase in the CO and hydrocarbon emissions for the water-suppressed detonation of amatol (an oxygen-balanced energetic) may seem surprising, but conforms to detonation theory. That is, the oxygen balance in amatol is achieved by mixing a strong oxidizer (AN) with the oxygen-deficient TNT. Thus, for the optimum energy release from amatol, the oxidant and reductant radicals formed behind the shock wave must diffuse between two molecules in order to react with each other. In contrast, when the redox reaction occurs within the same molecule, the affect of fireball-suppression on the emissions is less severe.

The results show that placing an oxygen source in contact with the explosive molecule will not ensure an efficient detonation when it is conducted under a soil or water blanket cover. Unfortunately, there is no information on the TNT emissions which might have resulted from the water suppressed detonations, because the air samples collected for the energetic analytes were not analyzed (SFC/MS unit was broken).

Table 6.1. Comparison of Emission Factors for Unsuppressed and Water-Suppressed Detonations of Tritonal and Amatol.

Analyte	Tritonal-H_2O (T-H_2O)	Tritonal (T)	(T-H_2O)/(T)	Amatol-H_2O (A-H_2O)	Amatol (A)	(A-H_2O)/(A)
CO_2	0.28	1.2	0.23	0.3	0.7	0.43
CO	2700E-04	29E-04	93	2.3E-04	97E-04	0.24
NO	40E-04	59E-04	0.68	77E-04	180E-04	0.43
NO_2	2.7E-04	0.3E-04	9	2.4E-04	1.2E-04	2
Ethane	120E-06	0.4E-06	300	1100E-06	4.1E-06	268
Propane	55E-06	0.7E-06	78	190E-06	0.1E-06	1900
Butane	15E-06	0.3E-06	50	52E-06	0.6E-06	87
Other Saturated HC	30E-06	8E-06	4	158E-06	135E-06	1
Ethylene	1100E-06	25E-06	44	980E-06	31E-06	32
Propene	160E-06	5E-06	32	360E-06	5.5E-06	65
Acetylene	4400E-06	43E-06	102	140E-06	1.0E-06	140
Other Unsaturated HC	240E-06	87E-06	6	20E-06	103E-06	5
Benzene	200E-06	1.5E-06	133	270E-06	23E-06	12
Toluene	73E-06	1.8E-06	40	120E-06	6.7E-06	18
Other Aromatics	87E-06	11E-06	8	0.0E+00	13E-06	NM

Table 6.2. Distribution of C and N Across Selected Analyte Classes for Tritonal and Amatol Detonations

Analyte Class	Tritonal-H_2O	Tritonal	Amatol-H_2O	Amatol
%C as COx	65%	106%	98%	104%
%CO/COx	49%	0.2%	0.07%	1.3%
%N as NOx	2.7%	0.95	2.2%	5.0%
%NO/NOx	94%	99%	97%	99%
%(E+P+B)/Total Saturated HC[a]	86%	14%	100%	30%
%(E+P+A)/Total Unsaturated HC[b]	96%	46%	99%	27%
%(B+T)/Total Aromatics[c]	76%	24%	100%	55%

a. (Ethane + propane + butane) emission factors/total saturated HC emission factor.

b. (Ethylene + propene + acetylene) emission factors/total unsaturated HC emission factor.

c. (Benzene + toluene)/total aromatic HC emission factor.

Chapter 7
Discussion of Results from Burns

AP-Waste Burn Results

This surrogate waste was supposed to simulate the mix of AP-contaminated plastic gloves, cotton rags, Kimwipes, wood towel rods and similar materials that result from the clean-up of the vessels used to manufacture AP-based propellants. These materials are usually disposed of by open burning in pans or by incineration. The original plan was to bring an actual AP-based manufacturing waste to DPG for the experiment, however, this was prohibited because DPG did not have a permit for destroying this type of waste. In hindsight, the surrogate waste burned was not truly representative of a real manufacturing waste. The chemical composition was appropriate, i.e., 65% aluminized AP (69% AP, 19% aluminum), 20% plastic material (polyethylene gloves), 11% paper/wood/cloth and 4% diesel fuel; the problem lies with the manner in which the propellant was placed in contact with the combustible materials. That is, 1-in. cubes randomly dispersed on top of the combustible materials. In an actual waste, the propellant would be dispersed on the combustible materials as a fine powder.

Also, because the first burn resulted in a hole in the bottom of the pan, the second and third burns were done with the surrogate waste sitting on top of a 7.6 cm layer of pea gravel. At the completion of each of these last two burns, holes were found in the side of the burn pan, and melted plastic was found in the pea gravel. Approximately 110g of ash remained in the burn pan after the first burn, 40g of ash after the second burn and 65g of ash after the third burn. It was difficult to determine the weight of ash remaining when the pea gravel was used. The weight of waste surrogate burned in the three trials was 1,139g, including the 4g of Hercules Unique Smokeless Powder used to initiate each burn.

The unique mix of emission products, the melted plastic and the 17% conversion of N to NOx observed for the surrogate AP-manufacturing waste demonstrates that this burn was very different from all other burns which involved energetic materials. Most of the emission factors for chlorinated VOC's, those for the five furans, and two of those for the SVOCs are associated only with this material. There were also notable quantities of diesel-fuel-related VOCs in the emissions.

These results are consistent with a combination deflagration (AP) and incineration type burn (melting of polyvinyl gloves and charring of the wood dowel sticks by the heat released from the deflagration). This environment would have provided the conditions which favor the formation of SVOCs and dioxins and furans. These conditions are[17]: low temperature (250-400°C), long residence time (seconds), presence of Cl and organic materials and a metal that could serve as a catalyst. Additional work should be done on this type of material.

Dunnage Burn Results

The dunnage burn is unique in that it did not involve any energetic-containing materials. Not surprising, almost all of the emission factors in the database for C_7 and higher saturated hydrocarbons are associated with the diesel fuel used in this burn and the AP-waste burn. These emission factors could be useful for predicting the VOC emissions from diesel fuel-initiated or supported burns of energetic-containing materials.

Smokey Sam Burn Results

The smokey sam is an HC-type obscurant (Chemical Agent, Group B Class). Its energetic composition is: 110.0g AP, 100.2g Zn, 30g hydroxyl-terminated polybutadiene and 7.5g dioctyl adipate. It was the only encapsulated propelling material burned in the BangBox. In use, its purpose is to provide a screening smoke of $ZnCl_2$ particles. The burn was very dirty; the BangBox airlock was filled with a pungent, noxious odor and the BangBox test chamber was filled with a dense fog. In comparison to the other AP-based propellant burns, its CO emissions were very high (17%) relative to its CO_2 emissions. Although the emission factors are included in the database, this item is sufficiently unique to justify not using it to calculate summary statistics for bulk propellants.

Discussion of Results for Other Energetic Materials

The other materials burned in the BangBoxes were placed into two categories: BangBox organic-based propellants and BangBox AP-based propellants. A third category (DPG field organic-based propellants) was also created using the emission factors from the 2000-3100 kg propellant burns conducted at DPG in 1989 and 1990.[8] The mean emission factors and associated standard deviations were then calculated for the following analytes within each category (if the data were available): total saturated hydrocarbons; ethylene; propene; acetylene; (total of) other unsaturated hydrocarbons; benzene; toluene; (total of) other aromatics; and PM - 10 (Table 7.1). The mean %C and %N converted to the corresponding oxides (COx, NOx) and the ratios $\%CO/CO_2$ and $\%NO/NO_2$ and the associated standard deviations were also calculated (Table 7.2).

The means were then subjected to a Student's t-test to determine if the means for the same ratio or analyte were statistically the same across at least two of the three categories. These t-tests determined that the means were statistically equivalent across all three categories for %C Converted to COx, %CO/COx, %N Converted to NOx, %NO/NOx and PM-10 mass, and, therefore the individual values could be combined to create larger data sets (Table 7.3).

Users of the database should consider using the data in Table 7.3 rather than the average CO_2, CO, NO and NO_2 emission factors in the validated database. Also, in contrast to the detonation PM-10 data, the BangBox-derived PM-10 mass emission factors likely provide reasonable estimates of the emissions from the open burning of propellants.

Analogous to the detonation data, the differences between the means for the organic analytes are too large to permit combining them into larger data sets. The means in Table 7.1 are normalized to the mass of the energetic material (MEM) burned. While it would be desirable for some applications to have these emission factors normalized to the carbon content of the material burned, this could not be done because the information necessary to do the calculations was available for too few materials.

Other VOC Compounds

No other VOC compounds were found at notable levels for the bulk propellant burns. This is consistent with the theory of propellant burns.[4,5]

HCl and Cl_2

The mean, median and standard deviation of the mean % Recoveries for the five Cl-containing materials burned in the BangBox are: 68%, 73% and 32.8%, respectively. For the four materials for which both HCl and Cl_2 values were available, at least 98% of the Cl was found as HCl, regardless of the amount of total Cl recovered. These results are similar to those obtained by Ornellas for AP-based explosive materials.[5] At this time, it would be prudent to assume that all the Cl in an AP-based propellant will be released to the environment as HCl.

Lead and Aluminum

The low and variable recoveries for Pb and Al were not expected and should be investigated further. It is possible that some of the Pb is converted to a chemical form which is not collected by a quartz fiber filter. Until the reasons for the low recoveries are determined, it would be prudent to assume that all the Pb and Al not accounted for in the ash, was released to the environment.

Method 8270 Compounds (SVOCs)

No Method 8270 SVOC compounds were found for the bulk propellant burns. This is consistent with detonation theory.

Dioxins and Furans

Dioxins and furans were not detected, despite the extremely sensitive sampling and analysis method employed (MQL emission factor of 2.6E-11).

Residual Energetics

No residual energetics were detected for any of the bulk propellant burns. However, as mentioned earlier, the air samples collected for energetic analyses in the last two studies were not be analyzed because the SFC/MS unit was broken.

Table 7.1. Mean Emission Factors (kg Analyte/kg MEM) for Selected Burn Analytes

Analyte	Category	MEM (kg)	No. Of Values	Mean	Std.. Dev.
PM-10	BB, AP-Based	0.2	4	0.15	0.19
	BB, Organic-Based	0.2	7	0.28	0.36
Total Saturated HC	BB, AP-Based	0.2	4	0.0E+00	NM
	BB, Organic-Based	0.2	7	4.7E-06	9.7E-06
Ethylene	BB, AP-Based	0.2	4	0.0E+00	NM
	BB, Organic-Based	0.2	7	3.7E-06	3.5E-06
Propene	BB, AP-Based	0.2	4	0.0E+00	NM
	BB, Organic-Based	0.2	7	1.0E-06	1.1E-06
Acetylene	BB, AP-Based	0.2	4	9.0E-06	9.0E-06
	BB, Organic-Based	0.2	7	4.6E-06	5.0E-06
Other Unsaturated HC	BB, AP-Based	0.2	4	26E-06	NM
	BB, Organic-Based	0.2	7	3E-06	NM
Benzene	BB, AP-Based	0.2	4	1.5E-06	[illegible]
	BB, Organic-Based	0.2	7	3.0E-06	[illegible]
Toluene	BB, AP-Based	0.2	3	0.0E+00	NM
	BB, Organic-Based	0.2	7	0.8E-06	1.0E-06
Other Aromatics	BB, AP-Based	0.2	4	0.0E+00	NM
	BB, Organic-Based	0.2	7	8E-06	NM

NC = not calculable

Table 7.2. % Conversion of C and N to the Oxides from Burns

Parameter	Category	MEM (kg)	No. Of Values	Mean	Std. Dev.
%C as COx	BB, AP-Based	02	4	99%	14%
	BB, Organic-Based	0.2	3	91%	8%
	Field, Organic-Based	3200	3	100%	2%
%CO/COx	BB, AP-Based	0.2	4	0.55%	0.32%
	BB, Organic-Based	0.2	7	0.27%	0.37%
	Field, Organic-Based	3200	3	0.007%	0.01%
%N as NOx	BB, AP-Based	0.2	2	1.8%	1.0%
	BB, Organic-Based	0.2	4	0.5%	0.4%
	Field, Organic-Based	3200	3	0.9%	0.4%
%NO/NOx	BB, AP-Based	0.2	3	75%	16%
	BB, Organic-Based	0.2	4	72%	46%
	Field, Organic-Based	3200	3	75%	6%

Table 7.3. Emission Factor Averages Across Categories for Burns

Parameter	No of Values	Median	Mean	Std. Dev
%C as COx	10	98.5%	95.0%	9.87%
%CO/COx	14	0.20%	0.300%	0.366%
%N as NOx	9	0.90%	0.89%	0.74%
%NO/NOx	10	77.0%	73.9%	25.6%
PM-10	10	0.019	0.233	0.300

Chapter 8
Suggestions For Using the Database

Detonation Emission Factors

Rather than using all the emission factors, user's of the database should consider using the means and medians in Tables 5.1, 5.3 and 5.4 as the starting point for predicting the emissions from OD-based processes and adjust the data for their own situation using commonly accepted information on detonation theory and processes, such as that presented in Chapter 1 and the information presented in Chapters 5 and 6 of this document.

For example, a database user attempting to estimate the emissions at a facility which surface-detonated a wide variety of bulk and assembled energetic-containing materials, could calculate an average emission factor for each analyte which covers both bulk and encapsulated energetic materials. On the other hand, if the detonations are to be conducted under a soil cover, one should consider the likelihood that the fireball will be suppressed and use either the data in Tables 6.1 and 6.2 or select the uppermost part of the ranges for %CO/COx and hydrocarbons species in Tables 5.3 and 5.4.

Unfortunately, if the energetic contains Pb or Al, at this time, one has to assume that all the Pb and Al is released to the atmosphere. More research is needed on these release of these and other metals from OD activities. The low and variable % recoveries for Cl and S observed in all the studies also needs to be studied further to more fully characterize the environmental safety of OD practices. At this time, one has to assume that all the metals, S and Cl enter the environment and attempt to estimate how they will disperse in the environment.

The most difficult emissions to estimate are those for PM-10 and undegraded energetic starting materials. It would be reasonable to assume that the PM-10 emission factors in Table 5.1 and 5.3 underestimate the PM-10 emissions for a surface detonation, but how low is the estimate? Also, if the mass of the energetic being detonated is small and the ratio "donor charge to total energetic mass," is large, one can assume that some amount of undegraded energetic will be released to the environment. But again, how much?

Open Burning Emission Factors

Users should apply the data in Tables 7.1, 7.2 and 7.3 and the other information presented in Chapter 7 in a manner analogous to that recommended above for the detonation emission factors, e.g., one has to assume that all Pb, Al Cl and S in the energetic material being burned will be released to the environment, except for whatever was recovered in the burn pan ash. However, for burns, one can assume that undegraded energetic emissions would be low and that the PM-10 emission factors in Tables 7.1 and 7.3 are reasonable estimates of the PM-10 emissions expected.

Chapter 9
Recommendations for Future Work

The low and variable % recoveries for metals and for Cl and S observed in all studies reviewed needs to be determined to more fully characterize the environmental safety of OB and OD practices. At this time, one has to assume that all the metals, S and Cl enter the environment.

All emission products studies to date have used relatively clean energetic materials. Recovered high and low explosives should be burned and detonated in chambers to confirm the representativeness of these earlier studies.

Existing knowledge on the affect that accelerators and retardants have on the rate of energetic processes should be applied to OB and OD technologies to see if the environmental safety of OB and OD can be improved further.

Buried detonations should be avoided until the impact that burial and partial confinement have on the emission is established through rigorous research testing. Computer simulations using computational fluid dynamic techniques followed by experimental confirmation should be an integral part of these studies, because of the large number of factors which could affect the emissions. Other noise suppression techniques which do not inhibit the formation of the fireball, such as detonating in chambers, should also be developed and evaluated.

References

1. Title 40, Code of Federal Regulations, Part 264, Subpart X, Miscellaneous Units.

2. Military Explosives. Chapter 3 in Department of the Army Technical Manual TM 9-1300-214. Headquarters, Department of the Army, September 1984.

3. M. A. Cook and G. Thompson, "Chemical Explosives - Rocket Propellants". Chapter 19 in Riegel's Handbook of Industrial Chemistry, Seventh Edition. J.A. Kent, Editor. Van Nostrand Reinhold Co., NY, NY. 1974 (pp 570-595).

4. D.L. Ornellas, "Calorimetric Determinations of the Heat and Products of Detonation for Explosives; October 1961 to April 1982." Lawrence Livermore Laboratory Publication No. UCRL-52821, University of California, Livermore, CA 94550 (April 1982). Available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield VA 22161.

5. R. R. McGuire and D. L. Ornellas, "Detonation Chemistry: Diffusion Control in Non-Ideal Explosions." Propellants and Explosives, 4, 23-26, 1979.

6. M. Johnson, "Development of Methodology and Techniques for Identifying and Quantifying Products from Open Burning and Open Detonation Thermal Treatment Methods - Proceedings of the Technical Steering Committee Symposium (July 6-8,1988)." U.S. Army, AMMCOM, Rock Island, IL 61299-6000, August 1991.

7. M. Johnson, "Development of Methodology and Techniques for Identifying and Quantifying Products from Open Burning and Open Detonation Thermal Treatment Methods - Bang Box Test Series, Volume 1 (Test Summary)."U.S. Army, AMMCOM, Rock Island, IL 61299-6000, January 1992.

8. M. Johnson, "Development of Methodology and Techniques for Identifying and Quantifying Products from Open Burning and Open Detonation Thermal Treatment Methods - Field Test Series A, B and C, Volume 1 (Test Summary)." U.S. Army, AMMCOM, Rock Island, IL 61299-6000, January 1992.

9. W.A. Keenan and P.C. Wager, "Mitigation of Confined Explosive Effects by Placing Water in Proximity of Explosives." In Proceedings of the 25th U.S. Department of Defense Explosive Safety Seminar, Anaheim, CA, August 1992, pp. 311-339.

10. S.H. Salter and J.H. Parkes "The Use of Water-filled bags to reduce the effects of explosives." In Proceedings of the 27th U.S. Department of Defense Explosive Safety Seminar, Miami, FL, August, 1994.

11. A.E.A. Wilkinson and P. Goddard, "Explosive ordnance engineering at the Defence Test and Evaluation Organization's Shoeburyness facility in the UK." Paper presented at the 1995 COPEX Conference, Washington, D.C., May 1995

12. G. Barrett, "The Use of Water in the Mitigation of Explosives." Realtor, October 1988, pp 51-52.

13. Summary Report for 1997 on the Emissions Released from the Detonation of M107, 155 mm Artillery Rounds in the NTS (Nevada Test Site) Tunnels, in Preparation.

14. Summary Report for 1997 on the Emissions Released from the Burning of NIKE Rocket Motors in the NTS (Nevada test Site) Tunnels, in Preparation.

15. Operating Experience with NOx Abatement at Stationary Sources. Special Report form the NOx Task Force to the Economic Commission for Europe, December 1992. pp. 6-12.

16. Pulverized Coal Combustion: Pollutant Formation and Control, 1970-1980. U.S. Environmental Protection Agency Report Number EPA 600/8-90-049, Research Triangle Park, NC 27711, May 1990, p. 4-17.

17. K. Olie, R. Addink and M. Schoonenboom., "Metals as Catalysts During the Formation of Dioxins and Furans." J. Air and Waste management Association, 48, 101-105, 1998.

Appendix A

Detailed Descriptions of the Energetic Materials

Description of Materials Used in Study 1

This study, which was funded by the United States Army Matériel Command (AMCCOM), was conducted in the SNL Bang Box between January 30 and February 16, 1989. In this study TNT blocks were detonated while suspended approximately 1 m above the concrete floor and two propellants were burned in stainless steel pans 103 cm in diameter and 12.7 cm deep. During the propellant burns, the pan was covered with a coarse stainless steel screen to prevent pieces of the propellant from sputtering out of the pan during the burn. The propellants were ignited with an Atlas electric match.

TNT Block

TNT blocks weighing 227g were detonated on January 31, February 2 and February 6, 1989. The TNT was obtained by removing the Mylar film from TNT demolition block and cutting the TNT into the shape and weight desired. The TNT block was made from pressed TNT grains ranging in size from 35 to 65 mesh; graphite (used to facilitate the pressing process) was the only other component in the block. An RP-83 initiator, which consisted of PETN and RDX encased in an aluminum alloy casing, was used as the initiator.

Foam Suppressed TNT Block Detonation

The suspended TNT block was encased in a glycol-based foam which had an expansion ratio of 130:1. The foam contained glycol ether, a 5-carbon alcohol, xanthin biopolymer, formaldehyde, a sulfonate surfactant and C_{12} - C_{14} fatty acids. The foam blanket was held in place with polyethylene sheeting. The diameter of the foam to that of the block was approximately 17:1. The TNT block was detonated on February 13, 1989 in the same manner as the bare TNT blocks had been detonated. This test was done to determine the capability of foam to reduce the blast wave and improve the environmental safety of OD activities. It was found that the foam did not substantially reduce the blast wave to the degree expected and that it impaired the efficiency of the detonation (as evident by the sharp reduction of the CO_2 emissions and the free carbon in the residue left on the floor after the detonation). **The results from this single test were not included in the database because of the uniqueness of the test.**

Double-base Propellant-NOSIH-AA2

The MEM burned was 471g. The major constituents of the propellant were: 240g NC, 184g NG, 26.6g ethyl cellulose, 12.3g triacetin, 9.1g of di-n-propyl adipate and 4.5g lead. A single burn was conducted on February 9, 1989.

Composite Propellant MK-6, 88 P-217

The MEM burned was 448g. The major energetic constituents of the propellant were: 381g AP, 35.9g hydroxy-terminated polybutadiene, 20.2g dioctyl sebacate and 4.5g aluminum oxide.

Description of Materials Used in Study 2

This Navy-funded study, which was conducted from January 19 to January 21, 1993, was the first study conducted in the DPG BangBox. Its objective was to collect emissions data for use in designing a confined-burn facility for propellants. Five propellants were burned in stainless steel pans and the dimensions of the pans were not recorded in the final report. The burn pans were placed at the center of the BangBox on the steel plate covering the 1 x 1 x 1 m detonation pit. The burns were ignited using Hercules Unique Smokeless Powder, which is a mixture of NC (95%) and NG (5%). A single burn was done on each material.

PBXN-110 Propellant

The MEM burned on January 19, 1993 was 1064g, which included 14g of smokeless powder. The major energetic components of the 1050g of PBXN-110 burned were: 924.1g HMX, 53g hydroxyl-terminated polybutadiene, and 53g isodecyl pelargonate.

MK-23 CTBN Propellant

The MEM of energetic material burned on January 19, 1993 was 1030g, including 30g Hercules smokeless powder. The major energetic components of the 1000g of MK-23 propellant burned were 800g AP, 142g carboxyl-terminated polybutadiene and 20 g Al.

MK-43 LOVA Propellant, MIL-P-70818

The MEM of energetic material burned on January 20, 1993 was 1060g, including 40g Hercules smokeless powder. The energetic composition of the MK-43 propellant burned was: 775g RDX, 41g NC, 122g cellulose acetate butyrate (CAB) and 78g of a mix of bis(2,2-dinitropropyl)acetal and bis(2,2-dinitropropyl)formal (BDNPA/F).

Hercules Unique Smokeless Powder

The MEM burned on January 21, 1993 was 454g; it was comprised only of smokeless powder (431.3g NC and 22.7g NG).

Smokey Sam (Obscurant)

The MEM of energetic material burned on January 21, 1993 was 273g, including 23g of Hercules smokeless powder. One smokey sam was burned in each trial. The energetic components of the smokey sam were: 110.0g AP, 100.2g Zn, 30g hydroxyl-terminated polybutadiene and 7.5g dioctyl adipate. The burn was very dirty; the BangBox airlock was filled with a pungent, noxious odor and the BangBox test chamber was filled with a dense fog.

Description of Materials Used in Study 3

Study 3 was funded by the United States Air Force (USAF) and was conducted from February 8 to February 12, 1993. Its objective was to obtain emissions data for a Subpart X permit application for a USAF base. Four USAF items were detonated in the BangBox; the detonations were initiated using C-4 and an electric blasting cap (EBC). (C-4 is the donor charge used in the routine detonation of the four USAF of the reducer charge was not given in the final report. The major energetic constituents of the 2,156g of M-1 propellant burned were: 1,815g NC, 213g dinitrotoluene, 106g dibutylphthalate and 22g diphenylamine. The three M-1 propellant burns were conducted on March 17 and 18, 1993; each burn was conducted under different temperature and humidity conditions. These conditions were generated using electric heaters and pans containing water. The first burn was conducted at low humidity and at a temperature above ambient temperature; the second burn was conducted early in the morning of March 18 under conditions of cool temperature and high relative humidity, and the third burn was conducted at ambient temperature. Unfortunately, the specific temperatures and humidities used are not given in the final report. Because the three trials gave emission factors which were essentially the same, the emission factors are identified in the database as M-1 propellant burn without referencing the environmental conditions under which each burn was done.

Description of Materials Used in Study 5

This study, which was funded by the USAF, was conducted from February 23 to March 9, 1995. Its objective was to obtain emissions data for a Subpart X permit application at a USAF base. During this study, the emission from 10 USAF items were characterized when these materials were detonated. C-4, detonation cord and an EBC assembly (detonation train) were use to initiate each detonation. Three detonations were conducted for each item. Each item detonated was suspended either 1 m or 0.5 m above the floor of the 1 x 1 x 1 m detonation pit. The C-4 was obtained by removing the Mylar film from M112 demolition charges; it was shaped to the size and weight needed for the test and then wrapped in a 12.7 cm x 30 cm sheet of polyethylene (weighing 1.9g) to prevent C-4 particles from falling to the floor of the BangBox before the detonation was initiated.

TNT Block

To ensure that the pollutant measurement instruments and other BangBox equipment was operating properly, three TNT blocks with a total MEM of 222g were tied together with 16 gauge iron wire, wrapped with 1.9g of polyethylene sheeting and detonated (using an EBC inserted in the bottom of the assembly) on February 23, 1995.

Detonation Train

This item represents the detonation train used to initiate the detonation of the other nine items used in the study. It was detonated to determine the effect that its detonation could have on the emissions measured from the other nine items. Each detonation train contained 57g C-4, 32g detonation cord (PETN), and an EBC. The C-4 was shaped into blocks weighing 57g with dimensions approximately 7.7 x 2.5 x 2.5 cm and the detonation cord was cut into 3 m lengths and coiled around the polyethylene-wrapped C-4. For this test, two detonation train assemblies were tied together with 16 gauge iron wire, wired in parallel to the firing line and detonated above the floor of the detonation pit using one EBC on each detonation train. The MEM used in each of the three detonations conducted on February

24, 1995 was 178g.

Cartridge, Impulse, M187 Mod O, ARD446-1, NSN 1377-00-516-9924
This item has a MEM of 12.5g. For each trial, ten ARD446's were wrapped together in polyethylene sheeting and detonated using one detonation train. The MEM of the assembly was 216g, including 91g from the detonation train. Each cartridge was stated to contain 0.9g charcoal, 0.9g sulfur and 5.0g potassium nitrate and approximately 8g of smokeless powder. It is assumed that the smokeless powder was 70% NC and 20% NG and 10% ethyl centralite. Three detonations were done on February 25, 1995.

Cartridge, Impulse, BBU 36B, NSN 1377-01-037-8650, Lot T0592A002012
This item deploys chaff from aircraft and contains a pyrotechnic filler which readily burns when initiated. Each cartridge has a MEM of 875mg. Sixty cartridges were used in each of the three detonations conducted on February 27, 1995. In each detonation, 42 cartridges were clustered around a 57g block of C-4 and 18 cartridges were placed on the sides of a 0.5 m length of detonation cord which had been folded into a 0.25 m length. In trial 1, the two assemblies were hung separately with one end of the detonation cord inserted in the block of C-4. An EBC was used to detonate the C-4. In trials 2 and 3, the C-4 and detonation cord assemblies were bound together using 16 gauge iron wire. The MEM of the assemblies detonated was 144g, including 91g from the detonation train. The energetic composition of the cartridge is not fully known; it did contain 0.1g potassium nitrate, 0.1g charcoal 0.7g NC, 0.2g NG and 0.06g amorphous boron.

Generator, Gas Pressure, Propellant Actuated, GCU-2/A, NSN-1336-00-420-2980
This item, which is used in the LGM30 minuteman missile, has a MEM of 95.3g; its energetic composition is classified. The item was prepared for detonation by removing the outer metal jacket to expose the solid propellant which is cast as a short hollow cylinder. Twenty-eight and a half grams of C-4 was packed into the hollow cylinder and the cylinder wrapped in polyethylene sheeting. This assembly was then wrapped with 1.5 m of detonation cord and the gas generator's plastic shipping plug was taped on top of the detonation cord. The gas generator was then oriented with its steel plug facing into the detonation pit and detonated with an EBC. One gas generator was used in each detonation; three detonations were done on March 1, 1995. The MEM of each assembly detonated was 139g.

Cartridge, Impulse, MK107, Mod 01, NSN-1377-00-779-2601
This cartridge has a MEM of 24.5g. Five cartridges were placed around a 57g block of C-4. Tney were parallel to each other, but alternated tip to base. This assembly was wrapped with 3 m of detonation cord and detonated over the detonation pit using an EBC. The MEM of each assembly was 208g, including 91g for the detonation train. The energetic composition of the MK107 cartridge was 17.4g NC, 5.0g NG, 1g barium nitrate and 1.2g of potassium nitrate. Three detonations were

conducted on March 3, 1995.

Signal, Illumination, Ground, Red Star, M158 NSN 1370-00-490-7363
This flare has a MEM of 36.8g. Four flares along with their bandoliers were used in each detonation. Two flares were placed on one side of a 57g block of C-4 and two were placed on the opposite side. This assembly was wrapped in polyethylene sheeting; 3 m of detonation cord was then wrapped around the assembly and secured with 16 gauge iron wire. This final assembly was detonated with the flare-releasing end pointed down into the pit. An EBC was used to initiate each of the three detonations conducted on March 4, 1995. The MEM of each assembly was 239g, including 91g from the detonation train. The complete energetic composition of the item is unknown. It did contain 2.5g of black powder, 5.2g of strontium nitrate, 2.5g magnesium, 11g potassium nitrate, 2.5g charcoal and milligram quantities of cadmium and zinc.

Fuze, Tail Bomb, Fuze Mechanical Unit (FMU) 54A/B, NSN-1325-00-613-0484
This fuze, which contains 163g of TETRYL, initiates the longitudinal detonator cast into general purpose (GP) air-dropped bombs such as the M117 and MK82. The MEM of the fuze is 163.3g. One fuze was used in each of the three detonations conducted on March 6, 1995. Each fuze was prepared for detonation as follows. A 28.5g block of C-4 was taped to the side of the fuze near its main explosive charge and the assembly wrapped in polyethylene sheeting. 1.5 m of detonation cord was then wrapped around the fuze and the fuze was screwed onto a threaded shaft. (The opposite end of the shaft was attached to a 1.9 cm thick by 30.5 cm diameter steel plate. The purpose of the steel plate was to break up any focused blast effect resulting from the detonation.) The fuze was detonated 0.5 m above the floor of the detonation pit using an EBC. The MEM was 209g, including 46g from the detonation train.

Flare, Countermeasure, Aircraft, M206, NSN-1370-01-0482138
This flare is used to decoy heat-seeking missiles away from aircraft. Each flare has a MEM of 150.2g and contains 102g powered magnesium, [illegible] potassium nitrate, 5g NC and 13g rubber. The flare, which had an aluminum case, was prepared for detonation as follows. A 57g block of C-4 was cut in half lengthwise and the two halves placed on the long axis of the flare such that two halves remained in contact. This assembly was wrapped in polyethylene sheeting and then 3 m of detonating cord was wrapped around the assembly starting at the end opposite the C-4. The plastic plug in the forward end of the flare was left in place and the final assembly suspended 0.5 m above the floor of the detonation pit. The pit cover was partially extended over the pit when the flare was detonated using an EBC to initiate the detonation. The MEM of the final assembly was 241g, including 91g from the detonation train. Three detonations were done on March 7, 1995.

Fuze, Tail Bomb, Fuze Mechanical Unit, 139A/B, NSN 1325-01-214-7311
This fuze contains 126g of TETRYL; it initiates the longitudinal

detonation cast into GP air-dropped bombs. The MEM of the fuze is 126g. One fuze was detonated in each of the three detonations conducted on March 8, 1997. The procedure employed was similar to that used for the FMU 54 A/B fuzes detonated on March 6, 1995. The MEM of the each assembly detonated was 172g, including 46g from the detonation train.

Signal, Illumination, Aircraft, Red Star M43A2, NSN-1370-00-618-5790
This flare has a MEM of 56.8g with 56.6g of this MEM in the illuminating charge. The illuminating charge contains 10.2g magnesium powder, 13.6g potassium perchlorate, 24.9g strontium nitrate, 3.4g hexachlorobenzene, 4g asphaltum and mg quantities of cadmium, barium, and lead. Three flares along with their bandoliers were used in each of the three detonations conducted on March 9, 1997. The three flares were tied to a 57g block of C-4 and detonated employing a procedure similar to that used for the M158 flares detonated on March 4, 1995. The MEM of each assembly detonated was 260g, including 91g from the detonation train.

Description of Materials Used in Study 6

Study 6 was a R&D study funded by the Strategic Environmental Research and Development Program (SERDP); its objective was to determine the emissions released when double-based and AP-based propellants were burned. The testing was conducted from July 26 to August 3, 1995. The four propellants burned were placed in stainless steel pans and ignited with an electric squib and 4g of Hercules Unique Smokeless Powder.

M31A1E1, Triple Based Propellant, NSN 1376-01-213-5669
During the first burn, the stick propellant was burned in an upright position, which resulted in extensive propellant kickout. To reduce propellant kickout, for the second and third burns, the propellant sticks were placed horizontally in the pan. For these latter burns, four propellant sticks were broken into fourths (18.4 cm) and placed in the pan. Then additional propellant sticks were broken in half (36.8 cm) and placed crosswise on top of the other propellant sticks. The MEM (including the 4g of smokeless powder) used in the three burns conducted on July 26, 1995 were 2,284g, 2,280g and 2,264g, for the first, second and third burns, respectively. The major energetic constituents of the M31A1E1 propellant burned were: 492g NC, 410g NG, 1,245g NQ, 34g ethyl centralite and 1g of charcoal.

Double-Based Propellant
Other than the following elemental composition, no information is available for this cast propellant which was burned on July 27, 1995: 20.36% C, 2.97% H, 28.73% N, 46.14% O, 0.89% Pb, 0.89% Zr and 0.02% Sn. The MEM of propellant burned in each of the two burns was 2,227g, including 4g of smokeless powder. Each propellant burn would potentially release 19.8g of Pb.

Ammonium Perchlorate (AP) Propellant
Other than the following elemental composition, no information is

available for this propellant which was burned on July 31, 1995: 25.87% Cl, 11.32% C, 4.31% H, 10.35% N, 47.31%O, and 0.89% Zr. This formulation implies that the propellant was 85% AP. The MEM burned in each of the two trials was 2,270g, including the 4g of smokeless powder used to initiate each burn. Based on the above elemental composition, the 2,270g of propellant burned contained: 1946g AP, 300g of a material or materials with the elemental formula of $C_{21}H_{32}$, 3.8g NC, 0.2g NG and 20g Zr.

Aluminized Ammonium Perchlorate (AP) Propellant

Other than the following elemental composition, no information is available for this propellant which was burned on August 3, 1995: 19% Al, 20.8% Cl, 10.09% C, 3.7% H, 8.3% N, 38.1% O and 0.008% P. This formulation implies that the propellant contained 69% AP by weight. The MEM (including 4g of smokeless powder) for the first and second burns were 1,216g and 1,159g, respectively for an average MEM of 1192g (821g AP, 226g Al, 141g of a material or materials with an elemental composition of $C_{20}H_{34}O$, 3.8g NC and 0.2g NG).

Description of Materials Used in Study 7

Study 7 was a SERDP-funded R & D project designed to determine the emissions released when TNT-based explosives are detonated at ground level and underground. This study was also done to obtain information on the emissions released to the atmosphere when waste from an aluminized AP propellant manufacturing process and diesel fuel-soaked dunnage are burned. All detonations and burns were done in triplicate. Except as indicated below, all detonations were done using an M-6 EBC and a 6.5g block of C-4 cut from an M112 demolition charge. The detonations were done with the material suspended 1 m above the floor of the BangBox.

Detonating Cord

Twenty-one and three tenths (21.3) meters of PETN-based detonating cord were shaped into a 61 cm diameter coil and the coil suspended over the detonating pit such that a 2.5 cm space existed between each successive turn of the coil. The MEM used in each of the three detonations conducted on August 15, 1995 was 205g, including the M6 EBC used to detonate the detonation cord. **For the reasons discussed in Chapter 3, all the detonation cord results were determined to be invalid and, therefore, were not included in the validated database.**

Tritonal Surrogate

Low density tritonal is used in 750 lb. air-dropped bombs; it consists of 80% TNT and 20% Al by weight. There is no commercial or military use for tritonal recovered from these out-of-date bombs. A tritonal surrogate was prepared using crushed TNT block and aluminum powder. These components were placed in a jar and mixed until the mixture appeared to be homogeneous. This mix contained 1274g TNT and 431g Al. Three, 227g portions of this mix were placed in thin polyethylene bags and the bags closed with cotton string. One bag was used in each detonation; the detonations were done with the bags suspended approximately 1 m above the concrete floor of the Bang Box. In the first two trials, a single M-6 EBC was used to initiate the detonation. It was apparent from the noise of the blast and the residues on the floor that the two detonations did not go high order. To ensure that the third detonation went high order, the EBC was inserted into a 6.5g block of C-4 for this detonation. The MEM of the material detonated in the three detonations was 229g for the first two detonations and 235g for the last detonation. Because they were not high order detonations, the results from the first two detonations are not included in the database. The detonations were done on August 16, 1995.

Tritonal Surrogate with 2.5% Calcium Stearate

The calcium stearate served as a surrogate for the organic materials associated with tritonal when it is steamed out of 750 lb. bombs. Three detonations were done on August 17, 1995; a 6.4g block of C-4 and an EBC were used to initiate each detonation. The tritonal/calcium stearate mixes detonated were contained in thin polyethylene bags in a manner identical to the tritonal surrogate detonations. Each bag contained 216g of the tritonal surrogate mix prepared earlier and 11g of calcium stearate. The MEM of the material detonated was 226g, including 8g from the C-4/EBC.

Water-Suppressed Tritonal Surrogate Detonation

The purpose of these water-suppressed detonations was to obtain a preliminary comparison between the emissions from unconfined, surface and buried detonations. The purpose of the water was to quench the fireball that forms when an energetic material is detonated. This fireball is important for ensuring that the molecular fragments of the energetic materials formed in the detonation are converted to CO and CO_2. Three, water-suppressed detonations of tritonal were done on August 22, 1995 using 227g of tritonal surrogate, 1,362g of water, a 6.5g block of C-4 and an EBC. For the first two detonations, the tritonal was in contact with three bags each of which contained 454g of water. (The four bags (3 water, 1 tritonal) were in a larger bag which was tied with cotton string such that the water bags remained in contact with the tritonal bag.) For the third detonation the 1,362g of water was divided equally among five polyethylene bags to increase the tritonal surface area covered by the water. In this latter detonation, three of the water bags were in the same plane as the tritonal bag, one was on top of the tritonal bag and the last was underneath the tritonal bag. The six bags were held in a larger bag which was tied with cotton string to keep the water bags in contact with the tritonal bag. The MEM detonated in each trial was 235g, including 8g from the C-4/EBC.

Amatol Surrogate

Amatol is a secondary explosive comprised of TNT and ammonium nitrate (AN). It is used in a wide variety of munitions. Three detonations of an amatol surrogate containing 113.5g of TNT and 113.5g AN were done on August 18, 1995. The amatol was prepared by mixing crushed TNT block with AN powder in a manner similar to that used to prepare the tritonal surrogate. The amatol surrogate was placed in the polyethylene bags and detonated in the same manner as the tritonal surrogate. The MEM of the material detonated in each of the three trials was 235g, including 8g from the C-4/EBC.

Water-suppressed Amatol Surrogate Detonation

Three detonations of 227g amatol surrogate in contact with 5 bags containing a total of 1362g of water were done on August 28, 1995. The five water bags were distributed around the amatol surrogate bag in a manner similar to that used for the third water-suppressed tritonal detonation on August 22, 1995. The MEM detonated was 235g, including 8g from the C-4/EBC.

Low-Density Composition B Surrogate

Composition B, a secondary explosive found in a wide variety of bombs and artillery projectiles, is a combination of RDX and TNT. The Composition B surrogate detonated on August 19, 1995 was prepared by mixing crushed TNT block with C-4. Three, 227g mixtures of the Composition B surrogate in thin polyethylene bags were detonated. The energetic composition of this composition B was 128g RDX, 86.3g TNT and 12.7g of mineral oil/polyisobutylene (from the C-4). The MEM detonated was 235g, including 8g from the C-4/EBC.

HBX Surrogate

HBX is an aluminized form of Composition B; it is used in a variety of bombs, depth charges and torpedoes. The HBX surrogate was prepared by mixing aluminum powder with Composition B surrogate. Two hundred and twenty seven gram quantities of the HBX surrogate were placed in thin polyethylene bags and detonated on August 21, 1995. Three detonations were done. The energetic composition of the HBX surrogate detonated was: 109g RDX, 72g TNT, 7.8g mineral oil/polyisobutylene and 38.5g Al. The MEM of the material detonated was 235g, including 8g from the C-4/EBC.

Aluminized Propellant Manufacturing Waste Surrogate

This surrogate waste simulated the mix of plastic gloves, cotton rags, kimwipes, wood towel rods and similar materials that result from the clean-up of the vessels used to manufacture propellants; it is usually disposed of by open burning. The composition of the surrogate waste burned in the stainless steel pans on August 23, 1995 was: 65% aluminized AP (69% AP, 19% aluminum), 20% plastic material (gloves, anti-static polyethylene), 11% paper/wood/cloth and 4% diesel fuel. The propellant in one inch cubes was randomly dispersed in the combustible materials. Because the first burn resulted in a hole in the bottom of the pan, the second and third burns were done with the surrogate waste sitting on top of a 7.6 cm layer of pea gravel. At the completion of each of these last two burns, holes were found in the side of the burn pan, and melted plastic was found in the pea gravel. Approximately 110g of ash remained in the burn pan after the first burn, 40g of ash after the second burn and 65g of ash after the third burn. It was difficult to determine the weight of ash remaining when the pea gravel was used. The weight of waste surrogate burned in the three trials was 1,139g, including the 4g of Hercules Unique

Smokeless Powder used to initiate each burn. Since this burn was done to characterize the emissions from the waste itself, the mass of the material burned (1,139g), rather than the mass of energetic burned (741.8g) was used to calculate the emission factors.

Diesel Fuel and Dunnage Surrogate

Scrap wood from ammunition boxes, dead branches from bushes/trees, styrofoam packing materials and other combustible materials (dunnage) are sometimes used with diesel fuel or other flammable liquid to assist in the open burning of munitions and other energetic materials found on training ranges, battlefields, etc. A surrogate diesel fuel-soaked dunnage was burned on August 29, 1995 to determine the emissions released when dunnage is burned. Three burns were done in unlined stainless steel pans using 909g of the surrogate material and 4g of smokeless powder. The composition of the surrogate material, which was prepared using styrofoam, pasteboard and irregularly shaped pieces of wood, was: 87.5% cellulose (795.4g), and 12.5% plastic/diesel fuel (114g). Since this burn was done to characterize the emissions from the diesel fuel and dunnage mixture itself, i.e., the mixture did not contain any energetic materials, the mass of the material burned (909g) was used to calculate the emission factors.

Appendix B
Sampling and Analysis Methodologies Used

Continuous Emission Monitors (CEMs)

Thermo Environmental (TECO) CEMs were used to measure the concentrations of CO_2, CO, NO, NO_2, SO_2, O_3 and HCl in the test chamber for a minimum of 25 minutes after a detonation or burn was initiated. The CEMs were located in the airlock and connected to the test chamber via a passivated stainless steel sampling manifold; their output voltages were recorded by a calibrated data acquisition system (DAS) comprised of five computers and a LAN. The pollutant concentrations measured before the detonation/burn was initiated were used to correct the pollutant concentrations measured after the detonation/burn was initiated. The model numbers and measurement principles of the TECO analyzers are: CO_2 (Model 41H, gas filter correlation); CO (Model 48, gas filter correlation); NO/NO_2 (Model 42, chemiluminescence); SO_2 (Model 43A, pulsed fluorescence); O_3 (Model 49, UV absorption); and HCl (Model 15, gas filter correlation). The analyzers were calibrated at least once each test day using NIST-traceable gas standards.

EPA Method 26 Sampling System for HCl and Cl_2.

Two EPA Method 26 samplers, located in the test chamber, were used to measure Cl_2 and HCl concentrations when chlorine-containing propellants were burned. This sampler uses a set of Midget impingers connected in series to collect HCl and Cl_2. The second and third impingers, which contain 0.1N H_2SO_4, remove HCl from the sampled gas stream, and the forth impinger, which contains 0.1 N NaOH, removes Cl_2. The impinger contents are analyzed for Cl by ion chromatography. The sampling flow rate is 1 L/min.

Evacuated Canisters for CO, CO_2, and SF_6

Evacuated canisters were used to measure the CO_2, CO and SF_6 concentrations in the test chamber. Generally, three CO_2/CO samples and five SF_6 samples were collected from the sampling manifold in the airlock during each trial. These samples were taken at 5 to 10 minute intervals and spanned the time during which the other pollutant samples were being collected/measured. Depending on the concentrations of the gases, the CO and CO_2 analyses were done using a GC equipped with either a flame ionization detector (GC/FID) or a thermal conductivity detector (GC/TCD) and the SF6 analyses were done using an electron capture detector (GC/ECD).

Evacuated Canisters for Volatile Organic Compounds (VOCs)

Three, 6-L canister samples were collected from the test chamber via the sampling manifold during each burn/detonation event. The first sample was taken approximately 5 min after the burn/detonation was initiated, the second was taken 5 to 10 minutes later and the third was taken 5 to 10 minutes after the second. Each sample was taken over a 1 to 3-min. period. The canister samples were analyzed for total non-methane hydrocarbons using EPA Method TO-12 (GC/FID) and for over 200 individual compounds using GC/FID and GC/MS. Most of these compounds were quantified by GC/FID; approximately 20 were quantified by GC/MS. Ten of these latter compounds were also quantified by GC/FID. The VOC target analytes are listed in Appendix C.

High Volume Sampler

This sampler collected samples for determination of: (1) particle mass; (2) metals; (3) EPA SW-846 Method 8270 SVOC compounds (Soxhlet extraction with analysis by GC/MS); and (4) remnants of the energetic materials (e.g., TNT, PETN, RDX, NG, NC, etc.) and other thermally-labile analytes. Three samplers, equipped with 20.3 x 30.8 cm quartz filters, were used for each detonation/burn event. They collected test chamber samples for 20 to 30 minutes after a detonation/burn was initiated. Although the initial flow rate was 1.1 m^3 /min, the flow rate generally decreased over the sampling period. Sometimes the filters were recovered after each trial; at other times they were recovered after the last trial had been done (composite samples). The filters were processed in the laboratory as follows.

Particle Mass and Metals

The weight gain of each filter was determined using a laboratory balance, and then two, 6.5-cm^2 sections were taken from each filter, combined, acid extracted and the extract analyzed using inductively coupled plasma atomic emission spectrometry (ICP) for Al, Sb, Ba, Be, Cd, Cr, Cu, Pb, Ni, Ti; and Zn. A portion of each filter was also analyzed for mercury using EPA SW-846 Method 7000. In some studies all filter sections from the same detonation/burn were combined, but in others, all filters from the same sampler were combined.

Method 8270 SVOCs

The composited filters were Soxhlet-extracted with 700 ml of acetonitrile, the extract was concentrated to 1 to 2 ml via rotary evaporation, and an aliquot analyzed using a HP Model 5890/5970 GC/MS operated in the full scan GC/MS mode. In some studies all filters from the same detonation/burn were combined before the Soxhlet extraction was done, but in other studies all filters from the same sampler were combined before the extraction was done. The Method 8270 target compounds are listed in Appendix C.

Energetic and Other Thermally-labile Compounds

To determine if these compounds were present, an aliquot from the above SVOC extract was analyzed by SFC/MS (supercritical fluid chromatography/MS) and, at times by SFC/TEA using a modified Lee Scientific Model 600/ Finnigan-Mat Incos 50. Two complementary SFC/MS analyses were performed: (1) negative chemical ionization for nitroaromatics, nitramines, nitrate esters and nitroso compounds; and (2) positive chemical ionization for polynuclear aromatic hydrocarbons, their nitrogen and oxygen heterocyclic counterparts, amines, and nitrosoamines. The SFC unit was run in the selected ion mode, rather than full scan mode. Extracts from some studies were also analyzed using full scan, SFC/TEA to seek out untargeted nitroso and nitro compounds and nitrate esters. The target energetic compounds are listed in Appendix C.

PM-10 Sampler (General Metals Works, Model GUV-10H)

This sampler is essentially a high volume sampler equipped with an inlet which prevents particles with aerodynamic size diameters larger than 10 microns from reaching the 20.3 by 30.8 cm, quartz filter; provided the sampling flow rate is maintained at 1.1 m^3/min. Only one PM-10 sampler was used in the BangBox; it was located in the test chamber. The filter samples were recovered after each detonation/burn, weighed, and analyzed for metals in a manner analogous to that used for the high volume samples.

PS-1 Sampler (General Metal Works, Inc. Model PS-1)

This sampler was used to collect air samples for determination of Method 8270 SVOCs and chlorinated dioxins and furans. (See Appendix A.) Separate samplers were used for the SVOCs and the dioxins/furans, because the extraction solvent for the SVOCs (methylene chloride) was not the same as that used for the dioxins/furans (toluene). Three SVOC samplers were used for each detonation/burn, but no more than two dioxins/furans samplers were used in any detonation or burn. The PS-1 samplers contained 65 to 75 g of XAD-2 resin in either a glass or aluminum cartridge. The cartridge had an internal diameter of 6 cm and was 12.5 cm in length; it contained a 10-cm diameter quartz fiber filter in its inlet. This filter was replaced after each detonation/burn, but the XAD-2 resin was not recovered until all detonation/burn trials planned for the test item had been accomplished. All filters from the same sampler were combined with the corresponding XAD-2 cartridge, extracted and analyzed using either full-scan GC/MS (SVOCs) or selective-ion-mode high resolution gas chromatography/high resolution MS (HRGC/HRMS).

Floor and Burn Pan Samples

In some studies, floor sweepings and burn pan residues were analyzed for metals, Method 8270 SVOC compounds, and dioxins and furans using procedures similar to those used for the air samplers. Unfortunately, the total mass of the metal in the ash/residue was not reported.

APPENDIX C
TARGET ANALYTES

VOCs

The individual target VOC compounds were:
acetaldehyde; acetone; acetonitrile;
acetylene; acrylonitrile; allyl chloride
benzaldehyde; benzene; benzyl chloride;
bromochloromethane; bromodichloromethane; bromoform;
bromomethane; 1,3-butadiene; n-butane;
1-butanol; 2-butanone; 1-butene;
cis-2-butene; trans-2-butene; butylacrylate;
n-butylbenzene; tert-butylbenzene; butylaldehyde;
carbon tetrachloride; chlorobenzene; chlorodifluoromethane;
chloroethane; chloroform; chloromethane;
chloroprene; (o,m,p)-chlorotoluene; cyclohexane;
cyclohexene; cyclopentane; cyclopentene;
n-decane; 1-decene; dibromochloromethane;
dichloromoethane; (o,m,p)-dichlorobenzene; dichlorodifluoromethane;
1,1-dichloroethane; 1,2-dichloroethane; 1,1-dichloroethene;
cis-1,2-dichloroethene; trans-1,2-dichloroethene; trichlorofluoromethane;
1,2-dichloropropane; cis-1,3-dichloropropene; diethyl ether;
trans-1,3-trichloropropene; (m, p)-diethylbenzene; 2,3-dimethylbutane;
2,2-dimethylheptane; 2,3-dimethylhexane; 2,5-dimethylhexane;
2,3-dimethylpentane; 2,4-dimethylpentane; 1,4-dioxane;
ethane; ethanol; ethylbenzene;
2-ethyl-1-butene; ethyl chloride; 3-ethylhexane;
ethylene; (o,m,p)-ethyltoluene; heptanal;
n-heptane; 1-heptene; hexachloro-1,3-butadiene;
hexanal; n-hexane; 1-hexene;
cis-2-hexene; trans-2-hexene; cis-3-hexene;
indan; indene; isobutane;
isobutene; isobutylbenzene; isoheptane;
isohexane; isopentane; isoprene;
isopropylbenzene; p-isopropyltoluene; methane;
methyl bromide; methyl tert-butyl ether; 2-methylpentane;
2-methyl-1-butene; 2-methyl-2-butene; 3-methyl-1-butene;
2-methyl-1-pentene; 4-methyl-1-pentene; 2-methyl-2-pentene;
cis-3-methyl-2-pentene; methylcyclohexane cis-4-methyl-2-pentene;
trans-4-methyl-2-pentene; methylcyclohexane; 1-methylcyclohexene;
methylcyclopentane; methylcyclopentene; methylene chloride;
2-methylheptane; 3-methylheptane; 3-methylhexane;
methylisobutylketone; 3-methylpentane naphthalene;
neohexane; neopentane; n-nonane;
1-nonene; 4-nonene; n-octane;
1-octene; cis-2-octene; n-pentane;
1-pentene; cis-2-pentene; trans-2-pentene;
alpha-pinene; beta-pinene; propane;
1-propanol; 2-propanol; n-propylbenzene;
propylene; styrene; Tetrachloroethene;
1,1,2,2-tetrachloroethane; toluene; 1,2,4-trichlorobenzene;
1,1,1-trichloroethane; 1,1,2-trichloroethane; trichloroethene;
trichloroethylene; trichlorofluoromethane; 1,2,3-trimethylbenzene;
1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene; 2,2,4-trimethylhexane;
2,2,4-trimethylpentane; 2,3,4-trimethylpentane; 2,2,5-trimethylhexane 2,4,4-trimethyl-1-pentene; 2,4,4-trimethyl-2-pentene; 2,2,3-trimethylpentane;
n-undecane; 1-undecene; vinyl acetate;
(o,m,p)-xylene; vinylidine chloride; vinyl chloride.

In addition to the above individual compounds, the following classes of VOC compounds were also measured and converted to emission factors:

Total Alkanes (saturated hydrocarbos) = sum of all alkanes measured in the sample, including non-target alkanes;

Total Alkenes (unsaturated hydrocarbons) = sum of all alkenes measured in the sample, including non-target alkenes and acetylene

Total Aromatics = sum of all aromatic compounds measured in the sample, including non-target aromatics;

Total Non-methane Hydrocarbons (TNMHC) = sum of total alkanes, total alkenes, total aromatics, and all other chromatographic peaks which did not contain halogen compounds;

Total Unidentified Hydrocarbons (TUHC) = sum of all chromatographic peaks known to be hydrocarbon compounds but not identified.

Method 8270 Analytes (Hi-Vol and PS-1 Sampling Systems)

Acenaphthylene; acetophenone; 2-acetylmninofluorene;
4-aminobiphenyl; aniline; anthracene;
benz(a)anthracene; benz(a)pyrene; benzidine;
benzo(b)fluoranthene; benzo(g,h,i)perylene; benzoic acid;
benzo(k)fluoranthene; benzyl alcohol; biphenyl;
bromophenylphenylether; butylbenzylphthalate; p-chloroaniline;
chlorobenzilate; bis(2-chloroethoxy)methane; bis(2-chloroethyl)ether;
bis(2-chloroisopropylether; 4-chloro-3-methylphenol; 2-chloronaphthalene;
2-chlorophenol; 4-chlorophenylphenyl ether; chrysene;
diallate; dibenz(a,h)anthracene; dibenzofuran;
1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene;
3,3'-dichlorobenzidine; 2,4-dichlorophenol; 2,6-dichlorophenol;
diethylphthalate; p-dimethylaminoazobenzene; dimethylbenz(a)anthracene;
3,3'-dimethylbenzidine; dimethylphenethylamine; 2,4-dimethylphenol;
dimethylphthalate; di-n-butylphthalate; 1,3-dinitrobenzene;
4,6-dinitro-2-methylphenol; 2,4-dinitrophenol; 2,4-dinitrotoluene;
2,6-dinitrotoluene; di-n-octylphthalate; 1,4-diphenylamine;
1,2 diphenylhydrazine; bis(2-ethylhexyl)phthallate; N-nitrosodiphenylamine;
ethyl methanesulfonate; fluoranthene; fluorene;
hexachlorobenzene; hexachlorobutadiene; hexachlorocyclopentadiene;
hexachloroethane; hexachloropropene; indeno(1,2,3-cd)pyrene;
isophoron; isosafrole; kepone;
methapyrilene; 3-methylcholanthrene; methyl methanesulfonate;
2-methylnaphthalene; 2-methylphenol; 4-methylphenol;
3-methylphenol; naphthalene; 1,4-naphthoquinone;
1-naphthylamine; 2-naphthylamine; 2-nitroaniline;
3-nitroaniline; 4-nitroaniline; nitrobenzene;
5-nitro-o-toluidine; 2-nitrophenol; 4-nitrophenol;
4-nitroquinoline-1-oxide; N-nitrosodiethylamine; N-nitrosodimethylamine;
N-nitroso-di-n-butylamine; N-nitroso-di-n-propylamine; N-nitrosomethylethylamine;
N-nitrosomorpholine; N-nitrosopiperidine; N-nitrosopyrrolidine;
pentachlorobenzene; pentachloroethane; pentachloronitrobenzene;
pentachlorophenol; perylene; phenacetin;
phenanthrene; phenol; 2-picoline;
pronamide; pyrene; pyridine;
safrole; 1,2,4,5-tetrachlorobenzene; 2,3,4,6-tetrachlorophenol;
o-toluidine; 1,2,4-trichlorobenzene; 2,4,5-trichlorophenol;
2,4,6-trichlorophenol; triethylphosphorothioate; 1,3,5-trinitrobenzene.

Energetic Target Analytes

Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX); dibenzofuran;
hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); 2,6-dichlorophenol;
methyl-2,4,5-trinitrophenylnitramine (TETRYL); 1,3,5-trinitrobenzene;
2,6 dichlorphenol; 1.3-dinitrobenzene;
nitrobenzene; 2-nitrodiphenylamine;

2,4,6-trinitrotoluene (TNT);
2-amino-4,6-dinitrotoluene;
2,4-dinitrotoluene;
2-nitronaphthalene;
1-nitropyrene;
4-nitrotoluene ;
nitroglycerin (NG);
nitrocellulose (NC);
pentaerythritol tetranitrate (PETN);
phenol.

4-amino-2,6-dinitrotoluene;
2,6-dinitrotoluene;
2-methylnaphthalene;
naphthalene;
2-nitrotoluene;
3-nitrotoluene;
nitroguanidine (NQ);
Benz(A)pyrene;
benz(a)anthracene;

Polychlorinated dibenzo-p-furan Analytes (Furans)

Total chlorinated dibenz-p-dioxin (TCDD);
Total pentachlorinated dibenzo-p-dioxin (PeCDD);
Total hexachlorinated dibenzo-p-dioxin (HxCDD);
Total heptachlorinated dibenzo-p-dioxin (HpCDD);
Octachlorinated dibenzo-p-dioxin (OCDD);
2378-TCDD; 1234678-HpCDD.

Polychorinated dibenzo-p-dioxin Analytes (Dioxins)

Total tetrachlorinated dibenzofurans (TCDF);
Total pentachlorinated dibenzofurans (PeCDF);
Total hexachlorinated dibenzofurans (HxCDF);
Total heptachlorinated dibenzofurans (HpCDF);
Octachlorinated dibenzofuran (OCDF);
2378-TCDF; 12378-PeCDF; 23478-PeCDF;
123478-HxCDF; 123678-HxCDF; 234678-HxCDF;
1234678-HpCDF; 1234789-HpCDF.

Appendix D
Emission Factors for Burns

SPECIAL NOTES:

The emission factors in this database apply to the open burning of energetic materials in a burn pan. A value of 0.00e+00 means that the compound (analyte) was either not detected, or, was detected at only the background level. Values of 0.00e+00 were not used in calculating the average (AVG) emission factors in the database. A blank cell means that either no sample was collected or that the sample collected was either lost or not valid.

The emission factors in this table are unitless. The user can convert them to any mass units desired (e.g., grams compound per gram NEW). A value e-06 means that the quantity in the numerator is to be multiplied by 10 to the -6 power. For example, 1.1 e-06 could be written as either 1.1 x 10^{-6} g/g NEW or 1 microgram/g NEW.

NOTE - M-3 PROPELLANT SHOULD BE M-1 PROPELLANT IN THIS APPENDIX

COMPOUND	ITEM	EMISSION FACTORS				
		TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE	UNCORR
cis-2-Pentene	diesel furel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Manufacturer's waste - aluminized propellant with diesel	3.80e-07	3.10e-07	1.00e-06	5.60e-07	6.60e-07
cis-2-Pentene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, M-43 (USN)	9.10e-08			9.10e-08	9.10e-08
cis-2-Pentene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, MK-23	0.00e+00			0.00e+00	9.80e-08
cis-2-Pentene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Propellant, PBXN-110	0.00e+00			0.00e+00	1.00e-07
cis-2-Pentene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butane	Diesel fuel and dunnage	0.00e+00	1.20e-06	0.00e+00	1.20e-06	1.40e-06
i-Butane	Manufacturer's waste - aluminized propellant with diesel	2.30e-07	1.80e-06	2.10e-06	1.40e-06	2.30e-06
i-Butane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butane	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.80e-06
i-Butane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	1.80e-07
i-Butane	Propellant, M-9	4.30e-08			4.30e-08	8.50e-08
i-Butane	Propellant, MK-23	0.00e+00			0.00e+00	2.00e-07
i-Butane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butane	Propellant, PBXN-110	0.00e+00			0.00e+00	2.00e-07
i-Butane	Propellant, Smokey Sam	0.00e+00			0.00e+00	7.80e-07
i-Butane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	9.60e-07
i-Butene	Diesel fuel and dunnage	0.00e+00	1.70e-06	2.30e-06	2.00e-06	2.00e-06
i-Butene	Manufacturer's waste - aluminized propellant with diesel	1.30e-05	2.10e-06	2.60e-06	5.80e-06	5.80e-06
i-Butene	Propellant, ammonium perchlorate, aluminized	1.00e-05	0.00e+00		1.00e-05	1.00e-05
i-Butene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butene	Propellant, M-3	7.90e-07	0.00e+00	0.00e+00	7.90e-07	8.00e-07
i-Butene	Propellant, M-43 (USN)	5.40e-07			5.40e-07	5.40e-07
i-Butene	Propellant, M-9	2.60e-07			2.60e-07	2.60e-07
i-Butene	Propellant, MK-23	4.90e-07			4.90e-07	4.90e-07
i-Butene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Butene	Propellant, PBXN-110	1.30e-06			1.30e-06	1.30e-06
i-Butene	Propellant, Smokey Sam	2.40e-06			2.40e-06	2.40e-06
i-Butene	Smokeless Powder (Hercules Unique)	9.60e-07			9.60e-07	9.60e-07

i-Pentane	Diesel fuel and dunnage	0.00e+00	6.90e-06	1.10e-05	8.90e-06	1.00e-05
i-Pentane	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	0.00e+00	2.30e-05	2.30e-05	1.80e-05
i-Pentane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Pentane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Pentane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Pentane	Propellant, M-3	3.00e-08	0.00e+00	0.00e+00	3.00e-08	1.80e-07
i-Pentane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	3.60e-07
i-Pentane	Propellant, M-9	0.00e+00			0.00e+00	8.50e-08
i-Pentane	Propellant, MK-23	0.00e+00			0.00e+00	6.90e-07
i-Pentane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Pentane	Propellant, PBXN-110	0.00e+00			0.00e+00	1.00e-06
i-Pentane	Propellant, Smokey Sam	7.80e-07			7.80e-07	2.70e-06
i-Pentane	Smokeless Powder (Hercules Unique)	1.20e-06			1.20e-06	3.80e-06
m-Ethyltoluene	Diesel fuel and dunnage	1.10e-04	1.40e-04	1.40e-04	1.30e-04	4.60e-04
m-Ethyltoluene	Manufacturer's waste - aluminized propellant with diesel	2.20e-06	1.50e-06	4.10e-06	2.60e-06	6.90e-05
m-Ethyltoluene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
m-Ethyltoluene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
m-Ethyltoluene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
m-Ethyltoluene	Propellant, M-3	5.00e-08	0.00e+00	1.40e-07	9.70e-08	5.50e-07
m-Ethyltoluene	Propellant, M-43 (USN)	0.00e+00			0.00e+00	3.60e-07
m-Ethyltoluene	Propellant, M-9	4.30e-08			4.30e-08	6.00e-07
m-Ethyltoluene	Propellant, MK-23	3.00e-07			3.00e-07	9.80e-07
m-Ethyltoluene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
m-Ethyltoluene	Propellant, PBXN-110	2.00e-07			2.00e-07	7.00e-07
m-Ethyltoluene	Propellant, Smokey Sam	2.00e-06			2.00e-06	5.90e-06
m-Ethyltoluene	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	2.20e-06
n-Butane	Diesel fuel and dunnage	1.30e-06	6.80e-06	5.70e-06	4.60e-06	5.40e-06
n-Butane	Manufacturer's waste - aluminized propellant with diesel	5.50e-06	2.40e-06	2.00e-05	9.30e-06	1.80e-05
n-Butane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Butane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Butane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Butane	Propellant, M-3	9.00e-08	1.80e-07	0.00e+00	1.50e-07	5.60e-07
n-Butane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	5.40e-07
n-Butane	Propellant, M-9	4.30e-08			4.30e-08	3.40e-07
n-Butane	Propellant, MK-23	0.00e+00			0.00e+00	5.90e-07
n-Butane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Butane	Propellant, PBXN-110	1.00e-07			1.00e-07	6.00e-07
n-Butane	Propellant, Smokey Sam	0.00e+00			0.00e+00	2.70e-06
n-Butane	Smokeless Powder (Hercules Unique)	4.80e-07			4.80e-07	3.80e-06
n-Decane	Diesel fuel and dunnage	1.50e-03	0.00e+00	2.00e-03	1.80e-03	1.80e-03
n-Decane	Manufacturer's waste - aluminized propellant with diesel	9.20e-06	1.10e-05	2.30e-05	1.40e-05	3.10e-05

n-Decane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Decane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Decane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Decane	Propellant, M-3	4.20e-07	8.70e-07	1.40e-07	5.90e-07	1.90e-06
n-Decane	Propellant, M-43 (USN)	8.20e-07			8.20e-07	3.70e-06
n-Decane	Propellant, M-9	0.00e+00			0.00e+00	1.30e-06
n-Decane	Propellant, MK-23	0.00e+00			0.00e+00	3.20e-06
n-Decane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Decane	Propellant, PBXN-110	1.30e-06			1.30e-06	4.40e-06
n-Decane	Propellant, Smokey Sam	5.90e-06			5.90e-06	2.20e-05
n-Decane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	8.60e-06
n-Heptane	Diesel fuel and dunnage	3.10e-05	8.00e-05	6.60e-05	5.90e-05	6.00e-05
n-Heptane	Manufacturer's waste - aluminized propellant with diesel	3.50e-06	2.40e-06	8.30e-06	4.70e-06	7.30e-06
n-Heptane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Heptane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Heptane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Heptane	Propellant, M-3	2.70e-07	5.10e-07	9.40e-08	3.10e-07	1.60e-06
n-Heptane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	2.70e-07
n-Heptane	Propellant, M-9	0.00e+00			0.00e+00	1.10e-06
n-Heptane	Propellant, MK-23	0.00e+00			0.00e+00	4.90e-07
n-Heptane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Heptane	Propellant, PBXN-110	0.00e+00			0.00e+00	8.00e-07
n-Heptane	Propellant, Smokey Sam	2.00e-06			2.00e-06	3.10e-06
n-Heptane	Smokeless Powder (Hercules Unique)	7.20e-07			7.20e-07	1.20e-06
n-Hexane	Diesel fuel and dunnage	6.40e-06	2.30e-05	1.90e-05	1.60e-05	1.70e-05
n-Hexane	Manufacturer's waste - aluminized propellant with diesel	2.70e-06	1.50e-06	6.70e-06	3.70e-06	5.70e-06
n-Hexane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Hexane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Hexane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Hexane	Propellant, M-3	1.60e-05	1.40e-05	4.90e-06	1.90e-05	9.00e-05
n-Hexane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	3.60e-07
n-Hexane	Propellant, MK-23	0.00e+00			0.00e+00	7.90e-07
n-Hexane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Hexane	Propellant, PBXN-110	0.00e+00			0.00e+00	1.30e-06
n-Hexane	Propellant, Smokey Sam	2.70e-06			2.70e-06	3.90e-06
n-Hexane	Smokeless Powder (Hercules Unique)	9.60e-07			9.60e-07	2.20e-06
n-Nonane	Diesel fuel and dunnage	8.00e-04	1.20e-03	1.10e-03	1.00e-03	1.00e-03
n-Nonane	Manufacturer's waste - aluminized propellant with diesel	1.10e-05	7.60e-06	2.10e-05	1.30e-05	2.40e-05
n-Nonane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Nonane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Nonane	Propellant, [illegible]	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

n-Nonane	Propellant, M-3	7.80e-08	1.40e-07	0.00e+00	1.20e-07	2.30e-07
n-Nonane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	9.10e-08
n-Nonane	Propellant, M-9	0.00e+00			0.00e+00	1.70e-07
n-Nonane	Propellant, MK-23	0.00e+00			0.00e+00	2.00e-07
n-Nonane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Nonane	Propellant, PBXN-110	2.00e-07			2.00e-07	5.00e-07
n-Nonane	Propellant, Smokey Sam	1.20e-06			1.20e-06	1.60e-06
n-Nonane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	4.80e-07
n-Octane	Diesel fuel and dunnage	1.50e-04	3.20e-04	2.80e-04	2.50e-04	2.50e-04
n-Octane	Manufacturer's waste - aluminized propellant with diesel	6.30e-06	4.20e-06	1.20e-05	7.60e-06	1.30e-05
n-Octane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Octane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Octane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Octane	Propellant, M-3	2.90e-07	6.40e-07	1.90e-07	4.30e-07	1.60e-06
n-Octane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	2.70e-07
n-Octane	Propellant, M-9	0.00e+00			0.00e+00	1.10e-06
n-Octane	Propellant, MK-23	0.00e+00			0.00e+00	2.00e-07
n-Octane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Octane	Propellant, PBXN-110	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Octane	Propellant, Smokey Sam	1.20e-06			1.20e-06	1.60e-06
n-Octane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	4.80e-07
n-Pentane	Diesel fuel and dunnage	2.00e-06	1.30e-05	1.20e-05	9.10e-06	1.00e-05
n-Pentane	Manufacturer's waste - aluminized propellant with diesel	2.60e-06	1.10e-06	9.00e-06	4.30e-06	7.20e-06
n-Pentane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Pentane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Pentane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Pentane	Propellant, M-3	5.30e-07	1.50e-06	4.20e-07	8.60e-07	3.30e-06
n-Pentane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	3.60e-07
n-Pentane	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Pentane	Propellant, MK-23	0.00e+00			0.00e+00	7.90e-07
n-Pentane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
n-Pentane	Propellant, PBXN-110	0.00e+00			0.00e+00	1.10e-06
n-Pentane	Propellant, Smokey Sam	7.80e-07			7.80e-07	2.70e-06
n-Pentane	Smokeless Powder (Hercules Unique)	9.60e-07			9.60e-07	2.60e-06
p-Ethyltoluene	Diesel fuel and dunnage	1.20e-04	1.70e-04	1.70e-04	1.50e-04	1.60e-04
p-Ethyltoluene	Manufacturer's waste - aluminized propellant with diesel	5.40e-06	2.90e-06	6.70e-06	5.00e-06	8.10e-06
p-Ethyltoluene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, M-3	5.60e-07	3.20e-07	2.20e-06	9.80e-07	2.10e-06
p-Ethyltoluene	Propellant, M-43 (USN)	1.80e-07			1.80e-07	9.10e-07

p-Ethyltoluene	Propellant, M-9	4.00e-06			4.00e-06	5.50e-06
p-Ethyltoluene	Propellant, MK-23	0.00e+00			0.00e+00	1.10e-06
p-Ethyltoluene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, PBXN-110	3.00e-07			3.00e-07	1.40e-06
p-Ethyltoluene	Propellant, Smokey Sam	7.10e-06			7.10e-06	1.10e-05
p-Ethyltoluene	Smokeless Powder (Hercules Unique)	4.80e-07			4.80e-07	2.40e-06
p-Ethyltoluene	Diesel fuel and dunnage	1.20e-04	6.60e-06	6.90e-07	4.10e-05	4.20e-05
p-Ethyltoluene	Manufacturer's waste - aluminized propellant with diesel	2.00e-06	2.00e-06	0.00e+00	2.00e-06	5.30e-06
p-Ethyltoluene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, M-3	0.00e+00	2.00e-07	2.80e-08	3.70e-08	5.70e-07
p-Ethyltoluene	Propellant, M-43 (USN)	0.00e+00			0.00e+00	3.90e-07
p-Ethyltoluene	Propellant, M-9	0.00e+00			0.00e+00	7.20e-07
p-Ethyltoluene	Propellant, MK-23	0.00e+00			0.00e+00	4.20e-07
p-Ethyltoluene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Propellant, PBXN-110	4.30e-07			4.30e-07	8.50e-07
p-Ethyltoluene	Propellant, Smokey Sam	1.70e-06			1.70e-06	3.30e-06
p-Ethyltoluene	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	1.00e-06
trans-2-Butene	Diesel fuel and dunnage	3.60e-06	1.80e-06	3.30e-06	2.90e-06	2.90e-06
trans-2-Butene	Manufacturer's waste - aluminized propellant with diesel	2.70e-05	1.40e-05	2.10e-05	2.10e-05	2.10e-05
trans-2-Butene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Propellant, M-3	1.90e-07	0.00e+00	0.00e+00	1.90e-07	1.90e-07
trans-2-Butene	Propellant, M-43 (USN)	1.80e-07			1.80e-07	1.80e-07
trans-2-Butene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Propellant, MK-23	2.00e-07			2.00e-07	2.00e-07
trans-2-Butene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Propellant, PBXN-110	4.00e-07			4.00e-07	4.00e-07
trans-2-Butene	Propellant, Smokey Sam	2.40e-06			2.40e-06	2.40e-06
trans-2-Butene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Hexene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Hexene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Diesel fuel and dunnage	0.00e+00	0.00e+00	1.10e-06	1.10e-06	1.10e-06
trans-2-Pentene	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	3.80e-07	1.50e-06	9.60e-07	1.20e-06
trans-2-Pentene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

trans-2-Pentene	Propellant, MK-23	0.00e+00			0.00e+00	9.80e-08
trans-2-Pentene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Propellant, PBXN-110	0.00e+00			0.00e+00	2.00e-07
trans-2-Pentene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Acetylene	Diesel fuel and dunnage	1.20e-04	7.30e-05	9.10e-05	9.50e-05	9.60e-05
Acetylene	Manufacturer's waste - aluminized propellant with diesel	1.80e-03	1.30e-03	1.50e-03	1.60e-03	1.60e-03
Acetylene	Propellant, ammonium perchlorate, aluminized	1.00e-05	0.00e+00		1.00e-05	1.00e-05
Acetylene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Acetylene	Propellant, composite (MK-6) (Sandia)	2.10e-05			2.10e-05	
Acetylene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Acetylene	Propellant, double base (Sandia)	2.00e-04			2.00e-04	
Acetylene	Propellant, M-3	7.70e-06	1.50e-05	1.90e-05	1.30e-05	7.90e-06
Acetylene	Propellant, M-43 (USN)	5.90e-06			5.90e-06	6.40e-06
Acetylene	Propellant, M-9	9.00e-06			9.00e-06	9.20e-06
Acetylene	Propellant, MK-23	5.50e-06			5.50e-06	6.20e-06
Acetylene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Acetylene	Propellant, PBXN-110	3.10e-06			3.10e-06	3.70e-06
Acetylene	Propellant, Smokey Sam	8.30e-04			8.30e-04	8.30e-04
Acetylene	Smokeless Powder (Hercules Unique)	1.20e-06			1.20e-06	3.60e-06
Acenaphthalene	Manufacturer's waste - aluminized propellant with diesel	1.10e-04	5.00e-04	3.20e-04	1.60e-04	0.00e+00
Aluminum	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.50e-06
Aluminum	Manufacturer's waste - aluminized propellant with diesel	6.10e-03	8.50e-03	9.30e-02	3.60e-02	3.60e-02
Aluminum	Propellant, ammonium perchlorate, aluminized	9.40e-03	1.20e-02		1.10e-02	1.10e-02
Aluminum	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.00e-05
Aluminum	Propellant, composite (MK-6) (Sandia)	1.30e-03			1.30e-03	
Aluminum	Propellant, M-3	6.80e-07	8.50e-07	1.40e-05	5.10e-06	5.10e-06
Aluminum	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Manufacturer's waste - aluminized propellant with diesel	1.60e-05	2.00e-05	2.20e-04	8.60e-05	8.90e-05
Barium	Propellant, ammonium perchlorate, aluminized	1.00e-05	1.00e-05		1.00e-05	1.00e-05
Barium	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Propellant, composite (MK-6) (Sandia)	1.60e-06			1.60e-06	
Barium	Propellant, double base (Sandia)	0.00e+00			0.00e+00	
Barium	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Benzene	Diesel fuel and dunnage	1.00e-04	5.20e-05	8.10e-05	7.80e-05	8.00e-05
Benzene	Manufacturer's waste - aluminized propellant with diesel	6.40e-04	2.90e-04	4.10e-04	4.50e-04	4.50e-04
Benzene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Benzene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Benzene	Propellant, composite (MK-6) (Sandia)	5.70e-05			5.70e-05	
Benzene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Benzene	Propellant, double base (Sandia)	1.20e-04			1.20e-04	
Benzene	Propellant, M-3	6.40e-06	1.10e-05	1.40e-05	1.00e-05	7.70e-06
Benzene	Propellant, M-43 (USN)	1.70e-06			1.70e-06	2.30e-06
Benzene	Propellant, M-9	3.20e-06			3.20e-06	4.20e-06
Benzene	Propellant, MK-23	0.00e+00			0.00e+00	2.00e-06
Benzene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Benzene	Propellant, PBXN-110	4.90e-06			4.90e-06	7.70e-06
Benzene	Propellant, Smokey Sam	6.60e-05			6.60e-05	7.00e-05
Benzene	Smokeless Powder (Hercules Unique)	1.20e-06			1.20e-06	3.10e-06
Carbon tetrachloride	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.90e-07
Carbon tetrachloride	Manufacturer's waste - aluminized propellant with diesel	3.30e-06	6.30e-06	7.30e-06	5.60e-06	6.00e-06
Carbon tetrachloride	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Propellant, M-43 (USN)	0.00e+00			0.00e+00	5.00e-07
Carbon tetrachloride	Propellant, M-9	2.30e-07			2.30e-07	2.30e-07
Carbon tetrachloride	Propellant, MK-23	1.10e-06			1.10e-06	1.60e-06
Carbon tetrachloride	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Propellant, PBXN-110	0.00e+00			0.00e+00	5.50e-07
Carbon tetrachloride	Propellant, Smokey Sam	0.00e+00			0.00e+00	2.20e-06
Carbon tetrachloride	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	1.30e-06
Chloroform	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Manufacturer's waste - aluminized propellant with diesel	2.20e-06	2.40e-06	2.30e-06	2.30e-06	2.50e-06
Chloroform	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, MK-23	4.20e-07			4.20e-07	4.20e-07
Chloroform	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, PBXN-110	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Propellant, ammonium perchlorate, aluminized	1.00e-05	1.00e-05		1.00e-05	1.00e-05
Chromium	Propellant, ammonium perchlorate, nonaluminized	1.00e-05	1.00e-05		1.00e-05	1.00e-05

Chromium	Propellant, composite (MK-6) (Sandia)	4.80e-05			4.80e-05	
Chromium	Propellant, double base (Sandia)	0.00e+00			0.00e+00	
Chromium	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cl2	Manufacturer's waste - aluminized propellant with diesel	2.80e-04	1.50e-05	1.60e-04	2.00e-04	
Cl2	Propellant, ammonium perchlorate, aluminized	5.00e-03	4.20e-03		4.60e-03	
Cl2	Propellant, ammonium perchlorate, nonaluminized	1.10e-02	8.20e-03		9.20e-03	
Copper	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Manufacturer's waste - aluminized propellant with diesel	1.50e-05	0.00e+00	0.00e+00	1.50e-05	1.90e-05
Copper	Propellant, ammonium perchlorate, nonaluminized	5.00e-05	1.00e-04		8.00e-05	8.00e-05
Copper	Propellant, double base	0.00e+00	3.20e-04		1.60e-04	1.60e-04
Copper	Propellant, double base (Sandia)	3.70e-02			3.70e-02	
Copper	Propellant, M-3	3.40e-06	8.30e-06	2.50e-06	4.40e-06	2.90e-05
Copper	Propellant, M-9	6.50e-06			6.50e-06	4.60e-05
Copper	Propellant, M31A1E1	1.00e-05			1.00e-05	
Cyclohexane	Diesel fuel and dunnage	1.30e-05	3.80e-05	3.00e-05	2.70e-05	2.70e-05
Cyclohexane	Manufacturer's waste - aluminized propellant with diesel	1.70e-06	9.20e-07	3.30e-06	2.00e-06	3.40e-06
Cyclohexane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Propellant, M-3	1.30e-07	1.40e-07	0.00e+00	1.50e-07	5.00e-07
Cyclohexane	Propellant, M-43 (USN)	9.10e-08			9.10e-08	1.80e-07
Cyclohexane	Propellant, M-9	0.00e+00			0.00e+00	4.70e-07
Cyclohexane	Propellant, MK-23	0.00e+00			0.00e+00	3.90e-07
Cyclohexane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Propellant, PBXN-110	0.00e+00			0.00e+00	8.00e-07
Cyclohexane	Propellant, Smokey Sam	1.20e-06			1.20e-06	2.00e-06
Cyclohexane	Smokeless Powder (Hercules Unique)	4.80e-07			4.80e-07	9.60e-07
Cyclopentane	Diesel fuel and dunnage	0.00e+00	1.50e-06	1.40e-06	1.50e-06	1.50e-06
Cyclopentane	Manufacturer's waste - aluminized propellant with diesel	1.50e-07	7.60e-08	5.40e-07	2.50e-07	4.30e-07
Cyclopentane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.70e-08
Cyclopentane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	9.10e-08
Cyclopentane	Propellant, M-9	4.30e-08			4.30e-08	8.50e-08
Cyclopentane	Propellant, MK-23	0.00e+00			0.00e+00	9.80e-08
Cyclopentane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Propellant, PBXN-110	0.00e+00			0.00e+00	2.00e-07
Cyclopentane	Propellant, Smokey Sam	0.00e+00			0.00e+00	3.90e-07
Cyclopentane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	2.40e-07

Cyclopentene	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Manufacturer's waste - aluminized propellant with diesel	9.80e-07	7.60e-07	1.10e-06	9.40e-07	9.40e-07
Cyclopentene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, M-43 (USN)	9.10e-08			9.10e-08	9.10e-08
Cyclopentene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, MK-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Propellant, PBXN-110	1.00e-07			1.00e-07	1.00e-07
Cyclopentene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
CO	Diesel fuel and dunnage	7.40e-03	4.70e-03	6.00e-03	6.00e-03	
CO	Manufacturer's waste - aluminized propellant with diesel	2.20e-02	1.90e-02	1.90e-02	2.00e-02	
CO	Propellant, ammonium perchlorate, aluminized	2.10e-03	3.50e-04		1.20e-03	
CO	Propellant, ammonium perchlorate, nonaluminized	1.30e-04	1.50e-04		1.40e-04	
CO	Propellant, composite (MK-6) (Sandia)	4.20e-03			4.20e-03	
CO	Propellant, double base	1.50e-03	1.50e-03		1.50e-03	
CO	Propellant, double base (Sandia)	9.50e-04			9.50e-04	
CO	Propellant, M-3	1.60e-02	1.60e-02	1.80e-02	1.40e-02	
CO	Propellant, M-43 (USN)	6.60e-04			6.60e-04	
CO	Propellant, M-9	2.70e-03			2.70e-03	
CO	Propellant, MK-23	2.70e-04			2.70e-04	
CO	Propellant, M31A1E1	1.40e-04	1.10e-04	1.30e-04	1.30e-04	
CO	Propellant, PBXN-110	1.20e-03			1.20e-03	
CO	Propellant, Smokey Sam	7.20e-02			7.20e-02	
CO	Smokeless Powder (Hercules Unique)	1.60e-03			1.60e-03	
CO2	Diesel fuel and dunnage	1.50e+00	1.50e+00	1.50e+00	1.50e+00	
CO2	Manufacturer's waste - aluminized propellant with diesel	1.10e+00	1.10e+00	1.20e+00	1.10e+00	
CO2	Propellant, ammonium perchlorate, aluminized	3.10e-01	3.20e-01		3.20e-01	
CO2	Propellant, ammonium perchlorate, nonaluminized	3.70e-01	3.70e-01		3.70e-01	
CO2	Propellant, composite (MK-6) (Sandia)	4.20e-01			4.20e-01	
CO2	Propellant, double base	6.70e-01	6.70e-01		6.70e-01	
CO2	Propellant, double base (Sandia)	9.70e-01			9.70e-01	
CO2	Propellant, M-3	1.20e+00	1.20e+00	1.20e+00	1.20e+00	
CO2	Propellant, M-43 (USN)	7.70e-01			7.70e-01	
CO2	Propellant, M-9	9.40e-01			9.40e-01	
CO2	Propellant, MK-23	5.40e-01			5.40e-01	
CO2	Propellant, M31A1E1	5.40e-01	5.60e-01	6.80e-01	5.90e-01	
CO2	Propellant, PBXN-110	1.00e+00			1.00e+00	
CO2	Propellant, [illegible]	4.20e-01			4.20e-01	

CO2	Smokeless Powder (Hercules Unique)	8.70e-01			8.70e-01	
Ethane	Diesel fuel and dunnage	0.00e+00	7.20e-06	1.20e-05	9.30e-06	1.00e-05
Ethane	Manufacturer's waste - aluminized propellant with diesel	1.80e-05	3.80e-06	6.90e-06	9.50e-06	1.00e-05
Ethane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethane	Propellant, M-3	1.10e-06	1.20e-06	2.80e-07	1.30e-06	1.50e-06
Ethane	Propellant, M-43 (USN)	1.80e-07			1.80e-07	1.50e-06
Ethane	Propellant, M-9	5.60e-07			5.60e-07	1.40e-06
Ethane	Propellant, MK-23	0.00e+00			0.00e+00	9.80e-07
Ethane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethane	Propellant, PBXN-110	1.00e-06			1.00e-06	2.10e-06
Ethane	Propellant, Smokey Sam	0.00e+00			0.00e+00	5.50e-06
Ethane	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	2.60e-06
Ethylbenzene	*Diesel fuel and dunnage*	4.30e-05	6.20e-05	6.10e-05	5.50e-05	5.70e-05
Ethylbenzene	Manufacturer's waste - aluminized propellant with diesel	2.30e-06	1.30e-06	3.50e-06	2.40e-06	4.20e-06
Ethylbenzene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylbenzene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylbenzene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylbenzene	Propellant, M-3	3.00e-07	0.00e+00	1.40e-07	2.60e-07	1.00e-06
Ethylbenzene	Propellant, M-43 (USN)	0.00e+00			0.00e+00	3.60e-07
Ethylbenzene	Propellant, M-9	0.00e+00			0.00e+00	8.50e-07
Ethylbenzene	Propellant, MK-23	0.00e+00			0.00e+00	6.90e-07
Ethylbenzene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylbenzene	Propellant, PBXN-110	8.00e-07			8.00e-07	1.60e-06
Ethylbenzene	Propellant, Smokey Sam	1.20e-06			1.20e-06	2.70e-06
Ethylbenzene	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	1.20e-06
Ethylene	Diesel fuel and dunnage	6.60e-05	7.20e-05	8.50e-05	7.40e-05	7.50e-05
Ethylene	Manufacturer's waste - aluminized propellant with diesel	3.10e-04	1.60e-04	2.30e-04	2.30e-04	2.30e-04
Ethylene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylene	Propellant, M-3	5.80e-06	8.80e-06	3.30e-06	7.80e-06	5.90e-06
Ethylene	Propellant, M-43 (USN)	4.80e-06			4.80e-06	5.00e-06
Ethylene	Propellant, M-9	6.50e-06			6.50e-06	6.60e-06
Ethylene	Propellant, MK-23	9.80e-07			9.80e-07	1.20e-06
Ethylene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylene	Propellant, PBXN-110	6.70e-06			6.70e-06	6.80e-06
Ethylene	Propellant, Smokey Sam	7.20e-05			7.20e-05	7.30e-05
Ethylene	Smokeless Powder (Hercules Unique)	2.40e-07			2.40e-07	1.40e-06
Fluoranthene	Manufacturer's waste - aluminized propellant with diesel	5.00e-05	0.00e+00	3.60e-04	2.00e-04	2.00e-04

HCl	Propellant, ammonium perchlorate, aluminized	2.10e-01	2.10e-01		2.10e-01	2.10e-01
HCl	Propellant, ammonium perchlorate, nonaluminized	2.10e-01	2.15e-01		2.15e-01	2.15e-01
HCl	Propellant, composite (MK-6) (Sandia)	9.40e-02			9.40e-02	
HCl	Propellant, M-43 (USN)	1.00e-03			1.00e-03	1.00e-03
HCl	Propellant, MK-23	1.90e-03			1.90e-03	1.90e-03
HCl	Propellant, PBXN-110	1.80e-04			1.80e-04	1.80e-04
HCl	Propellant, Smokey Sam	2.90e-02			2.90e-02	2.90e-02
HCl	Manufacturer's waste - aluminized propellant with diesel	8.50e-02	7.70e-02	8.80e-02	8.30e-02	
Lead	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	7.30e-05	4.90e-04	2.80e-04	2.80e-04
Lead	Propellant, ammonium perchlorate, aluminized	4.00e-05			4.00e-05	4.00e-05
Lead	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Propellant, double base	5.80e-03	5.50e-03		5.60e-03	5.60e-03
Lead	Propellant, double base (Sandia)	1.30e-02			1.30e-02	
Lead	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Manufacturer's waste - aluminized propellant with diesel	2.70e-05	1.40e-05	1.90e-05	2.00e-05	2.00e-05
Methyl chloride	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Propellant, M-3	1.60e-07	0.00e+00	1.10e-07	1.40e-07	4.50e-07
Methyl chloride	Propellant, M-43 (USN)	0.00e+00			0.00e+00	1.60e-07
Methyl chloride	Propellant, M-9	1.50e-07			1.50e-07	3.10e-07
Methyl chloride	Propellant, MK-23	7.10e-07			7.10e-07	8.90e-07
Methyl chloride	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Propellant, PBXN-110	1.80e-07			1.80e-07	1.80e-07
Methyl chloride	Propellant, Smokey Sam	5.70e-06			5.70e-06	6.40e-06
Methyl chloride	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	4.30e-07
Methylcyclohexane	Diesel fuel and dunnage	8.40e-05	2.10e-04	1.70e-04	1.60e-04	1.60e-04
Methylcyclohexane	Manufacturer's waste - aluminized propellant with diesel	7.30e-06	4.40e-06	1.20e-05	8.00e-06	1.40e-05
Methylcyclohexane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Propellant, M-3	9.90e-08	0.00e+00	4.70e-08	5.80e-08	4.30e-07
Methylcyclohexane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	1.80e-07
Methylcyclohexane	Propellant, M-9	0.00e+00			0.00e+00	4.70e-07
Methylcyclohexane	Propellant, MK-23	0.00e+00			0.00e+00	3.90e-07
Methylcyclohexane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Propellant, PBXN-110	0.00e+00			0.00e+00	5.00e-07
Methylcyclohexane	Propellant, Smokey Sam	7.80e-07			7.80e-07	1.60e-06

Methylcyclohexane	Smokeless Powder (Hercules Unique)	4.80e-07			4.80e-07	9.60e-07
Methylcyclopentane	Diesel fuel and dunnage	4.20e-06	1.40e-05	1.10e-05	9.90e-06	1.00e-05
Methylcyclopentane	Manufacturer's waste - aluminized propellant with diesel	7.60e-08	3.80e-07	2.70e-06	1.10e-06	2.00e-06
Methylcyclopentane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclopentane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclopentane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclopentane	Propellant, M-3	2.10e-06	2.00e-06	6.60e-07	2.50e-06	1.10e-05
Methylcyclopentane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	1.80e-07
Methylcyclopentane	Propellant, M-9	0.00e+00			0.00e+00	1.70e-06
Methylcyclopentane	Propellant, MK-23	0.00e+00			0.00e+00	4.90e-07
Methylcyclopentane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclopentane	Propellant, PBXN-110	0.00e+00			0.00e+00	7.00e-07
Methylcyclopentane	Propellant, Smokey Sam	1.60e-06			1.60e-06	2.00e-06
Methylcyclopentane	Smokeless Powder (Hercules Unique)	7.20e-07			7.20e-07	1.20e-06
Methylenechloride	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylenechloride	Manufacturer's waste - aluminized propellant with diesel	1.50e-05	9.80e-06	0.00e+00	1.20e-05	1.10e-05
Methylenechloride	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylenechloride	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylenechloride	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylenechloride	Propellant, M-3	5.60e-06	0.00e+00	5.20e-05	2.30e-05	5.80e-05
Methylenechloride	Propellant, M-43 (USN)	0.00e+00			0.00e+00	1.10e-06
Methylenechloride	Propellant, M-9	0.00e+00			0.00e+00	4.30e-05
Methylenechloride	Propellant, MK-23	6.00e-07			6.00e-07	6.00e-07
Methylenechloride	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylenechloride	Propellant, PBXN-110	0.00e+00			0.00e+00	9.00e-07
Methylenechloride	Propellant, Smokey Sam	1.20e-06			1.20e-06	4.70e-06
Methylenechloride	Smokeless Powder (Hercules Unique)	7.20e-07			7.20e-07	7.20e-07
NO	Diesel fuel and dunnage	6.30e-04	8.90e-04	8.80e-04	8.00e-04	
NO	Manufacturer's waste - aluminized propellant with diesel	9.30e-04	8.80e-04	1.20e-03	1.00e-03	
NO	Propellant, ammonium perchlorate, aluminized	2.20e-03	1.60e-03		1.90e-03	
NO	Propellant, ammonium perchlorate, nonaluminized	4.10e-03	3.90e-03		4.00e-03	
NO	Propellant, composite (MK-6) (Sandia)	2.10e-03			2.10e-03	
NO	Propellant, double base	1.70e-03	1.70e-03		1.70e-03	
NO	Propellant, double base (Sandia)	2.40e-02			2.40e-02	
NO	Propellant, M-43 (USN)	6.30e-03			6.30e-03	
NO	Propellant, M31A1E1		1.10e-03	1.20e-03	1.20e-03	
NO	Propellant, PBXN-110	2.60e-03			2.60e-03	
NO	Propellant, Smokey Sam	1.10e-02			1.10e-02	
NO2	Diesel fuel and dunnage	0.00e+00	5.10e-05	3.20e-05	4.20e-05	
NO2	Manufacturer's waste - aluminized propellant with diesel	4.40e-07	9.80e-06	9.70e-06	6.60e-06	
NO2	Propellant, ammonium perchlorate, aluminized	2.10e-04	7.00e-05		1.40e-04	

NO2	Propellant, ammonium perchlorate, nonaluminized	4.30e-03	4.70e-04		2.40e-03	
NO2	Propellant, composite (MK-6) (Sandia)	1.00e-03			1.00e-03	
NO2	Propellant, double base	9.00e-05	1.00e-04		1.00e-04	
NO2	Propellant, double base (Sandia)	2.80e-03			2.80e-03	
NO2	Propellant, M-43 (USN)	4.70e-04			4.70e-04	
NO2	Propellant, M31A1E1		1.00e-04	1.00e-04	1.00e-04	
NO2	Propellant, PBXN-110	2.80e-04			2.80e-04	
NO2	Propellant, Smokey Sam	2.70e-04			2.70e-04	
OCDD	Diesel fuel and dunnage	1.00e-11	0.00e+00	0.00e+00	1.00e-11	3.20e-11
OCDF	Manufacturer's waste - aluminized propellant with diesel	4.00e-08			4.00e-08	
Propane	Diesel fuel and dunnage	1.40e-06	2.20e-06	3.10e-06	2.20e-06	2.50e-06
Propane	Manufacturer's waste - aluminized propellant with diesel	4.20e-06	2.80e-06	6.50e-06	4.50e-06	5.00e-06
Propane	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propane	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propane	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propane	Propellant, M-3	3.30e-07	5.10e-07	5.20e-07	5.00e-07	7.20e-07
Propane	Propellant, M-43 (USN)	0.00e+00			0.00e+00	9.10e-07
Propane	Propellant, M-9	0.00e+00			0.00e+00	3.40e-07
Propane	Propellant, MK-23	4.90e-07			4.90e-07	1.30e-06
Propane	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propane	Propellant, PBXN-110	3.00e-07			3.00e-07	1.00e-06
Propane	Propellant, Smokey Sam	1.60e-06			1.60e-06	4.30e-06
Propane	Smokeless Powder (Hercules Unique)	2.40e-07			2.40e-07	3.40e-06
Propene	Diesel fuel and dunnage	1.00e-05	1.30e-05	1.60e-05	1.30e-05	1.30e-05
Propene	Manufacturer's waste - aluminized propellant with diesel	2.50e-05	2.10e-05	3.20e-05	2.60e-05	2.60e-05
Propene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Propene	Propellant, M-3	1.40e-06	2.00e-06	2.10e-06	2.00e-06	1.50e-06
Propene	Propellant, M-43 (USN)	1.10e-06			1.10e-06	1.20e-06
Propene	Propellant, M-9	7.30e-07			7.30e-07	8.10e-07
Propene	Propellant, MK-23	1.70e-06			1.70e-06	1.80e-06
Propene	Propellant, PBXN-110	3.00e-06			3.00e-06	3.10e-06
Propene	Propellant, Smokey Sam	2.70e-06			2.70e-06	2.70e-06
Propene	Smokeless Powder (Hercules Unique)	2.40e-07			2.40e-07	7.20e-07
PM10	Diesel fuel and dunnage	4.70e-03	4.90e-03	6.80e-03	5.40e-03	
PM10	Manufacturer's waste - aluminized propellant with diesel	3.80e-01	4.40e-01	4.90e+00	1.90e+00	
PM10	Propellant, ammonium perchlorate, aluminized	4.10e-01	4.30e-01		4.20e-01	
PM10	Propellant, ammonium perchlorate, nonaluminized	1.10e-02	1.80e-02		1.50e-02	
PM10	Propellant, double base	1.90e-02	1.90e-02		1.90e-02	
PM10	Propellant, M-3	8.80e-03	8.70e-03	8.20e-03	8.60e-03	

PM10	Propellant, M-43 (USN)	1.20e-03			1.20e-03	
PM10	Propellant, M-9	1.60e-02			1.60e-02	
PM10	Propellant, MK-23	5.90e-02			5.90e-02	
PM10	Propellant, M31A1E1	8.90e-01	9.30e-01	9.10e-01	9.10e-01	
PM10	Propellant, PBXN-110	4.90e-01			4.90e-01	
PM10	Propellant, Smokey Sam	2.60e-01			2.60e-01	
PM10	Smokeless Powder (Hercules Unique)	1.80e-03			1.80e-03	
Styrene	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, M-9	4.70e-07			4.70e-07	4.70e-07
Styrene	Propellant, MK-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, M31A1E1	0.00e+00			0.00e+00	1.00e-05
Styrene	Propellant, PBXN-110	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
SO2	Diesel fuel and dunnage	2.10e-04	7.90e-05	2.80e-04	1.90e-04	
SO2	Manufacturer's waste - aluminized propellant with diesel	8.60e-04	8.40e-04	8.80e-04	8.60e-04	
SO2	Propellant, ammonium perchlorate, aluminized	6.00e-05	4.00e-05		5.00e-05	
SO2	Propellant, ammonium perchlorate, nonaluminized	1.10e-04	1.10e-04		1.10e-04	
SO2	Propellant, composite (MK-6) (Sandia)	1.10e-03			1.10e-03	
SO2	Propellant, double base	3.00e-05	2.00e-05		3.00e-05	
SO2	Propellant, double base (Sandia)	3.20e-03			3.20e-03	
SO2	Propellant, M-43 (USN)	1.20e-04			1.20e-04	
SO2	Propellant, M31A1E1	1.00e-03	1.20e-03		1.20e-03	
SO2	Propellant, PBXN-110	3.50e-04			3.50e-04	
SO2	Propellant, Smokey Sam	1.50e-04			1.50e-04	
SO2	Smokeless Powder (Hercules Unique)	6.10e-04			6.10e-04	
Tetrachloroethylene	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	1.60e-06	1.80e-06	1.70e-06	1.70e-06
Tetrachloroethylene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, MK-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, PBXN-110	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Toluene	Diesel fuel and dunnage	8.00e-05	1.50e-04	1.40e-04	1.20e-04	1.30e-04
Toluene	Manufacturer's waste - aluminized propellant with diesel	3.40e-05	1.50e-05	3.40e-05	2.80e-05	3.90e-05
Toluene	Propellant, ammonium perchlorate, aluminized	0.00e+00			0.00e+00	1.00e-05
Toluene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00			0.00e+00	1.00e-05
Toluene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Toluene	Propellant, M-3	1.80e-06	2.00e-06	8.90e-07	1.80e-06	6.60e-06
Toluene	Propellant, M-43 (USN)	5.40e-07			5.40e-07	1.80e-06
Toluene	Propellant, M-9	0.00e+00			0.00e+00	5.40e-06
Toluene	Propellant, MK-23	0.00e+00			0.00e+00	2.90e-06
Toluene	Propellant, M31A1E1	0.00e+00			0.00e+00	3.00e-05
Toluene	Propellant, PBXN-110	0.00e+00			0.00e+00	4.50e-06
Toluene	Propellant, Smokey Sam	8.60e-06			8.60e-06	1.50e-05
Toluene	Smokeless Powder (Hercules Unique)	3.40e-06			3.40e-06	7.40e-06
Total Alkanes (Paraffins)	Diesel fuel and dunnage	2.70e-03	3.90e-03	3.90e-03	3.50e-03	3.50e-03
Total Alkanes (Paraffins)	Manufacturer's waste - aluminized propellant with diesel	9.40e-05	5.80e-05	2.30e-04	1.30e-04	2.30e-04
Total Alkanes (Paraffins)	Propellant, ammonium perchlorate, aluminized	0.00e+00			0.00e+00	2.00e-05
Total Alkanes (Paraffins)	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00		0.00e+00	1.00e-05
Total Alkanes (Paraffins)	Propellant, composite (MK-6) (Sandia)	5.90e-05			5.90e-05	
Total Alkanes (Paraffins)	Propellant, double base	0.00e+00				1.00e-05
Total Alkanes (Paraffins)	Propellant, double base (Sandia)	2.20e-04			2.20e-04	
Total Alkanes (Paraffins)	Propellant, M-3	3.00e-05	2.10e-05	7.40e-06	2.60e-05	1.30e-04
Total Alkanes (Paraffins)	Propellant, M-43 (USN)	5.40e-07			5.40e-07	1.00e-05
Total Alkanes (Paraffins)	Propellant, M-9	0.00e+00			0.00e+00	2.30e-05
Total Alkanes (Paraffins)	Propellant, MK-23	0.00e+00			0.00e+00	1.40e-05
Total Alkanes (Paraffins)	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Total Alkanes (Paraffins)	Propellant, PBXN-110	0.00e+00			0.00e+00	2.00e-05
Total Alkanes (Paraffins)	Propellant, Smokey Sam	2.30e-05			2.30e-05	7.20e-05
Total Alkanes (Paraffins)	Smokeless Powder (Hercules Unique)	6.70e-06			6.70e-06	4.20e-05
Total Alkenes (Olefins)	Diesel fuel and dunnage	2.00e-04	1.70e-04	2.10e-04	1.90e-04	2.00e-04
Total Alkenes (Olefins)	Manufacturer's waste - aluminized propellant with diesel	2.20e-03	1.50e-03	1.90e-03	1.90e-03	1.90e-03
Total Alkenes (Olefins)	Propellant, ammonium perchlorate, aluminized	3.00e-05	1.00e-05		2.00e-05	2.00e-05
Total Alkenes (Olefins)	Propellant, ammonium perchlorate, nonaluminized	1.00e-05	1.00e-05		1.00e-05	1.00e-05
Total Alkenes (Olefins)	Propellant, composite (MK-6) (Sandia)	1.00e-04			1.00e-04	
Total Alkenes (Olefins)	Propellant, double base	0.00e+00	1.00e-05		1.00e-05	1.00e-05
Total Alkenes (Olefins)	Propellant, double base (Sandia)	7.30e-04			7.30e-04	
Total Alkenes (Olefins)	Propellant, M-3	3.60e-05	2.80e-05	2.50e-05	2.90e-05	3.70e-05
Total Alkenes (Olefins)	Propellant, M-43 (USN)	1.30e-05			1.30e-05	1.40e-05
Total Alkenes (Olefins)	Propellant, M-9	1.70e-05			1.70e-05	1.80e-05
Total Alkenes (Olefins)	Propellant, MK-23	1.10e-05			1.10e-05	1.30e-05
Total Alkenes (Olefins)	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.00e-05
Total Alkenes (Olefins)	Propellant, PBXN-110	1.60e-05			1.60e-05	1.80e-05

Total Alkenes (Olefins)	Propellant, Smokey Sam	9.10e-04			9.10e-04	9.20e-04
Total Alkenes (Olefins)	Smokeless Powder (Hercules Unique)	2.20e-06			2.20e-06	7.40e-06
Total Aromatics	Diesel fuel and dunnage	1.60e-03	2.70e-03	2.60e-03	2.30e-03	2.30e-03
Total Aromatics	Manufacturer's waste - aluminized propellant with diesel	7.80e-04	3.60e-04	5.60e-04	5.70e-04	6.20e-04
Total Aromatics	Propellant, ammonium perchlorate, aluminized	0.00e+00				2.00e-05
Total Aromatics	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00		0.00e+00	2.00e-05
Total Aromatics	Propellant, composite (MK-6) (Sandia)	1.60e-04			1.60e-04	
Total Aromatics	Propellant, double base	0.00e+00	0.00e+00		0.00e+00	1.00e-05
Total Aromatics	Propellant, double base (Sandia)	4.40e-04			4.40e-04	
Total Aromatics	Propellant, M-3	1.60e-05	1.10e-05	1.90e-05	1.40e-05	3.50e-05
Total Aromatics	Propellant, M-43 (USN)	2.80e-06			2.80e-06	1.30e-05
Total Aromatics	Propellant, M-9	5.40e-06			5.40e-06	2.70e-05
Total Aromatics	Propellant, MK-23	0.00e+00			0.00e+00	1.70e-05
Total Aromatics	Propellant, M31A1E1	6.00e-05	7.00e-05	3.00e-05	5.00e-05	9.00e-05
Total Aromatics	Propellant, PBXN-110	7.10e-06			7.10e-06	2.80e-05
Total Aromatics	Propellant, Smokey Sam	1.00e-04			1.00e-04	1.50e-04
Total Aromatics	Smokeless Powder (Hercules Unique)	6.20e-06			6.20e-06	3.50e-05
Total Non-methane Hydrocarbons	Diesel fuel and dunnage	9.90e-03	1.30e-02	1.30e-02	1.20e-02	1.20e-02
Total Non-methane Hydrocarbons	Manufacturer's waste - aluminized propellant with diesel	3.50e-03	2.20e-03	3.10e-03	2.90e-03	3.20e-03
Total Non-methane Hydrocarbons	Propellant, ammonium perchlorate, aluminized	6.00e-05	3.00e-05		5.00e-05	1.10e-04
Total Non-methane Hydrocarbons	Propellant, ammonium perchlorate, nonaluminized	5.00e-05	4.00e-05		4.00e-05	7.00e-05
Total Non-methane Hydrocarbons	Propellant, double base	1.00e-05	1.00e-05		1.00e-05	4.00e-05
Total Non-methane Hydrocarbons	Propellant, M-3	1.10e-04	9.50e-05	5.30e-05	9.30e-05	3.00e-04
Total Non-methane Hydrocarbons	Propellant, M-43 (USN)	4.10e-05			4.10e-05	1.10e-04
Total Non-methane Hydrocarbons	Propellant, M-9	1.50e-05			1.50e-05	1.30e-04
Total Non-methane Hydrocarbons	Propellant, MK-23	0.00e+00			0.00e+00	1.40e-04
Total Non-methane Hydrocarbons	Propellant, M31A1E1	1.00e-04	9.00e-05	1.20e-04	1.00e-04	1.70e-04
Total Non-methane Hydrocarbons	Propellant, PBXN-110	5.10e-05			5.10e-05	1.80e-04
Total Non-methane Hydrocarbons	Propellant, Smokey Sam	1.10e-03			1.10e-03	1.60e-03
Total Non-methane Hydrocarbons	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	2.30e-04
Total Unidentified Hydrocarbons	Diesel fuel and dunnage	5.50e-03	6.00e-03	6.60e-03	6.00e-03	6.20e-03
Total Unidentified Hydrocarbons	Manufacturer's waste - aluminized propellant with diesel	4.10e-04	2.30e-04	4.20e-04	3.50e-04	4.70e-04
Total Unidentified Hydrocarbons	Propellant, ammonium perchlorate, aluminized	2.00e-05	3.00e-05		2.50e-05	4.00e-05
Total Unidentified Hydrocarbons	Propellant, ammonium perchlorate, nonaluminized	3.00e-05	2.00e-05		2.50e-05	3.00e-05
Total Unidentified Hydrocarbons	Propellant, double base	0.00e+00	0.00e+00		0.00e+00	1.00e-05
Total Unidentified Hydrocarbons	Propellant, M-3	2.80e-05	3.50e-05	1.70e-06	2.40e-05	9.10e-05
Total Unidentified Hydrocarbons	Propellant, M-43 (USN)	2.50e-05			2.50e-05	7.40e-05
Total Unidentified Hydrocarbons	Propellant, M-9	0.00e+00			0.00e+00	5.80e-05
Total Unidentified Hydrocarbons	Propellant, MK-23	2.90e-06			2.90e-06	9.10e-05
Total Unidentified Hydrocarbons	Propellant, M31A1E1	3.00e-05	1.00e-05	2.00e-05	2.00e-05	4.00e-05
Total Unidentified Hydrocarbons	Propellant, PBXN-110	4.40e-05			4.40e-05	1.10e-04

Total Unidentified Hydrocarbons	Propellant, Smokey Sam	7.50e-05			7.50e-05	4.30e-04
Total Unidentified Hydrocarbons	Smokeless Powder (Hercules Unique)	0.00e+00			0.00e+00	1.40e-04
Vinyl chloride	Diesel fuel and dunnage	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Manufacturer's waste - aluminized propellant with diesel	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Propellant, MK-23	1.50e-06			1.50e-06	1.50e-06
Vinyl chloride	Propellant, PBXN-110	2.20e-07			2.20e-07	2.20e-07
Vinyl chloride	Propellant, Smokey Sam	8.80e-07			8.80e-07	8.80e-07
Vinyl chloride	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Diesel fuel and dunnage	6.40e-05	6.50e-05	5.90e-05	6.30e-05	6.40e-05
Zinc	Manufacturer's waste - aluminized propellant with diesel	1.60e-04	1.10e-04	1.40e-03	5.70e-04	5.80e-04
Zinc	Propellant, ammonium perchlorate, aluminized	6.00e-05	2.00e-05		4.00e-05	4.00e-05
Zinc	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Propellant, double base	0.00e+00	1.00e-05		1.00e-05	1.00e-05
Zinc	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Diesel fuel and dunnage	0.00e+00	4.70e-06	4.60e-06	4.70e-06	4.70e-06
1-Butene	Manufacturer's waste - aluminized propellant with diesel	1.10e-05	5.70e-06	8.00e-06	8.30e-06	8.30e-06
1-Butene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Propellant, M-43 (USN)	2.70e-07			2.70e-07	2.70e-07
1-Butene	Propellant, M-9	2.60e-07			2.60e-07	2.60e-07
1-Butene	Propellant, MK-23	5.90e-07			5.90e-07	5.90e-07
1-Butene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Propellant, PBXN-110	6.00e-07			6.00e-07	6.00e-07
1-Butene	Propellant, Smokey Sam	1.20e-06			1.20e-06	1.20e-06
1-Butene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Diesel fuel and dunnage	1.10e-06	2.70e-06	2.80e-06	2.20e-06	2.20e-06
1-Hexene	Manufacturer's waste - aluminized propellant with diesel	1.10e-06	6.10e-07	1.30e-05	4.80e-06	4.80e-06
1-Hexene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, M-3	1.80e-07	0.00e+00	0.00e+00	1.80e-07	1.80e-07
1-Hexene	Propellant, M-43 (USN)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

1-Hexene	Propellant, M-9	2.10e-07			2.10e-07	2.10e-07
1-Hexene	Propellant, MK-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, PBXN-110	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Hexene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Diesel fuel and dunnage	0.00e+00	1.70e-06	0.00e+00	1.70e-06	1.80e-06
1-Pentene	Manufacturer's waste - aluminized propellant with diesel	*4.80e-06*	*3.30e-06*	*7.00e-06*	*5.10e-06*	*5.30e-06*
1-Pentene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Propellant, ammonium perchlorate, nonaluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Propellant, double base	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Propellant, M-3	1.60e-07	0.00e+00	0.00e+00	1.60e-07	2.20e-07
1-Pentene	Propellant, M-43 (USN)	9.10e-08			9.10e-08	9.10e-08
1-Pentene	Propellant, M-9	4.30e-08			4.30e-08	8.50e-08
1-Pentene	Propellant, MK-23	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Propellant, M31A1E1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Propellant, PBXN-110	1.00e-07			1.00e-07	2.00e-07
1-Pentene	Propellant, Smokey Sam	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Diesel fuel and dunnage	0.00e+00	1.30e-06	9.80e-07	1.20e-06	1.20e-06
1,3-Butadiene	Manufacturer's waste - aluminized propellant with diesel	5.40e-06	4.20e-06	2.40e-06	4.00e-06	4.00e-06
1,3-Butadiene	Propellant, ammonium perchlorate, aluminized	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Propellant, M-3	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Propellant, M-43 (USN)	9.10e-08			9.10e-08	9.10e-08
1,3-Butadiene	Propellant, M-9	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Propellant, MK-23	2.00e-07			2.00e-07	2.00e-07
1,3-Butadiene	Propellant, PBXN-110	5.00e-07			5.00e-07	5.00e-07
1,3-Butadiene	Propellant, Smokey Sam	1.20e-06			1.20e-06	1.20e-06
1,3-Butadiene	Smokeless Powder (Hercules Unique)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1234678-HpCDF	Manufacturer's waste - aluminized propellant with diesel	3.40e-08			3.40e-08	
123478-HxCDF	Manufacturer's waste - aluminized propellant with diesel	2.00e-08			2.10e-08	
1234789-HpCDF	Manufacturer's waste - aluminized propellant with diesel	7.90e-09			7.90e-09	
123678-HxCDF	Manufacturer's waste - aluminized propellant with diesel	9.50e-09			9.50e-09	
2-Chlorophenol	Propellant, ammonium perchlorate, nonaluminized	1.00e-05	1.00e-05		1.00e-05	1.00e-05

Appendix E
Emission Factors for Detonations

SPECIAL NOTES:

The emission factors in this database apply primarily to unconfined, ground level detonations of bulk and assembled energetic materials. They do not apply confined or otherwise suppressed detonations, except for the emission factors for the water-suppressed detonations of tritonal and amatol.

A value of 0.00e+00 means that the compound (analyte) was either not detected, or, was detected at only the background level. Values of 0.00e+00 were not used in calculating the average (AVG) emission factors in the database. A blank cell means that either no sample was collected or that the sample collected was either lost or not valid.

The emission factors in this table are unitless. The user can convert them to any mass units desired (e.g., grams compound per gram NEW). A value e-06 means that the quantity in the numerator is to be multiplied by 10 to the -6 power. For example, 1.1e-06 could be written as either 1.1 x 10^{-6} g/g NEW or 1 microgram/g NEW.

COMPOUND	ITEM	EMISSION FACTORS				
		TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE	UNCORR
cis-2-Pentene	Amatol	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Amatol surrogate with water	6.30e-06	1.10e-05	7.80e-06	8.50e-06	9.10e-06
cis-2-Pentene	Cartridge, Impulse, ARD 446-1	7.80e-07	2.60e-07	5.00e-07	5.10e-07	8.70e-07
cis-2-Pentene	Cartridge, Impulse, BBU-36/B	2.70e-07	2.80e-07	5.60e-07	3.70e-07	9.00e-07
cis-2-Pentene	Cartridge, Impulse, MK 107	2.60e-07	2.60e-07	2.60e-07	2.60e-07	2.60e-07
cis-2-Pentene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Detonating train	5.80e-07	3.00e-07	3.00e-07	3.90e-07	9.10e-07
cis-2-Pentene	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	3.40e-07	3.40e-07	3.40e-07
cis-2-Pentene	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	9.70e-07	4.80e-07	6.50e-07	6.50e-07
cis-2-Pentene	Fuze, Tail Bomb FMU-54 A/B	5.90e-07	8.90e-07	0.00e+00	7.40e-07	9.30e-07
cis-2-Pentene	Gas Generator, GGU-2/A	5.90e-07	1.20e-06	6.10e-07	7.90e-07	9.90e-07
cis-2-Pentene	HBX surrogate	3.70e-07	4.10e-07	0.00e+00	3.90e-07	3.80e-07
cis-2-Pentene	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	Signal, Illumination, Red Star AN-M43A2	3.50e-07	3.50e-07	3.50e-07	3.50e-07	3.50e-07
cis-2-Pentene	Signal, Illumination, Red Star M158	3.50e-07	3.50e-07	0.00e+00	3.50e-07	3.50e-07
cis-2-Pentene	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.70e-07
cis-2-Pentene	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	3.60e-07
cis-2-Pentene	Tritonal surrogate with water	2.30e-06	3.70e-06	3.40e-06	3.10e-06	3.30e-06
cis-2-Pentene	TNT (ACC1)	4.60e-07	0.00e+00	0.00e+00	4.60e-07	4.60e-07
cis-2-Pentene	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
cis-2-Pentene	T45E7 Adapter Booster	3.00e-06	2.40e-06	2.90e-06	2.70e-06	2.70e-06
cis-2-Pentene	20 mm HEI Cartridge	0.00e+00	0.00e+00	6.80e-07	6.80e-07	6.80e-07
cis-2-Pentene	40 mm HEI Cartridge	8.30e-07	0.00e+00	0.00e+00	8.30e-07	3.30e-06
i-Butane	Amatol surrogate	7.50e-07	7.50e-07	3.70e-07	6.20e-07	6.20e-07
i-Butane	Amatol surrogate with water	6.70e-06	6.30e-06	6.30e-06	6.40e-06	7.50e-06
i-Butane	Cartridge, Impulse, ARD 446-1	0.00e+00	2.60e-07	2.50e-06	1.40e-06	5.10e-06
i-Butane	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.10e-06
i-Butane	Cartridge, Impulse, MK 107	0.00e+00	1.10e-06	0.00e+00	1.10e-06	1.90e-06
i-Butane	Composition B surrogate	3.70e-07	3.70e-07	0.00e+00	3.70e-07	3.70e-07
i-Butane	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	6.00e-06
i-Butane	Flare, IR Countermeasure M206	6.60e-07	0.00e+00	0.00e+00	6.60e-07	5.00e-06
i-Butane	Fuze, Tail Bomb FMU-139 A/B	2.00e-06	3.90e-06	9.70e-07	2.30e-06	3.90e-06
i-Butane	Fuze, Tail Bomb FMU-54 A/B	3.00e-07	3.00e-07	0.00e+00	3.00e-07	3.70e-06
i-Butane	Gas Generator, GGU-2/A	1.20e-06	5.90e-07	0.00e+00	8.80e-07	9.50e-06
i-Butane	HBX surrogate	7.30e-07	0.00e+00	3.70e-07	5.50e-07	9.20e-07
i-Butane	Mine, Claymore, M18A1	4.90e-07	9.80e-07	0.00e+00	7.30e-07	2.40e-06
i-Butane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	3.50e-07	0.00e+00	3.50e-07	3.10e-06

i-Butane	Signal, Illumination, Red Star M158	2.10e-06	1.80e-06	6.90e-07	1.50e-06	5.70e-06
i-Butane	Tritonal surrogate	7.40e-07	0.00e+00	3.60e-07	5.50e-07	5.50e-07
i-Butane	Tritonal surrogate with calcium stearate		0.00e+00	7.30e-07	7.30e-07	9.10e-07
i-Butane	Tritonal surrogate with water	4.10e-06	4.40e-06	4.10e-06	4.20e-06	4.60e-06
i-Butane	TNT (ACC1)	4.60e-07	0.00e+00	0.00e+00	4.60e-07	4.60e-07
i-Butane	TNT (ACC2)	0.00e+00			0.00e+00	5.20e-06
i-Butane	T45E7 Adapter Booster	0.00e+00	1.20e-06	2.30e-06	1.70e-06	3.50e-06
i-Butane	20 mm HEI Cartridge	7.00e-07	1.40e-06	2.00e-06	1.40e-06	3.90e-06
i-Butane	40 mm HEI Cartridge	0.00e+00	0.00e+00	1.60e-06	1.60e-06	2.90e-06
i-Butene	Amatol surrogate	2.30e-06	0.00e+00	7.40e-07	1.50e-06	1.50e-06
i-Butene	Amatol surrogate with water	1.50e-05	3.10e-05	1.30e-05	2.00e-05	2.00e-05
i-Butene	Cartridge, Impulse, ARD 446-1	2.50e-05	2.00e-05	2.20e-05	2.20e-05	3.20e-05
i-Butene	Cartridge, Impulse, BBU-36/B	2.00e-05	2.10e-05	2.60e-05	2.20e-05	2.20e-05
i-Butene	Cartridge, Impulse, MK 107	6.80e-06	0.00e+00	2.90e-06	4.90e-06	4.90e-06
i-Butene	Composition B surrogate	3.70e-07	7.40e-07	1.80e-06	9.80e-07	9.80e-07
i-Butene	Detonating train	1.00e-05	3.10e-05	3.00e-05	2.40e-05	3.60e-05
i-Butene	Flare, IR Countermeasure M206	2.30e-06	2.40e-06	2.70e-06	2.50e-06	2.50e-06
i-Butene	Fuze, Tail Bomb FMU-139 A/B	5.40e-06	5.30e-06	5.30e-06	5.30e-06	5.50e-06
i-Butene	Fuze, Tail Bomb FMU-54 A/B	4.40e-06	5.60e-06	4.30e-06	4.80e-06	4.80e-06
i-Butene	Gas Generator, GGU-2/A	0.00e+00	2.90e-06	0.00e+00	2.90e-06	2.90e-06
i-Butene	HBX surrogate	3.70e-06	2.50e-06	4.50e-06	3.50e-06	3.50e-06
i-Butene	Mine, Claymore, M18A1	3.40e-06	3.40e-06	4.20e-06	3.70e-06	5.10e-06
i-Butene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	2.80e-06	3.50e-06	3.10e-06	3.30e-06
i-Butene	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	4.50e-06	4.50e-06	4.50e-06
i-Butene	Tritonal surrogate	3.00e-06	3.70e-07	7.30e-07	1.40e-06	1.40e-06
i-Butene	Tritonal surrogate with calcium stearate		2.60e-06	1.50e-06	2.00e-06	2.00e-06
i-Butene	Tritonal surrogate with water	1.30e-05	0.00e+00	0.00e+00	1.30e-05	1.30e-05
i-Butene	TNT (ACC1)	3.70e-06	3.40e-06	3.80e-06	3.60e-06	3.60e-06
i-Butene	TNT (ACC2)	1.50e-06			1.50e-06	1.50e-06
i-Butene	T45E7 Adapter Booster	7.30e-05	8.20e-06	1.30e-05	3.10e-05	3.10e-05
i-Butene	20 mm HEI Cartridge	4.10e-05	9.40e-06	1.70e-05	2.20e-05	2.20e-05
i-Butene	40 mm HEI Cartridge	1.20e-05	9.00e-06	4.90e-06	8.80e-06	8.80e-06
i-Pentane	Amatol surrogate	1.50e-06	1.50e-06	0.00e+00	1.50e-06	1.50e-06
i-Pentane	Amatol surrogate with water	1.50e-06	1.10e-05	5.60e-06	6.20e-06	3.70e-05
i-Pentane	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.90e-06
i-Pentane	Cartridge, Impulse, BBU-36/B	0.00e+00	5.60e-07	1.40e-06	9.70e-07	4.10e-06
i-Pentane	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.20e-06
i-Pentane	Composition B surrogate	3.70e-07	0.00e+00	0.00e+00	3.70e-07	7.40e-07
i-Pentane	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.10e-06
i-Pentane	Flare, IR Countermeasure M206	0.00e+00	3.40e-07	0.00e+00	3.40e-07	2.10e-06
i-Pentane	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	4.80e-07	0.00e+00	4.80e-07	1.10e-06

i-Pentane	Fuze, Tail Bomb FMU-54 A/B	2.70e-06	0.00e+00	0.00e+00	2.70e-06	1.00e-05
i-Pentane	Gas Generator, GGU-2/A	0.00e+00	5.90e-07	0.00e+00	5.90e-07	1.10e-05
i-Pentane	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.70e-06
i-Pentane	Mine, Claymore, M18A1	3.90e-06	0.00e+00	0.00e+00	3.90e-06	3.10e-06
i-Pentane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	0.00e+00	0.00e+00	3.50e-07	5.80e-07
i-Pentane	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.20e-06
i-Pentane	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.10e-06
i-Pentane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	4.20e-06
i-Pentane	Tritonal surrogate with water	3.70e-07	3.70e-07	3.70e-07	3.70e-07	4.70e-06
i-Pentane	TNT (ACC1)	1.40e-06	0.00e+00	0.00e+00	1.40e-06	1.20e-06
i-Pentane	TNT (ACC2)	7.40e-07			7.40e-07	1.50e-06
i-Pentane	T45E7 Adapter Booster	1.20e-06	2.90e-06	1.40e-05	6.20e-06	1.10e-05
i-Pentane	20 mm HEI Cartridge	0.00e+00	1.10e-05	1.20e-05	1.20e-05	1.50e-05
i-Pentane	40 mm HEI Cartridge	9.10e-06	0.00e+00	0.00e+00	9.10e-06	1.80e-05
i-Propylbenzene	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Amatol surrogate with water	1.90e-06	3.20e-06	0.00e+00	2.50e-06	3.20e-06
i-Propylbenzene	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	7.50e-07
i-Propylbenzene	Cartridge, Impulse, BBU-36/B	8.20e-07	1.10e-06	8.40e-07	9.20e-07	9.20e-07
i-Propylbenzene	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	5.20e-07	5.20e-07	5.20e-07
i-Propylbenzene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Flare, IR Countermeasure M206	0.00e+00	6.80e-07	1.00e-06	8.50e-07	8.50e-07
i-Propylbenzene	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	3.00e-07	0.00e+00	3.00e-07	7.90e-07
i-Propylbenzene	Gas Generator, GGU-2/A	1.20e-06	0.00e+00	0.00e+00	1.20e-06	8.80e-07
i-Propylbenzene	HBX surrogate	7.30e-07	0.00e+00	3.70e-07	5.50e-07	1.50e-06
i-Propylbenzene	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	Tritonal surrogate	7.40e-07	0.00e+00	1.10e-06	6.10e-07	1.70e-06
i-Propylbenzene	Tritonal surrogate with calcium stearate		0.00e+00	7.30e-07	7.30e-07	7.30e-07
i-Propylbenzene	Tritonal surrogate with water	0.00e+00	0.00e+00	1.10e-06	1.10e-06	1.90e-06
i-Propylbenzene	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
i-Propylbenzene	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
m-Ethyltoluene	Amatol surrogate	0.00e+00	3.70e-07	0.00e+00	3.70e-07	1.50e-05
m-Ethyltoluene	Amatol surrogate with water	1.50e-06	1.90e-06	1.50e-06	1.60e-06	3.80e-05
m-Ethyltoluene	Cartridge, Impulse, ARD 446-1	5.20e-07	2.60e-07	7.50e-07	5.10e-07	3.00e-06
m-Ethyltoluene	Cartridge, Impulse, BBU-36/B	1.10e-06	1.40e-06	5.60e-07	1.00e-06	4.20e-06

m-Ethyltoluene	Cartridge, Impulse, MK 107	0.00e+00	7.90e-07	5.20e-07	6.60e-07	1.20e-06
m-Ethyltoluene	Composition B surrogate	0.00e+00	3.70e-07	3.60e-07	3.70e-07	1.90e-05
m-Ethyltoluene	Detonating train	0.00e+00	3.00e-07	3.00e-07	3.00e-07	3.20e-06
m-Ethyltoluene	Flare, IR Countermeasure M206	3.30e-07	0.00e+00	3.40e-07	3.40e-07	7.90e-07
m-Ethyltoluene	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	9.70e-07	0.00e+00	9.70e-07	1.30e-06
m-Ethyltoluene	Fuze, Tail Bomb FMU-54 A/B	3.00e-07	3.00e-07	6.10e-07	4.00e-07	1.30e-06
m-Ethyltoluene	Gas Generator, GGU-2/A	0.00e+00	5.90e-07	0.00e+00	5.90e-07	2.80e-06
m-Ethyltoluene	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.50e-05
m-Ethyltoluene	Mine, Claymore, M18A1	6.80e-06	3.40e-06	6.60e-06	5.60e-06	6.60e-06
m-Ethyltoluene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.80e-07
m-Ethyltoluene	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	3.50e-07	3.50e-07	8.10e-07
m-Ethyltoluene	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.20e-05
m-Ethyltoluene	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	3.70e-05
m-Ethyltoluene	Tritonal surrogate with water	1.50e-06	0.00e+00	7.50e-07	1.10e-06	4.70e-05
m-Ethyltoluene	TNT (ACC1)	0.00e+00	4.80e-07	4.80e-07	4.80e-07	1.70e-06
m-Ethyltoluene	TNT (ACC2)	0.00e+00			0.00e+00	1.10e-06
m-Ethyltoluene	T45E7 Adapter Booster	1.80e-06	2.90e-06	2.90e-06	2.50e-06	2.50e-06
m-Ethyltoluene	20 mm HEI Cartridge	1.40e-06	4.30e-06	5.40e-06	3.70e-06	7.10e-06
m-Ethyltoluene	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.80e-06
n-Butane	Amatol surrogate	7.50e-07	7.50e-07	3.70e-07	6.20e-07	6.20e-07
n-Butane	Amatol surrogate with water	3.80e-05	6.80e-05	4.90e-05	5.20e-05	6.30e-05
n-Butane	Cartridge, Impulse, ARD 446-1	1.50e-06	2.30e-06	2.70e-06	2.20e-06	4.80e-06
n-Butane	Cartridge, Impulse, BBU-36/B	5.40e-06	3.60e-06	5.30e-06	4.80e-06	4.80e-06
n-Butane	Cartridge, Impulse, MK 107	0.00e+00	5.30e-07	7.90e-07	6.60e-07	3.10e-06
n-Butane	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.70e-07
n-Butane	Detonating train	3.80e-06	3.30e-06	2.10e-06	3.10e-06	1.00e-05
n-Butane	Flare, IR Countermeasure M206	3.30e-07	6.80e-07	6.80e-07	5.70e-07	5.10e-06
n-Butane	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	1.90e-06	4.40e-06	2.40e-06	5.20e-06
n-Butane	Fuze, Tail Bomb FMU-54 A/B	3.00e-06	2.10e-06	0.00e+00	2.50e-06	1.90e-05
n-Butane	Gas Generator, GGU-2/A	3.50e-06	2.90e-06	0.00e+00	3.20e-06	3.50e-05
n-Butane	HBX surrogate	7.30e-07	4.10e-07	3.70e-07	5.00e-07	8.90e-07
n-Butane	Mine, Claymore, M18A1	2.90e-06	1.50e-06	9.40e-07	1.80e-06	6.60e-06
n-Butane	Signal, Illumination, Red Star AN-M43A2	2.80e-06	2.40e-06	1.40e-06	2.20e-06	4.10e-06
n-Butane	Signal, Illumination, Red Star M158	3.50e-07	2.10e-06	0.00e+00	1.20e-06	7.10e-06
n-Butane	Tritonal surrogate	1.90e-06	0.00e+00	3.60e-07	1.30e-06	1.40e-06
n-Butane	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-07	3.60e-07	9.20e-07
n-Butane	Tritonal surrogate with water	8.60e-06	1.80e-05	1.80e-05	1.50e-05	1.60e-05
n-Butane	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.30e-06
n-Butane	TNT (ACC2)	0.00e+00			0.00e+00	7.40e-07
n-Butane	T45E7 Adapter Booster	5.30e-06	6.50e-06	1.60e-05	9.10e-06	1.60e-05
n-Butane	20 mm HEI Cartridge	2.10e-06	7.20e-06	1.30e-05	7.40e-06	1.40e-05

n-Butane	40 mm HEI Cartridge	1.70e-06	8.20e-07	1.60e-06	1.40e-06	1.10e-05
n-Decane	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.70e-07
n-Decane	Amatol surrogate with water	1.10e-06	1.30e-06	1.90e-06	1.40e-06	3.50e-06
n-Decane	Cartridge, Impulse, ARD 446-1	2.60e-07	5.10e-07	2.50e-07	3.40e-07	8.70e-07
n-Decane	Cartridge, Impulse, BBU-36/B	3.50e-06	3.90e-06	5.30e-06	4.20e-06	9.10e-06
n-Decane	Cartridge, Impulse, MK 107	2.60e-07	2.60e-07	2.60e-07	2.60e-07	6.40e-07
n-Decane	Composition B surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	4.90e-07
n-Decane	Detonating train	0.00e+00	9.00e-07	3.00e-07	6.00e-07	1.80e-06
n-Decane	Flare, IR Countermeasure M206	3.30e-07	3.40e-07	3.40e-07	3.40e-07	4.50e-07
n-Decane	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	9.70e-07	1.50e-06	1.10e-06	1.30e-06
n-Decane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.00e-07
n-Decane	Gas Generator, GGU-2/A	5.90e-07	5.90e-07	6.10e-07	6.00e-07	1.20e-06
n-Decane	HBX surrogate	3.70e-07	0.00e+00	0.00e+00	3.70e-07	6.40e-07
n-Decane	Mine, Claymore, M18A1	3.90e-06	1.00e-05	1.60e-05	1.00e-05	1.30e-05
n-Decane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	7.00e-07	0.00e+00	5.20e-07	4.60e-07
n-Decane	Signal, Illumination, Red Star M158	7.00e-07	3.50e-07	6.90e-07	5.80e-07	8.10e-07
n-Decane	Tritonal surrogate	0.00e+00	3.70e-07	3.60e-07	3.70e-07	6.10e-07
n-Decane	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-07	3.60e-07	5.50e-07
n-Decane	Tritonal surrogate with water	0.00e+00	0.00e+00	1.10e-06	1.10e-06	1.70e-06
n-Decane	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.00e-05
n-Decane	TNT (ACC2)	0.00e+00			0.00e+00	3.70e-07
n-Decane	T45E7 Adapter Booster	1.20e-06	0.00e+00	0.00e+00	1.20e-06	1.40e-05
n-Decane	20 mm HEI Cartridge	4.90e-06	5.00e-06	9.50e-06	6.50e-06	2.90e-05
n-Decane	40 mm HEI Cartridge	5.00e-06	2.50e-06	8.20e-06	5.20e-06	4.20e-05
n-Heptane	Amatol surrogate	1.10e-06	3.70e-07	7.40e-07	7.50e-07	1.60e-06
n-Heptane	Amatol surrogate with water	5.90e-06	1.30e-05	7.40e-06	8.70e-06	1.20e-05
n-Heptane	Cartridge, Impulse, ARD 446-1	1.50e-06	1.50e-06	2.20e-06	1.80e-06	4.30e-06
n-Heptane	Cartridge, Impulse, BBU-36/B	1.60e-06	1.70e-06	1.10e-06	1.50e-06	4.70e-06
n-Heptane	Cartridge, Impulse, MK 107	1.00e-06	1.10e-06	1.00e-06	1.00e-06	1.90e-06
n-Heptane	Composition B surrogate	0.00e+00	3.70e-07	1.10e-06	7.30e-07	1.20e-06
n-Heptane	Detonating train	8.70e-07	1.50e-06	1.80e-06	1.40e-06	5.00e-06
n-Heptane	Flare, IR Countermeasure M206	3.30e-07	3.40e-07	6.80e-07	4.50e-07	1.00e-06
n-Heptane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	9.70e-07	4.80e-07	6.50e-07	1.10e-06
n-Heptane	Fuze, Tail Bomb FMU-54 A/B	5.90e-07	5.90e-07	0.00e+00	5.90e-07	1.50e-06
n-Heptane	Gas Generator, GGU-2/A	5.90e-07	5.90e-07	1.20e-06	8.00e-07	2.80e-06
n-Heptane	HBX surrogate	7.30e-07	0.00e+00	3.70e-07	5.50e-07	3.30e-06
n-Heptane	Mine, Claymore, M18A1	2.90e-06	3.40e-06	4.70e-06	3.70e-06	5.60e-06
n-Heptane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	1.10e-06	3.50e-07	5.80e-07	1.00e-06
n-Heptane	Signal, Illumination, Red Star M158	1.10e-06	7.00e-07	1.00e-06	9.30e-07	1.60e-06
n-Heptane	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	4.30e-06
n-Heptane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	4.20e-06

n-Heptane	Tritonal surrogate with water	2.30e-06	1.80e-06	5.60e-06	3.20e-06	9.50e-06
n-Heptane	TNT (ACC1)	4.60e-07	1.40e-06	0.00e+00	9.50e-07	5.50e-06
n-Heptane	TNT (ACC2)	3.70e-07			3.70e-07	1.50e-06
n-Heptane	T45E7 Adapter Booster	3.60e-06	1.80e-06	4.60e-06	3.30e-06	8.00e-06
n-Heptane	20 mm HEI Cartridge	2.10e-06	5.00e-06	8.90e-06	5.30e-06	1.50e-05
n-Heptane	40 mm HEI Cartridge	5.00e-06	0.00e+00	0.00e+00	5.00e-06	2.20e-05
n-Hexane	Amatol surrogate	0.00e+00	3.70e-07	7.40e-07	5.60e-07	9.90e-07
n-Hexane	Amatol surrogate with water	7.10e-06	1.50e-05	1.10e-05	1.10e-05	1.60e-05
n-Hexane	Cartridge, Impulse, ARD 446-1	1.50e-06	1.50e-06	1.50e-06	1.50e-06	4.00e-06
n-Hexane	Cartridge, Impulse, BBU-36/B	1.60e-06	1.40e-06	2.20e-06	1.70e-06	5.40e-06
n-Hexane	Cartridge, Impulse, MK 107	2.60e-07	7.90e-07	5.20e-07	5.30e-07	1.40e-06
n-Hexane	Composition B surrogate	0.00e+00	7.40e-07	3.60e-07	5.50e-07	1.20e-06
n-Hexane	Detonating train	1.50e-06	1.50e-06	2.40e-06	1.80e-06	5.80e-06
n-Hexane	Flare, IR Countermeasure M206	6.60e-07	6.80e-07	6.80e-07	6.80e-07	1.20e-06
n-Hexane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	9.70e-07	4.80e-07	6.50e-07	1.10e-06
n-Hexane	Fuze, Tail Bomb FMU-54 A/B	3.00e-07	5.90e-07	0.00e+00	4.40e-07	1.30e-06
n-Hexane	Gas Generator, GGU-2/A	1.20e-06	1.20e-06	6.10e-07	9.90e-07	3.20e-06
n-Hexane	HBX surrogate	7.30e-07	0.00e+00	3.70e-07	5.50e-07	4.70e-06
n-Hexane	Mine, Claymore, M18A1	2.00e-06	1.50e-06	4.70e-07	1.30e-06	3.20e-06
n-Hexane	Signal, Illumination, Red Star AN-M43A2	6.90e-07	1.10e-06	6.90e-07	8.10e-07	1.30e-06
n-Hexane	Signal, Illumination, Red Star M158	1.40e-06	1.10e-06	6.90e-07	1.10e-06	1.90e-06
n-Hexane	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	7.00e-06
n-Hexane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	6.80e-06
n-Hexane	Tritonal surrogate with water	1.90e-06	1.50e-06	4.50e-06	2.60e-06	1.30e-05
n-Hexane	TNT (ACC1)	1.40e-06	4.80e-07	0.00e+00	9.30e-07	3.30e-06
n-Hexane	TNT (ACC2)	0.00e+00			0.00e+00	1.10e-06
n-Hexane	T45E7 Adapter Booster	3.00e-06	4.70e-06	9.80e-06	5.80e-06	9.90e-06
n-Hexane	20 mm HEI Cartridge	1.40e-06	3.60e-06	5.40e-06	3.50e-06	1.30e-05
n-Hexane	40 mm HEI Cartridge	1.90e-05	0.00e+00	0.00e+00	1.90e-05	3.50e-05
n-Nonane	Amatol surrogate	3.70e-07	3.70e-07	0.00e+00	3.70e-07	3.70e-07
n-Nonane	Amatol surrogate with water	2.20e-06	4.40e-06	3.00e-06	3.20e-06	3.70e-06
n-Nonane	Cartridge, Impulse, ARD 446-1	2.60e-07	7.70e-07	7.50e-07	5.90e-07	1.40e-06
n-Nonane	Cartridge, Impulse, BBU-36/B	2.70e-06	3.60e-06	3.30e-06	3.20e-06	6.90e-06
n-Nonane	Cartridge, Impulse, MK 107	0.00e+00	2.60e-07	7.90e-07	5.20e-07	9.60e-07
n-Nonane	Composition B surrogate	2.20e-06	3.70e-07	0.00e+00	1.30e-06	1.20e-06
n-Nonane	Detonating train	5.80e-07	9.00e-07	9.00e-07	7.90e-07	2.00e-06
n-Nonane	Flare, IR Countermeasure M206	6.60e-07	6.80e-07	6.80e-07	6.80e-07	9.00e-07
n-Nonane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	4.80e-07	0.00e+00	4.90e-07	7.30e-07
n-Nonane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	1.20e-06	1.20e-06	9.40e-07
n-Nonane	Gas Generator, GGU-2/A	5.90e-07	5.90e-07	0.00e+00	5.90e-07	1.20e-06
n-Nonane	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.20e-07

n-Nonane	Mine, Claymore, M18A1	4.90e-07	1.50e-06	1.90e-06	1.30e-06	1.80e-06
n-Nonane	Signal, Illumination, Red Star AN-M43A2	1.00e-06	3.50e-07	0.00e+00	7.00e-07	9.30e-07
n-Nonane	Signal, Illumination, Red Star M158	1.10e-06	7.00e-07	1.00e-06	9.30e-07	1.30e-06
n-Nonane	Tritonal surrogate	3.40e-06	0.00e+00	3.60e-07	1.20e-06	1.60e-06
n-Nonane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	5.50e-07
n-Nonane	Tritonal surrogate with water	0.00e+00	7.30e-07	7.50e-07	7.40e-07	1.50e-06
n-Nonane	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.40e-06
n-Nonane	TNT (ACC2)	0.00e+00			0.00e+00	3.70e-07
n-Nonane	T45E7 Adapter Booster	1.80e-06	5.90e-07	1.70e-06	1.40e-06	2.50e-06
n-Nonane	20 mm HEI Cartridge	7.00e-07	0.00e+00	6.80e-07	6.90e-07	3.60e-06
n-Nonane	40 mm HEI Cartridge	1.70e-06	1.70e-06	2.50e-06	1.90e-06	4.80e-06
n-Octane	Amatol surrogate	0.00e+00	3.70e-07	3.70e-07	3.70e-07	6.20e-07
n-Octane	Amatol surrogate with water	3.30e-06	7.00e-06	4.40e-06	4.90e-06	5.80e-06
n-Octane	Cartridge, Impulse, ARD 446-1	5.20e-07	1.00e-06	0.00e+00	7.70e-07	1.40e-06
n-Octane	Cartridge, Impulse, BBU-36/B	1.40e-06	2.80e-07	1.90e-06	1.20e-06	4.00e-06
n-Octane	Cartridge, Impulse, MK 107	5.30e-07	5.30e-07	2.60e-07	4.40e-07	7.70e-07
n-Octane	Composition B surrogate	3.70e-07	3.70e-07	3.60e-07	3.70e-07	7.40e-07
n-Octane	Detonating train	0.00e+00	1.50e-06	0.00e+00	1.50e-06	2.70e-06
n-Octane	Flare, IR Countermeasure M206	1.00e-06	3.40e-07	0.00e+00	6.70e-07	7.80e-07
n-Octane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	4.80e-07	0.00e+00	4.90e-07	9.70e-07
n-Octane	Fuze, Tail Bomb FMU-54 A/B	3.00e-07	3.00e-07	6.10e-07	4.00e-07	1.10e-06
n-Octane	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	1.20e-06	1.20e-06	1.80e-06
n-Octane	HBX surrogate	1.10e-06	0.00e+00	3.70e-07	7.30e-07	1.80e-06
n-Octane	Mine, Claymore, M18A1	2.00e-06	7.80e-06	1.20e-05	7.20e-06	9.10e-06
n-Octane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	3.50e-07	0.00e+00	3.50e-07	5.80e-07
n-Octane	Signal, Illumination, Red Star M158	1.40e-06	1.10e-06	6.90e-07	1.10e-06	1.40e-06
n-Octane	Tritonal surrogate	3.70e-07	0.00e+00	3.60e-07	3.70e-07	1.70e-06
n-Octane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	1.50e-06
n-Octane	Tritonal surrogate with water	1.50e-06	1.50e-06	2.20e-06	1.70e-06	3.70e-06
n-Octane	TNT (ACC1)	0.00e+00	2.90e-06	0.00e+00	2.90e-06	1.00e-05
n-Octane	TNT (ACC2)	0.00e+00			0.00e+00	7.40e-07
n-Octane	T45E7 Adapter Booster	2.40e-06	0.00e+00	1.20e-06	1.80e-06	8.80e-06
n-Octane	20 mm HEI Cartridge	4.90e-06	7.90e-06	1.60e-05	9.50e-06	2.50e-05
n-Octane	40 mm HEI Cartridge	2.50e-06	8.20e-07	7.40e-06	3.60e-06	2.90e-05
n-Pentane	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	6.20e-07
n-Pentane	Amatol surrogate with water	1.30e-05	2.30e-05	1.50e-05	1.70e-05	2.40e-05
n-Pentane	Cartridge, Impulse, ARD 446-1	7.80e-07	1.30e-06	1.30e-06	1.10e-06	4.00e-06
n-Pentane	Cartridge, Impulse, BBU-36/B	1.10e-06	1.10e-06	1.40e-06	1.20e-06	5.20e-06
n-Pentane	Cartridge, Impulse, MK 107	0.00e+00	2.60e-07	2.60e-07	2.60e-07	1.50e-06
n-Pentane	Composition B surrogate	3.70e-07	0.00e+00	3.60e-07	3.70e-07	7.40e-07
n-Pentane	Detonating train	5.80e-07	1.20e-06	1.20e-06	1.00e-06	6.10e-06

n-Pentane	Flare, IR Countermeasure M206	0.00e+00	6.80e-07	3.40e-07	5.10e-07	1.50e-06
n-Pentane	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	1.50e-06	4.80e-07	9.70e-07	1.90e-06
n-Pentane	Fuze, Tail Bomb FMU-54 A/B	3.00e-07	5.90e-07	0.00e+00	4.40e-07	3.70e-06
n-Pentane	Gas Generator, GGU-2/A	1.20e-06	1.20e-06	0.00e+00	1.20e-06	4.80e-06
n-Pentane	HBX surrogate	7.30e-07	0.00e+00	7.40e-07	7.40e-07	2.30e-06
n-Pentane	Mine, Claymore, M18A1	4.40e-06	8.80e-06	1.40e-05	9.10e-06	1.30e-05
n-Pentane	Signal, Illumination, Red Star AN-M43A2	3.50e-07	7.00e-07	6.90e-07	5.80e-07	1.20e-06
n-Pentane	Signal, Illumination, Red Star M158	7.00e-07	7.00e-07	3.50e-07	5.80e-07	2.10e-06
n-Pentane	Tritonal surrogate	0.00e+00	0.00e+00	7.30e-07	7.30e-07	3.80e-06
n-Pentane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	3.30e-06
n-Pentane	Tritonal surrogate with water	1.10e-06	0.00e+00	6.70e-06	3.90e-06	5.50e-06
n-Pentane	TNT (ACC1)	1.80e-06	4.80e-06	0.00e+00	3.30e-06	1.10e-05
n-Pentane	TNT (ACC2)	3.70e-07			3.70e-07	1.90e-06
n-Pentane	T45E7 Adapter Booster	3.60e-06	1.80e-06	9.80e-06	5.00e-06	1.60e-05
n-Pentane	20 mm HEI Cartridge	5.60e-06	1.20e-05	2.20e-05	1.30e-05	3.20e-05
n-Pentane	40 mm HEI Cartridge	1.30e-05	0.00e+00	0.00e+00	1.30e-05	5.20e-05
p-Ethyltoluene	Amatol surrogate	0.00e+00	6.00e-06	9.30e-06	7.60e-06	1.10e-05
p-Ethyltoluene	Amatol surrogate with water	2.00e-05	4.00e-05	3.70e-05	3.20e-05	3.80e-05
p-Ethyltoluene	Cartridge, Impulse, BBU-36/B	4.90e-06	5.60e-07	1.40e-06	2.30e-06	9.40e-06
p-Ethyltoluene	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	Composition B surrogate	7.40e-07	7.40e-07	1.50e-06	9.80e-07	3.30e-06
p-Ethyltoluene	Detonating train	8.70e-07	1.50e-06	1.20e-06	1.20e-06	8.20e-06
p-Ethyltoluene	Flare, IR Countermeasure M206	0.00e+00	3.40e-07	6.80e-07	5.10e-07	2.20e-06
p-Ethyltoluene	Fuze, Tail Bomb FMU-139 A/B	2.00e-06	4.80e-07	9.70e-07	1.10e-06	2.30e-06
p-Ethyltoluene	Fuze, Tail Bomb FMU-54 A/B	5.90e-07	5.90e-07	4.60e-06	1.90e-06	4.70e-06
p-Ethyltoluene	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	6.80e-06
p-Ethyltoluene	HBX surrogate	7.30e-07	0.00e+00	0.00e+00	7.30e-07	5.50e-06
p-Ethyltoluene	Mine, Claymore, M18A1	1.50e-05	7.30e-06	2.80e-05	1.70e-05	1.90e-05
p-Ethyltoluene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	7.00e-07	0.00e+00	7.00e-07	1.60e-06
p-Ethyltoluene	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.70e-06
p-Ethyltoluene	Tritonal surrogate	7.40e-06	4.10e-06	1.50e-06	4.30e-06	9.20e-06
p-Ethyltoluene	Tritonal surrogate with calcium stearate		0.00e+00	7.30e-07	7.30e-07	4.60e-06
p-Ethyltoluene	Tritonal surrogate with water	3.90e-05	1.50e-05	2.80e-05	2.70e-05	3.40e-05
p-Ethyltoluene	TNT (ACC1)	4.60e-07	1.90e-06	0.00e+00	1.20e-06	7.70e-06
p-Ethyltoluene	TNT (ACC2)	0.00e+00			0.00e+00	2.60e-06
p-Ethyltoluene	T45E7 Adapter Booster	1.10e-05	9.40e-06	1.20e-05	1.10e-05	1.10e-05
p-Ethyltoluene	20 mm HEI Cartridge	0.00e+00	1.10e-05	1.60e-05	1.40e-05	2.60e-05
p-Ethyltoluene	40 mm HEI Cartridge	7.50e-06	4.10e-06	4.10e-06	5.20e-06	2.60e-05
p-Ethyltoluene	Amatol surrogate	3.70e-07	0.00e+00	0.00e+00	3.70e-07	1.60e-06
p-Ethyltoluene	Amatol surrogate with water	2.20e-06	2.20e-06	1.90e-06	2.10e-06	4.10e-06
p-Ethyltoluene	Cartridge, Impulse, ARD 446-1	1.10e-06	1.10e-06	1.10e-06	1.10e-06	4.20e-06

p-Ethyltoluene	Cartridge, Impulse, BBU-36/B	2.30e-06	1.20e-06	1.20e-06	1.60e-06	5.40e-06
p-Ethyltoluene	Cartridge, Impulse, MK 107	0.00e+00	1.10e-06	1.10e-06	1.10e-06	1.10e-06
p-Ethyltoluene	Composition B surrogate	7.40e-07	3.70e-07	1.10e-06	7.40e-07	2.60e-06
p-Ethyltoluene	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.90e-06
p-Ethyltoluene	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.50e-06
p-Ethyltoluene	Fuze, Tail Bomb FMU-139 A/B	2.10e-06	0.00e+00	0.00e+00	2.10e-06	2.10e-06
p-Ethyltoluene	Fuze, Tail Bomb FMU-54 A/B	1.30e-06	2.60e-06	1.30e-06	1.70e-06	2.90e-06
p-Ethyltoluene	Gas Generator, GGU-2/A	2.50e-06	5.10e-06	0.00e+00	3.80e-06	4.20e-06
p-Ethyltoluene	HBX surrogate	3.70e-07	0.00e+00	7.40e-07	5.60e-07	4.80e-06
p-Ethyltoluene	Mine, Claymore, M18A1	4.20e-06			4.20e-06	4.20e-06
p-Ethyltoluene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	1.50e-06	0.00e+00	1.50e-06	1.50e-06
p-Ethyltoluene	Signal, Illumination, Red Star M158	0.00e+00	1.50e-06	0.00e+00	1.50e-06	1.50e-06
p-Ethyltoluene	Tritonal surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	3.30e-06
p-Ethyltoluene	Tritonal surrogate with calcium stearate		3.70e-07	0.00e+00	3.70e-07	4.20e-06
p-Ethyltoluene	Tritonal surrogate with water	1.10e-06	0.00e+00	0.00e+00	1.10e-06	4.70e-06
p-Ethyltoluene	TNT (ACC1)	0.00e+00			0.00e+00	2.00e-06
p-Ethyltoluene	TNT (ACC2)	0.00e+00			0.00e+00	1.60e-06
p-Ethyltoluene	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
p-Ethyltoluene	20 mm HEI Cartridge	0.00e+00			0.00e+00	4.10e-06
p-Ethyltoluene	40 mm HEI Cartridge	0.00e+00			0.00e+00	9.50e-06
trans-2-Butene	Amatol surrogate	0.00e+00	0.00e+00	1.50e-06	1.50e-06	1.50e-06
trans-2-Butene	Amatol surrogate with water	2.40e-05	4.60e-05	3.40e-05	3.50e-05	3.50e-05
trans-2-Butene	Cartridge, Impulse, ARD 446-1	1.00e-05	7.70e-06	7.20e-06	8.30e-06	8.30e-06
trans-2-Butene	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Cartridge, Impulse, MK 107	1.00e-05	8.20e-06	7.10e-06	8.40e-06	8.40e-06
trans-2-Butene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Butene	Detonating train	4.70e-06	2.70e-06	4.80e-06	4.00e-06	4.00e-06
trans-2-Butene	Flare, IR Countermeasure M206	3.00e-06	2.70e-06	2.70e-06	2.80e-06	2.80e-06
trans-2-Butene	Fuze, Tail Bomb FMU-139 A/B	1.20e-05	1.30e-05	1.40e-05	1.30e-05	1.30e-05
trans-2-Butene	Fuze, Tail Bomb FMU-54 A/B	5.90e-06	9.50e-06	7.90e-06	7.80e-06	1.10e-05
trans-2-Butene	Gas Generator, GGU-2/A	1.40e-05	1.50e-05	1.60e-05	1.50e-05	1.50e-05
trans-2-Butene	HBX surrogate	4.00e-06	2.50e-06	7.10e-06	4.50e-06	4.50e-06
trans-2-Butene	Mine, Claymore, M18A1	1.50e-05	1.90e-05	2.10e-05	1.80e-05	1.80e-05
trans-2-Butene	Signal, Illumination, Red Star AN-M43A2	6.90e-06	9.10e-06	7.30e-06	7.80e-06	7.80e-06
trans-2-Butene	Signal, Illumination, Red Star M158	5.30e-06	6.00e-06	4.80e-06	5.40e-06	5.40e-06
trans-2-Butene	Tritonal surrogate	0.00e+00	1.90e-06	1.10e-06	1.50e-06	1.50e-06
trans-2-Butene	Tritonal surrogate with calcium stearate		2.90e-06	7.30e-07	1.80e-06	1.80e-06
trans-2-Butene	Tritonal surrogate with water	4.10e-05	2.80e-05	4.60e-05	3.80e-05	3.80e-05
trans-2-Butene	TNT (ACC1)	9.20e-07	9.60e-07	9.60e-07	9.50e-07	9.50e-07
trans-2-Butene	TNT (ACC2)	7.40e-07			7.40e-07	7.40e-07
trans-2-Butene	T45E7 Adapter Booster	2.60e-05	1.80e-05	1.60e-05	2.00e-05	2.00e-05

trans-2-Butene	20 mm HEI Cartridge	1.10e-05	7.20e-06	1.00e-05	9.50e-06	9.50e-06
trans-2-Butene	40 mm HEI Cartridge	2.50e-06	1.70e-06	1.60e-06	1.90e-06	1.90e-06
trans-2-Pentene	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Amatol surrogate with water	8.50e-06	1.70e-05	1.20e-05	1.20e-05	1.30e-05
trans-2-Pentene	Cartridge, Impulse, ARD 446-1	5.20e-07	7.70e-07	5.00e-07	6.00e-07	1.20e-06
trans-2-Pentene	Cartridge, Impulse, BBU-36/B	8.20e-07	5.60e-07	5.60e-07	6.40e-07	1.40e-06
trans-2-Pentene	Cartridge, Impulse, MK 107	2.60e-07	2.60e-07	2.60e-07	2.60e-07	2.60e-07
trans-2-Pentene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Detonating train	1.50e-06	9.00e-07	3.00e-07	8.80e-07	2.00e-06
trans-2-Pentene	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.40e-07
trans-2-Pentene	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	3.90e-06	9.70e-07	1.90e-06	1.90e-06
trans-2-Pentene	Fuze, Tail Bomb FMU-54 A/B	5.90e-07	1.20e-06	9.20e-07	9.00e-07	1.60e-06
trans-2-Pentene	Gas Generator, GGU-2/A	2.40e-06	1.20e-06	6.10e-07	1.40e-06	2.00e-06
trans-2-Pentene	HBX surrogate	3.70e-07	0.00e+00	0.00e+00	3.70e-07	3.80e-07
trans-2-Pentene	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	Signal, Illumination, Red Star AN-M43A2	3.50e-07	7.00e-07	3.50e-07	4.60e-07	4.60e-07
trans-2-Pentene	Signal, Illumination, Red Star M158	7.00e-07	1.40e-06	3.50e-07	8.20e-07	9.30e-07
trans-2-Pentene	Tritonal surrogate	3.70e-07	3.70e-07	0.00e+00	3.70e-07	8.60e-07
trans-2-Pentene	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-07	3.60e-07	7.30e-07
trans-2-Pentene	Tritonal surrogate with water	2.30e-06	3.30e-06	3.70e-06	3.10e-06	3.60e-06
trans-2-Pentene	TNT (ACC1)	4.60e-07	0.00e+00	0.00e+00	4.60e-07	4.60e-07
trans-2-Pentene	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
trans-2-Pentene	T45E7 Adapter Booster	4.20e-06	4.10e-06	4.00e-06	4.10e-06	4.10e-06
trans-2-Pentene	20 mm HEI Cartridge	0.00e+00	1.40e-06	1.40e-06	1.40e-06	1.40e-06
trans-2-Pentene	40 mm HEI Cartridge	5.00e-06	0.00e+00	0.00e+00	5.00e-06	1.10e-05
Acetylene	Amatol surrogate	1.90e-04	4.60e-05	5.40e-05	9.60e-05	9.70e-05
Acetylene	Amatol surrogate with water	7.60e-05	1.30e-04	2.20e-04	1.40e-04	1.40e-04
Acetylene	Cartridge, Impulse, ARD 446-1	2.80e-04	1.90e-04	1.80e-04	2.20e-04	3.20e-04
Acetylene	Cartridge, Impulse, BBU-36/B	1.50e-04	1.30e-04	1.70e-04	1.50e-04	3.00e-04
Acetylene	Cartridge, Impulse, MK 107	2.80e-04	2.50e-04	1.90e-04	2.40e-04	3.50e-04
Acetylene	Composition B surrogate	6.70e-06	8.90e-06	2.70e-05	1.40e-05	1.50e-05
Acetylene	Detonating train	1.80e-04	7.30e-05	1.40e-04	1.30e-04	2.10e-04
Acetylene	Flare, IR Countermeasure M206	2.60e-04	3.10e-04	2.80e-04	2.90e-04	2.90e-04
Acetylene	Fuze, Tail Bomb FMU-139 A/B	5.40e-04	6.60e-04	6.60e-04	6.20e-04	6.20e-04
Acetylene	Fuze, Tail Bomb FMU-54 A/B	3.00e-04	5.70e-04	5.00e-04	4.60e-04	6.10e-04
Acetylene	Gas Generator, GGU-2/A	5.50e-04	6.30e-04	7.30e-04	6.40e-04	6.40e-04
Acetylene	HBX surrogate	1.80e-05	1.80e-05	5.20e-05	2.90e-05	3.00e-05
Acetylene	Mine, Claymore, M18A1	7.70e-04	1.10e-03	1.10e-03	9.80e-04	9.80e-04
Acetylene	Signal, Illumination, Red Star AN-M43A2	2.80e-04	3.50e-04	2.90e-04	3.10e-04	3.10e-04
Acetylene	Signal, Illumination, Red Star M158	2.80e-04	2.80e-04	2.30e-04	2.70e-04	2.70e-04
Acetylene	Tritonal surrogate	2.00e-04	1.30e-04	4.30e-05	1.20e-04	1.30e-04

Acetylene	Tritonal surrogate with calcium stearate		2.10e-05	1.60e-05	1.90e-05	2.00e-05
Acetylene	Tritonal surrogate with water	4.30e-03	4.40e-03	4.50e-03	4.40e-03	4.40e-03
Acetylene	TNT (ACC1)	2.20e-05	1.60e-05	1.40e-05	1.70e-05	1.80e-05
Acetylene	TNT (ACC2)	1.60e-05			1.60e-05	1.70e-05
Acetylene	TNT (Sandia)	5.00e-06	2.40e-06	8.50e-06	5.30e-06	
Acetylene	T45E7 Adapter Booster	7.50e-04	4.50e-04	3.60e-04	5.20e-04	5.30e-04
Acetylene	20 mm HEI Cartridge	2.20e-04	1.30e-04	1.90e-04	1.80e-04	2.50e-04
Acetylene	40 mm HEI Cartridge	5.20e-05	4.30e-05	3.20e-05	4.20e-05	6.40e-05
Allylchloride	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Cartridge, Impulse, BBU-36/B	5.20e-06	1.10e-05	1.10e-05	9.30e-06	9.30e-06
Allylchloride	Cartridge, Impulse, MK 107	1.00e-05	2.90e-06	2.10e-06	5.10e-06	5.10e-06
Allylchloride	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Flare, IR Countermeasure M206	2.10e-05	1.60e-05	1.80e-05	1.80e-05	1.80e-05
Allylchloride	Fuze, Tail Bomb FMU-139 A/B	3.00e-05	3.30e-05	2.80e-05	3.00e-05	3.00e-05
Allylchloride	Fuze, Tail Bomb FMU-54 A/B	2.10e-05	8.30e-06	0.00e+00	1.50e-05	1.50e-05
Allylchloride	Gas Generator, GGU-2/A	9.20e-05	8.80e-05	1.60e-04	1.10e-04	1.10e-04
Allylchloride	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Signal, Illumination, Red Star AN-M43A2	1.60e-05	1.40e-05	2.30e-05	1.80e-05	1.80e-05
Allylchloride	Signal, Illumination, Red Star M158	2.20e-05	1.10e-05	1.40e-05	1.60e-05	1.60e-05
Allylchloride	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Allylchloride	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Aluminum	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Aluminum	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Aluminum	Cartridge, Impulse, ARD 446-1	3.90e-03	3.40e-03	4.30e-03	3.90e-03	6.00e-03
Aluminum	Cartridge, Impulse, BBU-36/B	8.40e-03	1.20e-02	1.30e-02	1.10e-02	2.30e-02
Aluminum	Cartridge, Impulse, MK 107	8.70e-03	9.70e-03	1.00e-02	9.50e-03	1.40e-02
Aluminum	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Aluminum	Detonating train	0.00e+00	9.20e-05	0.00e+00	0.00e+00	3.00e-04
Aluminum	Flare, IR Countermeasure M206	1.90e-02	1.40e-02	1.20e-02	1.50e-02	1.50e-02
Aluminum	Fuze, Tail Bomb FMU-139 A/B	4.00e-02	3.20e-02	3.20e-02	3.40e-02	3.50e-02
Aluminum	Fuze, Tail Bomb FMU-54 A/B	1.00e-02	1.30e-02	1.30e-02	1.20e-02	1.60e-02

Aluminum	Gas Generator, GGU-2/A	6.30e-03	5.60e-03	4.30e-03	5.40e-03	5.80e-03
Aluminum	HBX surrogate	6.10e-03	8.90e-03	1.10e-02	8.60e-03	8.60e-03
Aluminum	Mine, Claymore, M18A1	6.20e-03			6.20e-03	8.60e-04
Aluminum	Signal, Illumination, Red Star AN-M43A2	1.90e-02	1.70e-02	2.10e-02	1.90e-02	1.90e-02
Aluminum	Signal, Illumination, Red Star M158	2.80e-03	1.80e-03	1.80e-03	2.10e-03	2.70e-03
Aluminum	Tritonal surrogate	4.20e-02	1.80e-02	1.60e-02	2.50e-02	2.50e-02
Aluminum	Tritonal surrogate with calcium stearate		1.60e-02	1.70e-02	1.70e-02	1.70e-02
Aluminum	Tritonal surrogate with water	3.10e-03	7.00e-03	8.00e-03	6.00e-03	6.00e-03
Aluminum	TNT (ACC1)	0.00e+00			0.00e+00	0.00e+00
Aluminum	TNT (ACC2)	1.30e-03			1.30e-03	1.30e-03
Aluminum	T45E7 Adapter Booster	8.80e-03			8.80e-03	1.70e-03
Aluminum	20 mm HEI Cartridge	9.60e-04			9.60e-04	7.10e-05
Aluminum	40 mm HEI Cartridge	1.50e-02			1.50e-02	3.90e-03
Antimony	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Cartridge, Impulse, ARD 446-1	1.80e-04	1.60e-04	2.00e-04	1.80e-04	1.80e-04
Antimony	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Fuze, Tail Bomb FMU-139 A/B	2.90e-04	2.20e-04	1.50e-04	2.20e-04	2.20e-04
Antimony	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	TNT (Sandia)	3.20e-07	7.00e-07	1.00e-06	6.70e-07	
Antimony	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Antimony	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Amatol surrogate	0.00e+00	2.40e-05	3.20e-05	6.00e-06	8.00e-06
Barium	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.00e-06
Barium	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Barium	Cartridge, Impulse, MK 107	0.00e+00	2.50e-05	3.70e-05	1.60e-05	1.90e-04
Barium	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Flare, IR Countermeasure M206	1.50e-04	3.10e-04	2.60e-04	2.40e-04	2.40e-04
Barium	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	Mine, Claymore, M18A1	0.00e+00			0.00e+00	0.00e+00
Barium	Signal, Illumination, Red Star AN-M43A2	7.80e-05	7.70e-05	1.80e-04	1.10e-04	1.10e-04
Barium	Signal, Illumination, Red Star M158	2.10e-04	1.60e-04	1.40e-04	1.70e-04	2.60e-04
Barium	Tritonal surrogate	4.70e-04	0.00e+00	1.60e-04	1.60e-04	1.60e-04
Barium	Tritonal surrogate with calcium stearate		3.10e-04	4.10e-04	3.60e-04	3.60e-04
Barium	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Barium	TNT (ACC1)	1.10e-04			1.10e-04	1.10e-04
Barium	TNT (ACC2)	3.60e-04			3.60e-04	3.70e-04
Barium	TNT (Sandia)	7.90e-03	7.70e-03	8.90e-03	8.20e-03	
Barium	T45E7 Adapter Booster	6.10e-04			6.10e-04	6.10e-04
Barium	20 mm HEI Cartridge	0.00e+00			0.00e+00	0.00e+00
Barium	40 mm HEI Cartridge	0.00e+00			0.00e+00	0.00e+00
Benzene	Amatol surrogate	4.20e-05	1.00e-05	1.60e-05	2.30e-05	2.50e-05
Benzene	Amatol surrogate with water	1.90e-04	3.60e-04	2.70e-04	2.70e-04	2.80e-04
Benzene	Cartridge, Impulse, ARD 446-1	7.70e-05	6.30e-05	6.10e-05	6.70e-05	1.00e-04
Benzene	Cartridge, Impulse, BBU-36/B	2.10e-05	1.90e-05	2.30e-05	2.10e-05	4.70e-05
Benzene	Cartridge, Impulse, MK 107	6.90e-05	6.70e-05	5.50e-05	6.40e-05	9.60e-05
Benzene	Composition B surrogate	2.20e-06	2.20e-06	3.30e-06	2.60e-06	5.00e-06
Benzene	Detonating train	2.40e-05	2.30e-05	2.60e-05	2.50e-05	4.60e-05
Benzene	Flare, IR Countermeasure M206	4.60e-05	3.90e-05	5.00e-05	4.50e-05	4.80e-05
Benzene	Fuze, Tail Bomb FMU-139 A/B	1.10e-04	1.20e-04	1.30e-04	1.20e-04	1.20e-04
Benzene	Fuze, Tail Bomb FMU-54 A/B	6.40e-05	1.70e-04	1.00e-04	1.10e-04	1.50e-04
Benzene	Gas Generator, GGU-2/A	1.10e-04	1.30e-04	1.50e-04	1.30e-04	1.40e-04
Benzene	HBX surrogate	6.60e-06	4.50e-06	1.00e-05	7.20e-06	1.40e-05
Benzene	Mine, Claymore, M18A1	5.50e-04	9.40e-04	9.30e-04	8.10e-04	8.10e-04
Benzene	Signal, Illumination, Red Star AN-M43A2	3.00e-05	3.60e-05	3.50e-05	3.40e-05	3.60e-05
Benzene	Signal, Illumination, Red Star M158	3.00e-05	3.40e-05	2.60e-05	3.00e-05	3.30e-05
Benzene	Tritonal surrogate	1.20e-05	3.30e-06	1.50e-06	5.70e-06	1.60e-05
Benzene	Tritonal surrogate with calcium stearate		4.40e-06	1.80e-06	3.10e-06	1.40e-05
Benzene	Tritonal surrogate with water	2.90e-04	1.20e-04	2.10e-04	2.00e-04	2.20e-04
Benzene	TNT (ACC1)	4.60e-06	4.80e-06	2.90e-06	4.10e-06	8.80e-06
Benzene	TNT (ACC2)	4.10e-06			4.10e-06	7.40e-06
Benzene	TNT (Sandia)	1.40e-06	3.30e-06	4.20e-06	3.00e-06	

Benzene	T45E7 Adapter Booster	1.60e-04	1.40e-04	8.00e-05	1.30e-04	1.30e-04
Benzene	20 mm HEI Cartridge	1.50e-04	8.90e-05	9.90e-05	1.10e-04	1.70e-04
Benzene	40 mm HEI Cartridge	2.80e-05	0.00e+00	0.00e+00	2.80e-05	4.90e-05
Cadmium	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Cartridge, Impulse, MK 107	1.00e-03	1.80e-03	1.40e-03	1.40e-03	1.40e-03
Cadmium	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Detonating train	1.10e-05	1.40e-05	7.00e-06	1.10e-05	1.10e-05
Cadmium	Flare, IR Countermeasure M206	4.90e-05	3.00e-05	2.30e-05	3.40e-05	3.50e-05
Cadmium	Fuze, Tail Bomb FMU-139 A/B	2.40e-03	2.10e-03	2.20e-03	2.30e-03	2.30e-03
Cadmium	Fuze, Tail Bomb FMU-54 A/B	1.80e-04	1.50e-04	5.90e-04	3.10e-04	4.10e-04
Cadmium	Gas Generator, GGU-2/A	4.50e-05	2.10e-04	4.90e-05	1.00e-04	1.00e-04
Cadmium	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Mine, Claymore, M18A1	2.40e-04			2.40e-04	2.40e-04
Cadmium	Signal, Illumination, Red Star AN-M43A2	1.30e-04	7.00e-05	6.10e-05	8.80e-05	9.00e-05
Cadmium	Signal, Illumination, Red Star M158	1.30e-03	9.40e-04	1.10e-03	1.10e-03	1.30e-03
Cadmium	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cadmium	TNT (ACC2)	4.00e-05			4.00e-05	4.00e-05
Cadmium	TNT (Sandia)	2.90e-06	2.50e-06	2.80e-06	2.70e-06	
Cadmium	T45E7 Adapter Booster	5.80e-03			5.80e-03	5.80e-03
Cadmium	20 mm HEI Cartridge	8.60e-04			8.60e-04	4.00e-04
Cadmium	40 mm HEI Cartridge	3.20e-05			3.20e-05	3.20e-05
Carbon tetrachloride	Amatol surrogate	3.70e-07	0.00e+00	0.00e+00	3.70e-07	2.10e-06
Carbon tetrachloride	Amatol surrogate with water	3.70e-07	3.70e-07	3.70e-07	3.70e-07	2.20e-06
Carbon tetrachloride	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Composition B surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	2.20e-06
Carbon tetrachloride	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.90e-06
Carbon tetrachloride	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	2.70e-06	0.00e+00	2.70e-06	2.70e-06
Carbon tetrachloride	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.20e-06
Carbon tetrachloride	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.30e-06
Carbon tetrachloride	HBX surrogate	0.00e+00	4.10e-07	3.70e-07	3.90e-07	2.30e-06
Carbon tetrachloride	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.90e-06

Carbon tetrachloride	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.90e-06
Carbon tetrachloride	Tritonal surrogate	0.00e+00	3.70e-07	0.00e+00	3.70e-07	2.00e-06
Carbon tetrachloride	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	1.80e-06
Carbon tetrachloride	Tritonal surrogate with water	3.70e-07	3.70e-07	7.50e-07	4.80e-07	2.40e-06
Carbon tetrachloride	TNT (ACC1)	0.00e+00			0.00e+00	2.50e-06
Carbon tetrachloride	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Carbon tetrachloride	T45E7 Adapter Booster	3.20e-06			3.20e-06	6.50e-06
Carbon tetrachloride	20 mm HEI Cartridge	7.60e-06			7.60e-06	1.60e-05
Carbon tetrachloride	40 mm HEI Cartridge	4.50e-06			4.50e-06	1.20e-05
Chloroform	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.70e-07
Chloroform	Amatol surrogate with water	3.70e-07	3.70e-07	0.00e+00	3.70e-07	7.40e-07
Chloroform	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.70e-07
Chloroform	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Gas Generator, GGU-2/A	2.50e-06	2.50e-06	2.60e-06	2.60e-06	2.60e-06
Chloroform	HBX surrogate	3.70e-07	4.10e-07	3.70e-07	3.80e-07	7.60e-07
Chloroform	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	Tritonal surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	7.40e-07
Chloroform	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	3.70e-07
Chloroform	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chloroform	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Cartridge, Impulse, BBU-36/B	2.00e-05	0.00e+00	2.50e-05	2.20e-05	2.20e-05
Chromium	Cartridge, Impulse, MK 107	4.30e-05	2.90e-05	2.80e-05	3.30e-05	3.30e-05
Chromium	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Flare, IR Countermeasure M206	1.40e-04	1.70e-04	1.60e-04	1.60e-04	1.60e-04
Chromium	Fuze, Tail Bomb FMU-139 A/B	1.60e-04	1.20e-04	1.30e-04	1.40e-04	1.40e-04

Chromium	Fuze, Tail Bomb FMU-54 A/B	5.50e-05	3.50e-05	2.80e-05	3.90e-05	5.50e-05
Chromium	Gas Generator, GGU-2/A	5.30e-05	9.70e-05	1.40e-04	9.60e-05	9.60e-05
Chromium	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Mine, Claymore, M18A1	3.80e-05			3.80e-05	3.80e-05
Chromium	Signal, Illumination, Red Star AN-M43A2	6.60e-05	5.20e-05	5.30e-05	5.70e-05	5.80e-05
Chromium	Signal, Illumination, Red Star M158	1.30e-04	1.50e-04	1.50e-04	1.50e-04	1.50e-04
Chromium	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Chromium	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	9.10e-06
Chromium	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.20e-06
Chromium	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.00e-06
Chromium	TNT (ACC2)	2.30e-05			2.30e-05	2.50e-05
Chromium	TNT (Sandia)	1.30e-06	3.50e-06	2.50e-06	2.40e-06	
Chromium	T45E7 Adapter Booster	9.40e-05			9.40e-05	9.40e-05
Chromium	20 mm HEI Cartridge	3.50e-05			3.50e-05	3.50e-05
Chromium	40 mm HEI Cartridge	8.80e-05			8.80e-05	8.80e-05
Copper	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	9.50e-05
Copper	Cartridge, Impulse, BBU-36/B	8.80e-04	1.40e-03	1.40e-03	1.20e-03	2.90e-03
Copper	Cartridge, Impulse, MK 107	1.30e-03	1.50e-03	1.50e-03	1.40e-03	2.40e-03
Copper	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Detonating train	0.00e+00	4.70e-04	0.00e+00	0.00e+00	2.60e-04
Copper	Flare, IR Countermeasure M206	6.50e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Fuze, Tail Bomb FMU-139 A/B	7.70e-03	6.60e-03	5.90e-03	6.80e-03	6.80e-03
Copper	Fuze, Tail Bomb FMU-54 A/B	4.40e-04	4.50e-04	6.40e-04	5.10e-04	8.60e-04
Copper	Gas Generator, GGU-2/A	6.60e-04	7.00e-04	5.50e-04	6.40e-04	7.10e-04
Copper	HBX surrogate	1.90e-03	4.50e-03	3.10e-03	3.20e-03	3.20e-03
Copper	Mine, Claymore, M18A1	4.70e-03			4.70e-03	7.10e-04
Copper	Signal, Illumination, Red Star AN-M43A2	6.90e-04	2.00e-04	2.30e-04	3.70e-04	3.90e-04
Copper	Signal, Illumination, Red Star M158	0.00e+00	1.80e-03	0.00e+00	0.00e+00	0.00e+00
Copper	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Copper	Tritonal surrogate with calcium stearate		1.00e-04	0.00e+00	4.40e-05	7.50e-05
Copper	Tritonal surrogate with water	9.20e-04	7.70e-04	9.60e-04	8.80e-04	9.10e-04
Copper	TNT (ACC1)	3.00e-04			3.00e-04	0.00e+00
Copper	TNT (ACC2)	5.00e-04			5.00e-04	5.20e-04
Copper	T45E7 Adapter Booster	2.70e-03			2.70e-03	3.20e-04
Copper	20 mm HEI Cartridge	2.60e-02			2.60e-02	1.20e-02
Copper	40 mm HEI Cartridge	8.90e-03			8.90e-03	2.30e-03
Cyclohexane	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Amatol surrogate with water	7.40e-07	0.00e+00	0.00e+00	7.40e-07	1.50e-06
Cyclohexane	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Cyclohexane	Cartridge, Impulse, BBU-36/B	0.00e+00	5.60e-07	0.00e+00	5.60e-07	1.70e-06
Cyclohexane	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Detonating train	8.70e-07	0.00e+00	6.00e-07	7.30e-07	1.80e-06
Cyclohexane	Flare, IR Countermeasure M206	3.30e-07	0.00e+00	0.00e+00	3.30e-07	3.30e-07
Cyclohexane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	0.00e+00	0.00e+00	4.90e-07	4.90e-07
Cyclohexane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.80e-07
Cyclohexane	Mine, Claymore, M18A1	2.00e-06	4.90e-07	1.40e-06	1.30e-06	1.80e-06
Cyclohexane	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	7.40e-07
Cyclohexane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	7.30e-07
Cyclohexane	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.80e-06
Cyclohexane	TNT (ACC1)	2.30e-06	9.60e-07	0.00e+00	1.60e-06	3.00e-06
Cyclohexane	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclohexane	T45E7 Adapter Booster	1.80e-06	1.20e-06	4.00e-06	2.30e-06	4.70e-06
Cyclohexane	20 mm HEI Cartridge	7.00e-07	0.00e+00	6.80e-07	6.90e-07	6.50e-06
Cyclohexane	40 mm HEI Cartridge	7.50e-06	0.00e+00	0.00e+00	7.50e-06	1.60e-05
Cyclopentane	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Amatol surrogate with water	2.20e-06	4.40e-06	2.20e-06	3.00e-06	3.50e-06
Cyclopentane	Cartridge, Impulse, ARD 446-1	0.00e+00	2.60e-07	0.00e+00	2.60e-07	7.50e-07
Cyclopentane	Cartridge, Impulse, BBU-36/B	2.70e-07	2.80e-07	2.80e-07	2.80e-07	9.00e-07
Cyclopentane	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Detonating train	0.00e+00	0.00e+00	3.00e-07	3.00e-07	6.10e-07
Cyclopentane	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	HBX surrogate	0.00e+00	0.00e+00	1.10e-06	1.10e-06	7.50e-07
Cyclopentane	Mine, Claymore, M18A1	0.00e+00	9.80e-07	4.70e-07	7.20e-07	7.20e-07
Cyclopentane	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	Tritonal surrogate	3.70e-07	3.70e-07	3.60e-07	3.70e-07	7.40e-07
Cyclopentane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	5.50e-07
Cyclopentane	Tritonal surrogate with water	0.00e+00	1.50e-06	7.50e-07	1.10e-06	1.90e-06
Cyclopentane	TNT (ACC1)	4.60e-07	4.80e-07	0.00e+00	4.70e-07	4.70e-07
Cyclopentane	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentane	T45E7 Adapter Booster	0.00e+00	5.90e-07	5.80e-07	5.80e-07	9.70e-07

Cyclopentane	20 mm HEI Cartridge	0.00e+00	7.20e-07	6.80e-07	7.00e-07	1.60e-06
Cyclopentane	40 mm HEI Cartridge	1.70e-06	0.00e+00	0.00e+00	1.70e-06	3.30e-06
Cyclopentene	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Amatol surrogate with water	4.10e-06	2.00e-05	0.00e+00	1.20e-05	1.20e-05
Cyclopentene	Cartridge, Impulse, ARD 446-1	2.10e-06	5.10e-06	2.00e-06	3.10e-06	3.10e-06
Cyclopentene	Cartridge, Impulse, BBU-36/B	2.70e-06	0.00e+00	2.80e-06	2.70e-06	2.70e-06
Cyclopentene	Cartridge, Impulse, MK 107	1.00e-06	7.90e-07	1.00e-06	9.70e-07	9.70e-07
Cyclopentene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	Detonating train	3.80e-06	3.90e-06	3.30e-06	3.70e-06	3.70e-06
Cyclopentene	Flare, IR Countermeasure M206	6.60e-07	6.80e-07	1.00e-06	7.90e-07	7.90e-07
Cyclopentene	Fuze, Tail Bomb FMU-139 A/B	9.70e-07	9.70e-07	4.80e-07	8.10e-07	8.10e-07
Cyclopentene	Fuze, Tail Bomb FMU-54 A/B	1.20e-06	1.50e-06	1.20e-06	1.30e-06	1.30e-06
Cyclopentene	Gas Generator, GGU-2/A	4.10e-06	1.80e-06	4.90e-06	3.60e-06	3.60e-06
Cyclopentene	HBX surrogate	3.70e-07	4.10e-07	0.00e+00	3.90e-07	5.70e-07
Cyclopentene	Mine, Claymore, M18A1	4.90e-07	0.00e+00	0.00e+00	4.90e-07	4.90e-07
Cyclopentene	Signal, Illumination, Red Star AN-M43A2	1.00e-06	1.70e-06	1.00e-06	1.30e-06	1.30e-06
Cyclopentene	Signal, Illumination, Red Star M158	3.50e-06	2.10e-06	1.70e-06	2.50e-06	2.50e-06
Cyclopentene	Tritonal surrogate	0.00e+00	0.00e+00	7.30e-07	7.30e-07	7.30e-07
Cyclopentene	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-07	3.60e-07	3.60e-07
Cyclopentene	Tritonal surrogate with water	0.00e+00	0.00e+00	2.60e-06	2.60e-06	2.60e-06
Cyclopentene	TNT (ACC1)	4.60e-07	0.00e+00	0.00e+00	4.60e-07	4.60e-07
Cyclopentene	TNT (ACC2)	3.70e-07			3.70e-07	3.70e-07
Cyclopentene	T45E7 Adapter Booster	4.20e-06	4.10e-06	2.90e-06	3.70e-06	3.70e-06
Cyclopentene	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Cyclopentene	40 mm HEI Cartridge	8.30e-07	0.00e+00	0.00e+00	8.30e-07	1.70e-06
CO	Amatol surrogate	9.80e-03	8.60e-03	1.10e-02	9.70e-03	
CO	Amatol surrogate with water	1.90e-01	3.10e-01	1.90e-01	2.30e-01	
CO	Cartridge, Impulse, ARD 446-1	1.40e-02	1.20e-02	1.30e-02	1.30e-02	
CO	Cartridge, Impulse, BBU-36/B	8.10e-03	8.10e-03	9.00e-03	8.40e-03	
CO	Cartridge, Impulse, MK 107	1.40e-02	1.50e-02	1.30e-02	1.40e-02	
CO	Composition B surrogate	3.40e-03	4.70e-03	4.40e-03	4.20e-03	
CO	Detonating train	1.30e-02	7.90e-03	7.40e-03	9.40e-03	
CO	Flare, IR Countermeasure M206	7.40e-03	9.50e-03	7.90e-03	8.30e-03	
CO	Fuze, Tail Bomb FMU-139 A/B	2.10e-02	2.40e-02	2.50e-02	2.30e-02	
CO	Fuze, Tail Bomb FMU-54 A/B	1.50e-02	2.40e-02	1.70e-02	1.80e-02	
CO	Gas Generator, GGU-2/A	2.70e-02	2.80e-02	3.00e-02	2.80e-02	
CO	HBX surrogate	4.40e-03	4.20e-03	7.00e-03	5.20e-03	
CO	Mine, Claymore, M18A1	2.90e-02	3.20e-02	3.00e-02	3.00e-02	
CO	Signal, Illumination, Red Star AN-M43A2	1.70e-02	2.10e-02	2.80e-02	2.20e-02	
CO	Signal, Illumination, Red Star M158	1.10e-02	1.10e-02	1.20e-02	1.20e-02	
CO	Tritonal surrogate	5.60e-03	5.60e-03	2.90e-03	4.70e-03	

CO	Tritonal surrogate with calcium stearate		3.30e-03	2.00e-03	2.70e-03	
CO	Tritonal surrogate with water	2.80e-01	2.40e-01	2.80e-01	2.70e-01	
CO	TNT (ACC1)	9.50e-03	1.30e-02	9.30e-03	1.00e-02	
CO	TNT (ACC2)	6.70e-03			6.70e-03	
CO	T45E7 Adapter Booster	3.10e-02	3.10e-02	2.60e-02	2.90e-02	
CO	20 mm HEI Cartridge	1.20e-01	9.10e-02	1.10e-01	1.10e-01	
CO	40 mm HEI Cartridge	2.30e-02	2.30e-02	1.80e-02	2.10e-02	
CO2	Amatol surrogate	5.10e-01	7.80e-01	8.00e-01	7.00e-01	
CO2	Amatol surrogate with water	2.30e-01	4.50e-01	2.40e-01	3.10e-01	
CO2	Cartridge, Impulse, ARD 446-1	4.80e-01	4.60e-01	5.00e-01	4.80e-01	
CO2	Cartridge, Impulse, BBU-36/B	5.00e-01	4.80e-01	5.30e-01	5.00e-01	
CO2	Cartridge, Impulse, MK 107	8.40e-01	8.50e-01	8.60e-01	8.50e-01	
CO2	Composition B surrogate	1.10e+00	1.20e+00	1.10e+00	1.10e+00	
CO2	Detonating train	5.70e-01	1.10e+00	1.10e+00	9.10e-01	
CO2	Flare, IR Countermeasure M206	7.70e-01	8.10e-01	8.50e-01	8.10e-01	
CO2	Fuze, Tail Bomb FMU-139 A/B	1.50e+00	1.40e+00	1.50e+00	1.40e+00	
CO2	Fuze, Tail Bomb FMU-54 A/B	9.20e-01	9.10e-01	9.80e-01	9.40e-01	
CO2	Gas Generator, GGU-2/A	4.40e-01	4.30e-01	4.80e-01	4.50e-01	
CO2	HBX surrogate	9.70e-01	9.40e-01	1.10e+00	1.00e+00	
CO2	Mine, Claymore, M18A1	4.90e+00	5.10e+00	5.00e+00	5.00e+00	
CO2	Signal, Illumination, Red Star AN-M43A2	1.00e+00	1.10e+00	1.10e+00	1.10e+00	
CO2	Signal, Illumination, Red Star M158	5.00e-01	5.30e-01	5.10e-01	5.10e-01	
CO2	Tritonal surrogate	5.00e-01	2.20e-01	1.20e+00	6.40e-01	
CO2	Tritonal surrogate with calcium stearate		1.30e+00	1.30e+00	1.30e+00	
CO2	Tritonal surrogate with water	2.50e-01	3.30e-01	2.60e-01	2.80e-01	
CO2	TNT (ACC1)	1.40e+00	1.50e+00	1.50e+00	1.50e+00	
CO2	TNT (ACC2)	1.40e+00			1.40e+00	
CO2	TNT (Sandia)	1.30e+00			1.30e+00	
CO2	T45E7 Adapter Booster	5.10e+00	4.60e+00	4.70e+00	4.80e+00	
CO2	20 mm HEI Cartridge	2.30e+00	2.20e+00	1.90e+00	2.10e+00	
CO2	40 mm HEI Cartridge	9.10e-01	8.70e-01	8.80e-01	8.90e-01	
Diethyl phthalate	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.40e-05
Diethyl phthalate	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.80e-06
Diethyl phthalate	Cartridge, Impulse, BBU-36/B	4.40e-05	6.70e-04	4.90e-04	4.00e-04	7.80e-04
Diethyl phthalate	Cartridge, Impulse, MK 107	3.00e-04	0.00e+00	0.00e+00	3.00e-04	4.40e-04
Diethyl phthalate	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Fuze, Tail Bomb FMU-139 A/B	1.40e-03	1.70e-03	1.50e-03	1.50e-03	1.50e-03
Diethyl phthalate	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Diethyl phthalate	Gas Generator, GGU-2/A	2.30e-04	0.00e+00	1.60e-03	8.90e-04	0.00e+00
Diethyl phthalate	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Signal, Illumination, Red Star M158	0.00e+00	7.70e-05	0.00e+00	7.70e-05	7.70e-05
Diethyl phthalate	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.40e-06
Diethyl phthalate	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Diethyl phthalate	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethane	Amatol surrogate	0.00e+00	2.20e-06	6.00e-06	4.10e-06	5.20e-06
Ethane	Amatol surrogate with water	8.70e-04	1.50e-03	1.00e-03	1.10e-03	1.10e-03
Ethane	Cartridge, Impulse, ARD 446-1	3.00e-05	1.20e-05	2.90e-05	2.40e-05	3.90e-05
Ethane	Cartridge, Impulse, BBU-36/B	1.40e-06	5.60e-07	8.40e-06	3.40e-06	1.30e-05
Ethane	Cartridge, Impulse, MK 107	5.30e-07	2.60e-06	1.60e-06	1.60e-06	9.50e-06
Ethane	Composition B surrogate	1.90e-06	0.00e+00	7.30e-07	1.30e-06	4.70e-06
Ethane	Detonating train	1.70e-06	1.80e-06	9.60e-06	4.40e-06	1.40e-05
Ethane	Flare, IR Countermeasure M206	1.00e-06	0.00e+00	1.00e-06	1.00e-06	7.60e-06
Ethane	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	9.20e-06	0.00e+00	9.80e-06	1.90e-05
Ethane	Fuze, Tail Bomb FMU-54 A/B	9.80e-06	1.20e-05	0.00e+00	1.10e-05	1.90e-05
Ethane	Gas Generator, GGU-2/A	2.50e-05	3.70e-05	3.00e-05	3.00e-05	3.90e-05
Ethane	HBX surrogate	0.00e+00	1.60e-06	1.50e-06	1.60e-06	4.90e-06
Ethane	Mine, Claymore, M18A1	8.80e-06	1.50e-06	5.60e-06	5.30e-06	7.20e-06
Ethane	Signal, Illumination, Red Star AN-M43A2	9.00e-06	0.00e+00	9.00e-06	9.00e-06	1.30e-05
Ethane	Signal, Illumination, Red Star M158	1.50e-05	2.40e-05	0.00e+00	2.00e-05	2.60e-05
Ethane	Tritonal surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	2.60e-06
Ethane	Tritonal surrogate with calcium stearate		7.40e-07	0.00e+00	7.40e-07	4.40e-06
Ethane	Tritonal surrogate with water	5.00e-05	1.10e-04	2.10e-04	1.20e-04	1.30e-04
Ethane	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.70e-06
Ethane	TNT (ACC2)	7.40e-07			7.40e-07	4.10e-06
Ethane	T45E7 Adapter Booster	2.80e-05	2.40e-05	2.40e-05	2.50e-05	3.90e-05
Ethane	20 mm HEI Cartridge	1.10e-04	7.60e-05	9.90e-05	9.40e-05	1.40e-04
Ethane	40 mm HEI Cartridge	2.90e-05	3.60e-05	2.50e-05	3.00e-05	4.60e-05
Ethyl chloride	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Ethyl chloride	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Detonating train	0.00e+00	6.90e-07	6.90e-07	6.90e-07	6.90e-07
Ethyl chloride	Flare, IR Countermeasure M206	3.90e-06	3.20e-06	2.40e-06	3.10e-06	3.10e-06
Ethyl chloride	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Gas Generator, GGU-2/A	2.70e-06	4.10e-06	7.10e-06	4.70e-06	4.70e-06
Ethyl chloride	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethyl chloride	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Ethylbenzene	Amatol surrogate	7.50e-07	1.10e-06	1.90e-06	1.20e-06	4.00e-06
Ethylbenzene	Amatol surrogate with water	1.20e-05	2.20e-05	1.50e-05	1.60e-05	2.10e-05
Ethylbenzene	Cartridge, Impulse, ARD 446-1	1.00e-06	2.10e-06	2.70e-06	1.90e-06	8.10e-06
Ethylbenzene	Cartridge, Impulse, BBU-36/B	2.70e-06	2.50e-06	1.90e-06	2.40e-06	1.00e-05
Ethylbenzene	Cartridge, Impulse, MK 107	7.90e-07	1.10e-06	1.00e-06	9.70e-07	2.90e-06
Ethylbenzene	Composition B surrogate	1.10e-06	1.90e-06	2.90e-06	2.00e-06	5.30e-06
Ethylbenzene	Detonating train	2.90e-07	6.00e-07	9.00e-07	6.00e-07	9.30e-06
Ethylbenzene	Flare, IR Countermeasure M206	2.70e-06	1.70e-06	2.70e-06	2.40e-06	4.10e-06
Ethylbenzene	Fuze, Tail Bomb FMU-139 A/B	3.40e-06	3.40e-06	2.90e-06	3.20e-06	4.50e-06
Ethylbenzene	Fuze, Tail Bomb FMU-54 A/B	1.50e-06	3.30e-06	2.40e-06	2.40e-06	6.00e-06
Ethylbenzene	Gas Generator, GGU-2/A	5.90e-07	1.80e-06	1.20e-06	1.20e-06	9.10e-06
Ethylbenzene	HBX surrogate	1.50e-06	1.60e-06	2.20e-06	1.80e-06	8.80e-06
Ethylbenzene	Mine, Claymore, M18A1	3.10e-05	4.10e-05	4.20e-05	3.80e-05	3.90e-05
Ethylbenzene	Signal, Illumination, Red Star AN-M43A2	6.90e-07	3.50e-07	3.50e-07	4.60e-07	1.90e-06
Ethylbenzene	Signal, Illumination, Red Star M158	7.00e-07	7.00e-07	0.00e+00	7.00e-07	2.20e-06
Ethylbenzene	Tritonal surrogate	1.50e-06	2.60e-06	3.30e-06	2.50e-06	1.10e-05
Ethylbenzene	Tritonal surrogate with calcium stearate		7.40e-07	2.60e-06	1.60e-06	9.90e-06
Ethylbenzene	Tritonal surrogate with water	8.20e-06	3.30e-06	7.50e-06	6.30e-06	1.50e-05
Ethylbenzene	TNT (ACC1)	4.60e-07	4.80e-07	0.00e+00	4.70e-07	2.70e-06
Ethylbenzene	TNT (ACC2)	0.00e+00			0.00e+00	3.30e-06
Ethylbenzene	T45E7 Adapter Booster	1.00e-05	7.70e-06	9.80e-06	9.20e-06	1.00e-05
Ethylbenzene	20 mm HEI Cartridge	2.80e-06	5.00e-06	6.10e-06	4.60e-06	1.00e-05
Ethylbenzene	40 mm HEI Cartridge	2.50e-06	0.00e+00	0.00e+00	2.50e-06	9.60e-06

Ethylene	Amatol surrogate	4.40e-05	2.00e-05	2.90e-05	3.10e-05	3.20e-05
Ethylene	Amatol surrogate with water	7.30e-04	1.30e-03	8.80e-04	9.80e-04	9.80e-04
Ethylene	Cartridge, Impulse, ARD 446-1	3.90e-04	3.10e-04	3.10e-04	3.30e-04	4.90e-04
Ethylene	Cartridge, Impulse, BBU-36/B	2.60e-04	2.50e-04	3.00e-04	2.70e-04	5.30e-04
Ethylene	Cartridge, Impulse, MK 107	2.00e-04	1.80e-04	1.60e-04	1.80e-04	2.60e-04
Ethylene	Composition B surrogate	1.20e-05	1.20e-05	1.70e-05	1.40e-05	1.50e-05
Ethylene	Detonating train	4.20e-04	4.10e-04	3.50e-04	3.90e-04	6.00e-04
Ethylene	Flare, IR Countermeasure M206	1.30e-04	7.70e-05	1.40e-04	1.20e-04	1.20e-04
Ethylene	Fuze, Tail Bomb FMU-139 A/B	2.40e-04	4.00e-04	3.80e-04	3.40e-04	3.40e-04
Ethylene	Fuze, Tail Bomb FMU-54 A/B	1.60e-04	2.60e-04	1.70e-04	1.90e-04	2.60e-04
Ethylene	Gas Generator, GGU-2/A	6.00e-04	5.80e-04	6.70e-04	6.10e-04	6.20e-04
Ethylene	HBX surrogate	2.80e-05	2.50e-05	4.30e-05	3.20e-05	3.30e-05
Ethylene	Mine, Claymore, M18A1	1.80e-04	2.30e-04	3.00e-04	2.40e-04	2.40e-04
Ethylene	Signal, Illumination, Red Star AN-M43A2	2.10e-04	2.20e-04	2.20e-04	2.20e-04	2.20e-04
Ethylene	Signal, Illumination, Red Star M158	2.30e-04	3.50e-04	1.00e-04	2.30e-04	2.30e-04
Ethylene	Tritonal surrogate	2.70e-05	1.30e-05	2.50e-05	2.20e-05	2.30e-05
Ethylene	Tritonal surrogate with calcium stearate		3.20e-05	1.80e-05	2.50e-05	2.60e-05
Ethylene	Tritonal surrogate with water	1.20e-03	9.00e-04	1.30e-03	1.10e-03	1.10e-03
Ethylene	TNT (ACC1)	3.00e-05	2.90e-05	8.60e-06	2.20e-05	2.30e-05
Ethylene	TNT (ACC2)	1.60e-05			1.60e-05	1.60e-05
Ethylene	T45E7 Adapter Booster	6.50e-04	5.60e-04	4.90e-04	5.70e-04	5.70e-04
Ethylene	20 mm HEI Cartridge	3.30e-04	2.40e-04	3.00e-04	2.90e-04	4.00e-04
Ethylene	40 mm HEI Cartridge	8.90e-05	9.00e-05	6.50e-05	8.10e-05	1.10e-04
Lead	Amatol surrogate	0.00e+00	3.20e-05	9.70e-05	3.30e-05	3.30e-05
Lead	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Cartridge, Impulse, ARD 446-1	3.60e-04	2.10e-04	3.60e-04	3.10e-04	3.10e-04
Lead	Cartridge, Impulse, BBU-36/B	1.20e-05	1.00e-04	8.80e-05	6.80e-05	6.80e-05
Lead	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Detonating train	2.80e-05	2.20e-04	2.90e-04	1.80e-04	1.80e-04
Lead	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Fuze, Tail Bomb FMU-139 A/B	2.80e-03	2.40e-03	2.50e-03	2.60e-03	2.60e-03
Lead	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Gas Generator, GGU-2/A	4.10e-04	4.10e-04	2.80e-04	3.70e-04	3.70e-04
Lead	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Mine, Claymore, M18A1	0.00e+00			0.00e+00	0.00e+00
Lead	Signal, Illumination, Red Star AN-M43A2	2.10e-04	0.00e+00	2.80e-05	7.00e-05	7.00e-05
Lead	Signal, Illumination, Red Star M158	7.00e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Lead	Tritonal surrogate	1.90e-03	7.20e-04	6.70e-04	1.10e-03	1.10e-03
Lead	Tritonal surrogate with calcium stearate		9.10e-04	9.30e-04	9.20e-04	9.20e-04
Lead	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Lead	TNT (ACC1)	0.00e+00			0.00e+00	0.00e+00
Lead	TNT (ACC2)	9.00e-06			9.00e-06	9.00e-06
Lead	TNT (Sandia)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	
Lead	T45E7 Adapter Booster	1.80e-04			1.80e-04	1.80e-04
Lead	20 mm HEI Cartridge	7.00e-04			7.00e-04	8.00e-06
Lead	40 mm HEI Cartridge	3.70e-04			3.70e-04	3.70e-04
Methyl chloride	Amatol surrogate	1.10e-06	7.50e-07	3.70e-07	7.50e-07	7.50e-07
Methyl chloride	Amatol surrogate with water	2.20e-06	1.80e-06	2.60e-06	2.20e-06	2.20e-06
Methyl chloride	Cartridge, Impulse, ARD 446-1	1.90e-06	9.20e-07	9.00e-07	1.20e-06	2.00e-06
Methyl chloride	Cartridge, Impulse, BBU-36/B	4.90e-07	1.50e-06	1.00e-06	1.00e-06	3.00e-06
Methyl chloride	Cartridge, Impulse, MK 107	1.90e-06	4.80e-07	4.70e-07	9.60e-07	1.60e-06
Methyl chloride	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloride	Detonating train	1.10e-06	5.30e-07	5.30e-07	7.00e-07	1.90e-06
Methyl chloride	Flare, IR Countermeasure M206	1.20e-06	6.00e-07	1.20e-06	1.00e-06	1.60e-06
Methyl chloride	Fuze, Tail Bomb FMU-139 A/B	4.50e-06	6.10e-06	3.50e-06	4.70e-06	5.30e-06
Methyl chloride	Fuze, Tail Bomb FMU-54 A/B	1.10e-06	2.20e-06	6.20e-06	3.10e-06	4.90e-06
Methyl chloride	Gas Generator, GGU-2/A	5.30e-06	7.60e-06	3.60e-05	1.60e-05	1.70e-05
Methyl chloride	HBX surrogate	3.70e-07	4.10e-07	1.10e-06	6.30e-07	1.00e-06
Methyl chloride	Mine, Claymore, M18A1	4.40e-06			4.40e-06	4.40e-06
Methyl chloride	Signal, Illumination, Red Star AN-M43A2	1.90e-06	1.20e-06	1.80e-06	1.70e-06	2.10e-06
Methyl chloride	Signal, Illumination, Red Star M158	0.00e+00	1.30e-06	1.30e-06	1.30e-06	1.10e-06
Methyl chloride	Tritonal surrogate	7.40e-07	3.70e-07	0.00e+00	5.60e-07	5.60e-07
Methyl chloride	Tritonal surrogate with calcium stearate		3.70e-07	3.60e-07	3.70e-07	3.70e-07
Methyl chloride	Tritonal surrogate with water	3.70e-06	3.70e-06	4.10e-06	3.80e-06	3.80e-06
Methyl chloride	TNT (ACC1)	0.00e+00			0.00e+00	1.70e-06
Methyl chloride	TNT (ACC2)	0.00e+00			0.00e+00	6.70e-07
Methyl chloride	T45E7 Adapter Booster	2.20e-06			2.20e-06	3.20e-06
Methyl chloride	20 mm HEI Cartridge	1.30e-06			1.30e-06	3.50e-06
Methyl chloride	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloroform	Amatol surrogate	3.70e-07	3.70e-07	0.00e+00	3.70e-07	1.70e-06
Methyl chloroform	Amatol surrogate with water	3.70e-07	0.00e+00	3.70e-07	3.70e-07	1.70e-06
Methyl chloroform	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	1.20e-06	1.20e-06	1.80e-06
Methyl chloroform	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.60e-06
Methyl chloroform	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.80e-06
Methyl chloroform	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methyl chloroform	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.20e-06
Methyl chloroform	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.60e-06
Methyl chloroform	Fuze, Tail Bomb FMU-139 A/B	1.20e-05	1.80e-05	1.80e-05	1.60e-05	1.90e-05
Methyl chloroform	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.90e-06
Methyl chloroform	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.90e-06
Methyl chloroform	HBX surrogate	3.70e-07	4.10e-07	3.70e-07	3.80e-07	1.90e-06

Methyl chloroform	Mine, Claymore, M18A1	2.30e-06			2.30e-06	4.60e-06
Methyl chloroform	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.60e-06
Methyl chloroform	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.70e-06
Methyl chloroform	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	1.60e-06
Methyl chloroform	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	1.80e-06
Methyl chloroform	Tritonal surrogate with water	3.70e-07	0.00e+00	3.70e-07	3.70e-07	1.70e-06
Methyl chloroform	TNT (ACC1)	0.00e+00			0.00e+00	6.60e-06
Methyl chloroform	TNT (ACC2)	0.00e+00			0.00e+00	1.80e-06
Methyl chloroform	T45E7 Adapter Booster	0.00e+00			0.00e+00	5.60e-06
Methyl chloroform	20 mm HEI Cartridge	3.30e-06			3.30e-06	1.40e-05
Methyl chloroform	40 mm HEI Cartridge	0.00e+00			0.00e+00	2.10e-05
Methylcyclohexane	Amatol surrogate	7.50e-07	2.20e-06	4.50e-06	2.50e-06	4.40e-06
Methylcyclohexane	Amatol surrogate with water	4.50e-06	1.20e-05	7.40e-06	8.00e-06	1.10e-05
Methylcyclohexane	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Cartridge, Impulse, BBU-36/B	5.40e-07	2.80e-07	0.00e+00	4.10e-07	1.60e-06
Methylcyclohexane	Cartridge, Impulse, MK 107	7.90e-07	0.00e+00	2.60e-07	5.20e-07	9.60e-07
Methylcyclohexane	Composition B surrogate	2.20e-06	3.00e-06	1.80e-06	2.30e-06	4.10e-06
Methylcyclohexane	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	3.40e-07	3.40e-07	6.80e-07
Methylcyclohexane	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	HBX surrogate	4.40e-06	7.00e-06	7.10e-06	6.10e-06	1.00e-05
Methylcyclohexane	Mine, Claymore, M18A1	5.40e-06	5.90e-06	4.70e-06	5.30e-06	6.30e-06
Methylcyclohexane	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Methylcyclohexane	Signal, Illumination, Red Star M158	3.50e-07	0.00e+00	0.00e+00	3.50e-07	7.00e-07
Methylcyclohexane	Tritonal surrogate	4.80e-06	5.90e-06	1.00e-05	7.00e-06	1.40e-05
Methylcyclohexane	Tritonal surrogate with calcium stearate		0.00e+00	4.40e-06	4.40e-07	6.20e-06
Methylcyclohexane	Tritonal surrogate with water	4.90e-06	5.10e-06	9.40e-06	6.50e-06	1.10e-05
Methylcyclohexane	TNT (ACC1)	9.20e-06	9.60e-07	0.00e+00	5.10e-06	4.30e-06
Methylcyclohexane	TNT (ACC2)	0.00e+00			0.00e+00	3.70e-07
Methylcyclohexane	T45E7 Adapter Booster	2.40e-06	2.90e-06	3.50e-06	2.90e-06	4.10e-06
Methylcyclohexane	20 mm HEI Cartridge	1.40e-06	2.90e-06	4.10e-06	2.80e-06	5.80e-06
Methylcyclohexane	40 mm HEI Cartridge	2.50e-06	0.00e+00	0.00e+00	2.50e-06	1.40e-05
Methylcyclopentane	Amatol surrogate	0.00e+00	0.00e+00	3.70e-07	1.90e-07	5.00e-07
Methylcyclopentane	Amatol surrogate with water	4.80e-06	1.20e-05	3.00e-06	6.60e-06	8.90e-06
Methylcyclopentane	Cartridge, Impulse, ARD 446-1	1.00e-06	2.60e-07	5.00e-07	6.00e-07	1.70e-06
Methylcyclopentane	Cartridge, Impulse, BBU-36/B	0.00e+00	1.10e-06	0.00e+00	1.10e-06	1.90e-06
Methylcyclopentane	Cartridge, Impulse, MK 107	0.00e+00	5.30e-07	0.00e+00	5.30e-07	7.70e-07
Methylcyclopentane	Composition B surrogate	0.00e+00	0.00e+00	3.60e-07	3.60e-07	4.90e-07
Methylcyclopentane	Detonating train	2.90e-07	0.00e+00	0.00e+00	2.90e-07	1.70e-06

Methylcyclopentane	Flare, IR Countermeasure M206	0.00e+00	3.40e-07	0.00e+00	3.40e-07	4.50e-07
Methylcyclopentane	Fuze, Tail Bomb FMU-139 A/B	4.90e-07	0.00e+00	0.00e+00	4.90e-07	4.90e-07
Methylcyclopentane	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	3.00e-07	0.00e+00	3.00e-07	8.00e-07
Methylcyclopentane	Gas Generator, GGU-2/A	2.40e-06	5.90e-07	0.00e+00	1.50e-06	1.80e-06
Methylcyclopentane	HBX surrogate	3.70e-07	8.20e-07	7.40e-07	6.40e-07	2.40e-06
Methylcyclopentane	Mine, Claymore, M18A1	1.40e-05	1.50e-05	1.80e-05	1.60e-05	1.70e-05
Methylcyclopentane	Signal, Illumination, Red Star AN-M43A2	0.00e+00	3.50e-07	0.00e+00	3.50e-07	7.00e-07
Methylcyclopentane	Signal, Illumination, Red Star M158	1.10e-06	0.00e+00	0.00e+00	1.10e-06	8.20e-07
Methylcyclopentane	Tritonal surrogate	7.40e-07	3.70e-07	0.00e+00	5.60e-07	3.50e-06
Methylcyclopentane	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	2.90e-06
Methylcyclopentane	Tritonal surrogate with water	0.00e+00	0.00e+00	7.50e-07	7.50e-07	4.70e-06
Methylcyclopentane	TNT (ACC1)	9.20e-07	4.80e-07	0.00e+00	7.00e-07	1.60e-06
Methylcyclopentane	TNT (ACC2)	3.70e-07			3.70e-07	7.40e-07
Methylcyclopentane	T45E7 Adapter Booster	1.20e-06	2.90e-06	4.60e-06	2.90e-06	4.70e-06
Methylcyclopentane	20 mm HEI Cartridge	7.00e-07	2.90e-06	4.80e-06	2.80e-06	7.70e-06
Methylcyclopentane	40 mm HEI Cartridge	9.10e-06	0.00e+00	0.00e+00	9.10e-06	1.60e-05
Methylenechloride	Amatol surrogate	1.50e-04	2.00e-04	1.10e-04	1.50e-04	2.00e-04
Methylenechloride	Amatol surrogate with water	2.10e-04	2.00e-04	2.20e-04	2.10e-04	2.60e-04
Methylenechloride	Cartridge, Impulse, ARD 446-1	1.30e-05	3.20e-05	1.10e-04	5.00e-05	1.90e-04
Methylenechloride	Cartridge, Impulse, BBU-36/B	8.20e-06	3.00e-04	2.10e-04	1.70e-04	1.10e-03
Methylenechloride	Cartridge, Impulse, MK 107	6.30e-04	3.10e-05	2.00e-05	2.30e-04	9.30e-04
Methylenechloride	Composition B surrogate	0.00e+00	3.70e-07	2.80e-04	1.40e-04	1.90e-06
Methylenechloride	Detonating train	0.00e+00	5.00e-05	3.50e-05	4.20e-05	5.60e-04
Methylenechloride	Flare, IR Countermeasure M206	4.80e-04	3.80e-04	3.80e-04	4.10e-04	1.90e-03
Methylenechloride	Fuze, Tail Bomb FMU-139 A/B	1.20e-04	1.60e-04	5.50e-05	1.10e-04	8.60e-04
Methylenechloride	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	7.10e-04	7.80e-04	7.40e-04	2.40e-03
Methylenechloride	Gas Generator, GGU-2/A	2.80e-04	7.00e-05	2.30e-03	8.70e-04	2.90e-03
Methylenechloride	HBX surrogate	0.00e+00	0.00e+00	2.70e-04	2.70e-04	2.80e-04
Methylenechloride	Mine, Claymore, M18A1	1.10e-04			1.10e-04	1.10e-04
Methylenechloride	Signal, Illumination, Red Star AN-M43A2	0.00e+00	8.10e-06	0.00e+00	8.10e-06	3.30e-04
Methylenechloride	Signal, Illumination, Red Star M158	1.00e-04	9.60e-05	1.00e-04	1.00e-04	3.20e-04
Methylenechloride	Tritonal surrogate	3.40e-06	4.80e-05	2.50e-06	1.80e-05	1.80e-05
Methylenechloride	Tritonal surrogate with calcium stearate		6.30e-06	3.10e-04	1.60e-04	1.60e-04
Methylenechloride	Tritonal surrogate with water	0.00e+00	8.80e-06	1.10e-06	5.00e-06	6.70e-06
Methylenechloride	TNT (ACC1)	1.80e-04			1.80e-04	2.40e-04
Methylenechloride	TNT (ACC2)	0.00e+00			0.00e+00	2.70e-04
Methylenechloride	T45E7 Adapter Booster	5.00e-04			5.00e-04	5.90e-04
Methylenechloride	20 mm HEI Cartridge	4.50e-04			4.50e-04	9.00e-04
Methylenechloride	40 mm HEI Cartridge	8.70e-04			8.70e-04	1.40e-03
NO	Amatol surrogate	2.20e-04	1.40e-02	1.70e-02	1.80e-02	
NO	Amatol surrogate with water	2.60e-03	7.50e-03	8.00e-03	7.70e-03	

NO	Cartridge, Impulse, ARD 446-1	6.50e-03	6.20e-03	6.50e-03	6.40e-03	
NO	Cartridge, Impulse, BBU-36/B	5.30e-03	3.50e-03	3.30e-03	4.00e-03	
NO	Cartridge, Impulse, MK 107	1.70e-02	1.40e-02	1.30e-02	1.50e-02	
NO	Composition B surrogate	9.20e-03	8.90e-03	9.70e-03	9.30e-03	
NO	Detonating train	6.80e-03	3.60e-03	4.30e-03	4.90e-03	
NO	Flare, IR Countermeasure M206	4.90e-03	6.00e-03	5.10e-03	5.30e-03	
NO	Fuze, Tail Bomb FMU-139 A/B	9.80e-03	1.00e-02	9.80e-03	9.90e-03	
NO	Fuze, Tail Bomb FMU-54 A/B	7.30e-03	6.90e-03	6.90e-03	7.00e-03	
NO	Gas Generator, GGU-2/A	1.50e-03	1.30e-03	1.90e-03	1.60e-03	
NO	HBX surrogate	9.30e-03	9.80e-03	1.00e-02	9.90e-03	
NO	Signal, Illumination, Red Star AN-M43A2	1.20e-02	1.50e-02	1.10e-02	1.30e-02	
NO	Signal, Illumination, Red Star M158	2.60e-03	2.70e-03	2.70e-03	2.60e-03	
NO	Tritonal surrogate	1.30e-03	1.70e-02	5.90e-03	8.20e-03	
NO	Tritonal surrogate with calcium stearate		6.50e-03	6.70e-03	6.60e-03	
NO	Tritonal surrogate with water	4.30e-03	3.90e-03	3.80e-03	4.00e-03	
NO	TNT (ACC2)	9.20e-03			9.20e-03	
NO	TNT (Sandia)	9.80e-03	1.00e-02	9.20e-03	9.70e-03	
NO2	Amatol surrogate	3.40e-04	1.80e-04	4.20e-04	1.20e-04	
NO2	Amatol surrogate with water	2.00e-04	2.10e-04	2.90e-04	2.40e-04	
NO2	Cartridge, Impulse, ARD 446-1	1.90e-03	1.60e-03	1.70e-03	1.70e-03	
NO2	Cartridge, Impulse, BBU-36/B	1.50e-03	1.70e-03	1.30e-03	1.50e-03	
NO2	Cartridge, Impulse, MK 107	7.70e-04	5.40e-04	5.30e-04	6.10e-04	
NO2	Composition B surrogate	1.10e-04	1.70e-04	3.00e-04	1.90e-04	
NO2	Detonating train	8.10e-03	3.30e-03	1.90e-03	4.40e-03	
NO2	Flare, IR Countermeasure M206	2.60e-03	3.10e-03	2.80e-03	2.80e-03	
NO2	Fuze, Tail Bomb FMU-139 A/B	1.70e-02	1.70e-02	1.70e-02	1.70e-02	
NO2	Fuze, Tail Bomb FMU-54 A/B	2.40e-03	2.50e-03	2.60e-03	2.50e-03	
NO2	Gas Generator, GGU-2/A	2.60e-03	2.40e-03	2.30e-03	2.40e-03	
NO2	HBX surrogate	5.90e-05	4.00e-05	3.40e-05	4.40e-05	
NO2	Signal, Illumination, Red Star AN-M43A2	9.80e-04	1.30e-03	1.00e-03	1.10e-03	
NO2	Signal, Illumination, Red Star M158	1.40e-03	1.60e-03	1.60e-03	1.50e-03	
NO2	Tritonal surrogate	2.50e-04	1.90e-04	1.80e-05	1.50e-04	
NO2	Tritonal surrogate with calcium stearate		3.00e-05	5.90e-05	4.50e-05	
NO2	Tritonal surrogate with water	2.60e-04	1.50e-04	3.90e-04	2.70e-04	
NO2	TNT (ACC2)	6.60e-05			6.60e-05	
NO2	TNT (Sandia)	3.90e-04	9.60e-04	9.20e-04	7.60e-04	
OCDD	Signal, Illumination, Red Star AN-M43A2	8.30e-10	1.60e-09	2.90e-09	1.80e-09	1.80e-09
Propane	Amatol surrogate	1.10e-06	7.50e-07	1.10e-06	1.00e-06	1.40e-06
Propane	Amatol surrogate with water	1.40e-04	2.40e-04	1.70e-04	1.90e-04	1.90e-04
Propane	Cartridge, Impulse, ARD 446-1	6.20e-06	5.40e-06	5.50e-06	5.70e-06	1.00e-05
Propane	Cartridge, Impulse, BBU-36/B	2.70e-06	3.90e-06	3.90e-06	3.50e-06	8.50e-06

Propane	Cartridge, Impulse, MK 107	0.00e+00	1.30e-06	1.60e-06	1.40e-06	5.20e-06
Propane	Composition B surrogate	7.40e-07	0.00e+00	7.30e-07	7.40e-07	1.40e-06
Propane	Detonating train	4.70e-06	4.50e-06	4.80e-06	4.70e-06	1.10e-05
Propane	Flare, IR Countermeasure M206	0.00e+00	6.80e-07	2.00e-06	1.40e-06	3.90e-06
Propane	Fuze, Tail Bomb FMU-139 A/B	4.40e-06	3.40e-06	3.90e-06	3.90e-06	7.90e-06
Propane	Fuze, Tail Bomb FMU-54 A/B	8.90e-07	1.80e-06	1.80e-06	1.50e-06	6.00e-06
Propane	Gas Generator, GGU-2/A	7.70e-06	7.10e-06	8.50e-06	7.70e-06	1.10e-05
Propane	HBX surrogate	1.50e-06	4.10e-07	7.40e-07	8.70e-07	2.20e-06
Propane	Mine, Claymore, M18A1	3.40e-06	4.40e-06	2.80e-06	3.60e-06	9.80e-06
Propane	Signal, Illumination, Red Star AN-M43A2	1.70e-06	3.50e-06	2.40e-06	2.60e-06	4.60e-06
Propane	Signal, Illumination, Red Star M158	6.00e-06	5.30e-06	3.10e-06	4.80e-06	8.00e-06
Propane	Tritonal surrogate	0.00e+00	7.40e-07	7.30e-07	7.30e-07	1.20e-06
Propane	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-07	3.60e-07	2.20e-06
Propane	Tritonal surrogate with water	5.20e-05	5.00e-05	6.30e-05	5.50e-05	5.70e-05
Propane	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	9.50e-07
Propane	TNT (ACC2)	3.70e-07			3.70e-07	1.50e-06
Propane	T45E7 Adapter Booster	1.50e-05	8.20e-06	8.60e-06	1.10e-05	2.10e-05
Propane	20 mm HEI Cartridge	9.10e-06	6.50e-06	2.40e-05	1.30e-05	2.30e-05
Propane	40 mm HEI Cartridge	1.70e-06	5.00e-06	4.90e-06	3.80e-06	1.50e-05
Propene	Amatol surrogate	6.70e-06	3.40e-06	6.30e-06	5.50e-06	5.80e-06
Propene	Amatol surrogate with water	2.60e-04	4.90e-04	3.40e-04	3.60e-04	3.60e-04
Propene	Cartridge, Impulse, ARD 446-1	6.70e-05	5.50e-05	5.70e-05	6.00e-05	8.70e-05
Propene	Cartridge, Impulse, BBU-36/B	4.30e-05	4.60e-05	5.80e-05	4.90e-05	9.70e-05
Propene	Cartridge, Impulse, MK 107	2.80e-05	2.60e-05	2.40e-05	2.60e-05	3.80e-05
Propene	Composition B surrogate	3.70e-06	1.10e-06	4.40e-06	3.10e-06	4.10e-06
Propene	Detonating train	7.50e-05	7.10e-05	7.10e-05	7.30e-05	1.10e-04
Propene	Flare, IR Countermeasure M206	2.20e-05	2.00e-05	2.60e-05	2.20e-05	2.30e-05
Propene	Fuze, Tail Bomb FMU-139 A/B	5.90e-05	6.30e-05	5.50e-05	5.90e-05	5.90e-05
Propene	Fuze, Tail Bomb FMU-54 A/B	3.80e-05	5.20e-05	3.90e-05	4.30e-05	4.30e-05
Propene	Gas Generator, GGU-2/A	6.90e-05	6.80e-05	7.80e-05	7.20e-05	7.30e-05
Propene	HBX surrogate	8.40e-06	7.80e-06	1.20e-05	9.40e-06	9.90e-06
Propene	Mine, Claymore, M18A1	2.10e-05	2.70e-05	2.60e-05	2.40e-05	2.50e-05
Propene	Signal, Illumination, Red Star AN-M43A2	3.20e-05	3.90e-05	3.40e-05	3.50e-05	3.50e-05
Propene	Signal, Illumination, Red Star M158	6.00e-05	5.80e-05	5.00e-05	5.60e-05	5.60e-05
Propene	Tritonal surrogate	2.60e-06	1.50e-06	5.40e-06	3.20e-06	3.60e-06
Propene	Tritonal surrogate with calcium stearate		8.10e-06	4.00e-06	6.10e-06	6.60e-06
Propene	Tritonal surrogate with water	1.70e-04	1.20e-04	1.80e-04	1.60e-04	1.60e-04
Propene	TNT (ACC1)	7.80e-06	8.10e-06	5.80e-06	7.20e-06	7.70e-06
Propene	TNT (ACC2)	4.10e-06			4.10e-06	4.10e-06
Propene	T45E7 Adapter Booster	2.00e-04	1.60e-04	1.30e-04	1.60e-04	1.60e-04
Propene	20 mm HEI Cartridge	6.20e-05	4.00e-05	5.00e-05	5.10e-05	7.20e-05

Propene	40 mm HEI Cartridge	1.80e-05	1.70e-05	1.20e-05	1.60e-05	2.40e-05
PETN	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
PETN	Cartridge, Impulse, BBU-36/B	0.00e+00	9.30e-04	2.30e-04	5.80e-04	5.80e-04
PETN	Cartridge, Impulse, MK 107	2.30e-05	1.10e-04	1.80e-05	5.10e-05	7.60e-05
PETN	Detonating train	5.60e-04	7.30e-04	4.10e-04	5.60e-04	8.80e-04
PETN	Flare, IR Countermeasure M206	2.40e-06	1.90e-06	4.00e-07	1.60e-06	2.10e-06
PETN	Fuze, Tail Bomb FMU-139 A/B	2.60e-05	1.50e-05	8.90e-06	1.70e-05	1.90e-05
PETN	Fuze, Tail Bomb FMU-54 A/B	1.20e-05	1.10e-05	5.80e-06	9.60e-06	1.40e-05
PETN	Gas Generator, GGU-2/A	1.10e-04	2.90e-05	1.10e-05	4.90e-05	6.30e-05
PETN	Signal, Illumination, Red Star AN-M43A2	1.70e-05	8.20e-06	1.10e-05	1.20e-05	1.20e-05
PETN	Signal, Illumination, Red Star M158	1.30e-05	5.60e-06	6.10e-06	8.40e-06	8.40e-06
PETN	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
PM10	Amatol surrogate	1.50e-02	2.10e-02	2.00e-02	1.90e-02	
PM10	Amatol surrogate with water	2.40e-02	3.10e-02	4.00e-02	3.20e-02	
PM10	Cartridge, Impulse, ARD 446-1	8.30e-02	1.20e-01	8.60e-02	8.30e-02	
PM10	Cartridge, Impulse, BBU-36/B	1.60e-01	1.90e-01	1.90e-01	1.80e-01	
PM10	Cartridge, Impulse, MK 107	2.40e-01	2.60e-01	2.50e-01	2.50e-01	
PM10	Composition B surrogate	1.00e-02	1.10e-02	1.50e-02	1.20e-02	
PM10	Detonating train	3.60e-02	4.00e-02	3.20e-02	3.60e-02	
PM10	Flare, IR Countermeasure M206	4.90e-01	5.90e-01	5.80e-01	5.50e-01	
PM10	Fuze, Tail Bomb FMU-139 A/B	6.50e-01	5.60e-01	5.90e-01	6.00e-01	
PM10	Fuze, Tail Bomb FMU-54 A/B	3.10e-01	3.40e-01	3.40e-01	3.30e-01	
PM10	Gas Generator, GGU-2/A	9.80e-02	9.20e-02	8.90e-02	9.30e-02	
PM10	HBX surrogate	6.80e-02	3.70e-02	4.40e-01	1.80e-01	
PM10	Mine, Claymore, M18A1	2.40e-01	2.30e-01	2.10e-01	2.30e-01	
PM10	Signal, Illumination, Red Star AN-M43A2	4.30e-01	4.50e-01	4.80e-01	4.50e-01	
PM10	Signal, Illumination, Red Star M158	9.20e-02	8.30e-02	7.20e-02	8.20e-02	
PM10	Tritonal surrogate	6.30e-01	2.50e-01	2.20e-01	3.70e-01	
PM10	Tritonal surrogate with calcium stearate		2.30e-01	3.00e-01	2.60e-01	
PM10	Tritonal surrogate with water	1.10e-01	2.20e-01	2.30e-01	1.90e-01	
PM10	TNT (ACC1)	7.20e-02	7.30e-02	7.50e-02	7.30e-02	
PM10	TNT (ACC2)	9.30e-02			9.30e-02	
PM10	T45E7 Adapter Booster	2.40e-01	2.70e-01	2.70e-01	2.60e-01	
PM10	40 mm HEI Cartridge	4.70e-01	4.80e-01	4.50e-01	4.70e-01	
RDX	Cartridge, Impulse, ARD 446-1	2.30e-03	1.20e-02	1.10e-02	8.40e-04	1.20e-03
RDX	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.10e-04
RDX	Cartridge, Impulse, MK 107	1.70e-04	1.80e-04	1.50e-04	1.70e-04	2.40e-04
RDX	Detonating train	1.10e-02	7.90e-03	3.70e-03	7.40e-03	1.20e-02
RDX	Flare, IR Countermeasure M206	8.70e-05	5.40e-05	3.80e-05	6.00e-05	6.20e-05
RDX	Fuze, Tail Bomb FMU-139 A/B	3.50e-04	3.80e-04	3.00e-04	3.40e-04	3.40e-04
RDX	Fuze, Tail Bomb FMU-54 A/B	9.70e-05	9.20e-05	8.00e-05	9.00e-05	1.30e-04

RDX	Gas Generator, GGU-2/A	2.10e-04	1.10e-04	1.00e-04	1.40e-04	1.60e-04
RDX	Mine, Claymore, M18A1	1.00e-05	6.50e-07	1.90e-05	9.90e-06	1.20e-05
RDX	Signal, Illumination, Red Star AN-M43A2	1.50e-04	2.00e-04	2.30e-04	1.90e-04	1.90e-04
RDX	Signal, Illumination, Red Star M158	5.20e-05	5.40e-05	6.00e-05	5.50e-05	6.70e-05
RDX	TNT (ACC1)	1.40e-06	1.30e-06	9.70e-07	1.20e-06	2.10e-06
RDX	TNT (ACC2)	9.60e-06			9.60e-06	1.00e-05
RDX	T45E7 Adapter Booster	2.50e-04	2.90e-04	1.80e-04	2.40e-04	2.80e-04
RDX	20 mm HEI Cartridge	1.30e-05	1.50e-05	7.10e-06	1.20e-05	3.00e-05
RDX	40 mm HEI Cartridge	2.60e-05	3.30e-05	5.20e-05	3.70e-05	3.20e-05
Styrene	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Cartridge, Impulse, ARD 446-1	6.70e-06	4.10e-06	5.20e-06	5.40e-06	5.40e-06
Styrene	Cartridge, Impulse, BBU-36/B	2.40e-06	2.80e-06	5.60e-06	3.60e-06	3.60e-06
Styrene	Cartridge, Impulse, MK 107	9.50e-06	9.50e-06	9.20e-06	9.40e-06	1.40e-05
Styrene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Detonating train	4.10e-06	3.00e-06	5.10e-06	4.10e-06	4.10e-06
Styrene	Flare, IR Countermeasure M206	7.60e-06	4.10e-06	9.50e-06	7.10e-06	7.80e-06
Styrene	Fuze, Tail Bomb FMU-139 A/B	3.20e-05	2.70e-05	3.00e-05	2.90e-05	3.10e-05
Styrene	Fuze, Tail Bomb FMU-54 A/B	5.60e-06	9.80e-06	7.90e-06	7.80e-06	1.10e-05
Styrene	Gas Generator, GGU-2/A	7.70e-06	8.80e-06	8.50e-06	8.30e-06	9.10e-06
Styrene	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Mine, Claymore, M18A1	2.10e-03	1.40e-03	1.50e-03	1.70e-03	1.70e-03
Styrene	Signal, Illumination, Red Star AN-M43A2	6.20e-06	4.90e-06	2.40e-06	4.50e-06	5.40e-06
Styrene	Signal, Illumination, Red Star M158	2.10e-06	3.50e-06	1.00e-06	2.20e-06	2.60e-06
Styrene	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Styrene	TNT (ACC2)	1.50e-06			1.50e-06	1.50e-06
Styrene	T45E7 Adapter Booster	2.30e-04	7.40e-05	3.70e-05	1.20e-04	1.30e-04
Styrene	20 mm HEI Cartridge	0.00e+00	3.60e-06	0.00e+00	3.60e-06	3.60e-06
Styrene	40 mm HEI Cartridge	4.20e-05	0.00e+00	0.00e+00	4.20e-05	4.20e-05
SO2	Amatol surrogate	3.20e-04	2.10e-04	2.50e-04	2.60e-04	
SO2	Amatol surrogate with water	1.10e-04	1.70e-04	1.10e-04	1.30e-04	
SO2	Cartridge, Impulse, ARD 446-1	2.30e-04	2.30e-04	2.60e-04	2.40e-04	
SO2	Cartridge, Impulse, BBU-36/B	3.80e-04	4.00e-04	4.20e-04	4.00e-04	
SO2	Cartridge, Impulse, MK 107	3.00e-04	2.40e-04	2.30e-04	2.60e-04	
SO2	Composition B surrogate	1.40e-04	1.40e-04	1.10e-04	1.30e-04	
SO2	Detonating train	6.70e-04	3.20e-04	3.70e-04	4.60e-04	
SO2	Flare, IR Countermeasure M206	5.80e-04	1.20e-03	1.30e-03	1.00e-03	
SO2	Fuze, Tail Bomb FMU-139 A/B	1.40e-03	1.30e-03	1.40e-03	1.40e-03	

SO2	Fuze, Tail Bomb FMU-54 A/B	4.80e-04	3.60e-04	3.80e-04	4.10e-04	
SO2	Gas Generator, GGU-2/A	3.40e-04	4.50e-04	3.90e-04	4.00e-04	
SO2	HBX surrogate	1.00e-04	1.10e-03	1.90e-03	1.10e-03	
SO2	Signal, Illumination, Red Star AN-M43A2	1.30e-02	1.30e-02	1.30e-02	1.30e-02	
SO2	Signal, Illumination, Red Star M158	2.70e-04	2.40e-05	4.10e-05	1.10e-04	
SO2	Tritonal surrogate	1.20e-04	2.80e-04	7.80e-05	1.60e-04	
SO2	Tritonal surrogate with calcium stearate		1.80e-04	6.70e-05	1.20e-04	
SO2	Tritonal surrogate with water	2.60e-05	5.70e-05	5.90e-05	4.70e-05	
SO2	TNT (ACC2)	1.40e-04			1.40e-04	
SO2	TNT (Sandia)	1.90e-04	1.20e-04	1.10e-04	1.40e-04	
Tetrachloroethylene	Amatol surrogate	3.70e-07	3.70e-07	0.00e+00	3.70e-07	3.70e-07
Tetrachloroethylene	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Cartridge, Impulse, ARD 446-1	2.20e-05	5.90e-05	2.80e-05	3.60e-05	8.30e-05
Tetrachloroethylene	Cartridge, Impulse, BBU-36/B	3.20e-06	1.60e-06	0.00e+00	2.40e-06	6.40e-06
Tetrachloroethylene	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Composition B surrogate	2.10e-05	1.90e-05	1.40e-05	1.80e-05	3.50e-05
Tetrachloroethylene	Detonating train	1.20e-05	1.20e-05	1.00e-05	1.10e-05	3.40e-05
Tetrachloroethylene	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Gas Generator, GGU-2/A	7.00e-06	7.00e-06	3.60e-06	5.90e-06	5.90e-06
Tetrachloroethylene	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Mine, Claymore, M18A1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	Tritonal surrogate	1.90e-06	3.30e-06	2.90e-06	2.70e-06	4.10e-06
Tetrachloroethylene	Tritonal surrogate with calcium stearate		3.70e-07	3.60e-07	3.70e-07	7.30e-07
Tetrachloroethylene	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Tetrachloroethylene	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	
Titanium	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

Titanium	Fuze, Tail Bomb FMU-139 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Gas Generator, GGU-2/A	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Mine, Claymore, M18A1	1.30e-04			1.30e-04	0.00e+00
Titanium	Signal, Illumination, Red Star AN-M43A2	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Titanium	TNT (ACC1)	0.00e+00			0.00e+00	0.00e+00
Titanium	TNT (ACC2)	0.00e+00			0.00e+00	0.00e+00
Titanium	T45E7 Adapter Booster	8.70e-05			8.70e-05	8.70e-05
Titanium	20 mm HEI Cartridge	0.00e+00			0.00e+00	0.00e+00
Titanium	40 mm HEI Cartridge	0.00e+00			0.00e+00	0.00e+00
Toluene	Amatol surrogate	1.10e-05	3.70e-06	5.20e-06	6.70e-06	2.00e-05
Toluene	Amatol surrogate with water	8.10e-05	1.60e-04	1.20e-04	1.20e-04	1.60e-04
Toluene	Cartridge, Impulse, ARD 446-1	1.50e-05	1.50e-05	2.00e-05	1.70e-05	5.40e-05
Toluene	Cartridge, Impulse, BBU-36/B	1.30e-05	7.90e-06	6.40e-06	9.10e-06	4.70e-05
Toluene	Cartridge, Impulse, MK 107	8.40e-06	9.70e-06	8.90e-06	9.00e-06	2.00e-05
Toluene	Composition B surrogate	4.80e-06	3.70e-06	9.50e-06	6.00e-06	2.10e-05
Toluene	Detonating train	1.70e-06	3.60e-06	7.20e-06	4.20e-06	5.70e-05
Toluene	Flare, IR Countermeasure M206	3.10e-05	2.30e-05	3.00e-05	2.80e-05	4.10e-05
Toluene	Fuze, Tail Bomb FMU-139 A/B	2.30e-05	2.20e-05	2.50e-05	2.30e-05	3.00e-05
Toluene	Fuze, Tail Bomb FMU-54 A/B	2.00e-05	4.30e-05	3.20e-05	3.20e-05	5.70e-05
Toluene	Gas Generator, GGU-2/A	5.90e-06	1.90e-05	1.30e-05	1.30e-05	5.40e-05
Toluene	HBX surrogate	4.80e-06	8.20e-07	4.50e-06	3.30e-06	5.30e-05
Toluene	Mine, Claymore, M18A1	1.90e-04	2.50e-04	3.10e-04	2.50e-04	2.60e-04
Toluene	Signal, Illumination, Red Star AN-M43A2	2.90e-05	2.90e-05	3.00e-05	3.00e-05	4.30e-05
Toluene	Signal, Illumination, Red Star M158	2.50e-05	2.40e-05	2.70e-05	2.50e-05	3.90e-05
Toluene	Tritonal surrogate	1.90e-06	0.00e+00	1.80e-06	1.80e-06	6.30e-05
Toluene	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	6.40e-05
Toluene	Tritonal surrogate with water	1.10e-04	3.40e-05	7.90e-05	7.30e-05	1.60e-04
Toluene	TNT (ACC1)	6.50e-06	3.80e-06	0.00e+00	5.10e-06	1.20e-05
Toluene	TNT (ACC2)	1.50e-06			1.50e-06	2.10e-05
Toluene	T45E7 Adapter Booster	5.50e-05	4.50e-05	5.60e-05	5.20e-05	7.40e-05
Toluene	20 mm HEI Cartridge	2.80e-05	3.40e-05	2.90e-05	3.00e-05	6.40e-05
Toluene	40 mm HEI Cartridge	2.60e-05	0.00e+00	0.00e+00	2.60e-05	6.40e-05
Total Alkanes (Paraffins)	Amatol surrogate	1.00e-05	1.60e-05	2.10e-05	1.60e-05	4.10e-05
Total Alkanes (Paraffins)	Amatol surrogate with water	1.10e-03	1.10e-03	1.40e-03	1.20e-03	1.40e-03
Total Alkanes (Paraffins)	Cartridge, Impulse, ARD 446-1	5.20e-05	4.10e-05	6.10e-05	5.10e-05	1.30e-04

Total Alkanes (Paraffins)	Cartridge, Impulse, BBU-36/B	3.30e-05	3.60e-05	4.60e-05	3.80e-05	1.40e-04
Total Alkanes (Paraffins)	Cartridge, Impulse, MK 107	2.90e-06	1.00e-05	7.60e-06	6.90e-06	3.90e-05
Total Alkanes (Paraffins)	Composition B surrogate	1.30e-05	6.30e-06	1.50e-05	1.10e-05	4.30e-05
Total Alkanes (Paraffins)	Detonating train	1.80e-05	2.80e-05	3.80e-05	2.80e-05	1.50e-04
Total Alkanes (Paraffins)	Flare, IR Countermeasure M206	8.00e-06	0.00e+00	1.20e-05	9.90e-06	3.80e-05
Total Alkanes (Paraffins)	Fuze, Tail Bomb FMU-139 A/B	1.30e-05	2.60e-05	5.30e-06	1.50e-05	4.20e-05
Total Alkanes (Paraffins)	Fuze, Tail Bomb FMU-54 A/B	2.20e-05	2.30e-05	0.00e+00	2.20e-05	8.90e-05
Total Alkanes (Paraffins)	Gas Generator, GGU-2/A	4.50e-05	5.80e-05	2.70e-05	4.30e-05	1.70e-04
Total Alkanes (Paraffins)	HBX surrogate	2.50e-05	8.20e-07	1.70e-05	1.40e-05	1.50e-04
Total Alkanes (Paraffins)	Mine, Claymore, M18A1	6.50e-05	6.80e-05	8.10e-05	7.10e-05	1.20e-04
Total Alkanes (Paraffins)	Signal, Illumination, Red Star AN-M43A2	2.30e-05	9.10e-06	1.20e-05	1.50e-05	3.60e-05
Total Alkanes (Paraffins)	Signal, Illumination, Red Star M158	3.70e-05	4.10e-05	4.10e-06	2.70e-05	6.70e-05
Total Alkanes (Paraffins)	Tritonal surrogate	3.70e-06	0.00e+00	1.60e-05	1.00e-05	2.10e-04
Total Alkanes (Paraffins)	Tritonal surrogate with calcium stearate		0.00e+00	0.00e+00	0.00e+00	2.00e-04
Total Alkanes (Paraffins)	Tritonal surrogate with water	1.40e-04	1.60e-04	3.70e-04	2.20e-04	5.40e-04
Total Alkanes (Paraffins)	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	7.50e-05
Total Alkanes (Paraffins)	TNT (ACC2)	3.30e-06			3.30e-06	4.00e-05
Total Alkanes (Paraffins)	TNT (Sandia)	1.20e-05	8.50e-06	5.40e-06	8.60e-06	
Total Alkanes (Paraffins)	T45E7 Adapter Booster	5.60e-05	6.70e-05	1.40e-04	8.70e-05	2.10e-04
Total Alkanes (Paraffins)	20 mm HEI Cartridge	1.20e-04	1.40e-04	2.40e-04	1.70e-04	3.90e-04
Total Alkanes (Paraffins)	40 mm HEI Cartridge	1.60e-04	0.00e+00	0.00e+00	1.60e-04	4.70e-04
Total Alkenes (Olefins)	Amatol surrogate	2.50e-04	7.20e-05	9.60e-05	1.40e-04	1.40e-04
Total Alkenes (Olefins)	Amatol surrogate with water	1.30e-03	1.40e-03	1.70e-03	1.50e-03	1.50e-03
Total Alkenes (Olefins)	Cartridge, Impulse, ARD 446-1	8.10e-04	6.20e-04	6.10e-04	6.80e-04	1.00e-03
Total Alkenes (Olefins)	Cartridge, Impulse, BBU-36/B	5.10e-04	5.00e-04	6.20e-04	5.40e-04	1.10e-03
Total Alkenes (Olefins)	Cartridge, Impulse, MK 107	5.60e-04	4.90e-04	4.10e-04	4.80e-04	7.10e-04
Total Alkenes (Olefins)	Composition B surrogate	2.50e-05	2.30e-05	5.30e-05	3.40e-05	3.80e-05
Total Alkenes (Olefins)	Detonating train	7.70e-04	6.40e-04	6.60e-04	6.90e-04	1.10e-03
Total Alkenes (Olefins)	Flare, IR Countermeasure M206	4.40e-04	4.30e-04	4.80e-04	4.50e-04	4.60e-04
Total Alkenes (Olefins)	Fuze, Tail Bomb FMU-139 A/B	9.20e-04	1.20e-03	1.20e-03	1.10e-03	1.10e-03
Total Alkenes (Olefins)	Fuze, Tail Bomb FMU-54 A/B	5.40e-04	9.30e-04	7.50e-04	7.40e-04	9.90e-04
Total Alkenes (Olefins)	Gas Generator, GGU-2/A	1.30e-03	1.40e-03	1.60e-03	1.40e-03	1.50e-03
Total Alkenes (Olefins)	HBX surrogate	8.00e-05	6.70e-05	1.30e-04	9.40e-05	9.90e-05
Total Alkenes (Olefins)	Mine, Claymore, M18A1	1.00e-03	1.40e-03	1.50e-03	1.30e-03	1.30e-03
Total Alkenes (Olefins)	Signal, Illumination, Red Star AN-M43A2	5.50e-04	6.50e-04	5.90e-04	6.00e-04	6.00e-04
Total Alkenes (Olefins)	Signal, Illumination, Red Star M158	6.40e-04	7.80e-04	4.50e-04	6.20e-04	6.30e-04
Total Alkenes (Olefins)	Tritonal surrogate	2.40e-04	1.50e-04	8.30e-05	1.60e-04	1.70e-04
Total Alkenes (Olefins)	Tritonal surrogate with calcium stearate		7.60e-05	4.70e-05	6.10e-05	6.90e-05
Total Alkenes (Olefins)	Tritonal surrogate with water	5.90e-03	5.50e-03	6.10e-03	5.90e-03	5.90e-03
Total Alkenes (Olefins)	TNT (ACC1)	7.70e-05	6.50e-05	3.90e-05	6.00e-05	6.40e-05
Total Alkenes (Olefins)	TNT (ACC2)	4.20e-05			4.20e-05	4.40e-05

Total Alkenes (Olefins)	TNT (Sandia)	5.00e-06	1.70e-05	1.70e-05	1.30e-05	
Total Alkenes (Olefins)	T45E7 Adapter Booster	1.80e-03	1.30e-03	1.10e-03	1.40e-03	1.40e-03
Total Alkenes (Olefins)	20 mm HEI Cartridge	6.80e-04	4.60e-04	6.10e-04	5.80e-04	8.20e-04
Total Alkenes (Olefins)	40 mm HEI Cartridge	2.00e-04	1.50e-04	1.10e-04	1.50e-04	2.40e-04
Total Aromatics	Amatol surrogate	5.80e-05	2.80e-05	4.20e-05	4.30e-05	8.30e-05
Total Aromatics	Amatol surrogate with water	3.30e-04	3.70e-04	4.80e-04	3.90e-04	4.70e-04
Total Aromatics	Cartridge, Impulse, ARD 446-1	1.00e-04	9.50e-05	1.00e-04	1.00e-04	2.40e-04
Total Aromatics	Cartridge, Impulse, BBU-36/B	7.40e-05	6.20e-05	5.70e-05	6.40e-05	2.10e-04
Total Aromatics	Composition B surrogate	1.70e-05	1.80e-05	3.60e-05	2.40e-05	7.10e-05
Total Aromatics	Detonating train	3.40e-05	4.00e-05	4.40e-05	3.90e-05	2.00e-04
Total Aromatics	Flare, IR Countermeasure M206	9.10e-05	7.00e-05	9.70e-05	8.60e-05	1.20e-04
Total Aromatics	Fuze, Tail Bomb FMU-139 A/B	1.80e-04	1.80e-04	2.00e-04	1.90e-04	2.10e-04
Total Aromatics	Fuze, Tail Bomb FMU-54 A/B	9.90e-05	2.40e-04	1.70e-04	1.70e-04	2.70e-04
Total Aromatics	Gas Generator, GGU-2/A	1.20e-04	1.70e-04	1.80e-04	1.60e-04	2.80e-04
Total Aromatics	HBX surrogate	0.00e+00	1.10e-05	3.10e-05	2.10e-05	1.50e-04
Total Aromatics	Mine, Claymore, M18A1	3.10e-03	3.00e-03	3.10e-03	3.00e-03	3.10e-03
Total Aromatics	Signal, Illumination, Red Star AN-M43A2	7.00e-05	7.80e-05	6.80e-05	7.20e-05	1.00e-04
Total Aromatics	Signal, Illumination, Red Star M158	6.30e-05	6.70e-05	5.80e-05	6.30e-05	9.60e-05
Total Aromatics	Tritonal surrogate	3.40e-05	2.20e-05	2.30e-05	2.70e-05	1.70e-04
Total Aromatics	Tritonal surrogate with calcium stearate		0.00e+00	1.40e-05	1.40e-05	1.60e-04
Total Aromatics	Tritonal surrogate with water	4.70e-04	1.80e-04	3.60e-04	3.40e-04	5.20e-04
Total Aromatics	TNT (ACC1)	1.70e-05	1.50e-05	0.00e+00	1.60e-05	6.10e-05
Total Aromatics	TNT (ACC2)	3.00e-06			3.00e-06	6.00e-05
Total Aromatics	TNT (Sandia)	2.70e-06	9.90e-06	1.20e-05	8.20e-06	
Total Aromatics	T45E7 Adapter Booster	5.10e-04	3.20e-04	2.50e-04	3.60e-04	4.20e-04
Total Aromatics	20 mm HEI Cartridge	2.10e-04	2.10e-04	2.30e-04	2.10e-04	3.80e-04
Total Aromatics	40 mm HEI Cartridge	1.00e-04	0.00e+00	0.00e+00	1.00e-04	2.60e-04
Total HpCDD	Signal, Illumination, Red Star AN-M43A2	2.60e-10	5.70e-10	1.00e-09	6.10e-10	6.10e-10
Total Non-methane Hydrocarbons	Amatol surrogate	7.50e-04	3.40e-04	2.60e-04	4.50e-04	5.90e-04
Total Non-methane Hydrocarbons	Amatol surrogate with water	3.60e-03	3.80e-03	4.00e-03	3.80e-03	4.20e-03
Total Non-methane Hydrocarbons	Cartridge, Impulse, ARD 446-1	1.10e-03	9.10e-04	9.10e-04	9.80e-04	1.70e-03
Total Non-methane Hydrocarbons	Cartridge, Impulse, BBU-36/B	7.50e-04	7.10e-04	8.40e-04	7.70e-04	1.70e-03
Total Non-methane Hydrocarbons	Cartridge, Impulse, MK 107	7.30e-04	6.50e-04	5.60e-04	6.40e-04	1.00e-03
Total Non-methane Hydrocarbons	Composition B surrogate	5.50e-05	1.30e-04	1.50e-04	1.10e-04	3.00e-04
Total Non-methane Hydrocarbons	Detonating train	9.20e-04	8.10e-04	8.30e-04	8.50e-04	1.60e-03
Total Non-methane Hydrocarbons	Flare, IR Countermeasure M206	5.80e-04	5.60e-04	6.90e-04	6.10e-04	7.10e-04
Total Non-methane Hydrocarbons	Fuze, Tail Bomb FMU-139 A/B	1.20e-03	1.50e-03	1.50e-03	1.40e-03	1.50e-03
Total Non-methane Hydrocarbons	Fuze, Tail Bomb FMU-54 A/B	7.10e-04	1.30e-03	9.80e-04	9.90e-04	1.50e-03
Total Non-methane Hydrocarbons	Gas Generator, GGU-2/A	1.60e-03	1.70e-03	2.00e-03	1.80e-03	2.10e-03
Total Non-methane Hydrocarbons	HBX surrogate	2.00e-04	7.70e-05	2.70e-04	1.80e-04	5.80e-04
Total Non-methane Hydrocarbons	Mine, Claymore, M18A1	4.70e-03	4.80e-03	5.20e-03	4.90e-03	5.10e-03

Total Non-methane Hydrocarbons	Signal, Illumination, Red Star AN-M43A2	6.80e-04	8.50e-04	7.10e-04	7.40e-04	8.40e-04
Total Non-methane Hydrocarbons	Signal, Illumination, Red Star M158	7.90e-04	9.50e-04	5.70e-04	7.70e-04	8.80e-04
Total Non-methane Hydrocarbons	Tritonal surrogate	3.90e-04	2.60e-04	1.80e-04	2.80e-04	7.50e-04
Total Non-methane Hydrocarbons	Tritonal surrogate with calcium stearate		2.80e-05	5.10e-05	4.00e-05	5.40e-04
Total Non-methane Hydrocarbons	Tritonal surrogate with water	7.00e-03	6.50e-03	7.90e-03	7.10e-03	7.80e-03
Total Non-methane Hydrocarbons	TNT (ACC1)	0.00e+00	2.80e-05	0.00e+00	2.80e-05	5.50e-04
Total Non-methane Hydrocarbons	TNT (ACC2)	4.00e-05			4.00e-05	2.10e-04
Total Non-methane Hydrocarbons	T45E7 Adapter Booster	2.70e-03	1.60e-03	1.40e-03	1.90e-03	2.60e-03
Total Non-methane Hydrocarbons	20 mm HEI Cartridge	1.30e-03	9.20e-04	1.30e-03	1.20e-03	2.60e-03
Total Non-methane Hydrocarbons	40 mm HEI Cartridge	6.50e-04	0.00e+00	9.00e-06	3.30e-04	2.40e-03
Total Unidentified Hydrocarbons	Amatol surrogate	4.40e-04	2.30e-04	1.00e-04	2.50e-04	3.30e-04
Total Unidentified Hydrocarbons	Amatol surrogate with water	8.10e-04	8.50e-04	4.30e-04	7.00e-04	8.00e-04
Total Unidentified Hydrocarbons	Cartridge, Impulse, ARD 446-1	1.50e-04	1.50e-04	1.30e-04	1.40e-04	2.80e-04
Total Unidentified Hydrocarbons	Cartridge, Impulse, BBU-36/B	1.30e-04	1.20e-04	1.20e-04	1.20e-04	3.10e-04
Total Unidentified Hydrocarbons	Cartridge, Impulse, MK 107	7.20e-05	6.00e-05	6.50e-05	6.60e-05	1.30e-04
Total Unidentified Hydrocarbons	Composition B surrogate	3.70e-07	8.60e-05	5.00e-05	4.50e-05	1.50e-04
Total Unidentified Hydrocarbons	Detonating train	1.00e-04	1.00e-04	8.20e-05	9.60e-05	2.40e-04
Total Unidentified Hydrocarbons	Flare, IR Countermeasure M206	3.80e-05	6.50e-05	9.50e-05	6.60e-05	9.00e-05
Total Unidentified Hydrocarbons	Fuze, Tail Bomb FMU-139 A/B	9.60e-05	1.30e-04	8.30e-05	1.00e-04	1.40e-04
Total Unidentified Hydrocarbons	Fuze, Tail Bomb FMU-54 A/B	5.10e-05	8.00e-05	7.00e-05	6.70e-05	1.20e-04
Total Unidentified Hydrocarbons	Gas Generator, GGU-2/A	1.40e-04	1.20e-04	1.80e-04	1.50e-04	2.10e-04
Total Unidentified Hydrocarbons	HBX surrogate	7.30e-05	0.00e+00	8.40e-05	7.90e-05	1.80e-04
Total Unidentified Hydrocarbons	Mine, Claymore, M18A1	5.10e-04	4.00e-04	5.60e-04	4.90e-04	6.30e-04
Total Unidentified Hydrocarbons	Signal, Illumination, Red Star AN-M43A2	3.30e-05	1.10e-04	4.20e-05	6.10e-05	1.00e-04
Total Unidentified Hydrocarbons	Signal, Illumination, Red Star M158	4.10e-05	6.80e-05	5.80e-05	5.60e-05	9.10e-05
Total Unidentified Hydrocarbons	Tritonal surrogate	1.20e-04	9.60e-05	5.40e-05	9.00e-05	2.00e-04
Total Unidentified Hydrocarbons	Tritonal surrogate with calcium stearate		0.00e+00	3.60e-06	3.60e-06	1.20e-04
Total Unidentified Hydrocarbons	Tritonal surrogate with water	4.70e-04	6.00e-04	1.10e-03	7.10e-04	8.70e-04
Total Unidentified Hydrocarbons	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	3.50e-04
Total Unidentified Hydrocarbons	T45E7 Adapter Booster	3.10e-04	0.00e+00	0.00e+00	3.10e-04	5.70e-04
Total Unidentified Hydrocarbons	20 mm HEI Cartridge	3.00e-04	1.20e-04	2.40e-04	2.20e-04	1.00e-03
Total Unidentified Hydrocarbons	40 mm HEI Cartridge	1.80e-04	0.00e+00	2.00e-04	1.90e-04	1.40e-03
Vinyl chloride	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Cartridge, Impulse, BBU-36/B	6.10e-07	2.50e-06	1.90e-06	1.70e-06	1.70e-06
Vinyl chloride	Cartridge, Impulse, MK 107	2.40e-06	0.00e+00	0.00e+00	2.40e-06	2.40e-06
Vinyl chloride	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Detonating train	1.30e-06	0.00e+00	0.00e+00	1.30e-06	1.30e-06
Vinyl chloride	Flare, IR Countermeasure M206	1.50e-06	1.50e-06	1.50e-06	1.50e-06	1.50e-06
Vinyl chloride	Fuze, Tail Bomb FMU-139 A/B	2.20e-06	2.20e-06	1.10e-06	1.80e-06	1.80e-06

Vinyl chloride	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	6.70e-07	6.90e-07	6.80e-07	6.80e-07
Vinyl chloride	Gas Generator, GGU-2/A	2.50e-05	2.80e-05	7.70e-05	4.40e-05	4.40e-05
Vinyl chloride	HBX surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Mine, Claymore, M18A1	1.10e-06			1.10e-06	1.10e-06
Vinyl chloride	Signal, Illumination, Red Star AN-M43A2	2.30e-06	2.30e-06	2.30e-06	2.30e-06	2.30e-06
Vinyl chloride	Signal, Illumination, Red Star M158	8.00e-07	1.60e-06	7.80e-07	1.10e-06	1.10e-06
Vinyl chloride	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Tritonal surrogate with calcium stearate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	TNT (ACC1)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	TNT (ACC2)	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	T45E7 Adapter Booster	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	20 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Vinyl chloride	40 mm HEI Cartridge	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Amatol surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Cartridge, Impulse, BBU-36/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Cartridge, Impulse, MK 107	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Detonating train	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Flare, IR Countermeasure M206	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Fuze, Tail Bomb FMU-139 A/B	8.20e-03	5.40e-03	5.00e-03	6.20e-03	6.30e-03
Zinc	Fuze, Tail Bomb FMU-54 A/B	0.00e+00	0.00e+00	0.00e+00	0.00e+00	8.20e-05
Zinc	Gas Generator, GGU-2/A	1.60e-04	2.40e-04	1.50e-04	1.80e-04	2.10e-04
Zinc	HBX surrogate	0.00e+00	2.10e-04	2.60e-04	1.40e-04	1.40e-04
Zinc	Mine, Claymore, M18A1	1.60e-03	0.00e+00	0.00e+00	1.60e-03	8.00e-05
Zinc	Signal, Illumination, Red Star AN-M43A2	5.80e-04	2.70e-04	1.80e-04	3.40e-04	3.50e-04
Zinc	Signal, Illumination, Red Star M158	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Tritonal surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	Tritonal surrogate with calcium stearate		1.60e-04	0.00e+00	7.00e-05	7.70e-05
Zinc	Tritonal surrogate with water	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
Zinc	TNT (ACC1)	0.00e+00			0.00e+00	0.00e+00
Zinc	TNT (ACC2)	1.00e-05			1.00e-05	2.00e-05
Zinc	T45E7 Adapter Booster	2.90e-03			2.90e-03	4.20e-04
Zinc	20 mm HEI Cartridge	1.60e-02			1.60e-02	7.40e-03
Zinc	40 mm HEI Cartridge	1.10e-03			1.10e-03	2.80e-04
1-Butene	Amatol surrogate	1.90e-06	0.00e+00	1.50e-06	1.70e-06	1.70e-06
1-Butene	Amatol surrogate with water	8.10e-05	1.50e-04	7.90e-05	1.00e-04	1.00e-04
1-Butene	Cartridge, Impulse, ARD 446-1	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Butene	Cartridge, Impulse, BBU-36/B	6.00e-06	6.40e-06	9.40e-06	7.30e-06	7.30e-06

1-Butene	Cartridge, Impulse, MK 107	1.10e-05	1.00e-05	8.60e-06	1.00e-05	1.00e-05
1-Butene	Composition B surrogate	7.40e-07	0.00e+00	1.80e-06	1.30e-06	1.10e-06
1-Butene	Detonating train	3.10e-05	0.00e+00	0.00e+00	3.10e-05	3.10e-05
1-Butene	Flare, IR Countermeasure M206	7.30e-06	6.20e-06	1.10e-05	8.10e-06	8.10e-06
1-Butene	Fuze, Tail Bomb FMU-139 A/B	1.70e-05	1.60e-05	1.60e-05	1.60e-05	1.60e-05
1-Butene	Fuze, Tail Bomb FMU-54 A/B	9.80e-06	1.30e-05	9.50e-06	1.10e-05	1.10e-05
1-Butene	Gas Generator, GGU-2/A	4.10e-05	3.90e-05	4.60e-05	4.20e-05	4.20e-05
1-Butene	HBX surrogate	8.00e-06	4.50e-06	6.30e-06	6.30e-06	6.30e-06
1-Butene	Mine, Claymore, M18A1	5.90e-06	9.80e-06	7.10e-06	7.60e-06	7.60e-06
1-Butene	Signal, Illumination, Red Star AN-M43A2	1.30e-05	1.20e-05	1.00e-05	1.20e-05	1.20e-05
1-Butene	Signal, Illumination, Red Star M158	2.40e-05	2.60e-05	1.90e-05	2.30e-05	2.30e-05
1-Butene	Tritonal surrogate	0.00e+00	1.50e-06	2.50e-06	2.00e-06	2.00e-06
1-Butene	Tritonal surrogate with calcium stearate		5.50e-06	1.80e-06	3.70e-06	3.70e-06
1-Butene	Tritonal surrogate with water	2.80e-05	1.90e-05	2.70e-05	2.50e-05	2.50e-05
1-Butene	TNT (ACC1)	1.80e-06	1.90e-06	1.90e-06	1.90e-06	1.90e-06
1-Butene	TNT (ACC2)	1.50e-06			1.50e-06	1.50e-06
1-Butene	T45E7 Adapter Booster	0.00e+00	4.50e-05	5.40e-05	4.90e-05	4.90e-05
1-Butene	20 mm HEI Cartridge	0.00e+00	2.20e-05	2.70e-05	2.40e-05	2.40e-05
1-Butene	40 mm HEI Cartridge	6.60e-06	5.00e-06	3.30e-06	5.00e-06	5.00e-06
1-Hexene	Amatol surrogate	2.60e-06	1.50e-06	1.90e-06	2.00e-06	2.00e-06
1-Hexene	Amatol surrogate with water	3.50e-05	7.40e-05	4.50e-05	5.10e-05	5.20e-05
1-Hexene	Cartridge, Impulse, ARD 446-1	1.90e-05	1.80e-05	1.70e-05	1.80e-05	1.80e-05
1-Hexene	Cartridge, Impulse, BBU-36/B	1.60e-05	1.80e-05	2.30e-05	1.90e-05	1.90e-05
1-Hexene	Cartridge, Impulse, MK 107	7.30e-06	6.60e-06	7.30e-06	7.10e-06	7.10e-06
1-Hexene	Composition B surrogate	1.50e-06	1.90e-06	1.50e-06	1.60e-06	1.60e-06
1-Hexene	Detonating train	2.30e-05	2.20e-05	2.80e-05	2.40e-05	2.40e-05
1-Hexene	Flare, IR Countermeasure M206	5.60e-06	5.50e-06	6.80e-06	6.00e-06	6.00e-06
1-Hexene	Fuze, Tail Bomb FMU-139 A/B	8.80e-06	9.20e-06	8.20e-06	8.70e-06	8.70e-06
1-Hexene	Fuze, Tail Bomb FMU-54 A/B	6.50e-06	8.60e-06	6.40e-06	7.20e-06	7.20e-06
1-Hexene	Gas Generator, GGU-2/A	1.20e-05	1.10e-05	1.20e-05	1.20e-05	1.20e-05
1-Hexene	HBX surrogate	2.20e-06	2.50e-06	3.30e-06	2.70e-06	3.00e-06
1-Hexene	Mine, Claymore, M18A1	2.40e-06	2.50e-06	2.40e-06	2.40e-06	2.40e-06
1-Hexene	Signal, Illumination, Red Star AN-M43A2	9.00e-06	1.10e-05	8.60e-06	9.50e-06	9.50e-06
1-Hexene	Signal, Illumination, Red Star M158	1.90e-05	1.80e-05	1.60e-05	1.70e-05	1.70e-05
1-Hexene	Tritonal surrogate	2.60e-06	1.10e-06	2.50e-06	2.10e-06	2.50e-06
1-Hexene	Tritonal surrogate with calcium stearate		2.90e-06	2.60e-06	2.80e-06	3.10e-06
1-Hexene	Tritonal surrogate with water	1.80e-05	1.90e-05	2.60e-05	2.10e-05	2.20e-05
1-Hexene	TNT (ACC1)	2.30e-06	2.40e-06	1.90e-06	2.20e-06	2.20e-06
1-Hexene	TNT (ACC2)	1.50e-06			1.50e-06	1.50e-06
1-Hexene	T45E7 Adapter Booster	3.40e-05	2.80e-05	2.30e-05	2.80e-05	2.80e-05
1-Hexene	20 mm HEI Cartridge	4.90e-06	4.30e-06	4.10e-06	4.40e-06	4.40e-06

1-Hexene	40 mm HEI Cartridge	1.70e-06	8.20e-07	1.60e-06	1.40e-06	4.10e-06
1-Pentene	Amatol surrogate	1.10e-06	1.90e-06	7.40e-07	1.20e-06	1.20e-06
1-Pentene	Amatol surrogate with water	3.30e-05	6.80e-05	4.80e-05	4.90e-05	5.00e-05
1-Pentene	Cartridge, Impulse, ARD 446-1	9.50e-06	8.70e-06	8.20e-06	8.90e-06	1.30e-05
1-Pentene	Cartridge, Impulse, BBU-36/B	9.00e-06	9.80e-06	1.20e-05	1.00e-05	1.00e-05
1-Pentene	Cartridge, Impulse, MK 107	4.50e-06	4.20e-06	4.50e-06	4.40e-06	4.40e-06
1-Pentene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1-Pentene	Detonating train	1.20e-05	1.40e-05	1.60e-05	1.40e-05	2.20e-05
1-Pentene	Flare, IR Countermeasure M206	4.00e-06	2.70e-06	3.70e-06	3.50e-06	3.50e-06
1-Pentene	Fuze, Tail Bomb FMU-139 A/B	5.80e-06	7.30e-06	5.30e-06	6.10e-06	6.10e-06
1-Pentene	Fuze, Tail Bomb FMU-54 A/B	5.30e-06	6.20e-06	3.60e-06	5.10e-06	7.00e-06
1-Pentene	Gas Generator, GGU-2/A	5.90e-06	5.30e-06	6.70e-06	6.00e-06	6.00e-06
1-Pentene	HBX surrogate	1.10e-06	1.60e-06	1.90e-06	1.50e-06	1.70e-06
1-Pentene	Mine, Claymore, M18A1	9.70e-07	1.50e-06	1.90e-06	1.40e-06	1.40e-06
1-Pentene	Signal, Illumination, Red Star AN-M43A2	0.00e+00	5.90e-06	5.20e-06	5.60e-06	5.60e-06
1-Pentene	Signal, Illumination, Red Star M158	9.80e-06	1.20e-05	8.60e-06	1.00e-05	1.00e-05
1-Pentene	Tritonal surrogate	1.50e-06	1.50e-06	1.50e-06	1.50e-06	1.70e-06
1-Pentene	Tritonal surrogate with calcium stearate		3.70e-07	1.50e-06	9.10e-07	9.10e-07
1-Pentene	Tritonal surrogate with water	1.50e-05	1.50e-05	2.40e-05	1.80e-05	1.80e-05
1-Pentene	TNT (ACC1)	1.80e-06	1.40e-06	9.60e-07	1.40e-06	1.40e-06
1-Pentene	TNT (ACC2)	7.40e-07			7.40e-07	7.40e-07
1-Pentene	T45E7 Adapter Booster	2.40e-05	1.90e-05	1.50e-05	1.90e-05	1.90e-05
1-Pentene	20 mm HEI Cartridge	2.80e-06	5.80e-06	2.00e-06	3.50e-06	5.90e-06
1-Pentene	40 mm HEI Cartridge	1.70e-06	0.00e+00	8.20e-07	1.20e-06	3.30e-06
1,3-Butadiene	Amatol surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Amatol surrogate with water	3.70e-06	8.90e-06	6.30e-06	6.30e-06	6.30e-06
1,3-Butadiene	Cartridge, Impulse, ARD 446-1	8.80e-06	6.70e-06	4.70e-06	6.70e-06	6.70e-06
1,3-Butadiene	Cartridge, Impulse, BBU-36/B	2.70e-06	2.50e-06	3.10e-06	2.80e-06	6.30e-06
1,3-Butadiene	Cartridge, Impulse, MK 107	2.10e-06	2.10e-06	1.80e-06	2.00e-06	2.00e-06
1,3-Butadiene	Composition B surrogate	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
1,3-Butadiene	Detonating train	5.50e-06	8.70e-06	1.30e-05	9.00e-06	9.00e-06
1,3-Butadiene	Flare, IR Countermeasure M206	3.70e-06	2.70e-06	2.70e-06	3.00e-06	3.00e-06
1,3-Butadiene	Fuze, Tail Bomb FMU-139 A/B	2.70e-05	1.70e-05	1.90e-05	2.10e-05	2.10e-05
1,3-Butadiene	Fuze, Tail Bomb FMU-54 A/B	3.30e-06	4.70e-06	5.50e-06	4.50e-06	4.50e-06
1,3-Butadiene	Gas Generator, GGU-2/A	2.20e-05	2.60e-05	3.30e-05	2.70e-05	2.70e-05
1,3-Butadiene	HBX surrogate	1.50e-06	8.20e-07	1.90e-06	1.40e-06	1.40e-06
1,3-Butadiene	Mine, Claymore, M18A1	3.90e-06	2.50e-06	1.90e-06	2.70e-06	2.70e-06
1,3-Butadiene	Signal, Illumination, Red Star AN-M43A2	2.40e-06	2.10e-06	1.00e-06	1.90e-06	1.90e-06
1,3-Butadiene	Signal, Illumination, Red Star M158	1.30e-05	1.30e-05	1.10e-05	1.20e-05	1.20e-05
1,3-Butadiene	Tritonal surrogate	3.70e-07	0.00e+00	1.50e-06	9.10e-07	9.10e-07
1,3-Butadiene	Tritonal surrogate with calcium stearate		1.80e-06	7.30e-07	1.30e-06	1.30e-06

1,3-Butadiene	Tritonal surrogate with water	1.70e-05	3.90e-05	3.30e-05	3.00e-05	3.00e-05
1,3-Butadiene	TNT (ACC1)	3.20e-06	9.60e-07	9.60e-07	1.70e-06	1.70e-06
1,3-Butadiene	TNT (ACC2)	3.70e-07			3.70e-07	3.70e-07
1,3-Butadiene	T45E7 Adapter Booster	4.30e-05	1.50e-05	1.30e-05	2.30e-05	2.30e-05
1,3-Butadiene	20 mm HEI Cartridge	5.60e-06	4.30e-06	5.40e-06	5.10e-06	5.10e-06
1,3-Butadiene	40 mm HEI Cartridge	4.20e-06	8.20e-07	8.20e-07	1.90e-06	1.90e-06

36. Oxley, J.C., 1998. *The Chemistry of Explosives*, Chapter 5. (Oxley 1998)

CHAPTER 5

The Chemistry of Explosives

Jimmie C. Oxley

5.1. Background

Explosive devices may be mechanical, chemical, or atomic. Mechanical explosions occur when a closed system is heated—a violent pressure rupture can occur. However, this doesn't make a heated can of soup an explosive. An explosive substance is one which reacts chemically to produce heat and gas with rapid expansion of matter. A detonation is a very special type of explosion. It is a rapid chemical reaction, initiated by the heat accompanying a shock compression, which liberates sufficient energy, before any expansion occurs, to sustain the shock wave. A shock wave propagates into the unreacted material at supersonic speed, between 1500 m/s and 9000 m/s.

Typical military explosives are organic chemicals, often containing only four types of atoms: carbon (C), hydrogen (H), oxygen, (O), and nitrogen (N) [Urbanski (1964, 1965, 1967, 1984); Gibbs and Popolato (1980); Dobratz (1981); Kaye (1960–1978); and Davis (1943)]. To maximize volume change, gas formation, and heat release, explosives are designed to be dense and have high oxygen content and positive heats of formation. In monomolecular organic explosives, which includes most military explosives, oxygen is available in NO_2 groups. Upon detonation, exothermic (heat releasing) reactions transform nitrogen atoms into nitrogen (N_2) gas, while the oxygen atoms combine with hydrogen and carbon atoms to form gaseous products (H_2O, CO, or CO_2). This is similar to a combustion process, but a detonation is different from burning in two ways. In combustion, there is an unlimited amount of oxidizer available, oxygen from the air. An explosive oxidizes so quickly that it usually must contain its own source of oxygen either in the same molecule, as with most military explosives (e.g., trinitrotoluene, TNT), or in a neighboring molecule, as in the intimate mixture of ammonium nitrate and fuel oil (ANFO).

TNT $4C_7H_5N_3O_6 \rightarrow 7CO_2 + 6N_2 + 10H_2O + 21C,$

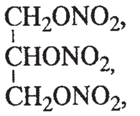
ANFO $37NH_4NO_3 + CH_3(CH_2)_{10}CH_3 \rightarrow 12CO_2 + 37N_2 + 87H_2O.$

"Oxygen Balance" is a method of quantifying how well an explosive provides its own oxidant. There are various ways of defining oxygen balance (OB). We can balance the oxygen so that every carbon has one oxygen (balanced for CO) or so that every carbon has two oxygen (balanced for CO_2) [Kaye (1960–1978)]. [Note that carbons in the molecule already bonded to oxygen do not contribute to the energy balance ($-n_{COO}$).] We can also balance in terms of weight percent oxygen in the explosive (OB) or in terms of oxidant per 100 grams explosive (OB_{100}) [Kamlet (1976)]:

$$OB_{100} = [100*(2n_O - n_H - 2n_C - 2n_{COO})]/\text{mol. wt. compound}$$

$$\text{(balanced to CO)}$$

example nitroglycerin:



$$\begin{array}{l} CH_2ONO_2, \\ | \\ CHONO_2, \\ | \\ CH_2ONO_2, \end{array}$$

$$9 = n_O; \quad 5 = n_H; \quad 3 = n_C; \quad 0 = n_{COO},$$

$$\text{mol. wt.} = 9 * 16 + 5 * 1 + 3 * 12 + 3 * 14 = 227,$$

$$OB_{100} = [100 * (2 * 9 - 5 - 2 * 3 - 0)]/227$$

$$= (700/227) = 3.08,$$

$$OB(\text{balanced to } CO_2) = [1600 * (n_O - 2n_C - 0.5n_H)]/\text{mol. wt. compound},$$

$$OB \text{ nitroglycerin} = [1600 * (9 - 6 - 5/2)]/227 = 800/227 = 3.52.$$

Another way in which a detonation differs from a fast burn (deflagration) is the manner in which the performance is evaluated. The performance of a fuel is directly related to the amount of heat released, while the performance of an explosive has a less direct relationship to heat released. Detonation is unique in the rapid rate at which energy is released. A detonating high explosive creates a tremendous power density compared to deflagration materials:

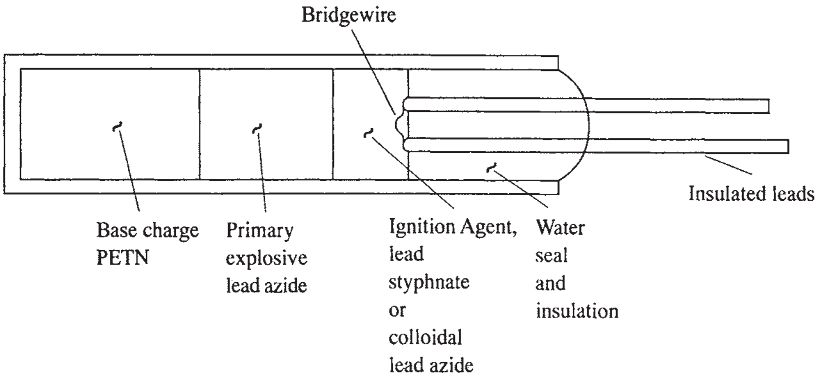
	W/cm^3
Burning acetylene	10^2
Deflagrating propellant	10^6
Detonating high explosive	10^{10}

The performance of an explosive cannot be expressed in a single characteristic. Performance is dependent on the detonation rate or velocity, the packing density, the gas liberated per unit weight, and the heat of explosion. Detonation velocity, itself, is dependent on packing density, charge diameter, degree of confinement, and particle size. Both the terms brisance and strength are used in describing performance of an explosive. When an explosive detonates there is a practically instantaneous pressure jump from the shock wave. The subsequent expansion of the detonation gases performs work, moves objects, but it is the pressure jump which shatters or fragments objects (see discussion of ideal and nonideal explosives, pp. 163–164). Brisance (from French for shatter) is a description of the destructive fragmentation effect of a charge upon its immediate vicinity. Since shattering effect is dependent upon the suddenness of the pressure rise, it is most dependent upon detonation velocity. Brisance is the term of importance in military applications. Brisance is often evaluated from detonation velocity, but there are "crusher" tests in which the compression of lead or copper blocks by the detonation of the test explosive is taken as a measure of brisance [Kaye (1960–1978)]. Strength is important in mining operations; it describes how much rock can be moved. The strength of an explosive is more related to the total gas yield and the heat of explosion. It is often quantified with the Trauzl lead block test, where 10 g of a test sample are placed in a 61 cm^3 hole in a lead block and initiated with a No. 8 blasting cap. Performance is evaluated from the size of the cavity created in the lead block [Meyer (1987)].

Explosives are often classified by the stimuli to which they respond and the degree of response. The term 'low explosives" is applied to propellants or deflagrating materials, such as black powder and smokeless powder (colloided nitrocellulose). Although they contain within themselves all oxygen needful for their combustion, their self-oxidization is slow and sensitive to degree of confinement. Detonating or "high" explosives are characterized by a very high rate of reaction and pressure release. TNT and nitroglycerin are examples of high explosives. The shock waves in high explosives travel at speeds in the range 5000–9000 m/s, compared to gun powder, a low explosive, at $\sim$100 m/s. High explosives may be difficult to burn, but with sufficient impulse detonation can be initiated regardless of the degree of confinement.

Based on their ease of initiation, high explosives are subdivided into the designation primary or secondary. Primary explosives are detonated by simple ignition—spark, flame, or impact. Examples of primary explosives are lead azide, lead picrate, lead styphnate, mercury fulminate, diazodinitrophenol (DDNP), *m*-nitrophenyldiazonium perchlorate, tetracene, nitrogen sulfide (N_4S_4), copper acetylide, fulminating gold, nitrosoguanidine, potassium chlorate with red phosphorus (P_4), and the tartarate and oxalate salts of mercury and silver (of these, modern detonators tend to use lead azide or DDNP). Secondary explosives differ from primary explosives in not being initiated readily by impact or electrostatic discharge; they do not easily undergo a deflagration-to-detonation transition (DDT). They can be initiated by large shocks; usually they are initiated by the shock created by a primary explosive. A blasting cap and frequently a booster are required. (A booster is a sensitive secondary explosive which reinforces the detonation wave from the detonator into the main charge.)

In general, secondary explosives are more powerful (brisant) than primary

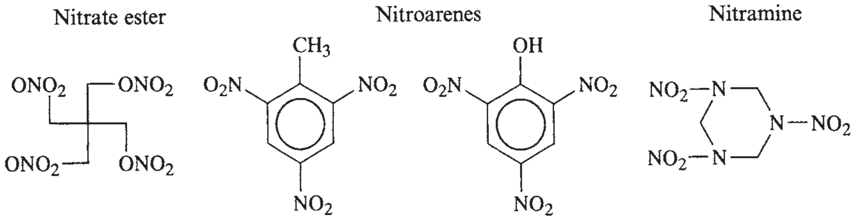


Low-energy detonator. Typical electric blasting cap.

explosives. Examples of secondary explosives include nitrocellulose, nitroglycerin, dynamite, TNT, picric acid, tetryl, RDX, HMX, nitroguanidine, ammonium nitrate, ammonium perchlorate, liquid oxygen mixed with wood pulp, fuming nitric acid mixed with nitrobenzene, compressed acetylene and cyanogen.

5.2. Conventional Explosives

Most military explosives are secondary explosives, and for the most part they fall in one of three categories all of which contain nitro (NO_2) groups. First, nitrate esters, such as nitroglycerin, nitrocellulose, PETN (active component in sheet explosives), contain $O—NO_2$ groups. These are the oldest type of explosives still used by the military. Nitration of alcohols was a popular research topic in the 1830s to 1840s. By the 1860s technological advances made nitroglycerin and nitrocellulose relatively safe and useful explosives.



PETN	TNT	Picric acid	RDX
1894	1863	1742	1899 discovery
1930	1900	1870	1940 used

Nitrate esters are the least stable military explosives; they lose NO_2 readily. Second, nitroarenes with a C—NO_2 linkage are typified by TNT (component of Composition B) or picric acid. Third, nitramines contain N—NO_2 groups; typical examples RDX and HMX are the active ingredients in plastic-bonded explosives such as Composition B, C-4, and Semtex [Urbanski (1964, 1965, 1967, 1984); Gibbs and Popolato (1980)].

The most general method of attaching a nitro (NO_2) group is treating the parent C—H, O—H, or N—H containing compound with mixed acid—equal volumes of concentrated nitric (HNO_3) and sulfuric (H_2SO_4) acids. Sulfuric acid protonates nitric acid forming nitronium cation (NO_2^+). Nitronium, a powerful electrophile, attacks the X—H bond (X = C, O, or N). Use of low temperature prevents undesired oxidation as well as violent reactions:

$$HNO_3 + H_2SO_4 \longrightarrow NO_2^+ + H_2O + HSO_4^-,$$

$$R_2N\text{—}H + NO_2^+ \longrightarrow R_2N\text{—}NO_2 + H^+.$$

Other reagents may be used for nitration depending on the species involved. Higher concentrations of nitric acid may be used (100% NHO_3 is produced by the distillation of KNO_3 with 98% H_2SO_4). Nitronium tetrafluoroborate (NO_2BF_4) is an expensive but gentle nitration reagent [Olah et al. (1989)]. Acetyl nitrate, formed in situ from an acetic acid solution of acetic anhydride and 98% NHO_3, is a hazardous but effective nitration reaction. The nitro group is usually introduced on to an arene by use of mixed acid. However, the presence of a nitro group or any other species on an arene ring influences and directs further substitution. Due to this consideration synthesis schemes may not be straightforward.

5.3. Nitrate Esters

Most alcohols can be converted into nitrate esters whose physical state is usually the same as the parent alcohol.

Methyl Nitrate is a powerful explosive, but of little practical use. Its vapors have a strongly aromatic odor and cause headaches if inhaled.

$$\underset{\text{methanol}}{CH_3OH} + HNO_3 \rightarrow \underset{\text{methyl nitrate}}{CH_3ONO_2}.$$

In World War II the Germans used land mines composed of sodium and methyl nitrate in separate compartments. Pressure facilitated mixing and then explosion.

Dinitroglycol or EGDN ethylene glycol dinitrate (bp, 197.5 °C; mp, −22.3 °C; p, 1.518 g/cc) is used as an ingredient in nonfreezing dynamites. It has many of the advantages of nitroglycerin and is somewhat safer to manufacture and handle. Its principal disadvantage is its greater volatility.

EGDN produces headaches similar to those produced by nitroglycerin, and in proportion to its greater volatility, the headaches are more violent but do not last as long.

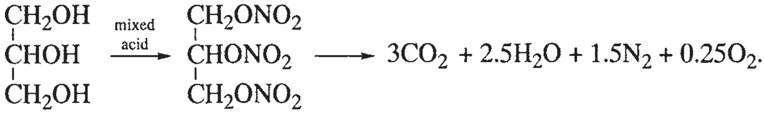
$$\underset{\text{glycol}}{HOCH_2CH_2OH} \xrightarrow{\text{mixed acid}} \underset{\text{dinitroglycol}}{O_2NOCH_2CH_2ONO_2}.$$

With a drop height of 20 cm, dinitroglycol is less sensitive than nitroglycerin. It has a perfect oxygen balance:

$$O_2NOCH_2CH_2ONO_2 \rightarrow 2CO_2 + 2H_2O + N_2.$$

TEGDN Triethylene Glycol Dinitrate $O_2NOCH_2CH_2OCH_2CH_2OCH_2$-$CH_2ONO_2$ and *DEGDN Diethylene Glycol Dinitrate* $O_2NOCH_2CH_2OCH_2$-CH_2ONO_2 are nitrate esters often used as plasticizers in propellants.

Nitroglycerin was first prepared by Italian chemist Ascanio Sobrero in 1846. For several years after its discovery there was little interest in using it as an explosive. It was first used as a medicine. In the 1860s Alfred Nobel found a way to improve the safety of its manufacture and use in dynamites and, more importantly, developed a practical way to initiate it. This material would correctly be named as the trinitrate, but historical use prevails in the name "nitroglycerin."



$$\begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array} \xrightarrow[\text{acid}]{\text{mixed}} \begin{array}{l} CH_2ONO_2 \\ | \\ CHONO_2 \\ | \\ CH_2ONO_2 \end{array} \longrightarrow 3CO_2 + 2.5H_2O + 1.5N_2 + 0.25O_2.$$

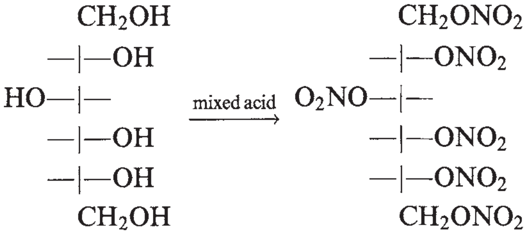
glycerin nitroglycerin

Nitroglycerin is a yellow oil with boiling point (bp) estimated as 245 °C and melting point (mp) as 13.1 °C. Pure nitroglycerin is odorless at ambient temperature but has a faint odor above 50 °C. It has high vapor pressure and prolonged exposure results in severe and persistent headaches. It is extremely shock sensitive, and its sensitivity is greater if it is warmed. Drop height at ambient is 4 cm with a 2 kg weight.

Vapor pressure of nitroglycerin [Marshall and Peace (1916)]

mm	°C	mm	°C
0.00025	20	0.019	60
0.00083	30	0.043	70
0.0024	40	0.098	80
0.0072	50	0.29	93

Nitrated Sugars (*Mono- and Oligo Saccharides*). Sugars are polyhydric alcohols which contain an aldehyde or ketone group or a cyclic acetal or ketal arrangement. Their nitrate esters are easy to prepare but are less stable than those of simple polyhydric alcohols; this instability may be due to the difficulty in purifying them. *d*-Glucose pentanitrate is a viscous colorless syrup, insoluble in water. It is unstable above 50 °C.



$$\begin{array}{r} CH_2OH \\ -|-OH \\ HO-|- \\ -|-OH \\ -|-OH \\ CH_2OH \end{array} \xrightarrow{\text{mixed acid}} \begin{array}{r} CH_2ONO_2 \\ -|-ONO_2 \\ O_2NO-|- \\ -|-ONO_2 \\ -|-ONO_2 \\ CH_2ONO_2 \end{array}$$

d-glucose *d*-glucose pentanitrate

Nitrated sugars can be used with nitroglycerin to make a nonfreezing dynamite. Nitrated sugars form many eutectics with nitroarenes.

Nitrated Polysacchrides: Guncotton, Nitrocellulose, Nitrostarch. Cellulose and starch are both polymers of glucose. They differ in the chemical linkage between glucose molecules. The chemical bonding in cellulose is such that 2000 to 3000 anhydroglucose units are linked in a straight chain which is essentially one dimensional. In starch, glucose monomers are joined by alpha-linkages which leads to a spiral structure. This results in a three-dimensional structure which, on the average, contains 25 to 30 anhydroglucose units. Starch is also susceptible to side chain branching.

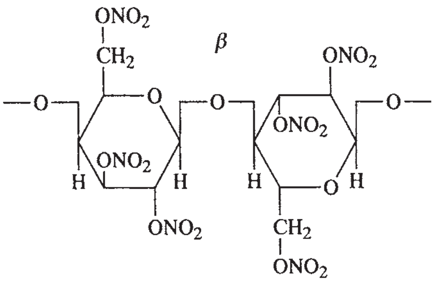
In 1833, Braconnot found nitrated starch produced a varnish-like coating impervious to water. Schonbein and Bottger, independently, discovered the nitration of cotton in 1846. Between 1865 and 1868 Abel patented improved preparations, which required pulping. The pulping allowed impurities to be more easily washed out by "poaching" and resulted in improved stability. Nitrocellulose, like most nitrate esters, is intrinsically unstable, but decomposition at ambient temperature is slow if it has been thoroughly purified. Cotton fiber is practically pure cellulose, but equally useful cellulose can be produced from wood. Cellulose contains three hydroxyl groups per anhydroglucose unit and yields a trinitrate on complete nitration (14.4% N). However, complete nitration is difficult. Nitrocellulose is rated by percent N, and this is dependent on the method of nitration:

12.7% N—95% HNO_3,

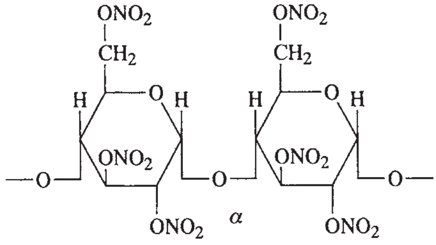
13.5% N—mixed acid,

14.1% N—HNO_3, H_3PO_4, P_2O_5.

Nitrocellulose is used with nitroglycerin to form double-based propellants and smokeless powders. Nitrocellulose with TNT forms a eutectic (mp, 63 °C) mixture.



Nitro cellulose



Nitro starch

5.3.1. Nitrate Ester Formulations

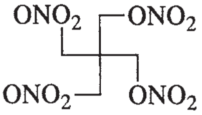
Smokeless Powder. The first successful smokeless powder appears to have been made by Captain Schultze of the Prussian Artillery in 1864. He used nitrated wood pulp (nitrocellulose). Nobel produced a smokeless powder in 1888 mixing nitroglycerin and soluble nitrocellulose. Over the years various proportions and ingredients have been mixed and various names applied, e.g., Ballistite, Cordite [Davis (1943)]. Most smokeless powders now contain about 1% diphenylamine (DPA) as a stabilizer. It removes acids formed during decomposition. The product of the reaction between DPA and the acid is diphenylnitrosamine, which itself decomposes at 110 °C. Excess diphenylamine (at the 10% level or above) produces unstable smokeless powders, and powders which contain 40% DPA combust spontaneously when heated in air at 110 °C. Ethyl centralite (diethyldiphenylurea) $[Ph(Et)N]_2CO$ is also used as stabilizer, a means to moderate the burn and reduce flash. Another way to produce a flashless powder is using cool explosives such as ammonium nitrate, guanidine nitrate, or nitroguanidine.

Dynamite. In 1863 Alfred Nobel invented the detonating blasting cap, making it possible to reproducibly initiate nitroglycerin. In 1866 he found that combining 75% NG with 25% kieselguhr (diatomaceous earth) made a relatively stable material, which he patented as "dynamite." After using the inactive base of kieselguhr, he developed dynamites with active bases, nitroglycerin absorbed by mixtures of materials such as nitrate salts and wood meal, charcoal, sugar, or starch. Early dynamites which contained only nitroglycerin froze at relatively high temperatures. When they were frozen, they were less sensitive to shock and initiation, but the intermediate state, half-frozen/half-thawed was quite sensitive. Furthermore, thawed explosives tended to exude nitroglycerin. A low-freezing dynamite was developed by nitrating a mixture of glycerin and ethylene glycol, but these were not available until the late 1920s when the production of ethylene glycol for antifreeze made the precursor chemical relatively inexpensive. Today no dynamite is produced using only NG as the active ingredient, rather mixtures of EGDN/NG, ranging 100/0 to 60/40; in addition, a non-NG dynamite is made using metriol trinitrate (MTN) and diethylene glycol dinitrate (DEGDN) as the active ingredients.

In 1875 Nobel incorporated collodion cotton (NC) into dynamites producing gelatinous formulations called blasting gelatin (6–8% NC) or less stiff formulations (< 2% NC), gelatin dynamites. These were more water resistant than straight dynamites. As of this writing, in the United States there is only one manufacturer of dynamite, Dyno Nobel in Carthage, MO; there are a variety of formulations, but the principle distinguishing ingredients are the amount of NG/EGDN, sodium nitrate (SN), ammonium nitrate (AN), salt, and nitrocellulose (NC) [Hopler (1993a)]. Blasting gelatin is basically NG/EGDN with NC; it is highly water-resistant. Straight dynamites are mixtures of NG/EGDN with SN and wood meal; these are quite sensitive and are sometimes termed "ditching" dynamites. Extra dynamite reduces the level of the NG/EGDN to 10–15% and uses high concentrations of AN as well as SN; and permissible dynamites incorporate salt (sodium chloride) to the extra dynamite formulation to lower the flame temperature for use in coal and other gaseous mines. A number of other ingredients called "dopes" may be used, usually at less than the 3% level: clear wheat, cob meal, balsa, starch, cork, guar gum, and calcium stearate. Chalk is used in all formulations as an anti-acid; and if hollow microspheres are added they are phenolic, rather than glass, which can cause friction problems. Most dynamites contain some nitrocotton, typically in the range of 0.1% to 0.2%; higher percentages of nitrocotton (0.4% to 2.5%) are used in dynamite products called "gelatins."

	Straight	Extra	Blasting gelatin	Nobel
NG/EGDN	40%	20%	90%	62.5%
NG only				
NC	0.1%	0.1%	7%	
AN (mixture course and fine)	15–30%	70%		
$NaNO_3$	20–30%			27%
Wood pulp	6–8%	6%	< 1%	8%

PETN or Pentaerythritol Tetranitrate. $C(CH_2ONO_2)_4$ is white crystalline solid. It is prepared by nitration of pentaerythritol with 95% HNO_3; PETN is insoluble in the acid and precipitates from the reaction mixture



Among explosive nitrate esters, PETN is the most stable. Its high symmetry results in a high melting point (141 °C), which is often correlated with high thermal stability [Oxley et al. (1995)]. Its boiling point has been measured (200 °C), but it explodes at 205 °C. In contrast, its less symmetric relatives, 2,2-methyl-1,3-propane dinitrate $(CH_3)_2C(CH_2ONO_2)_2$ and metriol trinitrate (MTN) $CH_3C(CH_2ONO_2)_3$ (an ingredient in non-NG dynamites) melt at substantially lower temperatures, 24 °C and −60 °C, respectively.

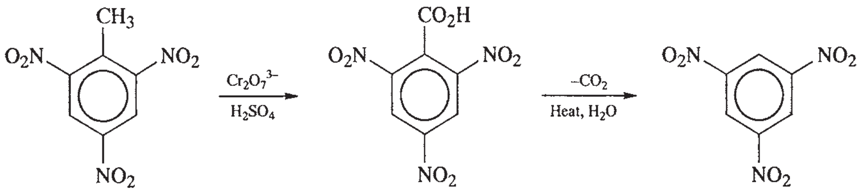
PETN is extraordinarily sensitive to explosive initiation. It is detonated by 0.01 g lead azide, whereas tetryl requires 0.025 g. PETN is extensively used in detonators, detonating fuzes (Primacord), priming compositions, and DETA sheet (DuPont trademark). A one-to-one mixture of TNT and PETN, called Pentolite, is used in boosters.

5.4. Nitroarenes

Nitroarenes can be synthesized from direct nitration of arene rings, such as benzene (C_6H_6), toluene ($C_6H_5CH_3$), and phenol (C_6H_5OH). However, roundabout synthetic schemes are often necessary to account for various practical considerations such as vapor pressure of an intermediate or the fact that the presence of nitro groups on an arene ring discourages subsequent nitration.

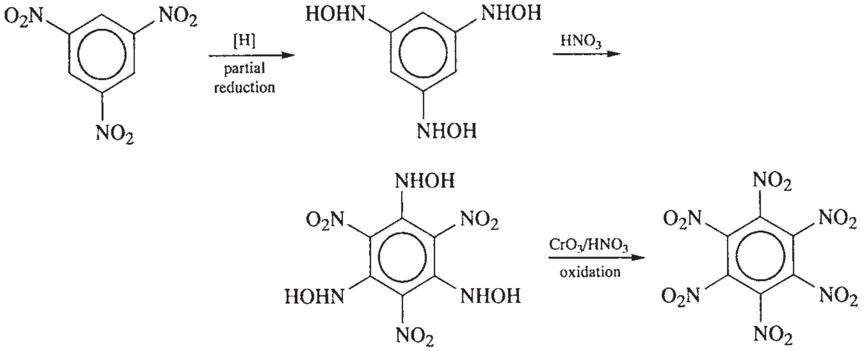
Nitrobenzene is the simplest nitroarene ($C_6H_5NO_2$). Termed in old literature "oil of mirbane," it is a pale yellow liquid with boiling point 208 °C. It has an almond-like odor and can be absorbed through the skin or by breathing its vapors. Its toxicity is typical of nitroarenes although nitrotoluenes tend to be slightly less toxic than nitrobenzenes. (Further discussion of explosive toxicity can be found in Chapter 9.) Nitrobenzene is not generally considered an explosive, though it is an energetic material and is sometimes mixed with ammonium nitrate.

1,3,5-*Trinitrobenzene* is one of the simplest nitroarenes used as an explosive. It can be prepared directly from the treatment of benzene with anhydrous nitric and fuming sulfuric acids. However, the yield by this route is so low that it is usually prepared by oxidation of TNT. The methyl group in TNT activates the benzene ring toward substitution, allowing addition of three nitro groups to toluene, in contrast to benzene which under forcing conditions only adds two nitro groups.



Symmetrical trinitrobenzene is a yellow solid with melting point 122.5 °C. Unsymmetrical isomers melt at 62 °C and 128 °C. These compounds are poisonous, as are all nitrobenzenes, and are readily oxidized. Trinitrobenzene is less sensitive to impact than TNT and more powerful and brisant, but its preparation is more expensive.

Hexanitrobenzene (HNB) at one time was sought as the ideal explosive, one with perfect oxygen balance. During World War II there were serious efforts to prepare it; the Germans succeeded using the route shown below. An easier route is the oxidation of pentanitroanaline by peroxydisulphuric acid ($H_2S_2O_8$) (fuming H_2SO_4 + 98% H_2O_2) to HNB in 90% yield.

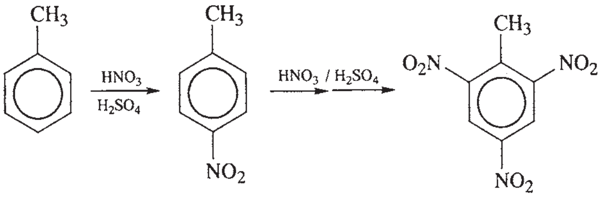


HNB has a wide melting range (246–262 °C) due to formation of decomposition products near its melting point. In the absence of moisture and light, HNB shows good stability at room temperature, but irradiation produces isomerization of nitro groups to nitrites, which in turn are hydrolyzed to hydroxyl groups:

$$—NO_2 \rightarrow —ONO \rightarrow —OH.$$

Thus, HNB is easily hydrolyzed to pentanitrophenol $(NO_2)_5C_6(OH)$, tetranitroresorcinol, $(NO_2)_4C_6(OH)_2$, and eventually trinitrophloroglucinol $(NO_2)_3C_6(OH)_3$.

2,4,6-*Trinitrotoluene* (TNT) has been a popular explosive because it melts at a relatively low temperature (80.65 °C) without decomposition and, therefore, is readily cast. Compared to other military explosives (RDX, HMX, PETN), TNT has high chemical stability and low sensitivity to impact. It is reported that it may be distilled under vacuum (10–20 mm) at 210–212 °C without evidence of decomposition. Although TNT is relatively simple and safe to manufacture, it is no longer made in the United States or Canada, due to environmental problems with its manufacture, to the existing United States surplus, and to the availability of more powerful explosives. Due to its low melting point, TNT is used in admixture with many other high explosives. Various names are applied to these formulations. Tritonal is a 80/20 mixture of TNT and aluminum. Baratol is a mixture of $(BaNO_3)_2$ with TNT in various ratios from 20/80 to 76/24. Octols and cyclotols are mixtures of TNT with HMX and with RDX, respectively. Adding more methyl groups as in trinitroxylene (TNX) or trinitromesitylene reduces the strength of the explosive.



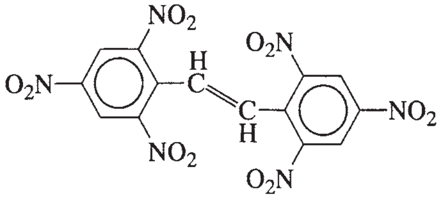
Nitrotoluenes are toxic, but their toxicity is lower than that of nitrobenzenes. It has been suggested that nitrotoluene is more easily oxidized by the body to nitrobenzoic acid, which is only slightly toxic. Slight TNT poisoning manifests itself by cyanosis, dermatitis, nose bleed, constipation, and giddiness. The severer form is characterized by toxic jaundice and aplastic anemia (see Chapter 9). Dinitrohydroxylaminotoluene may be detected in the urine.

The effect of the electron-withdrawing nitro groups on the arene ring is to strongly activate the methyl group. Consequently, most of TNT chemistry occurs on the methyl group. The methyl protons are fairly acidic for organic compounds (pK, 15.3). They may behave like the methyl hydrogens of acetone in certain condensation reactions

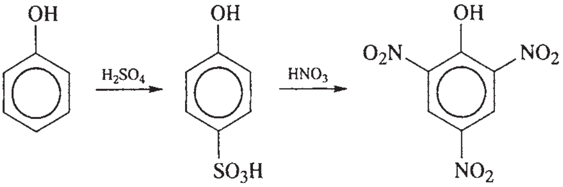
$$\text{TNT} + \text{PhCHO} \xrightarrow{0\,^{\circ}\text{C}} \text{Pic-CH{=}CH-Ph} + H_2O$$

where Pic = picryl = trinitrobenzyl, and Ph = C_6H_5.

Hexanitrostilbene (HNS) formed by the oxidative coupling of two TNT molecules is an explosive in its own right. Its thermal stability makes it useful in many high temperature applications:



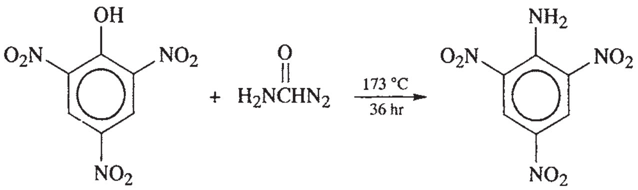
Picric Acid. Of all the nitroarenes, picric acid has been known the longest. It was first obtained in 1742 by Glauber with nitric acid on wool. In the second half of the nineteenth century, picric acid was widely used as a fast dye for silk and wool. At the same time the potassium salt was being used in Great Britain and the United States for filling shells. The general view was that picric acid was not an explosive, only its salts were. Eventually picric acid was accepted as a high explosive. Since it was high melting, it was mixed with various nitro compounds to depress its melting point. The acidic character of picric acid is corrosive to metal and results in formation of metal salts, which are very impact and friction sensitive. When picric acid and nitrophenols were used in ammunition, they were not allowed to come in contact with the metal. Thus, when TNT manufacture was simplified, picric acid use decreased; it has practically been eliminated from armaments.



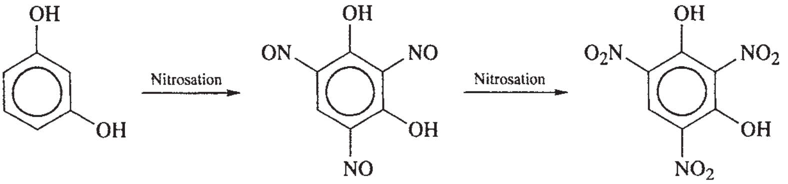
Picric acid could be made by direct nitration of phenol. However, due to the volatility of the intermediate nitrophenol, it is usually synthesized via the sulfate. Picric acid is a colorless or light yellow solid with melting point of 122.5 °C and a vapor pressure described by $\log P = 12.024 - (5729/T(\mathrm{K}))$ (58–103 °C). The trinitrophenol is called picric acid because the hydroxyl proton is very acidic (pK, 3); therefore, it is about 50% dissociated.

Salts of Picric Acid: Ammonium or Guanidine Picrate. Ammonium picrate is prepared by suspending picric acid in hot water and adding strong ammonium hydroxide until the acid completely dissolves. Ammonium picrate is less shock sensitive than picric acid and has a higher melting point (mp, 265–271 °C). It is sometimes referred to as Explosive D. Guanidine picrate is prepared from guanidine nitrate and ammonium picrate (mp, 319 °C).

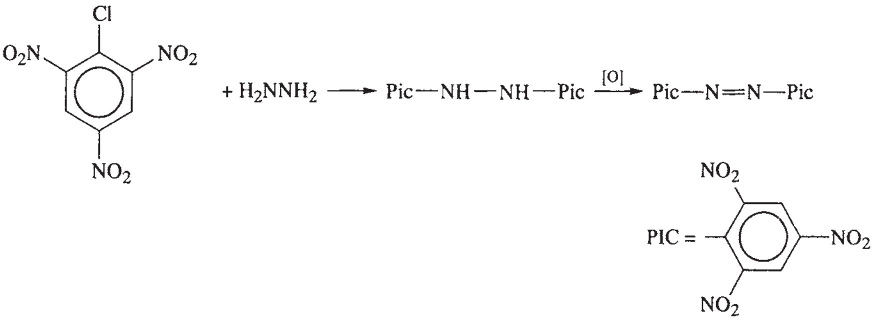
Picramide or Trinitroaniline finds little use as a military explosive since there are other more powerful explosive which can be prepared from the same materials. It may be prepared in about 90% yield by nitrating aniline in glacial acetic acid or using mixed acid or via picric acid by the route shown below. The presence of HONO acid must be avoided since it attacks the amino group, replacing it by HO, thus, making picric acid. Picramide forms orange–red crystals with melting point 186 °C and vapor pressure at 150 °C of 0.0059 mm. Both picric acid an picramide are more powerful than TNT.



Styphnic Acid or Trinitroresorcinol is readily formed by nitration of resorcinol. This yellow solid melts at 175 °C. Styphnic acid is more expensive and less powerful than picric acid. However, its salts are notably more violent explosives than picrates. Lead styphnate has been used to facilitate the ignition of lead azide in detonators.



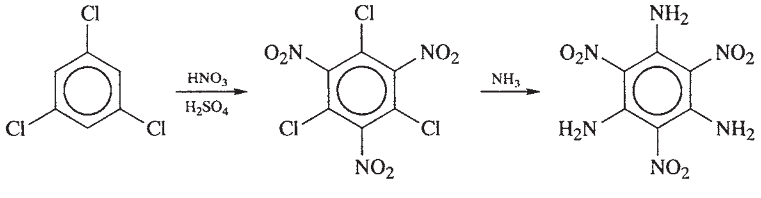
Hexanitroazobenzene is an orange solid (mp, 215–216 °C) formed by the condensation of picryl (trinitrobenzyl) chloride and hydrazine. The process is carried out in water suspension in the presence of agents to bind HCl evolved



5.4.1. Thermally Stable Nitroarenes

There is a tendency for the melting point of a nitroarene to increase with increasing molecular weight. Therefore, in an effort to increase thermal stability, synthetic design has aimed for large molecules. HNS is in this category.

TATB or 2,4,6-*Triamino*-1,3,5-*trinitrobenzene* has excellent thermal stability and is resistant to impact and shock initiation. Its high molecular weight undoubtedly contributes to its elevated melting point, but a greater contributing factor is the graphite-like structure of TATB with alternating NH_2 and NO_2 around the ring. TATB is a yellow solid with melting point sometimes listed as 448–449 °C [Gibbs and Popolato (1980)] and sometimes as 350 °C [Meyer (1987)] with decomposition. Exposure to sunlight or UV turns TATB green, and prolonged exposure eventually turns it brown to black. It is presently the insensitive explosive of choice in nuclear weapons, which can only be as safe as the conventional explosive component. Its synthesis can be accomplished by direct amination because the NO_2 groups are electron withdrawing. The difficulty in its preparation is its insolubility in most organic solvents; it quickly precipitates with little control of particle size possible.



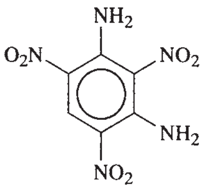
TATB can be oxidized by peroxydisulphuric acid ($H_2S_2O_8$) to hexanitrobenzene. This is a much easier route to hexanitrobenzene than the German synthesis shown earlier.

A number of other high molecular weight nitroarenes have been designed for high-temperature applications. They include DATB (2,4-diamino-1,3,5-trinitrobenzene), DIPAM (3,3′-diamino-2,2′,4,4′,6,6′-hexanitrodiphenyl; NONA, (2,2′,2″,4,4′,4″,6,6′,6″-nonanitro-terphenyl); and DuPont product, TACOT (tetranitro-2,3:5,6-dibenzo-1,3*a*,4,6*a*-tetrazapentalene). Some properties of these and other monomolecular explosives are shown in Table 5.1.

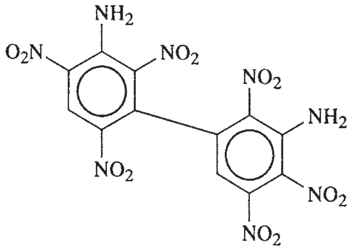
Table 5.1.

Explosive	Melting point, mp, °C	Density, g/cc	Detonation		Drop weight, H50 cm 12	Vapor pressure	
			Velocity, km/s	Pressure, kbar		log P (mmHg)	Temperature °C
AN	169	1.73			149		
AN							
ANFO	169						
AP (200 μm)					47		
AP (90 μm)					44		
ADN	94						
CL-20							
HNS	318	1.74	7			1.00E−09	100
HMX	285d	1.89	9.11	393	26	3.40E−05	150
NC							
NG	13	1.6	7.58	230			
NQ	245d	1.7	8.28	260	> 320		
NTO					86		
PETN	143	1.7	7.98	300		8.00E−05	100
RDX	204	1.77	8.64	347	22	0.013	150
TATB	448	1.85	7.66	275	> 320	1.00E−04	150
TNT	81	1.64	6.94	190	212		
TNAZ	101						
Tetryl	129	1.69	7.7		49	13.71−6776/T	
Styphnic acid					46		
Picric acid		1.76	7.68	265	79	12.024−5279/T	
Ammonium Picrate					152		
PYX	460	1.75			63		
DATB	286	1.78	7.6		> 320	13.73−7314/T	
TACOT	410	1.85	7.2				
NONA	440–450					2.50E−09	150
DIPAM	304	1.79					

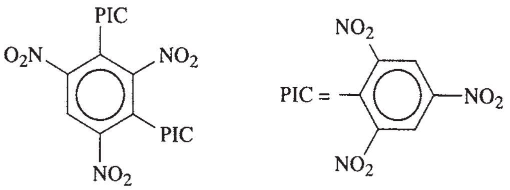
	Isothermal kinetics				Differential Scanning Calorimetry (DSC) data			
Explosive	*E*, kcal/mol	A s^{-1}	Temp. range °C	Moles gas/cmp	Heat (DSC) cal/g	Exo(20°/min), Temp °C	*E*, kcal/mol	A s^{-1}
AN	26.8	1.6E+07	200–290	0.88	400	320	29.1	6.46E+08
AN	46.2	5.0E+14	290–380					
ANFO	35.2	2.40E+11	270–370		750	290, 370	47.3	3.2E+16
AP (200 μm)	21.3	4.81E+04	215–385	1.2	360	360	22.7	8.32E+05
AP (90 μm)					460	310		
ADN	38.3	9.57E+15		1.4	—	194	31.3	1.66E+17
CL-20	42.4	4.00E+17	146–220, acetone		—	—		
HNS								
HMX	52.9	2.46E+18	230–270	5.4	850	280		
NC				0.00	760	220		
NG								
NQ					250	230		
NTO	38.4	1.05E+13	240–280	2.3	700	260		
PETN				6.3	1000	210		
RDX	37.8	1.99E+14	200–250	3.9	960	257		
TATB				3.4	930	397		
TNT	32.8	1.19E+10	240–280	3.2	610	330	34	2.5E+11
TNAZ	46.6	3.55E+17	220–250	3.8	—	—		
Tetryl							38	2.5E+15
Styphnic acid					800	280		
Picric acid				4.10	1000	320		
Ammonium Picrate					1000	310		
PYX					1000	380		
DATB				3.40				
TACOT								
NONA								
DIPAM								



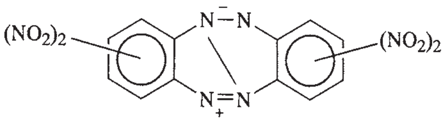
DATB



DIPAM



NONA



TACOT
orange

5.5. Nitroalkanes

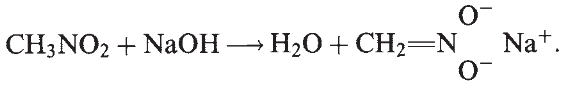
Nitromethane. CH_3NO_2 is one of the few nitroalkanes which finds occasional application as an explosive. It is a clear liquid with boiling point 101 °C, melting point −17 °C, density (p) 1.14 g/cc at 15 °C, and vapor pressure 37 mm (25 °C). Its industrial synthesis involves a very low yield (13%) vapor phase reaction:

$$CH_4 + HNO_3 \xrightarrow{400\text{–}450\,^\circ\mathrm{C}} CH_3NO_2 + H_2O.$$

In the laboratory it is more readily made by the reaction of sodium nitrite on chloroacetic acid.

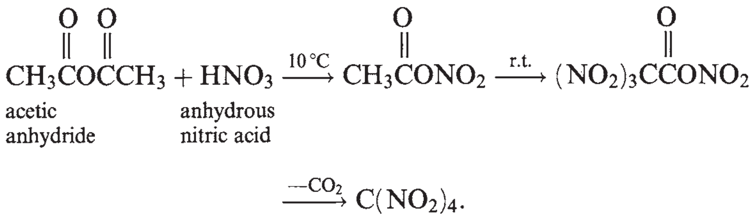
$$NaNO_2 + ClCH_2COOH \longrightarrow NaCl + CH_3NO_2 + CO_2.$$

Although the drop weight impact test (Chapters 10 and 11) shows that nitromethane reacts at fairly low drop heights (35 cm), nitromethane requires a strong initiator to detonate. Nitromethane can be made more sensitive to detonation by the addition of small amounts (5 wt%) of certain compounds—bases (aniline, ethylenediamine, methyl amine, diethylenetriamine) or acids (nitric or sulfuric acids). A nitromethane mixture, containing 95% nitromethane and 5% ethylenediamine [Kaye (1960–1978)] is called PLX (Picatinny Liquid Explosive). The methyl protons of nitromethane are acidic and in the presence of base the anion forms. The stabilization of the aci-ion by base has been suggested as the cause of their sensitization. Salts of nitromethane $NaCH_2NO_2$ are much more sensitive than CH_3NO_2.



$$CH_3NO_2 + NaOH \longrightarrow H_2O + CH_2{=}N\begin{smallmatrix}O^-\\ \\ O^-\end{smallmatrix}\ Na^+.$$

Tetranitromethane is a dense liquid (p, 1.64 g/cc) usually prepared by the method of Liang [Horning (1955)]. Although the boiling point of tetranitromethane is listed as 126 °C (mp, 14 °C) with an ambient vapor pressure of 13 mm, it is not distilled as it can decompose with explosive violence. Tetranitromethane is so rich in oxygen that it does not make a good explosive unless it is mixed with fuel such as nitrobenzene, toluene, or other arenes



$$\underset{\text{acetic anhydride}}{CH_3\overset{\overset{O}{\|}}{C}O\overset{\overset{O}{\|}}{C}CH_3} + \underset{\text{anhydrous nitric acid}}{HNO_3} \xrightarrow{10\,^\circ C} CH_3\overset{\overset{O}{\|}}{C}ONO_2 \xrightarrow{r.t.} (NO_2)_3C\overset{\overset{O}{\|}}{C}ONO_2 \xrightarrow{-CO_2} C(NO_2)_4.$$

Few other nitroalkanes are sufficiently thermally stable or readily preparable to be used as explosives.

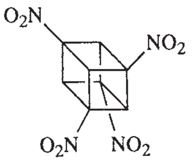
1,2 *Dinitroethane* (bp, 135 °C; mp, 39 °C; p, 1.46 g/cc) is prepared by the action of NO_2 on ethylene. Dinitroethane $(NO_2)\ CH_2{-}CH_2(NO_2)$ is a powerful explosive, but it is so highly reactive that it has not been used as explosive.

Polynitroethylene—$[CH_2{-}CH(NO_2)]_n$—is made from the monomer nitroethylene, $CH_2{=}CHNO_2$. The monomer is a yellow–green lachrymatory liquid (bp, 35 °C at 70 mm Hg) which readily polymerizes to a white water-insoluble powder. The polymer burns without melting; it is a weak explosive and has no practical use due to its low thermal stability. This is one of the few examples given in this document of an energetic polymer, but there are many others.

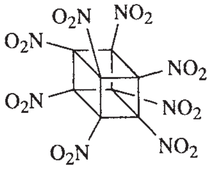
Hexanitroethane (mp, 142 °C) has the ability to gelatinize nitrocellulose; therefore, an attempt was made to use it in smokeless powder. However, its high production costs and low thermal stability (decomposition at 75 °C) prevented it from being of practical use.

2,2 *Dinitropropane*, a white crystalline (mp, 51–52 °C), is generally considered too thermally unstable for use. Held at 75 °C for 48 hours in a closed container, it loses two-thirds of its weight.

Nitrocubanes. Octanitrocubane with no hydrogen atoms would be an ideal explosive from an oxygen balance point of view; ring strain would give it added detonation energy. Although the octanitrocubane has yet to be made, the synthesis of hexanitrocubane and heptanitromethylcubane have been achieved by the Eaton group at Chicago [Eaton (1992), Borman (1994a), Picatinny (1996, 1997); Nielsen (1995)].



Tetranitrocubane



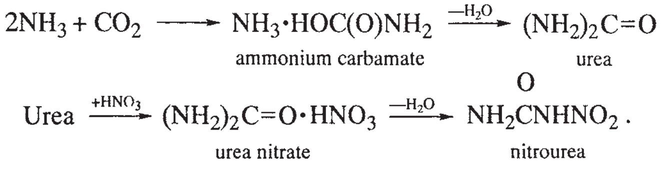
Octanitrocubane

5.6. Nitramines

Nitramine. NH_2NO_2 is the simplest nitramine, a white crystalline substance, melting at 72 °C. Unlike Me_2NNO_2, which has no hydrogens attached to the central N, nitramine is strongly acidic. Pure nitramine decomposes slowly on standing, forming nitrous oxide N_2O and water. It cannot be stored for more than a few days, and, therefore, is only of academic interest. The synthesis shown below is typical for all linear nitramines—dehydration of nitrate salt

$$NH_4NO_3 \xrightarrow{H_2SO_4} NH_2NO_2 + H_2O.$$

Urea Nitrate. Urea is manufactured by pumping ammonia and carbon dioxide into an autoclave where they are heated under pressure. Ammonium carbamate is formed first. This loses water to form urea. Urea is sometimes incorporated in blasting explosives for the purposes of lowering the temperature of explosion. It is also used as a stabilizer to remove acidity. Urea nitrate is formed by nitration of urea. It is stable, powerful, cool explosive; but it is corrosively acidic in the presence of moisture.

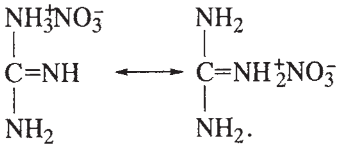


$$2NH_3 + CO_2 \longrightarrow \underset{\text{ammonium carbamate}}{NH_3{\cdot}HOC(O)NH_2} \xrightarrow{-H_2O} \underset{\text{urea}}{(NH_2)_2C{=}O}$$

$$\text{Urea} \xrightarrow{+HNO_3} \underset{\text{urea nitrate}}{(NH_2)_2C{=}O{\cdot}HNO_3} \xrightarrow{-H_2O} \underset{\text{nitrourea}}{NH_2\overset{O}{C}NHNO_2}\,.$$

Nitrourea is prepared by adding dry urea nitrate to concentrated sulfuric acid, while stirring and maintaining the temperature below 0 °C. Nitrourea decomposes in the presence of moisture.

Guanidine Nitrate (GN) is a intermediate in nitroguanidine manufacture and is itself a weak explosive sometimes used in mixture with other explosives, such as ammonium nitrate. Guanidine nitrate has a melting point of 215–216 °C and exists in two tautomeric forms:



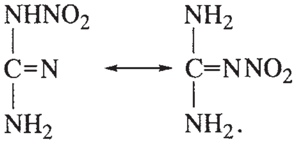
$$\begin{array}{l} \mathrm{NH_3^+NO_3^-} \\ | \\ \mathrm{C{=}NH} \\ | \\ \mathrm{NH_2} \end{array} \longleftrightarrow \begin{array}{l} \mathrm{NH_2} \\ | \\ \mathrm{C{=}NH_2^+NO_3^-} \\ | \\ \mathrm{NH_2}. \end{array}$$

The synthesis shown below is the British aqueous fusion method which produces guanidine nitrate (GN) in a single reactor. The GN magma is pumped to the next reactor for dehydration to nitroguanidine

$$\underset{\text{calcium carbide}}{\mathrm{CaC_2 + N_2}} \longrightarrow \mathrm{Ca(CN)_2 + CO_2 + H_2O} \xrightarrow[118\,^\circ\mathrm{C}]{-\mathrm{CaCO_3}} \underset{\text{cyanamide}}{\mathrm{NH_2C{\equiv}N}}$$

$$\text{Cyanamide} \xrightarrow{+\mathrm{NH_4NO_3}} \text{GN} \xrightarrow{-\mathrm{H_2O}} \text{Nitroguanidine}$$

Nitroguanidine (NQ) is prepared by dehydration (with fuming H_2SO_4) of guanidine nitrate. Nitroguanidine is relatively stable to impact and heat, but it decomposes upon melting. Two melting points are reported 232 °C and 257 °C, and two tautomeric forms exist.



$$\begin{array}{l} \mathrm{NHNO_2} \\ | \\ \mathrm{C{=}N} \\ | \\ \mathrm{NH_2} \end{array} \longleftrightarrow \begin{array}{l} \mathrm{NH_2} \\ | \\ \mathrm{C{=}NNO_2} \\ | \\ \mathrm{NH_2}. \end{array}$$

The decomposition of nitroguanidine is reported to be accelerated by ammonia. Since its decomposition produces ammonia, along with melamine and possible cyanuric acid, the reaction is autocatalytic.

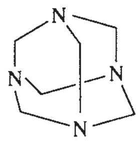
When nitroguanidine (NQ) is incorporated in nitrocellulose, the powder is flashless. However, flashless colloided powders containing NQ produce considerably more gray smoke than other flashless powders. NQ forms low melting eutectics with ammonium nitrate (AN) and guanidine nitrate (GN). It is an exception to the rule that most primary nitramine have no practical application as explosives.

20% NQ + 80% AN	132 °C,
41% NQ + 59% GN	167 °C,
17.5% NQ + 22.5% GN + 60% AN	113 °C.

RDX. Research Development Explosive, Cyclonite, Hexagen, cyclotrimethylenetrinitramine, and 1,3,5-trinitro-1,3,5,-tri-azacyclohexane are all names used to describe $[CH_2{-}N(NO_2)]_3$. RDX is more powerful than TNT and picric acid, replaces tetryl, and is less sensitive than PETN. In the original patent of 1899, the inventor suggested its might find medicinal use. RDX first became an important explosive in World War II. At the end of the war German production was 7000 tons/month and United States 15,000 tons/month.

There are two routes to RDX formation. Both require hexamethylene tetramine (also abbreviated hexamine), which is prepared as shown below

$$6CH_2O + 4NH_4NO_3 + 3(CH_3CO)_2O \longrightarrow \text{Hexamine} + 4HNO_3 + 6CH_3COOH$$



Hexamethylene
tetramine

The British synthesis of RDX is direct nitration of hexamethylene tetramine, where two reactions proceed simultaneously:

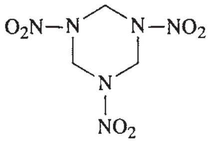
$$(CH_2)_6N_4 + 4HNO_3 \rightarrow (CH_2NNO_2)_2 + 3CH_2O + NH_4NO_3,$$

$$(CH_2)_6N_4 + 6HNO_3 \rightarrow (CH_2NNO_2)_3 + 6H_2O + 3CO_2 + N_2.$$

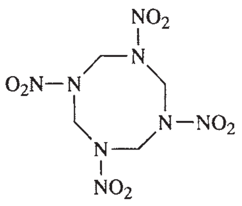
The American synthesis, the Bachmann process, nitrates hexamethylene tetramine by a mixture of nitric acid, NH_4NO_3, acetic anhydride. Initially, hexamethylene tetramine dinitrate is formed by the low-temperature (below 15 °C) action of 50% nitric acid on hexamine. Further reaction forms RDX, HMX, and a variety other nitramines. By maintaining the temperature at 75 °C undesirable open-chain nitramines are destroyed and a yield of 75–80% RDX with some (10%) HMX contamination is obtained. At the present writing, RDX is synthesized in a continuous process at Holsten in Kingsport, TN,

$$(CH_2)_6N_4 \cdot 2HNO_3 + 2NH_4NO_3 \cdot HNO_3 + 6(CH_3CO)_2O$$

$$\rightarrow 12CH_3COOH + 2(CH_2NNO_2)_3.$$



RDX



HMX

HMX. High Melting Explosive, cyclo-tetramethylenetetranitramine, octogen or 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclo-octane $[CH_2—N(NO_2)]_4$ is a by-product (10–15%) of the RDX Bachmann synthesis. In fact, the synthesis of HMX uses the same reagents as that of RDX, but the temperature is held at 43 °C to favor HMX formation (9/1) over RDX. HMX is more powerful than RDX and more thermally stable. It has four polymorphs. Usually it is obtained in the beta form, which is the least impact sensitive. Neither RDX nor HMX are particularly water soluble (5 mg RDX dissolves in 100 ml water at 20 °C), [Gibbs and Popolato (1980)] and their chemistry is similar. However, HMX does not react with hydroxide, while RDX does; and HMX is more soluble than RDX in 55% nitric acid. Both of these reactions can be exploited as a means of separating them.

5.6.1. Nitramine Composites

Since the melting points of RDX and HMX are too high to permit melt casting, they are rendered shapeable by mixture with various additives. Such composites fall in three general categories. The examples given are not intended to be exhaustive of the possibilities.

A. Cyclonites Desensitized (Phlegmatized) with Wax

Molten (88 °C) wax 5–10% is stirred into the RDX. Dye and aluminum are often added.

B. Castable Mixture of Nitramine and TNT

TNT is melted and powdered or flaked nitramine is added to it. Such mixtures have various names and formulations:

COMP B	60% RDX/39% TNT/1% wax
COMP-B2	60% RDX/40% TNT
Cyclotol	75–70% RDX/25–30% TNT
Torpex-2	70% Comp B/12% TNT/18% Al
Octol	75–70% HMX/25–30% TNT

C. Plastic-Bonded Explosives

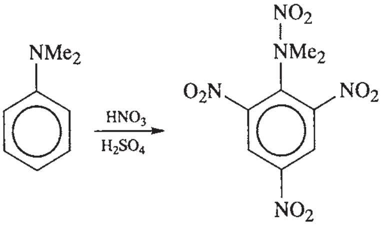
The nitramine is mixed with a plasticizer which allows it to be molded into the desired shape.

COMP C4 91% RDX, 9% plasticizer;
plasticizer = 5.3% di(-2-ethylhexyl)sebacate (recent, the sebacate has been replaced by the adipate);
2.1% polyisobutylene, 1.6% motor oil;

PBX 9407 94% RDX, 6% Exon 461;
Exon 461 copolymer = chlorotrifluoroethylene/tetrafluoroethylene/vinylidene fluoride.

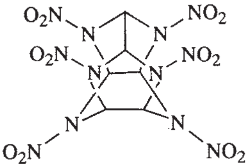
[In April 1997, the US Congress ratified the International Commerical Aviation Organization (ICAO) Convention on the Marking of Plastic Explosives for the Purpose of Detection. When in effect, it will mandate the tagging of all new and stored C4 with a minimum of 0.1 wt% 2,3-dimethyl-2,3-dinitrobutane (DMNB).]

Tetryl 2,4,6-trinitro-phenylmethylnitramine or picrylmethylnitramine or 2,4,6,-trinitro-N-methylaniline was first described in 1879. N,N-dimethylaniline dissolved in concentrated sulfuric acid is slowly mixed with HNO_3. The resulting light yellow solid is recrystallized from benzene or acetone.



Tetryl is more powerful and brisant than TNT and picric acid, but it is also more sensitive to shock. Tetryl is no longer commonly used as a United States military explosive due to the hazards of its preparation. Furthermore, if it is stored at 100 °C, it gives off nitrous fumes and formaldehyde; after 40 days a semiliquid mass is left.

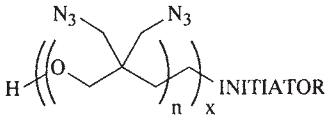
CL-20 (China Lake compound 20) or *HNIW* are the usual abbreviations for hexanitrohexaazaisowurtzitane. This is a polycyclic nitramine which exists in several different polymorphs. One is thought to be the densest (p, 2.0g/cm^3) and most energetic explosive known [Borman (1994b); Brill et al. (1996)]. HNIW contains one 6- and two 5- and two 7-membered nitramine rings.



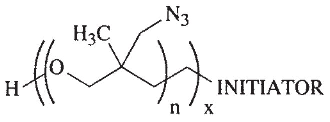
CL-20

5.7. Heterocyclic Explosives

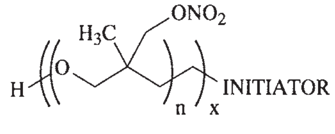
This is a not a true class of energetic material but is used here for explosives that don't fit well into the previous categories. Much effort is presently going into this area of explosive synthesis [Boyer (1986)]. These few compounds are meant to be representative of the type of compounds being prepared. Areas not discussed at all included proposed fluorinated energetic materials and energetic polymers.



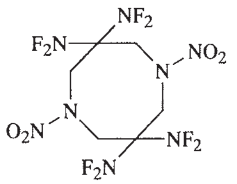
poly[bis(azidomethylene)oxetane]
(BAMO)

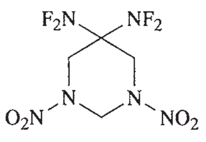


poly[(azidomethylenemethyl)oxetane]
(AMMO)

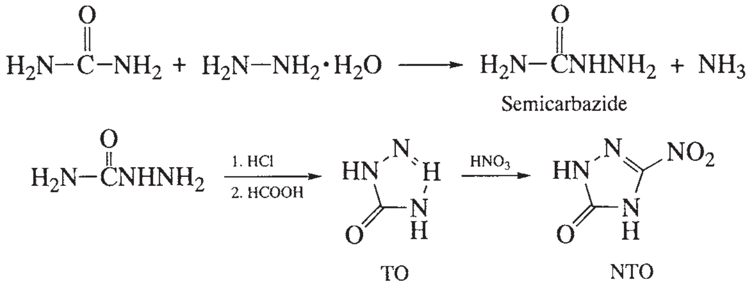


poly[(nitratomethylenemethyl)oxetane]
(NMMO)





NTO. 3-Nitro-1,2,4-triazole-5-one is a relatively new explosive (1980s) with performance about 80% of TNT and sensitivity less than TNT. It is prepared by condensation of semicarbazide hydrochloride with formic acid, followed by nitration of the resulting tetrazole. NTO decomposes about 240 °C. Unfortunately, it is quite acidic, and this affects its chemical stability. Since it does not melt and has low solubility in most solvents, it or its derivatives are being considered in admixture with TNT or ammonium nitrate [Oxley et al. (1997a)].



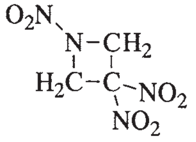
$$H_2N{-}\overset{\displaystyle O}{\overset{\|}{C}}{-}NH_2 + H_2N{-}NH_2{\cdot}H_2O \longrightarrow H_2N{-}\overset{\displaystyle O}{\overset{\|}{C}}NHNH_2 + NH_3$$

Semicarbazide

TO

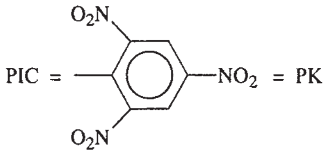
NTO

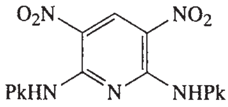
TNAZ. 1,3,3-Trinitroazetidine is a new (1984, Fluorochem) strained-ring explosive, which with a melting point of 101 °C is steam castable [Archibald et al. (1990); Lyer et al. (1991); Bottero (1996)]. Scale-up of its synthesis is in progress, improving a five-step route with low yield starting with epichlorohydrin and proceeding via the salt of *t*-butyl dintroazetidine. A discussion of one proposed synthetic route can be found in Coburn et al. (1997). Studies are underway to understand the thermal stability of TNAZ and to determine a mixture which would have a sufficiently low-melting point to retard sublimation [Oxley et al. (1997b); Picatinny (1997)].



TNAZ

PYX. [2,6-Bis(picrylamino)-3,5-dinitropyridine] [Coburn et al. (1986)] was an early product of a Los Alamos National Laboratory effort to find useful peacetime uses for explosive. This particular material has high thermal stability and finds use in oil-well applications.





PYX

5.8. Energetic Salts

Ammonium Nitrate (AN, NH_4NO_3) is prepared by reacting ammonia and nitric acid. Almost 18 billion pounds of AN are produced annually in the United States. Although its principal end use is fertilizer, about 20% is used in commercial explosives [Kirk-Othmer (1978)]. AN, ammonia, and nitric acid all rank in the top twenty chemicals produced [Chang and Tikkanen (1988)]. The synthesis is straightforward; ammonia vapor and nitric acid are mixed, and the exothermicity of the reaction causes the solution to boil and become more concentrated. It is further concentrated by vacuum evaporation. Variation in methods of removing the water produce different physical forms of AN. AN used in dynamites typically is concentrated in graining kettles, but in the late 1940s the development of a prilling process made the production of AN cheaper and faster. Today, AN, prepared for the fertilizer industry (FGAN) or the explosive industry (sometimes called industrial AN), typically, are prilled. A hot AN solution is pumped to the top of a prilling tower where it is sprayed into the cool air. As the AN spray falls, it forms small spherical pellets (1.5–2.5 mm) which are dried and dusted with talc to prevent sticking. Without coating, AN, being very hygroscopic, tends to form hard lumps. FGAN is prilled with less water (99% AN/1% water) than explosive-grade AN (95% AN/5% water). As a result, the explosive-grade AN requires a higher prilling tower (200 ft versus 60 ft for FGAN), and it is more porous than FGAN. The extra porosity helps the industrial grade AN soak up the fuel oil required to make it an explosive.

Some cite the Texas City disaster of April 1947, where two ships loaded with wax-coated AN detonated killing about 600 people, as the point at which the explosive power of AN was recognized. However, as early as 1867 two Swedish chemists patented an explosive which used AN alone or mixed with charcoal, sawdust, naphthalene, picric acid, nitroglycerin, or nitrobenzene. Nobel purchased the invention and used AN in dynamites. During World War I, Amatol, a mixture of AN and TNT in various proportions: 50/50, 60/40, or 80/20, was widely used. Amatols were not as brisant as TNT; detonation velocities decreased as the amount of AN increased.

	AN	TNT	Al flake	Stearic acid
German	54%	30%		16%
French	86%	8%	6%	

When combustible nonexplosives are added to AN, they react with the excess oxygen of AN to produce additional gas and heat and increase the power and temperature of the explosion. The combustible nonexplosive can be rosin, sulfur, charcoal, ground coal, flour, sugar, oil, or paraffin, but most often it is a fuel oil. AN was first used as the principle oxidizer in an explosive in 1953 by Akre of the Maumee Colliers in Terre Haute, Indiana. He mixed AN with coal dust. This process was used locally for several years before it was announced in 1955, but by 1958 it was widely accepted in the industry. In the Minnesota iron range, fuel oil replaced coal dust as the fuel. A mixture of AN with 5–6% fuel oil called ANFO is now a common blasting agent.

$$37NH_4NO_3 + CH_3(CH_2)_{10}CH_3 \rightarrow 12CO_2 + 13H_2O + 74H_2O + 37N_2.$$

AN may be mixed intimately with fuel in gels or emulsions. A typical aqueous emulsion contains 80% AN, 14% water, and 6% fuel mixed with an emulsifier such as sorbitan monooleate. AN becomes a more powerful explosive if mixed with an active fuel. An AN cartridge to which nitromethane is added just before use is sold commercially; AN with added hydrazine is a powerful liquid explosive, detonation velocity 6800 m/s. Because ANFO is easily prepared and was evidently used in the bombing of the Murrah building in Oklahoma City, April 19, 1995, there are a number of current research programs aimed at desensitizing commercially available AN.

AN has a melting point of 169 °C and begins to decompose as soon as it melts, the first step being dissociation into ammonia and nitric acid. At low temperature the decomposition mechanism is ionic, the slow step being the protonation of nitric acid. As a result, added acidic species, such as ammonium salts, accelerate its decomposition, while added basic species, such as the salts of weak bases, retard AN decomposition (see Chapter 9 for details).

AN/fuel formulations have almost completely replaced dynamites as a mining explosive [Hopler (1993b)]. As a result they are by far the explosives most widely used. AN formulations can be prepared which are quite powerful and cap-sensitive; nevertheless they perform as nonideal explosives. Ideal explosives such as TNT, RDX, HMX, and PETN have short (millimeter long) reaction zones; thus, upon initiation they release energy in a sharp pressure pulse supporting the detonation wave. This type of behavior has been modeled by a number of computer codes. Nonideal explosives have longer reaction zones than ideal explosives and, thus, release their energy more slowly. A smaller portion of their energy goes toward supporting the initial detonation wave and more of their energy is available for the following gas expansion which results in heaving power. Generally, heaving power is required from mining explosives although very hard rocks may require the penetrating power of an ideal explosive.

Ammonium Perchlorate (AP) is made by the electrochemical oxidation of sodium chloride NaCl to the chlorate $NaClO_3$ and on to the perchlorate $NaClO_4$. Metathesis with ammonium chloride produces ammonium perchlorae (AP) NH_4ClO_4. Energy-wise this is an expensive process, and both of the United States manufactures, Kerr–McGee and WECCO, are located near the Hoover Dam. Their combined yearly capacity is about 80 million pounds. Like ammonium nitrate, ammonium perchlorrate (greater than 45 μm particle size) has been classed as an oxidizer rather than as an explosive for purposes of shipping. The explosive capacity of AP was demonstrated in May 1988 when the one of the two United States AP manufacturing plants, PEPCON, blew up. Half the United States production capacity was temporarily lost, and two people were killed.

Both the French and Germans used AP explosives during World War I [Davis (1943)]. In World War II the United States used Galcit propellant that incorporated $KClO_4$ (75%) into molten asphalt (25%) [Kaye (1960–1978)]. It was the precursor of modern composite propellants in which AP is embedded in a polymer. The TNT equivalence of AP is about 0.31.

All the oxides of chlorine [hypochlorite (ClO^-), chlorite (ClO_2^-), chlorate (ClO_3^-), and perchlorate (ClO_4^-)] are energetic, but perchlorate salts are the most stable. Chlorates ClO_3^- are especially hazardous to handle. They decompose exothermically and are sensitive to heat, impact, and friction. Many chlorate mixtures, particularly those which contain sulfur, sulfide, or picric acid are extremely sensitive to blows and friction. The sensitivity can be reduced by phlegmatization in castor oil. Chlorate explosives with aromatic nitro compounds have higher detonation velocities and are more brisant than those in which the carbonaceous material is merely combustible. In 1885, 240,000 lb of a mixture of $KClO_3$ (79%) and nitrobenzene (21%) along with 42,000 lb dynamite were used to blast a portion of Hell Gate Channel in New York Harbor. Other similar mixtures are turpentine/phenol (90/10) absorbed on $KClO_3/MnO_2$ (80/20) or nitrobenzene/turpentine (80/20) absorbed on $KClO_3/KMnO_4$ (70/30). Flash powder is a mixture of potassium chlorate, sulfur, and aluminum. Mixtures of chlorate and fuel will spontaneously ignite with the addition of a drop of concentrated sulfuric acid (H_2SO_4). Spontaneous ignition or explosion can occur when alkali chlorates are combined with very reactive fuels (such as phosphorus, sulfur, powdered arsenic, or selenium) or with moist fuels. In fact, when powdered, dry, unoxidized $KClO_3$ and red phosphorus (Armstrong's powder) are pushed together, they ignite; this reaction has been tamed and utilized by use of separation and a binder in the common safety match. Armstrong's powder, wet with some volatile solvent such as methanol, has been used as an antipersonnel device. MnO_2 has been reported as a catalyst for the decomposition of chlorates and perchlorates.

Hypochlorites are generally highly reactive and unstable. The calcium salt (HTH), one of the most stable, ignites spontaneously with glycerin. Hypochlorite are used as liquid household bleach (an alkaline solution of NaOCl); as household dish washing detergents and scouring powders $[(Na_3PO_4 \cdot 11H_2O)_4 \cdot NaOCl]$; as a liquid bleach for pulp and paper bleaching [a mixture of $Ca(OCl)_2$ and $CaCl_2$]; and as a powdered swimming pool bleach $[Ca(OCl)_2/CaCl_2/Ca(OH)_2 \cdot 2H_2O]$.

Hydroxylammonium Nitrate (HAN) NH_3OHNO_3 is a low-melting (42 °C) energetic salt which for some time has been considered as a possible propellant oxidizer. It is very difficult to maintain as a solid since upon exposure to air, it picks up to 95% of its weight in water and immediately dissolves. As a possible aqueous propellant, it is stabilized by an amine, but the salt is stable over a very narrow pH range, being sensitive to both acid and base. It has low thermal stability decomposing to water, N_2O, N_2, and HONO, an acid, which accelerates its decomposition.

Ammonium Dinitramide (ADN) $NH_4N(NO_2)_2$ is a low-melting (94 °C) energetic salt which was synthesized for the first time in the USSR (1971) and later in the United States (1991). Presently, it is considered the hot new candidate propellant, but much testing and formulating need to be done. This material is much less thermally stable than AN, probably due to its much lower melting point, and is light sensitive. One decomposition route produces ammonium nitrate and N_2O [Oxley et al. (1997c)].

Mercury Fulminate $Hg(ONC)_2$ is a primary explosive, sensitive to heat and friction. Its main use has been as a primer for initiating high explosives. Used in combination with $KClO_3$ it has a larger effect. It synthesis is mechanistically complex but in the laboratory simply involves dissolving mercury in concentrated nitric acid, adding ethanol, and thoroughly washing the white crystals of mercury fulminate when their formation is complete. Mercury fulminate is sensitive to light, undergoes marked decomposition above 50 °C, and is usually stored under water.

Azides are roughly divided into three class: stable ionic azides (alkali and alkaline earth azides); unstable covalent azides (haloazide) which frequently explode spontaneously, and heavy-metal azides $[Pb(N_3)_2, AgN_3]$ that explode on shock. It is the alter group that are often are used as primers for initiating high explosives. The usually synthetic route is reaction of the metal nitrate with sodium azide [Fair and Walker (1977)].

5.9. Composite Explosives

Many potential explosives can be broadly classed as composite explosives. Rather than containing the oxidizer and fuel in a single molecule, as do the organic military explosives, composite explosives are formed by intimately mixing oxidizing compound(s) with fuel(s). These can be premixed or mixed just prior to use. In such mixtures there can be problems due to inhomogeneities; the finer the solid particle size and the more intimate the mix, the better the performance. Classic examples of composite explosives are black powder [a mixture of the oxidizer potassium nitrate (75%) and sulfur (10%) with the fuel charcoal (15%)] and ANFO. The tables below list oxidizers and fuels which can be combined to form composite explosives.

Oxidizers	
Oxygen and halogens	
Perchlorates	$KClO_4$, NH_4ClO_4, $NaClO_4$, and Ba and Ca salts
Chlorates	$KClO_3$, and Li, Na, Ba salts
Hypochlorite	$Ca(OCl)_2$
Nitrates	KNO_3 and NH_4, Na, Ba, Ag, Sr salts
Chromates	$PbCrO_4$ and Ba, Ca, K salts
Dichromates	$K_2Cr_2O_7$ and $NH_4Cr_2O_7$
Iodates	KIO_3 and Pb, Ag salts
Permanganate	$KMnO_4$
Metal oxides	BaO_2, Cu_2O, CuO, Fe_2O_3, Fe_3O_4, PbO_2, Pb_3O_4, PbO, MnO_2, ZnO
Peroxides	Na_2O_2, H_2O_2 (80%), dibenzoylperoxide

Fuels

- nitrobenzene
- nitrotoluenes
- nitronaphthalene
- nitrocellulose
- picric acid
- petroleum
- turpentine
- naphtha
- castor oil
- sugar
- glycerin
- acetylene
- wax, paraffin
- sawdust
- halogenated-hydrocarbons
- halogens
- powdered metals
- carbon disulfide (CS_2)
- phosphorus (P_4)
- sulfur (S_8)

5.10. Liquid Oxidizers and Explosives

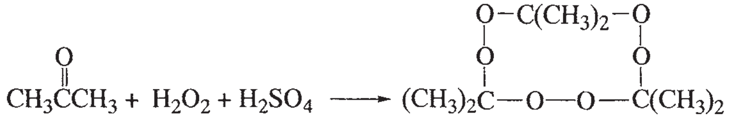
The ultimate oxidizer is oxygen. Shortly after a machine was developed for the liquefaction of gases (1895) liquid oxygen explosives (LOX) came into use. LOX are formed by impregnating porous combustible materials, such as lampblack, with liquid oxygen. Two problems exist with liquid oxygen containing explosives: they lose their explosiveness as the liquid oxygen evaporates (bp, −183 °C); and they are easily inflamed. During World War I the Germans used LOX when other explosives ran low. In 1926, LOX were used for the first time in commercial rock blasting operations; their use was continued into the 1960s. The combination of liquid oxygen with the detonable fuel acetylene (acetylene 25%/O_2 75%) produces an explosive with detonation velocity comparable to military explosives (6000 m/s) [Kaye (1960–1978)].

Nitrogen tetroxide (N_2O_4) is another liquid oxidizer capable of forming powerful explosives. Liquid nitrogen tetroxide exists over the narrow temperature range between its freezing point (−11 °C) and 21 °C, where it dissociaties into nitrogen dioxide (NO_2), a toxic gas. Panclastites, explosives made with liquid N_2O_4 and combustible liquids (carbon disulfide, nitrobenzene, nitrotoluene, gasoline, halogenated hydrocarbons), were first considered when the Germans tested marine torpedoes containing sealed glass containers of N_2O_4 and CS_2 in the 1880s; set-back forces broke the glass containers generating the explosive mixture, and an impact fuse initiated detonation. Similar N_2O_4/fuel devices were used in both World War I and World War II. Nitrogen tetroxide oxidizers are still in use in space shuttle propellants. Panclastites are inexpensive and easy to prepare; some are more brisant and have better detonation velocities than TNT. However, though their performance is favorable, panclastites are too shock sensitive, too hard to handle, to find common military use. Their extreme sensitivity dictates that they be mixed just prior to use, and the corrosive nature of N_2O_4 requires special vessels. Mixtures of N_2O_4 with 64% nitromethane have a detonation velocity of 6900 m/s [Kaye (1960–1978)]. Nitrogen tetroxide explodes on contact with a number of fuels: acetic anhydride, liquid ammonia, methyl and ethyl nitrate, propene, hydrazine-type fuels.

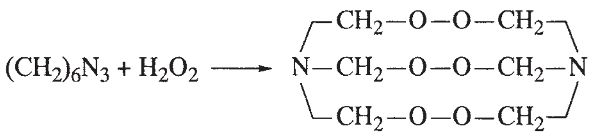
Peroxides. Peroxides, with oxygen bonded to oxygen, can be violent oxidizers in the presence of fuel. For example, sodium peroxide (Na_2O_2) instantly ignites in the presence of moisture and a fuel (magnesium and sawdust or paper, or sulfur or aluminum). In addition to this feature, peroxides can also undergo a violent self-decomposition. Peroxide decomposition into water and oxygen can be catalyzed by small amounts of alkaline lead, silver, or manganese salts, or even saliva [Kaye (1960–1978); Oxley (1993)]. Pure hydrogen peroxide decomposes violently above 80 °C; therefore, it is sold as aqueous solutions. It is available at pharmacies as a 3% solution for use as a disinfectant or as a 40% solution for use as a hair lightener or as a gel to brighten teeth. Hydrogen peroxide pure and in concentrations as low as 86% is detonable. Solutions of 90.7% peroxide have reported detonation velocities of 5500 m/s to 6000 m/s. Mixtures of hydrogen peroxide vapor in air with as little as 35 mol% H_2O_2 are reported to detonate at 1 atmosphere with a velocity of 6700 m/s. Furthermore, hydrogen peroxide, pure or in water, is readily detonable when mixed with organic materials. H_2O_2/water/ethanol has a detonation velocity of 6700 m/s [Kaye (1960–1978)].

Austria made unsuccessful attempts to use H_2O_2 as an explosive in World War I. In World War II, the US Navy used it for propulsion in submarine torpedoes. Peroxide explosives have been successfully used in blasting operations. In addition to its monergolic application, hydrogen peroxide can be used with a number of fuels. Hydrogen peroxide mixed with fuels such as methanol, ethanol, or glycerol showed detonation rates as high as 6700 m/s. One of the propellant systems on the space shuttle uses the combination of hydrogen peroxide and unsymmetrical dimethylhydrazine. H_2O_2 (60%) with paraformaldehyde forms a crystalline compound of high brisance and sensitive (mp, 50 °C). Hydrogen peroxide (70%) with diesel fuel and gelling agent also makes a good explosive. H_2O_2 (83%) plus cellulose forms a gelatinous mass which is more powerful than TNT and insensitive to shock or friction. It has an ignition temperature of 200 °C; however, it cannot be stored over 48 hours without evolution of peroxide and loss of explosive power. Other patented peroxide explosives include H_2O_2 with water and glycerol, H_2O_2 (70%) with powdered boron (30%), and H_2O_2 used with hexamethylenetetramine and HCl [Kaye (1960–1978)].

Recently two peroxides have received wide publicity in the terrorist communities: triacetone triperoxide (TATP) and hexamethylene triperoxide diamine (HMTD). TATP can be synthesized from acetone, hydrogen peroxide, and sulfuric acid [Black Book (1977)]. The white crystalline solid which forms after standing 24 hours explodes violently upon heating, impact, or friction. It is highly brisant, very sensitive, and detonable under water. Its reported detonation velocity is 5290 m/s [Meyer (1987)]. It has been suggested for use in primers and detonators, but due to its volatility and sensitivity it has not found military application. HMTD is formed by a similar synthesis from hexamethylene, hydrogen peroxide, and acid.



TATP



HMTD

5.11. Unconventional Explosives

Metals. Some alkali metals spontaneously ignite on exposure to water or air. As the alkali metals increase in weight, their reaction to air becomes more violent. While potassium may oxidize so rapidly that it melts and ignites when pressure is applied (as in cutting), cesium burns in air as soon as it is removed from an inert oil covering. Moisture in the air serves to enhance further reactivity. Sodium and potassium form a eutectic (NaK) which is spontaneously ignitable. Sodium/potassium alloys are reported to react explosively upon contact with silver halides or to detonate upon contact with halogenated organic materials such as carbon tetrachloride. Potassium and heavier alkali metals burst into flame upon contact with water. Sodium too will inflame in water if it can be anchored in one spot long enough to allow the heat of reaction to ignite the hydrogen being produced:

$$Na + H_2O \rightarrow NaOH + \tfrac{1}{2}H_2.$$

Lithium is the least reactive alkali metal but will ignite if thrown on water as a dispersion. In World War II the Germans used land mines composed of sodium and methyl nitrate in separate compartments. Pressure brought the two together and into action.

Some finely-divided (powdered) nonalkali metals will also burst into flame in the presence of air. The best known are lead, iron, nickel, cobalt, and aluminum. These can be prepared by pyrolysis of their organic salts or by reduction of their oxides, or in some cases, by formation of a mercury amalgam. These metals may also explosively react with water, halogenated hydrocarbons, and halogens.

$$Al + CCl_4 \rightarrow AlCl_3.$$

Magnesium is used in a number of pyrotechnics. When a magnesium/silver nitrate mixture is moistened, it reacts explosively. Teflon $(C_2F_4)_n$ with powdered magnesium reacts explosively upon ignition. Devices of this composition are used as decoys for heat-seeking missiles.

$$(C_2F_4)_n + 2n\,Mg \rightarrow 2n\,C + 2n\,MgF_2.$$

Some methyl- and ethyl-substituted metals are spontaneously ignitable in air. The alkylated metals most frequently exhibiting this behavior are the alkali metals (Li, Na), aluminum, zinc, and arsenic or nonmetals such as boron and phosphorus. Many of these compounds also react explosively with water and with carbon tetrachloride (CCl_4). It is reported that triethylaluminum [$Al(C_2H_5)_3$] in carbon tetrachloride reacts explosively when warmed to room temperature.

Thermite is generally the redox reaction between a metal oxide and a metal. However, the most important reaction and the one usually referred to by this name is that of aluminum and iron oxide:

$$8Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + 9Fe.$$

This reaction generates a tremendous amount of heat; molten iron is produced and its melting point is above 1530 °C. One peaceful application of this reaction is for welding in shipyards and railroads. With $KMnO_4$ in the metal mixture, reaction can be triggered with added glycerol. With sugar in the initial mix, reaction is triggered with a drop of concentrated H_2SO_4. Such initiating schemes are usually used in laboratory demonstrations. Thermite reactions using CuO or Mn_3O_4 are reported explosive. Mixtures of Pb, PbO_2, and PbO also undergo explosive thermite reactions.

Acetylides. A number of metal carbides exist which are explosive in their own right; most are termed acetylides rather than carbides. Copper acetylide and silver acetylide are most commonly prepared by teenagers. Being primary explosives, they explode violently upon heating, impact, or friction. Cuprous acetylide is the only acetylide which has been used in the explosives industry; it has been used in electric detonators. Acetylides can be formed by passing acetylene through a solution of the appropriate metal salt.

Self-Igniting Materials. Some chemicals are so reactive to the oxygen in air or to water that they spontaneously ignite. Three parameters affect the spontaneity of ignition in air: the dryness of the air, air pressure, and temperature. Most of these chemical systems cannot be classed as explosives, but if sufficient gas pressure and heat are evolved the effect could be catastrophic.

Hydrides. Phosphines, silanes, and boranes ignite on contact with air. Diphosphine (P_2H_4), a liquid at room temperature, can be made from the reaction of water with solid calcium phosphide (Ca_3P_2), which, in turn, can be formed from lime and red phosphorus. Adding water to calcium phosphide results in a mixture of phosphine and diphosphine, and a violent deflagration ensues. This reaction as been exploited in naval flares. Only mono- and di-silanes (SiH_4 and Si_2H_6) are stable to air at room temperature. The higher silanes decompose violently. Diborane (B_2H_6) is a gas available in cylinders or by the action of 85% phosphoric acid on $NaBH_4$. The gas is highly toxic, and, unless it is extremely pure, it reacts with oxygen at room temperature. Borane decomposition in oxygen is extremely exothermic; therefore, boranes, such as decaborane (14) ($B_{10}H_{14}$), have been seriously considered as a component in rocket fuel.

Phosphorus. White phosphorus tends to ignite with slight pressure or by contact with fuel. P_4 self-ignites in air above 34 °C; as a result, it is usually stored under water. The finely divided phosphorus left on the combustible material reacts exothermically with the oxygen in air:

$$P_4 + 5O_2 \rightarrow P_4O_{10}.$$

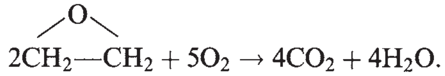
The heat of this reaction could initiate the reaction between carbon disulfide and air. Drying of the phosphorus can be delayed by addition of a high-boiling hydrocarbon such as gasoline or toluene. In contrast to white phosphorus, red phosphorus is nontoxic and less sensitive. Red phosphorus bursts into flames or explodes on mild friction or impact in mixture with chlorate, permanganates, lead dioxide (PbO_2), perchlorate, and other active oxidizers ($AgNO_3$).

Miscellaneous Energetics. Potassium permanganate and glycerin will ignite spontaneously after a small delay, due to the difficulty in wetting the $KMnO_4$ with viscose glycerin. Ethylene glycol, acetaldehyde, benzaldehyde, or DMSO could be used in place of glycerin. Potassium permanganate and concentrated sulfuric acid can readily inflame when in contact with fuels

$$14KMnO_4 + 4C_3H_5(OH)_3 \rightarrow 7K_2CO_3 + 7Mn_2O_3 + 5CO_2 + 16H_2O.$$

Fuels. In addition to the composite explosives resulting from direct mixing of fuels with the oxidizers, another class of explosives should be mentioned. Fuel/air explosives (FAE) involve ignition of fuel droplets dispersed in air. The first FAE bombs were used in VietNam to clear mine fields and open helicopter landings. They can produce very large static and dynamic impulses per weight fuel (since they do not have to carry their own oxygen) and can cause blase effects over large areas [Kaye (1960–1978)].

Ethylene oxide is a colorles gas (bp, 13.5 °C) with a wide detonable concentration range (3–100%). The reason it is detonable at any concentration is because oxygen is already incorporated in the ethylene oxide molecule. However, for complete combustion it requires additional oxygen from the air or from hydrogen peroxide



$$2\overset{\diagup\mathrm{O}\diagdown}{\mathrm{CH_2{-}CH_2}} + 5\mathrm{O_2} \rightarrow 4\mathrm{CO_2} + 4\mathrm{H_2O}.$$

Like ethylene oxide, acetylene is a colorless gas. Acetylene, with a carbon–carbon triple bond, releases a great deal of energy when these bonds are broken to combine with oxygen making CO_2. As a result, detonable limits of acetylene are nearly the same as its flammability limits [Burgess et al. (1968)]. Almost any mixture of the gas is flammable and detonable (from concentrations of 2.5% to 100% in air).

Cyanogen (C_2N_2) is a pungent gas that is easily prepared from mixing solutions of KCN and $CuSO_4$ or by heating $Hg(CN)_2$. It is used in warfare as a poisonous gas, but it should not be overlooked that cyanogen is also a high explosive. It explosive range is wide, from 7% to 73% in air.

References

Archibald, T.G., Gilardi, R., Baum, K., and George, C. (1990). *J. Org. Chem.*, **55**, 2920–2924.

Borman, S. (1994a). Military research on cubane explosive. *C&E News*, Nov. 28, p. 34.

Borman, S. (1994b). Advanced energetic materials emerge. *C&E News*, Jan. 17, p. 18.

Bottaro, J.C. (1996). Recent advances in explosives and solid propellants. *Chemistry and Industry*, April, pp. 249–252.

Boyer, J.H. (1986). *Nitroazoles.* Organic Nitro Chemistry Series, Vol. 1. VCH, Essen, Germany.

Brill, T., Russell, T., Tao, W., and Wardle, R., eds. (1996). *Decomposition, Combustion, and Detonation Chemistry of Energetic Materials.* MRS, Pittsburgh, PA.

Burgess, D.S., Murphy, J.N., Hanna, N.E., and Van Dolah, R.W. (1968). Large-scale studies of gas detonations. U.S. Bureau of Mines Report. Investigation No. 7196.

Chang, R. and Tikkanen, W. (1988). *The Top Fifty Industrial Chemicals.* Random House, New York.

Coburn, M.D., Harris, B.W., Lee, K.Y, Stinecipher, M.M., and Hayden, H.H. (1986). Explosives synthesis at Los Alamos. *I&EC Product Res. & Dev.*, **25**, 68.

Coburn, M.D., Hiskey, M.A., Oxley, J.C., Smith, J.L., Zheng, W., and Rogers, E. (1997). Synthesis and spectra of some ^{2}H, ^{13}C, and ^{15}N isomers of 1,3,3-trinitroazetidine and 3,3-dinitroazetidinium nitrate. *J. Energetic Materials* (to appear).

Davis, T.L. (1941, 1943, reprint of two volumes). *The Chemistry of Powder and Explosives.* Angriff Press, Hollywood, CA.

Dobratz, B.M. (1981). *LLNL Explosives Handbook: Properties of Chemical Explosives and Explosive Simulants.* Lawrence Livermore National Laboratory, UCRL-52997.

Eaton, P.E. (1992). Cubanes: Starting materials for the chemistry of the 1990s and new century. *Angew. Chem. Int. Ed. Engl.*, **31**, 1421–1436.

Fair, H.D. and Walker, R.F. (1977). *Energetic Materials*, vols. I and II. Plenum Press, New York.

Gibbs, T.R. and Popolato, A., eds. (1980). *LASL Explosive Property Data*. University of California Press, Berkeley, CA.

Hopler, R.B. (1993a). *The Story of Dynamite* (video). Ireco-Dyno.

Hopler, R.B. (1993b). Custom-designed explosives for surface and underground coal mining. *Mining Engineering*, October, pp. 1248–1252.

Horning, E. C., ed. (1955). *Organic Synthesis*, vol. 3. Wiley, New York, p. 803.

Kamlet, M.J. (1976). The relationship of impact sensitivity with structure of organic high explosives. I. Polynitroaliphatic explosives. *Sixth Symposium (International) on Detonation*. ONR ACR-211, pp. 312–322.

Kaye, S.M. (1960–1978). *Encyclopedia of Explosives and Related Items*. U.S. Army Armament Research and Development Command; PATR-2700. Dover, New York.

Kirk-Othmer (1978). *Encyclopedia of Chemical Technology*, 3rd ed., Wiley, New York.

Lyer, S., Eng, Y.S., Joyce, M., Perez, R., Alster, J., and Stec, D. (1991). *Proceedings of ADPA Manufacture Compatibility of Plastics and Other Materials with Explosives, Propellants, Pyrotechnics and Processing of Explosives, Propellants, and Ingredients*, San Diego, CA, p. 80.

Marshall and Peace (1916). Vapor pressure of glyceryl trinitrate. *J. Chem Soc. Ind.*, **109**, 298.

Meyer, R. (1987). *Explosives*, 3rd edn. VCH, Essen, Germany.

Nielsen, A.T. (1995). *Nitrocarbons*. Organic Nitro Chemistry Series, Vol. 5. VCH, Essen, Germany.

Olah, G.A., Malhotra, R., and Narang, S.C. (1989). *Nitration: Methods and Mechanisms*. Organic Nitro Chemistry Series, Vol. 3. VCH, Essen, Germany.

Oxley, J.C. (1993). Non-traditional explosives: Potential detection problems. *Terrorism and Political Violence*, **5** (2), 30–47.

Oxley, J.C., Smith, J.L., Ye, H., McKenney, R.L., and Bolduc, P.R. (1995). Thermal stability studies on homologous series of nitroarenes. *J. Phys. Chem.*, **99** (24), 9593–9602.

Oxley, J.C., Smith, J.L., Rogers, E., and Dong, X.X. (1997a). NTO decomposition products tracked with N-15 labels. *J. Phys. Chem.*, **101** (19), 3531–3536.

Oxley, J.C., Smith, J.L., Zheng, W., Rogers, E., and Coburn, M.D. (1997b). Thermal decomposition pathways of 1,3,3-trinitroazetidine (TNAZ), related 3,3-dinitrozetidinium salts, and ^{15}N, ^{13}C, and ^{2}H isotopomers. *J. Phys. Chem. A*, **101** (24), 4375–4483.

Oxley, J.C., Smith, J.L., Zheng, W., Rogers, E., and Coburn, M.D. (1997c). Thermal decomposition studies on ammonium dinitramide (ADN) and ^{15}N and ^{2}H isotopomers. *J. Phys. Chem.* (to appear).

Urbanski, T. (1964, 1965, 1967, 1984). *Chemistry and Technology of Explosives*, vols. 1–4. Pergamon Press, New York.

FEMEP (1977). *Field Expedient Methods for Explosive Preparation.* Desert Publications, Cornville, AZ.

IMBB (1981). *Improvised Munitions Black Book*, vols. 1–3. Desert Publications, Cornville, AZ.

Picatinny Arsenal (1996, 1997). "Fifteenth Annual Working Group Institute on Synthesis of High Energy Density Materials," June 12–13, 1996; and "Sixteenth Annual ...", June 18–19, 1997.

37. Rodriguez, J.M. and E.J. Abeyta, March 2021. *2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory*. LA-UR-21-22304. OSTI Identifier 1773305. (Rodriguez & Abeyta 2021)

LA-UR-21-22304

Title: 2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Author(s): Rodriguez, Jadzia Mira
Abeyta, Elisa Janelle

Intended for: Environmental Regulatory Document

Issued: 2021-03-25 (rev.1)

LA-UR-21-22304
March 2021

2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Prepared by: **Jadzia Rodriguez and Elisa Abeyta, Environmental Protection and Compliance Division, Environmental Stewardship Group, Los Alamos National Laboratory**

An Affirmative Action/Equal Opportunity Employer

Contents

Figures

Tables

EXECUTIVE SUMMARY

Los Alamos National Laboratory (LANL) biologists in the Environmental Protection and Compliance Division initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. In this annual report we compare monitoring results from these efforts among years to monitor trends. The objectives of this study are to 1) determine whether LANL operations impact bird species richness, diversity, or abundance and 2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. LANL biologists completed the eighth year of this effort in 2020.

Between May and July 2020, we completed three avian point count surveys at each of the treatment sites which are the Technical Area (TA)-36 Minie site, the TA-39 point 6, and the TA-16 burn ground. We recorded a total of 1,005 birds representing 63 species at the three treatment sites and compared these results to data from their associated control sites. We also compared occupancy and nest success data from nestboxes at treatment sites with the overall avian nestbox monitoring network.

In 2020, species richness and avian abundance showed variability, but treatment and controls were trending together year to year. The species diversity at the TA-36 Minie site and TA-16 burn ground were statistically different from their associated controls. To examine this further, we prepared rarefaction and extrapolation plots for all years and over time. The species diversity at all three treatment sites has been diverging from the controls over the last few years. We determined that the diversity was higher at the treatment sites than the controls which is not alarming. Nestbox results suggest natural fluctuations year to year.

The overall results from 2020 continue to indicate that operations at the three treatment sites are not negatively affecting bird populations. This long-term project will continue to monitor for any changes over time.

This page intentionally left blank.

INTRODUCTION

As part of the Resource Conservation and Recovery Act permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites, Technical Area (TA)-36 Minie site and TA-39 point 6, and one open burn site, TA-16 burn ground (hereafter referred to as Minie, TA-39, and TA-16, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017, 2018; Sanchez et al. 2020). The objectives of this long-term monitoring program are to (1) determine whether LANL operations impact bird species richness, diversity, or abundance and (2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. This involves making comparisons with control sites of similar habitat that LANL biologists have surveyed since 2011 (Hathcock et al. 2011).

LANL biologists used standard point count methodology to record avian richness, diversity, and abundance along transects at the three treatment sites and their associated control sites during the summer of 2020. Summer surveys provide information about what birds are breeding at each site. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

In addition to avian point counts, LANL biologists monitored nestboxes around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared to the overall avian nestbox monitoring network, which was established in 1997.

METHODS

Field Methods for Point Count Surveys

LANL biologists conducted the point count surveys along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon (*Pinus edulis*) – juniper (*Juniperus monosperma*) woodland (PJ) for Minie (Figure 1) and TA-39 (Figure 2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 3). The habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (Figure 4) are monitored annually. The control sites were originally established in 2011 (Hathcock et al. 2011). Each habitat type control contained two replicate transects that LANL biologists monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects are monitored randomly.

The treatment sites at Minie and TA-39 were similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was in an undeveloped area.

Transects were approximately 2.0 to 2.5 km in length with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys was May 1 through August 15. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site conducted between 0.5 hours before sunrise and four hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for five minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an “unlimited-distance circular plot”; however, surveyors should be recording the distance to each bird out to 100 m. A range finder should be used if available. Avoid re-counting individuals between points.
- While walking between points, surveyors should be recording any obvious species not recorded at the previous point that also wouldn’t be counted at the next point. The surveyor should not spend excess time looking for birds between points.
- Do not conduct surveys during rain events or winds greater than 24 kph.
- Use the “NOTES” section to indicate any additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Surveyors should be recording other wildlife or unusual sightings that could be used for other projects.

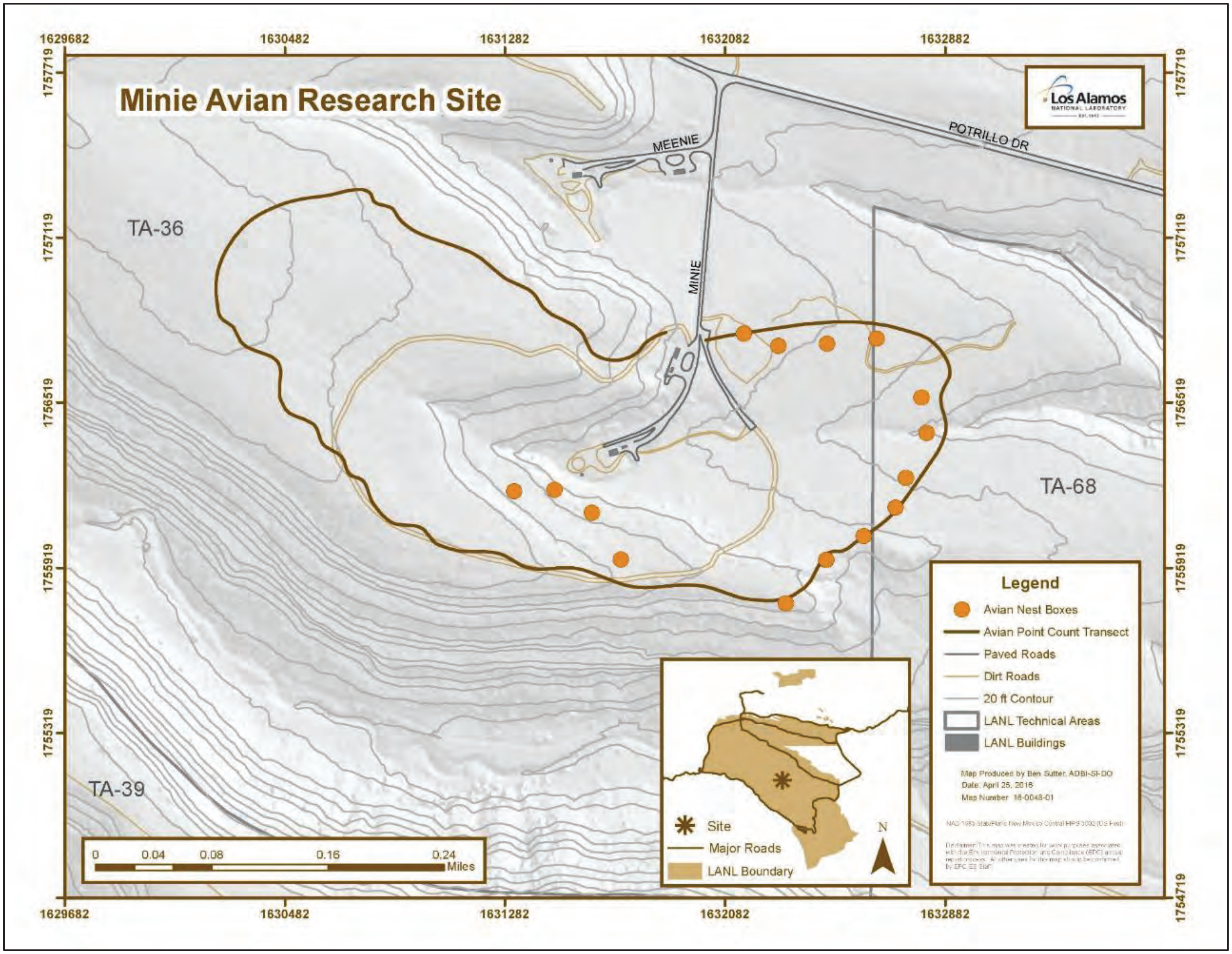


Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie Site

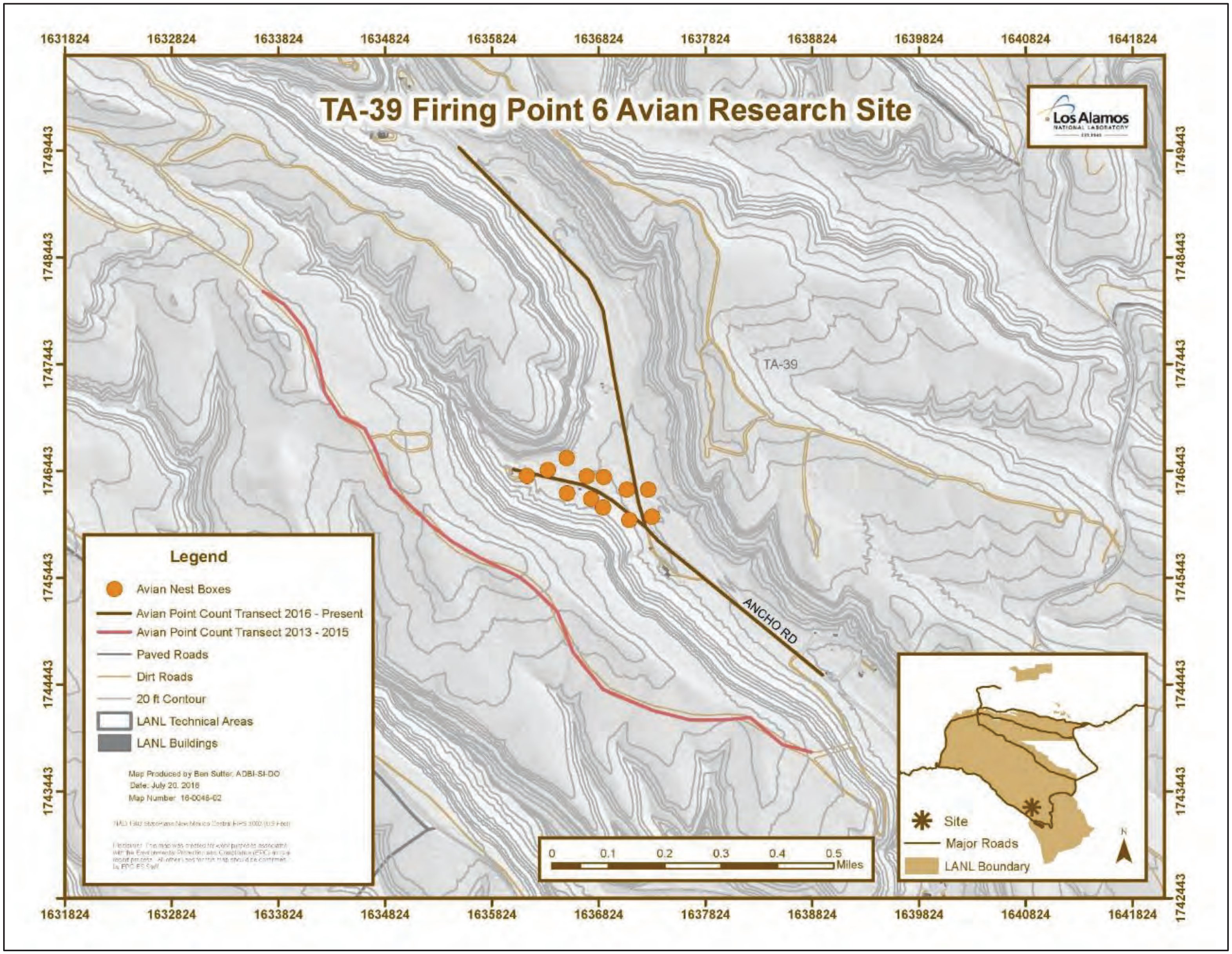


Figure 2. Breeding bird survey transect and nestbox locations around TA-39 Point 6

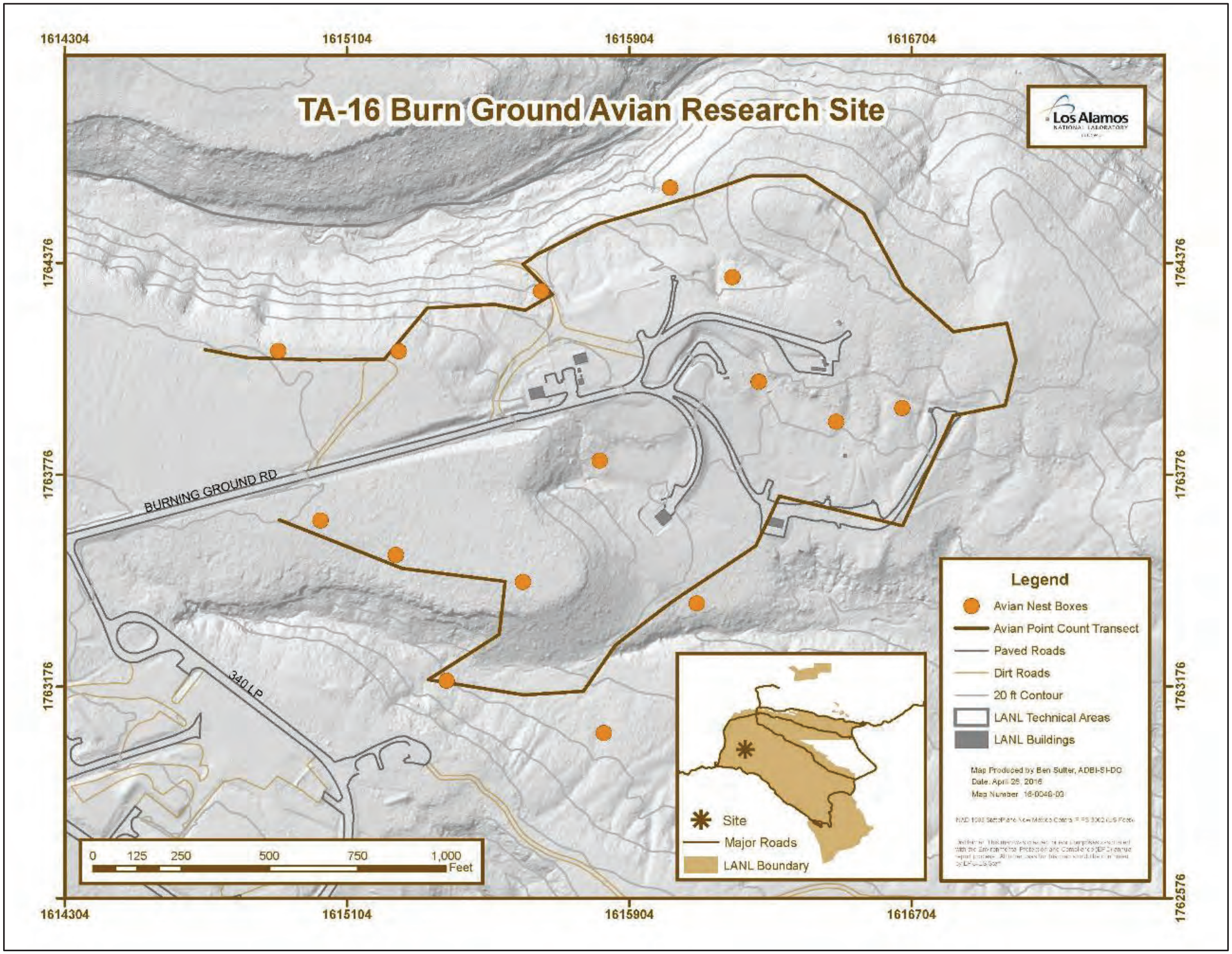


Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 Burn Ground

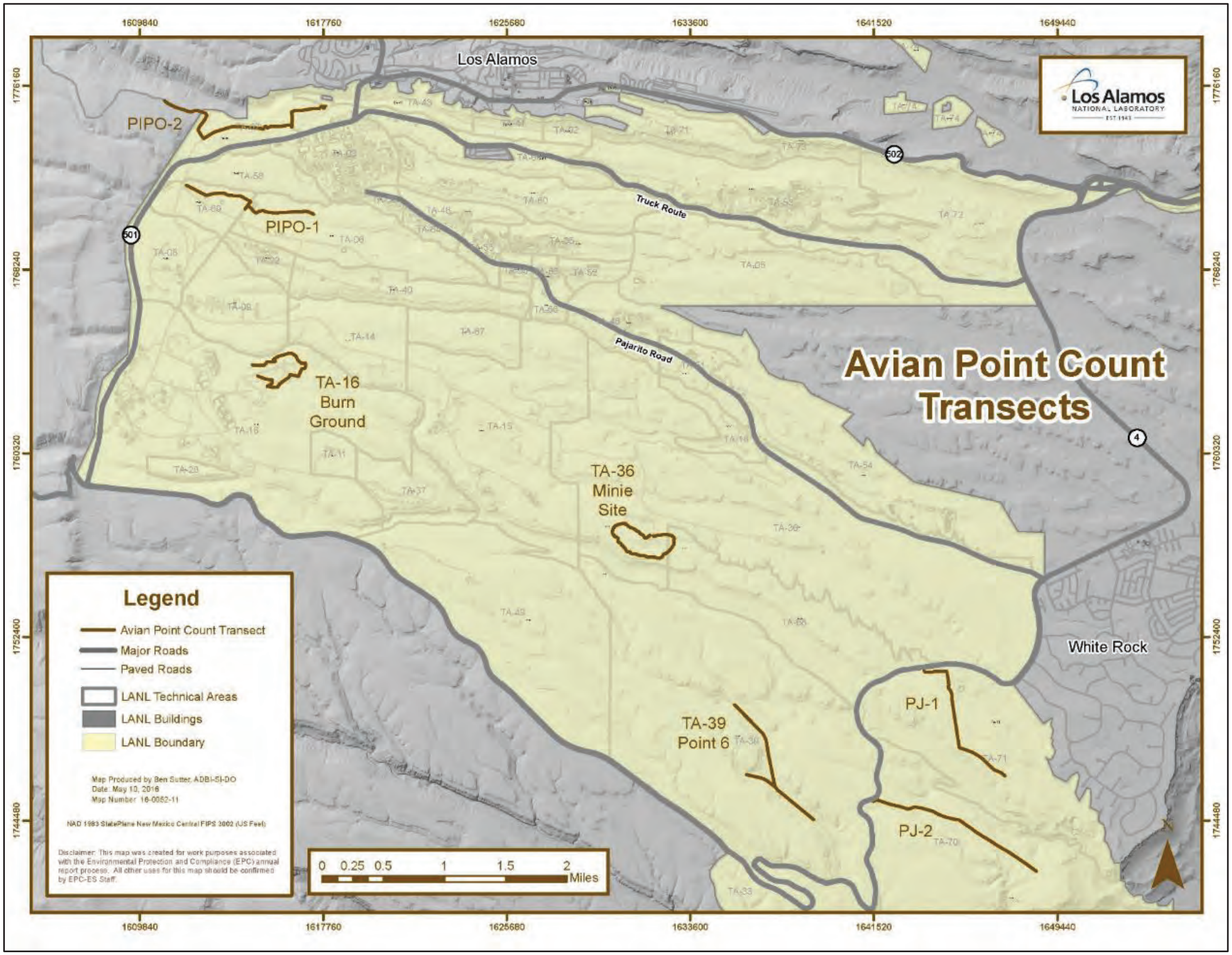


Figure 4. All avian point count transects around LANL

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Statistical Methods for Point Counts

We summarized these data to compare species richness, diversity, and abundance between treatment and control sites and over time. We considered each treatment site and control to be individual communities. Species richness is the number of different species represented in an ecological community and is simply a count of species (Boulinier et al. 1998). Species diversity is a measure that takes into account the species richness and the overall abundance to compare evenness across a community (Tramer 1969). Shannon's diversity index measures the probability that two individuals randomly selected from a sample will belong to different species (Shannon and Weaver 1949). The abundance is the total number recorded of a given species (Gotelli and Colwell 2011).

We calculated species richness and abundance using the statistical software R (version 3.6.1; R Core Team 2019) and computed species diversity using the statistical software PAST (Hammer et al. 2001). We used the Shannon's diversity index to compare diversity between habitats (Clarke et al. 2014). Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5, and are rarely greater than 4.5, where high values indicate high diversity. We used a diversity t-test in the PAST software to test for differences between treatment and combined control site diversity each year.

We also used the R-package 'iNEXT' to compute species rarefaction and extrapolation plots (Hsieh et al. 2016, Chao et al. 2014) that analyzed species richness and Simpson's diversity over time (Simpson 1949), which included all years of data with the control sites combined. We used the Simpson's diversity index for the interpolation and extrapolation plots of species diversity. The Simpson's diversity index differs from Shannon's diversity index because it is influenced by the dominant species in a community based on abundance (Fontana et al. 2011). Simpson's diversity is normally a measure between zero and one, with zero representing no diversity and one representing infinite diversity. This index resists drastic changes to diversity by placing more importance on species evenness. We analyzed species diversity using Hill numbers (Hsieh et al. 2016) in order to effectively report the number of dominant species in the plots.

We examined species composition at TA-39 using non-metric multidimensional scaling (NMDS) to determine dissimilarity among the years when surveys were conducted. This was done to try to explain how changing the transect location from the canyon rim to the canyon bottom affected the data over time at TA-39. We conducted an analysis of similarity (ANOSIM) using 1000 permutations to compare the species composition at TA-39 between survey years. We used the community ecology R-package 'vegan' (Dixon 2003) to complete the NMDS and ANOSIM analyses. NMDS is an ordination technique that condenses highly-dimensional multivariate datasets into a smaller number of dimensions (Dexter et al. 2018). An NMDS plot is usually reduced to two or three dimensions to observe patterns in community data between species composition and other environmental variables. The number of dimensions is used to calculate a measure of 'stress', which is the discrepancy between the rank order of distances in the actual data and the rank order of distances in the ordination. A high stress value (>0.2) indicates that the data is misleading while a low stress value (<0.1) indicates that the ordination is a good representation of the rank order of distances in the multivariate dataset (Dexter et al. 2018). Stress is reduced in an ordination by maintaining the rank order of distances while rearranging the sample points in slightly different positions (Dexter et al. 2018, De Fraga et al. 2014). A lower stress value can be attained by adding more dimensions, but too many dimensions could lead to misinterpretation of the data. We selected an NMDS plot with a low stress value and the minimum number of dimensions to minimize the distortion to the actual dataset. The R-package 'vegan' generated a Shepard diagram to display the stress in the NMDS plot. A Shepard diagram is a type of scatter plot with a fitted regression line that compares the distance between sample points in the actual data and in the ordination (Khan et al. 2020, Clarke 1993).

Field Methods for Nestbox Monitoring

In 2011, LANL biologists added nestboxes to Minie and TA-39 (Figures 1 and 2). In 2015, biologists added nestboxes to TA-16 (Figure 3). We monitored nestboxes every one to two weeks for active nests. When an active nest was found, we monitored it more frequently to determine whether the nest failed or successfully fledged young. We also banded nestlings and determined the sex after the age of 10 days. We compared the data from the nestboxes at the treatment sites to the data from the overall nestbox network at LANL. This year, due to the coronavirus pandemic (SARS-CoV-2) (Zhou et al. 2020) and its impact on personnel working together, we only managed a subset of the overall nestbox network.

Statistical Methods for Nestboxes

We calculated occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. We compared the 2020 data from the three treatment sites with the overall avian nestbox network at LANL which was established in 1997 (Fair and Myers 2002).

RESULTS AND DISCUSSION

Point Count Surveys-Year 2020

LANL biologists completed three surveys at each of the three treatment sites and the associated control sites between May and July 2020. A total of 1,005 birds representing 63 species were recorded at the three treatment sites. A full account of the 2013 – 2020 data is detailed in Appendix 1.

Table 1 details the species richness, diversity, and abundance for 2020 for each treatment and control site.

Table 1. The species richness, diversity, and abundance recorded at all treatment and control sites in 2020

	Minie	*TA-39*	*PJ Control 1*	*PJ Control 2*	*TA-16*	*PIPO Control 1*	*PIPO Control 2*
Richness	33	40	37	32	46	33	40
Diversity	3.134	3.076	2.874	2.862	3.367	2.900	3.176
Abundance	203	413	292	269	389	373	429

Table 2 outlines the species richness over time at the treatment and individual control sites. The three treatment sites were maintaining a steady species richness over time with almost all indicating a slight increase in the number of species in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in richness, diversity, and abundance in 2015 were most likely attributed to the increased precipitation. Links between moisture and habitat quality for migratory birds have been documented (Smith et al. 2010) and may be a causal factor. In addition, the winter of 2015 and into early 2016 was drier. The moisture for the winter of 2018 – 2019 was at or slightly above normal, but the species richness at all sites was similar to the previous year. Temperatures were above average during the summer of 2020 while the winter moisture of 2019 – 2020 was below average (Weather Machine 2020). Species richness at all sites varied during 2020, which may have been influenced by the above average total precipitation Los Alamos received in the middle of March. We predict that the species richness in 2021 will be lower at several sites due to an unusually early and cold storm system that occurred in September 2020. The cold front contributed to a mass mortality event of migratory songbirds across New Mexico (NMDGF 2020), which may influence the data collected for next year's surveys.

Table 2. Changes in species richness over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Minie	33	33	34	30	35	35	34	33
TA-39	31	31	39	38	34	36	38	40
PJ Control 1	29	30	33	36	37	30	30	37
PJ Control 2	30	29	37	33	39	23	33	32

TA-16	39	33	40	44	41	43	39	46
PIPO Control 1	34	34	30	40	46	40	41	33
PIPO Control 2	33	36	43	43	44	39	40	40

Tables 3 – 5 compare the species diversity over time between the treatment site and the combined controls. We combined the two control sites to analyze diversity because we were interested in the relative abundances among species and not the actual numbers. There have been some significant differences at times over the course of this study which are indicated in bold font with a darker shading. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Even though we see significant differences, the bird diversity at all sites is around 3, which compared with ecological systems in general is very high.

Table 3. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Minie	3.141	3.141	3.191	2.968	3.134	3.215	3.063	3.134
PJ Control	2.877	2.990	3.159	3.067	3.241	2.938	2.967	2.975
t-test	**t = -3.2012** **df = 508** **p = 0.001**	t = -1.8716 df = 455 p = 0.062	t = -0.52699 df = 663 p = 0.60	t = 1.291 df = 460 p = 0.20	t =1.4637 df = 498 p = 0.14	**t =-3.907** **df = 588** **p < 0.01**	t =-1.2465 df = 626 p = 0.21	**t = -2.139** **df = 502** **p = 0.033**

Table 4. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
TA-39	3.090	3.073	3.140	3.318	3.178	3.131	3.083	3.076
PJ Control	2.877	2.990	3.159	3.067	3.241	2.938	2.967	2.975

t-test	**t = -2.527** **df = 464** **p = 0.012**	t = -1.0396 df = 477 p = 0.30	t = 0.26785 df = 484 p = 0.79	**t = -3.7477** **df =664** **p <0.01**	t = 0.95934 df = 675 p = 0.34	**t = -2.7474** **df = 699** **p = 0.006**	t = -1.4205 df = 670 p = 0.16	t = -1.4646 df = 942 p = 0.14

Table 5. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
TA-16	3.304	3.207	3.236	3.293	3.238	3.357	3.291	3.367
PIPO Control	3.261	3.225	3.161	3.213	3.296	3.171	3.316	3.184
t-test	t = -0.66864 df = 404 p = 0.50	t = 0.26454 df = 494 p = 0.79	t = -1.2603 df = 689 p = 0.21	t = -1.1396 df = 511 p = 0.25	t = 0.88237 df = 539 p = 0.38	**t = -2.9553** **df = 578** **p = 0.003**	t = 0.44118 df =640 p = 0.66	**t = -3.3172** **df = 824** **p = 0.001**

We analyzed species richness and Simpson's diversity data between 2013 – 2020 using extrapolation curves (Figures 5A – 6B). Species rarefaction and extrapolation show a significant difference between treatment and control sites for species richness (Figure 5A). Figure 5A displays 95% confidence intervals where the TA-39 treatment site and the PJ Controls do not overlap. However, the species rarefaction and extrapolation for the PJ treatment and control sites between 2013 – 2018 did not show any significant differences for species richness (Hathcock et al. 2018). The Minie and TA-16 treatment sites and their associated controls had overlapping 95% confidence intervals for species richness (Figures 5A and 6A). The cause of the difference in species richness may be attributed to a change of transect locations at the TA-39 treatment site in 2016 (Figure 2). The original transect was located on the mesa above the treatment site and was more of a pinyon-juniper woodland while the replacement transect sited in 2016 was along the canyon bottom around the treatment site and contained more ponderosa pine trees. Slight differences in habitat structure have been shown to impact species composition (Seymour and Dean 2010). We looked at these data using an NMDS plot. Figure 7 represents the final configuration of survey years as points in the NMDS plot for TA-39 (dimensions = 2, stress = 0.0225). The Shepard diagram (Figure 8) shows minimal scatter around the regression line between the observed dissimilarity and ordination distance, which indicates that the NMDS plot has low stress (non-metric fit $R^2 = 0.999$, linear fit $R^2 = 0.997$). NMDS ordinations use the rank order of distances to show the dissimilarity between samples (Faith et al. 1987), which means samples in close proximity to one another are similar while samples that are distant from each other are not alike. Figure 7 shows how the species composition at TA-39 was more similar between years that are clustered together on the NMDS plot (Debinski et al. 2006). We separated the years when surveys occurred into early year (2013 – 2015) and later year (2016 – 2020) categories to reflect the change in habitat corresponding to the selection of a new transect location. The different species composition between the left and right and the upper and lower part of the graph (dotted lines = the reference lines) correlate with the associated categories of survey years. The NMDS plot grouped early years on the left and later years on the right (Figure 7). Our NMDS plot only displayed 16 species to improve clarity (Figure 7). These 16 species represent the top ten most commonly observed species for early years and later years (Table 6). Species that appeared in the list for both categories of survey years are in bold. The species that seem to be driving the difference between early and later years are the Juniper Titmouse, Cassin's Kingbird, and the Western Wood-Pewee. Even though the polygons for the early and later years are not closely aligned with one another and do not overlap, the categories of survey years were not statistically different from each other (ANOSIM: R = 0.05917, P = 0.08).

The rarefaction and extrapolation plots for species diversity (Figures 5B and 6B) were significantly different since the 95% confidence intervals did not overlap. In these cases, the treatment sites were higher in diversity than the controls with a higher number of dominant species. These results are similar to the 2013 – 2018 species rarefaction and extrapolation results presented in a previous report (Hathcock et al. 2018). Tables 3 – 5 show there were significant differences of diversity between the Minie and TA-16 treatment sites and their associated control sites in 2020. Since the extrapolation curves are not expected to change much between years, these will be reanalyzed every five years after this report.

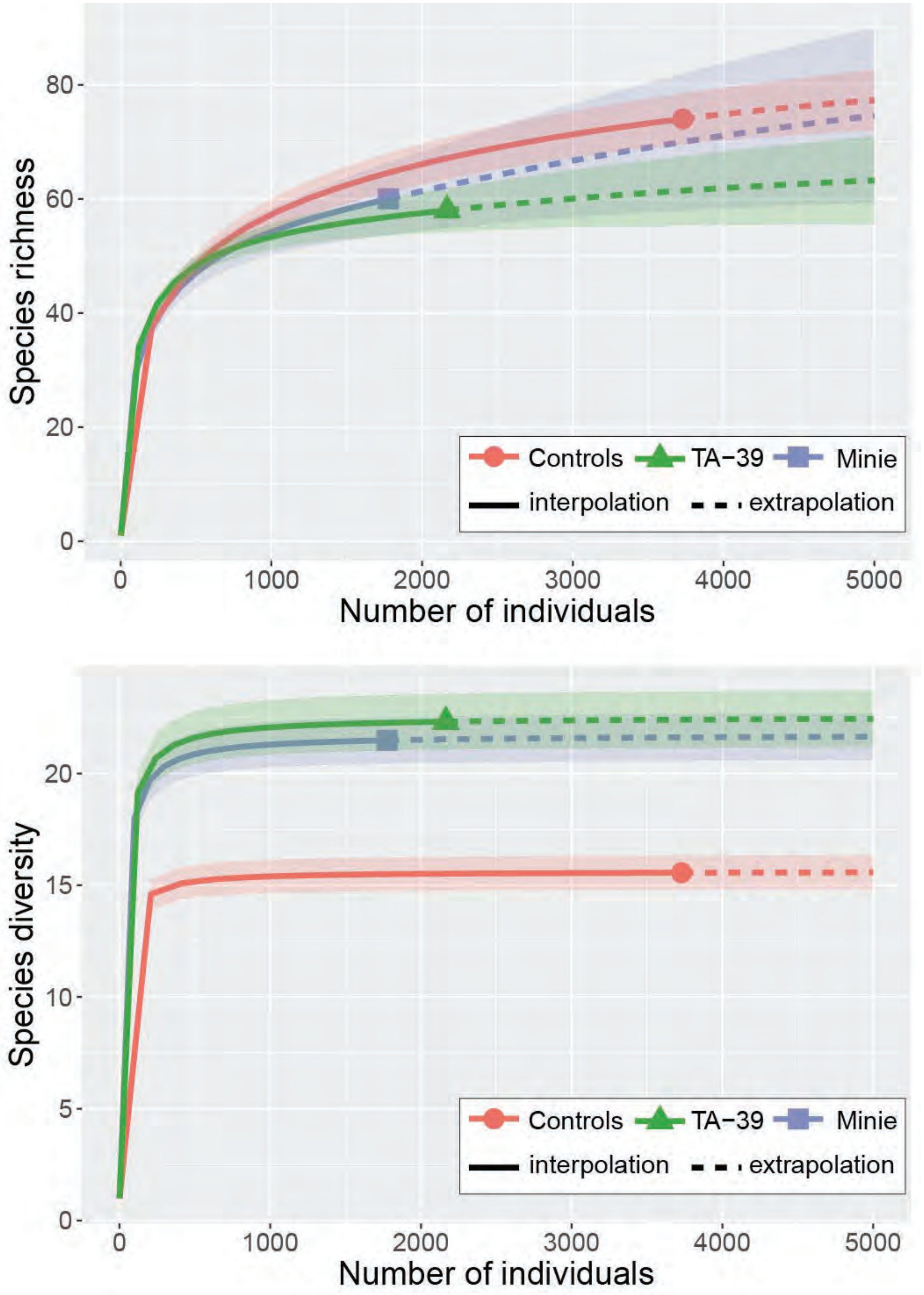
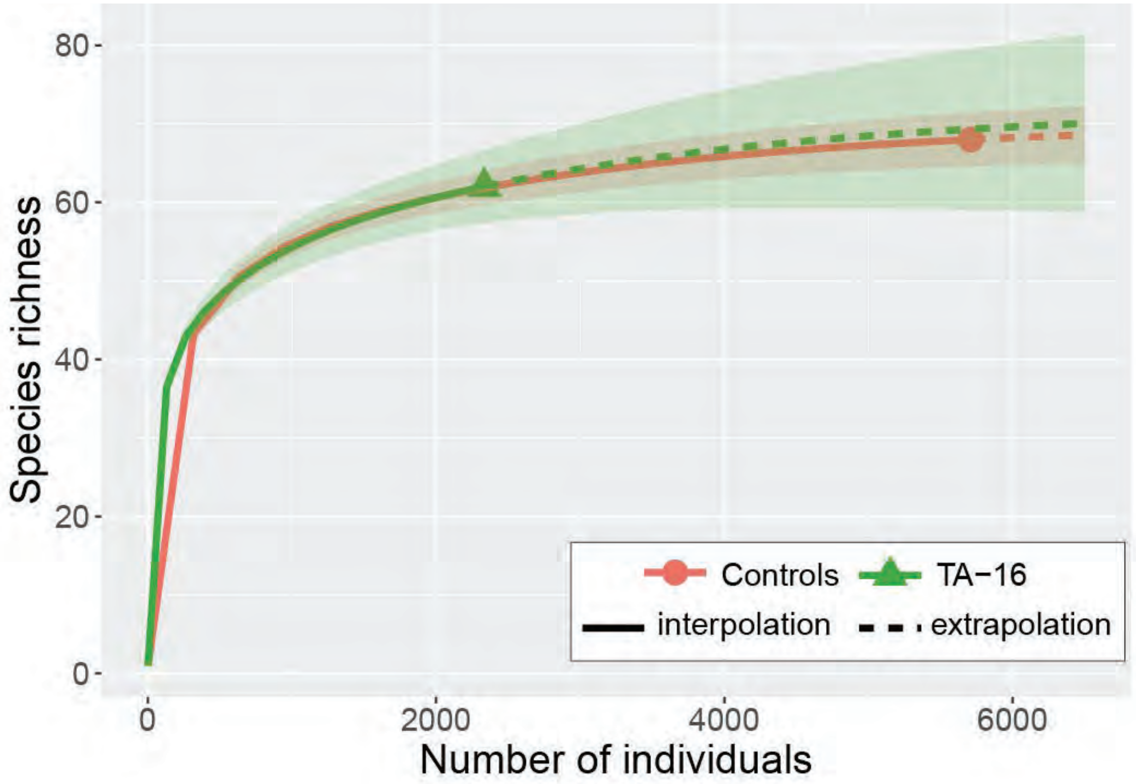


Figure 5. 2013 – 2020 Species rarefaction and extrapolation for species richness and diversity comparing Minie and TA-39 with the PJ controls. Top is "A" and bottom is "B".



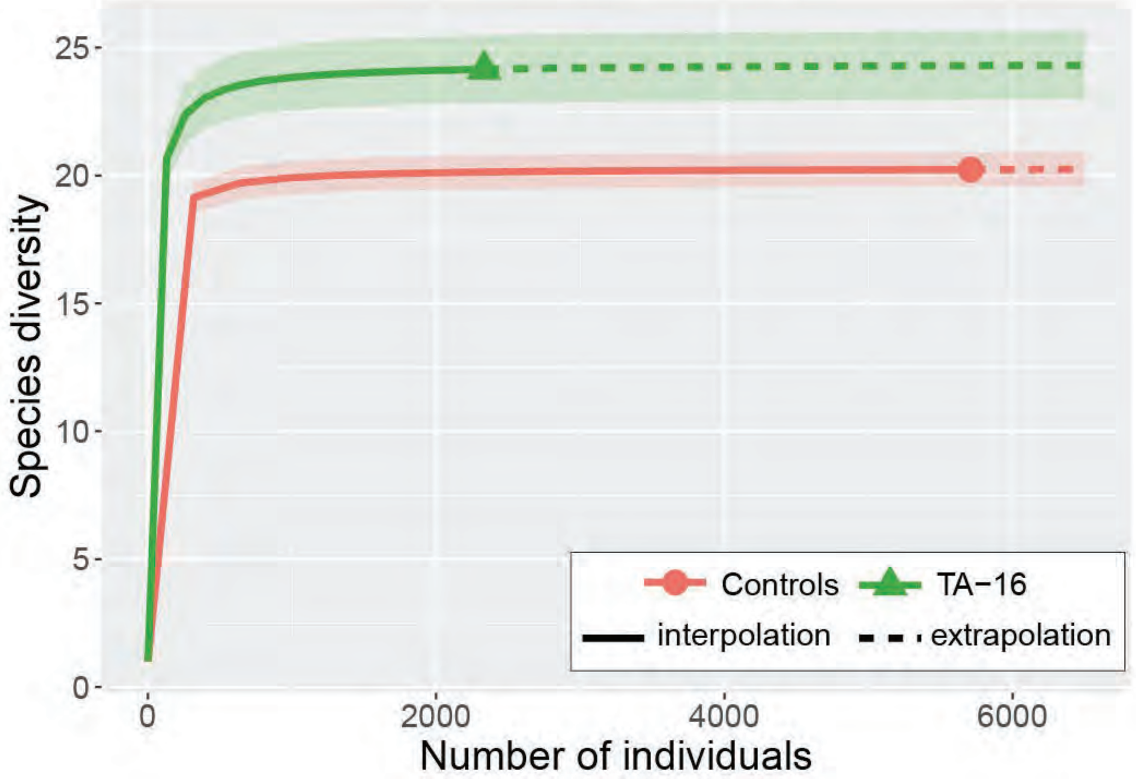


Figure 6. 2013 – 2020 Species rarefaction and extrapolation for species richness and diversity comparing TA-16 with the PIPO controls. Top is "A" and bottom is "B".

Table 6. Top 10 most common species of birds observed at TA-39 during Early Years (2013 – 2015) and Later Years (2016 – 2020)

Early Years		***Later Years***	
Species	*Abundance*	*Species*	*Abundance*
Ash-throated Flycatcher	60	**House Finch**	186
Spotted Towhee	51	Cassin's Kingbird	160
House Finch	48	Chipping Sparrow	99
Mourning Dove	45	**Lesser Goldfinch**	85
Juniper Titmouse	42	**Spotted Towhee**	79
Western Bluebird	36	Violet-green Swallow	77
Gray Flycatcher	31	Rock Wren	72
Bewick's Wren	28	**Western Bluebird**	64
Lesser Goldfinch	25	Western Wood-Pewee	59
Woodhouse's Scrub-Jay	22	White-winged Dove	53

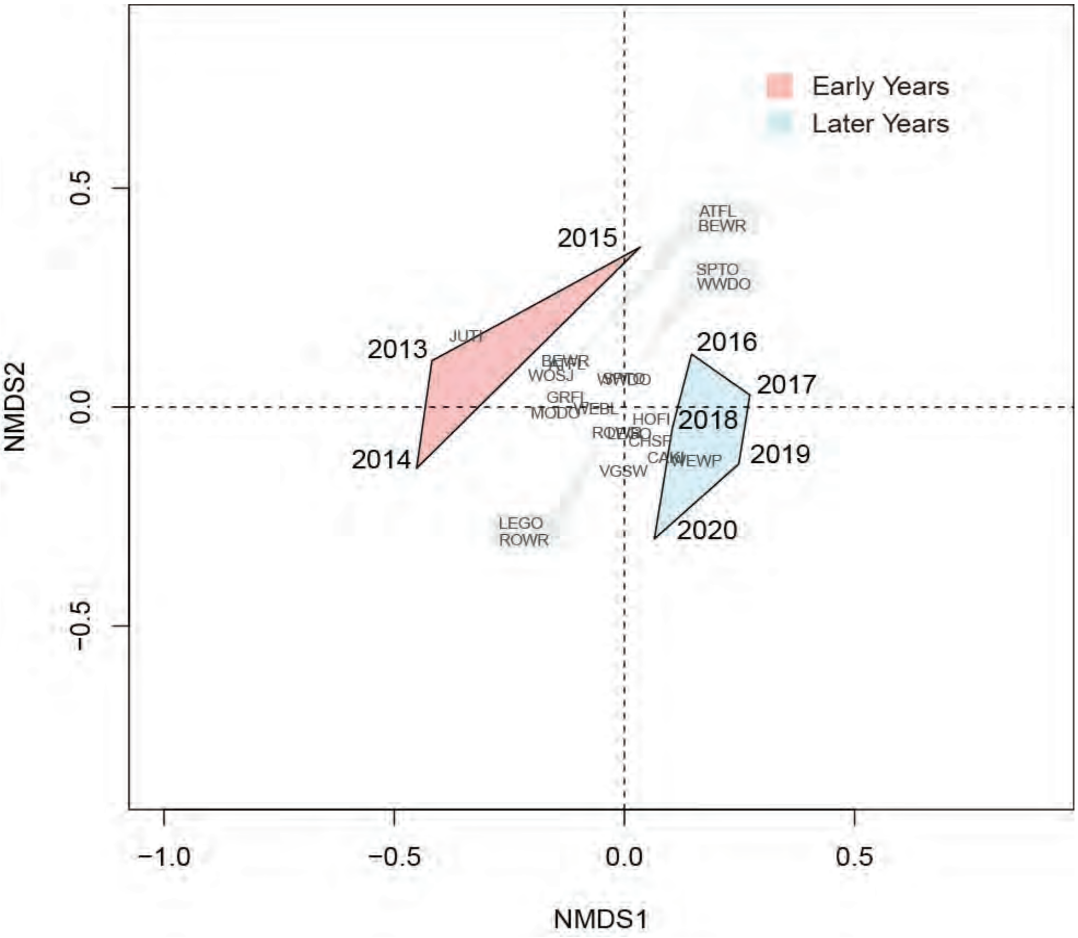


Figure 7. Non-metric multidimensional scaling (NMDS) of bird species and years at the TA-39 treatment site

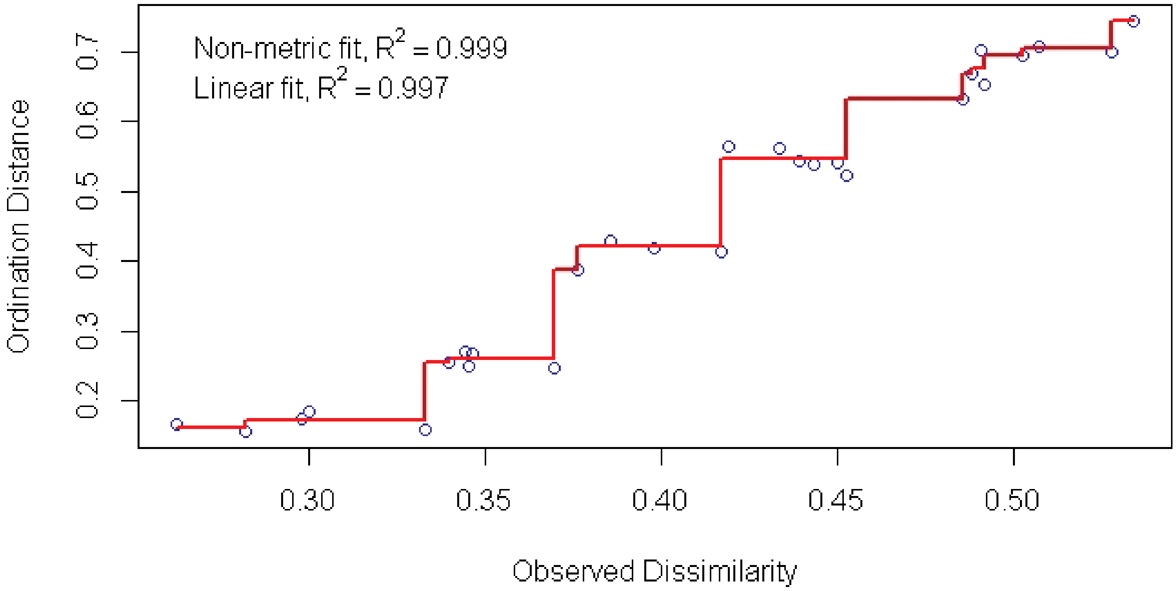


Figure 8. Shepard diagram of NMDS ordination for the TA-39 treatment site

The overall abundance of birds is trending the same for all treatment sites compared with the controls. At TA-16, the overall abundance is lower when compared with the PIPO 1 and PIPO 2 control sites. Table 7 compares the abundance between the treatment and control sites over time. Similar to the species richness trends, there was an increase in abundance in 2015. The fluctuations in bird abundances were not alarming, and the differences between the treatment sites and control sites were not biologically significant. The moisture for the winter of 2018 – 2019 was at or slightly above normal, but the species abundance at all sites were similar to previous years. The abundance increased in 2020, except at Minie, despite below average moisture for the winter of 2019 – 2020.

Table 7. Changes in species abundance over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Minie	193	186	275	210	222	242	245	203
TA-39	177	193	260	249	261	315	298	413
PJ Control 1	187	157	269	312	240	235	226	292
PJ Control 2	181	177	301	228	300	168	187	269
TA-16	220	209	347	271	302	285	310	389

PIPO Control 1	258	223	432	323	447	374	364	373
PIPO Control 2	256	254	371	396	449	366	394	429

Nestboxes

During the 2020 nesting season, LANL biologists actively monitored 15 nestboxes at each treatment site. We monitored 157 nestboxes throughout the overall avian nestbox network, without the three treatment sites. Of those, 117 contained active nests and 69 of those nests fledged young successfully. This was an overall occupancy rate of 58% with a 59% success rate.

Tables 7 and 8 compare the occupancy and nest success rates for each treatment site and the overall nestbox network since 2015.

Table 8. Comparison of occupancy for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*
Overall Network	40%	45%	48%	53%	44%	58%
Minie	66%	73%	46%	20%	60%	47%
TA-39	8%	58%	20%	33%	13%	27%
TA-16	-	73%	100%	53%	87%	87%

Table 9. Comparison of nest success for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*
Overall Network	66%	69%	57%	49%	51%	59%
Minie	64%	23%	29%	33%	44%	86%
TA-39	100%	57%	0%	40%	0%	75%
TA-16	-	63%	76%	63%	54%	54%

In 2020, there were six successful nests that fledged young at Minie, three at TA-39, and seven at TA-16. Occupancy at TA-39 was low in comparison to the other treatment sites and the overall network. The nest success rate at TA-39 seemed to fluctuate in 2020 since the occupied nestboxes had a higher success rate compared to previous years. TA-39 is the lowest elevation treatment site and occupancy has been decreasing over time at this site and surrounding areas of the avian nestbox network. Wysner et al. (2019) found that Western Bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. Western Bluebirds have the highest occupancy rates throughout the nestbox network, and the shift in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the other two treatment sites seem to be fluctuating naturally in comparison to the overall network and have not displayed a decreasing trend over time.

In 2020, LANL biologists submitted nonviable eggs collected from nestboxes at the treatment sites and the rest of the nestbox network to an analytical lab for chemical analyses. These data will be presented in a separate report.

MANAGEMENT RECOMMENDATIONS

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 63 species detected at the three treatment sites, the Migratory Bird Treaty Act protects all but one species. The Eurasian Collared-Dove is not native and therefore not protected under the Migratory Bird Treaty Act. In addition, LANL biologists have documented sensitive species from the Sensitive Species Best Management Practices Source Document (Berryhill et al. 2020) and the Birds of Management Concern and Focal Species list (USFWS 2011) at the treatment sites. Those species are the Juniper Titmouse, Grace’s Warbler, Virginia’s Warbler, Black-throated Gray Warbler, and the Mourning Dove. Sensitive species documented at the control sites are the Cassin’s Finch and the Gray Vireo. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901).

Continuing the research reported herein will provide a long-term dataset for the ecological health of avifauna at the three treatment sites at LANL. In addition, this research contributes to meeting the Department of Energy’s commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and it allows LANL to contribute to national goals in avian conservation monitoring and research.

ACKNOWLEDGMENTS

Thanks to the following individuals for technical and field support work in 2020: Andrew Bartlow, Jesse Berryhill, Chuck Hathcock, Audrey Sanchez, Jenna Stanek, Brent Thompson, Luciana Vigil-Holterman, and former staff and interns that helped in previous years.

LITERATURE CITED

Berryhill, J.T., J.E. Stanek, E.J. Abeyta, and C.D. Hathcock. 2020. Sensitive Species Best Management Practices Source Document, Revision 5. Los Alamos National Laboratory report number LA-UR-20-24514, Los Alamos, New Mexico.

Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Polluck. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79(3):1018–1028.

Chao, A., N.J. Gotelli, T.C. Hsieh, E.L. Sander, K.H. Ma, R.K. Colwell, and A.M. Ellison. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84:45–67.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18(1):117–143.

Clarke, K.R., R.N. Gorley, P.J. Somerfield, and R. Warwick. 2014. Change in marine communities; an approach to statistical analysis and interpretation, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262pp.

De Fraga, R., A.J. Stow, W.E. Magnusson, and A.P. Lima. 2014. The costs of evaluating species densities and composition of snakes to assess development impacts in Amazonia. PLoS One 9(8):e105453. https://doi.org/10.1371/journal.pone.0105453.

Debinski, D.M., R.E. VanNimwegen, and M.E. Jakubauskas. 2006. Quantifying relationships between bird and butterfly community shifts and environmental change. Ecological Applications 16(1):380–393.

Dexter, E., G. Rollwagen-Bollens, and S.M. Bollens. 2018. The trouble with stress: A flexible method for the evaluation of nonmetric multidimensional scaling. Limnology and Oceanography: Methods 16(7):434–443.

Dixon, P. 2003. VEGAN, a package of R functions for community ecology. Journal of Vegetation Science 14(6):927–930.

Fair, J.M., and O.B. Myers. 2002 Early reproductive success of western bluebirds and ash-throated flycatchers: a landscape-contaminant perspective. Environmental Pollution 118:321–330.

Faith, D.P., P.R. Minchin, and L. Belbin. 1987. Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 69(1):57–68.

Fontana, S., T. Sattler, F. Bontadina, and M. Moretti. 2011. How to manage the urban green to improve bird diversity and community structure. Landscape and Urban Planning 101(3):278–285.

Gotelli, N.J. and R.K. Colwell. 2011. Estimating species richness. Biological diversity: Frontiers in Measurement and Assessment 12:39–54.

Hammer, Ø., D.A.T. Harper, and P.D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1):1–9.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. Los Alamos National Laboratory report number LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. Los Alamos National Laboratory report number LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill. 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-18-22897, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow, A.A. Sanchez, J. Stanek, and B.E. Thompson. 2019. 2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-19-24156, Los Alamos, New Mexico.

Hsieh, T.C., K.H. Ma, and A. Chao. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution 7(12):1451–1456.

Khan, A., M. Ahmed, M.F. Siddiqi, M. Shah, E.S. Calixto, A. Khan, P. Shah, J. Iqbal, and M. Azeem. 2020. Vegetation-environment relationship in conifer dominating forests of the mountainous range of Indus Kohistan in northern Pakistan. Journal of Mountain Science 17(8):1989–2000.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. Los Alamos National Laboratory report number LA-14029, Los Alamos, New Mexico.

New Mexico Department of Game and Fish (NMDGF). 2020. Starvation, unexpected weather to blame in mass migratory songbird mortality. http://www.wildlife.state.nm.us/starvation-unexpected-weather-to-blame-in-mass-migratory-songbird-mortality/. Accessed February 2021.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Sanchez, A.A., C.D. Hathcock, and B.E. Thompson. 2020. 2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-20-20436, Los Alamos, New Mexico.

Seymour, C.L. and W.R.J. Dean. 2010. The influence of changes in habitat structure on the species composition of bird assemblages in the southern Kalahari. Austral Ecology 35(5):581–592.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, USA. 127pp.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874–2882.

Tramer, E.J. 1969. Bird species diversity: components of Shannon’s formula. Ecology 50(5):927–929.

U.S. Fish and Wildlife Service (USFWS). 2011. Birds of management concern and focal species. United States Department of Interior, Fish and Wildlife Service, Migratory Bird Program, Arlington, Virginia. 15 pp.

Weather Machine. 2015. Weather Machine Climatological Monthly Summary, September 2015, http://weather.lanl.gov/climo_monthly_summary.asp.

Weather Machine. 2020. Weather Machine Climatological Monthly Summary, December 2020, https://weathermachine.lanl.gov/climo_monthly_summary.asp.

Wysner, T.E., A.W. Bartlow, C.D. Hathcock, and J.M. Fair. 2019. Long-tern phenology of two North American secondary cavity-nesters in response to changing climate conditions. The Science of Nature 106:54. doi:10.1007/s00114-019-1650-9.

Zhou, P., Yang, XL., Wang, XG., Hu, B., Zhang, L., Zhang, W., Si, HR., Zhu, Y., Li, B., Huang, CL., Chen, HD., Chen, J., Luo, Y., Guo, H., Jiang, RD., Liu, MQ., Chen, Y., Shen, XR., Wang, X., Zheng, XS., Zhao, K., Chen, QJ., Deng, F., Liu, LL., Yan, B., Zhan, FX., Wang, YY., Xiao, GF., and ZL. Shi. 2020. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 579 (7798):270–273. doi:10.1038/s41586-020-2012-7.

APPENDIX 1. ALL BIRDS RECORDED AT THE THREE TREATMENT SITES FROM 2013–2020

	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020
Species	TA-36 Minie Site								TA-39 Point 6								TA-16 Burn Grounds							
	Pinyon-Juniper Woodland								Pinyon-Juniper Woodland								Ponderosa Pine Forest							
Acorn Woodpecker																	5		3	2	3	5	3	5
American Crow																					1	1		1
American Kestrel				1				1	1			2												
American Robin	1	1	2		2				1	1		2		4	2		7		9	4	4	6	12	6
Ash-throated Flycatcher	11	5	14	13	13	10	17	12	19	11	30	12	8	8	6	11	3	5	6	2	3	8	4	6
Audubon's Warbler		2				5						2				5	6	5	1	6		1	11	14
Bewick's Wren	4	8	9	9	14	14	5	10	3	10	15	9	2	8	1	2								
Black-chinned Hummingbird		1	1				1	2	3	2				1	2	3	1		1		1		1	12
Black-headed Grosbeak	1	3				1	1	2		2	4	1		3	2	1			1	2		2		1
Black-throated Gray Warbler			1		2			2	5	6	4													
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	11	2		7	5	4	2	13	5		6	2	1	3	6	4	9
Broad-tailed Hummingbird	2	1	3		1		3	2	3	1	2		3	1	2	9	5	11	11	5	7	10	8	
Brown Creeper																	1							
Brown-headed Cowbird	1										2			3	2	10	4	1			4	2	8	4
Bushtit		2		2		11			2	14			1	12		2								
Canada Goose											16				2									
Canyon Towhee	2		5	3	6	2	3	5	1	1	2	10	13	19	6	3	1			1		1		
Canyon Wren					1						2	3	8	6	2	4			2					
Cassin's Finch						4																		
Cassin's Kingbird	6	13	13	5	2	5	6	5	7	6	2	21	21	32	37	49				1				2
Chipping Sparrow	3	16	17	29	6	22	10	10	6	6	5	8	15	25	27	24	1	5	3	10	5	21	8	32
Clark's Nutcracker																		4		1				
Common Nighthawk	6		5	2	4	4	1	5	5	1	3	2	7	5	7	3			1	2	2			1
Common Raven	2	5	1		1	2	3		1		2	1		1	2	5	5	6	2	2	5	5	7	4
Cooper's Hawk					1												1			1			1	
Cordilleran Flycatcher																	5	10	6	3	3	1	2	4
Dark-eyed Junco														1	1		6	2	4		5	2		2
Downy Woodpecker				1								1	2		1	2		1		1	1	1		
Dusky Flycatcher				1							1		1											2
Eurasian Collared-Dove	3												4			2						1		
Evening Grosbeak	3		4								8						5		29			1		
Grace's Warbler							1							2	4	1	6	4	4	8	5	8	22	12

	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020
Species	TA-36 Minie Site								TA-39 Point 6								TA-16 Burn Grounds							
	Pinyon-Juniper Woodland								Pinyon-Juniper Woodland								Ponderosa Pine Forest							
Gray Flycatcher	12	6	5	7	3	6	3	2	10	10	11	10	5	8	3	14								
Great Horned Owl		3							1															
Green-tailed Towhee	3	1							1															1
Hairy Woodpecker			2	1		1		1			5	3			1	1	1	1		1	1	2	1	1
Hammond's Flycatcher																	8	9	12	5	7	5	10	5
Hepatic Tanager											1	2	1	2						1				
Hermit Thrush						1												4	6	1	2	2	5	5
House Finch	16	17	26	17	12	18	17	11	21	4	23	9	30	44	50	53	16	2	5	5	12	7	12	18
House Wren															1		1	1		2	2	6	8	2
Juniper Titmouse	12		7	6	9	3	26	8	11	13	18	6	1			3								
Lesser Goldfinch	2	6	7	4	9	12	8	4	4	12	9	10	14	19	15	27	3		8	9	4	8	5	6
MacGillivray's Warbler																				1	3			1
Mountain Bluebird		2	20	10	11	1	9	3		4						2			4	4	4	7	4	5
Mountain Chickadee	5	2	1	2								1	1		1		5	8	9	6	8	9	1	4
Mourning Dove	17	17	13	5	8	8	11	9	13	22	10	3	15	11	8	10	4		1	3	17	3	5	17
Northern Mockingbird					2		1	4		1														
Northern Rough-winged Swallow						3																		
Orange-crowned Warbler																								1
Peregrine Falcon											1													
Pine Siskin	10	2		5	1			1	6		3	3					12	4	5		4	2		6
Plumbeous Vireo	10	10	7	3	9	9	15	3	1		1	6	6	5	5	12	11	16	15	14	11	18	16	24
Pygmy Nuthatch				2		2	3				2	4	12	9	11	10	11	13	26	29	41	20	16	23
Red Crossbill					1					2						1		2	9	13	9		6	26
Red-shafted Flicker	3	1	3	2	5	2	1		3	2	4	8		3	2	2	3	4	11	11	5	5	2	7
Red-tailed Hawk							1	2			1	1	1	1										
Rock Wren	3	3	4		2	10	11	10	7	10	4	12	14	14	12	20	1	2	2	6			4	1
Ruby-crowned Kinglet																						2		
Savannah Sparrow																								1
Say's Phoebe	2	1	2		2	5	1	1	2	1		5	2	4		6	1		1	3	3	4	1	1
Scaled Quail			1																					
Spotted Towhee	17	8	19	27	32	24	19	20	12	6	33	16	12	16	15	20	11	18	16	14	21	22	34	24
Steller's Jay							1										3	2	5	6	3	4	4	2
Townsend's Solitaire	1																				1			
Turkey Vulture					1			2								1	1					1		
Vesper Sparrow																							1	
Violet-green Swallow		5	7	1	3	2	1	6	6	4	1	9	6	6	9	47		2	19	2	2	4	2	7

	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020	2013	2014	2015	2016	2017	2018	2019	2020
Species	TA-36 Minie Site								TA-39 Point 6								TA-16 Burn Grounds							
	Pinyon-Juniper Woodland								Pinyon-Juniper Woodland								Ponderosa Pine Forest							
Virginia's Warbler					1	3	1				1	2	4		5		17	11	21	13	7	5	5	8
Warbling Vireo						2											2	9	7	6	5	4	6	3
Western Bluebird	15	11	18	17	16	19	21	23	5	19	12	21	13	6	7	17	20	20	49	37	32	27	20	27
Western Tanager		2	3		1					2	1	1	2	2	6	1	2	3	7	2	4	6	16	10
Western Wood-Pewee	10	8	18	11	10	7	18	14		4	2	10	8	11	12	18	15	10	16	14	22	20	24	28
White-breasted Nuthatch	1	4	9	10	13	5	2	1			2	4	4	2	6	3	9	8	7	9	20	10	10	8
White-throated Swift										1						2								
White-winged Dove	1	5	9	2		3	2	1	7	5	6	16	15	15	5	2			1	2			1	
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	10	8	10	4	8	6	4	5		1							

38. Sanchez, A.A., C.D. Hathcock, and B.E. Thompson, February 2020. *2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at the Los Alamos National Laboratory*. LA-UR-20-20436. OSTI Identifier 1597317. (Sanchez *et al*. 2020)

LA-UR-20-20436

Title: 2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at the Los Alamos National Laboratory

Author(s):
Sanchez, Audrey Anna
Hathcock, Charles Dean
Thompson, Brent Eugene

Intended for:
Report
Environmental Regulatory Document

Issued: 2020-02-03 (rev.1)

LA-UR-20-20436

January 2020

2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by: Charles D. Hathcock, Audrey, A. Sanchez, and Brent E. Thompson

Environmental Protection and Compliance Division
Environmental Stewardship Group
Los Alamos National Laboratory

An Affirmative Action/Equal Opportunity Employer

Contents

Figures

Tables

Executive Summary

Los Alamos National Laboratory biologists in the Environmental Compliance and Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. Monitoring results from these efforts were compared among years to monitor trends. The objectives of this study were to 1) determine whether LANL operations impact bird species richness, diversity, or abundance 2) evaluate trends in species abundance by feeding guild, and 3) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. LANL biologists completed the seventh year of this effort in 2019.

Three bird point count surveys were completed at each of the treatment sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground between May and July 2019. A total of 853 birds representing 53 species were recorded at the three treatment sites and compared to their associated controls. Occupancy and nest success data from nestboxes at treatment sites were compared with the overall avian nestbox monitoring network.

In 2019 the species richness and diversity at the treatment sites were not statistically different from their associated controls. Rarefaction and extrapolation plots for all years through 2018 suggest that over time the species diversity was statistically different between treatments and controls, although the diversity was higher at the treatment sites than the control sites. Avian abundance showed more variability but treatment and controls were trending together year to year. The mean number of granivores, insectivores, and omnivores varies from year to year, but there is not a significant trend at any of the treatment sites. The dominant feeding guild at the treatment sites continues to be insectivores.

The overall results from 2019 continue to indicate that operations at the three treatment sites are not negatively affecting bird populations. This long-term monitoring will continue to monitor for any changes over time.

This page intentionally left blank.

Introduction

As part of the Resource Conservation and Recovery Act (RCRA) permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites, Technical Area (TA)-36 Minie site and TA-39 point 6, and one open burn site, TA-16 burn ground (hereafter referred to as Minie, TA-39, and TA-16, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017, 2018). This program supported a study with the objectives to (1) determine whether LANL operations impact bird species richness, diversity, or abundance (2) evaluate species abundance by feeding guilds over time and (3) examine nest success of secondary-cavity nesting birds using nestboxes. Comparisons were made with control sites of similar habitat that have been surveyed since 2011 (Hathcock et al. 2011).

Biologists at LANL used standard point count methodology to record avian richness, diversity, and abundance along transects at the three treatment sites and associated control sites during the summer of 2019. Summer surveys provide information about what birds are breeding at each site. These surveys are most valuable when they are conducted over multiple years since they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

In addition to avian point counts, nestboxes were monitored around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success data were compared with the overall avian nestbox monitoring network, which was established in 1997.

Methods

Field Methods for Point Count Surveys

The point count surveys were conducted along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon (*Pinus edulis*) –juniper (*Juniperus monosperma*) woodland (PJ) for Minie (Figure 1) and TA-39 (Figure 2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 3). These habitat descriptions were based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (Figure 4) were monitored annually in ongoing surveys that have been conducted at LANL since 2011 as described in Hathcock et al. (2011). Each habitat type control contained two replicate transects that were monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects were randomized and surveyed according to the random order.

The treatment sites at Minie and TA-39 were similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was in an undeveloped area.

Transects were approximately 2.0 to 2.5 km in length with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The time frame for breeding bird surveys was May 1 through August 15. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for 5 minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an “unlimited-distance circular plot”; however, the distance to each bird out to 100 m should be recorded. A range finder should be used if available. Avoid re-counting individuals between points.
- While walking between points, any obvious species not recorded at the previous point that also wouldn’t be counted at the next point should be recorded. The surveyor should not spend excess time looking for birds between points.
- Do not conduct surveys during rain events or winds greater than 24 kph.
- Use the “NOTES” section to indicate any additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Other wildlife or unusual sightings that could be used for other projects should be recorded.

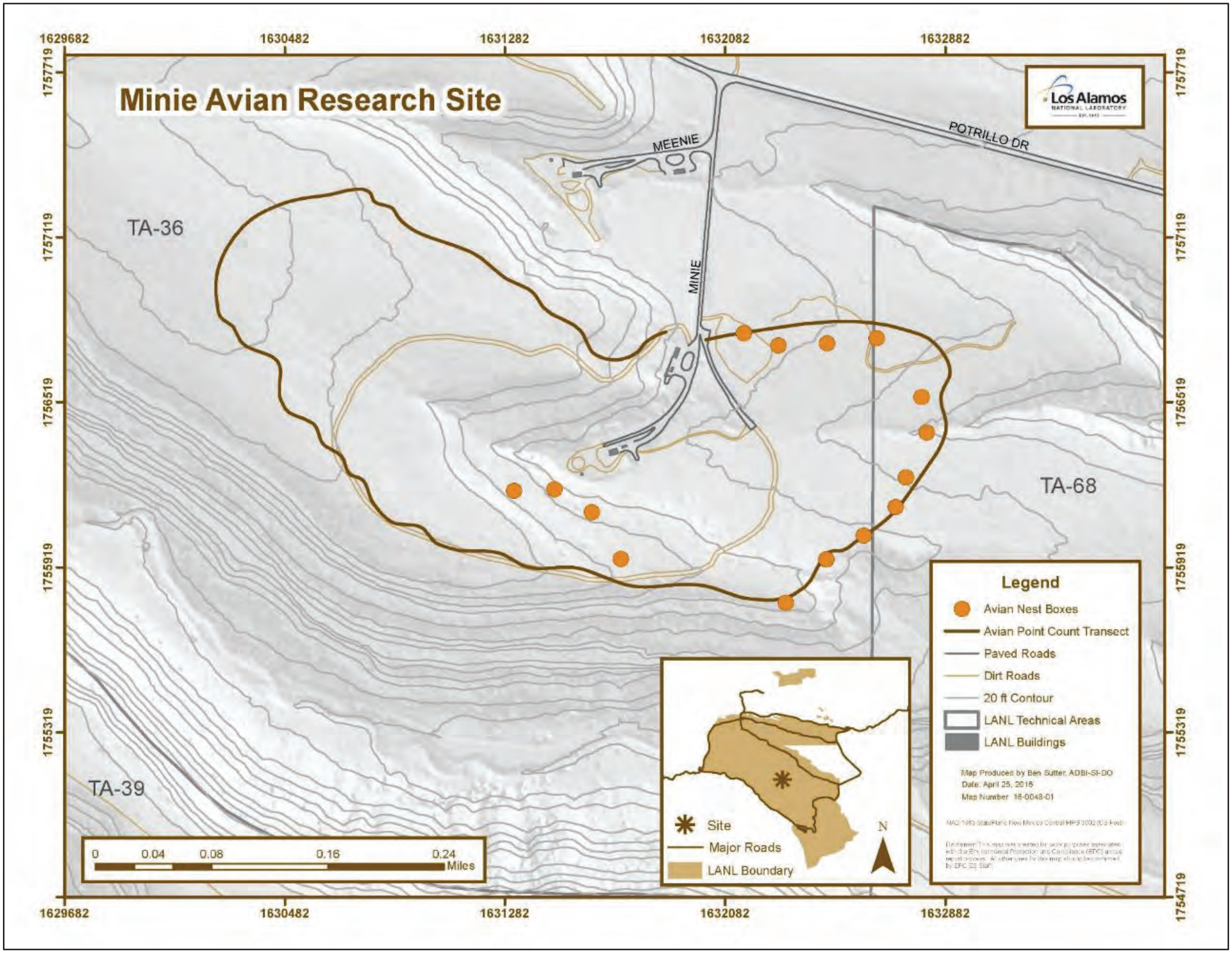


Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie site

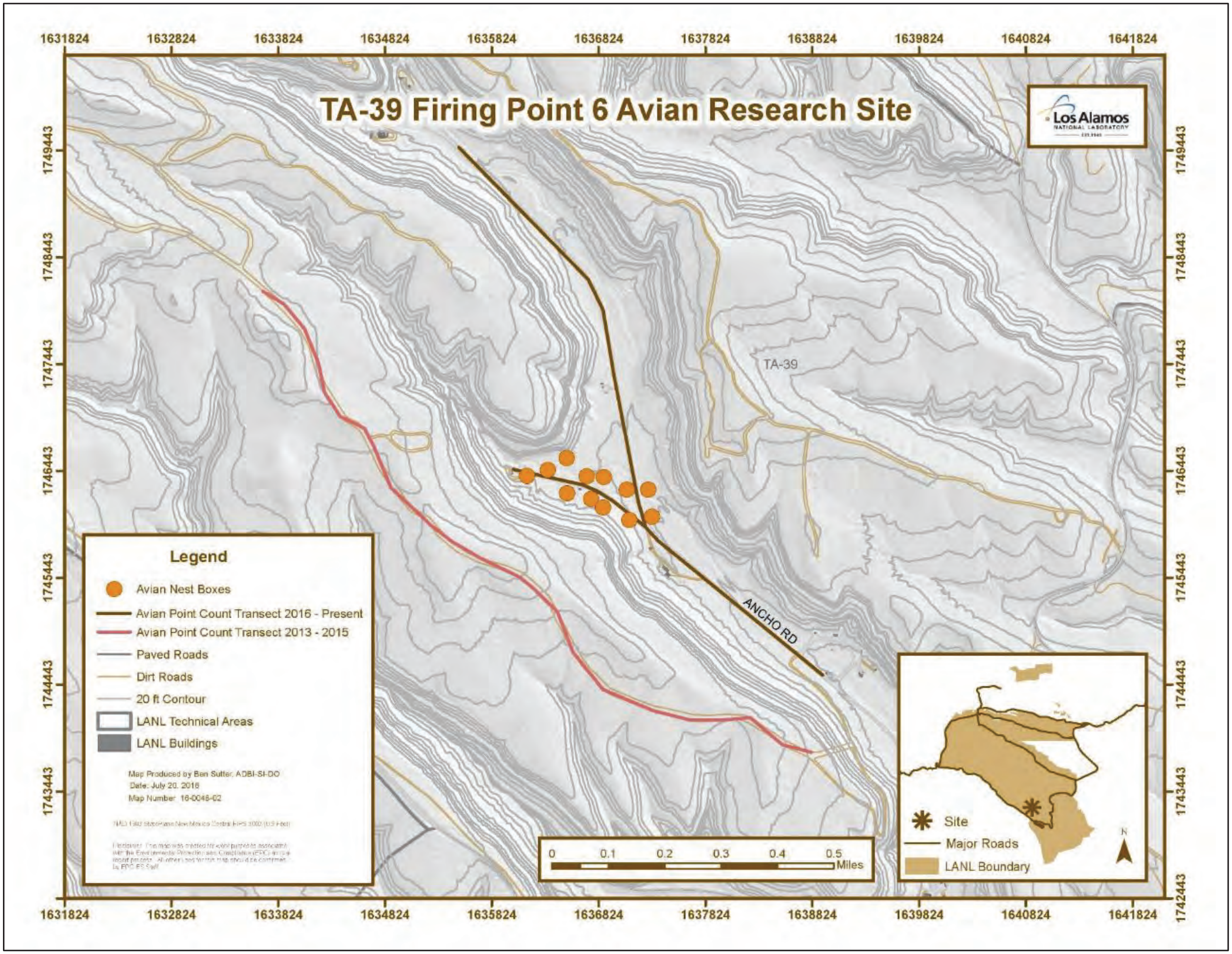


Figure 2. Breeding bird survey transect and nestbox locations around TA-39 point 6

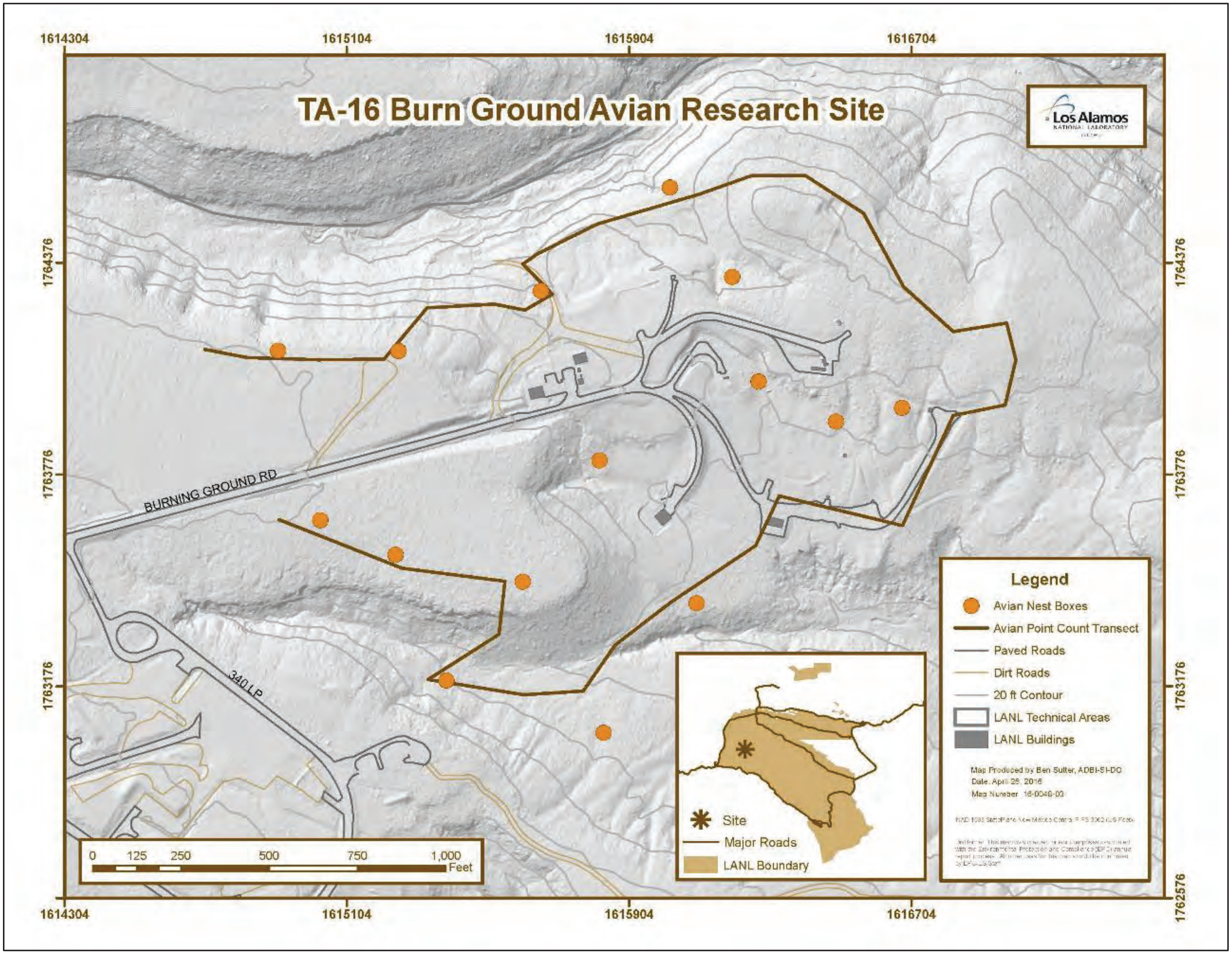


Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 burn ground

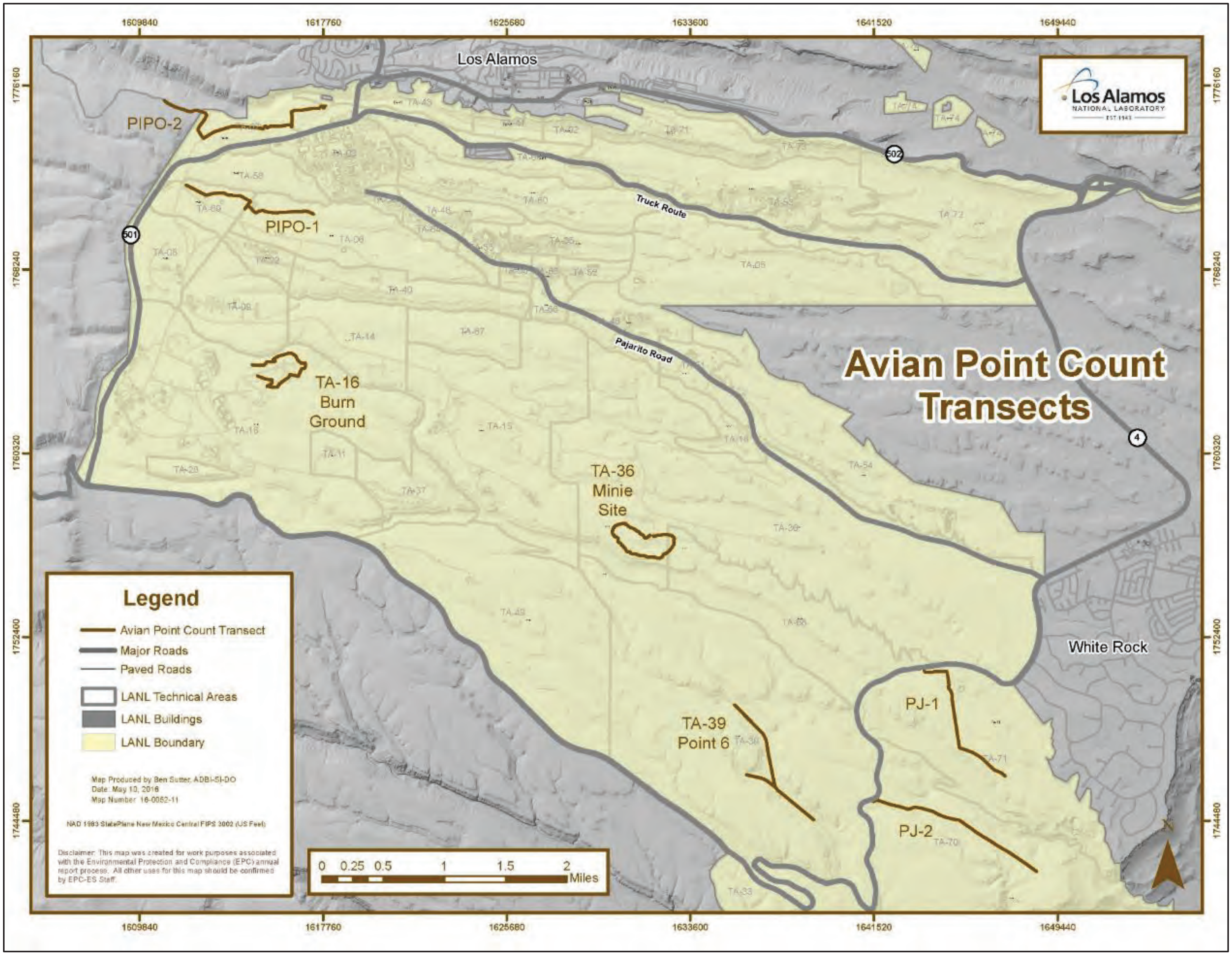


Figure 4. All avian point count transects around LANL

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Statistical Methods for Point Counts

These data were summarized to compare species richness, diversity, and abundance between treatment and control sites and over time. Species richness and abundance were calculated in Microsoft Excel©, and species diversity was computed using the statistical software PAST (Hammer et al. 2001). The Shannon's diversity index (Shannon and Weaver 1949) was used to compare diversity between habitats (Clarke et al. 2014). Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5, and are rarely greater than 4.5, where high values indicate high diversity. A t-test was used to test for differences between treatment and control site diversity each year.

In addition, these data were summarized to compare species of three feeding guilds at each transect over time. The three feeding guilds included granivores, insectivores, and omnivores. Since there are three surveys completed at each transect per year, these data at each transect were averaged and compared over time.

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to Minie and TA-39 (Figures 1 and 2). In 2015, nestboxes were added to TA-16 (Figure 3). Nestboxes were monitored every one to two weeks for active nests. When an active nest was found, it was monitored more frequently to determine whether the nest failed or successfully fledged young. Nestlings were also banded and the sex was determined after the age of 10 days.

Statistical Methods for Nestboxes

Occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network were calculated. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. Annually, data from the three treatment sites were compared with the overall avian nestbox network at LANL which was established in 1997.

Results and Discussion

Point Count Surveys-Year 2019

Three surveys were completed at each of the three treatment sites and the associated control sites between May and July 2019. A total of 853 birds representing 53 species were recorded at the three treatment sites. A full account of the 2013–2019 data is detailed in Appendix 1.

Species richness is the number of different species represented in an ecological community and is simply a count of species. In this case, each treatment site and control are individual communities. Species diversity is a measure that takes into account the species richness and the overall abundance to compare evenness across a community. Here we used the Shannon's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species. The abundance is the total number recorded of a given species. Tables 1 and 2 detail the species richness, diversity, and abundance for 2019 for each treatment and control site.

Table 1. The species richness, diversity, and abundance recorded at all treatment and control sites in 2019

	Minie	*TA-39*	*PJ Control 1*	*PJ Control 2*	*TA-16*	*PIPO Control 1*	*PIPO Control 2*
Richness	34	38	30	33	39	41	41
Diversity	3.063	3.083	2.755	2.901	3.291	3.127	3.292
Abundance	245	298	226	187	310	364	394

Table 2 outlines the species richness over time at the treatment and individual control sites. The three treatment sites were maintaining a steady species richness over time with almost all indicating a slight increase in the number of species in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in richness, diversity, and abundance in 2015 were most likely attributed to the increased precipitation. Links between moisture and habitat quality for migratory birds have been documented (Smith et al. 2010) and may be a causal factor. In addition, the winter of 2015 and into early 2016 was drier. The moisture for the winter of 2018–2019 was at or slightly above normal, but the species richness at all sites was similar to the previous year.

Table 2. Changes in species richness over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Minie	33	33	34	30	35	35	34
TA-39	31	31	39	38	34	39	38
PJ Control 1	29	30	33	36	37	30	30
PJ Control 2	30	29	37	33	39	23	33
TA-16	33	33	40	44	41	43	39

PIPO Control 1	34	34	30	41	41	37	41
PIPO Control 2	33	36	43	43	44	40	41

Tables 3–5 compare the species diversity over time between the treatment site and the combined control. The two control sites were combined to analyze diversity because we were interested in the relative abundances among species and not the actual numbers. There have been some significant differences at times over the course of this study. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Even though we see significant differences, the bird diversity at all sites is around 3, which compared with ecological systems in general is very high.

Table 3. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Minie	3.141	3.141	3.161	2.968	3.134	3.220	3.060
PJ Control	2.895	2.990	3.159	3.075	3.241	2.940	2.970
t-test	**t = -3.2012** **df = 508** **p = 0.001**	t = -1.8716 df = 455 p = 0.06	t = -0.5269 df = 663 p = 0.60	t = 1.291 df = 460 p = 0.20	t =1.4637 df = 498 p = 0.14	**t =-3.907** **df = 588** **p < 0.01**	t =-1.2465 df = 626 p = 0.21

Table 4. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
TA-39	3.090	3.073	3.143	3.318	3.178	3.130	3.080
PJ Control	2.895	2.990	3.159	3.075	3.241	2.940	2.970
t-test	**t = -2.527** **df = 464** **p = 0.012**	t = -1.0396 df = 477 p = 0.30	t = 0.2166 df = 483 p = 0.83	**t = -3.7477** **df =664** **p <0.01**	t = 0.95934 df = 675 p = 0.34	**t = -2.7474** **df = 699** **p = 0.006**	t = -1.4205 df = 670 p = 0.16

Table 5. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
TA-16	3.304	3.207	3.236	3.293	3.238	3.360	3.290
PIPO Control	3.261	3.225	3.161	3.216	3.296	3.170	3.320
t-test	t = -0.66864 df = 404 p = 0.50	t = 0.26454 df = 495 p = 0.79	t = -1.2603 df = 689 p = 0.21	t = -1.1396 df = 511 p = 0.25	t = 0.88237 df = 539 p = 0.38	**t = -2.9553** **df = 578** **p = 0.003**	t = 0.51719 df =648 p = 0.61

To further analyze richness and Simpson's diversity (Simpson 1949) over time, species rarefaction and extrapolation plots (Hsieh et al. 2016, Chao et al. 2014) were developed in 2018 that included all years of data with the control sites combined. Species rarefaction and extrapolation show no differences between treatment and control sites for species richness. There were overlapping 95% confidence intervals for species richness (Figures 5A–6A) for all three treatments and their controls. Simpson's diversity is normally a measure between 0 and 1, but when analyzed using Hill numbers (Hsieh et al. 2016) it effectively reports the number of dominant species. The rarefaction and extrapolation plots for species diversity (Figures 5B–6B) were significantly different since the 95% confidence intervals did not overlap. In these cases, the treatment sites were higher in diversity than the controls with a higher number of dominant species. Tables 3-5 show there were no significant differences of diversity between treatment and control sites in 2019. Since the extrapolation curves are not expected to change much between years, these will be reanalyzed every five years.

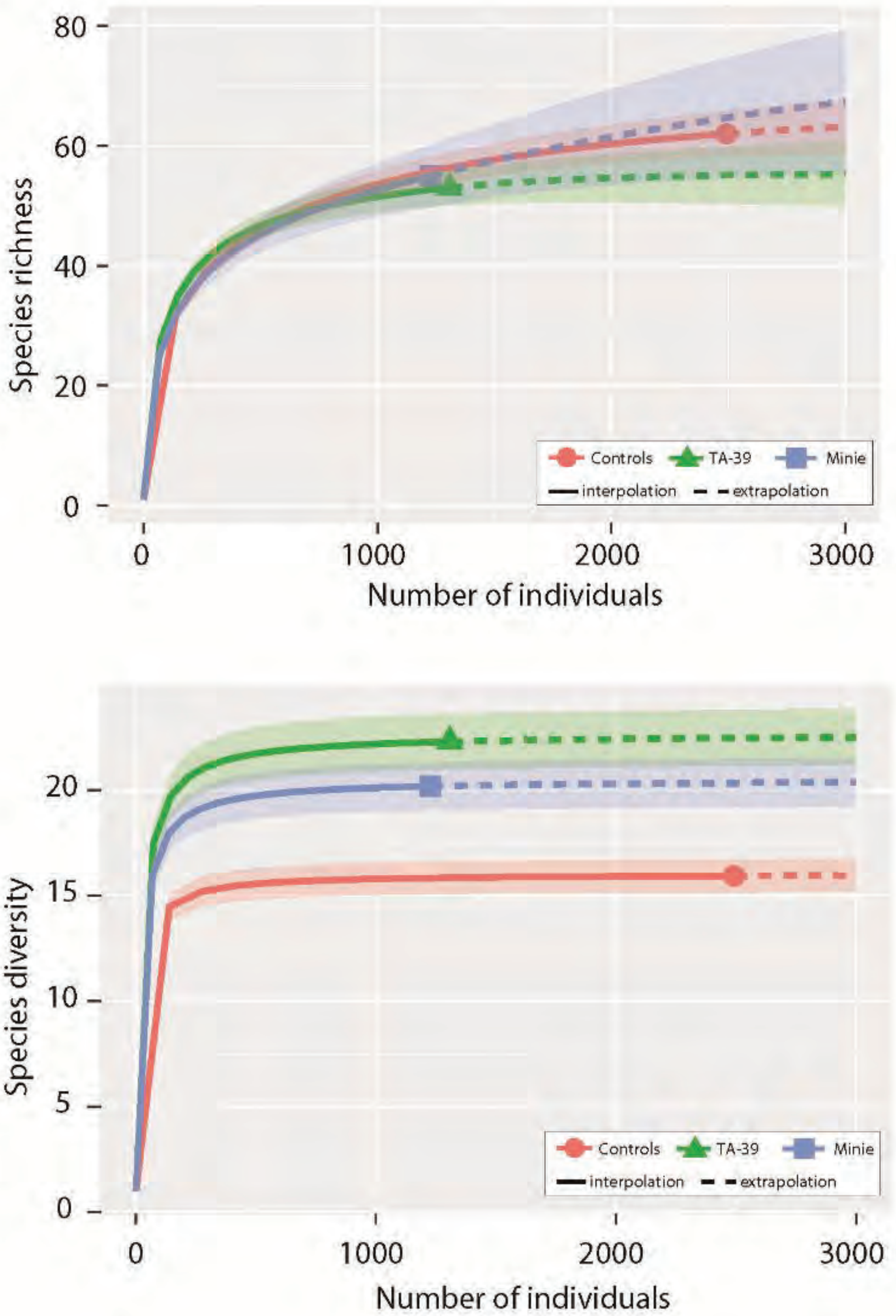


Figure 5. 2013 – 2018 Species rarefaction and extrapolation for species richness and diversity comparing Minie and TA-39 with the PJ controls

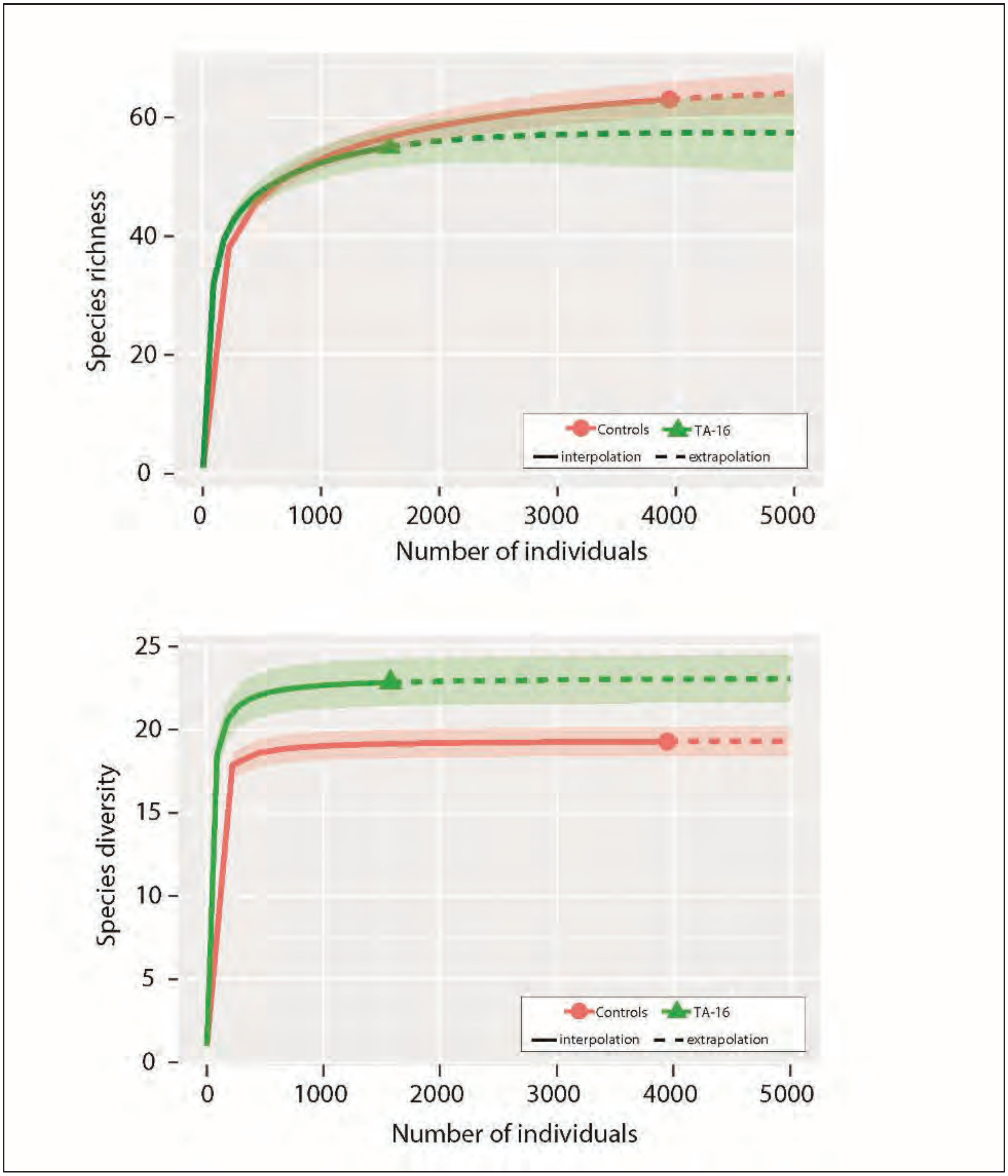


Figure 6. 2013 – 2018 Species rarefaction and extrapolation for species richness and diversity comparing TA-16 with the PIPO controls

The overall abundance of birds is trending the same for all treatment sites compared with the controls. At TA-16, the overall abundance is lower, but the percent abundance is similar year to year when compared with the control sites. Table 6 compares the abundance between the treatment and control sites over time. Similar to the species richness trends, there was an increase in abundance in 2015. The fluctuations in bird abundances were not alarming, and the differences between the treatment sites and control sites were not biologically significant. The moisture for the winter of 2018–2019 was at or slightly above normal, but the species abundance at all sites were similar to previous years.

Table 6. Changes in species abundance over time for all treatment and control sites

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Minie	193	186	275	210	222	242	245
TA-39	177	193	259	249	261	315	298
PJ Control 1	187	157	269	312	240	235	226
PJ Control 2	181	177	301	228	300	168	187
TA-16	220	209	347	271	302	285	310
PIPO Control 1	258	223	432	323	447	374	364
PIPO Control 2	256	254	371	396	449	366	394

Figures 7-9 summarize the feeding guild trends over time at the treatment sites and the combined control sites. Overall, there are fewer granivores at all transect locations. Most of the species documented are insectivores and omnivores. Tracking bird abundance by feeding guild is important, because recent studies have shown changes in food sources, specifically for insectivores, have cascading effects on bird populations (Hallmann et al. 2017). Although there are periods of significant differences between years, they tend to follow the fluctuations in abundance and species richness.

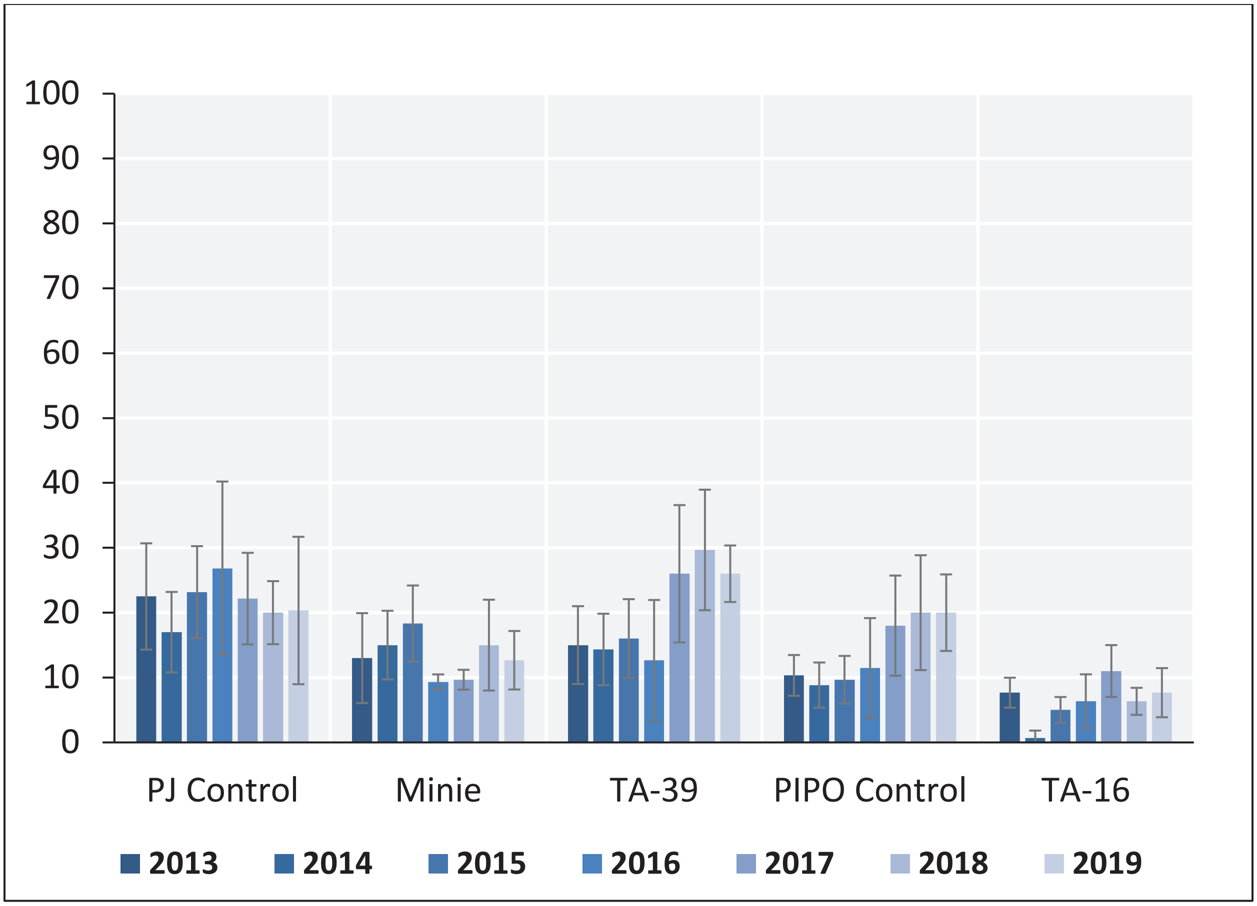


Figure 7. Average number of granivores +/- 1 standard deviation during breeding bird surveys at treatment sites and combined control sites over time.

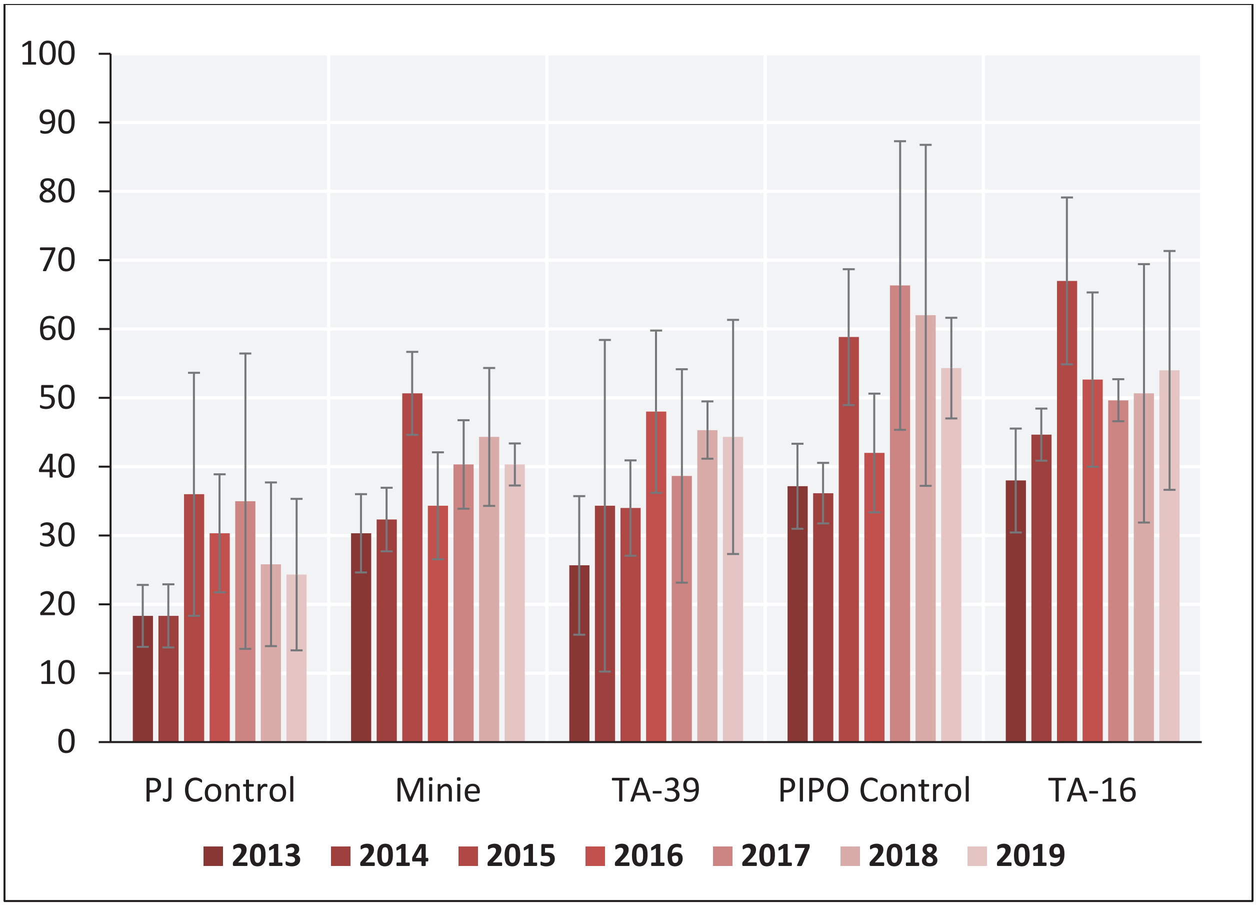


Figure 8. Average number of insectivores +/- 1 standard deviation during breeding bird surveys at treatment sites and combined control sites over time.

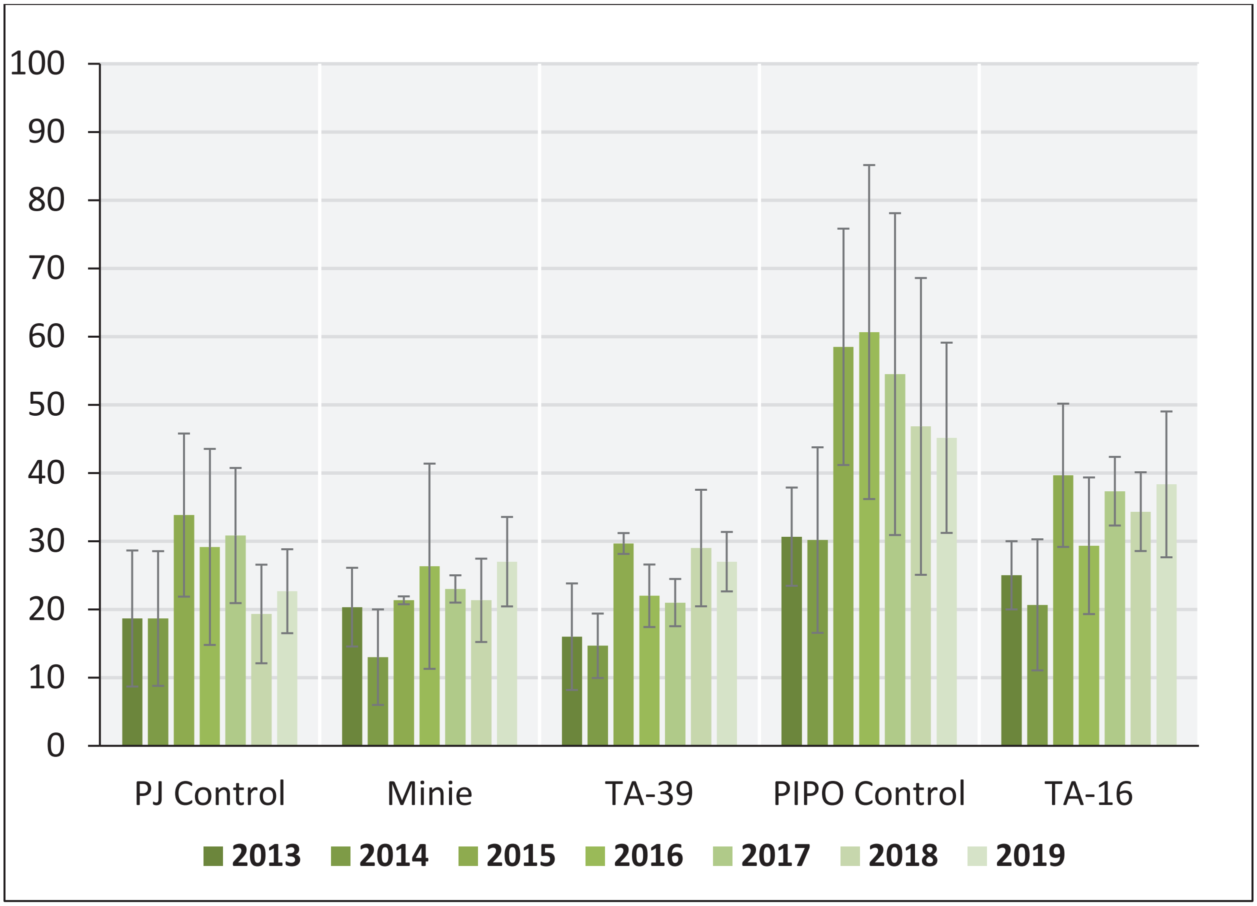


Figure 9. Average number of omnivores +/- 1 standard deviation during breeding bird surveys at treatment sites and combined control sites over time.

The number of granivores at TA-16 in comparison with the PIPO controls is lower overall. TA-16 is located on a mesa top surrounded by canyons with rocky cliff faces. Perhaps there is less understory vegetation on the cliff faces surrounding TA-16, resulting in less food for granivores. More study on habitat components between TA-16 and the PIPO control is needed to determine potential causes of the granivore variation.

Nestboxes

During the 2018 season, the overall avian nestbox network was managed at lower levels. Treatment sites were maintained at previous years' effort, but site-specific constraints from increased fire restrictions in 2018 limited the overall network management. In 2019, there were no restrictions and the nestbox network was managed throughout the breeding season with no limitations.

During the 2019 nesting season, 15 nestboxes at each treatment site were actively monitored. The overall avian nestbox network, without the three treatment sites, contained 378 nestboxes in

2019. Of those, 167 contained active nests and 85 of those nests fledged young successfully. This was an overall occupancy rate of 44% with a 51% success rate.

Tables 7 and 8 compare the occupancy and success rates for each treatment site and the overall nestbox network since 2015.

Table 7. Comparison of occupancy for the treatment sites and the overall nestbox network over time.

	2015	*2016*	*2017*	*2018*	*2019*
Overall Network	40%	45%	48%	53%	44%
Minie	66%	73%	46%	20%	60%
TA-39	8%	58%	20%	33%	13%
TA-16	-	73%	100%	53%	87%

Table 8. Comparison of success for the treatment sites and the overall nestbox network over time.

	2015	*2016*	*2017*	*2018*	*2019*
Overall Network	66%	69%	57%	49%	51%
Minie	64%	23%	29%	33%	44%
TA-39	100%	57%	0%	40%	0%
TA-16	-	63%	76%	63%	54%

In 2019, there were four successful nests that fledged young at Minie, zero at TA-39, and seven at TA-16. Both occupancy and success rates at TA-39 were low in comparison to the other treatment sites and the overall network. TA-39 is the lowest elevation treatment site and occupancy has been decreasing over time at this site and surrounding areas of the avian nestbox network. Wysner et al. (2019) found that Western Bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. Western Bluebirds have the highest occupancy rates throughout the nestbox network, and the shift in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the other two treatment sites seem to be fluctuating naturally in comparison to the overall network and have not displayed a decreasing trend over time.

In 2019, nonviable eggs collected from nestboxes at the treatment sites and the rest of the nestbox network were submitted to an analytical lab for chemical analyses. These data will be reported in a separate report.

Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Of the 53 species detected at the three treatment sites, all are protected under the Migratory Bird Treaty Act. In addition, sensitive species from the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008), the New Mexico Avian Conservation Partners Species Conservation Level One List (NMACP 2019), and the Birder’s Conservation Handbook (Wells 2007) have been documented at the treatment sites. Those species are the Juniper Titmouse, Grace’s Warbler, Virginia’s Warbler, and the Woodhouse’s Scrub Jay. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901).

Continuing the research reported herein will provide a long-term dataset for the ecological health of avifauna at the three treatment sites at LANL. In addition, this research contributes to meeting the Department of Energy’s commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service, and it allows LANL to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Thanks to the following individuals for technical and field support work in 2019: Jesse Berryhill, Jenna Stanek, Luciana Vigil-Holterman, Elisa Abeyta, Maricela Salazar, Jadzia Rodriguez, Makenzie Quintana, and former staff and interns that helped in previous years.

Literature Cited

Chao, A., N.J. Gotelli, T.C. Hsieh, E.L. Sander, K.H. Ma, R.K. Colwell, and A.M. Ellison. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84:45–67.

Clarke, K.R., R.N. Gorley, P.J. Somerfield, and R. Warwick. 2014. Change in marine communities; an approach to statistical analysis and interpretation, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262pp.

Hallmann, C.A., M. Sorg, E. Jongejans, H. Siepel, N. Hofland, H. Schwan, W. Stenmans, A. Müller, H. Sumser, T. Hörren, D. Goulson, and H. de Kroon. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PloS One 12(10): e0185809.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1):1–9.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. Los Alamos National Laboratory report number LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. Los Alamos National Laboratory report number LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill. 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-18-22897, Los Alamos, New Mexico.

Hsieh, T.C., K.H. Ma, and A. Chao. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution 7(12):1451–1456.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. Los Alamos National Laboratory report number LA-14029, Los Alamos, New Mexico.

New Mexico Avian Conservation Partners (NMACP). 2019. Species conservation level list one. http://avianconservationpartners-nm.org/. Accessed January 2020.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, USA. 127pp.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874–2882.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine 2015. Weather Machine Climatological Monthly Summary, September 2015, http://weather.lanl.gov/climo_monthly_summary.asp.

Wells, J.V. 2007. Birder's Conservation Handbook: 100 North American Birds at Risk. Princeton University Press. Princeton, New Jersey. 452 pp.

Wysner, T.E., A.W. Bartlow, C.D. Hathcock, and J.M. Fair. 2019. Long-tern phenology of two North American secondary cavity-nesters in response to changing climate conditions. The Science of Nature 106:54. doi:10.1007/s00114-019-1650-9.

Appendix 1. All birds recorded at the three treatment sites from 2013–2019

	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019
Species	TA-36 Minie Site							TA-39 Point 6							TA-16 Burn Grounds						
	Pinyon-Juniper Woodland							Pinyon-Juniper Woodland							Ponderosa Pine Forest						
Acorn Woodpecker															5		3	2	3	5	3
American Crow																			1	1	
American Kestrel				1				1			2										
American Robin	1	1	2		2			1	1		2		4	2	7		9	4	4	6	12
Ash-throated Flycatcher	11	5	14	13	13	10	17	19	11	29	12	8	8	6	3	5	6	2	3	8	4
Audubon's Warbler		2				5					2				6	5	1	6		1	11
Bewick's Wren	4	8	9	9	14	14	5	3	10	15	9	2	8	1							
Black-chinned Hummingbird		1	1				1	3	2				1	2	1		1		1		1
Black-headed Grosbeak	1	3				1	1		2	4	1		3	2			1	2		2	
Black-throated Gray Warbler			1		2			5	6	4											
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	2		7	5	4	2	13		6	2	1	3	6	4
Broad-tailed Hummingbird	2	1	3		1		3	3	1	2		3	1	2	5	11	11	5	7	10	8
Brown Creeper															1						
Brown-headed Cowbird	1									2			3	2	4	1			4	2	8
Bushtit		2		2		11		2	14			1	12								
Canada Goose										16				2							
Canyon Towhee	2		5	3	6	2	3	1	1	2	10	13	19	6	1			1		1	
Canyon Wren					1					2	3	8	6	2			2				
Cassin's Finch						4															
Cassin's Kingbird	6	13	13	5	2	5	6	7	6	2	21	21	32	37				1			
Chipping Sparrow	3	16	17	29	6	22	10	6	6	5	8	15	25	27	1	5	3	10	5	21	8

	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019
Species	TA-36 Minie Site							TA-39 Point 6							TA-16 Burn Grounds						
	Pinyon-Juniper Woodland							Pinyon-Juniper Woodland							Ponderosa Pine Forest						
Clark's Nutcracker																4		1			
Common Nighthawk	6		5	2	4	4	1	5	1	3	2	7	5	7			1	2	2		
Common Raven	2	5	1		1	2	3	1		2	1		1	2	5	6	2	2	5	5	7
Cooper's Hawk					1										1			1			1
Cordilleran Flycatcher															5	10	6	3	3	1	2
Dark-eyed Junco													1	1	6	2	4		5	2	
Downy Woodpecker				1							1	2		1		1		1	1	1	
Dusky Flycatcher				1						1		1									
Eurasian Collared-Dove	3											4								1	
Evening Grosbeak	3		4							8					5		29			1	
Grace's Warbler							1						2	4	6	4	4	8	5	8	22
Gray Flycatcher	12	6	5	7	3	6	3	10	10	11	10	5	8	3							
Great Horned Owl		3						1													
Green-tailed Towhee	3	1						1													
Hairy Woodpecker			2	1		1				5	3			1	1	1		1	1	2	1
Hammond's Flycatcher															8	9	12	5	7	5	10
Hepatic Tanager										1	2	1	2					1			
Hermit Thrush						1										4	6	1	2	2	5
House Finch	16	17	26	17	12	18	17	21	4	23	9	30	44	50	16	2	5	5	12	7	12
House Wren														1	1	1		2	2	6	8
Juniper Titmouse	12		7	6	9	3	26	11	13	18	6	1									
Lesser Goldfinch	2	6	7	4	9	12	8	4	12	9	10	14	19	15	3		8	9	4	8	5
MacGillivray's Warbler																		1	3		
Mountain Bluebird		2	20	10	11	1	9		4								4	4	4	7	4
Mountain Chickadee	5	2	1	2							1	1		1	5	8	9	6	8	9	1

	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019
Species	TA-36 Minie Site							TA-39 Point 6							TA-16 Burn Grounds						
	Pinyon-Juniper Woodland							Pinyon-Juniper Woodland							Ponderosa Pine Forest						
Mourning Dove	17	17	13	5	8	8	11	13	22	10	3	15	11	8	4		1	3	17	3	5
Northern Mockingbird					2		1		1												
Northern Rough-winged Swallow						3															
Peregrine Falcon										1											
Pine Siskin	10	2		5	1			6		3	3				12	4	5		4	2	
Plumbeous Vireo	10	10	7	3	9	9	15	1		1	6	6	5	5	11	16	15	14	11	18	16
Pygmy Nuthatch				2		2	3			2	4	12	9	11	11	13	26	29	41	20	16
Red Crossbill					1				2							2	9	13	9		6
Red-shafted Flicker	3	1	3	2	5	2	1	3	2	4	8		3	2	3	4	11	11	5	5	2
Red-tailed Hawk							1			1	1	1	1								
Rock Wren	3	3	4		2	10	11	7	10	4	12	14	14	12	1	2	2	6			4
Ruby-crowned Kinglet																				2	
Say's Phoebe	2	1	2		2	5	1	2	1		5	2	4		1		1	3	3	4	1
Scaled Quail			1																		
Spotted Towhee	17	8	19	27	32	24	19	12	6	33	16	12	16	15	11	18	16	14	21	22	34
Steller's Jay							1								3	2	5	6	3	4	4
Townsend's Solitaire	1																		1		
Turkey Vulture					1										1					1	
Vesper Sparrow																					1
Violet-green Swallow		5	7	1	3	2	1	6	4	1	9	6	6	9		2	19	2	2	4	2
Virginia's Warbler					1	3	1			1	2	4		5	17	11	21	13	7	5	5
Warbling Vireo						2									2	9	7	6	5	4	6
Western Bluebird	15	11	18	17	16	19	21	5	19	12	21	13	6	7	20	20	49	37	32	27	20
Western Tanager		2	3		1				2	1	1	2	2	6	2	3	7	2	4	6	16
Western Wood-Pewee	10	8	18	11	10	7	18		4	2	10	8	11	12	15	10	16	14	22	20	24

	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019
Species	TA-36 Minie Site							TA-39 Point 6							TA-16 Burn Grounds						
	Pinyon-Juniper Woodland							Pinyon-Juniper Woodland							Ponderosa Pine Forest						
White-breasted Nuthatch	1	4	9	10	13	5	2			2	4	4	2	6	9	8	7	9	20	10	10
White-throated Swift									1												
White-winged Dove	1	5	9	2		3	2	7	5	6	16	15	15	5			1	2			1
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	8	10	4	8	6	4	5	1						