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Author(s): Hansen, Leslie Ann; Salzman, Sonja L.; Bruggeman, David Alan; Mcnaughton, Michael; Kowalewski, Ashley; Krehlik, Audrey; Gaukler, Shannon Marie; Thompson, Brent Eugene; Sartor, Karla Anne

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Los Alamos NATIONAL LABORATORY

ASER

2022 Annual Site Environmental Report

Los Alamos
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Los Alamos National Laboratory
Governing Policy for the Environment

- We are committed to act as stewards of our environment to achieve our mission in accordance with all applicable environmental requirements.
- We set continual improvement objectives and targets, measure and document our progress, and share our results with our workforce, sponsors, and public.
- We reduce our environmental risk through legacy cleanup, pollution prevention, and long-term sustainability programs.

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Los Alamos National Laboratory
2022 Annual Site Environmental Report

National Nuclear Security Administration-Los Alamos Field Office
Contact: (505) 667-5491

Environmental Management-Los Alamos Field Office
Contact: (505) 257-7950 or publicaffairs.emla@em.doe.gov

Los Alamos
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Abstract

Los Alamos National Laboratory (Laboratory) annual site environmental reports are prepared each year by the Laboratory's environmental organizations as required by U.S. Department of Energy Order 231.1B, Administrative Change 1, *Environment, Safety, and Health Reporting*, and Order 458.1, Administrative Change 4, *Radiation Protection of the Public and the Environment*.

The chapters in this report discuss our compliance with environmental laws, regulations, and orders (Chapter 2, Compliance Summary); how we manage the Laboratory's environmental performance and assure the quality of data from analysis of environmental samples (Chapter 3, Environmental Programs and Analytical Data Quality); how we monitor for air emissions of radioactive materials and for weather conditions (Chapter 4, Air Quality); how we monitor for effects of Laboratory operations on groundwater quality (Chapter 5, Groundwater Protection); how we monitor the levels of chemicals and radionuclides in storm water runoff and sediment (Chapter 6, Watershed Quality); how we monitor for the levels and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and finally, what radioactive dose or risk from chemical exposure that members of the public could experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

This report follows plain language guidelines as required for federal agencies by the Plain Language Act of 2010. More information about plain language can be found at http://www.plainlanguage.gov. We have substantially reduced the use of acronyms and abbreviations and are using active voice and personal pronouns.

We hope you find this report useful. If you have questions or suggestions to improve this report or if you want copies of the *Annual Site Environmental Report Summary*, please contact us at ASER@lanl.gov. You may also contact Environmental Communication & Public Involvement at envoutreach@lanl.gov or call (505) 667-3792.

This report, its supplemental tables, and the *Annual Site Environmental Report Summary* are available at https://environment.lanl.gov/resources/annual-site-environmental-reports.

Changes and Corrections

You are looking at the second published version of the Los Alamos National Laboratory 2022 Annual Site Environmental Report, released in February 2024.

The most recent version of this report will be published on our Environmental Reports website at https://environment.lanl.gov/resources/annual-site-environmental-reports. If you want to confirm that future versions are the most recent, please look at this "Changes and Corrections" section in our online report. We will update this page with the version and a description of updates for all revisions of this report.

Revision History

Description	Release Date	Reason for Update
ASER 2022, Version 1	September 2023	First published version
ASER 2022, Version 2	February 2024	Corrected misspelled author's name in document metadata; Corrected error on page 2-16 by changing "The estimated maximum dose of air emissions to a member of the public in 2022 was 0.45 millirem, less than 1 percent of the limit allowed by the Clean Air Act regulations" to "The estimated maximum dose of air emissions to a member of the public in 2022 was 0.45 millirem, less than 5 percent of the limit allowed by the Clean Air Act regulations"

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Kari Garcia
Leslie Hansen
David Holtkamp
Ben Sutter
Brent Thompson
Kenneth Waight III

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Candie Arellano
Alethea Banar
Aimee Blanchard
David Bruggeman
Mary Jo Chastenet
Aaron Dailey
Leslie Dale
Emily Day
Sean Dolan
Mike Erickson
David Forster
Robert Gallegos
Ellen Gammon
Kari Garcia
Tony Garcia
Tim Goering
Sarah Gould
Jennifer Griffin
Jeff Holland
David Holtkamp
Brian Iacona
Scot Johnson
Ashley Kowalewski
Rebecca Lattin
Ali Livesay
Frazer Lockhart
Alan Madsen
Christian Maupin
Mike McNaughton
Avril Millensted
Steve Pearson
Stephen Pierett
Kent Rich
Bruce Robinson
Sonja Salzman
Sabrina Sanchez
Karla Sartor
Brad Schilling
Roz Sereda
Jenna Stanek
Margie Stockton
Anthony Stone
Shawn Stone
Richard Sturgeon
Brent Thompson
Don Ulrich
John Valdez
Steve Veenis
Luciana Vigil-Holterman
Kenneth Waight III
Holly Wheeler
Walt Whetham
Dave Wirkus

3.0 Environmental Programs and Analytical Data Quality

Dalinda Bangert
Shannon Blair
David Bruggeman
Christine Bullock
Robert Gallegos
Kari Garcia
Shannon Gaukler
Sarah Holcomb
David Keller
Terill Lemke
Alan Madsen
Stas Marczak
Philip Moss
Andrea Pistone
Kent Rich
Renee Robinson
Karla Sartor
Sean Seaborg
Margie Stockton
Shawn Stone
Sue Terp
Brent Thompson
Kenneth Waight III
Genna Waldvogel

4.0 Air Quality

David Bruggeman
David Fuehne
Rebecca Lattin
Michael McNaughton
Kenneth Waight III

5.0 Groundwater Protection

Ashley Kowalewski
Pat McGuire
Keith McIntyre
Brinson Willis

6.0 Watershed Quality

Audrey Krehlik
Russell Lyon
Sophie Stauffer
Daria Cuthbertson
Karly Rodriguez

7.0 Ecosystem Health

Shannon Gaukler
Jenna Stanek
Jessica Celmer
Justin Clements
Elisa Abeyta
Brent Thompson
Karla Sartor
Bridget Bloodwood
Michael McNaughton

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Shannon Gaukler
Michael McNaughton
Jenna Stanek
Justin Clements

Executive Summary

LANL Biological Resources Program staff are training to delineate wetlands.

Los Alamos National Laboratory (LANL or Laboratory) is sited in Los Alamos County in north-central New Mexico, about 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. The Laboratory's mission is to solve national security challenges through scientific excellence. Environmental stewardship and compliance are core values of operations at the Laboratory. Part of that commitment includes reporting on the Laboratory's environmental performance.

This site environmental report

- characterizes the Laboratory's environmental performance, including effluent releases, environmental monitoring, and estimated radiological doses to the public and the environment;
- summarizes environmental occurrences and responses;
- confirms compliance with environmental standards and requirements;
- highlights significant programs and efforts; and
- describes property clearance activities in accordance with U.S. Department of Energy (DOE) Order 458.1.

LANL has changed substantially since it was founded in 1943. Undoubtedly, the future will continue to bring significant changes to the Laboratory mission and operations. Regardless of these changes, we are committed to operating the site sustainably.

Environmental stewardship requires an active management system to provide environmental policy, planning, implementation, corrective actions, and management review. We use an Environmental Management System to accomplish this. The Laboratory has been certified to the International Organization for Standardization's 14001 standard for the Environmental Management System since April 2006.

The Laboratory's Governing Policy on Environment

We are committed to act as stewards of our environment to achieve our mission in accordance with all applicable environmental requirements. We set continual improvement objectives and targets, measure and document our progress, and share our results with our workforce, sponsors, and the public. We reduce our environmental risk through legacy cleanup, pollution prevention, and long-term sustainability programs.

The chapters in this report discuss a range of topics:

- our compliance with environmental laws, regulations, and orders (Chapter 2, Compliance Summary);

- how we manage the Laboratory's environmental performance and assure the quality of data from analysis of environmental samples (Chapter 3, Environmental Programs and Analytical Data Quality);
- how we monitor for air emissions of radioactive materials and for weather conditions (Chapter 4, Air Quality);
- how we monitor for effects of Laboratory operations on groundwater quality (Chapter 5, Groundwater Protection);
- how we monitor the levels of chemicals and radionuclides in storm water runoff and sediment (Chapter 6, Watershed Quality);
- how we monitor for the levels and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and finally,
- what radioactive dose or risk from chemical exposure that members of the public could experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

2022 Environmental Performance Summary

Our environmental performance can be summarized as follows (see Chapters 2 and 3).

- The Laboratory operated under 17 different types of environmental permits and legal orders (Chapter 2, Table 2-23).
- For the legacy waste cleanup project, we received one certificate of completion for a corrective action site.
- Mixed wastes managed under the Laboratory's Site Treatment Plan decreased by approximately 72 cubic yards for mixed low-level waste and 146 cubic yards for mixed transuranic waste.
- The Laboratory was fully in compliance with its Clean Air Act, Title V Operating Permit emission limits.
- We discharged approximately 131 million gallons of liquid effluents from seven permitted outfalls. Four permitted outfalls had no discharge. Six of the 785 outfall samples collected (less than 1.0 percent) exceeded a permit limit in the outfall permit (Chapter 2, Table 2-6).
- In fiscal year 2022, we reported to the New Mexico Environment Department nine instances of a contaminant detected in groundwater at a location where the contaminant had not been previously detected above a standard or screening level (Chapter 2, Table 2-13).
- The New Mexico Environment Department issued a final discharge permit for the Technical Area 50 Radioactive Liquid Waste Treatment Facility that requires us to conduct operational, monitoring, and closure actions.
- Two areas of the regional aquifer at the Laboratory have groundwater contaminants that are of sufficient concentration and extent to warrant actions, such as interim measures, further characterization, and potential remediation under the 2016 Compliance Order on Consent: RDX contamination in the vicinity of Technical Area 16 and chromium

- contamination beneath Sandia and Mortandad canyons. Interim measures to control the chromium plume boundary are ongoing (Chapter 5).
- One environmental occurrence was reported under DOE Order 232.2, *Occurrence Reporting and Processing of Operations Information*, related to an oil leak from a transformer at Technical Area 53 (Chapter 2, Table 2-19).
- The Laboratory had four inspections/audits conducted in 2022 by regulating agencies or external auditors (Chapter 2, Table 2-20).
- We made seven reports of unplanned nonradioactive liquid releases to the New Mexico Environment Department (Chapter 2, Table 2-21).
- The Laboratory's Pollution Prevention Program completed a climate change vulnerability assessment and resilience plan for LANL, which considered the risks from climate change impacts to Laboratory operations during the next 4 years.
- Radiological doses to the public from Laboratory operations were less than 1 millirem per year, and health risks are indistinguishable from zero.

2022 Environmental Program Highlights

During 2022, programs comprising the Laboratory's Environmental Management System reported the following new initiatives or highlights.

- LANL hired a new transportation director and partnered with the Texas A&M Transportation Institute to develop a comprehensive transit and transportation plan. In addition to reducing traffic and parking congestion on site, this plan will reduce Scope 3 greenhouse gas emissions that result from employee commuting.
- Triad subject matter experts reviewed 309 management and operating contractor projects in the Permits and Requirements Identification tool and 717 projects in the Excavation/Fill/Soil Disturbance permitting tool. In addition, 23 legacy waste cleanup projects were reviewed in the Permits and Requirements Identification tool.
- In 2022, we resumed employee and public tours at Technical Area 18 following the COVID-19 pandemic as part of the Manhattan Project National Historical Park activities. These tours highlight the history of the Manhattan Project through stories related to the people, buildings, and landscapes of Los Alamos. Additional tours for LANL employees took place at other Manhattan Project sites within areas less accessible to the public.
- The Laboratory funded a 5-year plan developed by its Wildland Fire and Forest Health Program to reduce the overall wildland fire risk at LANL beginning in fiscal year 2023.

2022 Environmental Monitoring Highlights

During 2022, we completed the following.

- Several environmental monitoring programs had to change analytical laboratories mid-year because of the closure of ALS Environmental Laboratory in Fort Collins, Colorado. Differences in procedures between the old and new laboratories made data analysis for 2022 more challenging than in previous years. Ways in which these programs addressed these challenges are noted in the individual chapters.

- The Laboratory operated 43 environmental air-monitoring stations and conducted stack monitoring at 8 facilities to measure levels of airborne radiological materials. During 2022, the radioactive emissions from all Laboratory sources amounted to approximately 1 percent of the regulatory limit, and concentrations of airborne radioactive material measured in ambient air samples were below the applicable concentration levels for environmental compliance.
- The average temperature measured in Los Alamos during 2022 was 0.8 degrees Fahrenheit above the 1991–2020 average. A wind gust of 60 miles per hour (tied for the strongest wind gust of the year) was recorded on April 22, the day the Cerro Pelado wildfire started to the southwest of the Laboratory.
- Interim measures to maintain the boundary of the chromium groundwater plume within Laboratory boundaries continued during 2022. Chromium concentrations in samples from most wells that monitor the target area have either a declining level of chromium, concentrations below the 50 microgram per liter New Mexico groundwater standard, or both; however, chromium concentrations in regional well R-45 screen 2 have increased above the standard after sustained interim measure operations.
- The 2022 results of the storm water and base flow sampling fell within the ranges observed in the previous years, and the sediment sampling results continued to verify that sediment transport observed in Laboratory canyons generally results in lower concentrations of Laboratory-released chemicals in the new sediment deposits than previously existed in a given stream reach.
- Surveys confirmed the presence of Mexican spotted owls in two locations on Laboratory property again in 2022. We began monitoring for forest health conditions in fuel treatment areas under a formal, approved monitoring procedure.
- We completed our triennial sampling of foodstuffs (eggs, honey, milk, native vegetation, and crops) from onsite, perimeter, and background locations in 2022. Radiological doses to the public from Laboratory operations are less than 1 millirem per year, and health risks are indistinguishable from zero.

A summary of this *Annual Site Environmental Report*, the *Los Alamos National Laboratory Annual Site Environmental Report Summary*, was prepared by Laboratory summer students. Both of these reports are available on the Laboratory's website at https://environment.lanl.gov/resources/annual-site-environmental-reports.

Chapter 1: Overview

Major environmental events at Los Alamos National Laboratory (LANL or the Laboratory) during 2022 included the Cerro Pelado wildfire, the DOE National Nuclear Security Administration's initiation of a new Site-Wide Environmental Impact Statement for continued operation of the Laboratory, and the Laboratory's opening of new office space in Santa Fe, New Mexico.

Introduction

LANL was established in 1943. As Project Y of the Manhattan Project, the Laboratory's objective during World War II was to design and build the world's first atomic bombs. Surrounded by the diverse communities of northern New Mexico and employing approximately 18,700 people, the Laboratory continues today with a mission to solve national security challenges. Figure 1-1 is a photo of Technical Area 3, which contains the administrative headquarters for the Laboratory and several key facilities.

Figure 1-1. Aerial view to the southwest, showing Los Alamos Medical Center (lower right corner), Omega Bridge over Los Alamos Canyon, and Technical Area 3 (August 2020). Bandelier National Monument and Santa Fe National Forest property are visible in the distance.

Background

In March 1943, during World War II, a small group of scientists and military personnel came to New Mexico's Pajarito Plateau for Project Y of the Manhattan Project. Their goal was to develop the world's first atomic bombs. By 1945, more than 3,000 civilian and military personnel were working in Los Alamos.

The U.S. Army Corps of Engineers established Los Alamos Laboratory on land appropriated from private landowners and withdrawn from the U.S. Department of Agriculture Forest Service. In 1946, the U.S. Atomic Energy Commission took charge of Los Alamos Laboratory, and in 1947, Los Alamos Laboratory became Los Alamos Scientific Laboratory. Thirty years later, in 1977, the U.S. Department of Energy (DOE) became the federal agency in control. Los Alamos Scientific Laboratory underwent its most recent name change in 1981, becoming Los Alamos National Laboratory. The National Nuclear Security Administration, a semiautonomous agency within DOE, has overseen the management and operating contract for the Laboratory since 2000.

From 1943 through May 2006, the Laboratory was operated by the Regents of the University of California. In June 2006, Los Alamos National Security, LLC, took over as the contractor responsible for managing and operating the Laboratory. In 2014, DOE decided to separate the cleanup of legacy waste from the management and operating contract. Legacy waste cleanup work was transitioned in October 2015 to a bridge contract under DOE's Office of Environmental Management. A new contractor, Newport News Nuclear BWXT Los Alamos, LLC (N3B), became responsible in April 2018 for legacy waste cleanup operations. Triad National Security, LLC (Triad), was awarded the most recent management and operating contract for the Laboratory and began managing the Laboratory in November 2018. Currently, both the National Nuclear Security Administration and DOE's Office of Environmental Management maintain field offices in Los Alamos, New Mexico.

Purpose

This document is a consolidated site environmental report that fulfills the annual reporting requirements of the National Nuclear Security Administration and DOE's Office of Environmental Management under DOE Orders 231.1B Chg 1, *Environment, Safety, and Health Reporting*, and 458.1 Chg 3, *Radiation Protection of the Public and the Environment*.

In this document, "we" refers to the people who work at Los Alamos National Laboratory, including employees of DOE and contractor organizations.

As part of the Laboratory's commitment to protecting the environment, we monitor and report on how Laboratory activities affect the environment. The objectives of this annual report are to

- characterize the site's environmental performance, including effluent discharges, air emissions, environmental monitoring, and estimated radiological doses to the public from releases of radioactive materials;
- summarize environmental occurrences and responses;
- document compliance with environmental standards and requirements;
- highlight significant programs and efforts; and
- summarize property clearance activities.

The chapters in this report discuss

- our compliance with environmental laws, regulations, and orders (Chapter 2, Compliance Summary);
- how we manage the Laboratory's environmental performance and assure the quality of data from analysis of environmental samples (Chapter 3, Environmental Programs and Analytical Data Quality);
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- how we monitor for the levels and effects of chemicals and radionuclides in plants, animals, soil, and vegetation (Chapter 7, Ecosystem Health); and finally,
- the radioactive dose or chemical exposure risk that members of the public could experience as a result of Laboratory operations (Chapter 8, Public Dose and Risk Assessment).

Environmental Setting

Location

Los Alamos National Laboratory is sited in Los Alamos and Santa Fe counties in north-central New Mexico (see Figure 1-2). It sits on the Pajarito Plateau. The Sierra de los Valles range of the Jemez Mountains is directly west of the Laboratory, and White Rock Canyon (containing the Rio Grande) is east. The plateau is a series of mesas separated by canyons. Mesa tops range in elevation from about 7,800 feet on the western side to 6,200 feet on the eastern side.

The Laboratory property is about 40 square miles. It includes areas with active operations and additional DOE properties, such as a proposed land transfer tract in Rendija Canyon (labeled "DOE" in Figure 1-2). The land surrounding the Laboratory is largely undeveloped. Large tracts of land north, west, and south of the site are managed by the Santa Fe National Forest, the U.S. Bureau of Land Management, Bandelier National Monument, and Los Alamos County. The town of Los Alamos borders the Laboratory to the north. The Pueblo de San Ildefonso and the community of White Rock border the Laboratory to the east. Santa Clara Pueblo is north of the Laboratory but does not share a border (see Figure 1-2).

Geology

Continental rifts occur where tectonic plates in the earth's crust move apart. This movement allows magma to rise near the earth's surface, and volcanoes are common features of rifts. The Pajarito Plateau lies along a continental rift called the Rio Grande Rift.

Many of the rock formations that make up the Pajarito Plateau resulted from past volcanic eruptions. The mesas are mostly composed of Bandelier Tuff, a type of soft rock formed from hardened volcanic ash. The Bandelier Tuff is more than 1,000 feet thick on the western part of the plateau, thinning to about 260 feet thick on the eastern edge above the Rio Grande.

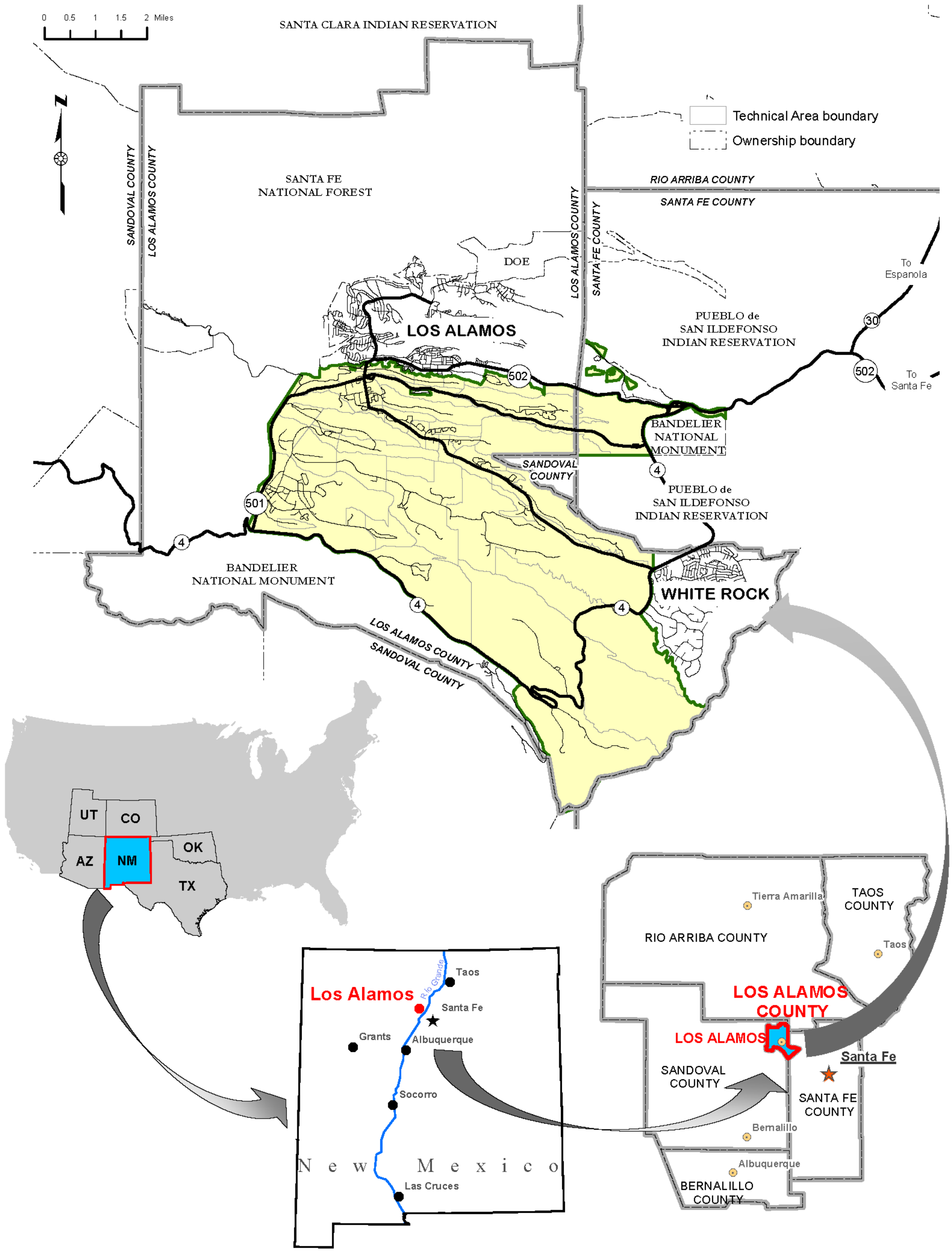


Figure 1-2. Regional location of Los Alamos National Laboratory (in yellow).

On the western side of the Pajarito Plateau, Bandelier Tuff overlaps the Tschicoma Formation of the Jemez Mountains. The Tschicoma Formation is an older rock layer made of volcanic dacite. Eastward near the Rio Grande, the Puye Formation—a layer of sand and gravel underneath the Bandelier Tuff—becomes visible in places. The Puye Formation can store groundwater. Basalt rocks formed by volcanic material from the Cerros del Rio volcanoes east of the Rio Grande mix with the Puye Formation along the river and extend beneath the Bandelier Tuff in places.

Santa Fe Group sediment formations lie below the Puye Formation and Bandelier Tuff. These sediment formations extend between the Jemez Mountains and the Sangre de Cristo Mountains and are more than 3,300 feet thick in places. The Santa Fe Group contains a large volume of groundwater and is the regional aquifer for this area.

Continental rifts are also associated with geologic faults, which are fractures between blocks of rocks that allow the blocks to move relative to each other. The Los Alamos area has a local master fault and three subsidiary faults—part of the Pajarito fault zone. Past and present studies at the Laboratory investigate earthquake hazards associated with these faults (Lee 2018).

Climate

Los Alamos County has a semiarid climate, meaning that more water is lost from the soil and plants through evaporation and transpiration than is received as annual precipitation. Annual temperatures and amounts of precipitation vary across the county because of the 5,000-foot change in elevation and the complex topography.

Four distinct seasons occur in Los Alamos County. Winters are generally mild with occasional snowstorms. Spring is the windiest season. Summer is the rainy season, with frequent afternoon thunderstorms. Fall is typically dry, cool, and calm.

On average, winter temperatures range from 30°F to 50°F during the day and from 15°F to 25°F during the night. The Sangre de Cristo Mountains to the east of the Rio Grande act as a barrier to wintertime arctic air masses, making the occurrence of subzero temperatures rare. On average, summer temperatures range from 70°F to 88°F during the day and from 50°F to 59°F during the night.

The rainy season begins in early July and ends in early September. Afternoon thunderstorms form in the summer as moist air from both the Pacific Ocean and the Gulf of Mexico lifts over the Jemez Mountains and then often moves eastward across the Laboratory. These thunderstorms produce short, heavy downpours and an abundance of lightning. Local lightning density is estimated at 15 strikes per square mile per year.

The average annual precipitation (which includes both rain and the water equivalent of snow, hail, and any other frozen precipitation) is about 17 inches. The average annual snowfall is about 43 inches.

The topography of the Pajarito Plateau influences local wind patterns. Daytime winds in the Los Alamos area are predominantly from the south, as heated daytime air moves up the Rio Grande valley. Nighttime winds on the Pajarito Plateau are lighter and more variable and are typically from the west because of prevailing upper-level winds and the downslope flow of cooled mountain air. See the Meteorology section in Chapter 4, Air Quality, for more information.

Hydrology

Surface water on the Laboratory occurs primarily as either ephemeral flow (associated with individual rainstorms and lasting from only a few hours to days) or intermittent flow (associated with events like snow melt and lasting from only a few days to weeks). Some springs on the edge of the Jemez Mountains supply water year-round to western sections of some canyons, but the amount of water is not enough to maintain surface flows across the plateau to the eastern Laboratory boundary.

Groundwater in the Los Alamos area occurs in three modes:

- water in the near-surface sediments in the bottoms of some canyons (alluvial groundwater),
- water in underground porous rock layers underlain by a more solid rock layer and therefore perched above the regional aquifer (intermediate-perched groundwater), and
- water in the regional aquifer.

The regional aquifer is the only aquifer in the area with enough water to serve as a municipal water supply. The source of most water added to the regional aquifer in the Los Alamos area appears to be rain and snow that fall on the Jemez Mountains. A secondary source is local infiltration of water in canyon bottoms on the Pajarito Plateau (Birdsell et al. 2005). Some groundwater from the regional aquifer beneath the Laboratory discharges into the Rio Grande through springs in White Rock Canyon.

Biological Resources

With a 5,000-foot elevation change from the Rio Grande up to the top of the Jemez Mountains and many steep canyons that dissect the area, the Pajarito Plateau is biologically diverse. The major types of vegetation are

- juniper woodlands with scattered piñon (*Pinus edulis*) trees between 5,300 and 7,500 feet in elevation, covering large portions of the mesa tops and south-facing canyon slopes at the lower elevations;
- ponderosa pine (*Pinus ponderosa*) woodlands on the western portion of the plateau between 6,200 and 8,700 feet in elevation;
- mixed-conifer woodlands and forests between 6,200 and 9,900 feet in elevation, overlapping the ponderosa pine community both in the deeper canyons and on north-facing canyon slopes and extending onto the slopes of the Jemez Mountains;
- grasslands at all elevations, ranging from blue grama grass near the Rio Grande to montane grasses above 8,100 feet;
- shrublands at all elevations but especially associated with areas severely burned by wildfire (Hansen et al. 2018); and
- local wetlands and riparian areas that enrich the diversity of plants and animals found on the plateau.

Frequent drought conditions throughout New Mexico since 1998 have resulted in the loss of many forest and woodland trees. Between 2002 and 2005, more than 90 percent of the mature piñon trees in the Los Alamos area died from a combination of water stress and bark beetle infestation (Breshears et al. 2005). Many mature ponderosa pine and other conifer trees in the area also have died. This mortality of forest trees is projected to continue into the 2050s due to ongoing water stress associated with increasing temperatures (Williams et al. 2013).

Cultural Resources

We have surveyed approximately 90 percent of the DOE land in Los Alamos County and identified more than 1,900 pre-contact and historic cultural sites. Nearly 73 percent of the sites were constructed by Ancestral Pueblo people during the thirteenth, fourteenth, and fifteenth centuries. However, evidence suggests that human activity on the plateau extends from the Paleoindian Period (16,000–8,000 BC) through the Historic Period (seventeenth century–present). We document and evaluate cultural sites for their eligibility on the National Register of Historic Places.

The Laboratory itself also is associated with events of national significance in recent history. We have evaluated more than 300 buildings and structures at the Laboratory used during the Manhattan Project (1943–1945) and the Cold War (1945–1990) historical periods for listing in the National Register of Historic Places. Of these, 168 buildings have been declared eligible.

Established in 2014, the Manhattan Project National Historical Park, managed by the National Park Service, includes units at Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos. Nine buildings associated with the design and assembly of The Gadget (the atomic bomb tested at Trinity Site in southern New Mexico in July 1945), the Little Boy weapon (the atomic bomb detonated over Hiroshima, Japan, near the end of World War II in August 1945), and the Fat Man weapon (the atomic bomb detonated over Nagasaki, Japan, near the end of World War II in August 1945) are part of the Manhattan Project National Historical Park at Los Alamos National Laboratory. Eight additional Laboratory buildings and structures identified in the park legislation are considered eligible for inclusion in the park.

Demography of Local Communities

New Mexico’s estimated 2022 population was 2,113,344 people, a decline of 0.2 percent from 2021 (Census 2023a). The estimated population within a 50-mile radius of Los Alamos based on 2020 census data was 439,295 people (CIESIN 2023). Figure 1-3 shows municipalities and tribal properties within 50 miles of the Laboratory.

Four counties have substantial land area within 50 miles of the Laboratory: Los Alamos, Santa Fe, Sandoval, and Rio Arriba. The estimated racial and ethnic composition of the population within these counties, based on the latest available data from the U.S. Census Bureau’s American Community Survey (2017–2021), is shown in Table 1-1 (Census 2023b).

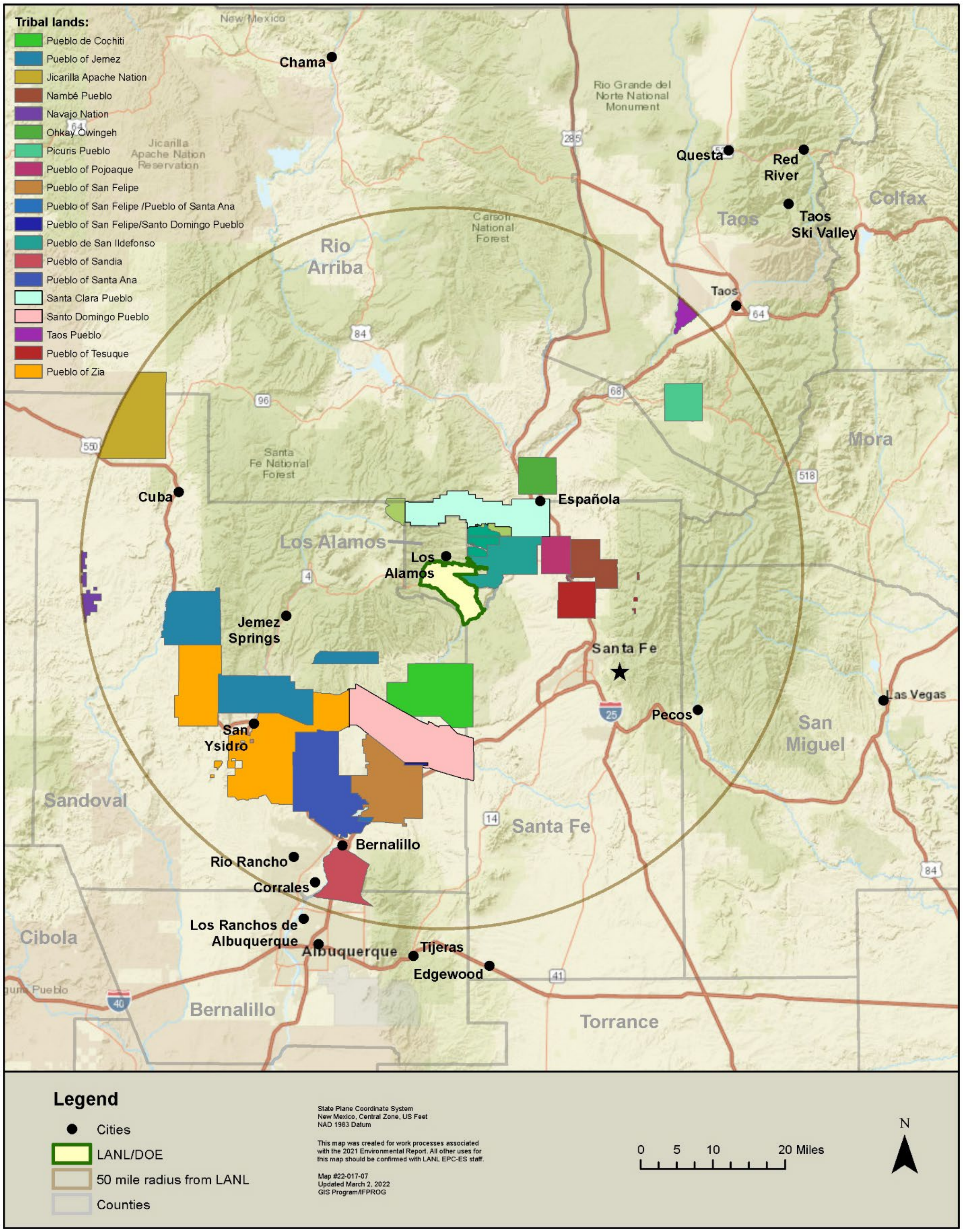


Figure 1-3. Municipalities and tribal properties within a 50-mile radius of the Laboratory.

Table 1-1. Estimated Racial and Ethnic Composition of the Population within Los Alamos, Santa Fe, Sandoval, and Rio Arriba Counties, 2017–2021 (Census 2023b)

Race	Number of People
White alone	242,303
Black or African American alone	5,195
American Indian and Alaska Native alone	29,136
Asian alone	5,591
Some other race alone	36,452
Two or more races	41,798
Ethnicity	**Number of People**
Hispanic or Latino, of any race	169,959
Not Hispanic or Latino	190,516

Laboratory Activities and Facilities

The Laboratory property is organized into 49 technical areas that contain buildings, experimental areas, support facilities, roads, and utility rights-of-way (see Figure 1-4 and Appendix C, Descriptions of Technical Areas and their Associated Programs). Developed areas account for less than half of the total land area; many portions of the Laboratory act as buffer areas for security, safety, and possible future expansion. The Laboratory has about 897 buildings, trailers, and transportable buildings that contain 8.2 million square feet under roof (LANL 2022).

At the end of 2022, 14,280 people were employed by the Laboratory, and an additional 4,455 people were employed by subcontractors. The LANL-affiliated workforce resides predominantly in Los Alamos, Santa Fe, Rio Arriba, Bernalillo, Sandoval, Taos, and Valencia counties and includes regular workers, temporary workers, and students.

In May 2008, the DOE’s National Nuclear Security Administration issued a site-wide environmental impact statement for continued operation of the Laboratory (DOE 2008). In this document, the Laboratory identified 15 facilities as being key for evaluating the potential environmental impacts of continued operation (see Figure 1-4 and Table 1-2). Activities that occur in the key facilities represent most environmental impacts associated with Laboratory operations.

The remaining Laboratory facilities were identified as non-key facilities. Examples of non-key facilities include the Nonproliferation and International Security Center; the National Security Sciences Building, which is the main administration building; and the Technical Area 46 sewage treatment facility.

In August 2022, the DOE National Nuclear Security Administration announced that they would be preparing a new Site-Wide Environmental Impact Statement for Los Alamos National Laboratory, covering environmental impacts of both continuing Laboratory operations and legacy waste remediation.

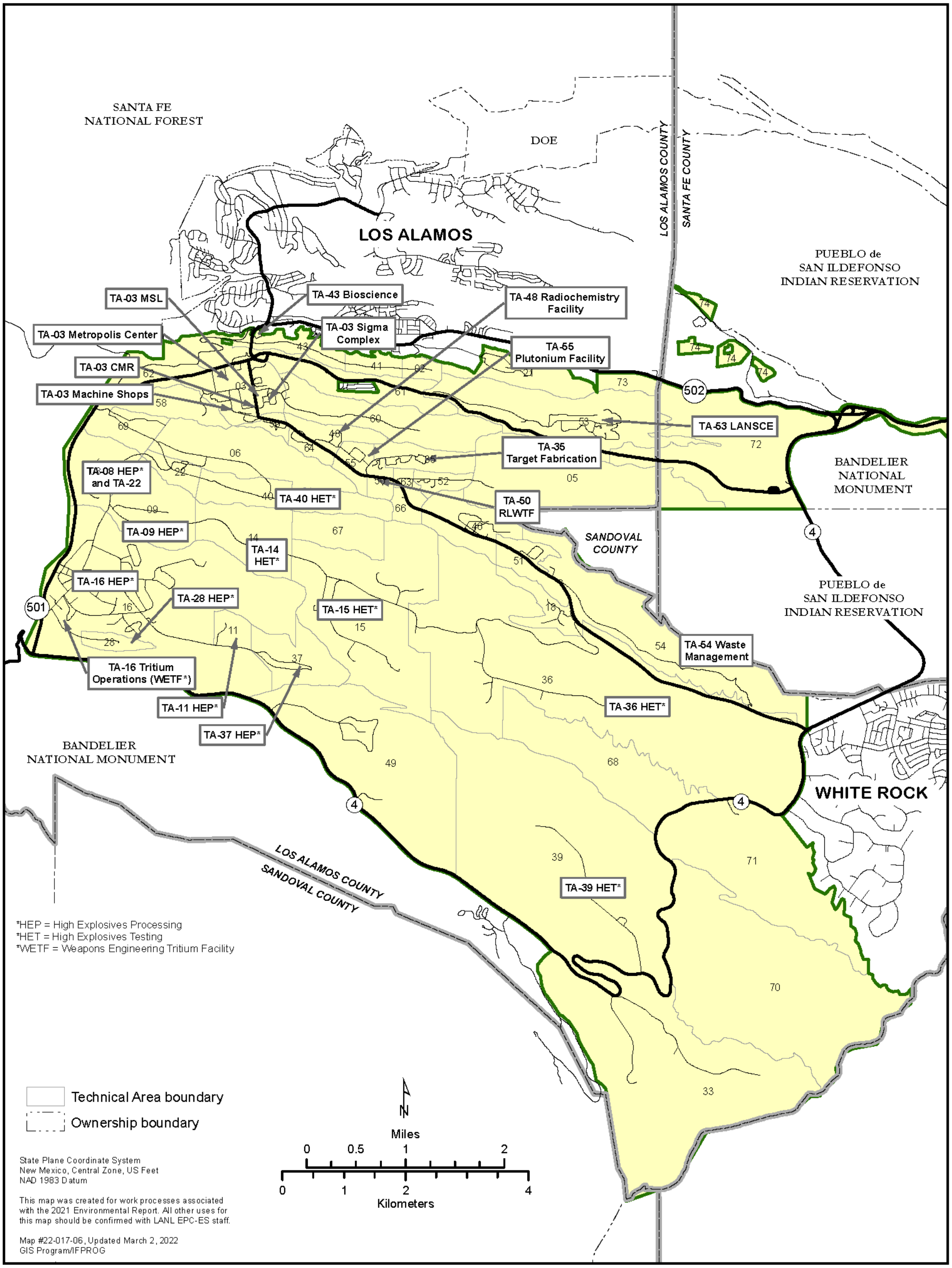


Figure 1-4. Technical areas and key facilities of the Laboratory.

Table 1-2. Key Facilities

Facility	Technical Areas
Plutonium Facility Complex	55
Chemistry and Metallurgy Research (CMR) Building	03
Sigma Complex	03
Materials Science Laboratory (MSL)	03
Target Fabrication Facility	35
Machine Shops	03
Nicholas C. Metropolis Center for Modeling and Simulation	03
High Explosives Processing (HEP) Facilities	08, 09, 11, 16, 22, 37
High Explosives Testing (HET) Facilities	14, 15, 36, 39, 40
Los Alamos Neutron Science Center (LANSCE)	53
Biosciences Facilities (formerly Health Research Laboratory)	03, 16, 35, 43, 46
Radiochemistry Facility	48
Radioactive Liquid Waste Treatment Facility (RLWTF)	50
Solid Radioactive and Chemical Waste Facilities	50, 54, 60, 63
Weapons Engineering Tritium Facility (WETF)	16

Environmental Impacts to Laboratory Operations

Several major wildfires have affected the Laboratory in recent decades. The Cerro Grande Fire in 2000 and the Las Conchas Fire in 2011 triggered multi-day closures of the Laboratory and evacuations of the Los Alamos townsite. Both fires damaged forests on the slopes of the Jemez Mountains west of the Laboratory and were followed by large flash floods that caused extensive soil erosion and some infrastructure damage. The Cerro Pelado fire in 2022 occurred close to the Laboratory but did not burn Laboratory property or trigger a closure of the Laboratory.

A 1,000-year rainfall event in September 2013 resulted in flooding and damage to infrastructure, and a “bomb cyclone” storm in March 2019 caused flooding and windfall of hundreds of trees, resulting in power outages and road closures.

Drought conditions are causing an increase wildfire activity in the southwestern U.S. and are triggering restrictions on water withdrawals from the Colorado River. Williams et al. (2022) found that 2000–2021 was the driest 22-year period in the region since at least the year 800 and labeled these conditions as a megadrought. Their analysis of climate-model simulations from the Coupled Model Intercomparison Project Phase 6 suggests that anthropogenic climate change accounted for 42 percent of the anomaly in soil moisture values during the 2000–2021 period. Wahl et al. (2022) concluded that full recovery of the current moisture deficit in the southwestern U.S. is unlikely even by mid-century and that “typical future conditions could well be like some of the driest periods that have occurred in the historical record and could potentially surpass them.” See the Site Resilience section in Chapter 2, Compliance Summary, for more information.

Workforce Location Changes

In response to lessons learned during the Covid-19 pandemic and to increased levels of staffing at the Laboratory, the Laboratory's management and operating contractor leased new office space in Santa Fe, New Mexico, and developed a work locations procedure to allow managers to approve staff to be on site (working on LANL-controlled property in either Los Alamos or Santa Fe), hybrid (performing work both on site and off site), telework (primarily working off site but within a 2 hour ground commute of LANL), or remote (working off site more than a 2-hour ground commute from LANL). At the end of 2022, of the 12,218 employees with a documented work location, 72 percent worked on site, 16 percent had a hybrid schedule, 11 percent were teleworking, and 2 percent were remote workers.

References

Birdsell et al. 2005, K. H. Birdsell, B. D. Newman, D. E. Broxton, and B. A. Robinson. 2005. "Conceptual Models of Vadose Zone Flow and Transport beneath the Pajarito Plateau, Los Alamos, New Mexico," Vadose Zone Journal 4 (3):620–636.

Breshears et al. 2005: D. D. Breshears, N. S. Cobb, P. M. Rich, K. P. Price, C. D. Allen, R. G. Balice, W. H. Romme, J. H. Kastens, M. L. Floyd, J. Belnap, J. J. Anderson, O. B. Myers, and C. W. Meyer. 2005. "Regional Vegetation Die-Off in Response to Global-Change-Type Drought," Proceedings of the National Academy of Sciences of the United States of America 102 (42):15144–15148.

Census 2023a: U.S. Census Bureau. 2023. "Quick Facts New Mexico." https://www.census.gov/quickfacts/NM (accessed February 9, 2023).

Census 2023b: U.S. Census Bureau. 2023. "Census Reporter." https://censusreporter.org (accessed February 9, 2023).

CIESIN 2023: Center for International Earth Science Information Network, Columbia University, Population Estimation Service, Version 3 (PES-v3). 2018. "NASA Socioeconomic Data and Applications Center (SEDAC)." https://doi.org/10.7927/H4DR2SK5 (accessed February 9, 2023).

DOE 2008: U.S. Department of Energy. 2008. "Final Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory," U.S. Department of Energy, DOE/EIS-0380.

Hansen et al. 2018: L. A. Hansen, A. N. Skurikhin, and B. J. Sutter. 2018. "An Updated Land Cover Map and Descriptions of Vegetative Communities for Los Alamos National Laboratory and Surrounding Areas," Los Alamos National Laboratory report LA-UR-18-23397.

LANL 2022: "SWEIS Yearbook 2021 Comparison of 2021 Data with Projections of the 2008 Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-22-32473.

Lee 2018: R. C. Lee. 2018. "Characterization of LANL Seismic Hazards: What, How and Why," Los Alamos National Laboratory report LA-UR-18-31656.

Wahl et al. 2022: E. R. Wahl, E. Zorita, H. F. Diaz, and A. Hoell. 2022. "Southwestern United States drought of the 21st century presages drier conditions into the future," *Communications Earth & Environment* 3:202. http://dx.doi.org/10.1038/s43247-022-00532-4 (accessed August 21, 2023).

Williams et al. 2013: A. P. Williams, C. D. Allen, A. K. Macalady, D. Griffin, C. A. Woodhouse, D. M. Meko, T. W. Swetnam, S. A. Rauscher, R. Seager, H. D. Grissino-Mayer, J. S. Dean, E. R. Cook, C. Gangodagamage, M. Cai, and N. G. McDowell. 2013. "Temperature as a Potent Driver of Regional Forest Drought Stress and Tree Mortality," *Nature Climate Change* 3:292–297.

Williams et al. 2022: A. P. Williams, B. I. Cook, and J. E. Smerdon. 2022. "Rapid Intensification of the Emerging Southwestern North America Megadrought in 2020–2021," *Nature Climate Change* 12:232–234.

Chapter 2: Compliance Summary

Compliance with environmental laws and orders is part of Los Alamos National Laboratory's (LANL's or the Laboratory's) environmental stewardship. This chapter provides a summary of the Laboratory's compliance with these laws and orders during 2022, including compliance with permit conditions and limits, inspections, notices of violations, occurrences, and accomplishments. Two tables—one that summarizes the Laboratory's permits and compliance orders and another that lists the LANL facilities in the U.S. Environmental Protection Agency Enforcement and Compliance History Online database—are provided at the end of this chapter.

Introduction

Environmental laws are designed to protect human health and the environment by

- regulating the handling, transportation, and disposal of materials;
- regulating impacts to biological and cultural resources, air, and water; and
- requiring analysis of the environmental impacts of new operations.

This chapter provides a summary of our compliance with state and federal environmental regulations and permits and DOE environmental orders during 2022, including inspections, notices of violations, and accomplishments. A table that summarizes the Laboratory's environmental permits and legal orders is provided at the end of this chapter.

Radiation Protection

DOE Order 458.1 Chg 4, Radiation Protection of the Public and the Environment

DOE Order 458.1 directs DOE facilities to keep radiological doses to the public and the environment as low as reasonably achievable and to monitor for routine and non-routine releases of radioactive materials. The order requires DOE sites to

- ensure that the radiological dose to the public from their site activities does not exceed 100 millirem in any given year;
- comply with the DOE's dose limits for wildlife and plants (DOE 2019);
- notify the public about any radiation doses that result from operations; and
- use radiological limits authorized by the DOE to evaluate property that has the potential to contain residual radioactivity (for example, surplus equipment, waste shipped for disposal off site, or land parcels transferred to new owners) before releasing it to ensure that the dose does not exceed 25 millirem per year above background for real estate or 1 millirem per year above background for moveable items

Estimated Maximum Possible Radiological Dose to the Public

During 2022, the estimated maximum radiological dose to a member of the public from Laboratory operations was less than 1 millirem, and radiation doses to wildlife and plants were below the annual DOE dose limits (McNaughton et al. 2022). Details of the Laboratory's annual radiological dose estimates for wildlife and plants are presented in Chapter 7, and estimates for the public are presented in Chapter 8.

Property Released from the Laboratory

Real Estate

We did not convey or transfer any land parcels during 2022.

Recycled Metals

A total of 1,895 tons of metal were recycled from the Laboratory in 2022. Metal that has been exposed to ionizing radiation during Laboratory operations (potentially activated metal) is evaluated for levels of radioactivity before being released for recycling. Potentially activated metal was evaluated using the protocol in the Multi-Agency Radiation Survey and Assessment for Materials and Equipment manual and was independently reviewed by DOE. About 95 tons of potentially activated metal was recycled in 2022 from the Los Alamos Neutron Science Center's accelerator operations. Other metal met the criteria for unrestricted radiological release under Title 10, Part 835, of the Code of Federal Regulations, *Occupational Radiation Protection*, and DOE Order 458.1. Metal items approved for release are sent to a metal recycler in Albuquerque, New Mexico, where they are broken up and sold as scrap.

Portable Property

Laboratory staff survey smaller personal property items (for example, tools and furniture) from radiologically controlled areas as needed. These items typically remain on site and, once cleared, their use is unrestricted. The policies and procedures for releasing these items comply with Title 10, Part 835, of the Code of Federal Regulations, *Occupational Radiation Protection*.

N3B surveyed and released property throughout 2022 as part of ongoing environmental remediation, waste packaging, and shipping operations. This effort included releasing 8 mixed low-level waste, 26 low-level waste, and 33 transuranic waste shipments for offsite disposal.

Establishment and Use of Authorized Limits

Screening action levels for radionuclides in soils are calculated for human health assessments based on exposure scenarios as part of LANL's corrective action process. DOE can determine whether a set of the screening action levels may be used as pre-approved authorized limits for unrestricted release of property being considered for conveyance and transfer to other agencies or entities. These pre-approved authorized limits for radionuclides in soils are evaluated every year to determine if an update is needed, for example, if screening action levels change because of revised exposure models. No updates were required in 2022.

Waste Management Summary

Management of wastes at LANL is a crucial component of our compliance with environmental laws and is discussed in the next several sections. Table 2-1 summarizes the disposal amounts and locations of several types of wastes that were either shipped off site or had an onsite final disposition in 2022. Some wastes are stored while we identify a disposal pathway. The following callout box explains the types of radioactive waste at LANL.

What are the types of radioactive waste?

Transuranic Waste – Waste that has an activity of alpha-emitting transuranic radionuclides with half-lives of 20 years or more (such as plutonium, cesium, and strontium) that is greater than 100 nanocuries per gram of waste.

Mixed Transuranic Waste – Transuranic waste along with at least one component defined as hazardous under the Resource Conservation and Recovery Act.

High-Level Waste – The highly radioactive waste that results from the reprocessing of spent nuclear fuel, transuranic waste, or tailings from the milling of uranium or thorium ore.

Low-Level Waste – Contains added radioactivity but does not contain high-level waste and also does not contain any waste defined as hazardous under the Resource Conservation and Recovery Act.

Mixed Low-Level Waste – Low-level waste along with at least one waste defined as hazardous under the Resource Conservation and Recovery Act.

Table 2-1. LANL Waste Disposal Methods and 2022 Disposal Amounts[a]

Waste Type	Method for Disposal	2022 Disposal Amount
Solid Transuranic Waste and Solid Mixed Transuranic Waste	The Laboratory sends solid transuranic and mixed transuranic wastes off site to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, when the waste meets the plant's waste acceptance criteria. Some transuranic and mixed transuranic waste is stored at LANL while waiting for an acceptable disposal pathway to be identified.	470 cubic yards (360 cubic meters)
Solid Low-Level Radioactive Waste	The Laboratory sends solid low-level radioactive waste off site to licensed treatment, storage, and disposal facilities. These sites include the Nevada Nuclear Security Site, operated by the DOE, and commercial facilities operated by Energy Solutions (Clive, Utah), Perma-Fix Northwest, Inc. (Richland, Washington), and Waste Control Specialists (Andrews County, Texas).	6,950 cubic yards (5,314 cubic meters)
Liquid Radioactive Waste	The Laboratory treats liquid radioactive waste on site at the Radioactive Liquid Waste Treatment Facility in Technical Area 50. The treated water is either evaporated or released at permitted outfall 051. The total volume treated was provided by the Radioactive Liquid Waste Treatment Facility. Additional liquid radioactive waste is dispositioned at offsite disposal facilities. This water has trace radionuclides.	279,146 gallons (1,056,684 liters)
Hazardous Waste	The Laboratory sends hazardous waste off site for treatment and disposal at licensed treatment, storage, and disposal facilities. These sites included Veolia North America (Henderson, Colorado) and Clean Harbors (Clive, Utah).	112 tons (101,587 kilograms)

Waste Type	Method for Disposal	2022 Disposal Amount
Solid Mixed Low-Level Waste	The Laboratory sends solid mixed low-level waste off site to licensed treatment, storage, and disposal facilities. These sites included Energy Solutions (Clive, Utah), Perma-Fix of Florida, Inc. (Gainesville, Florida), and Waste Control Specialists (Andrews County, Texas). Some mixed low-level waste is treated at one of the licensed facilities to meet land disposal restrictions and then disposed of at the Nevada Nuclear Security Site.	377 cubic yards (288 cubic meters)
Sanitary Solid Waste	The Laboratory sends sanitary solid waste, such as its office and cafeteria trash, to the Los Alamos County Eco Station for transfer to municipal landfills. Los Alamos County operates this transfer station and is responsible to the State of New Mexico for obtaining all related permits for these activities. The total weight of this waste was provided by the Los Alamos County Eco Station.	1,750 tons (1.59 million kilograms)
PCB Wastes[b]	Waste that contained polychlorinated biphenyls (PCBs), including transformers and objects contaminated with at least 50 parts per million PCBs, was sent to a U.S. Environmental Protection Agency–authorized treatment and disposal facility, Veolia North America (Henderson, Colorado).	0.21 tons (190 kilograms)
Asbestos Waste[c]	Waste that contains asbestos is deposited at any of several waste disposal sites operated in accordance with Title 40, Part 61, Section 154, of the Code of Federal Regulations.	260 cubic yards (199 cubic meters)

[a] Data from LANL's Waste Compliance and Tracking System database were used for totals of gross weights and volumes of waste shipped off site. Some categories of waste are not discussed in this report, such as nonhazardous waste, universal waste, and non-asbestos New Mexico special waste.
[b] This total includes waste that contained only PCBs. If a waste with PCBs also contains hazardous or low-level waste, the amount of that waste is captured in the other category.
[c] This total includes waste that contained only asbestos. If a waste with asbestos also contains hazardous or low-level waste, the amount of that waste is captured in the other category.

Radioactive Wastes

DOE Order 435.1 Chg 2, Radioactive Waste Management

Laboratory operations that use nuclear materials generate four types of radioactive wastes: low-level radioactive waste (also called "low-level waste"), mixed low-level waste, transuranic waste, and mixed transuranic waste. Radioactive waste generated during Laboratory operations must meet Laboratory onsite storage requirements and also requirements for transportation to and disposal at the final facility. All aspects of radioactive waste generation, storage, and disposal are regulated by DOE Order 435.1 Chg 2, *Radioactive Waste Management*, and DOE Manual 435.1-1.

Onsite Low-Level Radioactive Waste Disposal

Material Disposal Area G at Technical Area 54 (Area G) is the only active waste disposal facility at the Laboratory. Operations began at Area G in 1957 and included the historical disposal of low-level radioactive waste, certain infectious waste that contained radioactive materials, asbestos-containing material, PCBs, and temporary storage of transuranic waste. Mixed low-level waste and mixed transuranic waste have been stored in surface structures at Area G. The current capacity to dispose of low-level waste at Area G is very limited; waste is accepted for disposal only under special circumstances and with prior authorization. No waste was disposed of in Area G in 2022.

Planning for the closure of Area G has been underway since 1992. We are working with the New Mexico Environment Department Hazardous Waste Bureau under the 2016 Compliance Order on Consent to develop and implement corrective measures for the solid waste management units at Area G. Environmental monitoring at Area G includes

- a direct-penetrating radiation thermoluminescent dosimeter monitoring network (Chapter 4);
- an environmental air station monitoring network (Chapter 4);
- a groundwater monitoring network (Chapter 5); and
- periodic soil, vegetation, and small mammal sampling (Chapter 7).

What do these waste terms mean?

Treatment – Any process that changes the physical, chemical, or biological characteristics of a waste to minimize its threat to the environment.

Storage – Temporary holding of waste before the waste is treated, disposed of, or stored somewhere else. A **storage unit** stores hazardous waste. Examples include tanks, containers, drip pads, and containment buildings.

Disposal – Discharge, deposit, injection, or placing of any waste on or in the land or water. A disposal facility is any site where the waste is intentionally placed and where it will remain.

Table 2-2 provides the 2022 status of the DOE low-level waste disposal facility management process for Area G.

Table 2-2. DOE Low-Level Waste Disposal Facility Management Status for Area G

Management Process Phase	Status
Performance Assessment/ Composite Analysis	Revision 4 was approved in 2009 (LANL 2008). A determination of adequacy was published in April 2021.
Closure Plan	Plan issued in 2009 (LANL 2009).
Performance Assessment/ Composite Analysis Maintenance Program	Revised Plan issued in 2021 (Neptune 2021a). Updated analyses and modeling of erosion, cliff retreat, and infiltration were completed during 2020 (Neptune 2021b, Neptune 2021c).
Disposal Authorization Statement	Revision 2 was issued November 15, 2018. This revision identifies the DOE Environmental Management Field Office in Los Alamos as the responsible field office.

Hazardous Wastes

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act regulates wastes from generation to disposal. Hazardous wastes include all solid wastes that are

- listed as hazardous by the U.S. Environmental Protection Agency (listed wastes);
- ignitable, corrosive, reactive, or toxic (characteristic wastes); or
- batteries, pesticides, lamp bulbs, aerosol cans, or contain mercury.

Mixed radioactive waste (also called "mixed waste") is listed and/or characteristic hazardous waste that is mixed with radioactive waste. Under the Resource Conservation and Recovery Act, facilities that treat, store, or dispose of hazardous wastes—including mixed radioactive wastes—must obtain a permit from their regulatory agency.

LANL's Hazardous Waste Facility Permit

Permit Name	Los Alamos National Laboratory Hazardous Waste Facility Permit
Permit Number	NM 0890010515
Permit Issuer	New Mexico Environment Department
Permittee(s)	Department of Energy through its field offices, the National Nuclear Security Administration Los Alamos Field Office and the DOE-Environmental Management Los Alamos Field Office; Triad National Security, LLC (Triad); and Newport News Nuclear BWXT Los Alamos (N3B)
Permit Expiration Date	December 30, 2020
Permit Status	Administratively continued
Permit Regulator	New Mexico Environment Department Hazardous Waste Bureau
Permit Purpose	Authorize and regulate the storage and treatment of hazardous waste at Los Alamos National Laboratory

LANL's Hazardous Waste Facility Permit

- provides requirements for storage and sometimes treatment of hazardous waste at 27 separate hazardous waste management units (sites) at the Laboratory;
- provides requirements for waste management, sampling, reporting, inspection, training, waste minimization, preparedness and prevention, and emergency and contingency planning; and
- requires the Laboratory to post certain information for public review in an electronic information repository (electronic public reading rooms).

On June 29, 2020, we submitted a permit renewal application to the New Mexico Environment Department to renew and modify the 2010 LANL Hazardous Waste Facility Permit. The New Mexico Environment Department has issued two Administratively Incomplete Determinations for the permit renewal application. We have provided responses with additional information and supporting documents. The New Mexico Environment Department continued to review the application through 2022 and discuss with us necessary additional information.

Permit Modifications

The Hazardous Waste Facility Permit sometimes needs modification to address new information, changes in a facility, or changes in regulatory requirements. The three classes of modifications consist of minor modifications (Class 1 and Class 2) and major modifications (Class 3). Notices of all Class 2 and Class 3 proposed permit modifications are published in a newspaper of general circulation and include a request for public comment before approval by the regulatory agency. Notices of approvals of Class 1 permit modifications and proposed Class 2 and Class 3 permit modifications are mailed to members of the public who sign up for a LANL facility mailing list that is maintained by the New Mexico Environment Department.

We submitted two Class 1 permit modification requests and one Class 2 permit modification request in 2022:

- A Class 1 modification request to add a real-time radiography unit at Technical Area 54, Area G, Pad 10
- An administrative Class 1 modification request to update contact information and emergency equipment in the Contingency Plan in Attachment D
- A Class 2 modification request to add activities to the closure plan for the Technical Area 16 Building 399 Burn Tray

All permit modification requests were approved by the New Mexico Environment Department.

Reports and Other Activities

Triad and N3B sent coordinated demolition activity notifications to the New Mexico Environment Department for the quarters ending in March, June, September, and December of 2022. A 30-day demolition notification for Technical Area 64 Building 43 was sent in November of 2022. Annual waste minimization reporting, responses to requests for information from the New Mexico Environment Department, and annual electronic public reading room training were also coordinated between Triad and N3B.

We continued the process of certifying closure of the Technical Area 16 Building 399 Burn Tray unit that began in 2019 by proposing revisions to the closure plan to allow for additional removal of soil from the area and additional soil sample analysis. The revisions were approved.

During January through December 2022, we submitted five soil vapor monitoring reports for the Technical Area 63 Transuranic Waste Facility. These reports cover quarterly sampling events from November 2021 through October 2022. The results indicate that vapor concentrations at the site do not exceed the soil gas screening levels established by the Hazardous Waste Facility Permit. We also submitted a 15-day notification of detection of a new constituent in September 2022. One sample from vapor monitoring well VMW-3 indicated the presence of propanol[2-] (isopropyl alcohol) in the 5-foot sampling port for the first time since vapor sampling began.

The Hazardous Waste Report submitted in February 2022 covered hazardous and mixed waste generation, treatment, and storage activities performed at the Laboratory during calendar year 2021. During 2022 we completed the application, obtained an Emergency Permit, and produced a final report regarding the destruction of an unstable chemical container.

Inspections, Noncompliances, and Notices of Violation

The LANL Hazardous Waste Facility Permit requires us to provide the following notices and reports to the New Mexico Environment Department:

- advance written notice to the New Mexico Environment Department of any changes to any permitted unit or activity that may result in a noncompliance with the permit;
- verbal and written reports of the discovery of any noncompliance that may endanger human health or the environment; and
- an annual noncompliance report that includes releases and permit noncompliances that do not threaten human health or the environment.

The following identified releases or incidents of noncompliance for the reporting period October 1, 2021, through September 30, 2022, did not pose a potential threat to human health or the environment.

Triad reported two releases within or from a waste storage or treatment unit during the reporting period: water leakage from an eyewash station that was not completely closed after a monthly maintenance check and leakage from a valve in an anion exchange resin process that released a few milliliters of solution onto the secondary containment floor. These releases were reported to the New Mexico Environment Department in the FY 2021 Reporting of Releases and Instances of Noncompliance. Triad also reported a spill that totaled one liter or less of an unknown liquid in a dirt area at Technical Area 59. Although this spill did not meet notification requirements, we reported it to the New Mexico Environment Department in the FY 2022 Reporting of Releases and Instances of Noncompliance. During the reporting period, there were no releases at or from a permitted unit under N3B management.

Triad reported 10 instances of noncompliance with the permit. Reported instances included signage, container labeling, and personnel training:

- The danger signs along the outside of a treatment and storage facility were displayed only in English and Spanish. The signs are required to also be displayed in the Tewa language.
- Twelve containers were missing the hazard indicator(s) labels.
- Two containers had a Radioactive Waste label that covered the Hazardous Waste label.
- A container was missing the accumulation start date on the hazardous waste label.
- A waste stream profile was updated to remove the F003 waste code. The change was completed in the Waste Characterization and Tracking System, but the waste code was not immediately removed from the label on four waste containers.
- A required training for an individual working within a permitted area was expired.

Danger signs in Tewa were posted every 25 feet along the outside of the treatment and storage facility. All the labeling issues were immediately corrected upon discovery. The training was completed the day after discovery.

N3B reported eight instances of noncompliance with the permit. Reported instances included the following:

- Improper labeling
- A crack that redeveloped in the asphalt ground surface
- Out-of-service fire alarm pull stations
- Leakage from waste batteries onto secondary containment

- Improper signage
- Intrusion of stormwater in a dome
- Free liquids not stored on secondary containment
- Improperly characterized waste

N3B personnel conducted weekly inspections to identify noncompliance with the permit in the legacy waste cleanup program. Noncompliances have been corrected or are in the process of correction except for two containers with liquids. The two containers with liquids cannot immediately be placed on secondary containment because the action is not allowed by the approved nuclear evaluation of the safety of the situation. However, we are using multiple compensatory measures, including daily inspections and absorbent socks/pads around each container.

The New Mexico Environment Department conducted its annual compliance inspection for the Laboratory’s permit from November 14–17, 2022. The New Mexico Environment Department has not yet issued its Compliance Evaluation Inspection Report and Findings for the 2022 annual compliance inspections.

During 2022, the New Mexico Environment Department issued three notices of violation to LANL:

- A notice of violation and resolution was issued to LANL by the New Mexico Environment Department on July 19, 2022, based on the Department’s annual compliance inspection conducted on October 25, 2021. The violations included failure to keep a container of hazardous waste closed when not emptying or filling and failure to label hazardous waste containers storing hazardous waste with the words “Hazardous Waste.” The New Mexico Environment Department determined that the violations were adequately addressed.
- A notice of violation with proposed penalties was issued on July 26, 2022, based on the New Mexico Environment Department’s annual compliance inspection conducted on August 10, 2020. The violations included labeling, secondary containment, and waste characterization issues.
- A notice of violation with proposed penalties was issued to LANL by the New Mexico Environment Department on September 9, 2022, for failure to dispose of hazardous waste within 90 days or obtain a permit. The violations were corrected by February 24, 2022.

Settlement Agreement and Stipulated Final Order

On January 22, 2016, the DOE National Nuclear Security Administration, Los Alamos National Security, LLC (the previous management and operating contractor for the Laboratory), and the State of New Mexico signed a Settlement Agreement for resolution of potential penalties associated with the drum of transuranic waste that resulted in a 2014 contamination event at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. The settlement agreement included five supplemental environmental projects, which the National Nuclear Security Administration and the Laboratory implemented. The Watershed Enhancement Project and the Surface Water Sampling Project are complete. The following supplemental environmental project activities remain for 2022:

- Road Improvement Project – Improve routes at the Laboratory used for the transportation of transuranic waste to the Waste Isolation Pilot Plant; construction began in 2022 realigning the intersection of State Road 4 and East Jemez Road.
- Potable Water Line Replacement Project – Replace aging potable water lines and install metering equipment for Laboratory potable water systems; the final certification package for this Supplemental Environmental Project was submitted in 2022 to the New Mexico Environment Department.

Facility Groundwater Monitoring Program

The LANL Hazardous Waste Facility Permit requires the permittees to conduct groundwater monitoring for all regulated units subject to the groundwater monitoring requirements of Title 40, Part 264, Subpart F, of the Code of Federal Regulations and corrective action under Permit Section 11.2.

Currently, all groundwater monitoring is conducted under the Interim Facility-Wide Groundwater Monitoring Plan (N3B 2021), which is updated annually and fulfills the groundwater monitoring requirements of the Compliance Order on Consent. While the Consent Order is in effect, the groundwater monitoring requirements of the Consent Order fulfill the groundwater monitoring requirements under the LANL Hazardous Waste Facility Permit.

Groundwater monitoring activities conducted under the Interim Facility-Wide Groundwater-Monitoring Plan and monitoring results are discussed in Chapter 5, Groundwater Protection.

The 2016 Compliance Order on Consent

The 2016 Compliance Order on Consent (modified in 2017; available at https://www.env.nm.gov/hazardous-waste/lanl) is a settlement agreement between the New Mexico Environment Department and DOE that addresses cleanup of legacy wastes. It supersedes the Compliance Order on Consent issued in 2005. The order guides and governs the ongoing cleanup of legacy waste at the Laboratory through an annual work planning process.

The Laboratory has two types of legacy waste corrective action sites: Solid Waste Management Units and Areas of Concern. Solid Waste Management Units are areas where solid wastes were placed or spilled. Examples of these units include certain septic tanks, firing sites, landfills, sumps, and areas that historically received liquid effluents from outfalls. Areas of Concern are areas that could have received a hazardous waste or hazardous constituents through soil movement or the flow of liquid wastes from Laboratory facilities. Examples include canyon bottoms downstream from historical outfalls.

As of October 1, 2022, the Laboratory had 1,405 corrective action sites listed in Appendix A of the 2016 Compliance Order on Consent. During fiscal year 2022, no sites received certificates of completion with controls, one site received a certificate of completion without controls, and no sites were changed to a deferred status. Therefore, at the end of fiscal year 2022, 88 corrective action sites had certificates of completion with controls, 288 had certificates of completion without controls, and 134 sites were deferred until they no longer had active operations. The remaining 895 Solid Waste Management Units and Areas of Concern had investigations or corrective actions (or both) either in progress or pending.

The Compliance Order on Consent also addresses remediation of groundwater. Groundwater remediation activities are discussed in detail in Chapter 5, Groundwater Protection.

During fiscal year 2022, we submitted the following documents to the New Mexico Environment Department Hazardous Waste Bureau as part of the Consent Order deliverables:

- seven Periodic Monitoring Reports for five groundwater monitoring groups,
- one annual update on the Interim Facility-Wide Groundwater Monitoring Plan,
- one annual update for Los Alamos/Pueblo Canyon Watershed Sediment Transport Mitigation Project,
- one report on the Sandia Canyon Wetland Performance,
- one biennial erosion control inspection report,
- one investigation work plan and three investigation reports, and
- two Annual Long-Term Monitoring and Maintenance Reports for the Corrective Measures Implementation.

Mixed Wastes

Federal Facility Compliance Act

The Federal Facility Compliance Act requires federal facilities that generate or store mixed radioactive and hazardous wastes to submit a Site Treatment Plan that includes a schedule for developing capacities and technologies to treat all mixed waste. In October 1995, the State of New Mexico issued a Federal Facility Compliance Order to the Laboratory that required a Site Treatment Plan for mixed radioactive and hazardous wastes.

While identifying treatment and disposal options for the mixed waste inventory, the Laboratory's Site Treatment Plan allows us to store accumulated mixed waste at permitted storage units for more than 1 year, which is otherwise prohibited by the Land Disposal Restrictions provision of the Resource Conservation and Recovery Act. The Site Treatment Plan provides enforceable time periods for treating or otherwise meeting land disposal restriction requirements for the accumulated waste.

We update the Laboratory's Site Treatment Plan every year. An annual report describes the amount of mixed waste that has been stored at LANL under the provisions of the plan and the amount shipped to approved treatment, storage, and disposal facilities. This report must be submitted to the New Mexico Environment Department on March 31 each year and contains data from the previous fiscal year (October 1 to September 30).

During fiscal year 2022, the amount of mixed low-level waste covered under the Site Treatment Plan decreased from 200 cubic yards (153 cubic meters) to 128 cubic yards (98 cubic meters). This change was due to offsite shipments of 89 cubic yards (68 cubic meters), administrative adjustments of 7.8 cubic yards (6 cubic meters), and the addition of 7.8 cubic yards (6 cubic meters) of new waste.

During fiscal year 2022, the amount of mixed transuranic waste covered under the Site Treatment Plan decreased from approximately 1,963 cubic yards (1,501 cubic meters) to 1,817 cubic yards (1,389 cubic meters). This change was due to 339 cubic yards (259 cubic meters) shipped to the Waste Isolation Pilot Plant, administrative adjustments of 136 cubic yards (104 cubic meters), and 56 cubic yards (43 cubic meters) of new waste.

Volumes of mixed waste managed under the Site Treatment Plan at the Laboratory during fiscal year 2022 are provided in Table 2-3. These waste volumes may be adjusted slightly by reconciliation during the New Mexico Environment Department review of the Site Treatment Plan update. Approved Site Treatment Plan updates are available at http://www.env.nm.gov/hazardous-waste/lanl-ffco-stp/.

Table 2-3. Approximate Volumes of Mixed Waste Stored and Shipped Off Site for Treatment and/or Disposal under LANL's Site Treatment Plan by the Management and Operating Contractor (Triad) and the Legacy Waste Cleanup Contractor (N3B) during Fiscal Year 2022

LANL Contractor	Volume of mixed wastes stored at LANL under the Site Treatment Plan	Volume of mixed wastes shipped off site under the Site Treatment Plan
Mixed Low-Level Waste		
Triad	0.27 cubic yards (0.208 cubic meters)	17 cubic yards (13 cubic meters)
N3B	128 cubic yards (98 cubic meters)	71 cubic yards (54 cubic meters)
Mixed Transuranic Waste		
Triad	217 cubic yards (166 cubic meters)	67 cubic yards (51 cubic meters)
N3B	1,601 cubic yards (1,224 cubic meters)	272 cubic yards (208 cubic meters)

Other Wastes

Toxic Substances Control Act

The Toxic Substances Control Act addresses the production, import, use, and disposal of specific chemicals, including PCBs. The Laboratory is responsible for record keeping and reporting on the import or export of small quantities of chemicals used for LANL research activities and the disposal of PCB-containing substances. PCB-containing substances include dielectric fluids, solvents, oils, waste oils, heat-transfer fluids, hydraulic fluids, slurries, soil, and materials contaminated by spills.

We conducted 25 Toxic Substances Control Act reviews for regulated chemicals imported or exported by the Laboratory's Property Management Group Customs Office in 2022. These reviews ensure that the regulated chemicals follow Toxic Substance Control Act requirements before being imported or exported out of the country. These shipments were all properly categorized, and the chemical compound samples were sent to collaborative researchers in other countries.

Air Quality and Protection

Clean Air Act

Title V Operating Permit

Permit Name	Los Alamos National Laboratory Title V Operating Permit
Permit Number	P100-R2M4
Permit Issuer	New Mexico Environment Department Air Quality Bureau
Permittee(s)	Department of Energy, National Nuclear Security Administration and Triad National Security, LLC
Permit Expiration Date	Expired February 2020 (renewal application submitted February 2019)
Permit Status	Operations continue under the current permit under the "Permit Shield" provisions of Title 20 Chapter 2 Part 70 Section 400 of the New Mexico Administrative Code until a new permit is issued
Permit Regulator	New Mexico Environment Department Air Quality Bureau
Permit Purpose	Authorize and regulate emissions of specified air pollutants at Los Alamos National Laboratory

Under the Clean Air Act, the Laboratory is regulated as a major source of air pollutants based on its potential to emit nitrous oxides, carbon monoxide, and volatile organic compounds. The Laboratory has a Clean Air Act Title V Operating Permit and is required to keep air emissions of regulated pollutants below permit limits. In 2019, we submitted a five-year Title V permit renewal application. The current Title V Operating Permit expired on February 27, 2020. The Laboratory continues to operate under its existing Title V Operating Permit under the provisions of Title 20 Chapter 2 Part 70 Section 400 of the New Mexico Administrative Code until a new permit is issued.

We annually certify our compliance with the conditions of our Title V Operating Permit and report any deviations to the New Mexico Environment Department. Deviations occur when a permit condition is not met. In 2022, no deviations were reported for the Laboratory.

Table 2-4 summarizes the Laboratory's emissions data and provides a list of the major sources of these air pollutants at the Laboratory.

Table 2-4. Calculated Emissions of Regulated Air Pollutants Reported to the New Mexico Environment Department in 2022

Emission Unit	Pollutants (tons)					
	Nitrous Oxides	Sulfur Oxides	Particulate Matter	Carbon Monoxide	Volatile Organic Compounds	Other Hazardous Air Pollutants
Asphalt plant	0	0	0	0	0	0
Technical Area 3 power plant (3 boilers)	9.51	0.10	1.25	6.56	0.90	0.31
Technical Area 3 power plant (combustion turbine)	16.87	1.17	2.27	3.51	0.74	0.44
Research and development chemical use	n/a	n/a	n/a	n/a	11.46	5.57
Degreaser	n/a	n/a	n/a	n/a	0.036	0.036
Data disintegrator	n/a	n/a	0.30	n/a	n/a	n/a
Stationary standby generators[a]	3.12	0.08	0.12	0.58	0.12	0.001
Miscellaneous small boilers	18.91	0.10	1.52	15.90	1.09	0.36
Permitted generators (11 units)	2.74	0.02	0.29	2.08	0.13	0.06
TOTAL	51.15	1.47	5.75	29.59	14.78	6.78
Permit Limits (tons/year)	245	150	120	225	200	120

n/a = not applicable.

[a] The stationary standby generators are no longer sources in the Laboratory's Title V permit; however, they are included in this table for comparison with previous annual site environmental reports.

The Laboratory's emissions in 2022 were significantly lower than the permit limits; for example, nitrogen oxide emissions were approximately 21 percent of the permit limit, carbon monoxide emissions were 12 percent of the permit limit, and particulate matter emissions were 5 percent of the permit limit. No emissions above permit limits occurred from any of the permitted sources.

Figure 2-1 depicts a 5-year history of pollutant emissions at the Laboratory. The Laboratory has been generating more of its own electricity since 2019 using a combustion turbine at Technical Area 03. This electricity generation has caused an overall increase in the Laboratory's nitrogen oxide emissions, though still well within permit limits.

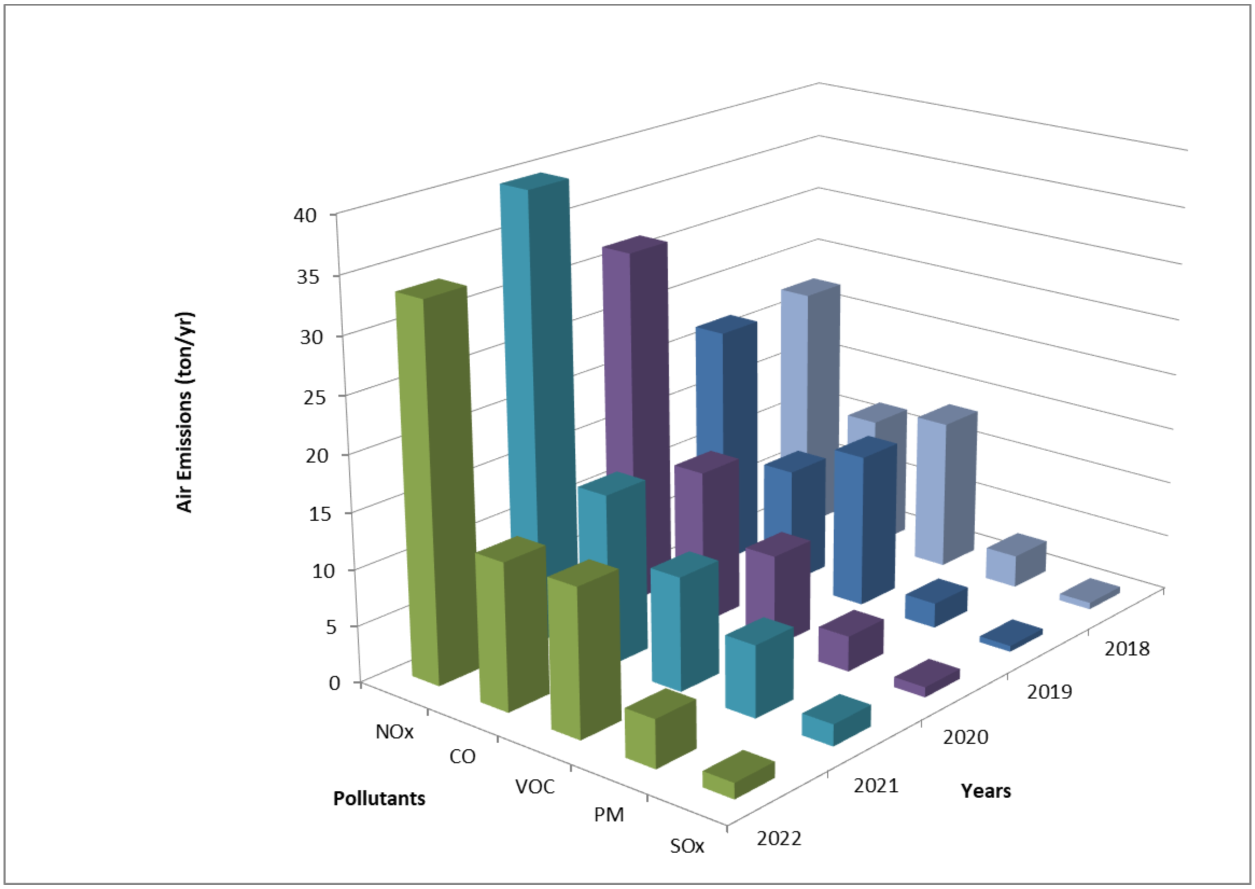


Figure 2-1. LANL criteria pollutant emissions from 2018 through 2022. These totals do not include small boilers or standby generators.

Management of Refrigerants and Halons under Title VI – Stratospheric Ozone Protection and the American Innovation and Manufacturing Act

Title VI of the Clean Air Act regulates chemicals known to deplete the ozone layer in our atmosphere, such as halons, chlorofluorocarbons, hydrochlorofluorocarbons, and other non-ozone-depleting chemicals such as hydrofluorocarbons. These chemicals are primarily used as refrigerants, solvents, propellants, and foam-blowing agents. The regulations prohibit the Laboratory from knowingly venting or otherwise releasing into the environment any of these chemicals during maintenance, service, repair, or disposal of refrigeration equipment (such as air conditioners, refrigerators, chillers, or freezers) or fire-suppression systems. All technicians who work on refrigeration equipment at the Laboratory are certified by the U.S. Environmental Protection Agency. We are working to remove refrigeration equipment that uses ozone-depleting substances and replace it with equipment that uses more environmentally friendly refrigerants identified as acceptable in the U.S. Environmental Protection Agency's Significant New Alternatives Program. In 2022, 3,226 pounds of refrigerant was sent off site for disposal. Of that amount, 1,374 pounds was hydrochlorofluorocarbons and 1,852 pounds was hydrofluorocarbons. Additionally, we decommissioned the last remaining fire-suppression system that used halon. The halon was removed and shipped off site for recycling.

Regulation of Airborne Radionuclide Emissions under the Radionuclide National Emission Standards for Hazardous Air Pollutants

Emissions of airborne radionuclides are regulated under the Radionuclide National Emission Standards for Hazardous Air Pollutants, which sets a dose limit of 10 millirem per year to any member of the public for air emissions. The estimated maximum dose of air emissions to a member of the public in 2022 was 0.45 millirem, less than 5 percent of the limit allowed by the Clean Air Act regulations (see Chapter 8, Public Dose and Risk Assessment).

Asbestos Notifications

The Asbestos National Emission Standards for Hazardous Air Pollutants require the Laboratory to provide advance notice to the New Mexico Environment Department Air Quality Bureau for large renovation jobs that involve asbestos and for all demolition projects. The standards also require that facilities that conduct activities involving asbestos mitigate visible airborne emissions and properly package and dispose of all asbestos-containing wastes. In 2022, 17 large renovation and demolition projects were completed by Triad. Advance notification to the New Mexico Environment Department was submitted for each of these projects. All asbestos waste was properly packaged and disposed of at approved landfills. N3B did not complete any large renovation or demolition projects in 2022.

New Mexico Air Quality Control Act

New Source Reviews

The State of New Mexico requires new or modified sources of emissions to be evaluated to determine whether they

- do not require a construction permit because they are exempted under the New Mexico Administrative Code (“exempted”),
- do not produce sufficient emissions to require a construction permit (“No Permit Required”),
- require a notice of intent to construct, or
- require a construction permit.

In 2022, we submitted one Administrative Permit Revision, one No Permit Required request, and five exemption notices to the New Mexico Environment Department Air Quality Bureau as follows:

- In February 2022, we filed an exemption notice for an emergency stand-by generator at Technical Area 3, Building 1398. Emergency stand-by generators are exempt from construction permitting if they operate only during the unavoidable loss of commercial power and operate less than 500 hours per year.
- In March 2022, we filed an exemption notice for a small portable diesel-fired generator to support projects in remote locations within LANL property. Based on its small size, the generator has the potential to emit less than 0.5 tons per year of any regulated pollutant.
- In March 2022, we also filed an exemption notice for 24 exempt sources (fuel-burning equipment used solely for heating buildings for personal comfort or for producing hot

water for personal use that use gaseous fuel and are rated at less than or equal to five million British Thermal Units per hour).

- In April 2022, we filed an exemption notice for a small, portable, diesel-fired generator to support air-monitoring activities. Based on its small size, the generator has potential to emit less than 0.5 tons per year of any regulated pollutant.
- In July 2022, we filed an exemption notice for a paint booth that has a potential emission rate of volatile organic carbons of less than 10 pounds per hour.
- In July 2022, we filed an Administrative Permit Revision application for our construction permit for the Technical Area 3 combustion turbine, requesting an identical turbine engine replacement.
- In November 2022, we filed a No Permit Required determination request for a project that involves synthesis and characterization of beryllium compounds that does not result in any emissions to the ambient air.

Additionally, during 2022 we continued discussions with the New Mexico Environment Department Air Quality Bureau to address public comments and revise draft permit language on a permit application submitted in 2021. In December 2021, we applied for a modification of the construction permit for beryllium machining at the LANL Target Fabrication Facility at Technical Area 35, Building 213.

The active Construction Permits issued to the Laboratory under the New Mexico Air Quality Control Act are listed in the Summary of Permits and Compliance Orders section.

Surface Water Quality and Protection

Clean Water Act

The primary goal of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The Act requires National Pollutant Discharge Elimination System permits for several types of effluent and storm water discharges. The following permits contain specific chemical, physical, and biological criteria and management practices that the Laboratory must meet when discharging water. The U.S. Environmental Protection Agency, Region 6, provides and enforces the Laboratory's Clean Water Act permits. The New Mexico Environment Department certifies the permits as protective of waters of the state and performs some compliance inspections and monitoring on behalf of the U.S. Environmental Protection Agency.

LANL's National Pollutant Discharge Elimination System Industrial and Sanitary Point-Source Outfall Permit (Outfall Permit)

Permit Name	Los Alamos National Laboratory National Pollutant Discharge Elimination System Industrial and Sanitary Point-Source Outfall Permit
Permit Number	NM0028355
Permit Issuer	U.S. Environmental Protection Agency
Permittee(s)	U.S. Department of Energy, Triad National Security, LLC.
Permit Expiration Date	August 2027
Permit Status	Effective
Permit Regulator(s)	U.S. Environmental Protection Agency and New Mexico Environment Department Water Quality Bureau
Permit Purpose	Authorize and regulate liquid effluent discharges to the environment from LANL's industrial and sanitary outfalls.

The Laboratory's current National Pollutant Discharge Elimination System Industrial and Sanitary Point-Source Outfall Permit includes 1 sanitary and 10 industrial outfalls that discharge into four watersheds (see Table 2-5).

Table 2-5. Volume of Effluent Discharged from Permitted Outfalls in 2022

Outfall No.	Building No.	Description	Canyon Receiving Discharge	2022 Discharge (gallons)
03A048	53-963/978	Los Alamos Neutron Science Center cooling tower	Los Alamos	26,215,620
051	50-1	Technical Area 50 Radioactive Liquid Waste Treatment Facility	Mortandad	220,556
03A022[a]	3-2238	Sigma emergency cooling system	Mortandad	1,134,244
03A160	35-124	National High Magnetic Field Laboratory cooling tower	Mortandad	0
03A181	55-6	Plutonium Facility cooling tower	Mortandad	4,221,429
13S	46-347	Sanitary wastewater system plant	Canada del Buey	0
001	3-22	Power plant (includes treated effluent from sanitary wastewater system plant)	Sandia	86,056,541
03A027	3-2327	Strategic Computing Complex cooling tower	Sandia	0
03A113	53-293/952	Los Alamos Neutron Science Center cooling tower	Sandia	296,970
03A199	3-1837	Laboratory Data Communications Center	Sandia	12,755,900
05A055	16-1508	High Explosives Wastewater Treatment Facility	Water	0
2022 Total:				130,901,260

[a] This outfall's designation was changed back to 03A022 from 04A022 in the March 2022 permit renewal to reflect cooling water, emergency cooling water, and roof drain/storm water discharges to the outfall (cooling tower blowdown was diverted to the sanitary wastewater system plant).

The Laboratory's Outfall Permit requires weekly, monthly, quarterly, yearly, and term sampling of liquid effluents discharged to the environment from the outfalls. The sampling results are compared with the permit limits and are reported every month in an electronic Discharge Monitoring Report to the U.S. Environmental Protection Agency and the New Mexico Environment Department. Additionally, any engineering changes or flow changes that would affect quality or quantity of the effluents are reported in a Notice of Planned Change to the U.S. Environmental Protection Agency and the New Mexico Environment Department.

We collected 785 samples in 2022 from Outfalls 001, 03A048, 03A113, 03A181, 03A199, 03A022, and 051. Six of these samples (less than 1.0 percent) exceeded a permit limit (see Table 2-6). Each exceedance was addressed immediately by correcting the cause or ceasing the discharge until corrective actions could be implemented. Outfalls 13S, 03A027, 03A160, and 05A055 did not discharge in 2022.

Table 2-6. Exceedances at National Pollutant Discharge Elimination System–Permitted Industrial and Sanitary Outfalls in 2022

Outfall No.	Parameter	Date	Permit Limit	Result	Corrective Action
001	Total Residual Chlorine Daily Max	2/10/2022	0.011 milligrams per liter	0.02 milligrams per liter	Increased the amount of dechlorination chemical.
03A113	Total Residual Chlorine Daily Max	2/10/2022	0.011 milligrams per liter	0.03 milligrams per liter	Filled the dechlorination chemical feed tank and restored chemical addition to the cooling tower blowdown.
001	pH	5/2/2022	6.6–8.8	6.5	Result was not consistent with operational sampling. Sampling team replaced the pH probe.
051	Total Copper Daily Max and Monthly Average	7/6/2022	0.014 milligrams per liter	0.0144 milligrams per liter	Investigated potential causes including evaluating sampling technique, equipment, upstream operations, and operational data collected from the facility. The facility operational sample collected prior to discharge was not above the permit limit. Cause could not be determined.
051	Whole Effluent Toxicity	11/8/2022	100%	56%	Investigated potential causes including alkalinity, hardness, dissolved oxygen, and metals concentrations. Collected an operational sample for whole effluent toxicity testing prior to the next outfall discharge. Results could not be duplicated.
001	Total Residual Chlorine Daily Max	12/19/2022	0.011 milligrams per liter	0.02 milligrams per liter	Refilled the dechlorination chemical feed container.

National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites (Construction General Permit)

Permit Name	National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites (Construction General Permit)
Permit Number	This is the 2022 Construction General Permit.
Permit Issuer	U.S. Environmental Protection Agency
Permittee(s)	Nation-wide permit covers all eligible construction activities
Permit Expiration Date	February 16, 2027
Permit Status	Currently in effect
Permit Regulator(s)	U.S. Environmental Protection Agency
Permit Purpose	Authorize and regulate discharges of storm water from construction sites or common plans of development covering one or more acres.

To comply with the Construction General Permit, we develop storm water pollution prevention plans for construction sites covering 1 or more acres, or projects less than 1 acre that are part of a common plan of development. A storm water pollution prevention plan describes the project activities, site conditions, best management practices for sediment and erosion control, and permanent control measures (such as storm water detention ponds) required for reducing pollutants in storm water discharges. We inspect the location and condition of storm water controls during construction and identify corrective actions if needed. Upon completion of each project, a notice of termination is submitted to the U.S. Environmental Protection Agency to terminate permit coverage.

In 2022, Triad was responsible for 32 storm water pollution prevention plans and performed 908 inspections, with 95.2 percent of inspections fully compliant. Triad also successfully completed site-wide implementation of the new 2022 Construction General Permit issued by the U.S. Environmental Protection Agency, which was effective February 17, 2022.

During 2022, N3B operated eight projects that were covered under the Construction General Permit. These projects were routinely inspected and operated in accordance with Construction General Permit requirements.

National Pollutant Discharge Elimination System Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activities (Multi-Sector General Permit)

Permit Name	National Pollutant Discharge Elimination System Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activities
Permit Tracking Number(s)	NMR050011 (N3B), NMR050012 (N3B), and NRM050013 (Triad)
Permit Issuer	U.S. Environmental Protection Agency
Permittee(s)	General permit covers all eligible industrial activities in jurisdictions regulated by the U.S Environmental Protection Agency
Permit Expiration Date	February 28, 2026
Permit Status	Currently in effect
Permit Regulator(s)	U.S. Environmental Protection Agency
Permit Purpose	Authorize and regulate discharges of storm water and specific types of non-storm water associated with industrial activities and facilities.

Industrial activities conducted at the Laboratory and covered under the Multi-Sector General Permit include metals fabrication, vehicle and equipment maintenance, hazardous waste treatment and storage, recycling, warehousing activities, and asphalt manufacturing.

The Multi-Sector General Permit directs permittees to minimize releases of pollutants and to meet the permit's restrictions on quantities, rates, and concentrations of chemical, physical, biological, and other constituents in discharged waters. Mandatory activities include minimizing exposure of industrial materials to storm water, good housekeeping practices at covered facilities, maintenance, spill prevention and response, and employee training. Permittees conduct facility inspections and visual assessments of industrial storm water discharges and take corrective actions as needed.

Under the current Multi-Sector General Permit, we are required to monitor storm water at our covered facilities for the types of water quality parameters at the frequency and durations listed in Table 2-7.

Table 2-7. Multi-Sector General Permit Storm Water Monitoring Requirements

Parameter	Monitoring Schedule
Quarterly Indicator Parameters; Total Suspended Solids, Chemical Oxygen Demand, and pH	Quarterly for the duration of the permit
Semi-annual Indicator Parameters; Polycyclic Aromatic Hydrocarbons	Twice annually in Years 1 and 4 of the permit

Parameter	Monitoring Schedule
Benchmark Parameters	Quarterly in Years 1 and 4 of the permit unless an event occurs that triggers corrective action; if a triggering event occurs, the parameter is monitored quarterly until results indicate a return-to-baseline status
Effluent Limitations Guideline Parameters	Annually for the duration of the permit
Impaired Waters Parameters	Annually in Years 1 and 4 of the permit; if a parameter is detected, it is monitored annually until the parameter is not detected

The permit requires specific corrective actions called "Additional Implementation Measures" for exceedances of benchmark parameters. Three levels of Additional Implementation Measures prescribe increasingly robust storm water controls. A benchmark exceedance means that the concentration of a parameter exceeded the industry-sector-specific benchmark value specified in the Multi-Sector General Permit. Benchmark values are not permit limits.

All types of exceedances require evaluation of potential sources and either follow-up action or documentation of why no action is required.

Responsibilities for Multi-Sector General Permit compliance at the Laboratory are identified by Permit Tracking Number and Operator in Table 2-8.

Table 2-8. Multi-Sector General Permit Tracking Numbers by Operator and Covered Industrial Activity

Permit Tracking No.	Industrial Activities Covered	Responsible Operator	Operator Role
NMR050011	Technical Area 54 Maintenance Facility West	N3B	Environmental Management Legacy Cleanup
NMR050012	Technical Area 54 Areas G and L	N3B	Environmental Management Legacy Cleanup
NMR050013	Metal fabrication, vehicle and equipment maintenance, recycling activities, warehousing activities, and asphalt manufacturing	Triad National Security, LLC	National Nuclear Security Administration Management and Operations

Annual compliance activities are reported separately for each operator.

Management and Operating Contractor (Triad) Compliance Summary

Eight facilities operated by Triad are covered under the current Multi-Sector General Permit. We conduct permit-related storm water monitoring year-round. All corrective actions associated with exceedances recorded in 2022 have been completed.

In 2022, we completed the following tasks as part of the Multi-Sector General Permit compliance for Triad:

- 88 inspections of storm water controls

- 1 annual inspection at each of 39 sites having "no exposure" status
- collection of 190 samples
- 457 inspections of ISCO automated sampler equipment
- 103 inspections of single-stage samplers at substantially identical discharge points (discharge points that discharge storm water from the same source and with the same control measures and amount of storm water runoff per unit area)
- 38 visual inspections at 14 monitored discharge points
- 40 visual inspections at 10 substantially identical discharge points, and
- 144 corrective actions:
  - 18 control measures maintained, repaired, or replaced
  - 80 corrective actions to remedy control measures inadequate to meet non-numeric effluent limitation guidelines
  - 40 corrective actions to address unauthorized releases (spills) or discharges
  - 1 corrective action in response to a numeric effluent limitation guideline exceedance
  - 5 actions establishing additional implementation measures in response to benchmark exceedances

By meeting permit-defined criteria, we were able to discontinue monitoring as summarized in Table 2-9. Monitoring was discontinued for the following reasons:

- Impaired Waters parameters were not detected in storm water samples during Calendar Year 2 of the permit.
- Polycyclic Aromatic Hydrocarbons (Indicator Parameter) were not detected in storm water samples.
- The average of four quarterly results for Benchmark parameters was less than the benchmark value.

Table 2-9. 2022 Parameters with Discontinued Monitoring until Permit Year 4 at Specified Discharge Points

Parameter Type	Parameter	Discharge Points
Impaired Waters	Mercury, total	043
Impaired Waters	Total Aroclors	037, 079
Impaired Waters	Adjusted Gross Alpha	031
Indicator Parameter – Semi Annual	Polycyclic Aromatic Hydrocarbons	043
Benchmark	Zinc, dissolved	022, 076, 077
Benchmark	Nitrate plus Nitrite Nitrogen	022

Table 2-10 summarizes Triad's 2022 exceedances of benchmark parameters and the associated Additional Implementation Measure level applied as a corrective action.

Table 2-10. 2022 Exceedances of the Management and Operating Contractor's National Pollutant Discharge Elimination System Multi-Sector General Permit Benchmark Values and the Applied Additional Implementation Measure Level

Discharge Point	Exceeded Parameter[a] and Additional Implementation Measure Level[b]		Last Sample Date
	Aluminum, total recoverable	Nitrate plus Nitrite Nitrogen	
022	Level 1	No exceedance	3/17/2022
077	Level 2	Level 1	7/30/2022

[a] An exceedance of a benchmark value means that the reported average concentration of the identified parameter in four (or fewer) representative quarterly storm water samples exceeded an industry-sector-specific benchmark value specified in the Multi-Sector General Permit. Benchmark values are not permit limits.
[b] As quarterly monitoring continues, additional implementation measure levels could advance to the next level or return to baseline. This table reflects the additional implementation measure level at the end of calendar year 2022.

Legacy Cleanup Contractor (N3B) Compliance Summary

Two Laboratory facilities (Technical Area 54, Areas G and L, and Maintenance Facility West) subject to N3B control are permitted under the 2021 Multi-Sector General Permit. Monitoring of storm water discharges at N3B-permitted facilities occurs between April 1 and November 30 each year.

We completed the following tasks during 2022 as part of Multi-Sector General Permit compliance for N3B:

- Performed 4 routine facility inspections at each Multi-Sector General Permit–covered facility
- Performed 67 quarterly visual inspections of storm water discharges from monitored outfalls/substantially identical discharge points
- Collected Annual Impaired Waters monitoring samples from all 6 monitored outfalls (5 at Technical Area 54 Areas G and L and 1 at Maintenance Facility West)
- Collected 14 quarterly benchmark samples from 5 monitored outfalls at Technical Area 54, Areas G and L
- Completed 7 corrective actions to address needed maintenance or in response to storm water exceedances of benchmark values or a New Mexico surface water quality standard
- Completed employee training in accordance with Part 2.1.2.8 of the Multi-Sector General Permit

Table 2-11 summarizes exceedances of Impaired Waters parameters and benchmark values in storm water samples collected in 2022 from N3B-operated facilities.

Table 2-11. 2022 Exceedances of N3B's National Pollutant Discharge Elimination System Multi-Sector General Permit Benchmark Values[a] or Impaired Waters Parameters[b]

N3B Facility	Monitored Discharge Point	Exceedance									Sample Date(s)
		Benchmark Values						Impaired Waters Parameters			
		Total Cadmium	Dissolved Cadmium	Total Selenium	Total Lead	Ammonia	Chemical Oxygen Demand	Adjusted Gross Alpha	Total Recoverable Aluminum	Dissolved Copper	
Technical Area 54 Maintenance Facility West	049	n/a[c]	n/a	n/a	n/a	n/a	n/a	✓	✓		6/25/2022
Technical Area 54 Areas G and L	050						✓		n/a	n/a	10/02/2022
Technical Area 54 Areas G and L	051			✓	✓						8/11/2022
Technical Area 54 Areas G and L	053					✓	✓				6/17/2022, 11/13/2022 (chemical oxygen demand only)
Technical Area 54 Areas G and L	069						✓		✓	✓	6/22/2022, 10/02/2022 (chemical oxygen demand only)
Technical Area 54 Areas G and L	072						✓		n/a	n/a	6/22/2022, 8/11/2022

[a] An exceedance of a benchmark value means that the concentration of the identified parameter in a quarterly storm water sample exceeded a benchmark value for that parameter specific to the type of industrial activity at the facility. Benchmark values are not permit limits.

[b] An impaired waters exceedance means that the reported concentration of the identified parameter in a storm water sample exceeded a New Mexico surface water quality standard for the receiving stream segment as provided in Standards for Interstate and Intrastate Surface Waters, Title 20 Chapter 6, Part 4, of the New Mexico Administrative Code.

[c] "n/a" indicates that monitoring for the identified parameter is not required at that discharge point; blank indicates that the substance was tested for and did not exceed the parameter.

LANL's Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System (from Solid Waste Management Units and Areas of Concern) (Storm Water Individual Permit)

Permit Name	Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System
Permit Number	NM0030759
Permit Issuer	Issued by U.S. Environmental Protection Agency and certified by the New Mexico Environment Department
Permittee(s)	Newport News Nuclear BWXT-Los Alamos, LLC (N3B) and U.S. Department of Energy
Permit Expiration Date	July 31, 2027
Permit Status	Effective as of August 1, 2022
Permit Regulator(s)	U.S. Environmental Protection Agency
Permit Purpose	Authorize and regulate discharges of storm water from specified solid waste management units and areas of concern at Los Alamos National Laboratory.

The Individual Permit Authorization to Discharge under the National Pollutant Discharge Elimination System (Storm Water Individual Permit) authorizes discharges of storm water from certain Solid Waste Management Units and Areas of Concern (hereafter called "sites") at the Laboratory. The objective is to prevent storm water runoff from transporting pollutants of concern from these sites to surface waters. Pollutants of concern that potentially occur at these sites include metals, organic chemicals, high explosives, and radionuclides.

The U.S. Environmental Protection Agency first issued the permit in 2009. The 2022 permit, which supersedes and replaces the 2010 modification of the original permit, became effective August 1, 2022. A minor modification to address administrative changes was issued on September 9, 2022. The 2022 permit covers 397 sites.

The Storm Water Individual Permit has technology-based requirements for storm water control. Technology-based requirements mean that storm water controls that reflect best industry practices—considering their availability, economic achievability, and practicability—are required at each of the current 397 sites. Examples of controls used to manage storm water under the Storm Water Individual Permit include retention berms and coir logs. These storm water controls are routinely inspected and are maintained as needed. The original permit required LANL to install baseline controls at the listed sites. These controls were completed and certified to the U.S. Environmental Protection Agency by 2011. We plan to complete baseline controls for new sites added to the 2022 permit in 2023.

The 397 sites are grouped into 239 small sub-watersheds, called "site-monitoring areas," for permit monitoring. Pollutants of concern for each site-monitoring area are identified by reviewing site histories and soil data. Each year, we will submit an updated Sampling Implementation Plan to the U.S. Environmental Protection Agency. The plan reviews current and historical site histories, soil data, and stormwater data to determine the course of action for each site-monitoring area.

Specific locations within each of the site-monitoring areas are used to sample the storm water runoff from the sites. If target action levels of pollutants, which are based on the New Mexico surface water quality standards, are exceeded in the storm water samples, corrective action and additional controls called "enhanced controls" are installed. Additional storm water sampling is required and is referred to as "corrective action monitoring." Site-monitoring areas where we have not collected sufficient storm water samples to evaluate the target action levels, for example, because of a lack of local rainfall, are referred to as being in "extended baseline monitoring."

If all control measures have been installed and the results of sampling confirm that all pollutants of concern for a site-monitoring area are below the target action levels, the Laboratory certifies to the U.S. Environmental Protection Agency that the corrective actions are complete for the sites in that site-monitoring area.

If all the storm water control measures have been installed but the Laboratory cannot demonstrate that all results are below target action levels (for example, if natural background concentrations at the site are above the target action levels), the Laboratory can request that a site be placed in alternative compliance. For a site placed in alternative compliance, the corrective action is completed under an individual site compliance schedule determined by the U.S. Environmental Protection Agency.

To summarize, the process of complying with the Storm Water Individual Permit can be broken down into five steps:

- installation and maintenance of control measures,
- storm water sampling to determine effectiveness of control measures,
- additional corrective action if a target action level is exceeded,
- reporting results of fieldwork and monitoring to the U.S. Environmental Protection Agency and the New Mexico Environment Department, and
- placing the site into long-term stewardship or initiating a site deletion request.

2022 Accomplishments

In 2022, we completed the following tasks to comply with the requirements of the Storm Water Individual Permit:

- Published the 2021 update to the Site Discharge Pollution Prevention Plan, which identified pollutant sources, described control measures, and defined monitoring at all permitted sites
- Published the "Storm Water Individual Permit Annual Report for Reporting Period January 1–December 31, 2021," which presents the compliance status for all permitted sites, activities conducted, and milestones accomplished to comply with the Storm Water Individual Permit
- Completed 1,142 inspections of storm water controls at 250 site-monitoring areas. Note that the number of site-monitoring areas changed to 239 once the new permit became effective on August 1, 2022
- Completed 917 sampling equipment inspections

- Conducted storm water monitoring at 136 site-monitoring areas
- Collected extended baseline confirmation samples at eight site-monitoring areas
- Collected corrective action confirmation monitoring samples at 12 site-monitoring areas
- Installed 32 additional control measures at 21 site-monitoring areas
- Held a public meeting in November 2022
- Submitted analytical results following certification of enhanced controls at 12 site/site-monitoring area combinations
- Resubmitted certification of completion of corrective action following certificate of completion from the New Mexico Environment Department at two site/site-monitoring area combinations
- Submitted the 2022 Annual Sampling Implementation Plan, a requirement of the new permit, to the New Mexico Environment Department for comment

For more information on surface water quality at the Laboratory, see Chapter 6, Watershed Quality.

Table 2-12 summarizes the exceedance of target action levels for storm water samples collected in 2022 for the Storm Water Individual Permit. Because the 2022 permit became effective mid-year, samples were screened using the target action levels from the 2010 permit.

Table 2-12. 2022 Exceedances of LANL's National Pollutant Discharge Elimination System Storm Water Individual Permit Target Action Levels

Site-Monitoring Area (SMA)	Parameter	Type of Exceedance[a] of the Target Action Level for the Parameter	Number of Exceedances	Total Number of Samples Taken	Sample Date
3M-SMA-0.5	Copper	maximum	1	1	07/27/2022
	Gross alpha	average	1	1	
A-SMA-2.8	Gross alpha	average	1	1	07/27/2022
	Selenium	maximum and average	1	1	
A-SMA-3.5	Gross alpha	average	1	1	07/12/2022
	Total PCB	average	1	1	
CHQ-SMA-1.01	Copper	maximum	1	1	07/12/2022
	Gross alpha	average	1	1	
	Mercury	maximum and average	1	1	
	Selenium	average	1	1	
	Total PCB	average	1	1	
CHQ-SMA-6	Copper	maximum	1	1	07/12/2022
	Gross alpha	average	1	1	
DP-SMA-1	Copper	maximum	1	1	06/27/2022

Site-Monitoring Area (SMA)	Parameter	Type of Exceedance[a] of the Target Action Level for the Parameter	Number of Exceedances	Total Number of Samples Taken	Sample Date
F-SMA-2	Aluminum	maximum	1	1	07/27/2022
	Copper	maximum	1	1	
	Gross alpha	average	1	1	
	Selenium	maximum	1	1	
M-SMA-12.7	Gross alpha	average	1	1	08/16/2022
	Mercury	average	1	1	
M-SMA-3	Total PCB	average	1	1	07/27/2022
PJ-SMA-2	Aluminum	average	1	1	07/31/2022
	Copper	average	1	1	
	Zinc	average	1	1	
PJ-SMA-3.05	Copper	maximum	1	2	07/20/2022 08/06/2022
	Gross alpha	average	1	2	
PJ-SMA-5	Copper	maximum	1	1	07/26/2022
PJ-SMA-9	Copper	maximum	1	1	07/27/2022
	Gross alpha	average	1	1	
PT-SMA-2	Copper	maximum	1	1	08/11/2022
	Gross alpha	average	1	1	
PT-SMA-3	Aluminum	maximum	1	1	07/04/2022
	Copper	maximum	1	1	
	Gross alpha	average	1	1	
S-SMA-3.7	Copper	maximum	1	1	07/30/2022
	Total PCB	average	1	1	
	Zinc	maximum	1	1	
S-SMA-6	Copper	maximum	1	1	07/26/2022
	Gross alpha	average	1	1	
	Lead	maximum	1	1	
STRM-SMA-4.2	Aluminum	maximum	1	1	07/04/2022
	Copper	maximum	1	1	
W-SMA-1.5	Aluminum	maximum	1	1	07/04/2022
	Copper	maximum	1	1	
	Zinc	maximum	1	1	
W-SMA-9.05	Copper	maximum	1	1	06/26/2022

[a] The maximum target action level is the target for individual maximum values recorded at a site; the average target action level is the target for the geometric mean of applicable monitoring results at a site. Target action levels are benchmarks, not permit limits.

Aboveground Storage Tank Program

The Aboveground Storage Tank Program staff manage compliance with New Mexico storage tank regulations administered by the New Mexico Environment Department Petroleum Storage Tank Bureau and with U.S. Environmental Protection Agency storage tank requirements. The federal regulations require Spill Prevention, Control, and Countermeasure plans for facilities with aboveground storage tank systems and regulated oil-filled equipment. We manage 10 aboveground storage tank systems and 17 spill prevention, control, and countermeasure plans.

The New Mexico Environment Department Petroleum Storage Tank Bureau conducted no formal onsite inspections in 2022; however, a Petroleum Storage Tank Bureau inspector conducted four site visits to oversee tank system maintenance and repair work and assessments by American Petroleum Institute personnel. We are working with the Petroleum Storage Tank Bureau to remove an aboveground fuel storage tank that has been out of service since 2013.

In 2022, we completed amendments to two spill prevention, control, and countermeasure plans, renewed two plans, began updates to three plans, and completed one new plan. Laboratory staff conducted all annual and periodic inspections for the facilities as required.

Clean Water Act Section 404/401 Permits

Section 404 of the Clean Water Act requires that we receive verification from the U.S. Army Corps of Engineers that our proposed projects within certain watercourses comply with Clean Water Act nationwide permit conditions.

Section 401 of the Clean Water Act requires states to certify that Section 404 permits issued by the U.S. Army Corps of Engineers comply with state water quality standards. The New Mexico Environment Department Water Quality Bureau reviews Section 404/401 permit applications and issues separate Section 401 certification letters that may include additional requirements to meet state stream standards for individual Laboratory projects.

Section 404/401 verifications and certifications that were issued or active at the Laboratory in 2022 are listed in Summary of Permits and Legal Orders section at the end of this chapter.

Energy Independence & Security Act: Storm Water Management Practices

Section 438 of the Energy Independence and Security Act of 2007 establishes requirements for managing storm water runoff for development projects financed with federal funds. Any federally funded project of more than 5,000 square feet that alters the flow of water over the surface of the ground must use low-impact development practices to maintain the water temperatures, flow rates, flow volumes, and flow durations that were present before development. Examples of such practices include use of vegetated swales, infiltration basins, permeable pavement, vegetated strips, rain barrels, and cisterns. The goal is to manage runoff through infiltration, evapotranspiration, or harvest and reuse.

We comply with Section 438 by identifying eligible projects through the permits and requirements identification process and excavation permitting process. Environmental Protection and Compliance Division staff work with internal and subcontractor design and construction personnel to manage a project’s storm water runoff. Section 438 guidance is also published in the LANL Engineering Standards Manual.

In 2022, approximately 11 projects subject to Energy Independence and Security Act requirements were in design or construction. As part of their Section 438 compliance, project designs have incorporated vegetated swales, detention/infiltration basins, and revegetation to manage storm water discharge.

New Mexico Water Quality Act: Surface Water Protection

Under the New Mexico Water Quality Act, the New Mexico Water Quality Control Commission adopts standards for surface waters of the state. *Standards for Interstate and Intrastate Surface Waters* (Title 20, Chapter 6, Part 4, of the New Mexico Administrative Code) defines designated surface water uses for the state, sets water quality criteria to protect those uses, and provides an anti-degradation policy. The Laboratory's National Pollutant Discharge Elimination System permits, along with any dredge-and-fill activities approved under Section 404 of the Clean Water Act, must be certified by the New Mexico Environment Department to ensure that the state's water quality standards are met.

Additionally, under Section 303(d) of the Clean Water Act, the New Mexico Environment Department determines which stream reaches (delineated as assessment units) within the state are impaired for the assessment units' designated use(s). The New Mexico Environment Department uses the Laboratory's surface water monitoring data in developing its list of impaired waters for the assessment units on Laboratory property. The discharge limits and monitoring requirements in the Laboratory's National Pollutant Discharge Elimination System permits are determined, in part, by the impairment status of affected water courses.

In 2022, during the Triennial Review, the Water Quality Control Commission considered changes to the Laboratory's surface water classifications based on studies conducted by LANL and the New Mexico Environment Department. The changes, formally adopted by the Water Quality Control Commission in March of 2022, applied more protective aquatic life uses to three miles of streams on Laboratory property. The U.S. Environmental Protection Agency approved these changes for the purposes of Clean Water Act compliance in January 2023.

See Chapter 6, Watershed Quality, for more information.

Groundwater Quality and Protection

Safe Drinking Water Act

The Los Alamos County Department of Public Utilities supplies water for Los Alamos, White Rock, the Laboratory, and Bandelier National Monument. The Department issues an annual drinking water quality report, as required by the Safe Drinking Water Act. The 2022 report is available at Los Alamos Department of Public Utilities 2022 Annual Drinking Water Quality Report. For 2022, the drinking water quality for Los Alamos met all U.S. Environmental Protection Agency regulations.

New Mexico Water Quality Act: Groundwater Quality Standards

In fiscal year 2022, we reported to the New Mexico Environment Department nine instances of a contaminant detected in groundwater at a location where the contaminant had not been previously detected above a standard or screening level (see Table 2-13).

Table 2-13. 2022 Locations with First-Time Groundwater Quality Standard or Screening Level Exceedances

Parameter Name	Location (well or spring)	Groundwater Zone	Sample Date	Result	Standard or Screening Level Value	Units	Type of Standard or Screening Level
Chromium	R-61 S1	Regional Aquifer	03/08/2022	51.0	50	µg/l	New Mexico Groundwater Standard[a]
Perchlorate	CRPZ-1[b]	Regional Aquifer	05/27/2022	16.2	13.8	µg/l	New Mexico Environment Department Tap Water Screening Level[c]
Dibenz(a,h)anthracene	R-24	Regional Aquifer	06/17/2022	0.318	0.0343	µg/l	New Mexico Environment Department Tap Water Screening Level
Perfluorooctanesulfonic acid	POI-4	Regional Aquifer	06/20/2022	79.4	60	ng/l	New Mexico Environment Department Tap Water Screening Level
Dibromo-3-Chloropropane[1,2-]	CdV-16-2(i)r	Intermediate-depth perched groundwater	08/24/2022	1.28	0.2	µg/l	U.S. Environmental Protection Agency Maximum Contaminant Level
Dibromoethane[1,2-]	CdV-16-2(i)r	Intermediate-depth perched groundwater	08/24/2022	0.48	0.05	µg/l	New Mexico Groundwater Standard
Trichloropropane[1,2,3-]	CdV-16-2(i)r	Intermediate-depth perched groundwater	08/24/2022	0.56	0.00835	µg/l	New Mexico Environment Department Tap Water Screening Level
Iron	R-31 S3	Regional Aquifer	09/09/2022	1290	1000	µg/l	New Mexico Groundwater Standard
Benzo(a)anthracene	Spring 4	Regional Aquifer	10/13/2022	0.384	0.12	µg/l	New Mexico Environment Department Tap Water Screening Level

[a] New Mexico Environment Department Soil Screening Levels Summary Table A-1 Values for Tap Water (“Risk Assessment Guidance for Site Investigations and Remediation”) published June 2019.
[b] New Mexico Water Quality Control Commission groundwater standards published December 21, 2018.
[c] Regional aquifer piezometers in the Chromium Investigation monitoring group area were recently incorporated to be sampled as part of the Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year (see section 3.3 of the Monitoring Year 2022 Interim Facility-Wide Groundwater Monitoring Plan). This result was from the first sampling under this plan and therefore now qualifies for reporting under the Monthly Notification of Groundwater Data mechanism. Previous sampling of the piezometers provided screening level results and those values or trends generally conform with this reported result.
µg/l = micrograms per liter; ng/l = nanograms/liter New Mexico Ground Water Standard.

The standards and screening levels for this reporting requirement include

- the New Mexico Environment Department Soil Screening Levels Summary Table A-1 Values for Tap Water,
- the New Mexico Water Quality Control Commission groundwater standards, and
- the U.S. Environmental Protection Agency maximum contaminant levels.

New Mexico Water Quality Act: Groundwater Discharge Regulations

Under the New Mexico Water Quality Act, the New Mexico Water Quality Control Commission sets regulations for liquid discharges onto or below ground surfaces to protect groundwater. These groundwater discharge regulations are enforced by the New Mexico Environment Department, which may require a facility that discharges effluents to submit a discharge plan and obtain a permit. In 2022, the Laboratory had five discharge permits. Sampling results are compared with the standards and screening levels presented in the New Mexico Water Quality Act: Groundwater Quality Standards section and are reported to the New Mexico Environment Department.

Technical Area 46 Sanitary Wastewater System Plant Discharge Permit DP-857

Discharge Permit DP-857 applies to combined effluent discharges from the Technical Area 46 Sanitary Wastewater System plant, the Sanitary Effluent Reclamation Facility, and the Sigma Mesa evaporation basins. The permit requires quarterly, semi-annual, and/or annual sampling of

- the Sanitary Wastewater System Plant's treated water;
- effluent from National Pollutant Discharge Elimination System Outfalls 001, 03A027, and 13S, which can discharge treated water from the sanitary wastewater system plant;
- water collected in the Sigma Mesa evaporation basins; and
- groundwater from wells located in Sandia Canyon.

In 2022, one sample collected from National Pollutant Discharge Elimination System Outfall 001 exceeded the tap water screening guidance level for BHC[beta-], a pesticide. A confirmation sample was collected the same quarter, and the pesticide was not detected. In 2022, one sample collected from the Sanitary Wastewater System exceeded the tap water screening guidance for bromodichloromethane, a disinfection byproduct. The Sanitary Wastewater System is not a discharge location and did not trigger confirmatory sampling. A downgradient intermediate well, SCI-1, was monitored quarterly for bromodichloromethane in 2022, but this compound was not detected in any samples collected.

The DP-857 permit expired in December of 2021 and is administratively continued. The New Mexico Environment Department conducted a site inspection in support of the permit renewal process in March 2022. No major issues were identified by the New Mexico Environment Department during the site inspection.

Domestic Septic Tank Disposal Systems Discharge Permit DP-1589

Discharge Permit DP-1589 applies to discharges from septic tank disposal systems. These systems (a combined septic tank and leach field) are located in remote areas of the Laboratory where access to the sanitary wastewater collection system is not practicable. Six active septic tank disposal systems currently exist at the Laboratory.

The permit requires monitoring and inspections of the Laboratory's septic tank disposal systems. These actions include routine septic tank sampling, septic tank water-tightness testing, annual pumping and septic tank inspection, and inspection of the leach field disposal system.

We conduct semi-annual and annual sampling of water from active septic tank disposal systems. In 2022, the Technical Area 33-0375, Technical Area 33-0179, Technical Area 36-0274, Technical Area 39-0132, and Technical Area 58-0052 septic tanks each exceeded the state's groundwater standard for total nitrogen. All results were reported to the New Mexico Environment Department. The New Mexico Environment Department conducted a site inspection in support of the DP-1589 permit renewal in March 2022 and identified no issues.

Technical Area 50 Radioactive Liquid Waste Treatment Facility Discharge Permit DP-1132

The Technical Area 50 Radioactive Liquid Waste Treatment Facility operated under Temporary Permissions granted by the New Mexico Environment Department through the first part of 2022 until the final permit was issued on May 5, 2022. DP-1132 requires us to conduct operational, monitoring, and closure actions at the Radioactive Liquid Waste Treatment Facility. Examples of these actions are

- monthly and quarterly sampling of treated effluent;
- quarterly and annual groundwater monitoring at seven alluvial, perched-intermediate, and regional aquifer wells;
- the installation and implementation of a soil moisture monitoring system beneath the Technical Area 52 solar evaporation tanks; and
- the removal from service of seven facility units that have ceased operation.

In 2022, the chemical acrolein was detected above the applicable tap water screening guidance level at National Pollutant Discharge Elimination Outfall 051 during the first quarter. Acrolein was not detected in any additional samples of treated effluent in 2022. No external compliance inspections were conducted in 2022. All groundwater monitoring well samples met groundwater quality standards except for detections of nitrate, perchlorate, chromium, and 1,4-dioxane at MCOI-6. More information about well sampling results is presented in Chapter 5, Groundwater Protection.

Land Application of Treated Groundwater Discharge Permit DP-1793

Discharge Permit DP-1793 applies to the discharge of treated groundwater by land application (spraying treated groundwater onto the surface of the ground). Activities that involve land application of treated groundwater include well pumping tests, aquifer tests, and well rehabilitation. Under the permit, individual work plans must be submitted for each land application project. Work plans are posted to the Electronic Public Reading Room for a 30-day public comment period. Each work plan addresses how groundwater will be treated so that constituent concentrations are less than 90 percent of their New Mexico groundwater standard level before discharge.

DP-1793 expired in 2020. We submitted a renewal application in January 2020. The Laboratory continues to operate under the original DP-1793 permit until a final renewal permit is issued by the New Mexico Environment Department Ground Water Quality Bureau.

Injection of Treated Groundwater into Class V Underground Injection Control Wells Discharge Permit DP-1835

Discharge Permit DP-1835 applies to the injection of treated groundwater into six Class V underground injection control wells in Mortandad Canyon. To continue operations, a renewal application was submitted on June 4, 2021. The Laboratory continues to operate under the existing Discharge Permit DP-1835 permit until a final renewal permit is issued by the New Mexico Environment Department Ground Water Quality Bureau.

On June 6, 2022, the New Mexico Environment Department issued a notice of noncompliance for exceedances of the groundwater standard for chromium to N3B and DOE Environmental Management regarding this permit. The permittees are working with the New Mexico Environment Department on the development and implementation of a corrective action plan.

See Compliance Order on Consent Groundwater Activities and Chapter 5, Groundwater Protection, for more information.

Resource Conservation and Recovery Act: Groundwater Protection Activities

Hazardous Waste Facility Permit Groundwater Activities

The Hazardous Waste Facility Permit contains requirements for groundwater monitoring of operational facilities. During 2022, groundwater monitoring completed under the 2016 Compliance Order on Consent met this requirement. Chapter 5, Groundwater Protection, provides more details on groundwater monitoring activities and monitoring results.

Compliance Order on Consent Groundwater Activities

In 2022, the Laboratory performed groundwater protection activities as approved by the New Mexico Environment Department under the Compliance Order on Consent.

Activities included sampling and testing groundwater from wells and springs for general monitoring of groundwater quality, characterizing the chromium groundwater plume and an RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) groundwater plume, and implementing an interim measure to control migration of the chromium groundwater plume.

The goal of the chromium interim measure is to control migration of the chromium plume while the Laboratory evaluates methods for the final remediation of the plume. In 2022, interim measure operations included

- withdrawing chromium-contaminated groundwater from the regional aquifer using extraction wells (referred to as CrEX wells, for “chromium extraction”),
- treating the water using ion exchange to remove the chromium, and
- injecting the treated groundwater back into the regional aquifer using injection wells (referred to as CrIN wells, for “chromium injection”).

More information is available in Chapter 5, Groundwater Protection.

Other Environmental Statutes and Orders

National Environmental Policy Act

The National Environmental Policy Act requires federal agencies to consider the environmental impacts of proposed activities, operations, and projects. The DOE has analyzed the impacts of LANL operations and activities in Site-Wide Environmental Impact Statements, with the most recent one published in 2008 (DOE 2008a). Records of Decision for the 2008 Site-Wide Environmental Impact Statement describe the operations and activities that the DOE has approved and any required mitigations (DOE 2008b, DOE 2009).

National Environmental Policy Act specialists review proposed projects at the Laboratory to determine if the associated impacts were analyzed as part of the 2008 Site-Wide Environmental Impact Statement or in other existing National Environmental Policy Act documents. In 2022, staff reviewed approximately 1,160 proposed projects. Those projects or activities that are not covered under existing documents may require new or additional analyses. One Laboratory project that received additional National Environmental Policy Act analyses in 2022 is explained as follows:

- In April 2021, the DOE/National Nuclear Security Administration published a notice of its intent to prepare an environmental assessment for the Los Alamos National Laboratory Electrical Power Capacity Upgrade Project (DOE 2021). The purpose of the project is to upgrade the Laboratory's electrical power capacity by constructing and operating a new 115-kilovolt power transmission line and by improving LANL's existing electrical infrastructure. The proposed new transmission line would cross public lands managed by the U.S. Department of Interior Bureau of Land Management and the U.S. Department of Agriculture Santa Fe National Forest. The Environmental Assessment is currently being drafted.

Three Los Alamos National Laboratory projects were categorically excluded from further DOE National Environmental Policy Act review in 2022:

- Categorical Exclusion for Leasing Properties for Warehousing and Storage (CX-270763)
- Categorical Exclusion for Pacheco Microwave Tower Project (CX-270680)
- Categorical Exclusion for Offsite Graphite Machining (CX-270683)

On August 19, 2022, the DOE/National Nuclear Security Administration published a Notice of Intent to prepare a new Site-Wide Environmental Impact Statement for Los Alamos National Laboratory. Public meetings for this new Site-Wide Environmental Impact Statement were held on September 13 and 14, 2022.

National Historic Preservation Act

The National Historic Preservation Act of 1966, as amended, requires federal agencies to consider the effects of their activities on historic properties (archaeological sites and historic buildings) and to implement a mitigation plan for any adverse effects. LANL's Cultural Resources Management Plan (LANL 2017) describes the Laboratory's process for complying with cultural resources laws and regulations and its strategy for managing cultural resources. We conduct overall LANL historic property inventory reviews under Section 110 of the National Historic Preservation Act and project-specific historic property reviews under Section 106.

Both the management and operating contractor (Triad) and the legacy waste cleanup contractor (N3B) support project compliance with the National Historic Preservation Act and other cultural resources laws and regulations. In 2022, N3B archaeologists monitored and supported the following projects in avoiding archeological sites:

- A new chromium monitoring well (R-73) in Technical Area 5
- Tree thinning for wildland fire mitigation in Technical Areas 36 and 54
- Aggregate area soil sampling at the concrete bowl in Technical Area 06

In fiscal year 2022, Triad archaeologists' compliance activities included the following:

- Conducting surveys or verifying previous results for 27 projects
- Supporting seven major construction projects for cultural resources compliance
  - Technical Area 51 Sprung Warehouse Structures
  - Lower Slobbovia Contingency Fire Break
  - Dual-Axis Radiographic Hydrodynamic Test Facility Complex Vessel Repair Facility
  - Dual-Axis Radiographic Hydrodynamic Test Facility Complex Vessel Inspection and Staging Facility
  - Energetic Materials Characterization Facility in Technical Areas 6 and 9
  - Bandelier National Monument Utility Upgrades
  - High Explosives Transfer Station and Blast Fence at Technical Area 8
- Supporting the Cerro Pelado Wildfire Fuels Reduction project by flagging archaeological sites for avoidance on LANL lands
- Assisting National Park Service personnel with flagging archaeological sites for avoidance on Bandelier National Monument lands

Artifacts excavated from Laboratory property are curated at the Museum of Indian Arts and Culture in Santa Fe, New Mexico. We conduct annual inspections to ensure that artifacts are curated in compliance with Title 36 Part 79 of the Code of Federal Regulations, *Curation of Federally Owned and Administered Archaeological Collections*. Owing to the COVID-19 pandemic, no annual inspections of the museum took place from 2020–2022.

In fiscal year 2022, Triad historic buildings staff's accomplishments included the following:

- Performing inspections and research on the historical use of the buildings using the LANL National Security Research Center, publicly released documents, and historical photographs for 21 Laboratory projects
- Preparing an eligibility and historical context report for the Health Research Laboratory building (Technical Area 43, Building 1)
- Completing a context and documentation report for a property in Technical Area 16 to support its decontamination and decommissioning

- Surveying the area where former Technical Area 6 Manhattan Project/early Cold War–era facilities were located and recording the debris that remains following their removal and/or demolition in 1960
- Conducting interior and exterior photography of Technical Area 22, Building 1, for the potential adaptive reuse, rehabilitation, and restoration of this historic building
- Participating in surveillance and maintenance evaluations for historic properties, including the 17 buildings and structures that are either included in the Manhattan Project National Historical Park or that are eligible for the park (see Chapter 3)

The DOE National Nuclear Security Administration continues to consult with the Accord Pueblos (Pueblo de San Ildefonso, Santa Clara Pueblo, Pueblo of Jemez, and Pueblo de Cochiti) regarding the identification and preservation of traditional cultural properties, human remains, and sacred objects in compliance with the National Historic Preservation Act and the Native American Graves Protection and Repatriation Act.

For more information on the Laboratory's Cultural Resources Management, see Chapter 3.

Endangered Species Act

The Endangered Species Act requires federal agencies to protect federally listed threatened or endangered species, including their habitats. We implement these requirements through our Habitat Management Plan (Thompson et al. 2022).

The Laboratory contains habitat for three federally listed species: the southwestern willow flycatcher (*Empidonax traillii extimus*), the Jemez Mountains salamander (*Plethodon neomexicanus*), and the Mexican spotted owl (*Strix occidentalis lucida*). Two other federally listed species occur near the Laboratory: the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) and the western distinct population segment of the yellow-billed cuckoo (*Coccyzus americanus*). The southwestern willow flycatcher, yellow-billed cuckoo, and New Mexico meadow jumping mouse have not been observed on Laboratory property. In addition, several federal species of concern and state-listed species potentially occur within the Laboratory (Berryhill et al. 2020, BISON-M 2023). Table 2-14 identifies federal- and state-listed species that potentially occur on Laboratory property, along with species that have been identified as having conservation concerns but do not currently have a protected status.

Table 2-14. Threatened, Endangered, and Other Sensitive Species Occurring or Potentially Occurring at the Laboratory

Common Name	Scientific Name	Protected Status[a]	Potential to Occur[b]
Southwestern willow flycatcher	*Empidonax traillii extimus*	E, NME, S1	Moderate
Mexican spotted owl	*Strix occidentalis lucida*	T, NMS	High
Yellow-billed cuckoo (western distinct population segment)	*Coccyzus americanus*	T, NMS	Low
New Mexico meadow jumping mouse	*Zapus hudsonius luteus*	E, NME, S1	Low
Bald eagle	*Haliaeetus leucocepahlus*	NMT, S1	High

Common Name	Scientific Name	Protected Status[a]	Potential to Occur[b]
Common black hawk	*Buteogallus anthracinus*	NMT, S1	Low
Broad-billed hummingbird	*Cynanthus latirostris magicus*	NMT, S1	Low
Violet-crowned hummingbird	*Amazilia violiceps*	NMT, S1	Low
Jemez Mountains salamander	*Plethodon neomexicanus*	E, NME	High
Peregrine falcon	*Falco peregrinus*	NMT	High
Northern goshawk	*Accipiter gentiles*		High
Loggerhead shrike	*Lanius ludovicianus*		High
Gray vireo	*Vireo vicinior*	NMT	High
Spotted bat	*Euderma maculatum*	NMT	High
Townsend's pale big-eared bat	*Corynorhinus townsendii pallescens*		High
Wood lily	*Lilium philadelphicum var. andinum*	NME	High
Greater yellow lady's slipper	*Cypripedium calceolus var. pubescens*	NME	Moderate
Springer's blazing star	*Mentzelia springeri*	FSS	Moderate
Monarch butterfly	*Danaus plexippus*	See Note[c]	High

[a] E = Federal Endangered; T = Federal Threatened; NME = New Mexico Endangered; NMT = New Mexico Threatened; NMS = New Mexico Sensitive Taxa (informal); S1 = Heritage New Mexico: Critically Imperiled in New Mexico; FSS = Forest Service Sensitive Species;
[b] Low = No known habitat exists at the Laboratory. Moderate = Habitat exists, though the species has not been recorded recently. High = Habitat exists, and the species occurs at the Laboratory.
[c] Warranted (for federal listing) but precluded by higher priorities December 15, 2020.

We review proposed projects to determine if they have the potential to affect federally listed species or their habitats. In 2022, Triad biologists reviewed 750 excavation permits, 330 project profiles in the permits and requirements identification system, 38 minor siting proposals, and 10 storm water pollution prevention plans for potential impacts to threatened or endangered species. N3B subject matter experts reviewed 37 excavation permits and 8 project profiles in the permits and requirements identification system. If a potential for impacts exists, biologists work with project personnel to either modify the project to avoid the impacts or to prepare a biological assessment for consultation with the U.S. Fish and Wildlife Service. In 2022, we prepared one biological assessment to analyze the impacts to listed species (LANL 2021a). We did not find any projects out of compliance with endangered species protection requirements in 2022.

We also conduct surveys for the Mexican spotted owl, southwestern willow flycatcher, Yellow-billed cuckoo, and Jemez Mountains salamander. In 2022, Mexican spotted owls were found on Laboratory property in the same nesting locations as past years. We heard male Mexican spotted owls on multiple surveys, but no successful breeding was confirmed. Southwestern willow flycatchers were not found during surveys, but seven willow flycatchers of unknown subspecies were recorded during bird banding. One Yellow-billed cuckoo was heard during the first survey period along the Rio Grande (Technical Areas 70 and 71). No Jemez Mountains salamanders were found during surveys on LANL lands.

Migratory Bird Treaty Act

Under the Migratory Bird Treaty Act, it is unlawful "by any means or manner to pursue, hunt, take, capture [or] kill" any migratory birds except as permitted by regulations issued by the U.S. Fish and Wildlife Service. As part of the Laboratory's Migratory Bird Treaty Act compliance, we review projects for potential impacts to migratory birds and conduct bird population monitoring projects. These efforts support DOE's commitment to "promote monitoring, research, and information exchange related to migratory bird conservation and program actions that may affect migratory birds . . ." as stated in the September 12, 2013, Memorandum of Understanding between the DOE and the U.S. Fish and Wildlife Service.

In project reviews, Laboratory biologists provide specific comments for projects that have the potential to affect migratory birds, their eggs, or nestlings. In general, projects that remove vegetation that may contain bird nests are scheduled before or after the bird nesting season. In 2022, we did not find any projects out of compliance with migratory bird protection requirements.

In 2022, we continued annual breeding season and winter surveys for birds in all major habitat types and continued monitoring nest box use by birds. As part of a long-term monitoring project at two open-detonation sites and one open-burn site, our point count surveys and nest box monitoring results continue to suggest that operations at these sites are not negatively affecting bird populations. In addition, biologists continued to capture and band birds during the breeding season in Sandia Canyon to monitor breeding bird populations and during fall migration in Pajarito Canyon to monitor use of Laboratory lands by migrating birds.

Floodplain and Wetland Executive Orders

We comply with Executive Order 11988, *Floodplain Management*, and Executive Order 11990, *Protection of Wetlands*, by preparing floodplain and wetland assessments for projects in floodplains or wetlands. In 2022, we prepared three floodplain assessments and one wetland assessment. The floodplain assessments covered the installation of post-and-cable fencing along West Road in Los Alamos Canyon; the installation of eight permanent flagpoles, a weatherproof electronic range status board, and removal of a berm and two storage structures at the Outdoor Live Fire Range in Sandia Canyon (Technical Area 72); and the installation of three firing range gates and replacement of one firing range gate at the Outdoor Live Fire Range in Sandia Canyon (Technical Area 72). The wetland assessment was performed for a project to install 12-inch water lines near two wetlands (Technical Area 48 to Technical Area 55). No violations of the DOE floodplain/wetland environmental review requirements were recorded.

Invasive Species Executive Order

In accordance with Executive Order 13751, Safeguarding the Nation from the Impacts of Invasive Species, we identify invasive species and treat isolated invasive plant species populations. Larger, well-established populations of some species such as Siberian elm (*Ulmus pumila*), Russian olive (*Elaeagnus angustifolia*), and saltcedar (*Tamarix ramosissima*) are removed opportunistically in conjunction with other construction or forest management projects. We have a software application for electronic devices that allows users to identify and mark the locations of invasive plant species at the Laboratory to track their spread and plan for future removals. A current list of invasive species known to occur at LANL is presented in Table 2-15.

Table 2-15. List of Invasive Species Known to Occur at LANL

Common Name	Latin Name
Leopard slug	*Limax maximus*
Eurasian collared dove	*Streptopelia decaocto*
European starling	*Sturnus vulgaris*
Bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Cheatgrass	*Bromus tectorum*
Dalmatian toadflax	*Linaria dalmatica*
Diffuse knapweed	*Centaurea diffusa*
Field bindweed	*Convolvulus arvensis*
Giant reed	*Arundo donax*
Jointed goatgrass	*Aegilops cylindrica*
Kochia	*Kochia scoparia*
Leafy spurge	*Euphorbia esula*
Lehmann lovegrass	*Eragrostis lehmanniana*
Mullein	*Verbascum spp.*
Myrtle spurge	*Euphorbia myrsinites*
Musk thistle	*Carduus nutans*
Oxeye daisy	*Leucanthemum vulgare*
Puncturevine	*Tribulus terrestris*
Red brome	*Bromus rubens*
Redtop	*Agrostis gigantea*
Rough cocklebur	*Xanthium strumarium*
Russian knapweed	*Acroptilon repens*
Russian olive	*Elaeagnus angustifolia*
Russian thistle	*Salsola tragus*
Saltcedar	*Tamarix ramosissima*
Scotch thistle	*Onopordum acanthium*
Siberian elm	*Ulmus pumila*
Skeletonleaf bursage	*Ambrosia tomentosa*
Smooth brome	*Bromus inermis*
Spotted knapweed	*Centaurea biebersteinii*
Tansy mustard	*Descurainia sophia*
Teasel	*Dipsacus spp.*
Tree of heaven	*Ailanthus altissima*
Whitetop/Hoary cress	*Lepidium draba*
Yellow salsify	*Tragopogon dubius*
Yellow star thistle	*Centaurea solstitialis*
Yellow toadflax	*Linaria vulgaris*

DOE Order 436.1, Departmental Sustainability, including Executive Order 14057, Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability

The purpose of the DOE order on sustainability is to ensure that the DOE carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges. As directed by this order, the Laboratory adopted an Environmental Management System and prepares and implements an annual Site Sustainability Plan. LANL's Environmental Management System and Site Sustainability Plan are discussed in detail in Chapter 3.

Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, outlines aggressive net-zero goals for all federal agencies. The intent of the Executive Order is to use a whole-of-government approach to reduce greenhouse gas emissions and move toward clean energy and sustainable technologies. LANL's plans to meet Executive Order 14057 are discussed in detail in Chapter 3 in the Site Sustainability and Greenhouse Gas Reduction sections.

Relevant goals include the following:

- Achieve 100 percent carbon pollution-free electricity by 2030, including 50 percent on a 24/7 basis
- Reach 100 percent zero-emission vehicle acquisition by 2035, including 100 percent light-duty acquisitions by 2027
- Achieve net-zero building emissions by 2045, including a 50 percent reduction by 2032
- Reduce Scope 1 and 2 greenhouse gas emissions by 65 percent from 2008 levels by 2030
- Establish targets to reduce energy and potable water use intensity by 2030
- Reduce procurement emissions to net zero by 2050
- Have climate-resilient infrastructure and operations
- Develop a climate-focused and sustainability-focused workforce
- Advance environmental justice and equity-focused operations
- Accelerate progress through domestic and international partnerships

In August 2022, DOE issued implementing instructions for Executive Order 14057 that requires LANL to begin actions to meet net-zero goals. In response to Executive Order 14057, LANL is taking the following actions:

- Develop and begin implementing a net-zero plan
- Procure additional carbon pollution-free electricity
- Expand and improve electric vehicle charging infrastructure to support the zero-emissions vehicle fleet
- Begin the Sustainable Climate Ready Sites Program and assessment

Executive Order 14008, Tackling the Climate Crisis at Home and Abroad

America the Beautiful Initiative

Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, set a goal of conserving 30 percent of land and water by 2030, among other goals. The DOE submitted its first conservation action plan under the America the Beautiful Initiative associated with this executive order in December 2021, with the following focus areas:

- Create More Parks and Safe Outdoor Opportunities in Nature-Deprived Communities
- Support Tribally Led Conservation and Restoration Priorities
- Expand Collaborative Conservation of Fish and Wildlife Habitats and Corridors
- Increase Access for Outdoor Recreation
- Incentivize and Reward the Voluntary Conservation Efforts of Fishers, Ranchers, Farmers and Forest Owners
- Create Jobs by Investing in Restoration and Resilience
- Other Activities Supportive of the America the Beautiful Initiative

Laboratory plans and programs that supported the DOE's conservation action plan in 2022 are described as follows.

Expand Collaborative Conservation of Fish and Wildlife Habitats and Corridors

In the following paragraphs, we describe several activities we undertook to conserve wildlife habitat and travel corridors at the Laboratory.

Pajarito Road is one of the busiest roads on Laboratory property, crossing through developed and undeveloped areas. High-speed traffic, Rocky Mountain elk, and mule deer along the Pajarito Corridor result in a high risk for wildlife-vehicle collisions. To better understand and mitigate this risk, Biological Resources Program staff deployed motion-activated cameras along Pajarito Canyon from May 2021 to May 2022 to identify animal movement paths and examine spatial and temporal trends in animal distributions. Using regional and national guidelines and plans, they suggested a series of possible mitigations to reduce the risk of wildlife-vehicle collisions and support habitat connectivity. Mitigation options are still in review and may be incorporated into the upcoming Site-Wide Environmental Impact Statement or project-specific scope.

During 2022, we assisted National Park Service personnel from two neighboring units—Bandelier National Monument and Valles Caldera National Preserve—on their large-mammal monitoring project. The goal of the project is to assess large-mammal habitat use, including use of areas influenced by fire and fire prevention measures, such as prescribed fires and restoration thinning. We have tracked radio-collared mountain lions that have territories that overlap Laboratory property, collected mountain lion kill locations, and contributed data for the parks' habitat assessment analyses. We have also shared spatial landcover data with descriptions of vegetative communities to assist with habitat analyses.

Pollinators are animals (frequently but not always insects) that assist plant reproduction by moving pollen from the male part of the flower to the female part of the same or another flower. Pollinators are critical to our food supply as well as to the health and resilience of ecosystems.

As directed in the 2014 presidential memorandum "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," the DOE developed a Pollinator Protection Plan (Pollinator Health Task Force 2015, Appendix E). Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," reiterates that the disappearance of bees and other pollinators is reducing crop yields and threatens food security.

Los Alamos National Laboratory finalized a Pollinator Protection Plan in the spring of 2021 (LANL 2021b) and is implementing this plan to give site-specific guidance to protect pollinators and enhance pollinator habitat in all aspects of facility management where consistent with the site's mission, including

- assessments of the sitewide status of native pollinators, such as the monarch butterfly and native bees;
- strategies that include sitewide native pollinator-friendly plants in seed mixes and other landscaping for maintenance of bees and other pollinators;
- identifying opportunities sitewide to improve habitat for pollinators by planting pollinator-friendly vegetation and increasing flower diversity;
- strategies to increase internal and external public awareness of the importance of pollinators and the steps that can be taken to protect them; and
- minimizing the impact of LANL activities sitewide on pollinator populations when possible, such as following mowing management guidelines.

Other Activities that Support the "America the Beautiful" Initiative

We produced the Sensitive Species Best Management Practices Source Document (LANL 2020) to support conservation of species in decline that occur at Los Alamos National Laboratory and are not currently covered by the Endangered Species Act. One such species is the Pinyon Jay (*Gymnorhinus cyanocephalus*), which was petitioned to be listed under the Endangered Species Act in April 2022.

To better understand sensitive species occurrence on site, we have developed a software application for electronic devices that allows users to identify and mark the locations of sensitive species at the Laboratory. Additionally, we use remote cameras and audio-recording units to efficiently survey our sensitive species and track where they occur on Laboratory property.

Justice40 Initiative

In July 2021, interim implementation guidance for the Justice40 Initiative was released as a new requirement of Executive Order 14008. The aim of this initiative is to secure environmental justice and spur economic opportunity for disadvantaged communities that have been historically marginalized and overburdened by pollution and underinvestment in housing, transportation, water and wastewater infrastructure, and health care. The Justice40 initiative provides guidance on how certain federal investments might be made toward a goal that 40 percent of the overall benefits from federal investments flow to disadvantaged communities. The Environmental Management Los Alamos Field Office was selected as one of five Department of Energy pilot programs to implement this requirement of the Executive Order.

Compliance Summary

Following the completion of the Justice40 Initiative Pilot program and required deliverables, the Environmental Management Los Alamos Field Office embarked on extensive listening efforts in surrounding communities, including the Accord Pueblos (Pueblo de Cochiti, Pueblo of Jemez, Santa Clara Pueblo, and Pueblo de San Ildefonso), to inform implementation of Justice40 Initiative efforts. Key components of implementation completed or underway include the following:

- Soil and groundwater remediation efforts for the LANL legacy cleanup mission. In accordance with the Justice40 Initiative Interim Guidance, the Environmental Management Los Alamos Field Office's Federal Covered Program is "remediation and reduction of legacy pollution."
  - Preventing migration of the hexavalent chromium plume beyond the LANL boundary
  - Installation of a real-time gaging station on Pueblo de San Ildefonso land to monitor streamflow to the Rio Grande
  - Conducting storm water monitoring to capture runoff from 397 solid waste management units and areas of concern at 239 site management areas across LANL
  - Investigation and remediation, where required, of contaminated soil and debris in canyons throughout LANL. Investigations are currently underway in five Aggregate Areas with more than 140 solid waste management units and areas of concern
- Modifications to three of the four Accord Pueblos' Los Alamos Pueblos' Project cooperative agreements, which support sampling and monitoring on pueblo land under pueblo direction. The modifications were designed to address concerns expressed during the Justice40 listening sessions and include
  - data gaps in sampling and monitoring that pueblos are performing on pueblo lands,
  - additional pueblo staff to support the Natural Resource Damage Assessment process, and
  - enhanced engagement with DOE.
- Engaging stakeholders, pueblos, and the public in cleanup activities at the Environmental Management Los Alamos Field Office through participation in the Strategic Vision process. Participants receive a presentation on the legacy cleanup mission at LANL and then share values and priorities in an extensive listening session to inform a long-term Strategic Vision for the remaining cleanup projects.
- Disadvantaged Communities, as identified in the Climate and Economic Justice Screening Tool, involved in the Environmental Management Los Alamos Field Office Strategic Vision include
  - Pueblo de Cochiti,
  - Pueblo de San Ildefonso,
  - Pueblo of Jemez,
  - Santa Clara Pueblo, and
  - Rio Arriba County.
- A full-time employee dedicated to community outreach functions:
  - Building community relationships where candid exchanges can occur
  - Enhancing the Environmental Management Los Alamos Field Office's public engagement

  - Supporting consultation with Accord Pueblos
  - Facilitating consideration of stakeholder and pueblo input in decision-making
- New Grant
  - The Environmental Management Los Alamos Field Office awarded a new grant to the UNM-Taos Hub of Internet-based Vocation and Education to support its efforts to build capacity. Programing supports non-traditional students in accessing education and job training, particularly in the fields of science, technology, engineering, and math.

Federal Insecticide, Fungicide, and Rodenticide Act; New Mexico Pesticide Control Act; and National Pollutant Discharge Elimination System Pesticide General Permit

Two laws and one nationwide Clean Water Act permit regulate how the Laboratory uses and reports on its use of pesticides (chemicals that destroy plant, fungal, or animal pests). The Federal Insecticide, Fungicide, and Rodenticide Act regulates the distribution, sale, and use of pesticides. The New Mexico Pesticide Control Act regulates licensing and certification of pesticide workers, record keeping, equipment inspection, application of pesticides, and storage and disposal of pesticides. The National Pollutant Discharge Elimination System Pesticide General Permit requires annual reporting of pesticide use to the U.S. Environmental Protection Agency. The U.S. Environmental Protection Agency issued a new National Pollutant Discharge Elimination System Pesticide General Permit in 2021, which is effective until October 31, 2026.

Table 2-16 shows the amounts of pesticides the Laboratory used in 2022.

Table 2-16. Pesticides Used by LANL in 2022

Herbicide	Amount
Velossa	65.6 gallons
Ranger Pro Herbicide	36.1 gallons
Insecticide	**Amount**
Maxforce Complete Brand Granular Insect Bait	0.1 gallon
PT Wasp Freeze II and Hornet Insecticide	0.1 gallon
Tempo 20 WP	0.1 gallon
Virkon S	2.3 gallons
Water Treatment Chemical	**Amount**
Kurita Formula 630	362 pounds
Kurita Formula 358a	528 pounds
Garrett-Callahan Formula 316	8 pounds

DOE Order 231.1B, Environment, Safety, and Health Reporting

DOE Order 231.1B, *Environment, Safety, and Health Reporting*, requires the timely collection and reporting of information on environmental issues that could adversely affect the health and safety of the public and the environment at DOE sites. This report fulfills DOE Order 231.1B requirements to publish an annual site environmental report.

The intent of this report is to

- characterize site environmental management performance, including effluent releases, environmental monitoring, types and quantities of radioactive materials emitted, and radiological doses to the public;
- summarize environmental occurrences and responses reported during the calendar year;
- confirm compliance with environmental standards and requirements;
- highlight significant programs and efforts, including environmental performance indicators, performance measures programs, or both; and
- summarize property clearance activities.

The Laboratory began environmental monitoring in 1945 and published the first comprehensive environmental monitoring report in 1970. Current and past reports are available at https://environment.lanl.gov/resources/annual-site-environmental-reports.

Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act requires emergency plans for more than 360 hazardous substances if they are present at a facility in amounts above specified thresholds. We are required to notify state and local officials and the community under this Act about the following items:

- changes at the Laboratory that might affect the local emergency plan or if the Laboratory's emergency planning coordinator changes;
- leaks, spills, and other releases of listed chemicals into the environment if these releases exceed specified quantities;
- the annual inventory of the quantities and locations of hazardous chemicals above specified thresholds present at the facility; and
- total annual releases to the environment of listed chemicals that exceed specified thresholds.

Table 2-17 lists the community and emergency planning reporting the Laboratory performed in 2022.

Table 2-17. Status of Emergency Planning and Community Right-to-Know Act Reporting

Act Section	Description of Reporting	Status (Yes/No/Not Required)
Sections 302–303	Planning notification	Not required
Section 304	Extremely hazardous substance or hazardous substance release notification	Not required
Sections 311–312	Material safety data sheet/Hazardous chemical inventory	Yes
Sections 313	Toxics release inventory reporting	Yes

For Section 313 reporting, the listed chemicals that met the criteria for reporting in 2022 were lead and mercury. The largest source of reportable lead and mercury was from offsite waste transfers. Table 2-18 summarizes the reported releases in 2022. No compliance violations are associated with this use or release of lead or mercury.

Table 2-18. Summary of 2022 Total Annual Releases under Emergency Planning and Community Right-to-Know Act, Section 313

Reported Release	Lead (pounds)	Mercury (pounds)
Air emissions	3.14	4.79
Water discharges	0.30	0.04
Onsite land disposal (firing range)	1,226	0
Offsite waste transfers	17,921	170

DOE Order 232.2A, Occurrence Reporting and Processing of Operations Information

DOE Order 232.2A, *Occurrence Reporting and Processing of Operations Information*, requires reporting of abnormal events or conditions that occur during facility operations. An "occurrence" is one or more events or conditions that may adversely affect workers, the public, property, the environment, or the DOE mission. In 2022, Triad had one reportable environmental occurrence (see Table 2-19). N3B did not have any reportable environmental occurrences in 2022.

Table 2-19. 2022 Environmental Occurrences

Title	Description and Comments	Status
Oil Spill	At 0955 on June 28, 2022, an employee of the Accelerator Operation and Technology Radio Frequency Engineering Group discovered an oil leak from a transformer outside of Technical Area 53, Building 3. The employee observed mineral oil coming out of the north side of the voltage pad of the transformer; the oil had migrated into the soil. The employee immediately isolated the transformer electrically, drained the remaining oil below the leak point, and notified the Emergency Operations Support Center. The Emergency Operations Support Center dispatched the Emergency Response Hazardous Materials Team, who determined that the oil leak occurred due to electrical equipment failure. After investigating the facts, the event was categorized as reportable under Group 5A (2) - release of pollutant from a DOE facility above reporting criteria. There was no impact to personnel health, safety, the facility, or the environment.	Closed

Inspections and Audits

Table 2-20 lists the environmental inspections conducted by regulating agencies and external auditors at the Laboratory during 2022.

Table 2-20. Environmental Inspections and Audits Conducted at LANL during 2022

Date	Purpose	Performing Entity
October 25–29, 2022 December 12–16, 2022	Environmental Management System Surveillance Audits, covering clauses of the International Standards Organization 14001:2015 standard	NSF International
June 28–30, 2022	Carlsbad Field Office Annual Recertification	Environmental Protection Agency, Carlsbad Field Office
November 14–17, 2022	Annual Audit and Resource Conservation and Recovery Act Permit Site Inspections	New Mexico Environment Department Hazardous Waste Bureau

Unplanned Releases

Air Releases

In 2022, there were no unplanned air releases.

Liquid Releases

As required by the New Mexico Water Quality Control Commission regulations, Triad reported six unplanned liquid releases to the New Mexico Environment Department in 2022, and N3B reported one unplanned liquid release (see Table 2-21). Corrective actions were taken for all liquid releases, and the releases and corrective actions were communicated to the New Mexico Environment Department Ground Water Quality Bureau.

Table 2-21. 2022 Unplanned Reportable Liquid Releases

Material Released	Number of Instances	Approximate Total Release (gallons)
Sanitary Wastewater	3	51
Cooling Tower Water	2	5,000
Non-PCB Mineral Oil	1	26.5
Well purge water (N3B)	1	20

Site Resilience

Updated in 2018, the National Climate Assessment explains what current and future climate change is likely to mean for the United States (Gonzalez et al. 2018). Predictions are made for temperature, precipitation (including snowpack), and wildland fires. DOE Order 436.1, *Departmental Sustainability*, directs the Laboratory to determine how its facilities and operations can mitigate risks associated with climatic factors, such as increasing temperatures and increasing wildland fire risk, and to identify the types of facilities/operations that could be impacted.

In 2015, we began tracking climatic risk indices relating to temperature, precipitation, wind, indicator species, and storm water flow. These indices will assist us in identifying when actions are necessary to protect facilities and operations. Following are the results of indices that were available in 2022.

Temperature

Temperature data have been collected in Los Alamos since 1910. Long-term trends in annual average temperatures are reported in the Meteorological Monitoring section of Chapter 4 and are shown in Figure 2-2. The temperatures between 1960 and 2000 had no trend. The years 2001–2010 were approximately 1.5°F warmer than the previous 40 years, and the years 2011–2018 were approximately 3°F warmer than the 1960–2000 averages. Of the last 9 years, 8 had an annual average temperature of 50°F or greater. When average temperatures are broken down into summer and winter minimums and maximums, the summer maximum, minimum, and average temperatures (see Figure 2-3) demonstrate an increase of approximately 5°F.

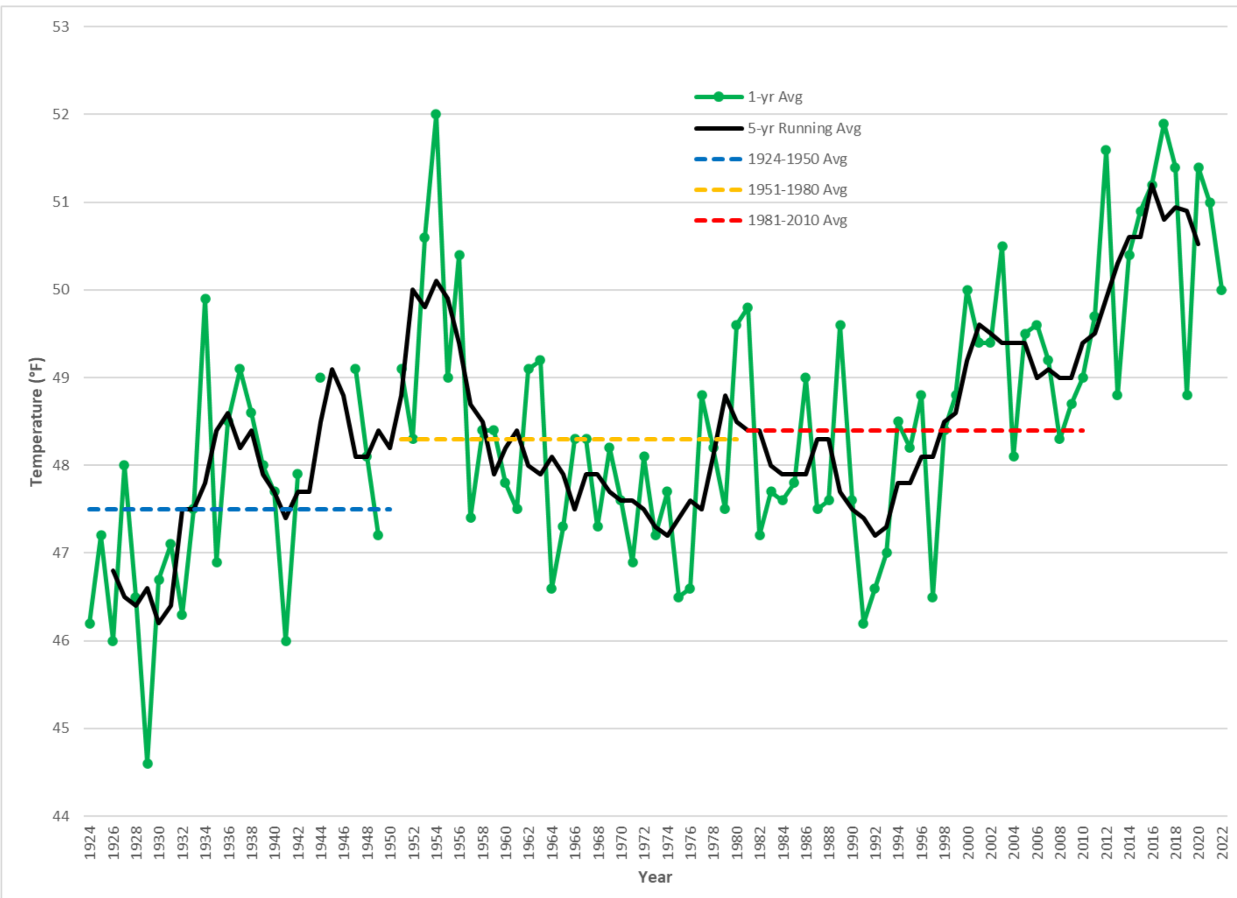


Figure 2-2. Annual average temperatures for Los Alamos. The dashed lines represent long-term climatological average temperatures, the black line represents the 5-year running average temperature, and the green line represents the 1-year average.

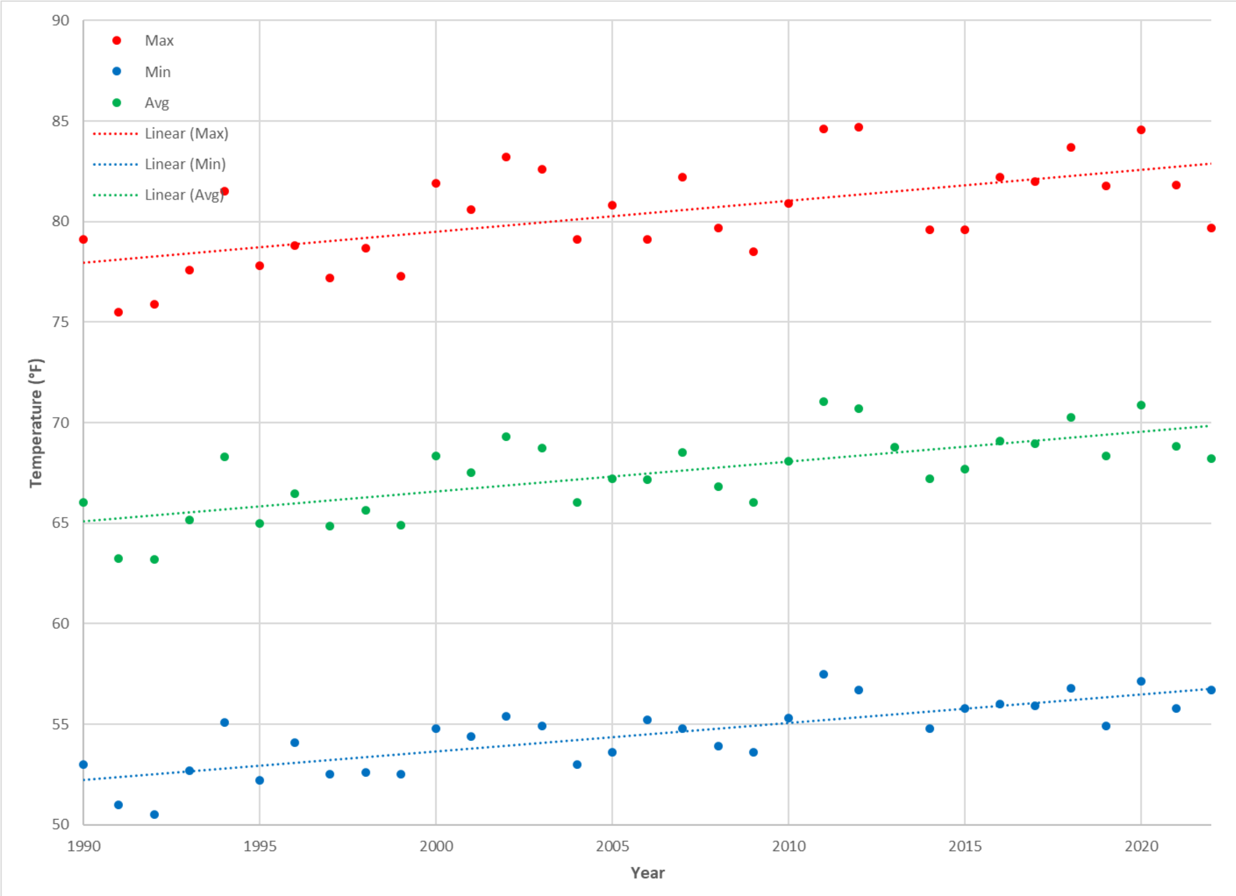


Figure 2-3. Average summer (June, July, August) Los Alamos temperatures. The dashed lines represent the trend line for maximum, minimum, and average summer temperatures, which show summer temperatures have been continuously increasing since 1990.

Changes in temperature can also be assessed by changes in the number of cooling and heating degree days. The number of cooling and heating degree days is used to estimate the annual power usage needed to heat or cool buildings. A cooling degree day represents a 1-degree increase in the average daily temperature above 65°F. As an example, if the average daily temperature was 80°F, that day would represent 15 cooling degree days. Heating degree days are calculated in the same way from the number of degrees an average daily temperature is below 65°F. Shown in Figure 2-4, cooling degree days have been increasing since 1990, while heating degree days have been decreasing (see Figure 2-5). Thus, less energy has been needed to heat buildings, and more energy has been needed to cool them.

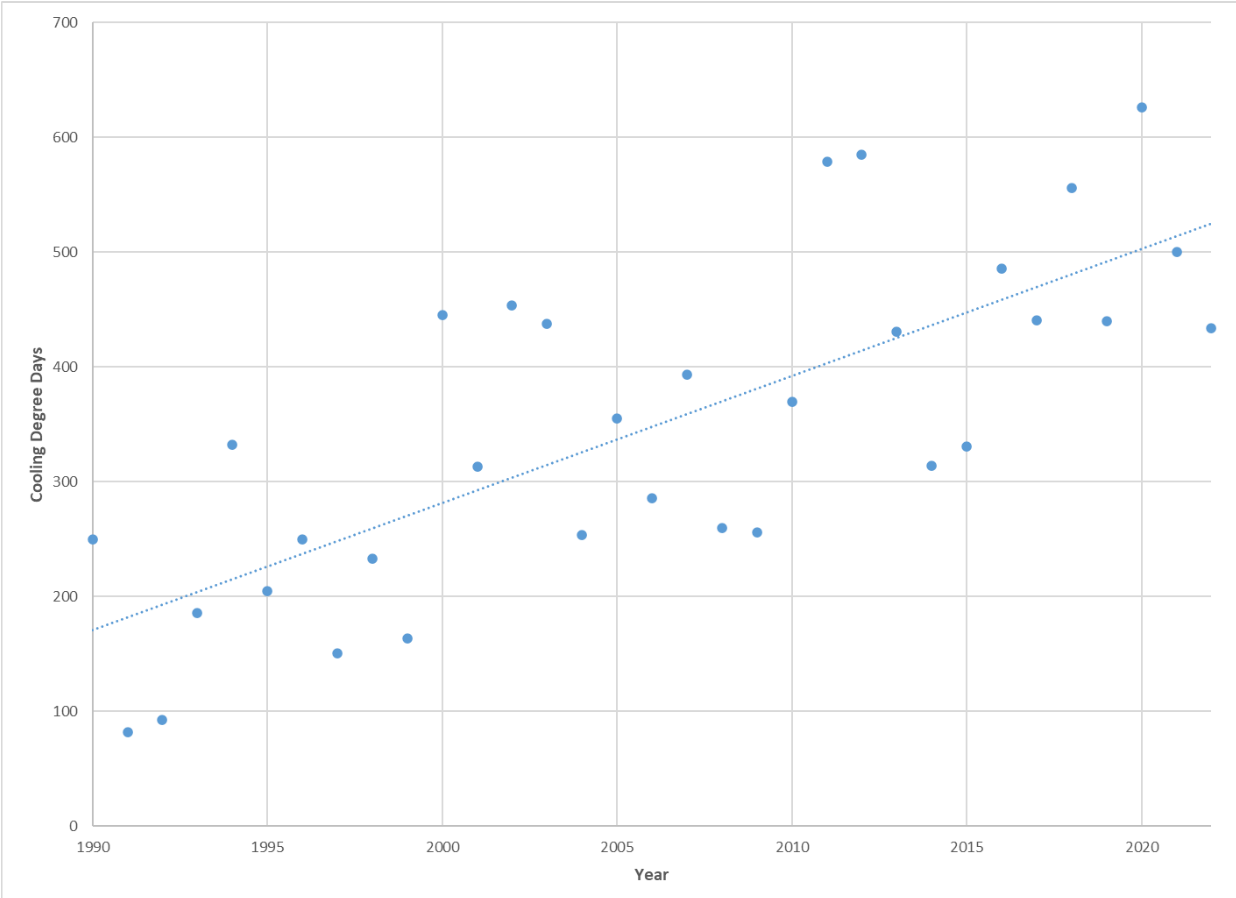


Figure 2-4. Los Alamos cooling degree days per year. The dashed line represents the trend line for cooling degree days, which shows cooling degree days have increased, resulting in more energy needed to cool buildings.

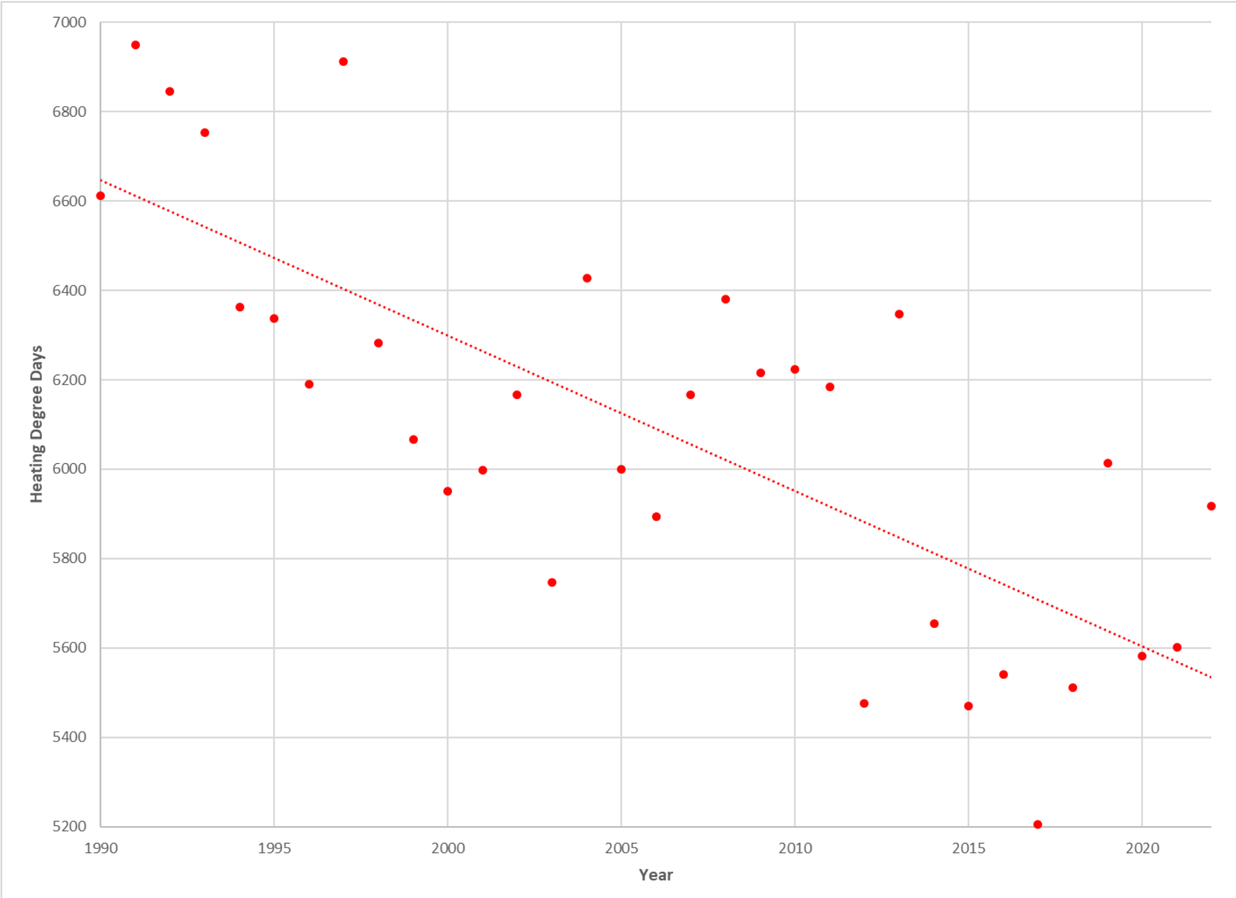


Figure 2-5. Los Alamos heating degree days. The dashed line represents the trend line for heating degree days, which shows heating degree days have decreased, resulting in less energy needed to heat buildings.

Wind Speed

The annual average wind speed measured at the Laboratory's meteorological tower of record at Technical Area 6 increased approximately 20 percent from 1994 to 2014 (see Figure 2-6). Since 2015, the annual average wind speed has remained around 2.9 meters per second. Although not shown here, the monthly average wind speed during the spring months (windiest months) shows an increase of approximately 1 meter per second. There is no trend in the annual peak gusts recorded at Technical Area 6 since 1990 (Kelly et al. 2015).

Winds are produced by low- and high-pressure weather systems that move across New Mexico. Near the ground's surface, wind speeds are also influenced by the type of vegetation present (for example, forests versus grasslands). Our current hypothesis is that the extensive loss of trees in the local area caused by wildfires, drought, and bark beetle infestations has led to a decrease in the amount of wind resistance provided by trees, allowing wind speeds near the surface to increase.

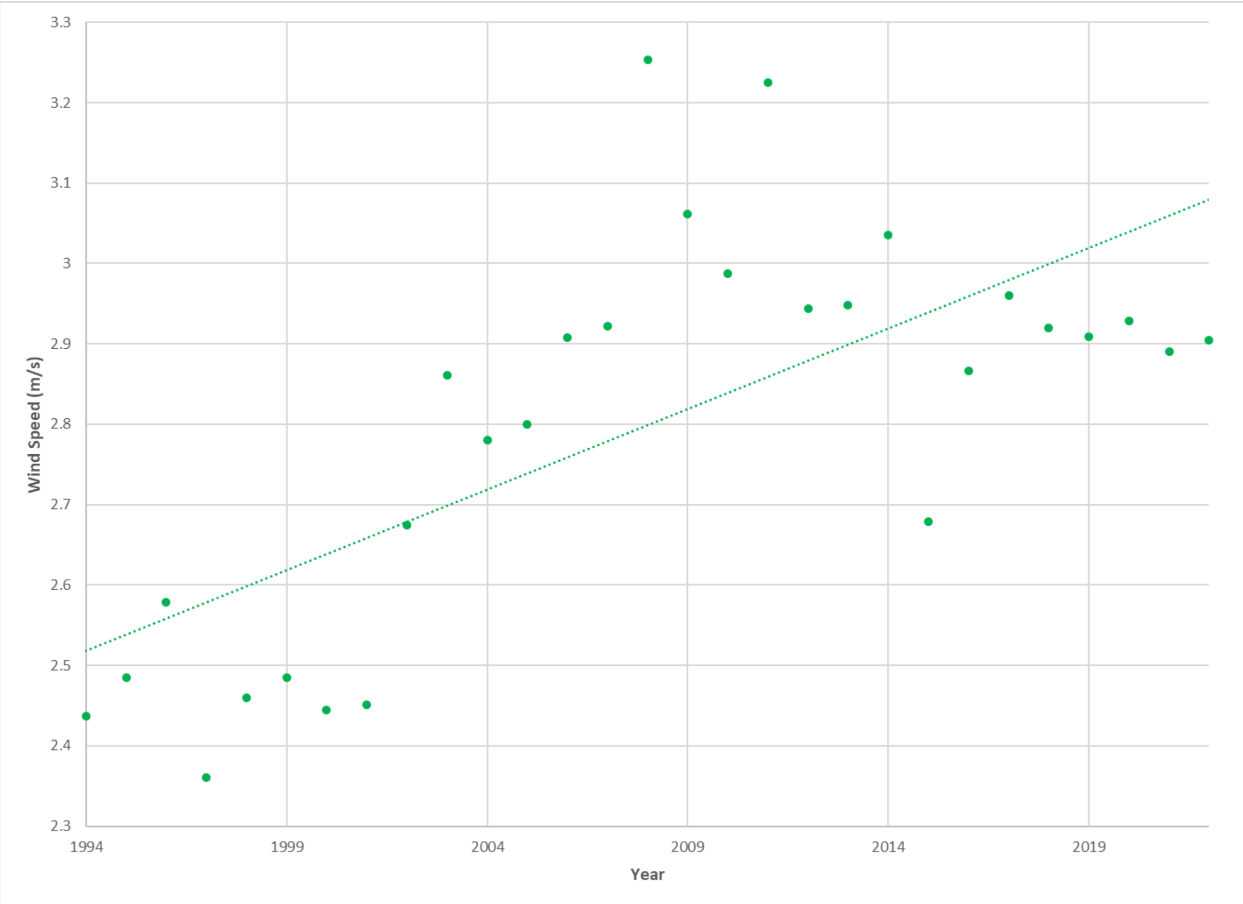


Figure 2-6. Technical Area 6 annual average wind speed at 12 meters above the ground. The dashed line represents the trend line for wind speed, which shows the annual average wind speed has been increasing since 1994.

Annual Red Flag Warnings

The National Weather Service issues Red Flag Warnings when critical weather conditions could result in extreme fire behavior. The National Weather Service began recording the number of Red Flag Warnings per year for the Los Alamos area in 2012 (see Figure 2-7). Red Flag Warnings have increased over the past 4 years, but since 2012, we have seen no trend. Some Laboratory operations, including explosives testing, are restricted on days with Red Flag Warnings.

If the following weather conditions occur simultaneously for 3 or more hours, a Red Flag Warning may be issued.

- Sustained winds at or above 20 miles per hour
- Relative humidity less than 15 percent
- Above-average temperatures

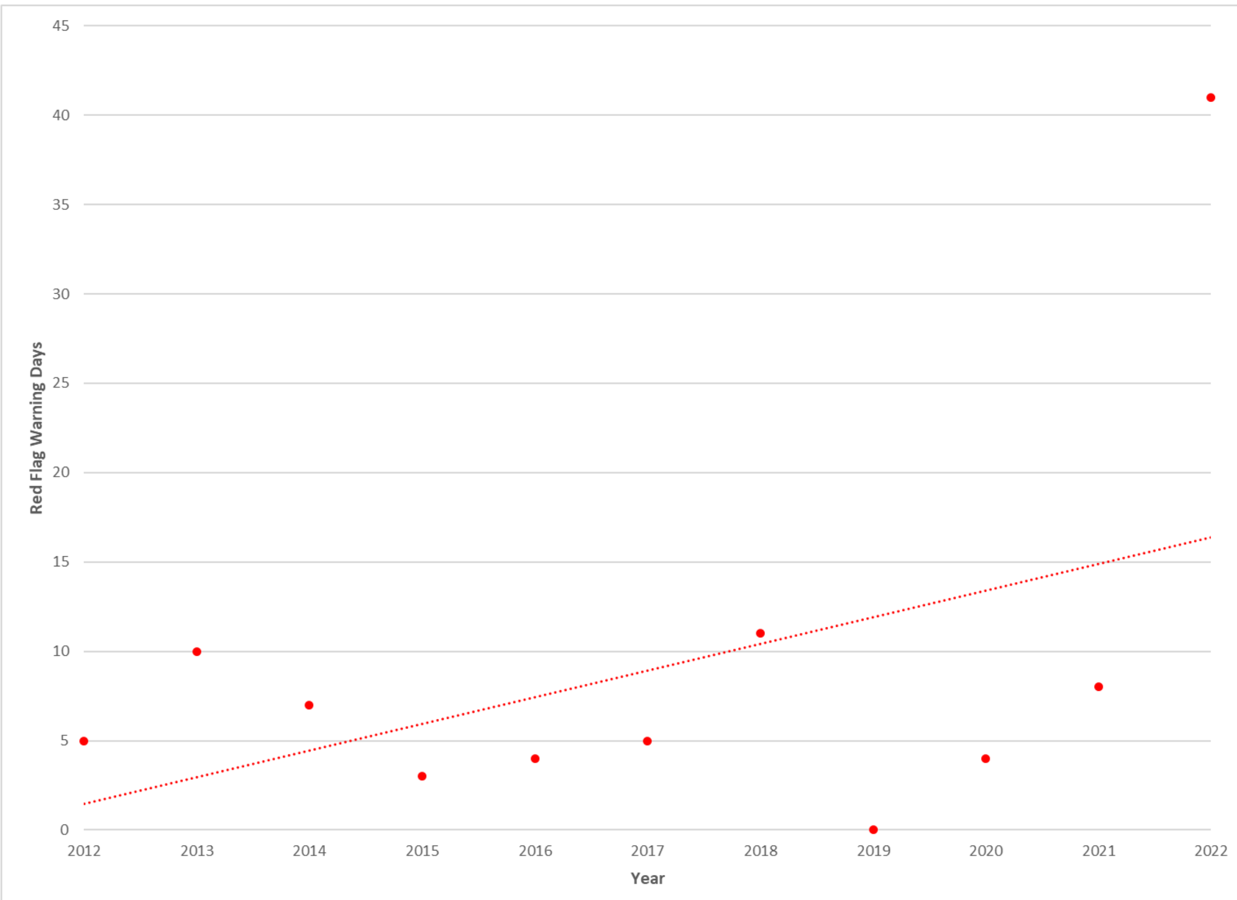


Figure 2-7. Number of National Weather Service Red Flag Warning days for zone 102 (Los Alamos).

Precipitation

We analyzed the annual average precipitation (see Figure 2-8) and the number of days per year with heavy rain events (see Figure 2-9). From 1924 through 2010, the annual average precipitation was 18 inches, with a standard deviation of 4.4 inches. A long-term drought began in 1998, with precipitation under 15 inches between 2000 and 2003 and again in 2011, 2012, 2019, 2020, and 2021. Annual precipitation values were as low as 10 inches in 2003 and 2012.

The frequency of heavy rain events (see Figure 2-9), defined as precipitation greater than 0.5 inches in 1 day, does not demonstrate a significant long-term trend since 1950. Although not shown here, no trend exists in the heaviest events (precipitation >0.75 inches or >1.0 inch per day) in the past 50 years.

Annual average snowfall (see Figure 2-10) demonstrates a decrease in the long-term trend since 1950. Since the drought began in 1998, the 30-year average snowfall has dropped from 59 to 43 inches.

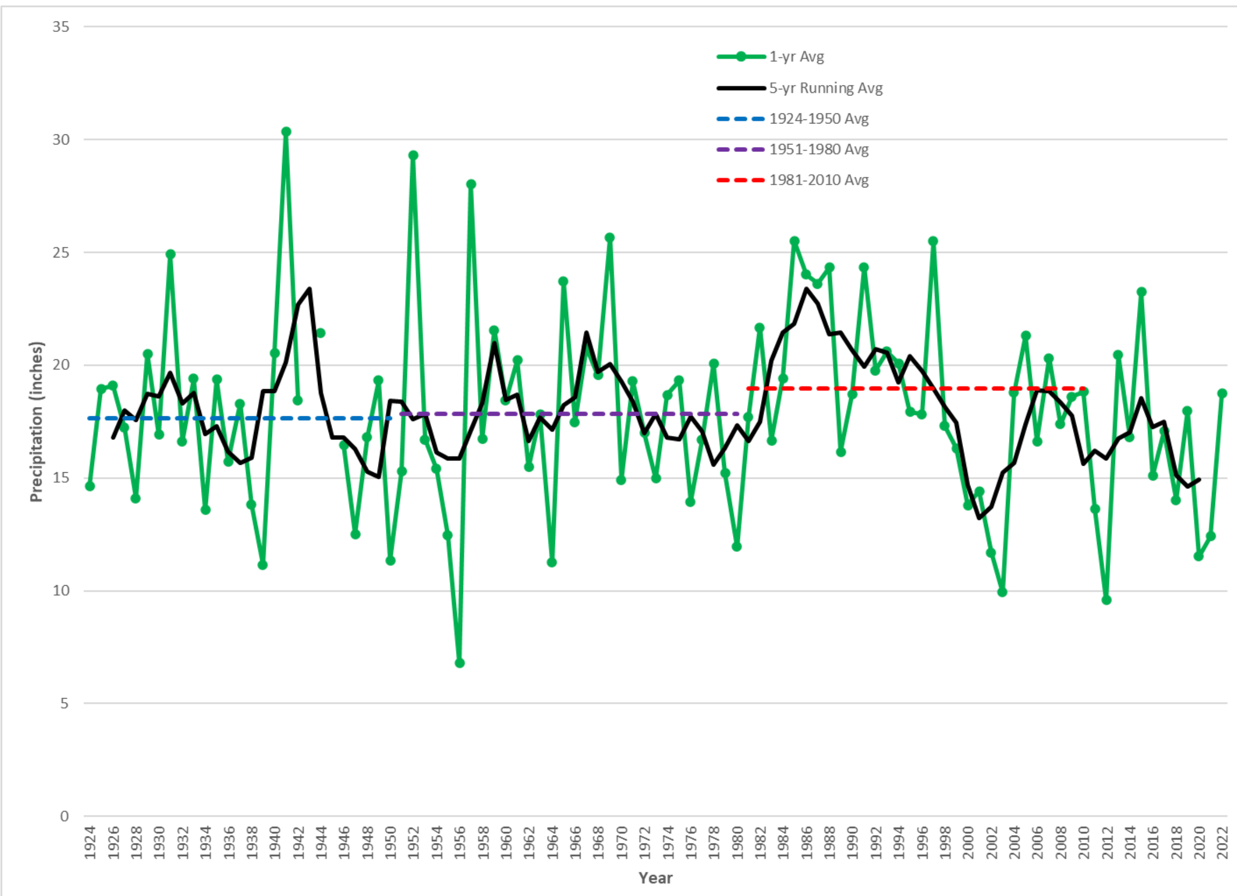


Figure 2-8. Annual precipitation totals for Los Alamos. The dashed lines represent long-term climatological average total precipitation, the black line represents the 5-year running average precipitation, and the green line represents the 1-year total precipitation. Significant drought since the 1990s has resulted in below average precipitation in many recent years.

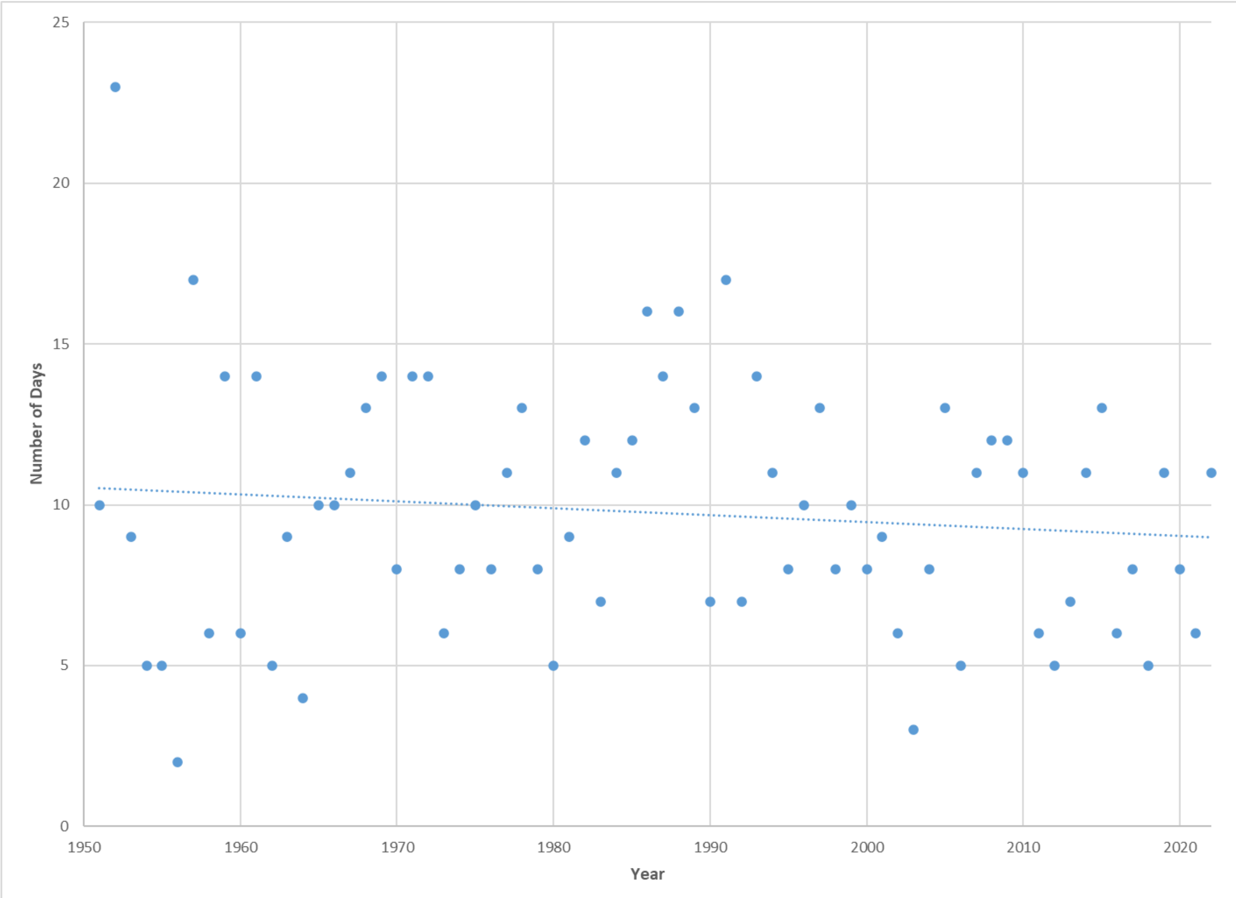


Figure 2-9. Number of days per year with precipitation >0.5 inches. The dashed line represents the trend line for days with precipitation >0.5 inches. The slight decreasing trend since 1950 is not statistically significant.

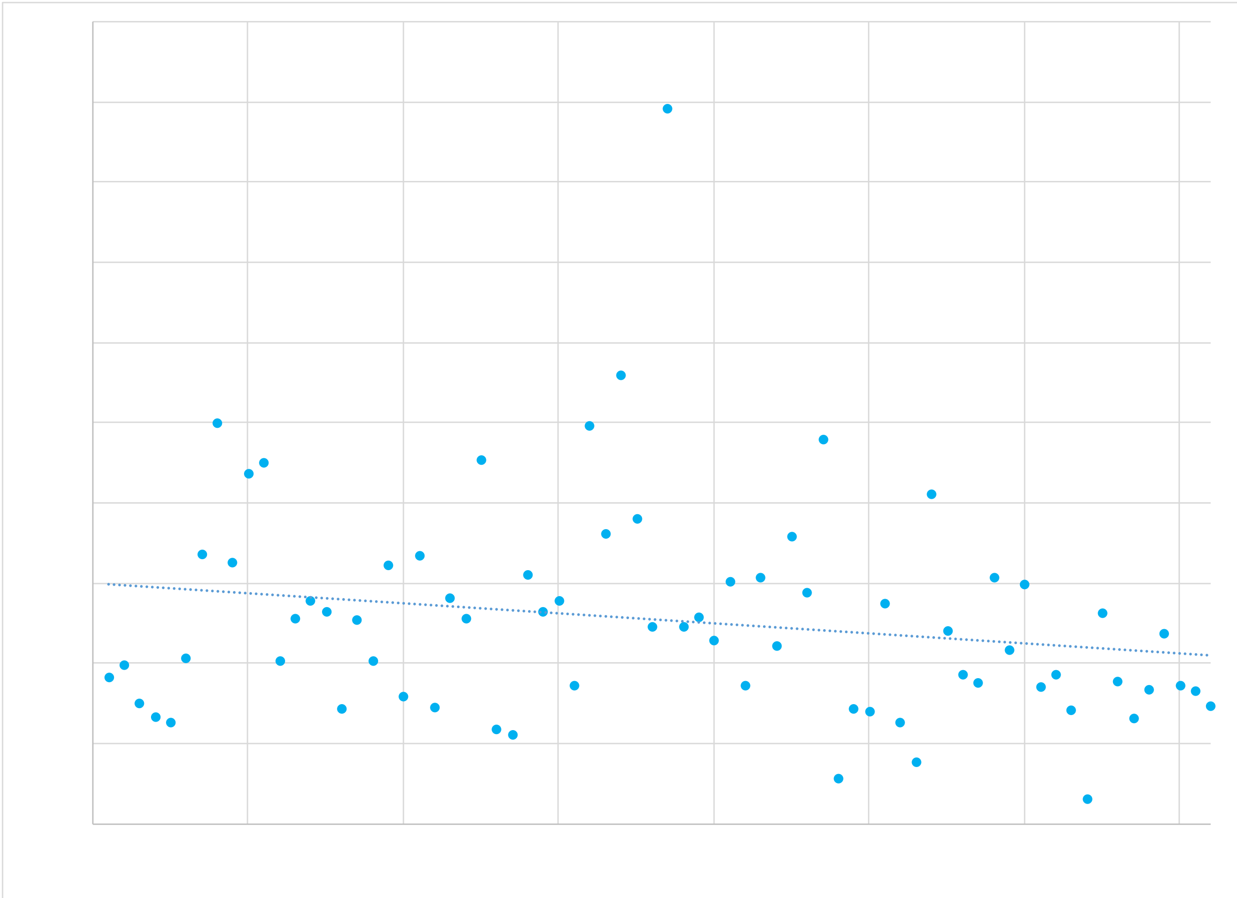


Figure 2-10. Annual Los Alamos snowfall. The dashed line represents the trend line for snowfall, which shows a decrease in annual snowfall.

Climatic Summary

Average temperatures in Los Alamos have increased over the past 25 years, consistent with the predictions of the National Climate Assessment for the southwestern U.S. The annual average temperatures for the southwest are predicted to rise by 3.7°F to 4.8°F by 2036–2065, and the temperatures measured at Los Alamos are consistent with these predictions. Increases in cooling degree days and reductions in heating degree days will produce increased summer air-conditioning costs and reduced winter heating costs.

Although the predictions of precipitation changes are less certain than temperature predictions, the National Climate Assessment predicts decreasing winter and spring precipitation in the southwest. The Laboratory's data are consistent with these predictions, particularly over the past 25 years, with below-average precipitation and snowfall in a majority of the years. The National Climate Assessment does not make a specific prediction for the southwest for heavy precipitation events. The Laboratory's data do not show a trend in heavy precipitation events in Los Alamos.

The National Climate Assessment predicts increasing wildland fires in the southwest because of warming, drought, and insect outbreaks. Three major wildland fires have impacted the Laboratory in the past 25 years: the 2000 Cerro Grande fire, the 2011 Las Conchas fire, and the

2022 Cerro Pelado fire. Precursors to these fires included warm, dry years and local bark beetle infestations (LANL 2012). The Los Alamos data are consistent with the predictions of increasing wildland fires. The annual average wind speed has been increasing, probably related to the reduction in forest cover caused by tree mortality. Increases in average wind speeds affect emergency planning in the event of an aerial release of hazardous substances.

Climate Change Vulnerability Assessment and Resilience Planning

In 2021, President Joseph Biden issued Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*. In part, the Order emphasizes taking a government-wide approach to the climate crisis and directs federal agencies to develop plans to increase their resilience to the impacts of climate change. The DOE's 2021 Climate Adaptation and Resilience Plan includes five priority actions. The first action is to assess vulnerabilities and implement resilience solutions at DOE sites.

As a DOE site, the Laboratory was directed to conduct a vulnerability assessment and develop a resilience plan. This effort was led in 2022 by staff from LANL's Pollution Prevention Program. A steering committee composed of representatives from DOE and the three main Laboratory directorates (Weapons, Operations, and Science, Technology & Engineering) identified and ranked mission-critical facilities and other assets. A total of 141 critical assets were identified for the Laboratory.

The likelihood and severity of climate-related hazards were evaluated through reviews of historical records, including LANL-specific sources and the published literature. We used a risk assessment tool developed by DOE to score vulnerabilities to specific climate hazards for each critical asset. Hazards projected to have high impacts to three or more asset types were characterized as high impact hazards. Five high impact hazards were identified for the Laboratory:

- increased frequency and intensity of extreme heat events;
- increased frequency, intensity, and duration of extreme precipitation events;
- thunderstorms (combined precipitation, wind, and lightning);
- increased flooding and erosion events; and
- increased wildfire frequency.

The hazard that presented the greatest risk across all critical assets was wildfire.

Using the results from the risk assessment tool, we created a risk matrix to help visualize the vulnerabilities of critical assets to climate change hazards. The summary risk matrix is shown in Table 2-22. Many of the risk scores are in the red/high-risk category. There was general agreement within the LANL Vulnerability Assessment and Resilience Plan team that this result did not mean that the Laboratory was in great danger from the hazards related to climate change; rather, these high scores indicated which hazards warranted the greatest degree of mitigation and which assets needed the most protection.

Table 2-22. LANL Risk Matrix Summary of Average Vulnerability Assessment and Resilience Plan Risk Scores for Climate Change Hazards across Asset Type

Type of Asset	Number of Assets	Climate Hazard					
		Increased Heat Wave Events	Increased Precipitation Events	Increased Thunderstorms	Increased Flooding Events	Increased Wildfire Frequency	Increased Severe Wind Events
Specialized or mission-critical equipment	48	8.5	8.8	8.4	7.7	8.4	7.8
Energy Generation and Distribution Systems	30	7.5	7.5	7.5	7.5	7.8	5.7
Onsite Waste Processing	18	8.6	8.0	7.8	7.6	8.1	6.9
Site Buildings	25	7.2	8.2	7.8	7.4	7.7	7.2
Water and Wastewater Systems	18	6.4	7.9	7.9	6.8	7.6	6.8
Information Technology and Telecommunication Systems	2	7.2	7.2	4.7	6.7	7.7	4.7

Legend:
high-risk score (>7); medium-risk score (3.5–7); low-risk score (<3.5)

We solicited ideas for resilience solutions from personnel across the Laboratory. A total of 48 projects were proposed for consideration. Each solution was evaluated against the hazard(s) that it addressed, expected effectiveness, feasibility, cost and funding type, and the timeline for the proposed project. The planning team recommended 19 resilience solution projects for inclusion and tracking in the DOE Sustainability Dashboard. Examples of resilience solutions include the following:

- Developing a 10-megawatt onsite solar photovoltaic array
- Implementing a heat recovery steam generator to supply heat to Technical Area 3
- Reducing tree density to increase forest resilience to wildfire, drought, and insects
- Installing shade structures and/or planting deciduous shade trees to decrease cooling energy needs for onsite buildings

The final portfolio of recommended resilience solutions includes mitigations for all asset types and climate change hazards with a risk score of medium or high. We will revisit the Vulnerability Assessment and Resilience Plan data and process every 4 years while following the progress of each resilience solution in the DOE Sustainability Dashboard annually.

Summary of Permits and Compliance Orders

Table 2-23 presents the environmental permits and administrative compliance orders under which the Laboratory operated in 2022.

Table 2-23. Environmental Permits and Legal Orders that the Laboratory Operated under in 2022

Name	Activity	Issuing & Revision Dates	Expiration Date
Los Alamos National Laboratory Hazardous Waste Facility Permit	A permit that regulates management of hazardous wastes at the Laboratory, including storage and treatment. Issued by the New Mexico Environment Department. https://www.env.nm.gov/hazardous-waste/lanl-permit/	Renewed November 2010	December 2020 (Administratively Continued until new permit is effective)
Administrative Compliance Order No. HWB-14-20 Settlement Agreement and Stipulated Final Order (Supplemental Environmental Projects)	Settlement of Administrative Compliance Order No. HWB-14-20 issued on December 6, 2014, for violations of the Hazardous Waste Act and the Laboratory's Hazardous Waste Facility Permit. As part of the settlement, DOE is funding a series of Supplemental Environmental Projects. https://www.env.nm.gov/wp-content/uploads/sites/10/2019/10/LANLSASFOFINAL1_22_16.pdf	Settlement Agreement and Stipulated Final Order finalized on January 22, 2016	None
Compliance Order on Consent	An order that gives requirements for the investigation, corrective actions, and monitoring of Solid Waste Management Units and Areas of Concern. Issued by the New Mexico Environment Department. Transferred to N3B on April 30, 2018. https://hwbdocuments.env.nm.gov/Los%20Alamos%20National%20Labs/Permit/37925.pdf	Issued March 1, 2005; Revised October 29, 2012; Replaced by 2016 Compliance Order on Consent on June 24, 2016; Modified February 2017	None
Federal Facilities Compliance Order (for Mixed Wastes)	An order that requires the Laboratory to submit an annual update to its Site Treatment Plan for treating all mixed hazardous and radiological wastes (mixed waste). Issued by the New Mexico Environment Department. Los Alamos National Laboratory FFCO (nm.gov).	Issued October 4, 1995; Amended May 20, 1997	None
Clean Air Act, Title V Operating Permit	A permit that regulates air emissions from Laboratory operations (i.e., emissions from the power plant, asphalt batch plant, permanent generators, etc.). These emissions are subject to operating, monitoring, and record-keeping requirements. Issued by the New Mexico Environment Department.	Issued August 7, 2009; Reissued October 17, 2018	February 27, 2020 (Administratively continued until new permit is effective)

Name	Activity	Issuing & Revision Dates	Expiration Date
New Mexico Air Quality Control Act Construction Permits: Permits issued by the New Mexico Environment Department, regulating construction or modification of air emissions sources	Technical Area 3 power plant Permit modification 2 (NSR 2195-B-M3)	Issued September 27, 2000; Reissued November 1, 2011; Major Modification July 26, 2018; Administrative Revision, August 3, 2022	None
	Asphalt plant at Technical Area 60 Permit revision 1 (GCP3-2195-G-R1)	Issued October 29, 2002 Reissued September 12, 2006; Reissued December 2, 2021	None
	1600-kilowatt generator at Technical Area 33 Permit revision 4 (NSR 2195-F R4)	Issued October 10, 2002; Reissued December 12, 2013	None
	Two 20-kilowatt generators and one 225-kilowatt generator at Technical Area 33 (NSR 2195-P)	Issued August 8, 2007	None
	Data disintegrator (NSR 2195-H R1)	Issued October 22, 2003; Revised June 14, 2006	None
	Chemistry and Metallurgy Research Replacement facility, Radiological Laboratory/Utility/Office Building Permit revision 2 (NSR 2195-N R2)	Issued September 16, 2005; Reissued September 25, 2012	None
	LANL exemption notifications - rock crusher removed (NSR 2195)	Issued June 16, 1999	None
	Technical Area 35, Building 213, beryllium machining (NSR 632)	Issued December 26, 1985	None
	Technical Area 3, Building 141, beryllium technology facility (NSR 634 M2)	Issued March 19, 1986; Revised October 30, 1998	None
	Technical Area 55 beryllium machining (NSR 1081 M1R6)	Issued July 1, 1994; Revised May 12, 2006	None
Authorization to Discharge (from Outfalls) Under the National Pollutant Discharge Elimination System	A permit that authorizes the Laboratory to discharge industrial and sanitary liquid effluents through outfalls under specific conditions. Issued by the U.S. Environmental Protection Agency. Los Alamos National Laboratory (LANL) Industrial Wastewater Permit - Final NPDES Permit No. NM0028355 | U.S. EPA	Issued May 1, 2022; Effective August 1, 2022	August 2027

Name	Activity	Issuing & Revision Dates	Expiration Date
National Pollutant Discharge Elimination System General Permit for Discharges of Storm Water from Construction Sites	A general permit (not LANL-specific) that authorizes the discharge of pollutants during construction activities under specific conditions. Issued by the U.S. Environmental Protection Agency. 2022 Construction General Permit | U.S. EPA	Effective February 16, 2022	February 16, 2027
National Pollutant Discharge Elimination System Multi-Sector General Permit for Storm Water Discharges Associated with Industrial Activity	A general permit (not LANL-specific) that authorizes facilities with some industrial activities to discharge storm water and some non-storm-water runoff under specific conditions. Issued by the U. S. Environmental Protection Agency. Stormwater Discharges from Industrial Activities-EPA's 2021 MSGP | U.S. EPA	Effective September 29, 2021	February 28, 2026
Authorization to Discharge (from Solid Waste Management Units and Areas of Concern) Under the National Pollutant Discharge Elimination System	A permit that authorizes the Laboratory to discharge storm water from 405 Solid Waste Management Units and Areas of Concern under specific conditions. Issued by the U.S. Environmental Protection Agency. LANL - Storm Water Individual Permit - NPDES Permit No. NM0030759 | U.S. EPA	Issued August 1, 2022	July 31, 2027
Clean Water Act, Section 404/401 Permits	The U.S. Army Corps of Engineers authorizes certain work within water courses at the Laboratory under Clean Water Act Section 404 permits. The projects below were authorized to operate under a Section 404 nationwide permit with Section 401 certification.	Effective January 4, 2021 (4 new nationwide permits; 12 nationwide permits reissued; 40 of the 2017 nationwide permits remain effective)	January 3, 2026 (all current nationwide Section 404 permits)
	Water Canyon Storm Drain Reconstruction Project	Annual monitoring and reporting required through 2023	
	Mortandad Wetland Enhancement	Annual monitoring and reporting required through 2022	
	Technical Area 72 Firing Site Storm Water Control	Annual monitoring and reporting required through 2023	

Name	Activity	Issuing & Revision Dates	Expiration Date
Clean Water Act, Section 404/401 Permits (cont)	Technical Area 8 and 16 Gas Line Replacement Project involving soil disturbing activities in Cañon de Valle headwaters under a Regional General Permit 16-01	Reporting start and finish of channel disturbances; Certificate of Completion due upon completion of project. Placing channel fill near channel expires 3 months from project initiation.	
Groundwater Discharge Permit DP-857	A permit that authorizes discharges to groundwater from the Laboratory's Sanitary Wastewater System plant and the Sanitary Effluent Reclamation Facility, and use of the Sigma Mesa evaporation basins. Issued by the New Mexico Environment Department.	Issued December 16, 2016	December 16, 2021 (Administratively continued)
Groundwater Discharge Permit DP-1589	A permit that authorizes discharges to groundwater from the Laboratory's septic tank/disposal systems. Issued by the New Mexico Environment Department.	Issued July 22, 2016	July 22, 2021 (Administratively continued)
Groundwater Discharge Permit DP-1793	A permit that authorizes discharges to groundwater from the Laboratory's land application of treated groundwater. Issued by the New Mexico Environment Department.	Issued July 27, 2015	December 16, 2021 Permit reapplication was submitted on June 17, 2021. Issuance of the renewed permit is pending.
Groundwater Discharge Permit DP-1835	A permit that authorizes discharges to groundwater from the Laboratory's injection of treated groundwater into six Class V underground injection control wells. Issued by the New Mexico Environment Department.	Issued August 31, 2016	July 22, 2021 A permit reapplication was submitted on January 20, 2021. Issuance of the renewed permit is pending.

Name	Activity	Issuing & Revision Dates	Expiration Date
Groundwater Discharge Permit DP-1132	A permit that authorizes discharges to groundwater from the Laboratory's Radioactive Liquid Waste Treatment Facility to three discharge locations: Outfall 051, mechanical evaporator system, or solar evaporation tank system. Issued by the New Mexico Environment Department.	Issued May 5, 2022	May 4, 2027
National Pollutant Discharge Elimination System Pesticide General Permit	A general permit that authorizes the discharge of pesticides that have potential to enter waters of the U.S. Issued by the U.S. Environmental Protection Agency https://www.regulations.gov/document?D=EPA-HQ-OW-2015-0499-0118	Issued October 31, 2011 Reissued October 31, 2016	October 31, 2026

Facilities Included in the Enforcement and Compliance History Online Database

Table 2-24 lists Laboratory facilities in the Enforcement and Compliance History Online database that the U.S. Environmental Protection Agency maintains at https://echo.epa.gov/. This database lists environmental violations in the program areas regulated by the U.S. Environmental Protection Agency, such as water quality under the Clean Water Act or air quality under the Clean Air Act. The facility with compliance monitoring activities recorded within the last 5 years is listed at the top of the table. We excluded individual Laboratory projects listed as facilities that were covered only under the National Pollutant Discharge Elimination System Construction General Permit.

Table 2-24. Los Alamos National Laboratory Facilities Included in the Enforcement and Compliance History Online Database

Facility Name	Facility Address (all in Los Alamos, NM)	Facility Registry Service ID	Program Area(s) Considered
Los Alamos National Laboratory	1 mile south of Los Alamos	110010571880	Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, Air Emissions Inventory, Toxics Releases Inventory
Los Alamos National Laboratory	P. O. Box 1663	110064871107	Clean Water Act
Los Alamos National Laboratory	Los Alamos National Laboratory	110070003747	Clean Water Act
Los Alamos National Laboratory	P. O. Box 1663	110071296607	Clean Water Act
Los Alamos National Security, LLC, LANL	P. O. Box 1663 Mailstop A104	110038446312	Clean Water Act
Los Alamos Nat'l Lab Industrial	528 35th Street	110064642445	Clean Water Act

Quality Assurance

Waste Management

Triad's programs for waste management, including quality assurance, are described in the institutional procedure P409, *LANL Waste Management*, and flow-down documents. N3B's programs for waste management, including quality assurance, are described in procedure N3B-P409-0, *N3B Waste Management*, and flow-down documents.

Air Quality and Protection

Air quality compliance activities are performed in accordance with the procedures and processes described in EPC-CP-QAP-001, *Environmental Compliance Programs Quality Assurance Plan*; EPC-CP-QAP-901, *EPC-CP Quality Procedure to Supplement ADESH-0007, Document Control;* and a series of program implementation plans:

- EPC-CP-PIP-0101, *Rad-NESHAP Compliance Program*

- EPC-CP-PIP-0340, *Title V Operating Permit Program*
- EPC-CP-PIP-0301, *Greenhouse Gas Monitoring and Emissions Reporting*
- EPC-CP-PIP-0310, *Air Quality Refrigerants*
- EPC-CP-PIP-0320, *Emergency Planning and Community Right-to Know Act (EPCRA) Section 313 Reporting*
- EPC-CP-PIP-0330, *Air Quality Regulatory Review and Permitting*
- EPC-CP-PIP-0370, *Asbestos NESHAP Compliance*
- EPC-CP-PIP-0380, *Beryllium NESHAP Compliance*

More than 20 detailed quality procedures flow down from these program implementation plans. Air Quality Compliance team personnel conduct semi-annual internal inspections of all permitted sources using detailed checklists to ensure that all permit requirements are being met. Additionally, the New Mexico Environment Department Air Quality Bureau conducts periodic external inspections of LANL's compliance with its Title V Operating Permit.

Analytical data are used to generate various compliance monitoring reports and deliverables that are submitted to regulatory agencies as required by the permit. Each report is subjected to a quality peer review before submittal to ensure that the data are correct, representative, and meet the established data quality objectives. All reports submitted to regulatory agencies are maintained as quality records in accordance with the permit and ADESH-QP-006, *Records Management Plan*.

Refrigerant program personnel also conduct internal semi-annual audits to ensure that refrigerant used in service, maintenance, repair, and disposal activities on refrigeration equipment is accounted for, thereby assuring compliance with the no-venting prohibition under federal regulations.

Members of the Radioactive Air Emissions Management Team conduct stack sampling and monitoring activities, sampler inspections, flow measurements, and data analyses to meet regulatory requirements. All activities are conducted in accordance with procedure and with peer review. Representatives of the U.S. Environmental Protection Agency, Region 6, periodically visit the site to evaluate operations. Analytical data calculations and compliance reports for the Radioactive Air Emissions Management Team are subject to reviews similar to those described for the Air Quality Control program.

Surface Water Quality and Protection

Triad surface water compliance activities are performed in accordance with the procedures and processes described in

- EPC-CP-QAP-001, *EPC-CP Quality Assurance Plan*;
- EPC-CP-QP-0901, *EPC-CP Quality Procedure to Supplement ESHQSS-AP-007, ESHQSS Document Control Procedure*;
- EPC-CP-PIP-1201, *NPDES Industrial Point Source Permit Self-Monitoring*.

These documents ensure that compliance activities are planned, performed, and documented using approved procedures, data quality objectives, monthly/quarterly/yearly sampling plans, and integrated work processes.

In 2022, the following procedures were used to collect samples, prepare discharge monitoring reports, develop Water Quality Standards, cover the Section 404 permit, and prepare reapplication surveys:

- EPC-CP-PIP-1201, *NPDES Industrial Point Source Permit Self-Monitoring*
- EPC-CP-TP-1202, *Sampling at NPDES Point-Source Outfalls*
- EPC-CP-QP-1204, *Performing NPDES Re-Application Surveys*
- EPC-CP-TP-1205, *Calibration/Standardization of Instruments for Field Analysis*
- EPC-CP-QP-060, *Preparing Discharge Monitoring Reports for the NPDES Industrial Point Source Permit Self-Monitoring Program*
- EPC-CP-PIP-1301, *404/401 Dredge and Fill Permit Program*
- EPC-CP-PIP-1001, *Water Quality Control Commission (WQCC) Program Implementation Plan*

Surface water compliance samples are collected, and the associated data are analyzed using established data quality objectives that define the appropriate type of data to collect and establish guidelines for the acceptance and use of the analytical data to make decisions regarding compliance at each outfall. These data quality objectives are developed in accordance with U.S. Environmental Protection Agency QA/G-4, Guidance for the Data Quality Objectives Process.

In 2022, the following procedures were used to collect samples and prepare reports for the Triad Construction General Permit and the Multi-Sector General Permit programs:

National Pollutant Discharge Elimination System Construction General Permit

- EPC-CP-PIP-2001, *NPDES Construction General Permit Program Implementation Plan*
- EPC-CP-QP-2002, *Performing CGP[1] Stormwater Inspections*
- EPC-CP-TP-2003, *CGP Rain Gage Operation and Maintenance*

National Pollutant Discharge Elimination System Multi-Sector General Permit

- EPC-CP-PIP-2101, *NPDES Multi-Sector General Permit*
- EPC-CP-TP-2102, *Installing, Setting Up, and Operating ISCO Samplers*
- EPC-CP-TP-2103, *Inspecting ISCO Stormwater Runoff Samplers and Retrieving Samples*
- EPC-CP-QP-2104, *Installing, Inspecting, and Maintaining MSGP[2] Single Stage Samplers*
- EPC-CP-QP-2105, *MSGP Stormwater Visual Assessments*

[1] CGP = Construction General Permit
[2] MSGP = Multi-Sector General Permit

- EPC-CP-QP-2106, *Processing MSGP Stormwater Samples*
- EPC-CP-QP-2107, *Preparing Discharge Monitoring Reports for the NPDES Multi-Sector General Permit*
- EPC-CP-QP-2108, *MSGP Routine Facility Inspections*
- EPC-CP-QP-2109, *MSGP Corrective Actions*
- EPC-CP-QP-2110, *MSGP Stormwater Pollution Prevention Plan Preparation and Maintenance*

In 2022, N3B used the following procedures to collect samples and prepare reports for the surface water monitoring under the Storm Water Individual Permit, Multi-Sector General Permit and environmental surveillance programs.

- N3B-AP-ER-5008, *Verifying and Certifying Individual Permit Corrective Action Measures*
- N3B-DI-ER-4010, *Desk Instruction for Managing Electronic Precipitation Data for Storm Water Projects*
- N3B-DI-ER-4011, *Desk Instruction for Managing Electronic Stage and Discharge Data from Stream Gauge Stations*
- N3B-SOP-ER-3002, *Spring and Surface Water Sampling*
- N3B-SOP-ER-4001, *Processing Surface Water Samples*
- N3B-SOP-ER-4003, *Operation and Maintenance of Gauge Stations for Storm Water Projects*
- N3B-SOP-ER-4004, *Installing, Setting Up, and Operating Automated Storm Water Samplers*
- N3B-SOP-ER-5002, *Inspection, Installation, and Maintenance of Non-Engineered NPDES Individual Permit Storm Water Control Measures*
- N3B-SOP-ER-5004, *Inspecting Automated Storm Water Samplers and Retrieving Samples*
- N3B-SOP-ER-5006, *Determining and Evaluating Drainage Area Boundaries*
- N3B-GDE-ER-5013, *Inspection Guidance for Environmental Programs Watershed, Retention, and No Exposure Controls*
- N3B-GDE-ER-5011, *Hydrology for Individual Permit Corrective Actions and Control Measures – Design Guide*
- N3B-GDE-ER-5015, *Stormwater Best Management Practices Manual*
- N3B-SOP-ER-5016, *Multi-Sector General Permit Storm Water Corrective Actions*
- N3B-QP-RGC-003, *Land Application of Drill Cuttings*
- N3B-AP-RGC-0002, *Minor Spill Response Reporting Procedure*
- N3B-PLN-RGC-0001, *Sediment Management Decision Tree Guidance*
- N3B-PLN-RGC-0003, *Un-permitted Discharge Reporting*
- N3B-QP-RGC-0002, *Land Application of Groundwater*

- N3B-EPC-CP-QP-064, *MSGP Stormwater Visual Assessments*
- N3B-AOP-TRU-3003, *Material Release or Spill*
- N3B-SOP-RP-0005, *Radiological Emergency Response*

Groundwater Quality and Protection

Triad's Ground Water Quality and Protection program operates in accordance with EPC-CP-QAP-001, *EPC-CP*[3] *Quality Assurance Plan*. Discharges to treatment facilities that are part of this program are conducted in accordance with the Laboratory's P409-1, *LANL Waste Acceptance Criteria*.

References

Berryhill et al. 2020: J. T. Berryhill, J. E. Stanek, E. J. Abeyta, and C. D. Hathcock. 2020. "Sensitive Species Best Management Practices Source Document, Revision 5," Los Alamos National Laboratory, LA-UR-20-24514.

BISON-M 2023: Biota Information System of New Mexico. 2023. http://www.bison-m.org (accessed August 21, 2023).

DOE 2008a: "Final Site-Wide Environmental Impact Statement for the Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico," U.S. Department of Energy report DOE/EIS-0380.

DOE 2008b: "Record of Decision: Final Site-Wide Environmental Impact Statement for the Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico," *Federal Register*, Volume 73, p. 55833. Washington, DC.

DOE 2009: "Record of Decision: Final Site-Wide Environmental Impact Statement for the Continued Operation of Los Alamos National Laboratory Los Alamos, New Mexico," Document no. E9-16343. Washington, DC.

DOE 2019: "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," U.S. Department of Energy, DOE-STD-1153-2019.

DOE 2021: "Public Notice and Public Scoping Meeting for an Environmental Assessment for the Los Alamos National Laboratory Electrical Power Capacity Upgrade Project," Department of Energy, April 19, 2021.

Gonzalez, et al. 2018: P. Gonzalez, G. M. Garfin, D. D. Breshears, K. M. Brooks, H. E. Brown, E. H. Elias, A. Gunasekara, N. Huntly, J. K. Maldonado, N. J. Mantua, H. G. Margolis, S. McAfee, B. R. Middleton, and B. H. Udall. 2018. "Southwest," in *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, U.S. Global Change Research Program, 1101–1184. https://nca2018.globalchange.gov/ (accessed August 21, 2023).

Kelly et al. 2015: E. Kelly, J. Dewart, and R. Deola. 2015. "Analysis of Precipitation (Rain and Snow) Levels and Straight-line Wind Speeds in Support of the 10-year Natural Phenomena Hazards Review for Los Alamos National Laboratory," Los Alamos National Laboratory, LA-UR-15-29420.

[3] EPC-CP = Environmental Protection and Compliance-Compliance Programs

LANL 2008: "Performance Assessment and Composite Analysis for Los Alamos National Laboratory Technical Area 54, Area G, Revision 4," Los Alamos National Laboratory report LA-UR-08-6764.

LANL 2009: "Closure Plan for Los Alamos National Laboratory Technical Area 54, Area G," Los Alamos National Laboratory report LA-UR-09-02012.

LANL 2012: "Los Alamos National Laboratory Environmental Report 2011," Los Alamos National Laboratory report LA-14461-ENV.

LANL 2017: "A Plan for the Management of the Cultural Heritage at Los Alamos National Laboratory, New Mexico," Los Alamos National Laboratory report LA-UR-19-21590.

LANL 2020: "Sensitive Species Best Management Practices Source Document, Revision 5," Los Alamos National Laboratory report LA-UR-20-24514.

LANL 2021a: "Request to Amend the Consultation for the Modernization and Development of the Weapons and Facility Operation's High Explosive Testing and Processing Facilities at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-CP-21-20371.

LANL 2021b: "Pollinator Protection Plan for Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-21-21113.

Thompson et al. 2022: B. E. Thompson, C. D. Hathcock, and A. A. Sanchez. 2022. "Threatened and Endangered Species Habitat Management Plan for Los Alamos National Laboratory," Los Alamos National Laboratory, LA-UR-22-20556.

McNaughton et al. 2022: M. McNaughton, C. Bullock, and M. J. Chastenet. 2022. "2021 LANL Environmental ALARA Program Status Report for CY 2020." Los Alamos National Laboratory report LA-UR-21-22997.

N3B 2021: "Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year, October 2021–September 2022." EM2021-0131. Los Alamos, NM, May 2021.

Neptune 2021a: "Maintenance Plan for the Performance Assessment and Composite Analysis for Technical Area 54, Area G at Los Alamos National Laboratory," NAC-0157_R1, Neptune and Company Inc., Los Alamos NM, March 2021.

Neptune 2021b: "Erosion Modeling at Area G: Response to LFRG Secondary Issues 3.1.1.1, 3.1.5.5, 3.1.6.3, and 3.1.9.1," NAC-0159_R1, Neptune and Company Inc., Los Alamos NM, March 2021.

Neptune 2021c: "Infiltration Modeling at Area G: Response to LFRG Secondary Issues 3.1.1.5, 3.1.5.3, 3.1.6.3," NAC-0160_R1, Neptune and Company Inc., Los Alamos NM, March 2021.

Pollinator Health Task Force 2015: Pollinator Health Task Force. 2015. "National Strategy to Promote the Health of Honey Bees and Other Pollinators." The White House, Washington, D.C. Online at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20Strategy%202015.pdf

Chapter 3: Environmental Programs and Analytical Data Quality

This chapter highlights the programs that Los Alamos National Laboratory (LANL or the Laboratory) has in place to comply with environmental laws and regulations and to reduce the risk of Laboratory operations adversely affecting the environment. All of the Laboratory's environmental programs contribute to and are part of our environmental management system.

We first discuss processes and programs that support Laboratory-wide activities to improve our environmental performance. These processes and programs include the Pollution Prevention Program, the Site Sustainability Program, the Site Cleanup and Workplace Stewardship Program, and the Integrated Project Review.

Next, we discuss our dedicated "core" programs that lead our compliance with specific environmental laws. Core programs are generally composed of subject matter experts who are well versed in the requirements of laws such as the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act.

Finally, we discuss the process the Laboratory uses to ensure that the results from its monitoring and compliance sampling meet Department of Energy standards for data quality.

Introduction

This chapter includes information from both the management and operating contractor, Triad National Security, LLC (Triad), and the legacy waste cleanup contractor, Newport News Nuclear BWTX-Los Alamos (N3B). Both organizations use processes and programs to manage and improve the Laboratory's environmental performance. However, Triad manages a larger scope of work at the Laboratory than does N3B. Therefore, except for analytical data quality for sampling of environmental media, the bulk of the discussion in this chapter relates to programs managed by Triad. The analytical data quality is crucial for both environmental compliance and legacy waste cleanup and is managed in partnership by N3B and Triad.

Institutional Processes and Programs

Environmental Management System

Certification of the Laboratory's Environmental Management System to the International Organization for Standardization's 14001 Standard

The International Organization for Standardization is independent and nongovernmental. It brings together experts to develop voluntary international standards. These standards describe the best practices for conducting a range of activities. The 14001 Standard specifies the best practices for an environmental management system, which is the set of processes and practices that encourages continuous improvement of an organization's environmental performance to reduce its environmental footprint. The Laboratory has maintained independent, third-party certification for its environmental management system under the 14001 Standard since April 2006.

When the legacy waste cleanup contract was separated from the management and operating contract in 2018, each contractor organization took responsibility for its own environmental management system. Triad, the Laboratory's management and operating contractor, currently manages the certified environmental management system described above. N3B, the legacy waste cleanup contractor, has an environmental management system that aligns with DOE Order 436.1, *Departmental Sustainability*, and the International Standard for Organizations 14001 standard. This environmental management system is integrated with other N3B procedures and controls to expedite environmental performance and compliance. N3B is working toward having its conformance with the 14001 Standard confirmed by an external organization.

Environmental Management System Program Activities

The Deputy Laboratory Director for Operations chairs Triad's Environmental Senior Management Steering Committee. The committee sets institutional objectives and annual targets for environmental performance. The three institutional objectives for the Laboratory's environmental performance are

- clean the past,
- control the present, and
- create a sustainable future.

Within these three objectives, Triad's Environmental Senior Management Steering Committee identified the goals and targets (desired actions) for the 2022 fiscal year, as listed in Table 3-1.

Table 3-1. Institutional Objectives for the Laboratory's Environmental Performance

Objective	Goal	Targets
Clean the Past	Clean it out	• Identify and dispose of legacy/abandoned equipment, materials, and metals. • Plan and execute excess facility risk management and demolition projects for legacy-process contaminated facilities.
	No new backlog	• Right-purpose existing space; upgrade for ongoing and future use. • Identify, characterize, and process wastes on time.
Control the Present	Comply and protect	• Create a world-class waste management system (planning and turnkey, cradle-to-grave support). • Create a site-wide maintenance policy and implementation program plus tools, including programmatic, operations, and research-and-development-owned equipment in addition to facility-owned equipment. • Identify, characterize, and document all industrial waste streams that discharge to the Sanitary Waste Water System. Implement planning for waste/unneeded items for all projects and programs to ensure timely and proper disposition.
	Optimize resources	• Implement an effective chemical management program. • Reduce the environmental impacts for material acquisition and life cycle management. • Transition the institutional comprehensive site-planning process from the Campus Master Plan development into implementation consistent with the future implementation scope presented in the "Los Alamos National Laboratory 2021 Campus Master Plan" (LANL, 2022) deliverable.

Objective	Goal	Targets
Create a Sustainable Future	Advance and apply new technology	• Advance characterization technologies and reduce waste life cycle by using research and development to address key science and technology gaps. • Incorporate best-in-class sustainable design criteria into new construction and campus planning efforts.
	Communicate and collaborate	• Engage a wide variety of internal and external stakeholders at local, state, federal, and tribal levels on matters pertaining to our environmental plans and activities. • Work closely with key stakeholders such as the Department of Energy's Office of Environmental Management, the New Mexico Environment Department, Los Alamos County, the Eight Northern Indian Pueblos, and the Four Accord Pueblos to keep the public informed of our plans to protect the environment now and in the future.
	Enable effective institutional planning	Refine and maintain the Campus Master Plan-Landlord Stewardship Program Integrated Project Team between Triad and DOE as a key component of implementing the Campus Master Plan.

The Laboratory annually updates a list of the significant environmental aspects that could be associated with its activities. In the language of the 14001 Standard, an environmental aspect is an ". . . element of an organization's activities or products or services that interacts or can interact with the environment." Table 3-2 lists and describes the environmental aspects identified for 2022 that have the potential for significant environmental impacts, along with some example activities.

Managers and teams from each Laboratory directorate develop environmental action plans annually using the institutional goals and targets, along with their evaluation of their work activities. In 2022, Triad managed and tracked 370 actions in 13 of these action plans.

Table 3-2. LANL Significant Environmental Aspects

Environmental Aspects	Description	Examples
Air emissions	Activities that release or have the potential to release material into the air	• Point-source air emissions from stacks, vents, ducts, or pipes • Activities that produce greenhouse gases
Interaction with surface water and storm water	Activities that release or have the potential to release pollutants into a watercourse or through direct discharge to or contact with storm water (for example, discharge onto the ground near a waterway)	• Discharges from permitted outfalls • Spills and unintended discharges • Activity within the boundary of a watercourse
Discharge to wastewater systems	Activities that release or have the potential to release material to or from a wastewater treatment system (sanitary, chemical, or radiological)	• Laboratory sinks • Wastewater collected and transported to a wastewater facility
Interaction with drinking water supplies/systems or groundwater	Activities that release or have the potential to release material into a drinking water supply system or into groundwater; these activities include planned or unplanned releases onto the ground or into surface water that have the potential to migrate to groundwater	• Work involving groundwater wells or associated systems • Land application of water • Septic systems and sanitary holding tanks
Work within or near floodplains and wetlands	Activities that release or have the potential to release material onto or into a floodplain, wetland, or area of overland flow, or placing structures or impoundments in a floodplain or wetland	• Structures built in a floodplain or wetland • Activities that disrupt the integrity of a floodplain or wetland
Interaction with wildlife and/or habitat	Activities that impact or have the potential to impact federally protected wildlife or their habitats, migratory birds, and other wildlife not managed under any federal law	• Removal of trees or brush • Installation and operation of night lighting • Work operations that generate noise
Biological hazards	Activities that generate, use, or dispose of biological agents. These agents exclude human viral, bacterial, or blood-borne pathogens.	Management of medical materials and byproducts
Interaction with soil resources	Activities that disturb surface or subsurface soils or release or have potential to release material onto or into the ground, including planned or unplanned deposition of airborne particulates and releases of solids or liquids onto or into the ground and activities that could result in migration or deposition of radioactive constituents onto or into the ground; activities could result from routine work or from emergency or off-normal events	• Ground-disturbing activities • Operations that are sources of diffuse air emissions, such as open-detonation or remediation activities • New construction, site selection, and brownfield versus greenfield development

Environmental Aspects	Description	Examples
Spark- or flame-producing activities	Activities that cause or have the potential to start a fire or wildfire	• Off-road vehicle use • Outdoor spark- or flame-producing operations
Cultural/historical resources	Activities that impact or have the potential to impact cultural or historical resources, including historical buildings, buildings of special significance, archaeological sites, traditional cultural properties, historic homesteads, and trails; activities could result from routine work or from emergencies or off-normal events	• Maintenance or expansion of existing areas (trails, walkways, roads, easements) • Ground-disturbing activities • Maintenance, modification, or demolition of potentially or designated historic structures
Visual resources	Activities that impact or have the potential to impact visual landscapes	• Construction, management, and maintenance of access roads, fencing, and utility corridors • Security or after-hours lighting
Hazardous or radioactive material and waste packaging and transportation	Activities that handle, package, or transport hazardous waste or radioactive materials	• Transportation of chemicals • Transportation of low-level radiological waste, mixed low-level waste, or transuranic waste
Radioactive waste generation and management	Activities that generate or manage (handle, store, or dispose of) radioactive waste	• Laboratory or research and development procedures using or generating radioactive material • Cleanup of historical waste disposal areas
Hazardous or mixed-waste generation and management	Activities that generate or manage (handle, store, treat, or dispose of) hazardous or mixed waste	• Research and development procedures using or generating hazardous materials • Disposal of unused laboratory chemicals
Solid or sanitary waste generation and management	Activities that generate or manage (handle, store, treat, or dispose of) nonhazardous and nonradioactive waste intended for disposal at a municipal or industrial waste landfill	Laboratory, machining, and process operations wastes (nonhazardous or nonradioactive)
Interaction with contaminated sites	Activities that have the potential to increase or spread contamination because they are conducted within the boundary of or near contaminated areas, which include solid waste management areas, radiological sites, nuclear facilities, and high-explosives sites	• Construction • Mitigation • Demolition • Open detonation

Environmental Aspects	Description	Examples
Chemical (industrial and laboratory) use and storage	Activities that result in the purchase, use, management, movement, or storage of chemicals; activities could result from routine work or from emergency or off-normal events	• Chemical use in research laboratories • Vehicle operation and maintenance • Building cleaning and maintenance
Radioactive material use and storage	Activities that handle or store radioactive materials	Radioactive material machining or processing
Surplus properties and material management	Activities that manage (handle or store) in-use materials, surplus supplies, real estate, or other property	Managing (storing, using, recycling, reusing, disposing of) surplus property
Resource use and conservation	Activities or practices that affect resource use and conservation, could increase or reduce demand or wastes, or could drive increases in efficiency of resource use (labor, natural material, energy, etc.), use of alternative material, or reuse/recycling opportunities	Applying sustainable design principles; for example, cool roofs, natural lighting, insulated glass, and recycled or low-impact building materials
Storage of materials in tanks	Activities that involve handling or storing materials in tanks	Operating and/or maintaining aboveground tanks in accordance with the Laboratory's hazardous waste permit
Engineered nanomaterials	Activities that involve intentionally created particles with one or more dimensions between 1 and 100 nanometers	Nanotechnology research and development that generates nanoparticles that require environmental or worker safety controls

The online course, *Environmental Awareness Training*, is required for all employees (including subcontractors) who are on site for longer than 2 weeks. Retraining is required every 2 years.

The Laboratory's environmental management system has both external audits and internal assessments every year. All findings and corrective actions generated from these audits and assessments are tracked to closure in an issues management system. In 2022, two external certification audits were held. The first audit found one minor nonconformity (a minor deficiency that does not seriously affect the efficiency of the environmental management system) related to outdoor space management, and the second identified an opportunity for improvement in linking public inquiries about environmental issues to existing systems.

DOE sites are annually scored red, yellow, or green on metrics that evaluate their environmental management systems. In 2022, the Laboratory scored green on each of the following federal government metrics:

- Activities, products, and services (and their associated environmental aspects) and all newly identified activities, products, and services (and their associated environmental aspects) were evaluated for significance within the past fiscal year.
- Measurable environmental objectives were in place.
- Operational controls were established, implemented, controlled, and maintained in accordance with operating criteria.
- An environmental compliance audit program was in place, and audits were completed according to schedule. Audit findings were documented, and corrective actions were implemented.
- As directed by Executive Order 13834, Efficient Federal Operations, sustainability goals were addressed.

Site Sustainability

The Laboratory's sustainability efforts and goals align with the following climate-related Executive Orders:

- Executive Order 13990, *Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis*, sets the policy of the federal government to, among other things, reduce greenhouse gas emissions and bolster resilience to the impacts of climate change.
- Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, announced an economy-wide goal of net-zero emissions and 100 percent renewable energy by 2050.
- Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, established government-wide goals for net-zero carbon emissions.

Our site sustainability plan focuses on developing more-efficient and more-resilient operations through four key initiatives:

- efficiency improvements and reduction of carbon dioxide emissions for the steam plant and combustion gas turbine generator;
- construction and operation of an onsite, 10-megawatt photovoltaic facility;

- water and energy efficiency measures and reduction of carbon dioxide emissions for DOE-owned buildings, and
- transition to zero-emissions vehicles.

The site sustainability plan was developed in coordination with other plans for major infrastructure improvements and site upgrades, including the *2021 Campus Master Plan* (LANL 2022), and it supports Laboratory efforts for greenhouse gas reduction (see section on Greenhouse Gas Reduction).

We have made significant improvements in efficiency regarding energy use and water use over the past 10 years, including the following:

- Testing building systems, equipment, and operations to ensure that they are functioning optimally in an energy-efficient manner and identifying opportunities to address inefficiencies (a process called "recommissioning") in 40 facilities
- Replacing and upgrading building automation systems in 15 facilities
- Continuously monitoring the performance of building systems and equipment in 94 facilities using the fault-detection software SkySpark
- Participating in an energy savings performance contract for heating, ventilation, air conditioning, and lighting upgrades, currently in its performance period
- Participating in an energy savings performance contract for the steam plant replacement project
- Developing a photovoltaic facility, including completing the environmental assessment and biological assessment
- Creating the LANL Smart Labs Program to increase energy efficiency in laboratories
- Creating the "My Green LANL" Program for certified sustainable practices
- Updating the LANL Engineering Standards Manual to incorporate more comprehensive sustainable design criteria, including Smart Labs
- Insulating steam pits using infrared technology to save 112,000 British thermal units per year per pit, with a payback of just over 2 years
- Installing light-emitting diode and motion-sensing lighting in parking garages and solar lighting in outside parking lots
- Installing 69 electric vehicle charging stations
- Using a mobile shredding truck to improve paper recycling efficiency with savings in fuel, labor, and operating expenses
- Improving the Sanitary Effluent Reclamation Facility to increase reclaimed water usage in high-performance computing

Over the next 10 years, the Laboratory is expected to double its energy use in high-performance computing facilities, with accompanying increases in the use of water for cooling. To assist with sustainability efforts, two plans were completed in 2022:

- The Water Management Plan calls for the Laboratory to continue water efficiency initiatives, including operation of the Sanitary Effluent Reclamation Facility and investing in new water treatment systems that increase the number of concentration cycles in cooling towers and other projects that reduce water use.

- The Net-Zero Emissions Plan focuses on four key areas:
  – reducing or eliminating carbon dioxide emissions from LANL's electricity sources;
  – researching/using carbon capture, carbon-neutral hydrogen, bioenergy, and bioproducts;
  – electrifying LANL building heating systems; and
  – further reducing energy use in facilities and vehicles

Table 3-3 lists DOE's goals, LANL's 2022 efforts toward each goal, and its future planned efforts.

Table 3-3. Fiscal Year 2022 Status and Planned Strategies for the Laboratory's Site Sustainability Goals

DOE Goal	Fiscal Year 2022 Efforts	Planned Efforts
Reduce energy use intensity (British thermal units per gross square foot) in goal-subject buildings	We achieved a 4.6 percent reduction from the fiscal year 2015 baseline and designed efficiency conservation measures for seven facilities.	• Continue to install building automation in facilities • Continue lighting upgrades
Complete Energy Independence and Security Act Section 432 continuous energy and water evaluations on a 4-year cycle	We met the annual target of doing energy and water evaluations in 25 percent of eligible facilities and assessed software for use in life-cycle cost analysis.	Complete 21 energy and water evaluations on facilities covered under Section 432 and four evaluations on high-performance sustainable buildings that are not covered
Meter individual buildings for electricity, natural gas, steam, and water where cost-effective and appropriate	We have fully metered 23 LANL-owned facilities, and an additional 76 facilities are partially metered. More than 20 gas meters were purchased to replace broken meters on high-performance sustainable buildings and other facilities, and 14 natural gas meters have been replaced.	• Finish communication connections for the replaced gas meters • Continue meter replacement for more than 100 facilities consistent with the DOE metering plan
Reduce potable water use intensity (gallons per gross square foot)	We had a 0.7 percent increase in potable water use intensity from the fiscal year 2007 baseline. At the Sanitary Effluent Reclamation Facility, 28.1 million gallons of wastewater was treated, reducing the amount of potable water needed for cooling at the Strategic Computing Complex.	• Increase cycles of concentration at the Strategic Computing Complex cooling towers • Continue water reclamation at the Sanitary Effluent Reclamation Facility
Reduce nonpotable freshwater consumption (gallons) for industrial, landscaping, and agricultural uses	All water used at LANL is potable.	N/A
Reduce the amount of nonhazardous solid waste sent to treatment and disposal facilities	LANL diverted 42.9 percent of nonhazardous solid waste from disposal facilities. Some waste was diverted at the Los Alamos Eco Station, including concrete, metals, pallets, asphalt, tires, and brush.	Continue programs such as furniture reuse, reusable moving bins, and woody waste composting to reduce nonhazardous waste sent to landfills
Reduce construction and demolition materials and debris sent to treatment and disposal facilities	LANL diverted 47 percent of construction and demolition waste, including concrete and metals.	Continue onsite processing and reuse of concrete, including the recycling of the associated rebar
Reduce petroleum consumption	Fleet management makes every effort to downsize vehicles during the replacement cycle depending on mission requirements. We are increasing the use of ride-share programs and started an electric bike pilot program.	Require zero-emissions vehicles when replacing fleet vehicles

DOE Goal	Fiscal Year 2022 Efforts	Planned Efforts
Increase alternative fuel consumption	We continue to use alternative fuels (E85 and biodiesel) purchased through a contract with a local tribal business.	Continue to purchase E85 and biodiesel
Acquire alternative fuel and electric vehicles	We are increasing use of alternative fuels (E85 and biodiesel) and exploring electric vehicle/plug-in hybrid electric vehicle options.	• Require zero-emissions vehicles when replacing fleet vehicles • Install more electric vehicle charging stations
Increase consumption of clean and renewable electric energy	Thirteen percent of LANL's energy comes from clean and renewable sources, and 1.1 percent of that energy is from onsite sources or renewable sources located on federal land.	Begin construction of the 10-megawatt onsite photovoltaic system in 2024
Increase consumption of clean and renewable nonelectric thermal energy	We began planning for net-zero energy, net-zero carbon emissions, and net-zero-carbon-ready solutions at LANL, which will include thermal energy.	Identify thermal energy solutions to meet zero-emissions targets and executive order requirements
Increase the number of owned buildings that are compliant with the Guiding Principles for Sustainable Buildings	Currently, 4.9 percent of LANL-owned buildings have achieved compliance with the Guiding Principles. We reassessed 5 existing high-performance sustainable buildings to confirm compliance and assessed energy savings of 24 additional existing buildings to consider for certification.	• Repair meters to keep buildings compliant • Certify one new facility • Use the Guiding Principles for new construction projects • Reassess four existing sustainable buildings
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring that all sustainability clauses are included as appropriate	We continued development of a procurement system called "SAP Ariba" to capture sustainable product purchases.	• Continue development of a sustainable products catalog in Ariba • Expand use of biobased products
Implement lifecycle, cost-effective efficiency and conservation measures with appropriated funds and/or performance contracts	We continued installing building automation systems and upgrades for building lighting and heating, ventilation, and air conditioning systems throughout multiple facilities.	Implement more energy- and water-efficiency projects
Electronics stewardship from acquisition to operations to end of life	Currently 98.5 percent of LANL's eligible electronics procurements are environmentally sustainable and 100% of electronics were recycled at the end of life. We achieved 100% power management on all eligible personal computers and monitors and ensured that excess electronics are available internally and externally for reuse when safe.	Continue purchase of sustainable electronic office products

DOE Goal	Fiscal Year 2022 Efforts	Planned Efforts
Increase energy and water efficiency in high-performance computing and data centers	We began work on cooling tower upgrades at the super computing facility.	Begin design work on a new, highly efficient high-performance computing facility
Implement climate adaptation and resilience measures	We completed the Vulnerability Assessment and Resilience Plan.	Update the Vulnerability Assessment and Resilience Plan every 4 years
Reduce Scope 1 & 2 greenhouse gas emissions	We achieved a 24 percent decrease in emissions from the 2008 baseline, reduced the amount of sulfur hexafluoride being used across the site, and completed the LANL Net-Zero Emissions Plan.	• Acquire electrical power from renewable sources • Begin the second phase of Net-Zero emissions planning
Reduce Scope 3 greenhouse gas emissions	We have achieved a 6.7 percent reduction from the fiscal year 2008 baseline and piloted a telework program that reduces emissions from commuting. We hired a transportation director.	• Implement transportation plan • Work to identify data gaps and improve data collection

Greenhouse Gas Reduction

During fiscal year 2022, we achieved a 24.0 percent reduction in combined Scope 1 and 2 greenhouse gas emissions compared with fiscal year 2008. Scope 1 emissions are direct emissions from Laboratory-owned or leased equipment and vehicles, unplanned releases of gases or vapors on site, and use of natural gas on site. Scope 2 emissions are generated by utility companies while producing electricity, heat, or steam purchased by the Laboratory. The Site Sustainability Program's initiatives to reduce energy use helped reduce the Laboratory's greenhouse gas emissions. Additionally, the Site Sustainability Program and the Pollution Prevention Program are continuing a site-wide effort to reduce emissions from sulfur hexafluoride.

We achieved a 6.7 percent reduction in Scope 3 greenhouse gas emissions compared with fiscal year 2008 and have continued to prioritize Scope 3 emissions reductions as the workforce grows. Scope 3 emissions are generated by offsite activities, including employee commutes, employee ground and air travel, and electricity transmission and distribution losses. In 2022, LANL hired a new transportation director and partnered with the Texas A&M Transportation Institute to develop a comprehensive transit and transportation plan. In addition to reducing traffic and parking congestion on site, this plan will reduce Scope 3 commuter emissions.

In December 2021, the Biden-Harris administration issued Executive Order 14057, *Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability*, which set numerous goals to reduce emissions and capitalize on clean energy production. The Laboratory will strive to meet these goals in the coming years by installing additional electric vehicle charging stations, increasing our use of carbon-free electricity, and working with engineers to ensure that designs and materials used for equipment and buildings are cost effective from a life-cycle standpoint.

The Laboratory's energy use is expected to steadily increase over the next 10 years as high-performance computing and expanded activities at the Los Alamos Neutron Science Center use more electrical power. To help meet the growing electricity demand and reduce greenhouse gas emissions, we are working to finish Phase I of the Steam Plant Replacement project, including adding a more efficient generator and controls, a new high-pressure gas line, and two new, efficient, natural gas boilers. Once complete, these upgrades will avoid the equivalent emissions of roughly 507 passenger vehicles per year and save the Laboratory roughly $6 million in energy and maintenance costs per year. Additionally, we are in the beginning phases of installing a 10-megawatt, onsite photovoltaic array, which will help avoid roughly 14,000 metric tons of carbon-dioxide-equivalent per year. Implementation of the previously mentioned Net-Zero Emissions Plan will further help greenhouse gas reduction across the site.

Operating Experience Program

The Laboratory maintains an operating experience and lessons learned program called "OPEX at LANL." The purpose of the program is to capture and apply lessons from experiences and to communicate best practices to prevent or reduce the severity of future undesirable events. OPEX at LANL collects and distributes information internal to the Laboratory and from other sources, including the other DOE sites. The program provides an online database of relevant lessons learned, best practices, safety information, security information, and programmatic information for workers to use and share, as well as a quarterly publication that provides event trends, causes, and learning opportunities.

Pollution Prevention

The Laboratory's Pollution Prevention program works to reduce waste and pollution from Laboratory operations. The program activities include

- eliminating or reducing all types of radioactive and other wastes,
- funding and supporting projects that eliminate or reduce the use of hazardous chemicals, and
- identifying and researching emerging contaminants.

Program staff prepare an annual Hazardous Waste Minimization Report for the New Mexico Environment Department and support the Laboratory's annual Site Sustainability Plan and its Vulnerability Assessment and Resilience Plan.

The program also carries out site-wide initiatives to address emerging waste-related issues. For example, program staff work with subject matter experts to prepare the Laboratory for future state and federal regulations. We are currently addressing risk related to per- and polyfluoroalkyl substances (PFAS). Ongoing efforts include identifying possible point sources of PFAS in operations to find source reduction opportunities, as well as scoping the feasibility of various treatment technologies for water, soil, or other media containing PFAS.

The Pollution Prevention Program recognizes projects across the Laboratory through annual environmental awards and internal and external communications. We allocate funds to support the work of Laboratory scientists and engineers in minimizing the use of hazardous substances. For example, the program funded projects to develop a non-petroleum-based alternative to plastic and to research the use of bacteria as a replacement for strong acid in target component preparation.

Program staff worked in collaboration with the Site Sustainability team to reduce impacts of the potent greenhouse gas sulfur hexafluoride. Over the last few years, the two programs purchased equipment that is being used to avoid release of sulfur hexafluoride, and the Pollution Prevention program funded research to reduce the use of sulfur hexafluoride gas in a technology needed for weapons experiments.

Finally, the Pollution Prevention program is working to expand and improve sustainable acquisition practices by collaborating with Acquisition Services Management. The Laboratory can reduce its environmental impact by purchasing products that employ improved manufacturing practices, safer ingredients, energy-efficiency certifications, and/or recycled content.

Site Cleanup and Workplace Stewardship Program

In some locations at the Laboratory, materials and equipment have been abandoned after projects ended or staff retired. The Site Cleanup and Workplace Stewardship Program was established in 2013 to coach organizations on the proper disposition of these items and to prevent similar occurrences. The program staff work with responsible organizations to develop a work plan for removing abandoned items, clearing indoor and outdoor spaces, and implementing sustainable housekeeping practices. Goals of the program are to divert as much material as possible from waste streams and to establish or improve processes to help reduce legacy and abandoned items in the future.

The Site Cleanup and Workplace Stewardship Program works closely with the Property Management Group, Excess Operations, the Environmental Protection and Compliance Division, and other organizations to improve processes and policy. In 2020, the program moved into the Infrastructure Programs Office at LANL, allowing better integration with site planning activities. This move has helped integrate cleanup concerns into space management.

In 2022, the Site Cleanup and Workplace Stewardship Program accomplished the following:

- Continued improving the management of sheds and transportable storage buildings at LANL by working with organizations to identify points of contacts, install point-of-contact signage, and update structure number signage
- Drafted a process for assessing structures for reuse and reassigning them to better track and manage structures
- Coordinated more than 20 cleanup and metal recycling projects across the Laboratory, including the following:
  - A laboratory space in Technical Area 3, Building 281, had a legacy clean room frame that needed to be removed. The metal frame was recycled.
  - In Technical Area 3, Building 322, we coordinated the waste removal of many legacy geology samples and other items to allow a laboratory to be better utilized.
  - We relocated two transportable storage buildings with fitting supplies from Technical Areas 3 and 60 to a new consolidated yard, helping with work efficiency and safeguarding materials.
  - Laboratory employees reported a legacy meteorological cable running between Technical Areas 6 and 59. We removed the mile-long cable and the associated debris. After checking for contamination, the cable was recycled as metal.
  - In Technical Area 35, we assisted in the proper disposition of years of legacy material and equipment from Buildings 85, 86, and 125. We also dispositioned four 14-ton stainless steel and concrete shielding blocks in the technical area after removing and disposing of the associated oil and glass. Removing the shielding blocks mitigated an environmental hazard of oil being stored in sensitive habitat. The final work included breaking off the stainless steel shells, breaking up the concrete cores, and recycling both.
  - In the Technical Area 43 Health Research Laboratory building, we assisted in the identification and disposition of legacy equipment, including the proper recovery of refrigerant and oils for recycling. Removal of liquids ensures that they will not leak and cause environmental issues. This work supports the upcoming closure of this facility to prepare it for demolition.
  - In Technical Area 49, we dispositioned legacy and abandoned equipment and vehicles, making the area safer, more efficient, and more visually appealing to training customers participating in hazmat and other training scenarios.
  - In Technical Area 51, we assisted with the proper disposition of legacy equipment and old storage structures. Work included waste segregation, equipment salvage, and metal recycling.
  - The Technical Area 53 metal recycle program focuses on metal with potential for activation, which is found only at Technical Area 53. During 2022, 212,000 pounds

of metal was prepared, surveyed, released, and sent for recycle. We also completed map updates and new signage for most of the existing storage structures.

– Cleanup at Technical Area 60 Pole Yard on Sigma Mesa focused on removal of years of discarded debris. Piles were leveled, metal was removed for recycle, and concrete was removed. This work aided planning for new storm water regulations, allowed for more efficient use of space, and left some areas to return to a natural state.

Project Review Program

All new and modified activities, operations, and projects at the Laboratory must be reviewed for environmental and other compliance requirements before executing the work. This process includes changes in scope and location.

The Integrated Review Tool is a web-based platform that makes submitting projects for review easier and more consistent. It includes screening questions to direct users to appropriate project review tools, and it is the entry portal to the Permits and Requirements Identification tool, the Excavation/Fill/Soil Disturbance Permit Request system, and the Site Selection process. Work owners or planners enter their project information into the Integrated Review Tool, and subject matter experts review the projects and identify the relevant requirements, actions, and permits needed to perform the work compliantly.

The Environmental Protection and Compliance Division’s Project Review Program coordinates environmental subject matter expert reviews and interacts with work owners and planners. The program participants include subject matter experts employed by Triad from the following compliance programs: Air Quality, Biological Resources, Consent Order sites (Solid Waste Management Units and Areas of Concern), Cultural Resources, Environmental Health Physics, Individual Permit, Pollution Prevention, National Environmental Policy Act, Resource Conservation and Recovery Act, Waste and Materials Management, and Water Quality.

N3B project managers use the Integrated Review Tool for some projects and internal N3B procedures for the remaining projects. N3B uses procedures N3B-P351, *Project Review Process*, and N3B-P101-17, *Excavation/Fill/Soil Disturbance*, to identify compliance requirements for new or modified activities. The procedures engage subject matter experts from the following N3B compliance programs: Air Quality, Biological Resources, Cultural Resources, Safety and Industrial Hygiene, National Environmental Policy Act, Resource Conservation and Recovery Act, Waste and Materials Management, and Water Quality.

In 2022, Triad subject matter experts reviewed 309 management and operating contractor projects in the Permits and Requirements Identification tool and 717 projects in the Excavation/Fill/Soil Disturbance permitting tool. In addition, 23 legacy waste cleanup projects (performed by N3B) were reviewed in the Permits and Requirements Identification tool.

Over the past several years, the Project Review Program has supported improvements in the Integrated Review Tool. Several training courses were developed and implemented through the Laboratory’s institutional training system, including Integrated Review Tool & Permits and Requirements Identification for the Requestor; Integrated Review Tool Geographic Information Systems Mapping Training; and LANL Excavation/Fill/Soil Disturbance Permit Process using the EXID Request System. A *Permits and Requirements Identification for the Subject Matter Expert* training course is in development.

Dedicated Core Programs

Air Quality Program

Compliance and Permitting

LANL operates under several air emission permits issued by the New Mexico Environment Department Air Quality Bureau, as well as approvals issued by the U.S. Environmental Protection Agency for construction of new facilities or operations that involve radionuclide emissions. These permits and approvals have federally enforceable emission limits and require specific pollution-control devices, monitoring of emissions from stacks, and detailed recordkeeping and reporting.

> **What are these air quality terms?**
>
> **Stack** – vertical chimney or pipe that releases gases produced by industrial processes into the air.
>
> **Ambient air** – atmospheric air in its natural state.
>
> **Criteria air pollutants** – six specific pollutants regulated by the U.S. Environmental Protection Agency under the Clean Air Act because they cause smog, acid rain, or other health hazards.
>
> **Hazardous air pollutants** – chemicals and radionuclides that at high-enough levels are known or suspected to cause cancer, other serious health effects, or adverse environmental effects.

LANL is authorized to use materials and operate equipment that produces some air pollutants under the conditions defined in our Title V Operating Permit. Our permitted emission sources include a steam plant, a combustion turbine, boilers and heaters, emergency generators, beryllium operations, chemical use, degreasers, data destruction (paper shredding), evaporative sprayers, and a small asphalt batch plant. Each source type has its own emissions limits for criteria air pollutants and hazardous air pollutants. The Title V Operating Permit also includes facility-wide emissions limits for criteria and hazardous air pollutants. As part of compliance with the Title V Operating Permit, we report emissions and provide monitoring records from the permitted sources twice a year to the New Mexico Environment Department, which inspects the Laboratory periodically for compliance.

Stack Monitoring

As described in greater detail in Chapters 2 and 4, the Laboratory monitors emissions of radionuclides from building stacks. We evaluate operations to determine the potential for stack emissions to adversely affect the public or the environment. During 2022, 25 stacks were continuously sampled for the emission of radioactive materials into the air.

Ambient Air Monitoring

The Laboratory operates a network of ambient air quality monitoring stations to detect other possible radioactive air emissions (see Chapter 4). The network includes stations located on site, in adjacent communities, and in regional locations. In 2022, we operated 46 ambient air quality monitoring stations at distances up to 25 miles from the Laboratory.

Water Quality Programs

The Laboratory has multiple programs that address the quality of surface waters and groundwater. We comply with the following National Pollutant Discharge Elimination System permits: the industrial outfall permit, the individual permit for storm water discharges, the construction general permit, the multi-sector general permit, and the pesticide general permit (see Chapter 2). We also operate under groundwater discharge permits issued by the New Mexico Environment Department, covering discharges from the sanitary wastewater system plant and the sanitary effluent reuse facility, six septic tank systems, land application of treated groundwater, and injection of treated groundwater into the aquifer through underground injection control wells.

The Laboratory monitors and remediates groundwater (see Chapter 5) and conducts environmental surveillance monitoring on surface water base flow, storm water flow, and deposited sediments (see Chapter 6). We have also implemented low-impact development projects at Technical Areas 3 and 53 that reduce the amount of storm water runoff from developed areas to improve the quality of the storm water flow.

In 2022, we continued operating the Laboratory's site-wide network of storm water gaging stations to monitor stream flow and collect storm water samples in all major canyons. We also continued operating the early notification system that provides the operators of Santa Fe's Buckman Direct Diversion (which diverts water from the Rio Grande for Santa Fe's drinking water supply) with early notification of storm water flows through Los Alamos Canyon into the Rio Grande. A flow/no-flow gaging station—E110.7, located in Los Alamos Canyon just above the confluence with the Rio Grande—was constructed and added to the early notification system in July 2022. Finally, we documented the effectiveness of installed sediment-control measures for the Los Alamos/Pueblo Canyon watershed and the Sandia Canyon wetland to the New Mexico Environment Department.

The U.S. Environmental Protection Agency issued the Laboratory's original Storm Water Individual Permit in 2010. The new permit, which supersedes and replaces the original permit, was issued June 29, 2022, and became effective August 1, 2022. A minor modification to address administrative changes was issued on September 9, 2022.

Sanitary Sewage Sludge Management

The Laboratory composts solid wastes produced by its Sanitary Waste Water System to eliminate the need to transport sewage biosolids off site for landfill disposal. In 2018, the New Mexico Environment Department Solid Waste Bureau approved the Laboratory's registration renewal of the Sanitary Waste Water System Compost Facility. In 2022, the Sanitary Waste Water System Compost Facility produced 40.5 tons of composted biosolids. Finished compost has been continually stockpiled at the facility, although some land application of compost occurred at the Sanitary Waste Water System in 2018. We hope to use more of the compost at LANL for beneficial uses, such as landscaping and post-construction remediation. Before compost can be land-applied, it must meet pollutant concentration limits, Class A pathogen requirements, and vector attraction reduction requirements as specified in the U.S. Environmental Protection Agency's Standards for the Use or Disposal of Sewage Sludge in the Code of Federal Regulations Title 40, Part 503.

Cultural Resources Management

Approximately 90 percent of DOE land in Los Alamos County has been surveyed by the Laboratory's cultural resources staff for pre-European contact and historic cultural resources. Surveys have identified more than 1,900 cultural resources sites, with human occupation at the oldest sites dating back 10,000 years. About 73 percent of the Laboratory's sites (including structures, trails, agricultural features, and rock art) are associated with Ancestral Pueblo people. However, the sites at the Laboratory also include Archaic Period lithic scatters; late 19th and early 20th century homestead, ranching, and logging sites; and Laboratory buildings used during the Manhattan Project and Cold War eras (about 1943–1990). Current cultural resource management initiatives at the Laboratory include

- completing surveys on all DOE property;
- determining the eligibility of historic buildings and archeological sites for the National Register of Historic Places; and
- conducting outreach activities, tours, and educational events for the LANL workforce and other stakeholders.

We have a tiered approach to protecting archaeological sites and historic buildings from potential impacts by Laboratory projects. The most desired option is to avoid the sites. If avoidance is not possible, we work to minimize adverse effects. Finally, if an adverse effect determination is made, we consult on mitigation activities when all other options are exhausted.

Archaeologists who work for the legacy waste cleanup contractor, N3B, facilitate the cultural resources compliance reviews for legacy waste cleanup projects. N3B archaeologists, the DOE Environmental Management Los Alamos Field Office cultural resources program manager, the DOE National Nuclear Security Administration Los Alamos Field Office cultural resources program manager, and management and operating contractor archaeologists meet every 2 weeks to discuss legacy waste cleanup activities across the Laboratory on lands managed by the National Nuclear Security Administration Los Alamos Field Office.

In addition to supporting projects compliance with cultural resource laws and regulations (described in Chapter 2), we completed the following cultural resources management activities during 2022:

- conducted surveys and site recording in Technical Area 68
- assessed extent-of-condition of sites vulnerable to off-road driving impacts
- marked and monitored sites for avoidance during fire road and fire break maintenance
- assessed the condition and updated photographic records of Nake'muu Pueblo
- monitored seasonal recreational use of trails in Technical Areas 70 and 71
- monitored DOE preservation districts in Pueblo Canyon and Rendija Canyon
- re-routed a wellness trail
- conducted archival photography of buildings in Technical Area 43
- integrated historical artifacts into the Bradbury Science Museum's catalog system
- conducted tours of LANL historical sites for:
  - LANL employees
  - DOE Field Office staff
  - N3B and Triad Interface Office staff
  - National Park Service personnel
  - Weapons Engineering Study Halls
  - the Non-Destructive Testing & Evaluation Group
  - the International Atomic Energy Agency Department of Safeguards
  - Air Force Nuclear Weapon Center

  - Kai Bird, author of American Prometheus
  - Los Alamos County government members
- gave presentations and briefings during Native American History Month
- gave presentations to Leadership Los Alamos, the J. Robert Oppenheimer Memorial Committee, and the University of Oklahoma
- conducted outreach at Los Alamos Middle School, Mountain Elementary School, Earth Week, Challenge Tomorrow at Los Alamos Middle School, Science Fest in Los Alamos, and tutoring for Española Middle School students

We hosted meetings and site visits for San Ildefonso and Santa Clara Tribal Historic Preservation Officers and members. Staff presented and showcased their work at several conferences, including the Society for American Archaeology annual meeting, the Society for Historic Archaeology, and the Pecos Archaeological Conference. Lastly, cultural resources staff hosted and assisted with a field school for the University of New Mexico, which provided 11 undergraduate and 2 graduate students with an authentic opportunity to learn survey and site recording techniques.

During 2022, N3B archaeologists supported avoidance of sites and conducted monitoring for legacy waste cleanup projects, including for the new R-73 chromium monitoring well in Technical Area 5, tree thinning for wildland fire mitigation in Technical Areas 54 and 36, and Aggregate Area soil sampling at the Concrete Bowl in Technical Area 6.

Manhattan Project National Historical Park

The Manhattan Project was the unprecedented effort by the United States to develop an atomic weapon during World War II, and it took place at many sites across the country. In 2014, Congress passed legislation that established the Manhattan Project National Historical Park to interpret and preserve the remaining structures and landscapes associated with the Manhattan Project war effort. The park consists of three units located in Hanford, Washington; Oak Ridge, Tennessee; and Los Alamos, New Mexico. The park unit at Los Alamos features historic buildings and structures that are officially in the park boundary and other buildings that are listed in the park legislation. These buildings relate to the scientific and engineering aspects of developing the first atomic bombs.

In 2022, we resumed employee and public tours at Technical Area 18 following the COVID-19 pandemic. These tours highlight the history of the Manhattan Project through stories related to the people, buildings, and landscapes of Los Alamos. Additional tours for LANL employees took place at other Manhattan Project sites within areas less accessible to the public.

Completion of a 5-year preservation plan in 2021 kicked the implementation of preservation recommendations into high gear in 2022. Cultural resources staff monitored and consulted on ongoing preservation work and facilitated planning to address the long-term preservation of several Manhattan Project-era buildings. Small impacts identified in the 5-year plan were addressed, including ongoing maintenance such as rodent-proofing and vegetation management around the buildings. Larger projects are being planned, including roof replacement and lead and asbestos abatement for the V-Site buildings (Figure 3-1) and an adaptive reuse plan for the Technical Area 22 Quonset Hut (Figure 3-2 and Figure 3-3).

Figure 3-1. LANL tour at V-Site. Note that asbestos siding shingles have been removed and prepared for replacement of replica non-asbestos siding shingles.

Figure 3-2. Oblique view of Technical Area 22, Building 1 Quonset Hut.

Figure 3-3. Interior view of Technical Area 22, Building 1 Quonset Hut.

We initiated an ethnographic study in partnership with the National Park Service and the University of Arizona as part of understanding the cultural landscape of Technical Area 18. The Cultural Landscape Report will help planners and decision makers in the coming years manage the Technical Area 18 landscape from interpretive, archaeological, and historical standpoints. Our intent is to preserve Technical Area 18 in a manner consistent with the viewpoints of descendant communities, including members of neighboring pueblos.

Biological Resources Management

Our goal is to minimize impacts on sensitive wildlife and plant species and their habitats and to ensure that all Laboratory activities comply with federal and state requirements for biological resources protection. Laboratory property contains habitat for three species that are federally listed as either threatened or endangered. Two of these species—the Mexican spotted owl (*Strix occidentalis lucida*) and the Jemez Mountains salamander (*Plethodon neomexicanus*)—have been found on site. Willow flycatchers of unknown subspecies are sometimes detected during migration, but no southwestern willow flycatchers (*Empidonax traillii extimus*) have been documented breeding on Laboratory property.

Biological Resources Program Accomplishments

We annually inform and educate the Laboratory workforce about biological resources compliance requirements, including restrictions on the timing and location of work activities to protect federally listed species. The biological resources staff also provide safety briefings on encountering wildlife and information on avoiding impacts to migratory birds from vegetation removal projects and other known hazards to birds, such as open pipes and bollards.

Laboratory biologists conduct annual surveys for the presence of threatened and endangered species that have habitat on LANL property. In 2022, surveys for the Mexican spotted owl confirmed the presence of pairs of owls in two canyons. No evidence was found to suggest that either pair successfully bred in 2022. Southwestern willow flycatchers were not found during surveys in 2022. Surveys for Jemez Mountains salamander on LANL lands in 2022 did not locate any salamanders. Laboratory biologists participated in a regional training workshop for Jemez Mountains salamander surveys in 2022.

LANL biologists were authors on three peer-reviewed publications during 2022:

- "Does age, residency, or feeding guild coupled with a drought index predict avian health during Fall migration?" (Stanek et al. 2022)
- "Modeling the distribution of the endangered Jemez Mountains salamander (*Plethodon neomexicanus*) in relation to geology, topography, and climate" (Bartlow et al. 2022)
- "Comparative spatially explicit approach for testing effects of soil chemicals on terrestrial wildlife bioindicator demographics" (Murphy et al. 2023)

LANL biologists supported many projects across the Laboratory with compliance and monitoring activities in 2022. Published reports that supported these projects included the following:

- "Light-level geolocation of the LANL population of Western Bluebirds" (LA-UR-22-20314)
- "Small Mammal Prey Study for the Mexican Spotted Owl at Two Locations at Los Alamos National Laboratory" (LA-UR-22-20314)
- "Biological Assessment of the Potential Effects from Future Development along the Pajarito Corridor at Los Alamos National Laboratory" (LA-CP-22-20226)

Wildland Fire and Forest Management

The goals of the Wildland Fire and Forest Management Program are to restore and maintain landscapes, develop a fire-adapted community, and ensure implementation of wildland fire mitigation. We prepare for wildland fire with fuel mitigation and forest management projects and with interagency planning and training. Wildland Fire program staff are colocated with personnel from the United States Forest Service and the National Park Service. We collaborate with the Los Alamos Fire Department, the National Park Service, the United States Forest Service, the Bureau of Indian Affairs, the Northern Pueblo Agencies, and the New Mexico State Forestry Division.

The key functions of the LANL Wildland Fire and Forest Management Program are to

- coordinate the site wildland fire hazard analysis;
- develop wildland fire plans, procedures, and checklists;
- conduct LANL wildfire mitigation projects, such as thinning trees and establishing and maintaining fire breaks, defensible space, and fire roads;
- update the LANL website to ensure that fire conditions and fire danger ratings are available to the workforce;
- conduct open space forest inventory monitoring;
- document, analyze, and communicate short- and long-term treatment effects on vegetation communities; and
- use thinning treatment monitoring data to evaluate alternative management options for desired future vegetative conditions.

Wildland Fire and Forest Management Accomplishments

Our program highlights during 2022 included the following:

- Meeting our fiscal year 2022 objectives and performing additional work responding to the Cerro Pelado Fire, including
  - mitigating fuels in open space, utility corridors, and roadsides
  - serving on-call during the fire
  - coordinating fire restrictions with regional partners
- Developing, approving, and funding a 5-year program plan beginning in fiscal year 2023 to reduce the overall wildland fire risk at LANL
- inspecting all LANL fire roads with the Los Alamos Fire Department
- publishing three forest monitoring data reports:
  - "Forest Monitoring Data Summary for the 2022 Weapons Engineering Tritium Facility Area Thinning Project" (LA-UR-22-32466)
  - "Forest Monitoring Data Summary for the Los Alamos Canyon Thinning Project" (LA-CP-23-20027)
  - "Technical Area 8 and Technical Area 69 Thinning Project Pre-Treatment Monitoring Summary" (LA-UR-22-22563)

Waste Management

The Laboratory produces several types of wastes regulated by either the federal government or the state of New Mexico, including low-level radioactive wastes, hazardous wastes, mixed wastes (which are both radioactive and hazardous), transuranic wastes, New Mexico Special Wastes, and others. Transuranic wastes contain manufactured elements heavier than uranium on the periodic table (such as plutonium). Wastes from current operations at the Laboratory are managed by Triad's Waste Management and Nuclear Process Infrastructure Divisions, whereas legacy wastes—defined as wastes generated before 1999—and environmental remediation are managed by the legacy waste cleanup contractor, N3B.

The Laboratory's Enduring Mission Waste Management Plan describes our institutional strategy and implementation path to manage wastes from work for enduring DOE National Nuclear Security Administration missions and Strategic Partnerships Projects (formerly "work for others"). The plan incorporates pollution prevention strategies to significantly reduce the volume and toxicity of waste generated. All waste that has a disposal pathway generated at the Laboratory is shipped off site to government and commercial treatment, storage, and disposal facilities for proper disposal. We have a Transuranic Waste Facility that stages transuranic waste for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, and are currently building replacement low-level radioactive and transuranic liquid waste facilities. As part of our long-term strategy to manage waste safely and effectively, the Waste Management Division is proposing a new state-of-the-art, consolidated waste facility and is moving forward with requesting Critical Decision Level 0 approval for this facility from DOE.

See Chapter 2 for more information about waste disposal.

Environmental Remediation

In accordance with the 2016 Compliance Order on Consent, the Legacy Waste Cleanup Program investigates and, where necessary, remediates sites to ensure that chemicals and radionuclides associated with releases from past operations do not result in an unacceptable chemical risk or radiological dose to human health or the environment. (For more information about the 2016 Compliance Order on Consent, see Chapter 2.) We sample soil and other media at sites according to approved work plans to determine if releases have occurred and, if so, whether the nature and extent of contamination is well defined or if further sampling is needed. We conduct human health and ecological risk assessments using the results. Sites are remediated if the risk assessments indicate potential adverse impacts to human health, the environment, or both. Corrective actions are complete at a site when we have documented to the regulatory authority's satisfaction that further sampling is not needed and that the site does not pose an unacceptable risk or dose to humans, plants, or wildlife. Table 3-4 presents a summary of the reports submitted and site investigations conducted in 2022 by N3B in support of the 2016 Compliance Order on Consent.

Table 3-4. Summary of Reports Submitted and Site Investigations Conducted in 2022 under the N3B Environmental Remediation Program

Document/Activity Technical Area Number of Sites Addressed	Sampling and Remediation Activities and Recommendations
Progress Report for the Phase II Investigation North Ancho Canyon Aggregate Area • Appendix B Consent Order Milestone • Technical Area 39 • 7 Consent Order Sites	We began implementing the Phase II Investigation Work Plan for North Ancho Canyon Aggregate Area in 2022. Seven sites required additional sampling to define the nature and extent of contamination and potential human health and ecological risks. A progress report that summarized the status of site investigations was prepared and submitted to the New Mexico Environment Department in September 2022. The progress report summarized the status of investigations for two sites.
Conclusions: Investigations were initiated at two sites. Further corrective actions for the remaining sites will be addressed in 2023.	
Progress Report for the Twomile Canyon Aggregate Area • Appendix B Consent Order Milestone • Technical Areas 03, 06, 22, 40, 50, 59, and 69, and former Technical Area 7 • 61 Consent Order Sites	We began implementing the Investigation Work Plan for Twomile Canyon Aggregate Area in 2022. Sixty-one sites required additional sampling to define the nature and extent of contamination and potential human health and ecological risks. A progress report that summarized the status of site investigations was prepared and submitted to the New Mexico Environment Department in September 2022. The progress report summarized the status of investigations for two sites.
Conclusions: Investigations were initiated at two sites. Further corrective actions for the remaining sites will be addressed in 2023 and 2024.	
Progress Report for the Phase II Investigation of the Threemile Canyon Aggregate Area • Appendix B Consent Order Milestone • Technical Area 15 • 3 Consent Order Sites	We began implementing the Phase II Investigation Work Plan for Threemile Canyon Aggregate Area in 2022. Three sites required additional sampling to define the nature and extent of contamination and/or removal of contaminated soil and potential human health and ecological risks. A progress report that summarized the status of site investigations was prepared and submitted to the NMED in September 2022. The progress report summarized the status of investigations for two sites.
Conclusions: Investigations were initiated at two sites. Further corrective actions for the remaining sites will be addressed in 2023.	

Environmental Health Physics Program

The Environmental Health Physics Program provides technical support to the Laboratory for radiation protection of the public and the environment. We use sampling results and radiological assessment models to calculate dose estimates for the public and for plants and animals. These estimates are communicated to regulatory agencies and to the public.

> **What is health physics?**
>
> Health physics is the branch of radiation science that deals with effects of ionizing radiation on human health.

DOE Order 458.1, *Radiation Protection of the Public and the Environment*, also requires us to oversee releases to the public of real estate and portable property (such as surplus equipment and wastes) that could contain residual radioactivity. Examples include land tracts transferred to other owners and debris from demolishing buildings.

Our environmental health physicists support emergency planning and response by providing technical support and dispersion modeling in the case of an accident as well as recommendations for protective actions. We also support environmental remediation projects.

See Chapters 2, 7, and 8 for more information.

Soil, Foodstuffs, and Biota Monitoring

The Soil, Foodstuffs, and Biota Monitoring Program monitors levels of radionuclides, inorganic elements (mostly metals), and organic chemicals (for example, polychlorinated biphenyls [PCBs] and per- and polyfluoroalkyl substances [PFAS]) in local soil, plants, and animals. The program routinely samples surface soil; native vegetation; foodstuffs, including fruits, vegetables, grains, milk, eggs, fish, meat, and honey; small mammals, such as mice; and other animals that have died due to natural causes or accidents, such as roadkill. These samples are collected from Laboratory property, the surrounding communities, and regional background locations. The data are used to

- determine whether Laboratory operations are affecting levels of chemicals or radionuclides in the environment,
- monitor for new releases,
- calculate estimates of radiation dose for the public and for biota, and
- conduct risk assessments.

We compare levels of chemicals in our samples with background levels, screening levels, and effects levels, and we examine wildlife population and community characteristics. The program is described in detail in Chapter 7.

Accomplishments

In 2022, we collected foodstuffs samples from around the Laboratory, from surrounding communities, and from regional background locations. These samples were analyzed for radionuclides, inorganic elements (mostly metals), and PFAS, whereas animal products, such as milk and eggs, were also tested for PCBs.

We completed regular annual sampling of soil, native vegetation, and biota at several locations. Soil and tree samples collected around the perimeter of Area G and near the boundary between Technical Area 54 and the Pueblo de San Ildefonso were analyzed for radionuclides. Soil, sediment, honey, and nonviable bird eggs collected around the Dual-Axis Radiographic Hydrodynamic Test Facility were analyzed for radionuclides, inorganic elements, and/or organic chemicals. Small mammals and vegetation collected upstream of the sediment retention structures located in Los Alamos Canyon and Pajarito Canyon were analyzed for radionuclides, inorganic elements, and/or organic chemicals.

Small mammals were collected from Sandia Canyon and analyzed for PFAS. Nonviable bird eggs and nestlings that died of natural causes also were collected near Laboratory firing sites and from Bandelier National Monument and were analyzed for inorganic elements and/or organic chemicals. We opportunistically collected and analyzed tissues from deceased animals (primarily roadkills), including mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), coyote (*Canis latrans*), common raven (*Corvus corax*), and great horned owl (*Bubo virginianus*). Results from the program's 2022 foodstuffs monitoring efforts are discussed in Chapter 8, Public Dose and Risk Assessment; all other monitoring efforts are reported in Chapter 7, Ecosystem Health.

Meteorology Program

DOE Order 458.1, *Radiation Protection of the Public and the Environment*, and DOE Order 151.1D, *Comprehensive Emergency Management System*, require DOE sites to measure specific weather variables based on radiation-producing operations taking place, the site's topography, and the distances to critical receptors. The LANL Meteorology Program maintains a network of eight meteorological towers that measure temperature, wind, humidity, pressure, precipitation, and solar radiation across the site. These data are used for emergency planning in the event of a chemical or radiological release and regulatory compliance in the areas of air quality, water quality, and waste management. The data also support monitoring programs for surface water and environmental radiation. Weather data can be accessed through the Laboratory's internal (https://weather.lanl.gov) or external network (https://weathermachine.lanl.gov). Meteorological conditions at LANL for 2022 are reported in Chapter 4, Air Quality.

Natural Phenomena Hazard Assessment

DOE Order 420.1C, *Facility Safety*, requires that nuclear facility structures, systems, and components effectively perform their intended safety functions in the face of natural phenomena hazards (for example, earthquakes, floods, and high winds). As a part of this requirement, natural phenomena hazards are reviewed every 10 years to determine if major modifications to nuclear facilities are required by significant increases in risk from natural phenomena. The most recent review was completed in 2014 (LA-UR-14-27732), and the next review is due in 2024.

In support of the upcoming 2024 Natural Phenomena Hazards Assessment, in 2022 LANL subject matter experts have begun collecting and analyzing data that could be used to develop or modify design criteria of structures, systems, and components.

The LANL Seismic Engineering Team provides seismic hazard analyses of key Laboratory facilities and is focused on improving seismic monitoring, site characterization, and our understanding of the Pajarito Fault system. The Seismic Hazards Geology program conducts field mapping of the Pajarito Fault system in the vicinity of Los Alamos and performs site-specific hazard studies at current and planned facility sites. The Laboratory has operated a seismic monitoring station network since 1973 to detect and locate earthquake activity.

The LANL Storm Water Team is coordinating a hydrology and hydraulic modeling effort to develop flood levels associated with various storm events at key Laboratory facilities. The flood levels will be used to evaluate potential flooding impacts to existing structures, systems, and components.

The LANL Meteorology Team is performing extreme value analyses for surface wind speeds and precipitation events of various durations. The extreme precipitation results are then being used by the Storm Water Team as input into their flood modeling work.

Land Conveyance and Transfer

The Laboratory assists DOE with implementing the conveyance or transfer of specific parcels of land in and around the Laboratory to Los Alamos County and to the Secretary of the Interior in trust for the Pueblo de San Ildefonso. The direction from Congress to conduct this activity was first established in 1997 by Public Law 105-119 and has been amended periodically.

The specific DOE land tracts identified for conveyance or transfer were included in "Conveyance and Transfer of Certain Land Tracts Administered by the U.S. Department of Energy and Located at Los Alamos National Laboratory, Los Alamos and Santa Fe Counties, New Mexico" (DOE/EIS 0293), and the original tracts were subsequently subdivided into 32 tracts. To date, 26 of these tracts have been conveyed or transferred as follows: 20 tracts have been conveyed to Los Alamos County, 3 tracts have been conveyed to the Los Alamos County School District, and 3 tracts have been transferred to the Bureau of Indian Affairs to be held in trust for the Pueblo de San Ildefonso.

Tracts that could be conveyed to Los Alamos County include Tract A-14 in Rendija Canyon, Tracts C-2 and C-4 along New Mexico Route 4, Tract A-18-2 in Bayo Canyon, and tracts at Technical Area 21. The Land Conveyance and Transfer project staff continue to work with the DOE National Nuclear Security Administration Los Alamos Field Office to complete the outstanding compliance activities and requirements needed to convey the remaining DOE tracts.

Conveyances to Los Alamos County support local community economic development by providing lands for housing, commercial uses, and recreation. Nearly 460 housing units, including low-income apartments and about 160 market-rate, single-family homes, are being developed on tracts previously conveyed to Los Alamos County.

Awards and Recognition

A group of former and current members of LANL's Water Quality Permitting and Compliance Team received an National Nuclear Security Administration Excellence Award in 2022 for their work in finalizing groundwater discharge permit DP-1132 from the New Mexico Environment Department. This permit authorizes and sets conditions for Radioactive Liquid Waste Treatment Facility discharges of treated water so that these discharges meet groundwater quality standards.

Data Management and Quality Control Process for Analytical Data

Data management consists of collecting and processing samples and maintaining results using procedures that ensure that data comply with established requirements and fit their intended use (for example, compliance monitoring or site characterization). In the following paragraphs, we describe our system for sample and data processing and quality assurance.

Triad and N3B have similar data collection and management programs. Each contractor has its own sample management office, but they use the same environmental data management platform (see the following section, Environmental Data Management Platform). Individual programs plan and collect their samples in coordination with their sample management office (see Figure 3-4). Sample handling, analysis, and data review/evaluation are conducted or overseen by the respective sample management office. Individual programs report on data results; the sample management office may assist by providing data sets, but final reports are the responsibility of the program.

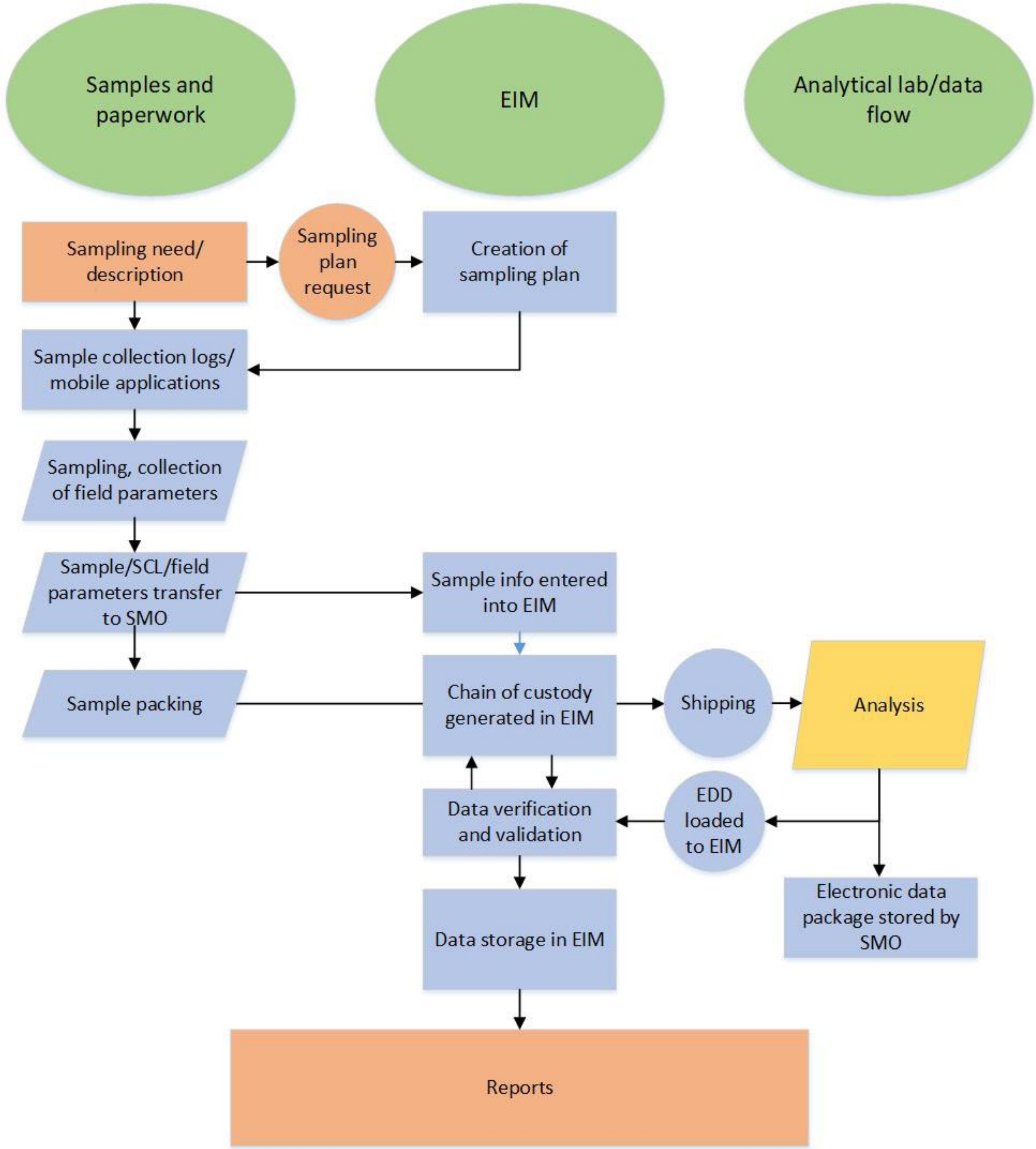


Figure 3-4. Functional diagram of the Sample Management Office workflow. Green ovals represent the three main Sample Management Office functions. Blue shapes show data collection steps that directly involve the Sample Management Office.

SMO = Sample Management Office
EIM = Environmental Information Management database
SCL = Sample Collection Log (serves as a field chain of custody)
EDD = Electronic Data Deliverable (text file used to load analytical data into Environmental Information Management database)

Environmental Data Management Platform

In 2022, N3B received and reviewed more than 1,168,000 analytical results, and Triad received and reviewed more than 92,000 analytical results. Not all results were used for this report; some results were related to programs that are not included in the Annual Site Environmental Report. The Environmental Information Management database is the core platform used for managing our sample collection and analytical results. This data platform is jointly used by N3B, Triad, and the DOE Oversight Bureau of the New Mexico Environment Department. It interfaces with IntellusNM, a fully searchable database available to the public through the IntellusNM website (http://www.intellusnm.com).

Locus Technologies developed and maintains the database structure, which consists of a cloud-based Structured Query Language server database platform with a web-based user interface. The database is designed to manage the sample collection and analysis process from planning through data review and reporting. It includes modules for planning sample collection, tracking samples, uploading field data, uploading electronic data deliverables, and conducting automated data review, as well as tools for notifications and reporting. The automated data review module is used in conjunction with manual examinations and full manual validation of selected data.

A Software Change Control Board—which comprises N3B, Triad, and New Mexico Environment Department representatives—oversees modifications to the database. This process ensures that changes requested by one organization will not adversely affect the others. Standardized naming conventions are used for sampling locations to create a single list of shared location names.

Data Quality Objective Process

N3B and Triad ensure that the data reported from the analytical laboratories are of sufficient quality to fulfill their intended purpose and that the data quality is documented so the data can be evaluated for current and future use. The data collected support defensible decision-making, as described in the Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4) (EPA, 2006).

N3B data quality objectives describe the minimum acceptable quality assurance and quality control on a project-specific basis. Examples of projects include samples collected to fulfill a set of permit requirements, to determine waste disposition, and to fulfill a memorandum of understanding or regulated agreement.

The project manager determines the project's specific data quality objectives within the boundaries of contracted services and standard operating procedures. If a project's needs exceed contracted services or standard operating procedures, we may initiate revisions to contracts and standard operating procedures.

Sample Collection and Handling

The first step is planning the sampling to ensure that the data will meet the data quality objectives for the project. Sample collection and handling follows established methods. Whenever possible, U.S. Environmental Protection Agency methods are used. When federal- or state-approved standard methods are unavailable, LANL-specific procedures are used.

A sampling plan is created in the Environmental Information Management database system. The data system generates sample collection logs and chain-of-custody forms based on the plan. The sample collection log lists the sampling containers and preservatives needed for each analysis requested. Personnel who conduct the sampling record information on the sample collection log, including location of sampling (if different from planned), sampling date and time (which are necessary to establish holding time), field parameters if required by the project, and any other applicable comments. Collected samples are placed in coolers with ice if required. From the time of sampling until delivery to the Sample Management Office, samples are under direct custody of the samplers. At the Sample Management Office, custody is transferred to Sample Management Office staff. Custody transfer is confirmed by signatures. Additionally, before the Sample Management Office accepts samples, tamper-indicating devices, which are also known as custody seals, are placed on every sample container. N3B has implemented an electronic chain of custody that arrives at the analytical laboratory before the official chain of custody. This practice allows the analytical laboratory to prepare for the upcoming sample receipt and reduces errors throughout the process.

Before samples are shipped, Sample Management Office staff store samples as required by the analysis method, including in temperature-controlled refrigerators if needed. Glass sample containers are wrapped in bubble bags to prevent breakage. Samples are packed in coolers with blue ice and/or bagged ice to ensure proper shipping temperature. Signed chain-of-custody documents are placed inside the coolers. Coolers are taped shut and protected with tamper-indicating devices. Samples are shipped overnight to the designated analytical laboratory. Upon arrival at the designated lab, the integrity of tamper-indicating devices is verified, shipping temperature on arrival is measured, and samples are compared with their respective chain of custody. If both the cooler and sample tamper-indicating devices have been damaged or tampered with, the sample is considered unusable. After the analytical laboratory logs samples into their information management system, the samples are analyzed.

Selection of Analytical Laboratories

Analytical laboratories have been selected through the request for proposal process. N3B and Triad have selected laboratories that meet the DOE Consolidated Audit Program–Accreditation Program requirements (see section on DOE Consolidated Audit Program–Accreditation Program for Commercial Analytical Laboratories). For Triad, National Environmental Laboratory Accreditation Program-accredited laboratories are chosen when a given analysis is not available from a contracted DOE Consolidated Audit Program-accredited laboratory. Along with the DOE Consolidated Audit Program accreditation, N3B selects laboratories that meet requirements in their Scope of Work Exhibit “D,” Scope of Work and Technical Specifications for Off-Site Analytical Laboratory Services. The Scope of Work Exhibit “D” was developed using the Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories. N3B has contracted with 10 analytical laboratories, 8 of which performed certifiable analyses for N3B in 2022. Beyond meeting the minimum requirements of the DOE Consolidated Audit Program and the scope of work, laboratories chosen for a specific analysis are selected for their capacity to maintain a project’s continuity of data, prevent disruptions caused by unforeseen lab closures or instrument failures, and deliver a cost-effective service. This approach allows for split sampling and data quality comparison.

Sample Analysis

Sample preparation and analyses are performed in the laboratories using industry-standard methods such as those from the U.S. Environmental Protection Agency SW-846, the Environmental Measurements Laboratory HASL 300, the Clean Water Act, the American Industrial Hygiene Association, the Occupational Safety and Health Administration, the National Institute of Safety and Health, the American Society for Testing and Materials, and the American Public Health Association. In the absence of an industry-standard method, analyses are performed using performance-based methods that meet project-specific data quality objectives.

The choice of a specific method is determined by program or permit requirements or by the desired detection limit. All analyses of laboratory quality control samples are reported back to Triad or N3B. Additionally, LANL sends field quality control samples (blank samples and duplicate samples) periodically for analysis. The frequency of field quality control samples is determined by analytical methods, permits, or LANL procedures.

Data Review and Evaluation

Laboratories generally return analytical results to LANL in two formats: as electronic data deliverables and as data packages. An electronic data deliverable is a data file transmitted in a format that can be directly uploaded into database programs. A data package consists of the combined analytical chain of custody, signed sample collection logs, a validation report if available, and the analytical data report. These documents are usually delivered as a portable document format (pdf) file. Some data users also request a hard copy of the data package. For N3B, laboratory data packages and electronic data deliverables adhere to the requirements specified in Exhibit “D,” Scope of Work and Technical Specifications for Off-Site Analytical Laboratory Services.

Electronic data deliverables are loaded into holding tables in the Environmental Information Management database. Automated programs in the database verify the data in these files by checking that

- the data deliverable file is formatted correctly, including in the number and types of fields (text/numeric/date-time);
- the analyses reported agree with those we ordered;
- the data were not already reported (to avoid duplicates);
- the sampling date used by the analytical laboratory agrees with the database sampling date (which is important for holding time evaluation); and
- the dates listed by the lab, such as sampling before preparation date and preparation before analysis date, are consistent.

Upon verification, a Sample Management Office chemist runs an auto-data review routine in the Environmental Information Management database to validate reported data. Auto-data review follows the U.S. Environmental Protection Agency’s National Functional Guidance documents and the Department of Energy/Department of Defense Consolidated Quality Systems Manual for validation of the analytical data. The important exclusions from auto-validation are examination of the spectra (mass spectra, ultraviolet spectra, rad alpha spectra), chromatograms (for methods using confirmation column), and filed blank/duplicate samples. The auto-validation checks and applies proper validation qualifiers and validation reason codes for the following:

- Holding time
- Method blank contamination
- Laboratory control samples and duplicates within limits
- Matrix spike recoveries within limits
- Missing laboratory quality control samples

When examination and verification and auto-data review are completed, data are transferred to production tables in the database.

Data may undergo a manual validation. We use two mechanisms for selecting data for manual validation: data may be randomly selected across different analytical methods and laboratories, or a new detection of a substance or a data quality issue may trigger an elevated, in-depth review (triggered validation). For N3B, a minimum of 10 percent of analytical data is manually validated by a chemist. Project personnel determine if a greater frequency of full validation is required to meet project-specific, data quality objectives and will notify the Sample Management Office accordingly. Triggered validation is performed on specific data at the request of the data owner or the person preparing reports.

During manual validation, selected samples undergo full validation. Data stored in the Environmental Information Management database tables and the data packages are reviewed. All aspects of data quality are evaluated, including spectral data. If manual validation results in a change of the data qualification, the changes are entered into the Environmental Information Management database. A description of the changes and a short explanation of reasons for the changes are included. All such changes are tracked in the Environmental Information Management database’s audit tables.

Field quality control samples are evaluated when data sets are prepared for individual programs or data owners. Any detections found in blank samples or large discrepancies in results between duplicated samples are reported back to a Sample Management Office chemist. If the chemist decides that field quality control samples warrant changes in the validation qualifiers or detection status, the changes are entered into the Environmental Information Management database.

The primary purpose of data validation is to assess and summarize the quality and defensibility of analytical data for end users. Combined guidelines and requirements ensure the necessary level of confidence in data quality and usability for project activities. The entire data validation process includes a description of the reasons for any failure to meet method, procedural, or contractual requirements and an evaluation of the failure’s impact on data or a data set.

All analytical data packages include the auto-data review report, the examination/verification report, and if performed, the data validation report. These reports are transferred to records management to meet records retention requirements. The compiled data packages are also uploaded to the IntellusNM website.

Environmental Data Management Platform Performance Testing

N3B chemists performed extensive testing of the Automated Data Review Data Validation Module of the Environmental Information Management database, including using electronic data deliverables from actual laboratory analyses. They identified specific issues and opportunities for enhancements. N3B personnel worked with Locus Technology to implement corrections and improvements to ensure that outputs meet requirements prescribed by the Quality Systems Manual and recommendations in the U.S. Environmental Protection Agency's National Functional Guidelines. This work was performed in coordination with Triad and the New Mexico Environment Department. The final Automated Data Review Module was implemented in January 2021, and continued enhancements and adjustments were made throughout 2022. The validation tracking and selection module was added in 2022. An increased number of full validations were performed to monitor Automated Data Review performance. No major issues were identified. Performance enhancements and improvements are ongoing.

A greater number of full validations increases transparency and ensures a unified treatment of data available to the public on IntellusNM. Tests by N3B chemists of the system's configuration provide proof of the system's capabilities to accurately perform routine data checks based on analytical methods and regulatory requirements. In addition, the Automated Data Review module was improved for all analytes, particularly radiochemistry data. During this process, N3B chemists manipulated test cases to verify that the actual outcomes matched expected outcomes. The results of this testing were shared with data system architects, who identified improvements. Additionally, during this process, N3B found that radiochemical capabilities were underutilized and so enhanced the Automated Data Review functionality regarding radioanalytical assessment.

Record Retention

Original hard copies of chain-of-custody forms and sample collection logs are stored temporarily at the Sample Management Office. Final records are then transmitted to Records Management. The ambient air-monitoring program requires that a hard copy Level IV data package remain on site. These records are packaged by the end of each fiscal year and transferred to the LANL Records Center, where they remain on site for 5 years.

Analytical records are stored in the Environmental Information Management database. The entire N3B and Triad Environmental Information Management database is backed up at least quarterly on N3B or Triad servers. Analytical results are copied daily to the publicly available IntellusNM database (www.intellusnm.com). Level IV data packages are uploaded into the LANL Electronic Records Management System to fulfill the long-term record retention requirement. Approximately once per month, the Level IV data packages are copied to IntellusNM.

Some data and analytical packages are withheld from public view for up to 90 days from the date of receipt. These packages are usually results from samples collected off site that LANL shares first with other entities, including nearby counties or Native American tribes.

Quality Assurance

N3B's Sample Data Manager and the Sample Management Office are subject to the N3B Quality Assurance and Transformation Audit and Surveillance program. They are also subject to the following:

- DOE Consolidated Audit Program audits of analytical laboratories used for environmental sampling
- DOE Consolidated Audit Program audits of Treatment, Storage, and Disposal Facilities used for disposal
- Internal audits under the management assessments program
- Quality assurance and transformation in developing project assessment criteria and issues responses in the N3B integrated Contractor Assurance System
- Management observation and verifications
- Performance tracking by personnel who monitor activities conducted under the scope of this sample and data management plan

DOE's Analytical Services Program

The DOE's Analytical Services Program provides environmental-management-related services and products to DOE Program Offices and field sites. The various parts of the Analytical Services Program that the Laboratory participates in are described here.

DOE Consolidated Audit Program–Accreditation Program for Commercial Analytical Laboratories

The DOE Consolidated Audit Program provides for assessments of commercial analytical laboratories that analyze environmental samples. Use of third-party auditors replaced the traditional DOE Consolidated Audit Program audits beginning in fiscal year 2018. This change has allowed for more in-depth approaches to quality control and oversight of these laboratory facilities in meeting the needs of the DOE. The DOE Consolidated Audit Program has qualified the following three accrediting bodies to perform these audits:

- Perry Johnson Laboratory Accreditation, Inc.
- The American Association for Laboratory Accreditation
- The American National Standards Institute National Accreditation Board

Analytical laboratories are audited against the International Organization of Standardization's Standard 17025, General Requirements for the Competence of Testing and Calibration Laboratories; the National Environmental Laboratory Accreditation Conference Standard; and the Department of Energy/Department of Defense Consolidated Quality Systems Manual (Quality Systems Manual). N3B uses the results from these third-party accreditation assessment reports as part of its oversight for its subcontracted commercial analytical laboratories.

Table 3-5 summarizes the DOE Consolidated Audit Program laboratories currently subcontracted to perform samples analysis for N3B and/or Triad.

Table 3-5. DOE Consolidated Audit Program-Accreditation Program Audits of Laboratories Contracted by N3B and/or Triad in Fiscal Year 2022

Laboratory	Audit Dates	Accrediting Body	Used in FY22
ARS Aleut Analytical, LLC (Port Allen, LA)	January 16–7, 2022	ANAB	Yes
Southwest Research Institute (San Antonio, TX)	June 13–17, 2022	A2LA	Yes
Eurofins TestAmerica (Denver, CO)	September 7, 2022	A2LA	No
Eurofins TestAmerica (St. Louis, MO)	December 5–6, 2022	ANAB	No
Eurofins TestAmerica (Knoxville, TN)	December 15–16, 2022	ANAB	No
Eurofins TestAmerica (Sacramento, CA)	December 5–8, 2022	ANAB	No
ALS Environmental (Salt Lake City, UT)	May 3–4, 2022	PJLA	Yes
ALS Environmental (Fort Collins, CO)	May 16–18, 2022	PJLA	No
Materials and Chemistry Laboratory, Inc. (Oak Ridge, TN)	May 11–13, 2022	PJLA	Yes
EMSL Analytical, Inc. (Cinnaminson, NJ)	June 13–16, 2022	A2LA	No
GEL Laboratories, LLC (Charleston, SC)	May 19–20, 2022	A2LA	Yes
Pacific EcoRisk (Fairfield, CA)	October 24–27, 2022	PJLA	Yes

ANAB = American National Standards Institute National Accreditation Board
A2LA = American Association for Laboratory Accreditation
PJLA = Perry Johnson Laboratory Accreditation, Inc.

N3B provided support to the DOE Consolidated Audit Program in various ways throughout fiscal year 2022. The team participated in the Analytical Services Program annual training workshop, which consisted of presentations related to the Analytical Services Program activities, the future direction of the program, and technical presentations about data quality and data management. N3B supported four DOE Consolidated Audit Program audits by providing audit observers to ARS Aleut Analytical, Southwest Research Institute, ALS Environmental, and Eurofins TestAmerica audits. Finally, N3B staff played an active role in the DOE Consolidated Audit Program Data Quality Work Group, participating in conference calls and answering questions or requests about issues that emerged during laboratory audits and general laboratory or data quality questions from around the complex. N3B radiochemists actively participated in the development of the Radiochemistry Module 6 of the Department of Energy/Department of Defense Consolidated Quality System Manual for Environmental Laboratories Version 6.0, which will replace version 5.4.

Findings from the third-party audits are reported back to the interested DOE sites through the DOE Consolidated Audit Program administrator. N3B tracks all findings from the analytical laboratories it has under contract. The significant findings from fiscal year 2022 are findings regarding

- verifying and calibrating support equipment,
- missing calibration, and
- record keeping; examples: a laboratory did not document all procedural deviations from standard test methods or a laboratory did not use appropriate methods and procedures for all laboratory activities.

Before receiving certificates of accreditation, analytical laboratories are required to submit corrective action reports to the accrediting bodies. The accrediting bodies must accept these corrective actions as sufficient before granting accreditation. All N3B subcontracted laboratories received their accreditations in 2022, indicating that the corrective actions were determined to have adequately addressed the identified issues.

DOE Mixed Analyte Performance Evaluation Program

The Mixed Analyte Performance Evaluation Program provides proficiency testing in various environmental matrices, although primarily for radionuclide identification and quantification. Results for proficiency testing help assure field managers of the quality and reliability of environmental data used in decision-making. Laboratories are required by the National Laboratory Accreditation Conference Standard and the Quality Systems Manual to participate in proficiency testing in all fields of accreditation, where available.

Although not a mandatory requirement of the Quality Systems Manual, the Mixed Analyte Performance Evaluation Program can be tool to determine a commercial laboratory’s analytical radiological capabilities across most environmental matrices. Participation in the Mixed Analyte Performance Program is required for laboratories that perform radiochemical analyses for N3B.

DOE Consolidated Audit Program—Treatment, Storage, and Disposal Facility Audits

Treatment, storage, and disposal facility audit reports produced by the DOE Consolidated Audit Program are one tool that DOE Field Office managers use in performing their DOE Order 435.1 annual acceptability reviews for commercial sites. These audits are conducted by volunteers from the DOE and site contractors who use these sites for the disposal of waste. Table 3-6 provides a summary of the most recent audit by the DOE Consolidated Audit Program for the Treatment, Storage, and Disposal Facilities subcontracted to accept radioactive waste from N3B.

Table 3-6. Most Recent Audits of Treatment, Storage, and Disposal Facilities Used by N3B under the DOE Consolidated Audit Program

Treatment, Storage, and Disposal Facility	Most Recent Audit Date
Waste Control Specialists, LLC (Andrews County, TX)	May 3–4, 10–11, 2022
Perma-Fix Northwest, Inc. (Richland, WA)	June 7–8, 14–15 2022
Clean Harbors, LLC (Colfax, LA)	April 4–5, 2022
Energy Solutions (Clive, UT)	April 4–5, 11–12, 2022

Priority I findings identified by the DOE consolidated audit team are reviewed and tracked by the Waste Management Program. Priority II findings are considered significant. The most recent audits identified Priority II findings that were not considered of immediate significance to compliance, policy, or performance. There were no Priority 1 findings, one Priority II finding, and two observations during audits performed in 2022.

References

Bartlow et al. 2022: A. W. Bartlow, J. T. Giermakowski, C. W. Painter, P. Neville, E. S. Schultz-Fellenz, B. M. Crawford, A. F. Lavadie-Bulnes, B. E. Thompson, and C. D. Hathcock. 2022. "Modeling the distribution of the endangered Jemez Mountains salamander (*Plethodon neomexicanus*) in relation to geology, topography, and climate," Ecol. Evol. 12(8), e9161 (August 23, 2022).

EPA 2006: "Guidance on Systematic Planning Using the Data Quality Objectives Process: EPA QA/G-4," U.S. Environmental Protection Agency report EPA/240/B-06/001, Washington, D.C.

LANL 2022: "Los Alamos National Laboratory 2021 Campus Master Plan," Los Alamos National Laboratory report LA-UR-22-21424, Los Alamos, New Mexico (2022).

Murphy et al. 2023: Sean M. Murphy, Charles D. Hathcock, Tatiana N. Espinoza, Philip R. Fresquez, Jesse T. Berryhill, Jenna E. Stanek, Benjamin J. Sutter, and Shannon M. Gaukler. 2023. "Comparative spatially explicit approach for testing effects of soil chemicals on terrestrial wildlife bioindicator demographics," *Environ. Pollut.* 316, Part 2, 120541.

Stanek et al. 2022: J. E. Stanek, B. E. Thompson, S. E. Milligan, K. A. Tranquillo, S. M. Fettig, and C. D. Hathcock. 2022. "Does Age, Residency, or Feeding Guild Coupled with a Drought Index Predict Avian Health during Fall Migration?" *Animals (Basel)* 12(4):454.

Chapter 4: Air Quality

We monitor air quality through five programs, each described in a section of this chapter: ambient air sampling at public locations, exhaust stack sampling at Laboratory facilities, gamma and neutron direct radiation monitoring near radiation sources and in public locations, particulate matter monitoring, and meteorological monitoring of the local climate and weather.

A primary objective of air quality surveillance is to measure levels of airborne radiological materials to calculate radiological doses to humans, plants, and animals. Results are compared with U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency standards. Weather data support many Laboratory activities, including emergency management and response, regulatory compliance, safety analysis, engineering studies, and environmental surveillance programs.

Introduction

The purpose of the Laboratory's air quality surveillance is to protect public health and the environment. Air quality is monitored by five programs, each described in a section of this chapter: ambient air sampling at public locations, exhaust stack sampling at Laboratory facilities, gamma and neutron direct radiation monitoring near radiation sources and in public locations, particulate matter monitoring, and meteorological monitoring of the local climate and weather.

A primary objective of air quality surveillance is to measure levels of airborne radiological materials to calculate radiological doses to humans, plants, and animals. Results are compared with U.S. Department of Energy and U.S. Environmental Protection Agency standards. Radioactivity levels in the air are compared with the dose limits for members of the public provided in DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, and in National Emission Standards for Hazardous Air Pollutants, Title 40 Part 61 of the Code of Federal Regulations. Estimates of public doses prepared using this data are provided in Chapter 8, Public Dose and Risk Assessment.

Ambient Air Sampling for Radionuclides

The Laboratory's air-sampling network measures levels of airborne radionuclides to monitor the emissions from Laboratory operations. Radioactivity levels in the air are compared with the U.S. Environmental Protection Agency's concentration levels for environmental compliance, provided in National Emission Standards for Hazardous Air Pollutants, Title 40 Part 61 of the Code of Federal Regulations, Appendix E, Table 2.

During 2022, the Laboratory operated 43 environmental air-monitoring stations to monitor radionuclides in the air (see Figure 4-1 and Figure 4-2). Station locations are categorized as regional (away from the Laboratory), perimeter, on site, or waste site. The waste site locations monitor radionuclides near the Laboratory's low-level radioactive waste disposal area and radioactive waste storage area, Area G, at Technical Area 54 (see Figure 4-2).

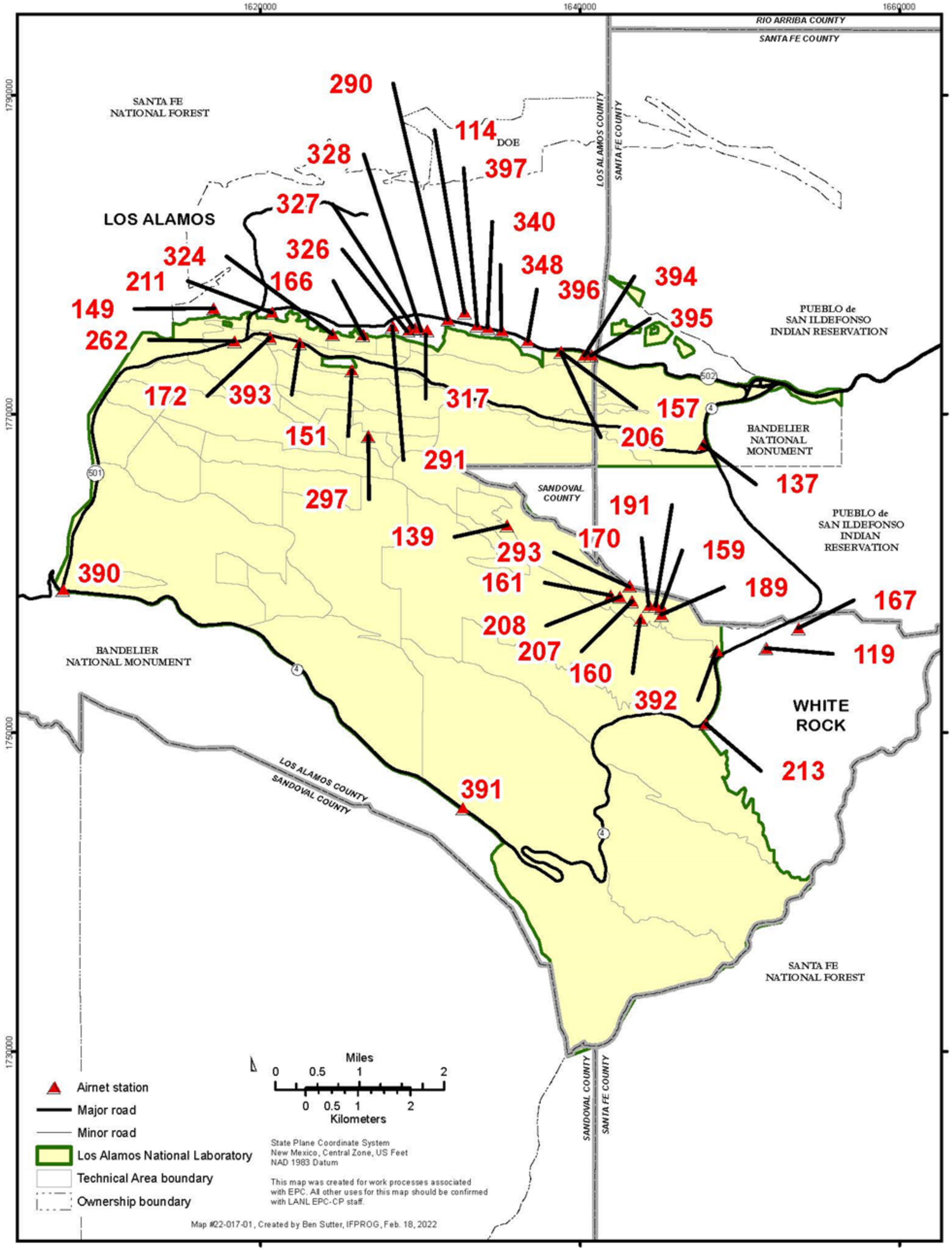


Figure 4-1. Environmental air-monitoring stations at and near the Laboratory.

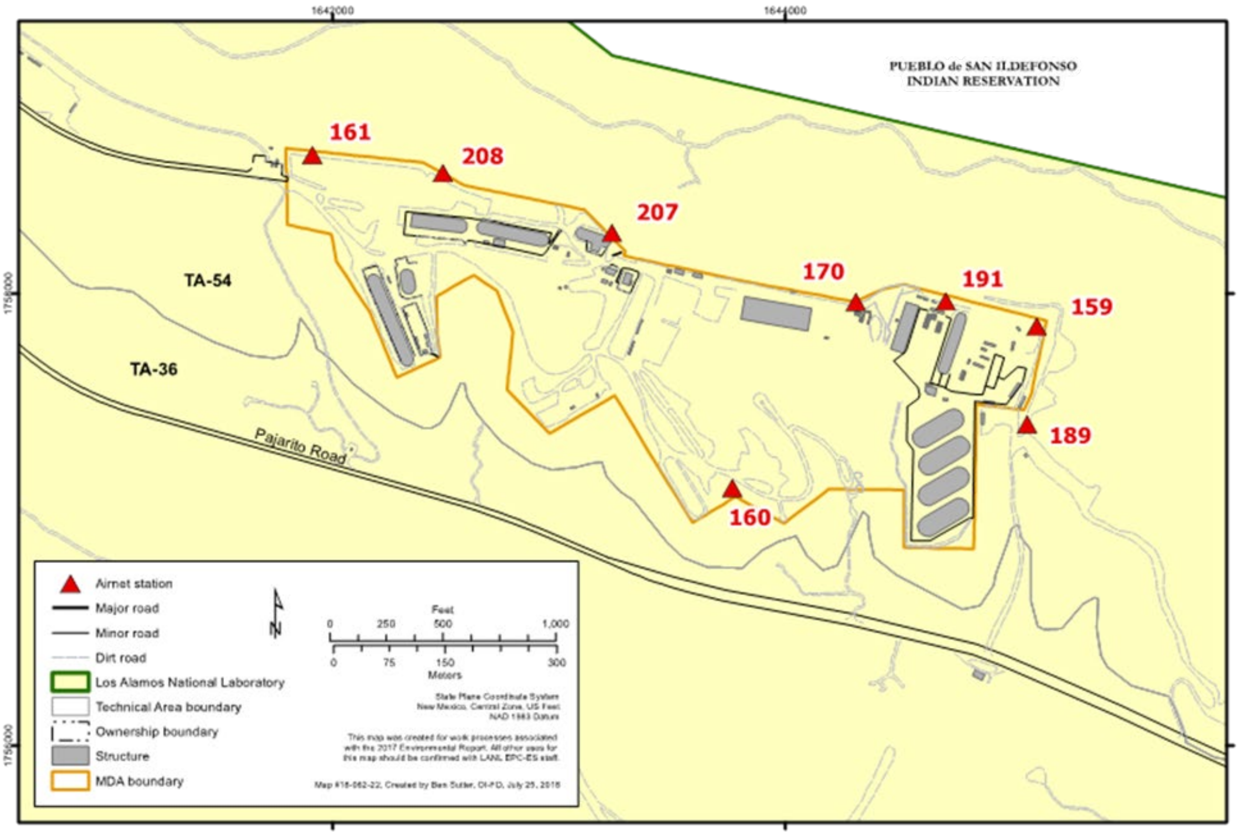


Figure 4-2. Environmental air-monitoring stations at the Laboratory's Technical Area (TA) 54, Area G. MDA = Material disposal area.

These stations operate by continuously pulling ambient air through a filter to capture airborne particulate matter. The filters are changed out every 2 weeks and are sent to an offsite analytical laboratory for analysis. During the first half of 2022, the filters were sent to the ALS Environmental Laboratory in Fort Collins, Colorado. During the second half of 2022, the ALS laboratory closed and thereafter, the filters were sent to Gel Laboratories LLC in Charleston, South Carolina.

As a result of different procedures, the data from Gel have generally higher results with much larger uncertainties than the data from ALS. If these two datasets are combined by using simple averages, the data with the larger uncertainties dominate. Alternatively, if they are combined by using weighted averages, the data with smaller uncertainties dominate.

If the objective is to find the maximum possible result, simple averages may be used; however, the large uncertainties mean comparison with previous data is inaccurate. If the objective is to compare with previous data, weighted averages are preferable. Either of these methods is adequate to demonstrate compliance with the DOE and U.S. Environmental Protection Agency standards.

In this chapter, weighted arithmetic means were used for Table 4-1 through Table 4-5, whereas simple addition was used for Table 4-6 and Table 4-7. The other tables of data do not depend on either ALS or Gel Laboratories and are not affected by the transition from ALS to Gel.

Regional Background Levels

The atmosphere contains background levels of radioactivity from naturally occurring radionuclides and airborne radioactive materials that result from nuclear weapons tests and nuclear accidents. Background levels are measured at regional monitoring stations located in the communities of El Rancho, Española, and Santa Fe. The results are summarized in Table 4-1.

Table 4-1. Average Background Radionuclide Activities in the Regional Atmosphere

Analyte	Units	U.S. Environmental Protection Agency Concentration Level for Environmental Compliance	Average Regional Background Activities
Tritium	pCi/m3	1500	0 ± 1
Americium-241	aCi/m3	1900	0 ± 1
Plutonium-238	aCi/m3	2100	1 ± 1
Plutonium-239/240	aCi/m3	2000	0 ± 1
Uranium-234	aCi/m3	7700	17 ± 4
Uranium-235	aCi/m3	7100	2 ± 2
Uranium-238	aCi/m3	8300	15 ± 3

pCi/m^3 = picocuries per cubic meter; aCi/m3 = attocuries per cubic meter.

Perimeter, Onsite, and Waste Site Radionuclides

Tritium

What are cosmic rays?

Cosmic rays are fragments of atoms that rain down upon the Earth from outside the solar system.

Tritium is present in the environment primarily as the result of past nuclear weapons tests and cosmic-ray interactions with the air (Eisenbud and Gesell 1997). Measurements of water vapor in the air and tritium in the water vapor are used to calculate the amount of tritium in the air. During 2022, tritium concentrations were similar to recent years and below the U.S. Environmental Protection Agency's concentration level for environmental compliance of 1,500 picocuries per cubic meter (see Table 4-2). The highest annual tritium activity at any offsite station was less than 1 percent of the concentration level for environmental compliance.

Table 4-2. Airborne Tritium as Tritiated Water Activities for 2022—Group Summaries

Station Grouping	No. of Stations	Mean ± 2 Standard Deviations (pCi/m^3)		Maximum Annual Station Activity (pCi/m^3)	U.S. Environmental Protection Agency Concentration Level for Environmental Compliance (pCi/m^3)
Regional	3	0	±1	0	1500
Perimeter	30	1	±1	2	1500
Onsite	2	2	±2	3	1500
Waste site	8	43	N/A	294	1500

Note: pCi/m^3 = picocuries per cubic meter, N/A = not applicable.

For the waste site, the largest tritium concentration was at the southern boundary of Area G (station 160; see Figure 4-2). The annual average concentration is well below 1,500 picocuries per cubic meter, which is the U.S. Environmental Protection Agency concentration level for the public.

The analytical methods comply with U.S. Environmental Protection Agency requirements in National Emission Standards for Hazardous Air Pollutants, Title 40 Part 61 of the Code of Federal Regulations, Appendix B, Method 114.

Americium-241

Table 4-3 summarizes the 2022 sampling data for americium-241. The results are similar to recent years and are less than 1 percent of the americium-241 concentration level for environmental compliance.

Table 4-3. Airborne Americium-241 Activities for 2022—Group Summaries

Station Grouping	No. of Stations	Mean ± 2 Standard Deviations (aCi/m^3)		Maximum Annual Station Activity (aCi/m^3)
Regional	3	0	±1	0
Perimeter	30	0	±1	1
Onsite	2	0	±1	1
Waste site	8	1	±1	2

aCi/m^3 = attocuries per cubic meter

Plutonium

Table 4-4 summarizes the LANL plutonium-238 and plutonium-239/240 data for 2022, which are generally similar to previous years.

Table 4-4. Airborne Plutonium-238 and Plutonium-239/240 Activities for 2022—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 2 Standard Deviations (aCi/m^3)		Maximum Annual Station Activity (aCi/m^3)	
		Plutonium-238	Plutonium-239/240	Plutonium-238	Plutonium-239/240
Regional	3	1 ± 1	0 ± 1	1	0
Perimeter	30	0 ± 1	1 ± 3	1	14
Onsite	2	0 ± 1	1 ± 1	1	2
Waste site	8	1 ± 1	1 ± 1	2	3

aCi/m^3 = attocuries per cubic meter.

Every year, dust blown from areas where Manhattan Project–era operations took place results in detectable amounts of plutonium-239 in the air near Technical Areas 01 and 21. The plutonium-239 concentrations at perimeter environmental air-monitoring stations 317 (DP Road), 324 (Hillside 138), and 326 (Middle DP Road) are less than 1 percent of the U.S. Environmental Protection Agency's plutonium-239 concentration level for environmental compliance, which is 2,000 attocuries per cubic meter.

Uranium

Table 4-5 summarizes the uranium data. The largest concentrations were the result of soil resuspended by springtime winds. All results are below the applicable concentration levels.

Table 4-5. Airborne Uranium-234, -235, and -238 Activities for 2022—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 2 Standard Deviations (aCi/m³)		
		Uranium-234	Uranium-235	Uranium-238
Regional	3	17 ± 4	2 ± 1	15 ± 3
Perimeter	30	12 ± 5	1 ± 1	13 ± 5
Onsite	2	11 ± 1	1 ± 1	10 ± 1
Waste site	8	13 ± 10	1 ± 1	12 ± 5

Note: aCi/m^3 = attocuries per cubic meter.

Gamma Spectroscopy Measurements

Air samples are analyzed by gamma spectroscopy for the following gamma-ray-producing radionuclides: cobalt-60, cesium-134 and -137, iodine-131, sodium-22, and protactinium-234m. These radionuclides were not detected.

Conclusion

All concentrations of airborne radioactive material measured in ambient air samples were below the applicable concentration levels for environmental compliance.

Exhaust Stack Sampling for Radionuclides

Radioactive materials are used in some Laboratory operations. The buildings that house those operations may vent radioactive materials to the environment through an exhaust stack or other release point. The Laboratory's stack-monitoring team monitors emission points that could cause a public dose greater than 0.1 millirem during a 1-year period. Each of these stacks is sampled in accordance with the National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities, Title 40, Part 61, Subpart H of the Code of Federal Regulations.

Sampling Methodology

Radioactive stack emissions can be one of four types: particulate matter, activated vapors and volatile compounds, tritium, or gaseous mixed activation products. Activated materials are made radioactive by exposure to neutron radiation. This section describes the sampling method for each of these emission types.

Emissions of particulate matter are sampled using a glass-fiber filter. A continuous sample of air from the stack is pulled through a filter that captures small particles. Filters are collected weekly and shipped to an offsite analytical laboratory for analysis.

Charcoal cartridges are used to sample emissions of activated vapors and volatile compounds generated by operations at the Los Alamos Neutron Science Center at Technical Area 53, the Chemistry and Metallurgy Research Building, and Technical Area 48.

Tritium emissions are measured with collection devices known as bubblers to determine the total amount of tritium released and whether it is in the elemental or oxide form. The bubblers pull a continuous sample of air from the stack, which is then "bubbled" through three sequential vials that contain ethylene glycol. The ethylene glycol collects any tritium oxide that may be part of a water molecule. Then the air is passed through a palladium catalyst that converts the elemental tritium to the oxide form. Following this conversion, the sample is pulled through three additional vials that contain ethylene glycol; these vials collect the newly formed tritium oxide.

The stack-monitoring team measures activities of gaseous mixed activation products emitted from the Los Alamos Neutron Science Center using real-time, air-monitoring data. To collect these data, a sample of air from the stack is pulled through an ionization chamber that measures the total amount of radioactivity in the sample.

Data Analysis

Methods

This section discusses the analysis methods used for each type of the Laboratory's emissions. The sampling methods comply with U.S. Environmental Protection Agency requirements in the National Emission Standards for Hazardous Air Pollutants, Title 40, Part 61 of the Code of Federal Regulations, Appendix B, Method 114.

Check of the Total Activity

Each week the glass-fiber filters are collected. The total activity is measured before the filters are shipped to an offsite analytical laboratory, where they are analyzed using spectroscopy to identify radionuclides. These data are used to quantify emissions of radionuclides. The results are compared with the total activity measurements to ensure that all radionuclides are identified.

Vaporous Activation Products

Each week, the charcoal cartridges are collected and shipped to an offsite analytical laboratory, where they are analyzed using spectroscopy. These data are used to identify and quantify the presence of vaporous material.

Tritium

Each week, tritium bubbler samples are collected and transported to the Laboratory's Health Physics Analysis Laboratory, where the amount of tritium in each vial is determined by liquid scintillation counting.

Gaseous Mixed Activation Products

Continuous monitoring is used for gaseous mixed activation products at the Los Alamos Neutron Science Center. There are two reasons for the use of continuous monitoring. First, standard filter paper and charcoal filters will not collect gaseous emissions. Second, the half-lives of these radionuclides are so short that the activity would decay away before any sample could be analyzed off site. The monitoring system includes a flow-through ionization chamber in series with a gamma spectroscopy system. The real-time current measured by this ionization chamber is recorded, and the total amount of charge collected in the chamber is integrated daily. The gamma spectroscopy system analyzes the composition of these gaseous mixed activation products.

Results

Table 4-6 provides detailed emissions data for Laboratory buildings with sampled stacks. Table 4-7 lists the stack emissions of the main activation products. Table 4-8 presents the half-lives of the main radionuclides typically emitted by the Laboratory.

Table 4-6. Airborne Radioactive Emissions[a] from LANL Buildings with Sampled Stacks in 2022

Technical Area and Building Number	Tritium (curies)	Americium-241 (curies)	Plutonium (curies)	Uranium (curies)	Thorium (curies)	Particulate or Vapor Activation Products (curies)	Gaseous Mixed Activation Products (curies)
TA-03-029		2.5×10^{-7}	4.3×10^{-6}	3.1×10^{-6}	4.3×10^{-7}		
TA-16-205/450	41.0						
TA-48-001		2.8×10^{-8}	1.4×10^{-7}			1.2×10^{-4}	
TA-50-001							
TA-50-069			6.4×10^{-11}			2.1×10^{-8}	
TA-53-003	7.3					3.7×10^{-5}	21.3
TA-53-007	1.3					1.3×10^{-1}	85.6
TA-55-004	13.2		1.1×10^{-7}	1.8×10^{-8}	4.5×10^{-8}		
Total	62.7	2.8×10^{-7}	4.6×10^{-6}	3.1×10^{-6}	4.7×10^{-7}	1.3×10^{-1}	107

[a] Values are expressed in scientific notation.

Table 4-7. Main Activation Products in 2022

Building Number	Nuclide	Emission (curies)[a]	
TA-53-003	Argon-41	0.85	8.5×10^{-1}
TA-53-003	Carbon-11	20	2.0×10^{1}
TA-53-007	Argon-41	4.3	4.3×10^{0}
TA-53-007	Carbon-10	0.10	1.0×10^{-1}
TA-53-007	Carbon-11	44	4.4×10^{1}
TA-53-007	Nitrogen-13	14	1.4×10^{1}
TA-53-007	Nitrogen-16	0.33	3.3×10^{-1}
TA-53-007	Sodium-24	0.13	1.3×10^{-1}
TA-53-007	Oxygen-14	0.19	1.9×10^{-1}
TA-53-007	Oxygen-15	22	2.2×10^{1}

[a] The value for emission for each building and nuclide is listed in both standard and scientific notation.

Table 4-8. Radionuclide Half-Lives

Nuclide	Half-Life
Americium-241	433 years
Argon-41	1.8 hours
Carbon-10	19.3 seconds
Carbon-11	20.4 minutes
Nitrogen-13	10.0 minutes
Nitrogen-16	7.1 seconds
Oxygen-14	70.6 seconds
Oxygen-15	122.2 seconds
Plutonium-238	87.7 years
Plutonium-239	24,100 years
Plutonium-240	6,560 years
Plutonium-241	14.3 years

Nuclide	Half-Life
Sodium-24	15.0 hours
Tritium	12.3 years
Uranium-234	245,500 years
Uranium-235	703,800,000 years
Uranium-238	4,468,000,000 years

Conclusions and Trends

Emission-control systems in Laboratory facilities for particulates such as plutonium and uranium continue to work as designed, and particulate emissions remain very low. Emissions of short-lived gases and vapors were similar to the last 10 years. The radioactive emissions from all Laboratory sources amounted to approximately 1 percent of the regulatory limit.

Monitoring for Gamma and Neutron Direct-Penetrating Radiation

Gamma and neutron radiation levels are monitored by the Direct-Penetrating Radiation Network (McNaughton 2018) and supplemented by the Neighborhood Environmental Watch Network. The objectives are to monitor gamma and neutron radiation in the environment as required by DOE Order 458.1.

Dosimeters are devices that measure exposure to ionizing radiation. We deployed dosimeters at 85 locations to monitor direct-penetrating radiation in the environment during 2022. Thermoluminescent dosimeters, which monitor gamma and neutron radiation, are deployed at every environmental air-monitoring station (see Figure 4-1 and Figure 4-2). Additional thermoluminescent dosimeters are deployed at Technical Areas 53 and 54, where potential Laboratory sources of direct-penetrating radiation exist (see Figure 4-3 and Figure 4-4). Together, all of these locations make up the Direct-Penetrating Radiation Network.

Gamma radiation occurs naturally, typically 100 to 200 millirem per year near Los Alamos, so it is difficult to distinguish the much smaller levels of radiation contributed by the Laboratory. Radiation from the Laboratory is identified by higher radiation levels near the source and reduced radiation levels at greater distances.

Neutron doses are measured near known or suspected sources of neutrons, including Technical Areas 53 and 54. At 61 locations, the accuracy of the neutron measurements is enhanced by the addition of Lucite blocks that reflect neutrons into the dosimeter. The neutron background is measured at locations far from Laboratory sources.

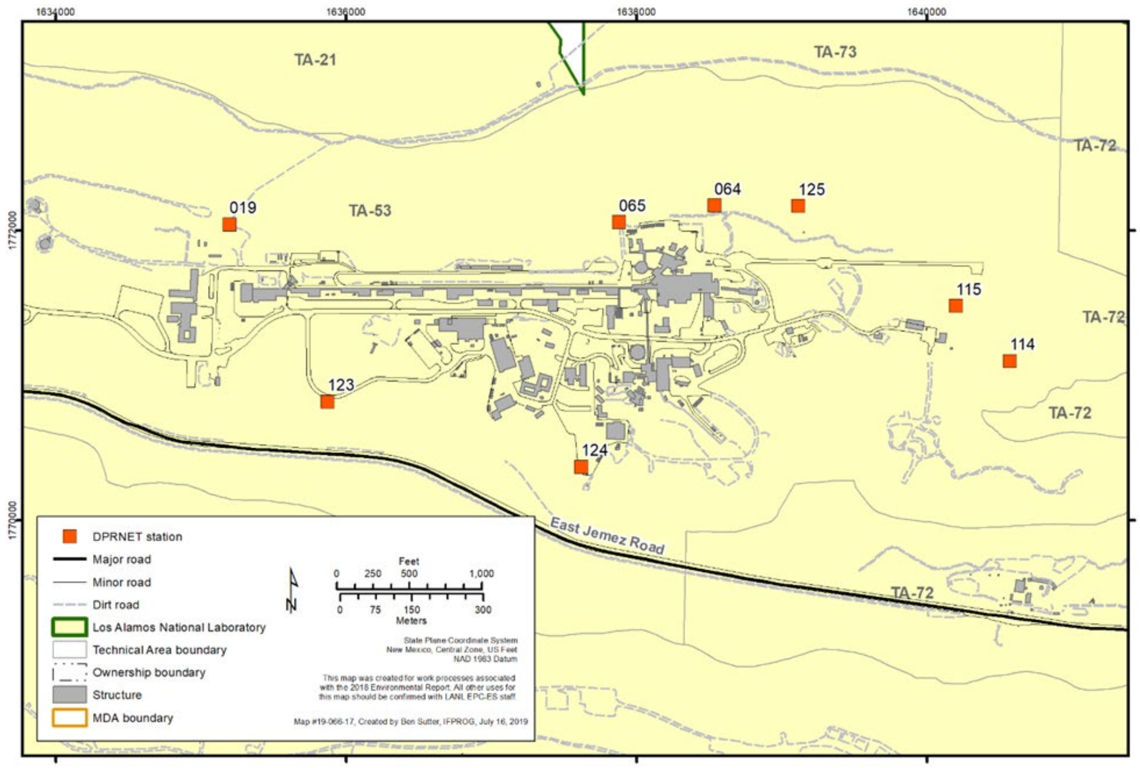


Figure 4-3. Locations of thermoluminescent dosimeters at Technical Area 53 that are part of the direct-penetrating radiation monitoring network (DPRNET).

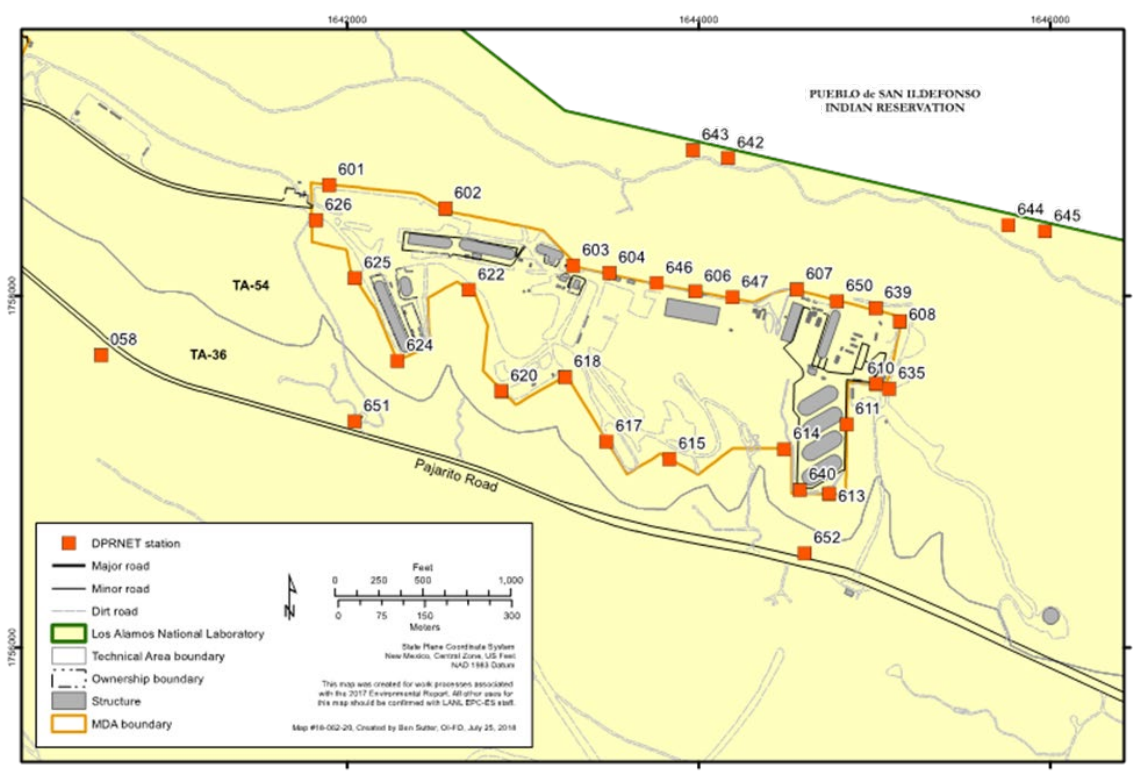


Figure 4-4. Locations of thermoluminescent dosimeters at Area G that are part of the direct-penetrating radiation monitoring network (DPRNET).

Quality Assurance

The Radiation Protection Division dosimetry laboratory is accredited by the DOE Laboratory Accreditation Program and provides quality assurance for the dosimeters.

Results

Table 4-9 summarizes the gamma radiation data for 2022. We compared the results with the values recorded in previous years at those stations. At regional locations, the gamma radiation is natural and, as expected, has not changed. At the perimeter stations, the gamma radiation is generally higher than at the regional stations because of increased cosmic radiation at higher altitudes and increased uranium and thorium in the soil. At these stations, the radiation is mostly natural and, as expected, 2022 data are similar to data from previous years. At the Los Alamos Neutron Science Center accelerator facility, measurable radiation occurs from the accelerator, which varies from year to year. At the Area G waste site, a downward trend is occurring as waste is sent to the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

Table 4-9. Gamma Radiation for 2022—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 1 Standard Deviation (millirem)	
		Previous	2022
Regional	11	118 ± 15	113 ± 13
Perimeter	30	125 ± 12	121 ± 11
Onsite	3	131 ± 11	130 ± 12
Los Alamos Neutron Science Center	8	142 ± 22	131 ± 19
Area G Waste Site	33	200 ± 106	132 ± 17

Table 4-10 summarizes the neutron radiation data. At regional stations, the radiation is natural, and the apparent increase is not statistically significant. The dose rates at the perimeter and onsite stations are similar to previous years. At waste site locations near Area G, a decreasing trend is occurring as waste is sent off site.

Table 4-10. Neutron Radiation for 2022—Group Summaries

Station Grouping	No. of Stations	Group Mean ± 1 Standard Deviation (millirem)	
		Previous	2022
Regional	7	2.5 ± 1.6	4.2 ± 3.1
Perimeter	3	4.4 ± 3.3	4.3 ± 0.7
Onsite	10	2.2 ± 0.5	2.7 ± 1.6
Los Alamos Neutron Science Center	8	3.8 ± 1.1	4.7 ± 2.1
Area G Waste Site	33	131 ± 167	39 ± 38

Locations with a measurable contribution of gamma or neutron radiation from Laboratory operations are discussed in the following sections.

Los Alamos Neutron Science Center at Technical Area 53

Figure 4-3 shows the locations of the dosimeters at Technical Area 53. Previous studies (McNaughton 2013) discuss the possibility that a member of the public on East Jemez Road, south of Technical Area 53, could be exposed to gamma and neutron radiation from the Los Alamos Neutron Science Center in Technical Area 53. We estimated the maximum gamma and neutron doses that a hypothetical person who remained on East Jemez Road continuously for a year would receive based on measurements from dosimeters around the facility.

During 2022, dosimeter #115 in Technical Area 53 measured a gamma dose of 143 millirem per year, which is 18 millirem per year above the background of 125 millirem per year. Calculations show that the gamma dose at East Jemez Road is 0.2 percent of the dose measured by dosimeter #115 (McNaughton 2013). Therefore, the gamma dose from Laboratory operations at East Jemez Road was less than 0.1 millirem per year near this location.

Dosimeter #124 at Technical Area 53 measured a neutron dose 6.4 millirem per year above background. Calculations show that the neutron dose at East Jemez Road is 10 percent of this value (McNaughton 2013). Therefore, the neutron dose from Laboratory operations at East Jemez Road was 0.64 millirem per year near this location. These doses are for continuous occupancy, which is not directly applicable at this location because no residences or work locations exist nearby. Adjustments for occupancy are discussed in Chapter 8.

Technical Area 54, Area G

Figure 4-4 shows the locations of the dosimeters at Technical Area 54, Area G. Area G is a controlled-access area, so Area G data do not represent a potential public dose.

Dosimeters #642 through #645 are in Cañada del Buey. After subtracting background, the 2022 annual neutron dose measured by dosimeter #644 was 4 millirem—the dose that would be received by a person who is at the location of the dosimeter 24 hours per day, 365 days per year. As discussed in Chapter 8 (Public Dose and Risk Assessment), an occupancy factor of 1/20 is applied (National Council on Radiation Protection 2005). Therefore, the dose in Cañada del Buey at the dosimeter is calculated to be 4 millirem multiplied by 1/20, equaling approximately 0.2 millirem per year, which is similar to previous years.

Neighborhood Environmental Watch Network

During 2022, the Neighborhood Environmental Watch Network detected gamma-ray emissions amounting to less than 0.01 mrem, which supports the measurements of the ambient air sampling and exhaust stack sampling discussed in this chapter and also the conclusion in Chapter 8 that the radiological dose to the public in 2022 was far below the annual limit of 10 millirem.

Conclusion

Generally, the data are similar to previous years and show that emissions of direct-penetrating radiation from Laboratory facilities were far below the DOE limits.

Total Particulate Matter Air Monitoring

Particulate matter consists of smoke, dust, and other material that can be inhaled. Generally, it is not radioactive. Particulate matter can be harmful in high concentrations.

The total amount of respirable particulate matter is monitored at two locations: near the intersection of New Mexico State Road 4 and Rover Boulevard in White Rock and at the Los Alamos Medical Center in Los Alamos. Data are available at https://airquality.lanl.gov/.

During 2022, the particulate matter concentrations remained well below the U.S. Environmental Protection Agency standard of 35 micrograms per cubic meter for particulate matter smaller than 2.5 micrometers. Typical concentrations (>95 percent of the time) were less than 10 micrograms per cubic meter. The highest concentrations occurred during the spring from windblown dust and during the spring and summer from wildfires. The Cerro Pelado fire started on April 22, 2022, and continued until significant rainfall began in mid-June.

Meteorological Monitoring

We collect weather data to support many Laboratory activities, including emergency management and response, regulatory compliance, safety analysis, engineering studies, and environmental surveillance programs. The meteorological monitoring program measures wind speed and direction, temperature, atmospheric pressure, relative humidity, dew point, precipitation, and solar and terrestrial radiation, among other atmospheric variables. The meteorological monitoring plan (Dewart and Boggs 2014) provides details of the meteorological monitoring program. Laboratory weather data are available at https://weathermachine.lanl.gov.

Monitoring Network

Eight meteorological towers gather weather data at the Laboratory (see Figure 4-5). These towers include three new meteorological towers added to the network in 2021 (towers 16B, 54B, and 63). Seven of the towers are sited on mesa tops (Technical Areas 6, 16, 49, 53, 63, and two towers at Technical Area 54), and one tower is sited in the bottom of Mortandad Canyon (Technical Area 5). An additional precipitation gauge is located in the North Community neighborhood of the Los Alamos town site. The Technical Area 6 tower is the official meteorological measurement station for the Laboratory. For more than 50 years, we have provided daily weather statistics to the National Weather Service.

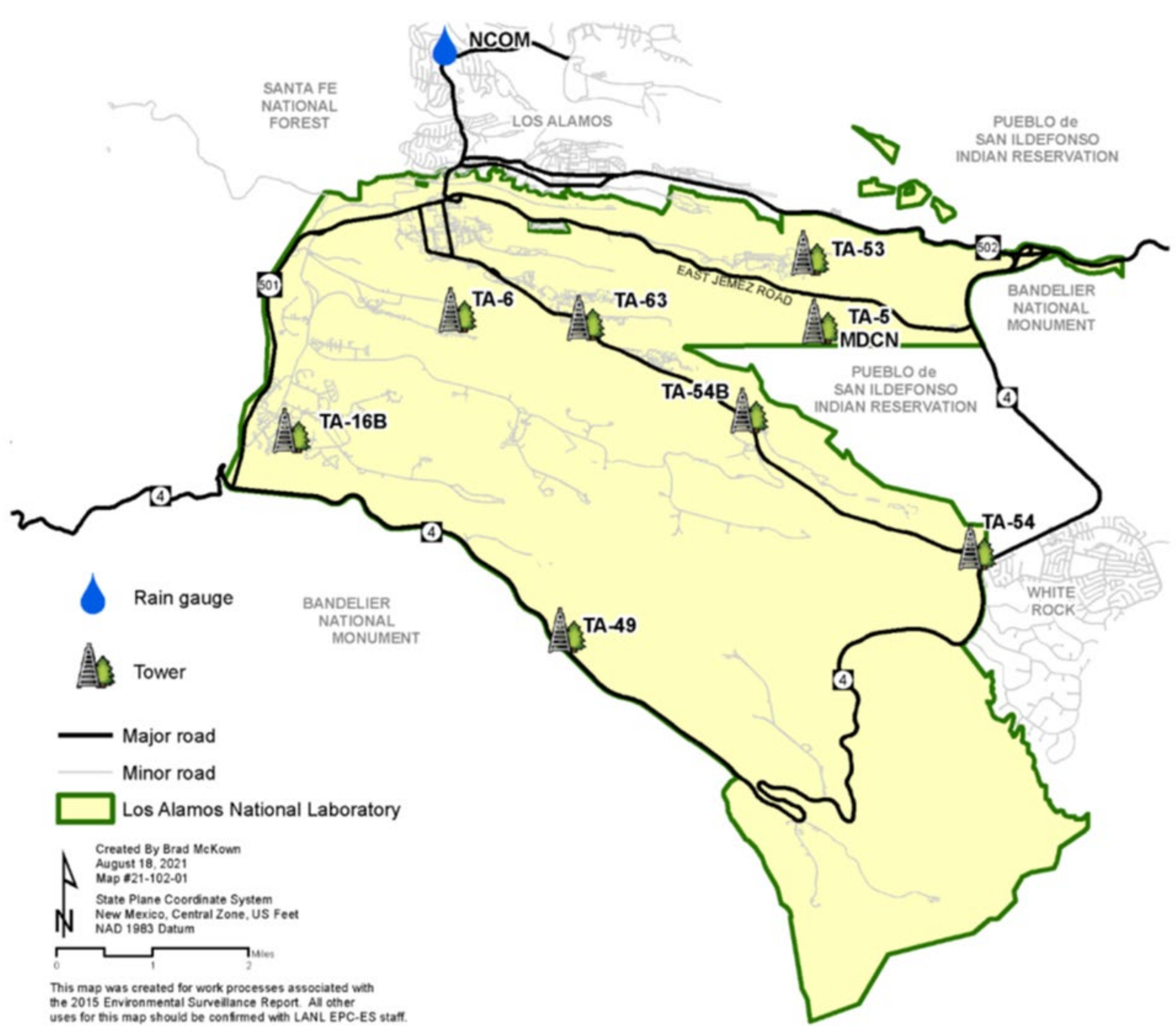


Figure 4-5. Locations of eight LANL meteorological monitoring towers and an offsite rain gauge.

Sampling Procedures and Data Management

Weather-sensing instruments are located at areas with good exposure—usually in open fields—to avoid impacts on wind and precipitation measurements. Temperature and wind are measured at multiple heights on open-lattice towers at Technical Areas 06, 49, 53, and 54. The multiple levels provide a vertical profile, which is important in assessing wind speed and direction at different heights above ground and in determining atmospheric stability conditions. The multiple levels also provide redundant measurements that enhance data quality checks. Boom-mounted temperature sensors on the towers are shielded from solar radiation and aspirated (provided with constant air circulation) to minimize effects from direct sunlight. Towers 16B, 54B, 63, and Mortandad Canyon are 10-meter tripod towers that measure wind speed, direction, and temperature at the top of the tower. Temperature is measured near ground level (approximately 5 feet high) at all stations except North Community, and humidity is measured at the same level only at the taller towers at Technical Areas 06, 49, 53, and 54. The North Community station measures only precipitation.

Data loggers at the stations collect most of the instrument results every 3 seconds, average the results over a 15-minute period, and transmit the averaged data by network connection, telephone modem, or cell phone to a computer workstation. The workstation program automatically edits measurements that fall outside of realistic ranges.

Climate

Los Alamos has a temperate, semiarid mountain climate. The humidity is generally low, and clear skies are present about 75 percent of the time. These conditions lead to high solar heating during the day and strong longwave radiative cooling at night. Winters are generally mild, with occasional winter storms. Spring is the windiest season. Summer is the rainy season, due to the Southwest monsoon, with frequent afternoon thunderstorms. Fall is typically dry and cool, with light wind speeds. Climate statistics are based on analyses of historical meteorological databases (Bowen 1990, Bowen 1992, Dewart et al. 2017, Bruggeman and Waight 2021).

December and January are the coldest months, when 90 percent of minimum temperatures are between 4°F and 31°F. Ninety percent of maximum temperatures, which are usually reached in midafternoon, are between 25°F and 55°F. Wintertime arctic air masses that descend into the central United States usually moderate before they reach the southern latitude of Los Alamos and are sometimes blocked by the Sangre de Cristo Mountains, so subzero temperatures are not common. Winds during the winter are relatively light, so extreme wind chills are not common.

June through August are the warmest months, when 90 percent of maximum temperatures are between 67°F and 89°F. During the summer months, 90 percent of minimum temperatures are between 45°F and 61°F.

Average annual precipitation is calculated using 30 years of data measured at the official Laboratory weather station at Technical Area 6. This nationally standardized period is updated every decade. (The averaged results are called the climate normals or climatological normal.) The averaged years for 2022 climatological normals are 1991 through 2020.

The average annual precipitation, which includes rain and the water equivalent from frozen precipitation, is 17.36 inches. The average annual snowfall is 43.4 inches. The greatest winter precipitation events in Los Alamos are caused by storms approaching from the west to southwest. Snowfall amounts are occasionally enhanced from orographic lifting as the storms travel up the high terrain.

Table 4-11 presents temperature and precipitation records for Los Alamos from 1924 through 2022.

Table 4-11. Records set between 1924 and 2022 for Los Alamos

Measurement	Record	Date or Period
Low temperature	–18°F	January 13, 1963
High temperature	97.5°F	July 11, 2020
Single-day rainfall	3.52 inches	September 13, 2013
Single-day snowfall	39 inches	January 15, 1987
Single-season snowfall	153 inches	1986–1987

The rainy season—when the Southwest monsoon is present—typically begins in early July and ends in mid-September. Afternoon thunderstorms form as moist air from the Gulf of California and the Gulf of Mexico is convectively and/or orographically lifted by the Jemez Mountains. The thunderstorms yield short, heavy downpours and abundant lightning.

The complex topography of Los Alamos influences local wind patterns, and often a distinct daily cycle of winds occurs. As air close to the ground is heated during the day, it becomes less dense and tends to flow uphill. During the night, as air close to the ground cools, it becomes denser and tends to flow downhill. As the daytime breeze flows up the Rio Grande Valley, it adds a southerly component to the prevailing westerly winds of the Pajarito Plateau. Nighttime airflow enhances the local westerly winds. Flow in the east-west-oriented canyons of the Pajarito Plateau is generally aligned with the canyons; therefore, canyon winds usually flow from the west at night and from the east during the day. Winds on the Pajarito Plateau are usually faster during the day than at night—a result of vertical mixing driven by solar heating. During the day, the vertical mixing is strong and brings momentum from higher wind speeds aloft down to the surface, thereby increasing the wind speed.

2022 in Perspective

Figure 4-6 presents a graphical summary of Los Alamos temperatures for 2022, with a comparison of the daily high and low temperatures at Technical Area 6 to the 1991 through 2020 climatological normal values and to the record values from 1924 to the present. Table 4-12 presents Los Alamos climatological data for 2022. The last line of Table 4-12 shows that the overall average temperature in 2022 was 0.8°F above the 1991 through 2020 average, and total precipitation was 18.75 inches, 1.4 inches above the 1991 through 2020 average and the highest annual total since 2015. Snowfall was 13.9 inches below the 1991 through 2020 average. The warmest temperature was 92°F on June 10, and the coldest temperature was –2°F on February 3. Monthly average temperatures in 2022 were above the 1991 through 2020 averages for 8 of the 12 months, with the highest above-average months recorded in September, November, and December. The average wind speed was 0.2 mph above the 1991 through 2020 average. In 2022, the strongest officially recorded wind gusts at Technical Area 6 occurred on April 22 and December 22, both at 60 miles per hour. The 60 mph gust on April 22 occurred on the same day that the Cerro Pelado wildfire started to the southwest of the Laboratory.

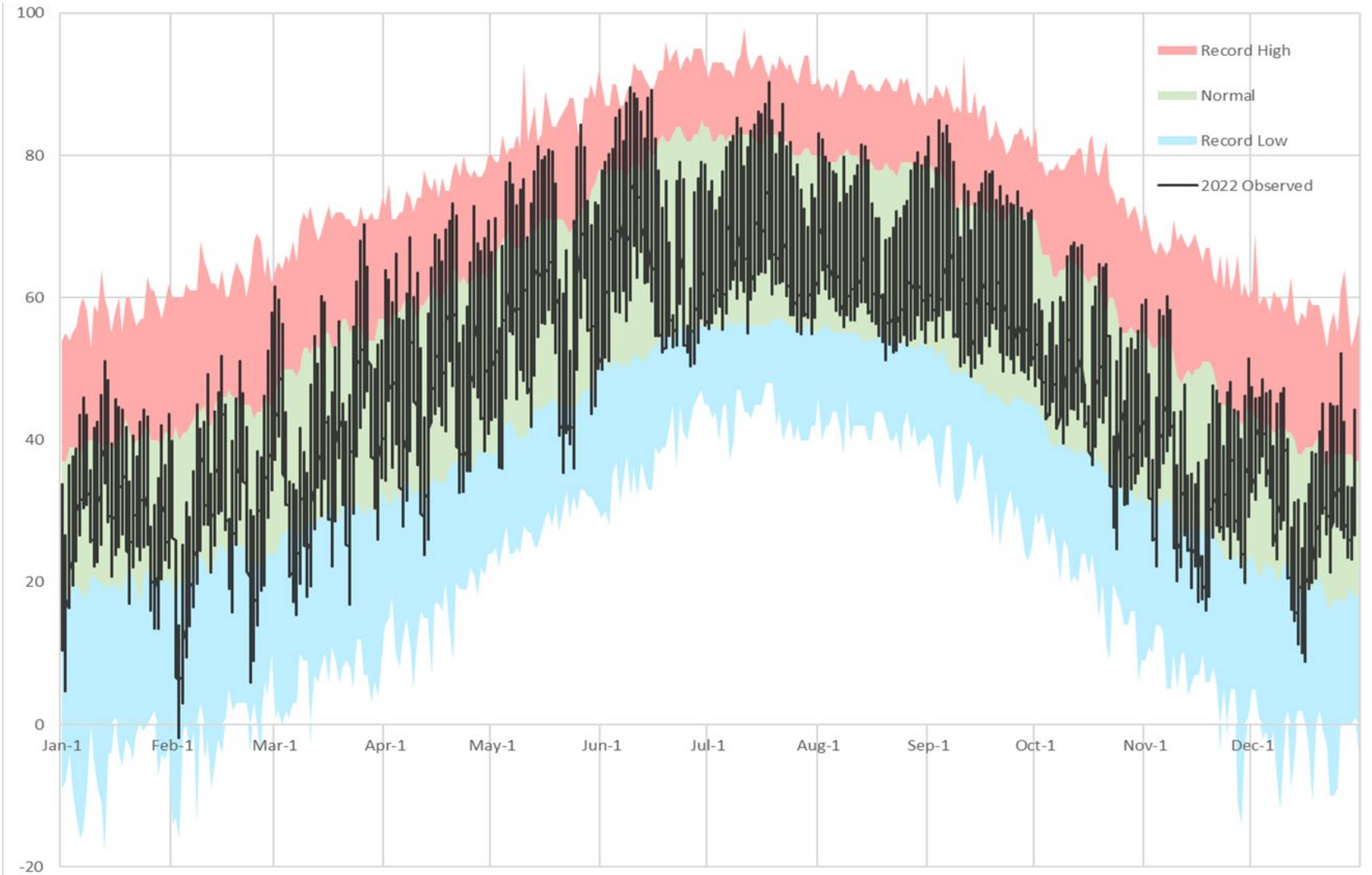


Figure 4-6. Los Alamos daily high and low temperatures in 2022 in degrees Fahrenheit (black line) compared with record (red = record highs; blue = record lows) and normal (green) values.

Table 4-12. Monthly and Annual Climatological Data for 2022 at Los Alamos

Month	Temperatures (°Fahrenheit)[a]								Precipitation (inches)[a]				12-meter[b] Wind (miles per hour)[a]				
	Averages				Extremes						Snowfall				Peak Gusts		
	Daily Maximum	Daily Minimum	Overall	Departure[c]	Highest	Date	Lowest	Date	Total	Departure[c]	Total	Departure[c]	Average Speed	Departure[d]	Speed	From	Date
January	40.9	21.0	30.9	1.2	52	13	3	2	0.59	–0.29	8.3	–1.3	3.3	–1.8	40	WNW	1
February	39.7	18.5	29.1	–4.3	54	28	–2	3	0.70	–0.06	12	3.7	5.6	–0.4	39	WSW	22
March	52.0	28.9	40.4	–0.4	73	27	14	8	0.84	–0.15	6.9	1.4	6.9	0	47	SSW	4
April	64.5	37.0	50.8	3.3	76	21	23	13	0.06	–0.87	0	–3.2	9.7	1.7	60	WNW	22
May	74.7	46.3	60.5	4	88	27	35	5	0	–1.16	0	–0.2	9.6	1.9	52	SW	3
June	80.5	55.5	68.0	1.4	92	10	50	2	4.67	3.51	0	0	7.5	0	47	S	18
July	81.9	58.4	70.2	1.1	91	19	54	13	6.38	3.53	0	0	5.4	–0.4	37	NNW	20
August	76.7	56.1	66.4	–0.3	84	2	51	21	2.23	–0.97	0	0	4.9	–0.6	34	NNW	28
September	77.4	52.1	64.8	3.8	86	5	48	30	0.66	–1.36	0	0	5.7	–0.2	35	W	14
October	59.0	38.9	49.0	–0.9	75	1	24	25	1.98	0.44	0	–1.6	5.4	–0.4	39	SW	23
November	46.1	25.1	35.6	–2.9	61	2	15	19	0.30	–0.64	0.2	–4.3	6.2	0.7	45	SW	9
December	42.2	23.4	32.8	2.8	54	27	6	17	0.34	–0.58	2.1	–8.4	6.0	1	60	NW	22
Year	61.4	38.6	50.0	0.8	92	Jun 10	–2	Feb 3	18.75	1.4	29.5	–13.9	6.4	0.2	60	NW	Dec 22

[a] Data from Technical Area 6, the official Los Alamos weather station.
[b] Wind data measured at 12 meters above the ground.
[c] Departure column indicates positive or negative departure from 1991 to 2020 (30-year) climatological average.
[d] Departure column indicates positive or negative departure from 1993 to 2020 (28-year) climatological average.

Figure 4-7 shows the Los Alamos cumulative precipitation for 2022. April and May were almost completely dry, but impressive monsoon rains in June and July pushed the total above average, which persisted to the end of the year even though August through November precipitation was below average. The U.S. Drought Monitor (https://droughtmonitor.unl.edu) classified Los Alamos County from the beginning of the year through July in the second driest category of "Extreme Drought," but then the monsoon precipitation improved Los Alamos and much of New Mexico by three categories, to "Abnormally Dry" for the rest of the year.

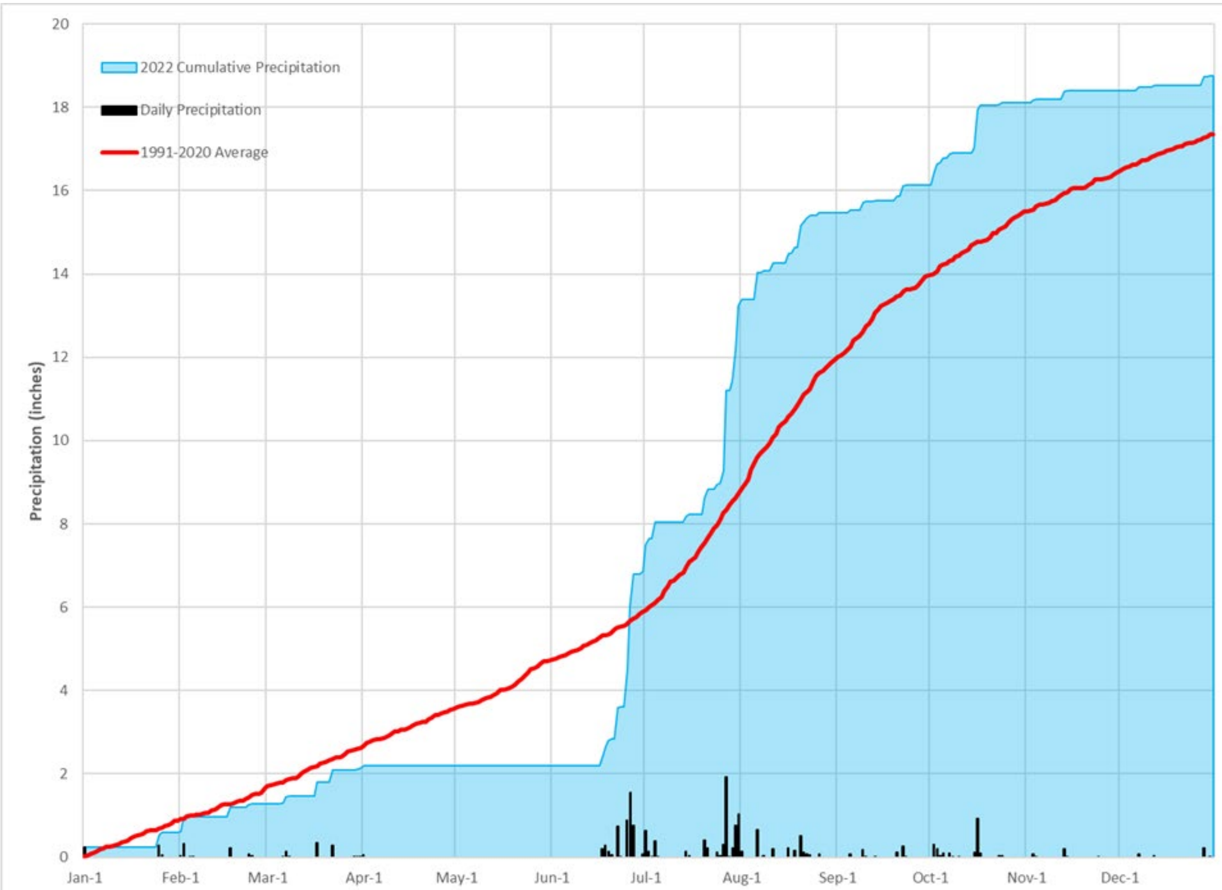


Figure 4-7. Technical Area 6 daily and cumulative precipitation in 2022 versus 30-year average.

At the Laboratory's weather stations, approximately 50 percent of the annual precipitation falls during the summer monsoon season, based on the National Weather Service definition of June 15 to September 30. Typically, more precipitation is measured at locations closer to the Jemez Mountains. The Technical Area 54 tower near White Rock tends to measure the least precipitation because it is farthest from the Jemez Mountains. Although not shown here, more precipitation fell during 2022 at Technical Area 6 and North Community compared with Technical Area 54.

Daytime (sunrise to sunset) winds and nighttime (sunset to sunrise) winds are shown in wind roses in Figure 4-8. The wind roses are based on 15-minute average wind observations for 2022 at four mesa-top stations (Technical Areas 6, 49, 53, and 54). Wind roses depict the percentage of time that wind blows from each of 16 cardinal compass point directions and the distribution of wind speed for each direction. During the day, winds are typically from the south and southwest, whereas at night, the winds are usually from the west and northwest. Although not shown in this figure, wind roses from different years are almost identical regarding the distribution of wind directions, indicating that wind patterns are consistent over time.

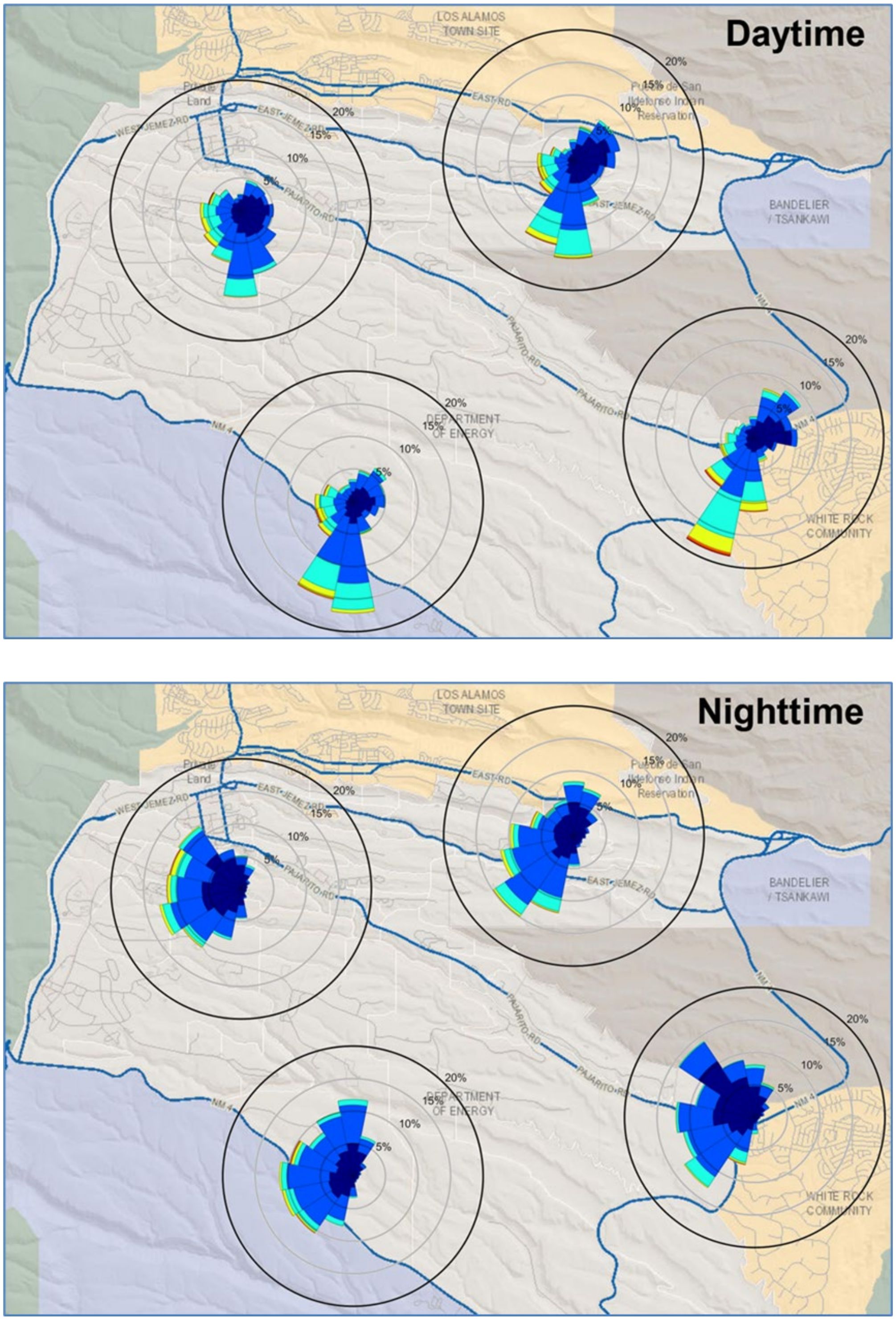


Figure 4-8. Wind roses for 2022 at four mesa-top meteorological towers.

Long-Term Climate Trends

Temperature and precipitation data have been collected in the Los Alamos area since 1910. Figure 4-9 shows the historical record of temperatures at Los Alamos from 1924 through 2022. The annual average temperature is the midpoint between daily high and low temperatures averaged for the year. Shown in green in Figure 4-9 are 1-year averages, and a 5-year running average—to show longer-term trends—is shown in black. The 5-year average shows that the warm spell during the past 15 years is more extreme than the warm spell during the early-to-mid 1950s and is longer lived. Although not shown in the figure, five of the hottest summers on record have occurred since 2002, and the highest summertime (June, July, and August) average temperature on record was 71.1°F, recorded during 2011.

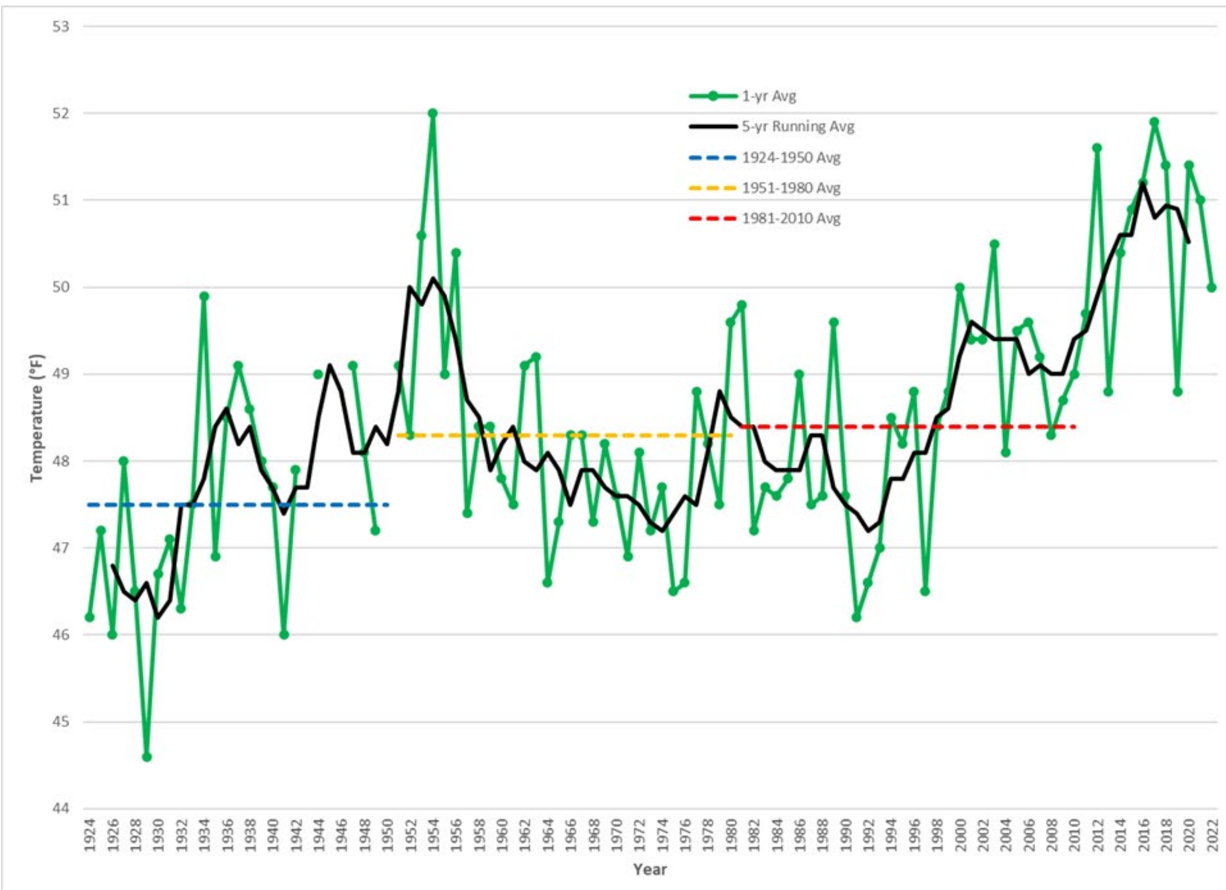


Figure 4-9. Temperature history for Los Alamos with the 1-year average in green and 5-year running average in black.The dashed lines represent long-term averages (25 and 30 years).

The average temperatures per decade, recorded at Technical Area 6, along with two times the standard deviation, are plotted in Figure 4-10 with the annual average temperature for 2020, 2021, and 2022. Ninety-five percent of the annual average temperatures during each decade are within the standard deviation bars. During the decades between 1960 and 2000, the annual average temperatures in Los Alamos varied only slightly from 48°F; however, during the 2001–2010 decade, the annual average temperature increased to above 49°F, and this value is statistically significantly higher than previous decades. During the recent 2011–2020 decade, the average temperature increased even more than the previous decade, with annual average temperatures above 50°F. The annual average temperatures in 2020–2022 continue to demonstrate a warming climate for Los Alamos, consistent with predictions for a warming climate in the southwestern United States (Intergovernmental Panel on Climate Change 2014).

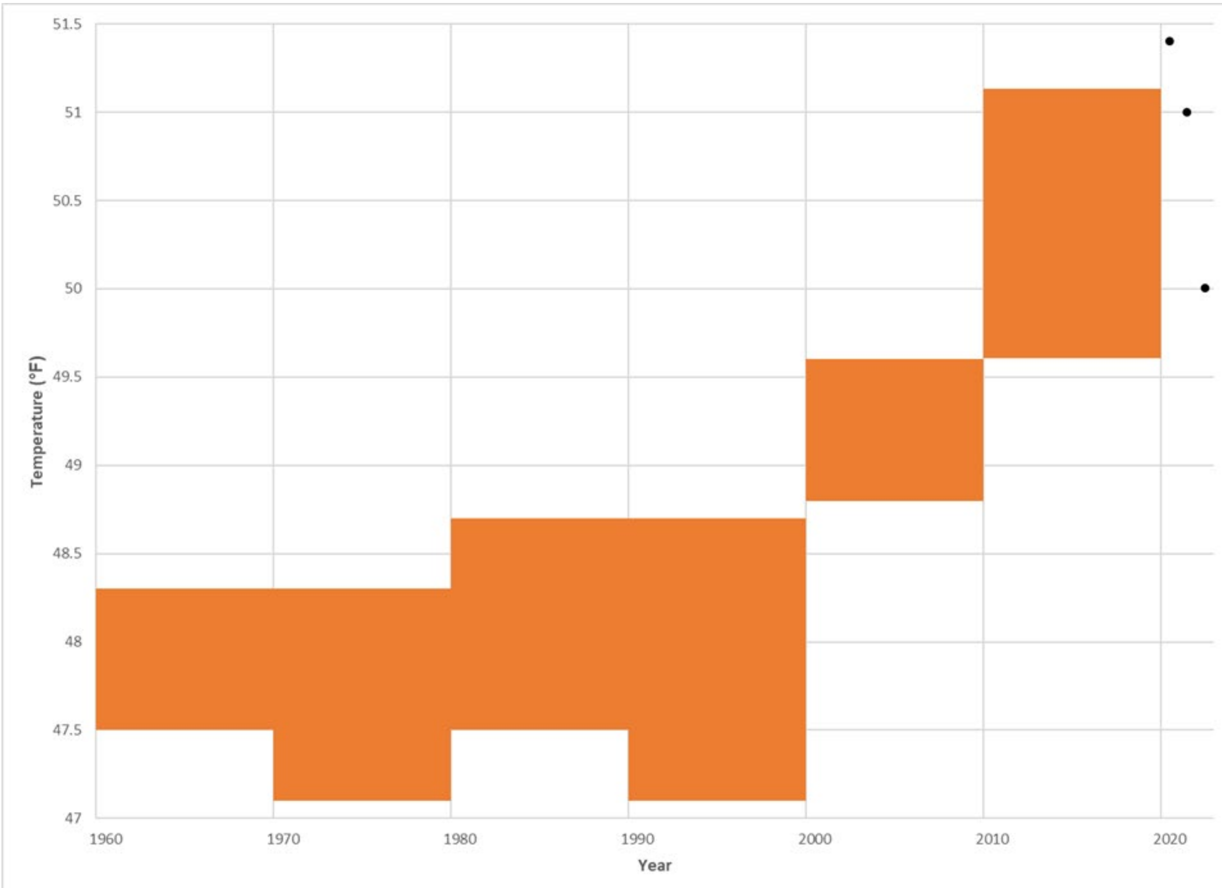


Figure 4-10. Technical Area 6 decadal average temperatures, with two times the standard deviation for 1960–2020 and the recent annual average temperatures (black points).

Figure 4-11 presents the historical record of the annual precipitation at Technical Area 6. As with the historical temperature profiles, the 5-year running averages and three long-term averages (25- or 30-year periods) are also shown. The 1998 through 2022 period shows the most recent drought, although near-average precipitation from 2004 to 2010 and a few above-average precipitation years did occur during this period.

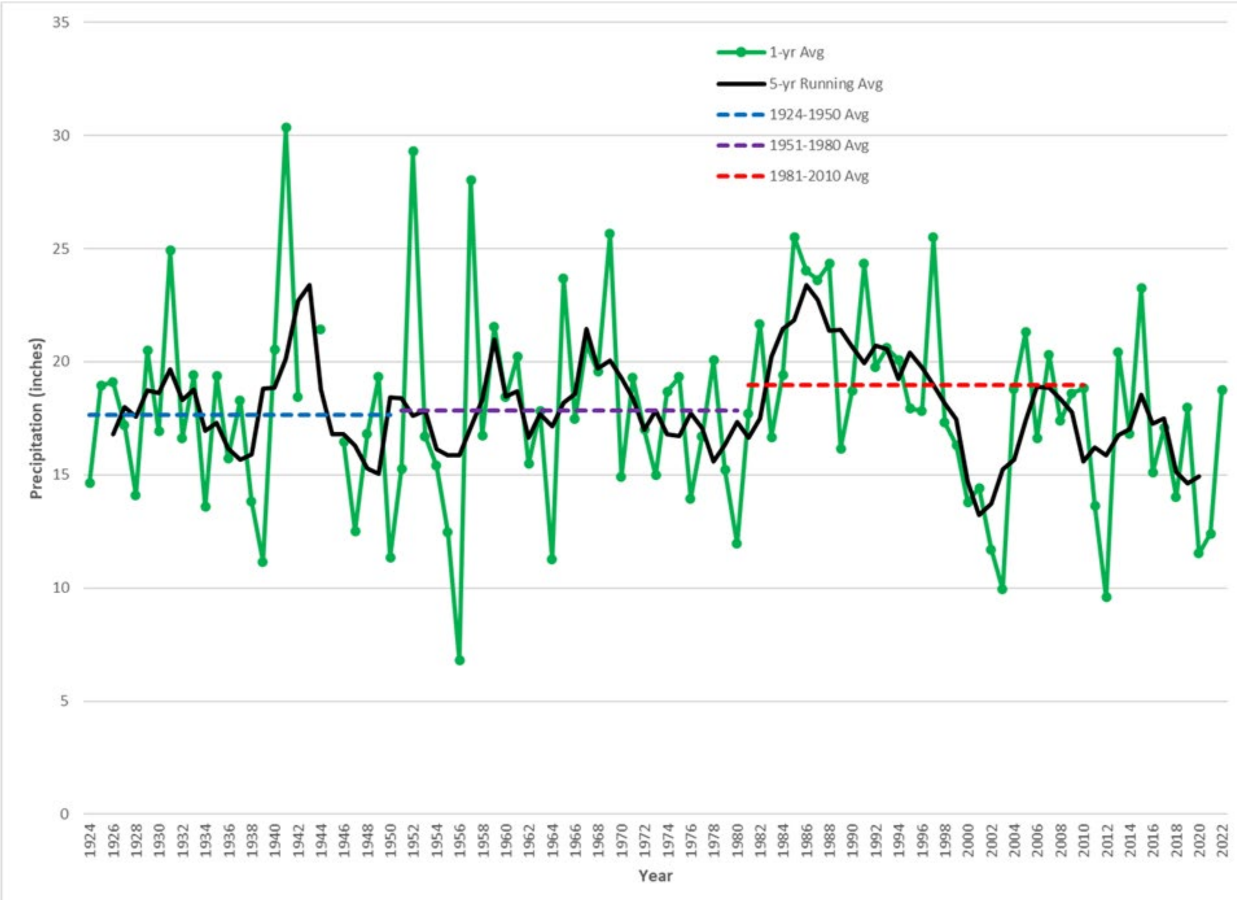


Figure 4-11. Total precipitation history for Los Alamos, with the 1-year total in green, the 5-year running average in black, and the dashed lines representing long-term averages (25 and 30 years).

Quality Assurance

Air Quality Sampling

The quality assurance program satisfies requirements in the U.S. Environmental Protection Agency's National Emission Standards for Hazardous Air Pollutants, Title 40, Part 61 of the Code of Federal Regulations, Appendix B, Method 114. Project plans and implementing procedures specify the requirements and implementation of sample collection, sample management, chemical analysis, and data management following U.S. Environmental Protection Agency methods for sample handling, chain of custody, analytical chemistry, and statistical analyses of data. The quality assurance plan for ambient air sampling is described in "Quality Assurance Project Plan for the Radiological Air Sampling Network," SOP-5140, and 25 supporting procedures. The stack-sampling quality assurance plan is described in "Rad-NESHAP Compliance Program, Program Implementation Plan," EPC-CP-PIP-0101, and 42 supporting procedures.

Direct Radiation Monitoring

The quality assurance plan for direct-penetrating radiation is described in "Direct Penetrating Radiation Monitoring Network (DPRNET)," EPC-ES-TPP-007; and "Obtaining the

Environmental Dose from the Model 8823 Dosimeter," EPC-ES-TP-002. Quality Assurance for the Model 8823 dosimeter is provided by the Radiation Protection Division dosimetry laboratory, which is accredited by the DOE Laboratory Accreditation Program.

Meteorological Monitoring

Time-series plots of data are generated for a meteorologist to conduct data-quality reviews. Daily statistics—such as daily minimum and maximum temperatures, daily total precipitation, and maximum wind gust—are also generated and checked for quality and out-of-range values.

Meteorological instrument and data logger manufacturers' recommendations are followed, and operating conditions determine how often to calibrate the weather sensing instruments. All wind instruments are calibrated every 6 months. All other sensors are calibrated annually except the solar radiation sensors, which are calibrated once every 5 years.

Internal self-assessments and external audits of the meteorological program (inclusive of the instruments and methods) are performed periodically, and annually, a qualified subcontractor inspects the tower and the instruments of all meteorological towers and performs maintenance.

References

Bowen 1990: B. M. Bowen. 1990. "Los Alamos Climatology," Los Alamos National Laboratory report LA-11735-MS.

Bowen 1992: B. M. Bowen. 1992. "Los Alamos Climatology Summary," Los Alamos National Laboratory report LA-12232-MS.

Bruggeman and Waight 2021: D. A. Bruggeman and K. T. Waight III. 2021. "Los Alamos Climatology 2021 Update," Los Alamos National Laboratory report LA-UR-21-29710.

Dewart and Boggs 2014: J. M. Dewart and M. J. Boggs. 2014. "Meteorological Monitoring at Los Alamos," Los Alamos National Laboratory report LA-UR-14-23378.

Dewart et al. 2017: J. M. Dewart, D. A. Bruggeman, and V. Carretti. 2017. "Los Alamos Climatology 2016 Update," Los Alamos National Laboratory report LA-UR-17-21060.

Eisenbud and Gesell 1997: M. Eisenbud and T. Gesell. 1997. Environmental Radioactivity from Natural, Industrial, and Military Sources, 4th ed., Academic Press, San Diego, California.

Intergovernmental Panel on Climate Change 2014: "Climate Change 2014: Synthesis Report." Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team: R. K. Pachauri and L. A. Meyer (Eds.)], Intergovernmental Panel on Climate Change, Geneva, Switzerland, 151.

McNaughton 2013: M. W. McNaughton. 2013. "On-site MEI Measurements and Calculations," Los Alamos National Laboratory report LA-UR-13-25871.

McNaughton 2018: M. W. McNaughton. 2018. "The DPRNET Program from 1972 to 2017," Los Alamos National Laboratory report LA-UR-18-24501.

National Council on Radiation Protection 2005: "Structural Shielding Design and Evaluation," National Council on Radiation Protection and Measurements report 151.

Chapter 5: Groundwater Protection

> **What is an aquifer?**
>
> The word aquifer literally means "water bearer" and refers to an underground layer of rock or sediment that contains enough accessible water to be of interest to humans (Buddemeier et al. 2000).

Our groundwater monitoring network includes 200 sampling locations in four types of water: base flow (persistent surface water), alluvial groundwater, perched-intermediate groundwater, and regional aquifer groundwater. Many sampling locations are grouped to monitor area-specific water quality potentially affected by historical releases of wastes. Areas with monitoring groups include Technical Area 16-260 (around the Building 260 former outfall), Technical Area 21, Technical Area 54, the Chromium Investigation area, Material Disposal Area AB, and Material Disposal Area C.

Site-wide groundwater monitoring indicates only two notable areas of groundwater contamination at the Laboratory: an RDX (royal demolition explosive; hexahydro-1,3,5-trinitro-1,3,5-triazine) plume beneath Cañon de Valle in the vicinity of Technical Area 16 and a chromium plume beneath Sandia and Mortandad canyons.

RDX, primarily associated with historical machining of high explosives at Technical Area 16, has infiltrated into groundwater beneath Cañon de Valle. In some areas, RDX concentrations exceed the New Mexico tap water screening level of 9.66 micrograms per liter in perched-intermediate groundwater and the regional aquifer. The RDX plume is completely within the LANL boundary and is approximately 3 miles from the nearest public water supply wells.

Hexavalent chromium is present in the regional aquifer beneath Sandia and Mortandad canyons at concentrations above the New Mexico groundwater standard of 50 micrograms per liter. The hexavalent chromium releases occurred from 1956 to 1972. An interim measure to address the plume is ongoing.

The groundwater protection program also provides monitoring to support current Laboratory operations. This program includes monitoring required by authorizations issued by the New Mexico Environment Department's Groundwater Quality Bureau—such as groundwater discharge permits—as well as monitoring required to meet facility groundwater monitoring plan requirements under the Laboratory's Hazardous Waste Facility Permit.

Introduction

U.S. Department of Energy (DOE) Order 458.1 Chg 4, Radiation Protection of the Public and the Environment, requires operators of DOE facilities to ensure that radionuclides from DOE activities do not cause private or public drinking water systems to exceed the drinking water maximum contaminant levels in the National Primary Drinking Water Regulations, Title 40, Part 141, of the Code of Federal Regulations. Operators also must document baseline conditions of the groundwater quantity and quality. In 2016, DOE and the New Mexico Environment Department signed a new Compliance Order on Consent (Consent Order) that addresses legacy waste cleanup.

Los Alamos National Laboratory (LANL or the Laboratory) monitors groundwater quality for the groundwater protection program and the 2016 Consent Order. The legacy waste cleanup contractor, Newport News Nuclear BWXT-Los Alamos, LLC (N3B), is responsible for implementing the groundwater program (N3B 2021, 2022).

The Consent Order continues to require the Laboratory to submit an Interim Facility-Wide Groundwater Monitoring Plan to the New Mexico Environment Department for approval each year. The monitoring locations, frequency of monitoring, and substances that LANL must monitor are updated in the plan each year. LANL's hazardous waste facility permit and groundwater discharge permits (see Chapter 2) require additional groundwater monitoring activities at the Laboratory. We collect hundreds of groundwater samples each year and analyze them for a wide range of organic and inorganic constituents and radionuclides. We also implement measures to control contaminant migration.

Hydrogeologic Setting

The following section describes the distribution and movement of groundwater at the Laboratory and includes a summary of groundwater contaminant sources and distribution. Additional details can be found in reports available at the Laboratory's electronic public reading room (https://eprr.lanl.gov) and at the DOE Environmental Management–Los Alamos electronic public reading room (https://ext.em-la.doe.gov/EPRR/).

The Laboratory is located in Northern New Mexico on the Pajarito Plateau. The Pajarito Plateau extends from the Sierra de los Valles range of the Jemez Mountains eastward to the Rio Grande. Rocks composed of Bandelier Tuff form the uppermost layer of the plateau (see Figure 5-1). The tuff resulted from ash and other volcanic materials that were ejected 1.6 to 1.2 million years ago from the volcanic field[4] of the Jemez Mountains. The tuff is more than 1,000 feet thick in the western part of the plateau and thins to about 260 feet above the Rio Grande.

On the western edge of the Pajarito Plateau, the Bandelier Tuff overlaps the Tschicoma Formation, which consists of older volcanic deposits (see Figure 5-2). The Puye Formation—a deposit of unconsolidated sedimentary materials such as sand, gravel, and silt—underlies the tuff beneath the central and eastern portion of the plateau. The Cerros del Rio basalt flows, which originated mostly from a volcanic center east of the Rio Grande, extend into the Puye Formation beneath the Laboratory. These formations overlie the sediments of the Santa Fe Group, which cross the Rio Grande Valley and are more than 3,300 feet thick.

The Laboratory sits atop a thick zone of mainly unsaturated rock and sediment. Groundwater beneath the Pajarito Plateau occurs in three modes (see Figure 5-2): perched alluvial groundwater in the bottom of some canyons, small areas of intermediate-depth perched groundwater, and the regional aquifer.

Hydrogeologic Terms

Saturated rock or sediment is completely wet.

Unsaturated rock or sediment has air in its pore spaces.

Perched groundwater is a zone of saturation of limited thickness that occurs above the regional aquifer.

Alluvial groundwater is a zone of saturation that exists in sands and gravels in the bottoms of canyons.

[4] A volcanic field is an area with a history of volcanic activity.

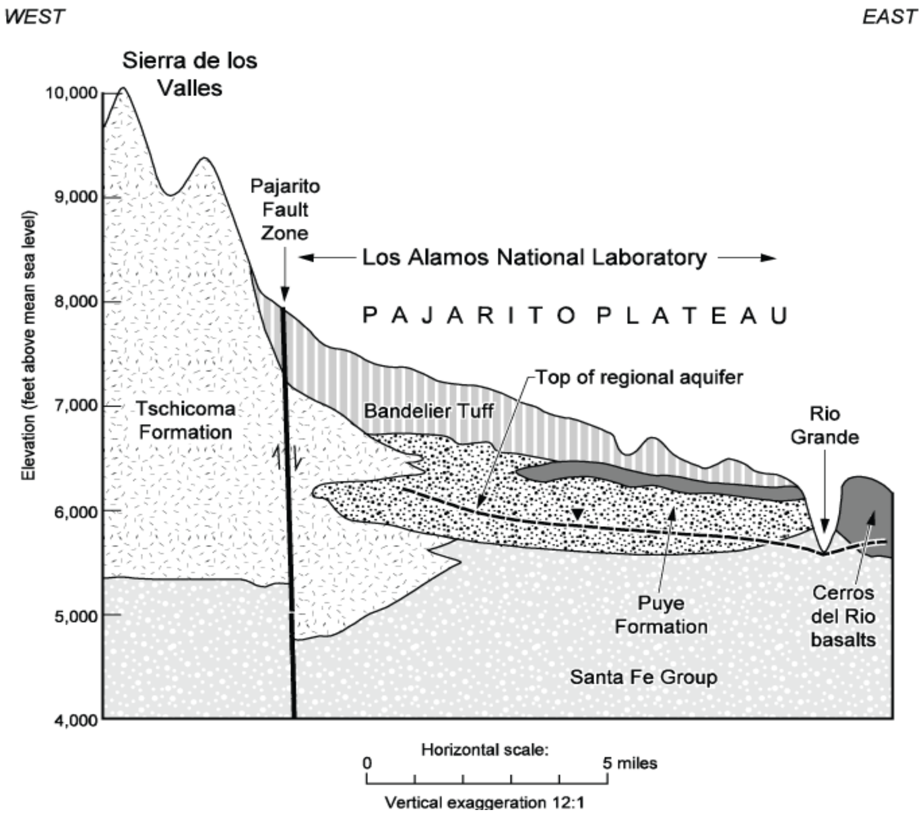


Figure 5-1. A geologic generalization of the Pajarito Plateau.

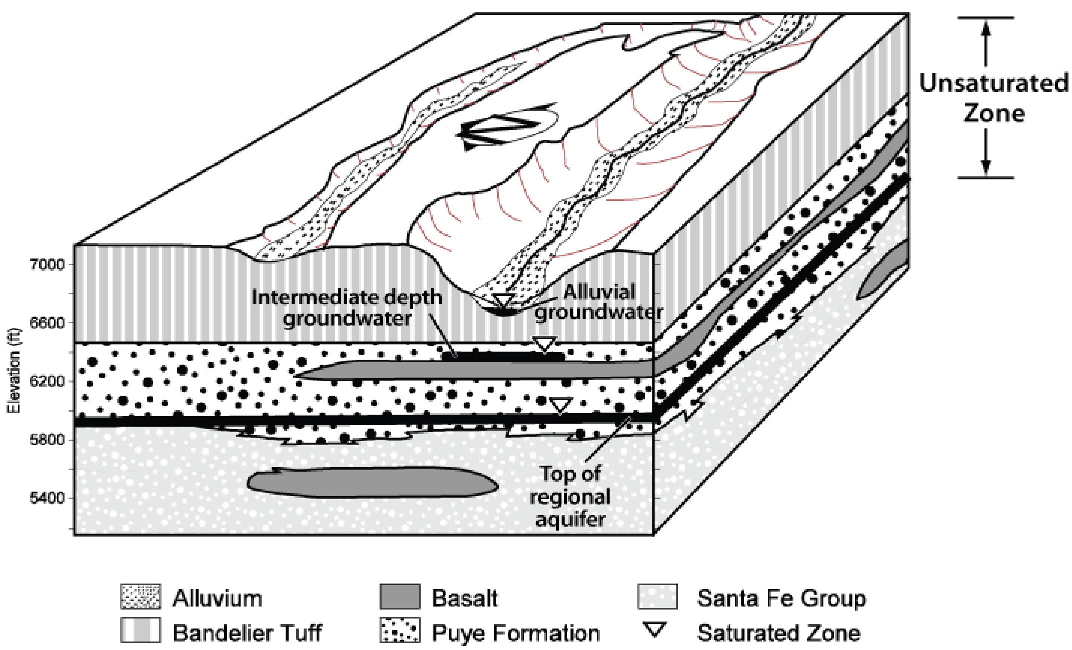


Figure 5-2. Diagram showing zones of unsaturated and saturated rock and sediments below the Laboratory.

Perched alluvial groundwater is a limited area of saturated rocks and sediments directly below canyon bottoms. Surface water moves through the alluvium (clay, sand, silt, or gravel deposited by running water) until less-permeable layers of rock disrupt downward flow, resulting in shallow perched bodies of groundwater. Most of the canyons on the Pajarito Plateau have infrequent surface water flow and, therefore, little or no alluvial groundwater. A few canyons have saturated alluvium in their western ends, supported by runoff from the Jemez Mountains. In some locations, discharges from Laboratory outfalls supplement or maintain surface water. As alluvial groundwater moves down a canyon, it is used and transpired by plants, or it percolates into underlying rock or sediments.

Perched-intermediate groundwater occurs within the lower part of the Bandelier Tuff, within the Puye Formation, and within the Cerros del Rio basalt layer beneath some canyons. These intermediate-depth groundwater bodies are formed in part by water moving downward from canyons until it reaches a layer of rock that allows little or no water to pass through. Depths of the perched-intermediate groundwater zones vary; for example, the depth to perched-intermediate groundwater is approximately 120 feet beneath Pueblo Canyon, 450 feet beneath Sandia Canyon, and 500 to 750 feet beneath Mortandad Canyon.

The uppermost extent of water in the regional aquifer, called the water table, occurs at a depth of approximately 1,200 feet below ground surface along the western edge of the plateau and 600 feet below ground surface along the eastern edge (see Figure 5-1 and Figure 5-3). Studies indicate that water from the Sierra de los Valles range is the main source of recharge for the regional aquifer (LANL 2005a). Groundwater near the water table generally flows east, with local northeast or southeast flows observed. The speed of groundwater flow varies but is typically around 30 feet per year. The regional aquifer is separated from alluvial and perched-intermediate groundwater by layers of unsaturated tuff, basalt, and sediment. The limited extent of the alluvial and intermediate groundwater bodies—along with unsaturated rock and sediment that underlies them—restricts their contribution to recharging the regional aquifer although locally, they are important parts of the complete hydrologic pathway to the regional aquifer.

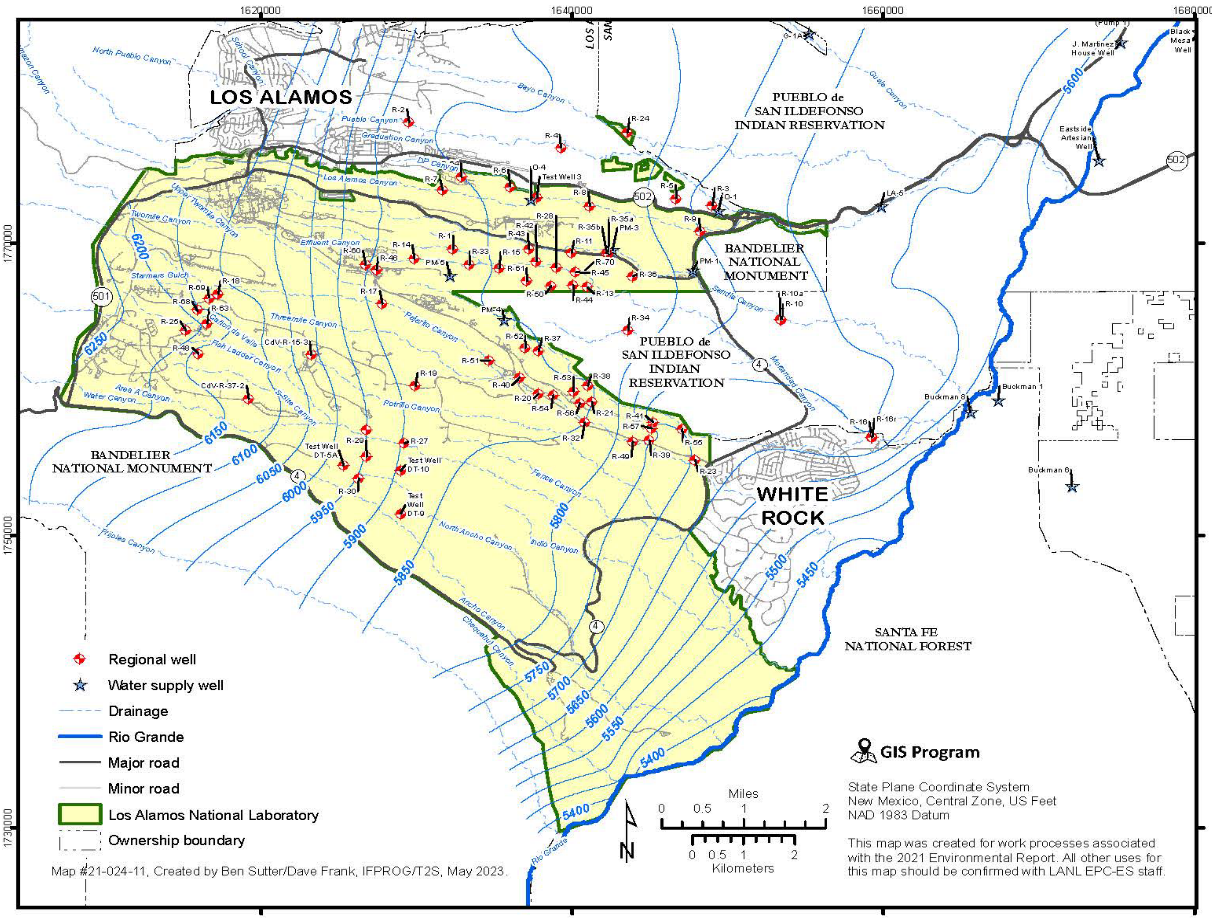


Figure 5-3. Contour map of average water table elevations for the regional aquifer.

Regulatory Overview

We use the screening values listed in Table 5-1 to evaluate our groundwater results. Section IX of the Consent Order describes the role of data screening in the corrective action process. Exceedance of a screening level indicates a possible need for further evaluation of risk. The groundwater standards and screening levels are set by three regulatory agencies: DOE, the U.S. Environmental Protection Agency, and the New Mexico Water Quality Control Commission.

DOE has authority under the Atomic Energy Act of 1954 to set standards for certain nuclear materials. DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, establishes dose limits for radiation exposure and provides derived concentration technical standards for radionuclide levels in air and water based on those dose limits. For drinking water, DOE calculates derived concentration technical standards based on the U.S. Environmental Protection Agency's 4-millirem-per-year drinking water dose limit.

The U.S. Environmental Protection Agency and the New Mexico Water Quality Control Commission set screening levels and standards for other constituents. The U.S. Environmental Protection Agency's maximum contaminant levels are the maximum permissible level of a contaminant in water delivered to any user of a public water system. The New Mexico Water

Quality Control Commission groundwater standards (found in Ground and Surface Water Protection, Title 20, Chapter 6, Part 2 of the New Mexico Administrative Code) apply to all groundwater with a total dissolved solids concentration of 10,000 milligrams per liter or less. The New Mexico standards include numeric criteria for many substances and also contain a separate list of toxic pollutants.

The Consent Order requires screening and reporting of groundwater data. In general, the required screening levels are the lower of either the New Mexico groundwater quality standard or the federal maximum contaminant level. If neither of these exist for a given chemical, the New Mexico Environment Department's tap water screening levels, provided in the Risk Assessment Guidance for Site Investigations and Remediation: Volume I, Soil Screening Guidance for Human Health Risk Assessments (New Mexico Environment Department 2022) are used. These values are available in Table A-1 of that document. If no New Mexico Environment Department tap water screening level has been established for the chemical, then the U.S. Environmental Protection Agency's regional human health medium-specific screening level for tap water, adjusted to a 1×10^{-5} excess risk for carcinogenic contaminants, is used. The U.S. Environmental Protection Agency updates the regional screening levels for tap water periodically; 2022 values were used to prepare this chapter. Updated New Mexico Water Quality Control Commission groundwater standards went into effect in December 2018, and revised standards for some additional constituents became effective in July 2020.

The New Mexico Water Quality Control Commission numeric criteria for contaminant concentrations apply mostly to filtered water samples. However, the standards for mercury, organic compounds, and nonaqueous-phase liquids apply to unfiltered samples, which represent both the dissolved concentration of the constituent in the water and the concentration associated with suspended sediments in the sample. The U.S. Environmental Protection Agency applies maximum contaminant levels and regional screening levels for tap water to both filtered and unfiltered sample results, depending on the chemical.

For radioactivity in groundwater, we compare sample results with screening levels, including the New Mexico Water Quality Control Commission groundwater standards for combined radium-226 and radium-228, DOE's drinking water concentration technical standards (derived from DOE's 4-millirem-per-year dose limit), and the U.S. Environmental Protection Agency maximum contaminant level drinking water standards.

Table 5-1. Application of Screening Levels to LANL Groundwater Monitoring Data

Sample Type	Constituent	Screening Levels	References	Notes
Water supply wells	Radionuclides	New Mexico groundwater standards Concentration technical standards derived from DOE's 4-millirem-per-year drinking water dose limit U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • DOE Order 458.1 Chg 4 • Code of Federal Regulations Title 40 Parts 141–143	This sampling is conducted in addition to the regulatory compliance sampling conducted by the water supply system operator. See Water Supply Well Monitoring (p. 5-14).
Water supply wells	Nonradionuclides	New Mexico groundwater standards U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • Code of Federal Regulations Title 40 Parts 141–143	This sampling is conducted in addition to the regulatory compliance sampling conducted by the water supply system operator. See Water Supply Well Monitoring (p. 5-14).
Non-water-supply groundwater samples	Radionuclides	New Mexico groundwater standards Concentration technical standards derived from DOE's 4-millirem-per-year drinking water dose limit U.S. Environmental Protection Agency maximum contaminant levels	• 20.6.2 New Mexico Administrative Code • DOE Order 458.1 Chg 4 • Code of Federal Regulations Title 40 Parts 141–143	New Mexico groundwater standards apply to all groundwater. The concentration technical standards (derived from DOE's 4-millirem-per-year drinking water dose limit), and U.S. Environmental Protection Agency maximum contaminant levels are provided for comparison only.
Non-water-supply groundwater samples	Nonradionuclides	New Mexico groundwater standards U.S. Environmental Protection Agency maximum contaminant levels U.S. Environmental Protection Agency regional screening levels for tap water	• 20.6.2 New Mexico Administrative Code • Code of Federal Regulations Title 40 Parts 141–143 • 2016 Compliance Order on Consent	A hierarchy of levels applies as screening levels for groundwater. See Regulatory Overview (p. 5-5) for explanation.

Potential Sources of Contamination

Historical discharges from Laboratory operations have affected all three groundwater zones. Figure 5-4 shows the key locations of historical effluent discharges. Most of the outfalls shown are currently inactive, with the exception of the sanitary wastewater treatment plant in Pueblo Canyon. Rogers (2001) and Emelity (1996) summarize effluent discharge history at the Laboratory.

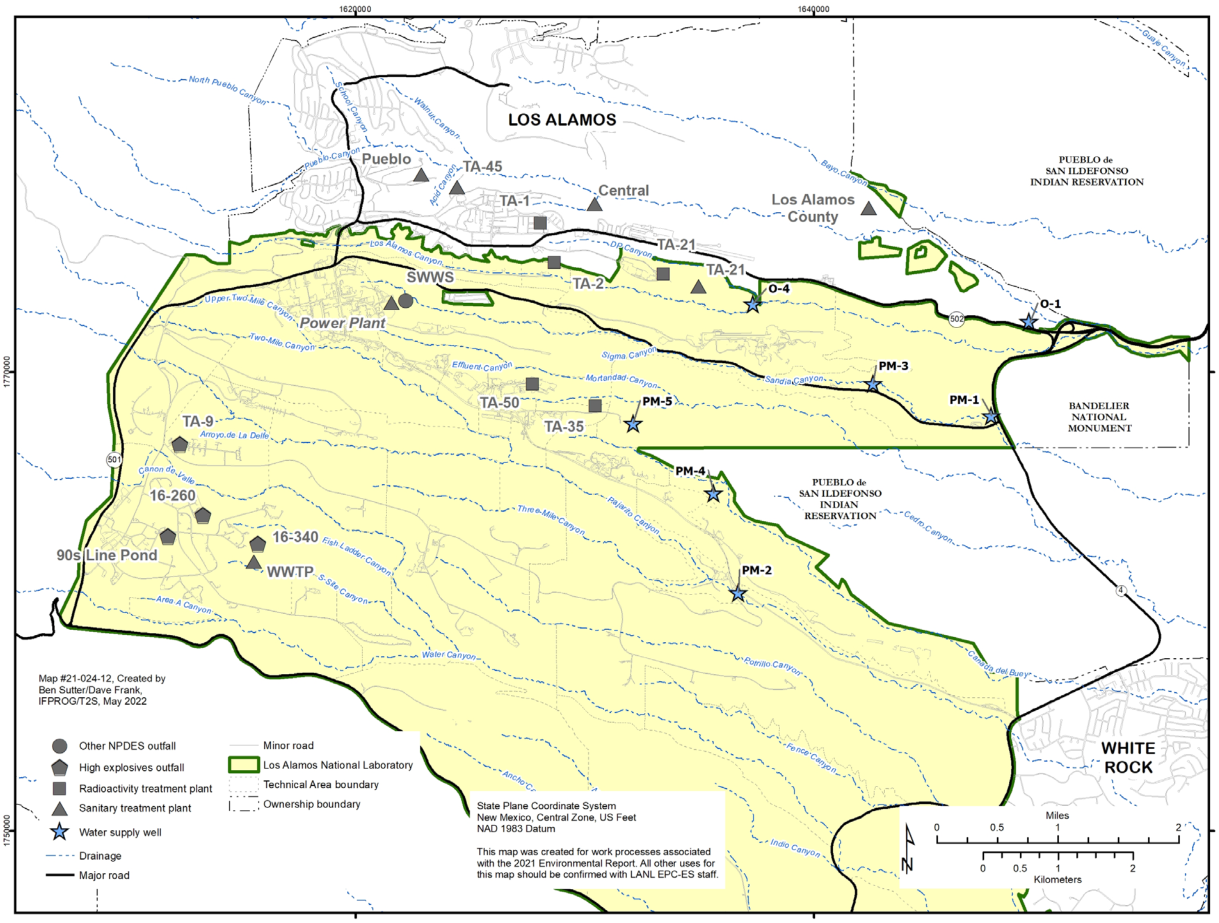


Figure 5-4. Map showing historical effluent outfalls that potentially affected all three groundwater zones.

Drainages that received some Laboratory effluents in the past include Mortandad Canyon, Pueblo Canyon from its tributary Acid Canyon, and Los Alamos Canyon from its tributary DP Canyon. Water Canyon and its tributary, Cañon de Valle, received effluents produced by high-explosives processing and experimentation. Sandia Canyon received discharges of power plant cooling water, other cooling tower water, and water from the Laboratory's Sanitary Wastewater Systems Plant. Over the years, Los Alamos County has operated several sanitary wastewater treatment plants and currently operates one in Pueblo Canyon.

Groundwater Monitoring Network

We monitor water quality and other characteristics by taking samples from wells in alluvial groundwater, perched-intermediate groundwater, and the regional aquifer; springs that discharge shallow perched-intermediate and regional aquifer groundwater; and streams that maintain perennial base flow. Some wells have multiple screens (entry points for water) at different depths.

Some wells and springs are part of six area-specific monitoring groups that include Technical Area 54, Technical Area 21, Material Disposal Area AB, Material Disposal Area C, the Chromium Investigation area, and the Technical Area 16-260 outfall (see Figure 5-5). We assign wells and springs not included within one of these six area-specific monitoring groups to the General Surveillance monitoring group (see Figure 5-6). We also monitor numerous springs along the Rio Grande (see Figure 5-7; Purtymun et al. 1980).

In addition, we monitor groundwater quality at three alluvial, two intermediate, and four regional aquifer wells for compliance with our groundwater discharge permits (see Chapter 2, New Mexico Water Quality Act: Groundwater Discharge Regulations). Alluvial wells SCA-3, MCA-RLW-1, and MCA-RLW-2 are monitored for discharge permit purposes only, and results are summarized in the Groundwater Discharge Permit Monitoring section that follows. We have included monitoring required under LANL’s Hazardous Waste Facility Permit within the Interim Facility-Wide Groundwater Monitoring Plan and report those results throughout this chapter.

We collect samples from Los Alamos County water supply wells (see Figure 5-7), from wells located on Pueblo de San Ildefonso lands, and from wells in the Buckman well field operated by the City of Santa Fe. Figure 5-7 shows groundwater monitoring locations on the Pueblo de San Ildefonso, which mostly represent the regional aquifer; however, Vine Tree Spring and Los Alamos Spring discharge from perched-intermediate groundwater and wells LLAO-1b and LLAO-4 monitor alluvial groundwater.

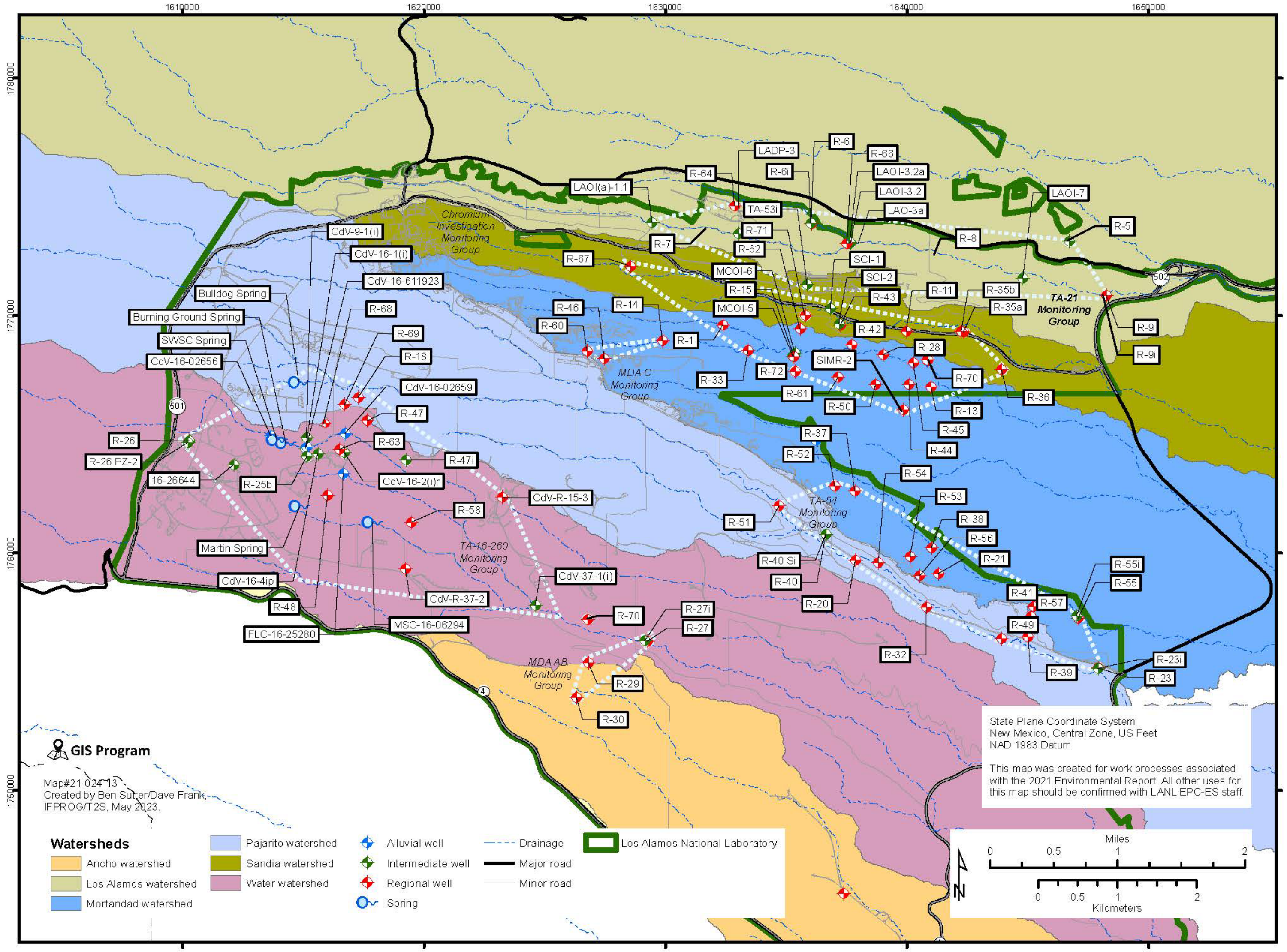


Figure 5-5. Map showing the wells and springs in the area-specific monitoring groups. Area-specific monitoring groups include Technical Area 54, Technical Area 21, Material Disposal Area AB, Material Disposal Area C, the Chromium Investigation area, and the Technical Area 16-260 outfall.

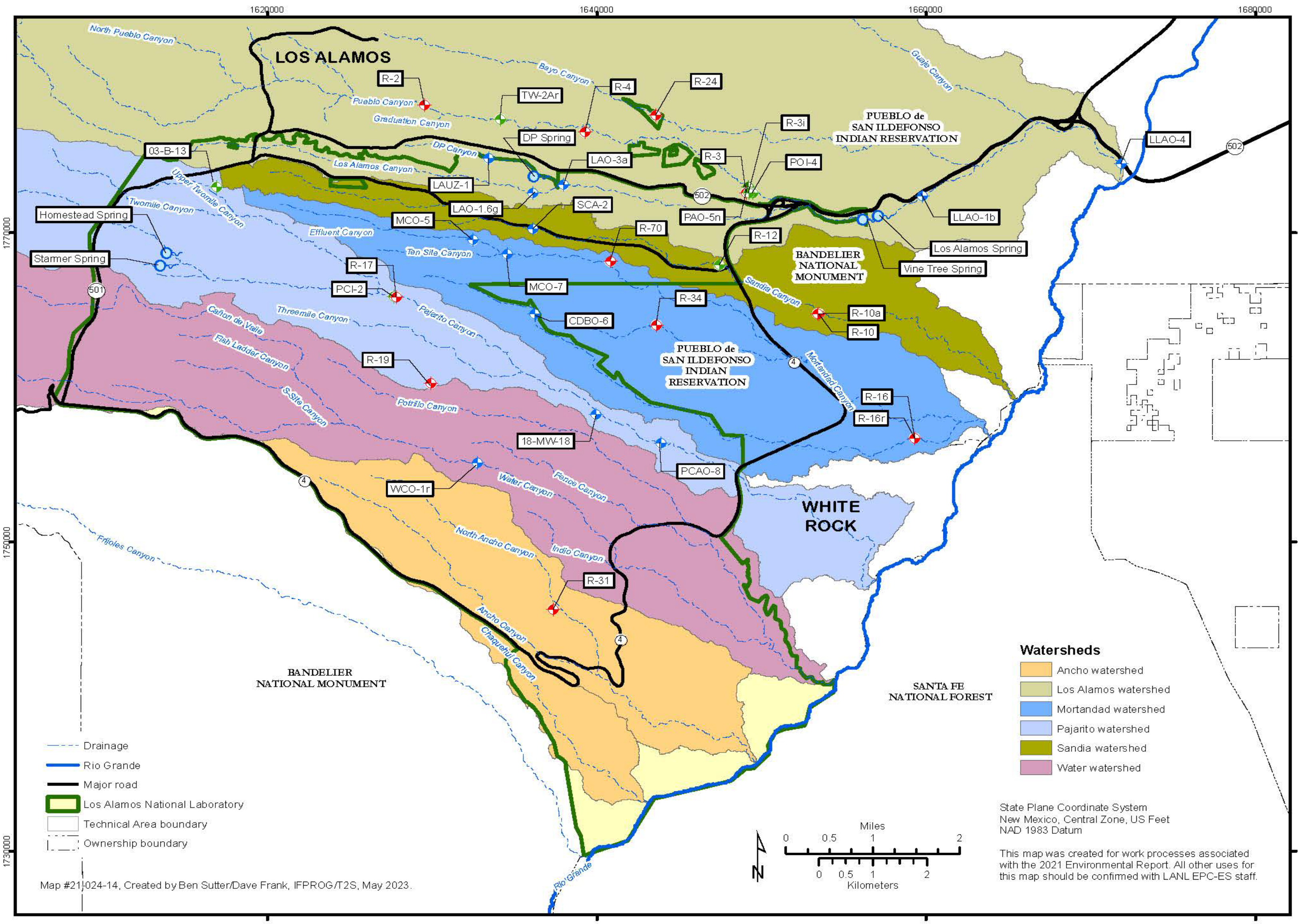


Figure 5-6. Map showing the groundwater monitoring wells and springs assigned to watershed-specific portions of the General Surveillance monitoring group that are not included within one of the six area-specific monitoring groups.

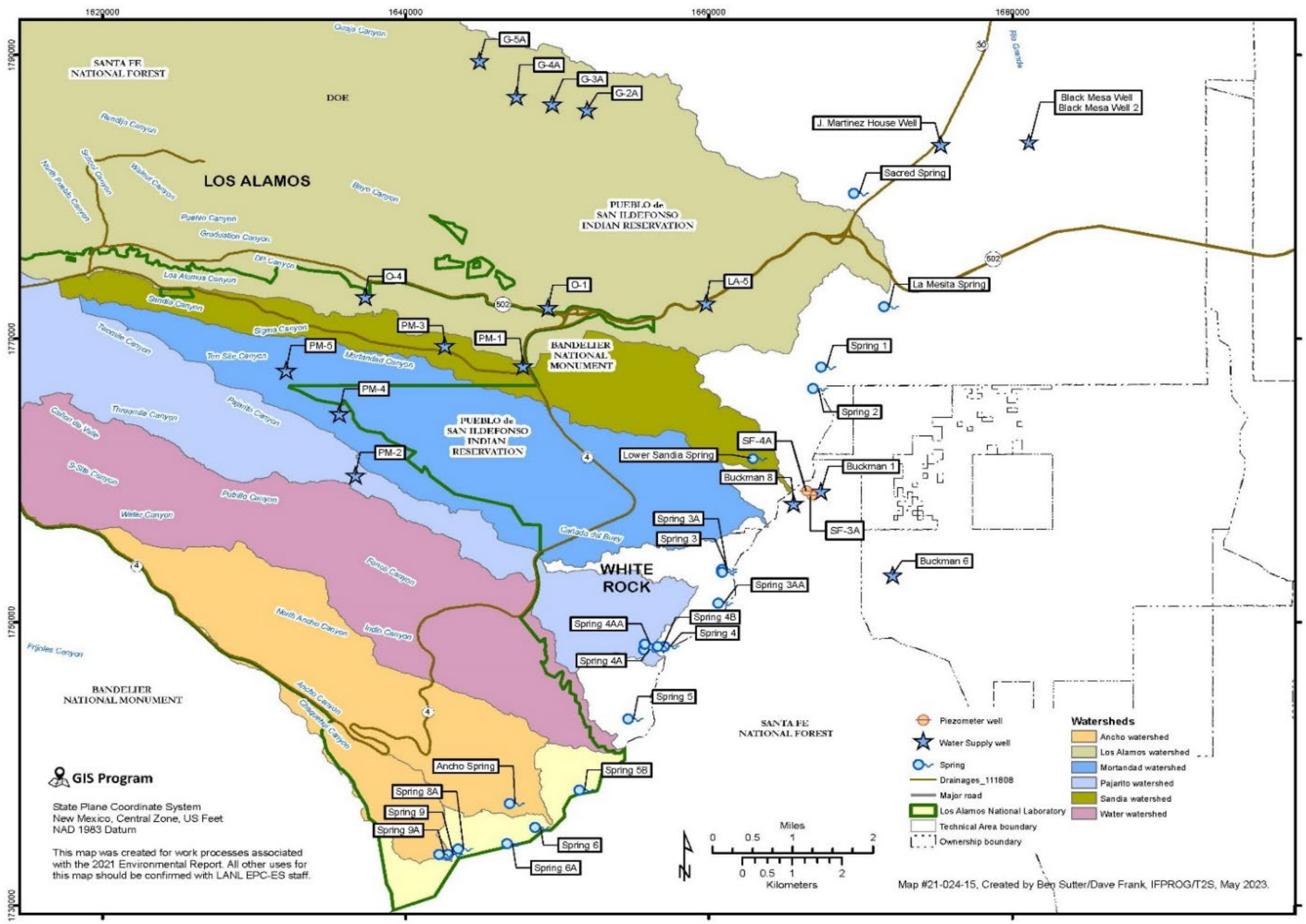


Figure 5-7. Map showing the Los Alamos County water supply wells, three water supply wells in the Santa Fe Buckman well field, and four Pueblo de San Ildefonso sampling locations. Various springs are sampled to monitor the groundwater discharged in White Rock Canyon.

Groundwater Data Interpretation

The groundwater monitoring data for 2022 are available from the Intellus New Mexico website at https://www.intellusnm.com.

We report analytical laboratory results relative to several limits. The method detection limit is the lowest concentration of a substance that the analytical laboratory can state with 99 percent confidence is greater than zero. It is determined from analysis of a set of standardized samples that contain the substance. The practical quantitation limit is the lowest concentration of a substance that can be accurately measured. The practical quantitation limit is approximately (but not always) three times the method detection limit. Concentrations between the method detection limit and the practical quantitation limit are identified as estimated concentrations and are marked with a "J" qualifier in the analytical report and in the results found on the Intellus website.

A nondetect result means that the analytical laboratory did not detect the substance in the sample. These results are marked with a "U" qualifier. In the past, the Laboratory sometimes reported nondetect results using the practical quantitation limit value. Therefore, for older results, the detected but estimated results (results between the method detection limit and the practical quantitation limit) could have a lower reported value than nondetect results for the same substance. Recent groundwater sample nondetect results are reported at the method detection limit.

The method detection limit and practical quantitation limit do not apply to radiological measurements. For radiological measurements, the minimum detectable activity is similar to the method detection limit. To be considered detected, a radiological measurement must be greater than the minimum detectable activity.

Groundwater Sampling Results by Monitoring Group

The following sections present results for the six area-specific monitoring groups, the General Surveillance monitoring group, springs along the Rio Grande, and Los Alamos County and City of Santa Fe water supply wells. We have grouped the tables and discussions according to the groundwater zone, from deepest (the regional aquifer) to shallowest (the alluvial groundwater). The accompanying tables and text mainly address constituents found at levels above screening values. In a few cases, we discuss other constituents that are below screening values, such as tritium, to track trends where we observed potential Laboratory influences. The discussion addresses radionuclides, inorganic compounds, inorganic elements (primarily metals), and organic compounds for each groundwater zone.

Beginning in monitoring year 2020, we implemented a site-wide sampling program for the emerging contaminants known as per- and polyfluoroalkyl substances (PFAS). During 2022, we sampled at selected locations with previous PFAS detections. A handful of locations have recorded results above the New Mexico Environment Department groundwater screening levels (see the section Summary – PFAS Monitoring Results near the end of this chapter).

Water Supply Well Monitoring

Los Alamos County

We collected samples from 11 Los Alamos County water supply wells (see Figure 5-7). This sampling is performed in addition to Los Alamos County's regular monitoring, and we specifically test for potential Laboratory contaminants. All drinking water produced by the Los Alamos County water supply system meets federal and state drinking water standards as reported in the county's annual drinking water quality report (Los Alamos Department of Public Utilities 2022 Annual Drinking Water Quality Report). In 2022, no water supply wells showed detections of Laboratory-related constituents above applicable drinking water standards.

City of Santa Fe

In 2022, we sampled three water supply wells (Buckman-1, Buckman-6, and Buckman-8) in the City of Santa Fe's Buckman well field. No Laboratory-related constituents were present above standards for these locations. The City of Santa Fe publishes an annual water quality report that provides additional information (City of Santa Fe Water 2022 Water Quality Report).

Technical Area 21 Monitoring Group

Technical Area 21 is located on a mesa bordered by Los Alamos Canyon on the south and DP Canyon on the north. It contains two historical operational areas, DP West and DP East, which produced liquid and solid radioactive wastes. The operations at DP West included plutonium processing; at DP East, operations included weapons initiators production and tritium research. From 1952 to 1986, a liquid waste treatment plant discharged effluent that contained radionuclides from the plutonium-processing facility into DP Canyon (see Figure 5-4).

Potential sources of groundwater pollutants in the vicinity of Technical Area 21 include Solid Waste Management Unit 21-011(k) (the former liquid waste treatment plant outfall location), Solid Waste Management Unit 02-005 (the former Omega West reactor cooling tower), adsorption beds and disposal shafts at Material Disposal Area T, adsorption beds at Material Disposal Area U, DP West, DP East, waste lines, an underground diesel fuel line, and sumps.

The Technical Area 21 monitoring group includes wells in perched-intermediate groundwater and in the regional aquifer. Samples from several wells that monitor perched-intermediate groundwater contain tritium that likely originated from the former liquid waste treatment plant, the Omega West Reactor, or both. Tritium concentrations in perched-intermediate wells R-6i, LAOI-3.2, LAOI-3.2a, and LAOI-7 in 2022 are generally consistent with concentrations measured in recent years (see Figure 5-8; see Figure 5-5 for well locations) and show long-term declines over time. The highest tritium concentration among these wells in 2022 was 804 picocuries per liter in R-6i, down from 1,070 picocuries per liter in 2021. For comparison, the U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water is 20,000 picocuries per liter.

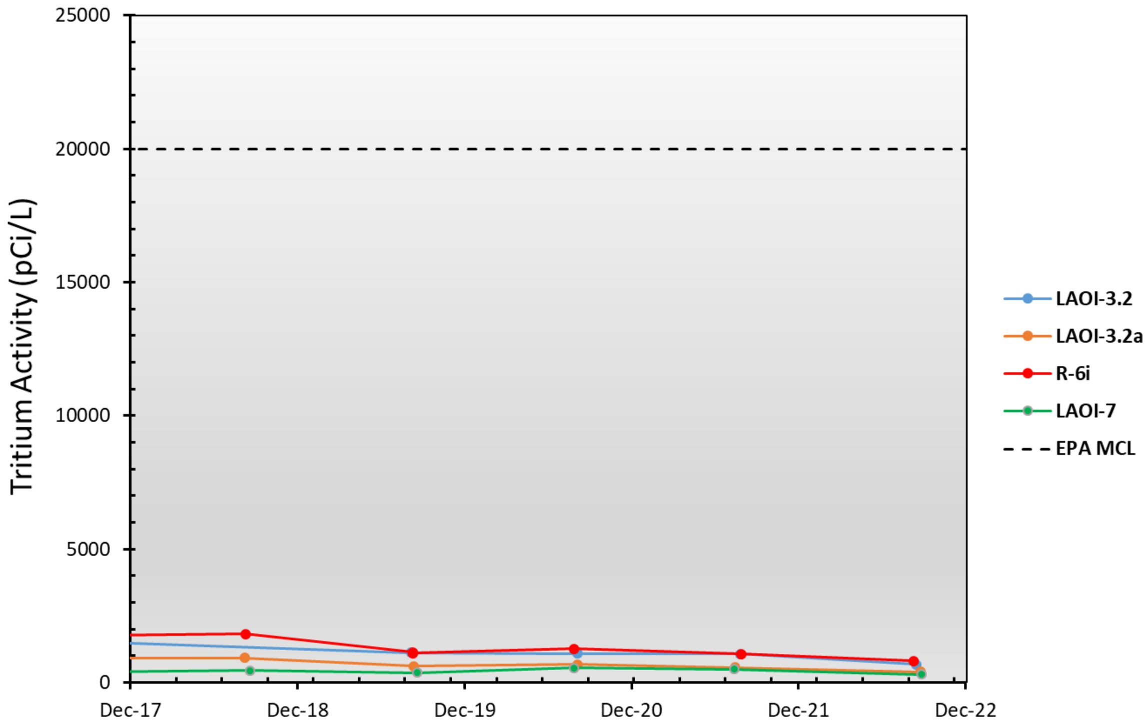


Figure 5-8. Graph of Technical Area 21 tritium concentrations in perched-intermediate wells. (EPA MCL = U.S. Environmental Protection Agency maximum contaminant level for tritium)

Chromium Investigation Monitoring Group

The Chromium Investigation monitoring group is located in Sandia and Mortandad Canyons. Chromium is present in the regional aquifer below these canyons at levels above the New Mexico Environment Department groundwater standard of 50 micrograms per liter in an area estimated to be approximately 1 mile in length and about a half-mile wide (see Figure 5-9 and Figure 5-10).

From 1956 to 1972, LANL used potassium dichromate as a corrosion inhibitor in the cooling system at the Laboratory's power plant (LANL 1973). Potassium dichromate was present in the effluent discharged through an outfall to Sandia Canyon. These discharges of potassium dichromate are the source of the hexavalent chromium observed in groundwater beneath Sandia and Mortandad Canyons.

A conceptual model for the sources and spatial distribution of chemicals and radionuclides in groundwater in this area is presented in the Investigation Report for Sandia Canyon (LANL 2009), the Phase II Investigation Report for Sandia Canyon (LANL 2012), and the Compendium of Technical Reports Conducted Under the Work Plan for Chromium Plume Center Characterization (LANL 2018a). The conceptual model indicates that chromium originated from releases into Sandia Canyon and then migrated below ground along geologic perching horizons to the regional aquifer beneath Sandia and Mortandad Canyons.

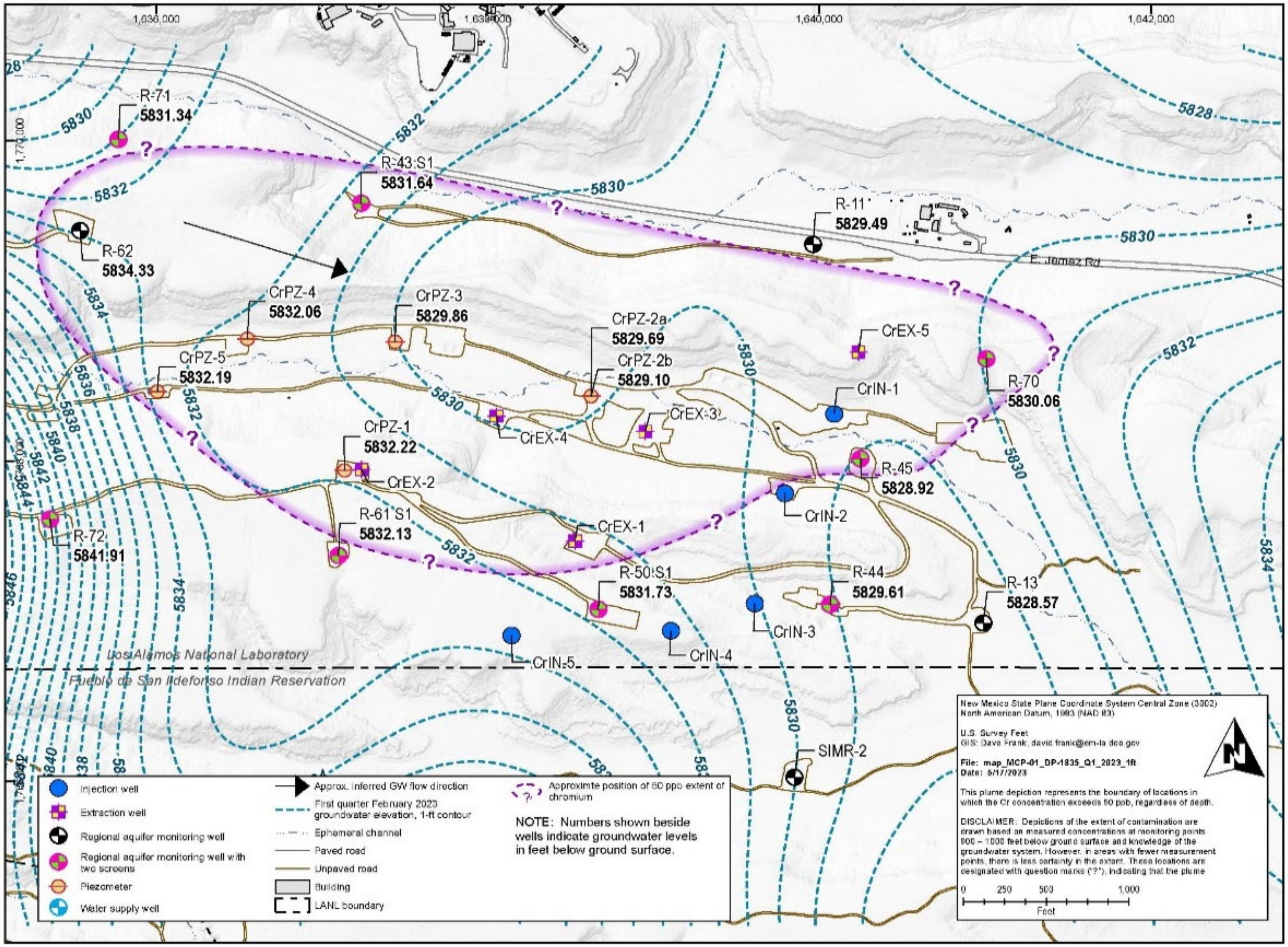


Figure 5-9. Map of the approximate chromium plume footprint in the regional aquifer in Mortandad Canyon.

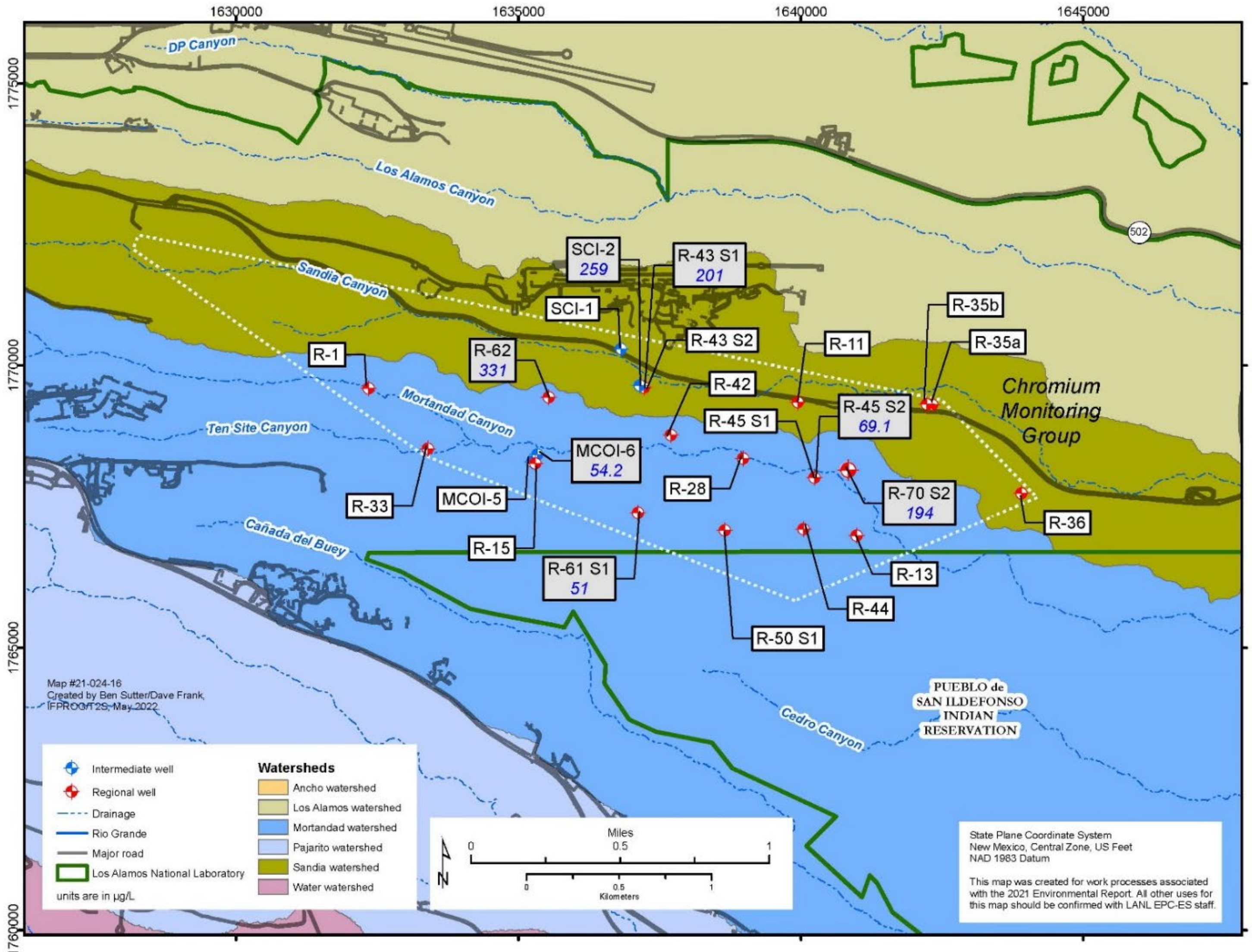


Figure 5-10. Map of the Chromium Investigation monitoring group perched-intermediate and regional aquifer monitoring wells. The white dashed outline encompasses the wells included in the monitoring group. In 2022, two perched-intermediate wells (MCOI-6 and SCI-2) and five regional aquifer wells (R-43 screen 1, R-45 screen 2, R-61 screen 1, R-62, and R-70 screen 2) exceeded the 50-micrograms-per-liter New Mexico groundwater standard for chromium.

Chromium contamination is generally detected within 100 feet of the top of the regional aquifer (LANL 2009, 2012, 2017, 2018b). A few locations (for example, the well R-70 area) are known to have chromium deeper than 100 feet. Additional investigations are underway to determine the depth of that contamination. Perchlorate contamination is also present in groundwater beneath Mortandad Canyon. The primary source of perchlorate is effluent discharges from the Radioactive Liquid Waste Treatment Facility from 1963 until March 2002.

Chromium Monitoring Results and the Chromium Plume Interim Measure

The chromium concentrations exceeded the New Mexico groundwater standard of 50 micrograms per liter in five regional aquifer wells within the monitoring group in 2022: R-43 screen 1, R-45 screen 2, R-61 S1, R-62, and R-70 screen 2 (see Figure 5-10 and Figure 5-11).

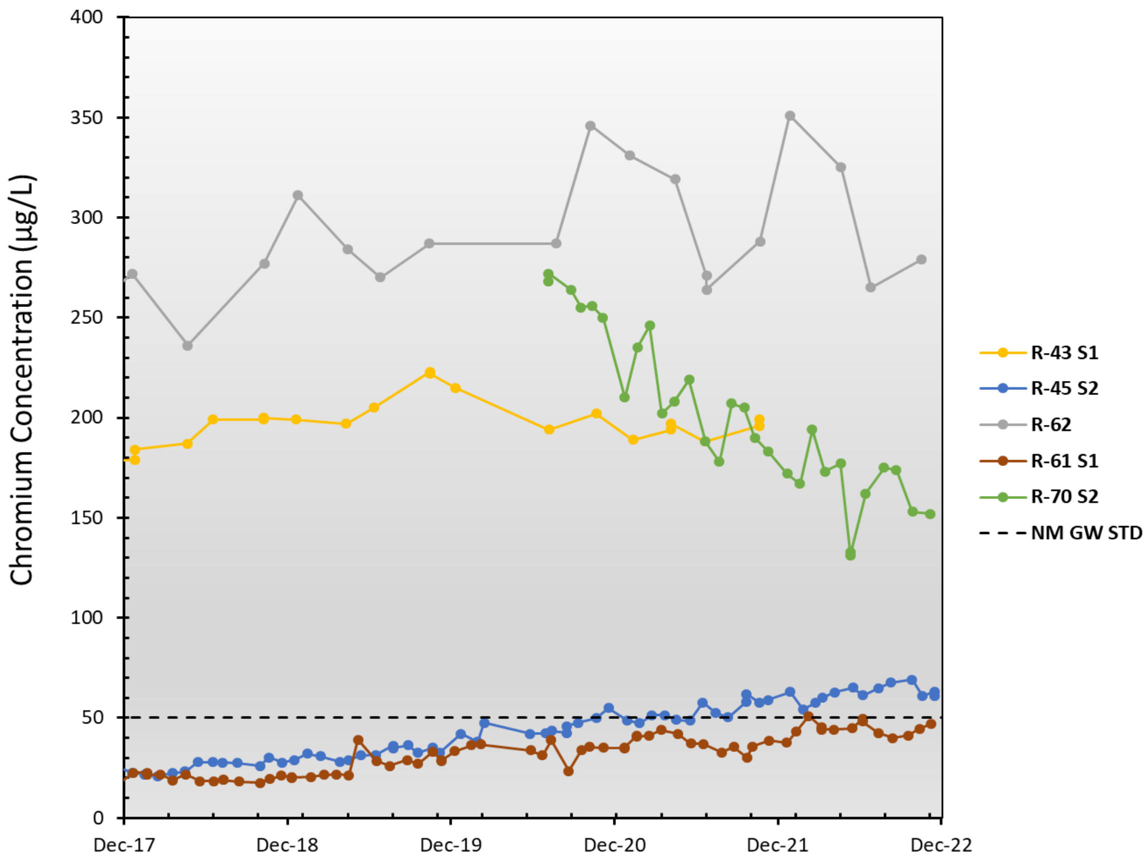


Figure 5-11. Chromium concentration trends for five regional aquifer wells that have exceeded the New Mexico groundwater standard (NM GW STD) of 50 micrograms per liter.

During 2022, we continued implementing an interim measure to maintain the portion of the plume that contains 50 micrograms per liter or more of chromium completely within the Laboratory boundary (LANL 2015). We extracted contaminated groundwater from a group of up to five extraction wells, piped the extracted water to an above-ground ion exchange treatment system, and following treatment, injected the treated water back into the regional aquifer through up to five injection wells located in the downgradient portion of the plume. Interim measure operations began on a limited scale in 2017 and were more fully implemented starting in 2018.

The interim measure targets the area along the boundary between the Laboratory and the Pueblo de San Ildefonso, on the southeastern downgradient portion of the plume (see Figure 5-9). Two regional aquifer wells, R-44 and R-50, monitor the effectiveness of the interim measure along the boundary (see Figure 5-12). Wells R-44 and R-50 each have two screens; R-44 screen 2 is near the water table at 985.3 to 995.2 feet below the ground surface, and R-50 screen 2 is approximately 100 feet below the water table at 1185.0 to 1205.6 feet below the ground surface. Well R-50 screen 2 has consistently shown chromium concentrations within naturally occurring (background) levels, indicating that the chromium contamination at that location is less than the depth of that screen. The levels of chromium in R-50 screen 1 have continued to decrease over time in response to the interim measure but showed a slight increase during the several months when the system was shut down because of the COVID-19 pandemic (see Figure 5-12). Chromium concentrations in R-44 screen 1 and screen 2 have historically been below the New Mexico groundwater standard for chromium and are dropping further in response to the interim measure (see Figure 5-12).

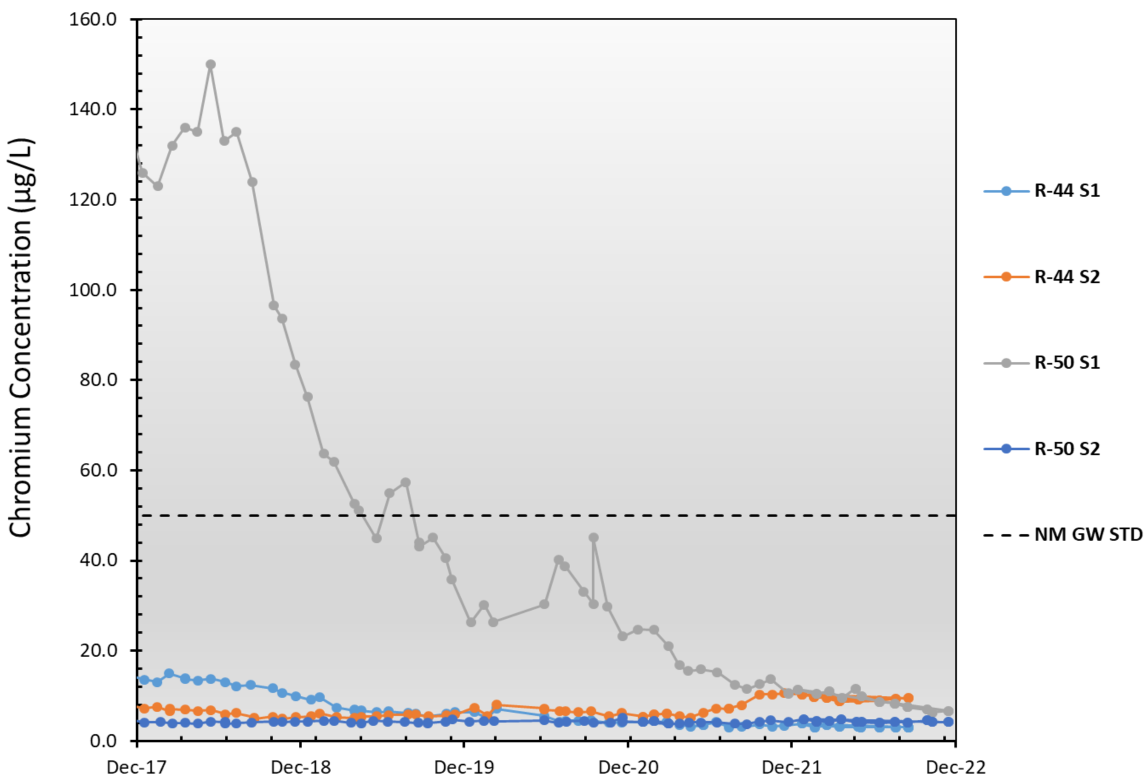


Figure 5-12. Chromium concentrations in four regional aquifer wells that monitor the effectiveness of the interim measure down gradient of the chromium plume.(NM GW STD = New Mexico groundwater standard)

We began operations began along the eastern portion of the plume in late 2019. There are five regional monitoring wells (R-11, R-45, R-70, R-35a, and R-35b) and one extraction well (CrEX-5) in this area (see Figure 5-9 and Figure 5-10). Wells R-35a and R-35b have consistently shown chromium concentrations within naturally occurring (background) levels from the start of interim measure operations to the present. Chromium concentrations at well R-11 continue to measure below the 50-micrograms-per-liter groundwater standard, with variations in concentrations that are likely not related to interim measure operations.

Well R-45 is located south and west of R-70 and is flanked by injection wells CrIN-1 and CrIN-2 to the north and southwest. This well was first sampled in 2009. Before interim measure operations began in this area, chromium concentrations in well R-45 screen 1 and screen 2 were below 50 micrograms per liter but above background and rising.

Since the start of sustained injection in 2018, chromium concentrations at R-45 screen 1 have declined, a trend that continued after injection was expanded to the eastern area of the plume in 2019. An injection water signature at R-45 screen 1 (an increase in chloride and sulfate), indicates that injection water is entering screen 1. Chromium concentrations in R-45 screen 2 have increased above the 50 micrograms per liter groundwater standard. There is no injection water signature at screen 2. Given the proximity of injection wells CrIN-1 and CrIN-2 to well R-45 and the injection water signature at screen 1, it is likely that eastern area interim measure operations have affected the R-45 screen 2 concentrations (see Figure 5-13 for R-11 and R-45 screens 1 and 2 chromium concentration trends).

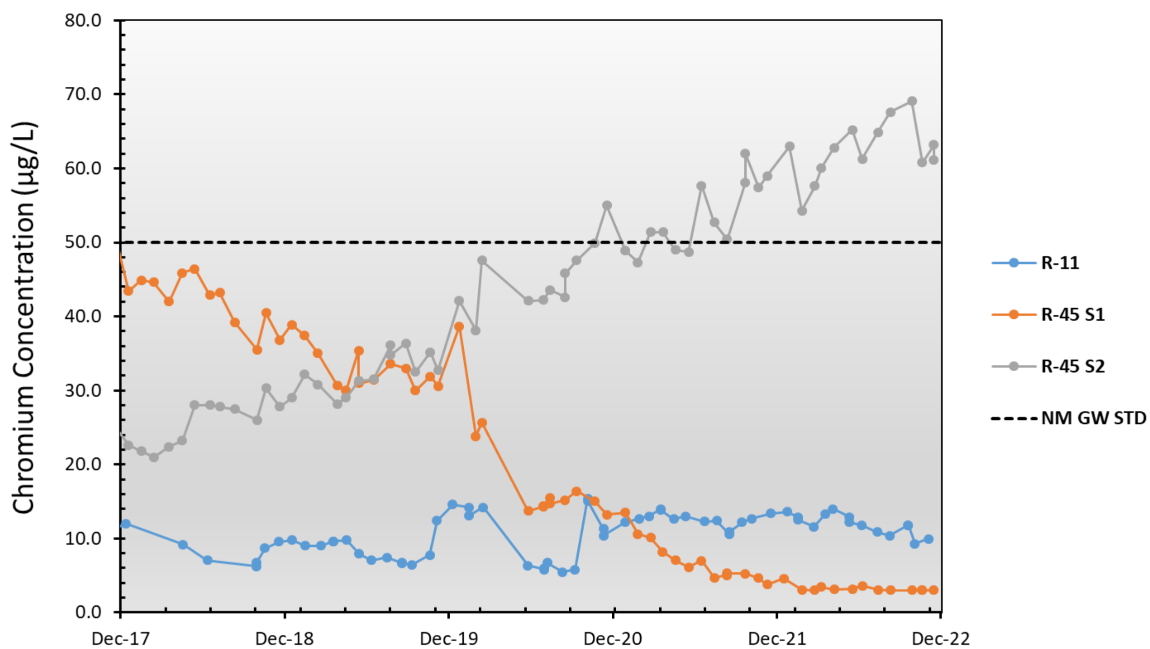


Figure 5-13. Chromium concentrations in two regional wells along the northeast edge of the plume (NM GW STD = New Mexico groundwater standard)

Two wells located along the northwestern upgradient portion of the chromium plume, R-62 and R-43 (two screens), continued to show an increase in the concentration of chromium in 2022 (see Figure 5-14). LANL will install new monitoring wells in this area and evaluate whether additional mitigation actions are necessary.

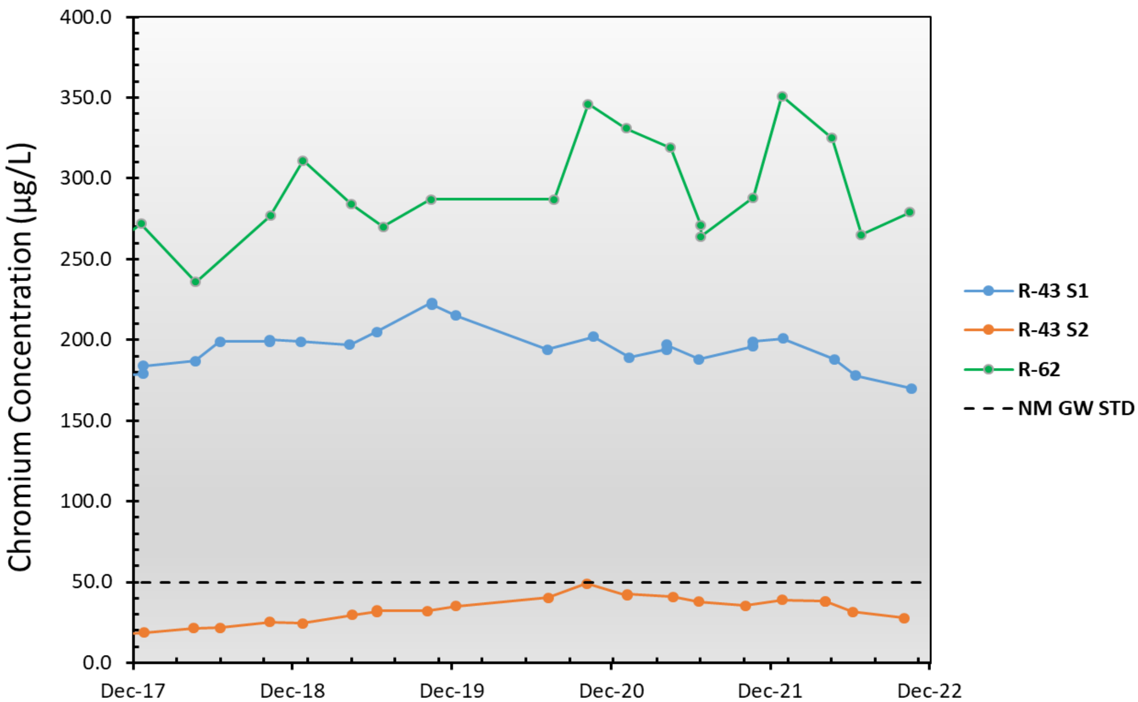


Figure 5-14. Chromium concentrations in two regional monitoring wells located on the northwestern side of the plume that show chromium concentrations above the New Mexico groundwater standard (NM GW STD) of 50 micrograms per liter.

Two perched-intermediate wells reported chromium concentrations above the standard: SCI-2 and MCOI-6. Chromium concentrations continue to decline in SCI-2 and remain steady in MCOI-6 (see Figure 5-15).

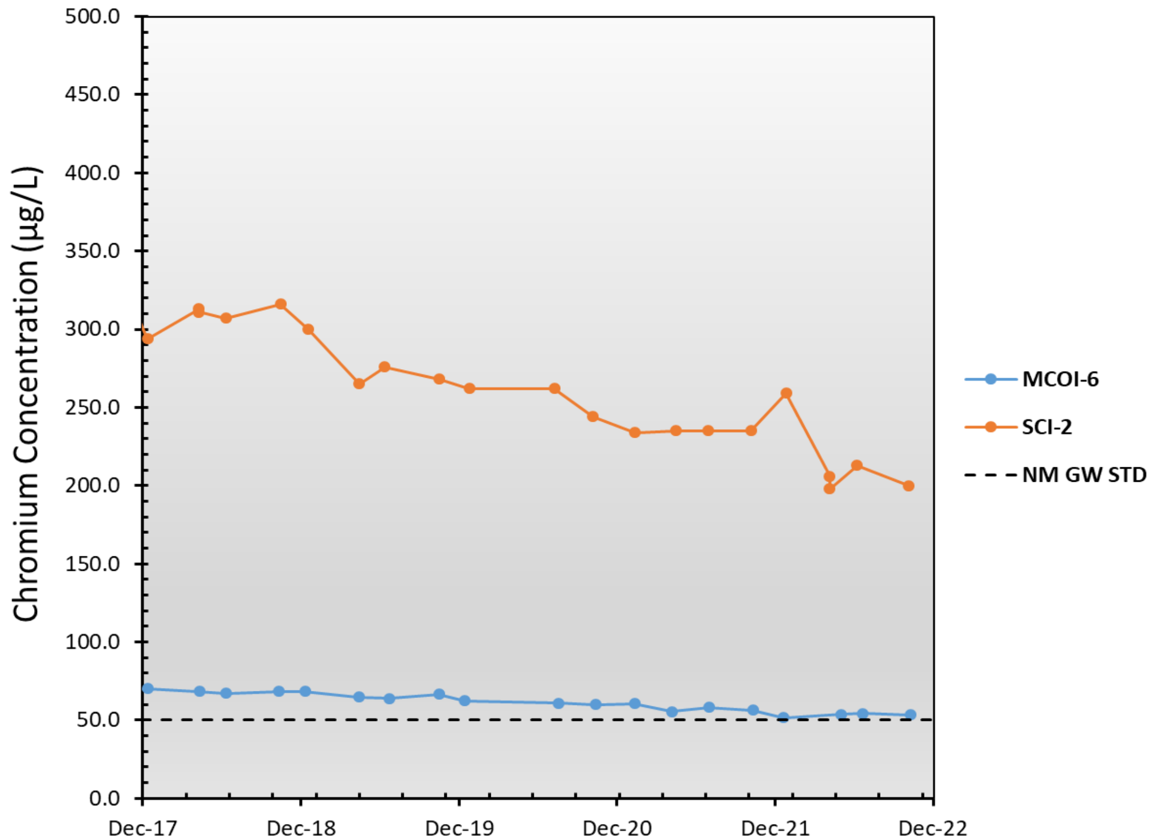


Figure 5-15. Chromium concentrations in two perched-intermediate groundwater monitoring wells that exceeded the New Mexico groundwater standard (NM GW STD) of 50 micrograms per liter.

Other Monitoring Results

Perchlorate is present above the New Mexico Environment Department tap water screening level of 13.8 parts per billion in two perched-intermediate wells: MCOI-5 and MCOI-6 (see Figure 5-16). In perched-intermediate well MCOI-6, the perchlorate concentration trends are relatively stable. Perchlorate concentrations at MCOI-5 were showing a decreasing trend, although we have not sampled the well since 2019 due to insufficient water in the well. Perchlorate concentrations in regional aquifer well R-15 are below 13.8 parts per billion, and R-61 screen 1 has historically shown concentrations near or slightly above 13.8 parts per billion. We continue to monitor perchlorate and, if necessary, will incorporate remedial actions for perchlorate as part of the chromium remediation efforts.

Other constituents detected in the Chromium Investigation monitoring group include 1,4-dioxane and tritium in perched-intermediate wells MCOI-5 and MCOI-6 (see Figure 5-17 and Figure 5-18). The trend for 1,4-dioxane concentrations at MCOI-6 has been increasing. As previously noted, additional sampling of MCOI-5 has not been completed since 2019 due to insufficient water. Concentrations of 1,4-dioxane are not present above the screening level of 4.59 micrograms per liter in the regional aquifer. Perched-intermediate wells MCOI-5 and MCOI-6 have tritium concentrations far below the U.S. Environmental Protection Agency maximum contaminant level for tritium in drinking water of 20,000 picocuries per liter.

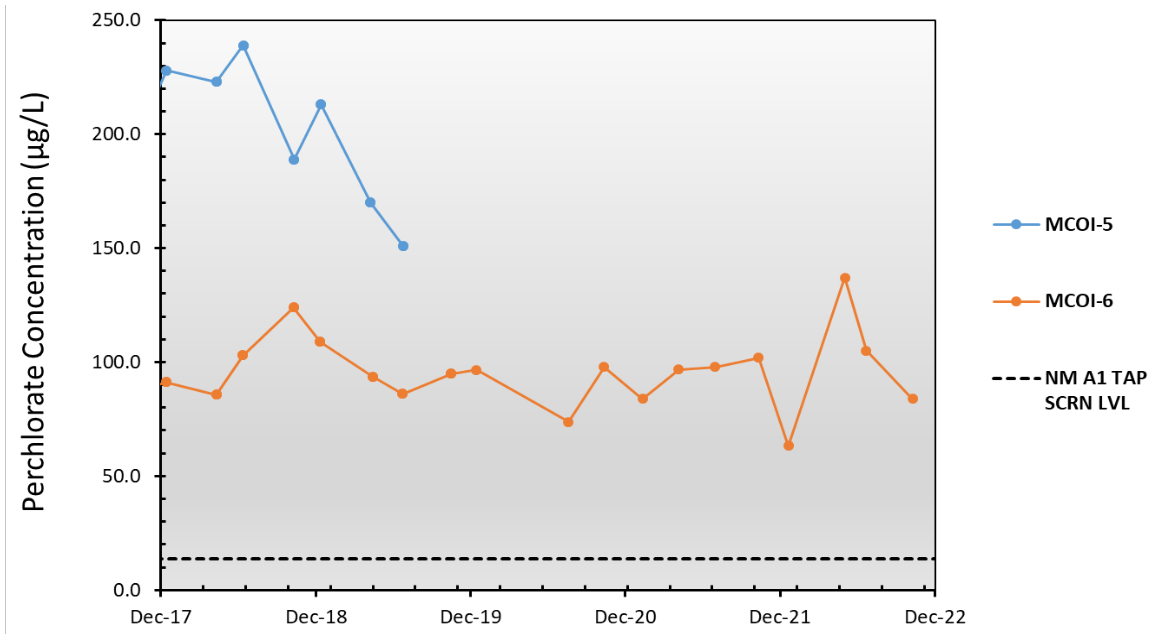


Figure 5-16. Perchlorate concentrations for two perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group with perchlorate detections above the New Mexico tap water screening level (NM A1 TAP SCRN LVL) of 13.8 micrograms per liter. MOI-5 has not been sampled since 2019 due to insufficient water at this location.

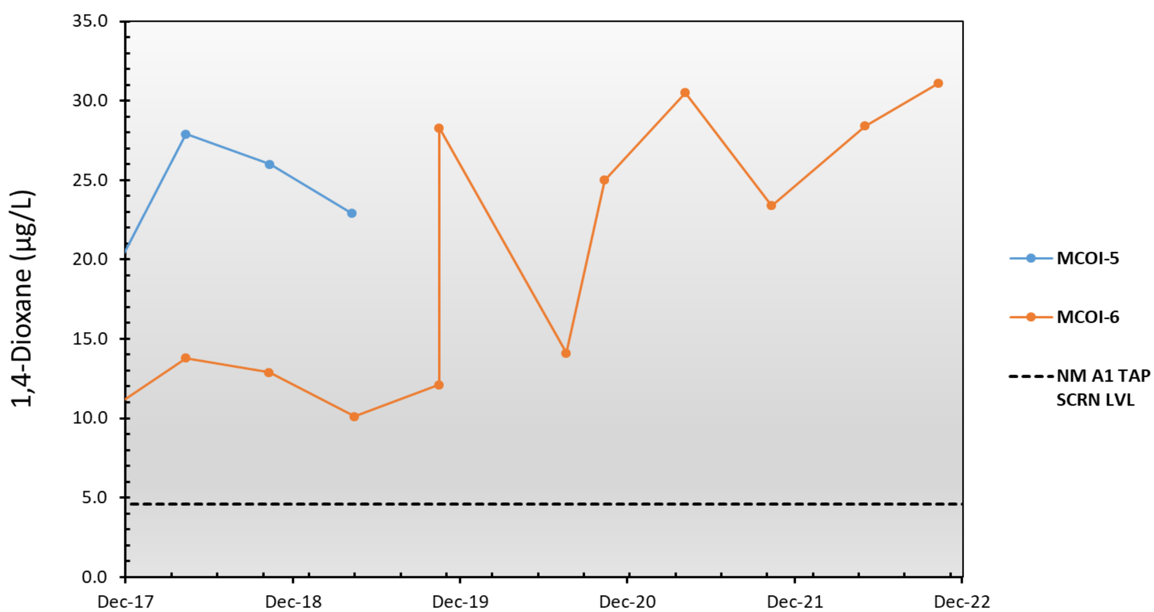


Figure 5-17. Concentrations of 1,4-dioxane in perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group. Both locations displayed concentrations above the New Mexico tap water screening level (NM A1 TAP SCRN LVL) for 1,4-dioxane of 4.59 micrograms per liter.

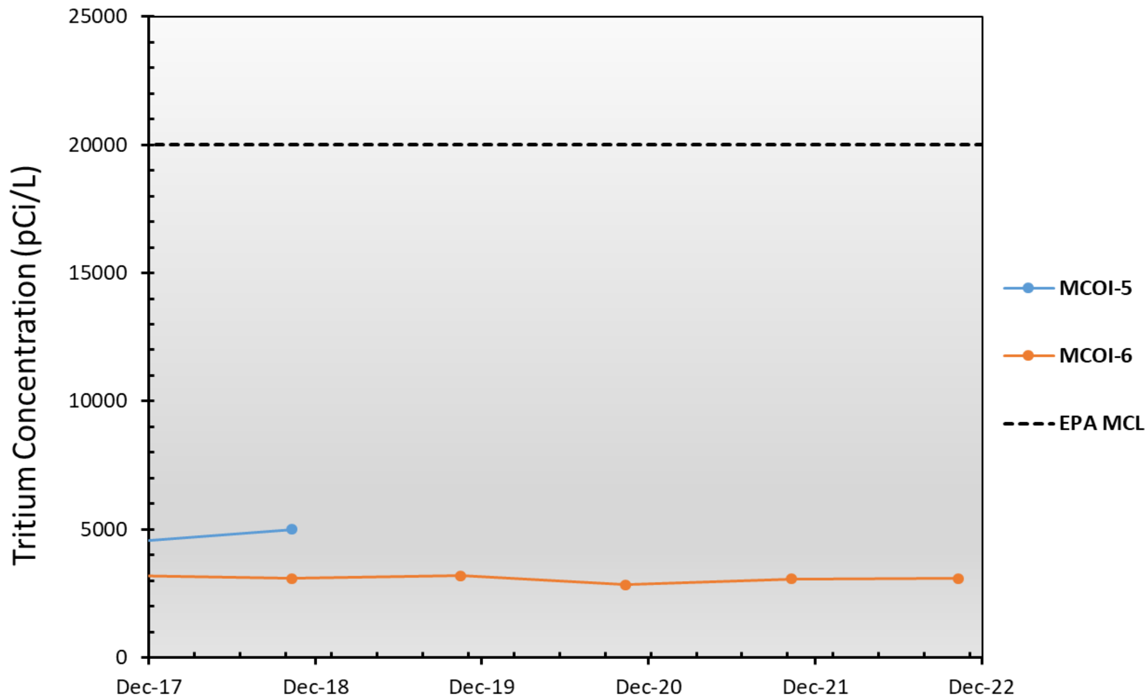


Figure 5-18. Tritium concentrations in two perched-intermediate groundwater monitoring wells in the Chromium Investigation monitoring group. The U.S. Environmental Protection Agency maximum contaminant level (EPA MCL) for tritium in drinking water is 20,000 picocuries per liter. MCOI-5 has not been sampled since 2018 due to insufficient water at this location.

Material Disposal Area C Monitoring Group

Material Disposal Area C is in Technical Area 50, at the head of Ten Site Canyon. It is an inactive landfill where solid low-level radioactive wastes and chemical wastes were disposed of between 1948 and 1974. Vapor-phase volatile organic compounds and tritium are present in the upper 500 feet of the unsaturated soil and rock beneath Material Disposal Area C (LANL 2011a). The primary volatile organic compound is trichloroethylene. The Material Disposal Area C monitoring group includes nearby regional aquifer monitoring wells (see Figure 5-5). Monitoring data indicate that no contamination is present in the groundwater in the regional aquifer immediately downgradient of Material Disposal Area C. No perched-intermediate groundwater is present beneath Material Disposal Area C.

Technical Area 54 Monitoring Group

Technical Area 54 is in the east-central portion of the Laboratory on Mesita del Buey. The technical area includes four material disposal areas designated as Areas G, H, J, and L; a waste characterization, storage, and transfer facility (Technical Area 54 West); active radioactive waste storage operations at Area G; hazardous and mixed-waste storage operations at Area L; and administrative and support areas.

At Technical Area 54, groundwater monitoring is conducted to support both monitoring of solid waste management units and areas of concern (particularly Areas G, H, and L) under the Compliance Order on Consent and the Laboratory's Hazardous Waste Facility Permit. The

Technical Area 54 monitoring group includes perched-intermediate and regional wells (see Figure 5-5).

Monitoring data show that vapor-phase volatile organic compounds are present in the upper portion of the unsaturated zone beneath Areas G and L. The primary vapor-phase volatile organic compounds at Technical Area 54 are 1,1,1-trichloroethane; trichloroethylene; and Freon-113. Tritium is also present (LANL 2005b, 2006, 2007).

We have periodically detected a variety of substances around Technical Area 54, including several volatile organic compounds from the groundwater monitoring network. In 2021, we detected the chemical 1,4-dioxane above the U.S. Environmental Protection Agency maximum contaminant level of 4.59 micrograms per liter at well R-37 screen 1, with a concentration of 6.22 micrograms per liter. This event is the third detection of 1,4-dioxane above the screening level at this well. Well R-37 screen 1 was not sampled in 2022 due to changing sampling frequency in the Interim Facility-Wide Groundwater Monitoring Plan. We will continue to monitor this trend.

Technical Area 16-260 Monitoring Group

Water Canyon and Cañon de Valle (a tributary of Water Canyon) cross the southwest portion of LANL. In the past, the Laboratory released wastewater into both canyons from several high-explosives processing facilities in Technical Areas 16 and 09 (see Figure 5-4). The Technical Area 16-260 outfall discharged high-explosives-bearing water from a high-explosives machining facility to Cañon de Valle from 1951 through 1996. These discharges served as a primary source of high-explosives and inorganic element contamination in the area (LANL 1998, 2003, 2011b).

The Technical Area 16-260 monitoring group monitors substances released from Consolidated Unit 16-021(c)-99, which includes the Technical Area 16-260 outfall and associated solid waste management units. Current evidence indicates that, over time, the effluent from the Technical Area 16-260 outfall—sometimes mixed with naturally occurring surface water and alluvial groundwater—infiltrated from Cañon de Valle and percolated through unsaturated rock layers to perched-intermediate groundwater zones and ultimately into the regional aquifer.

RDX is the primary groundwater contaminant in this area and the only contaminant that exceeds its screening level in the regional aquifer. We have detected RDX in the regional aquifer in wells R-18, R-63, R-68, and R-69 screens 1 and 2 (see Figure 5-19 and Figure 5-20). Wells R-68 and R-69 screens 1 and 2 have recorded RDX concentrations above the tap water screening level of 9.66 micrograms per liter. RDX concentrations in regional monitoring wells R-63 and R-18 remain below the screening level but are exhibiting stable-to-increasing trends. Other substances, including tetrachloroethene, trichloroethylene, boron, and barium, are present in all groundwater zones but are well below applicable standards in the regional aquifer.

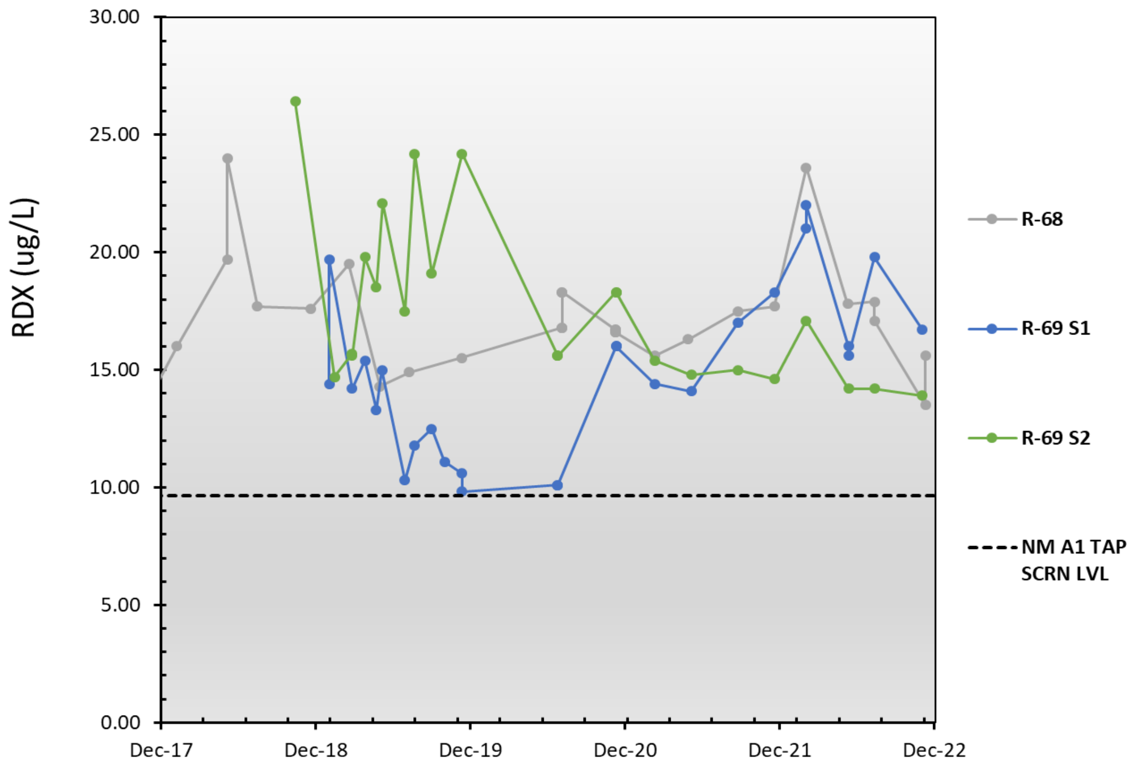


Figure 5-19. RDX concentrations in regional aquifer wells R-68 and R-69 screens 1 and 2. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for RDX is 9.66 micrograms per liter.

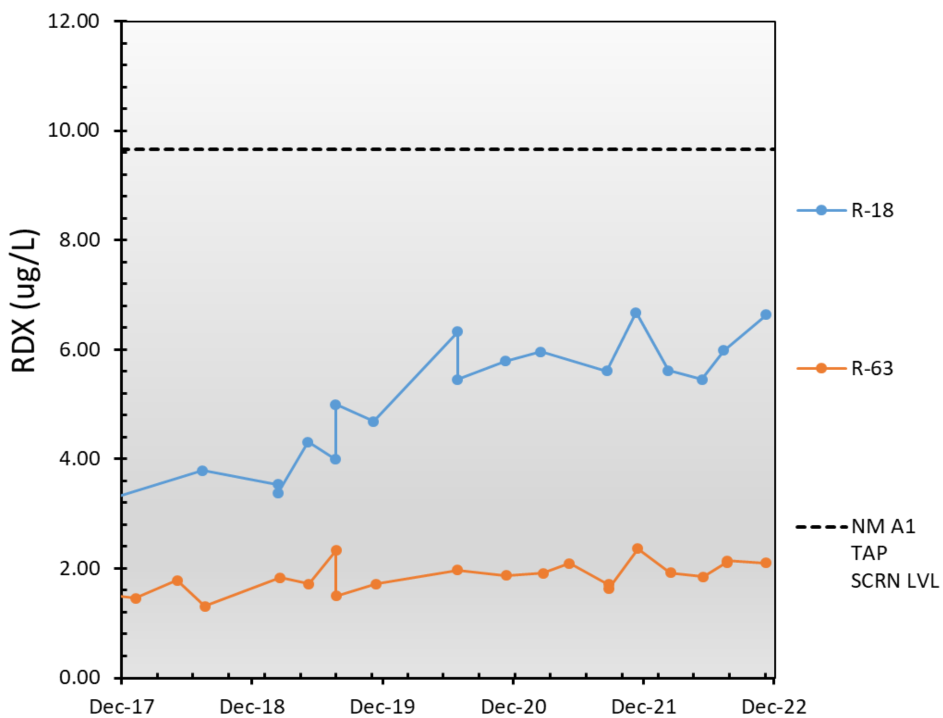


Figure 5-20. RDX concentrations in regional aquifer wells R-18 and R-63. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for RDX is 9.66 micrograms per liter.

Springs, surface water, alluvial groundwater, and perched-intermediate groundwater in the area contain explosive compounds, including RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), and TNT (2,4,6-trinitrotoluene). We have detected barium, boron, iron, manganese, nitrosodimethylamine[N-], amino-2,6-dinitrotoluene[4-], dibromo-3-Chloropropane[1,2-], dibromoethane[1,2-], and trichloropropane[1,2,3-] above their respective screening levels in some locations in springs, alluvial groundwater, and perched-intermediate groundwater. Figure 5-21 shows RDX concentrations in springs. The springs discharge from shallow perched-intermediate groundwater zones. Of the springs sampled, the concentrations of RDX are highest in Martin Spring, but it shows a declining trend over time (see Figure 5-21). RDX concentrations at Burning Ground Spring have been relatively steady over the past 5 years (see Figure 5-21) except for samples collected in July 2015 and March 2019. SWSC Spring, near the former location of the Technical Area 16-260 outfall, does not have consistent flow; it was not sampled in 2022. RDX was detected above the screening level at Bulldog Spring in a sample collected in September 2021; however, in the sample collected in March of 2022, the concentration of RDX was below the screening level.

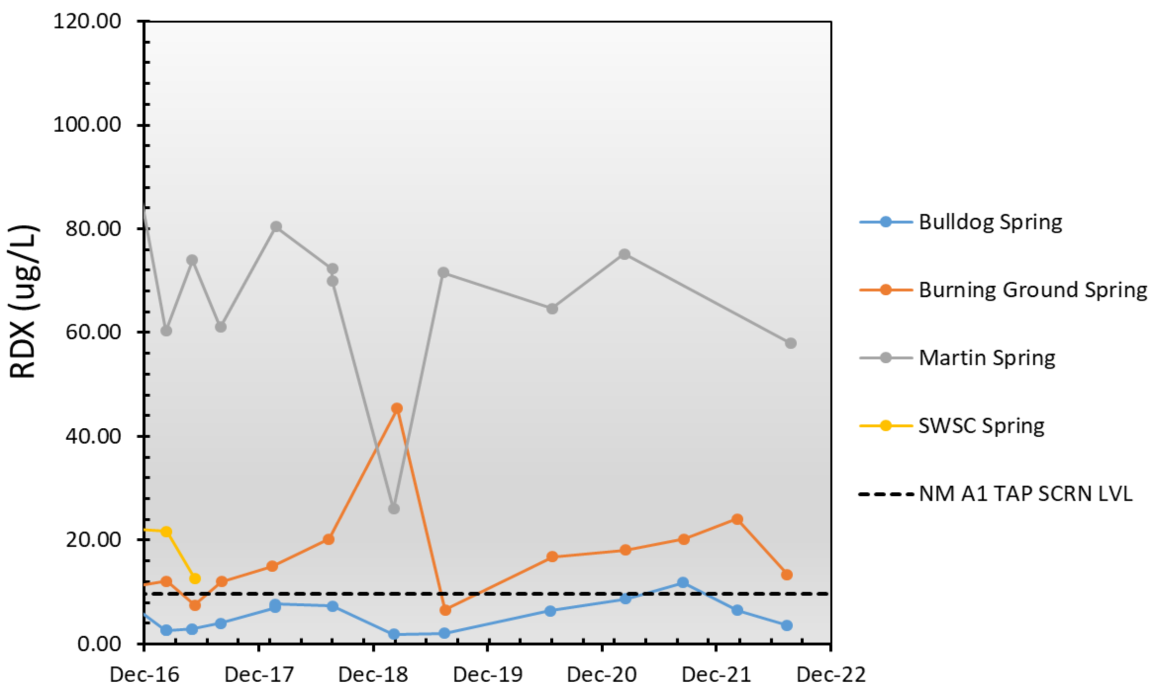


Figure 5-21. RDX concentrations in four springs in Technical Area 16. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for RDX is 9.66 micrograms per liter. SWSC Spring has not been sampled since 2017 due to the location being dry.

Figure 5-22 and Figure 5-23 show RDX concentrations in alluvial wells and perched-intermediate wells. RDX concentrations in alluvial monitoring wells show significant variability because of seasonal influences but remain relatively low (see Figure 5-22). RDX concentrations in each of the perched-intermediate wells show some variability (see Figure 5-23). Long-term monitoring of some of these springs and alluvial wells is now included in the annual Interim Facility-Wide Groundwater Monitoring Plan (N3B 2022).

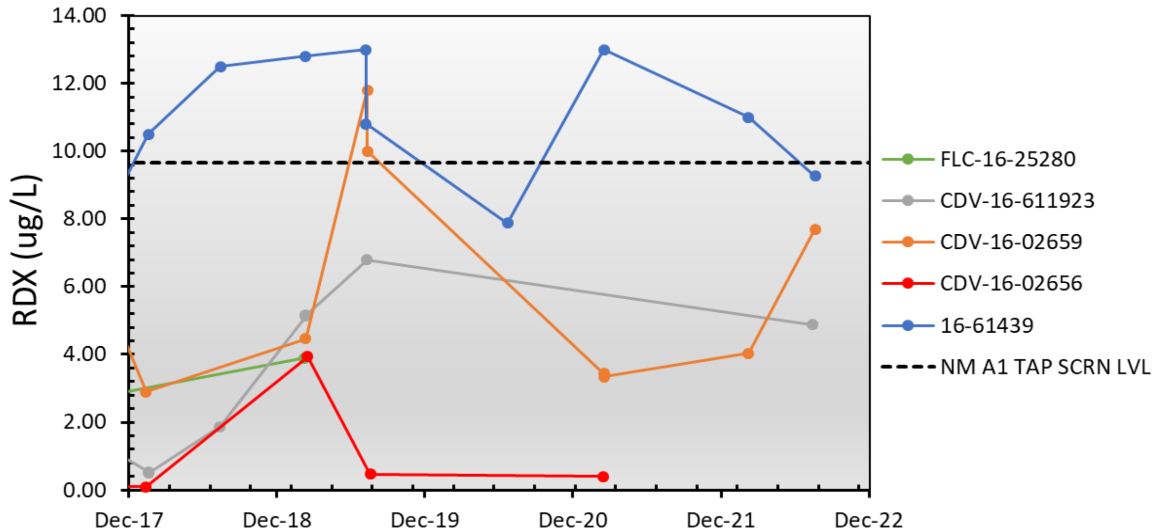


Figure 5-22. RDX concentrations in five alluvial groundwater wells in Technical Area 16. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for RDX is 9.66 micrograms per liter. Concentrations at locations CdV-16-02659 and 16-61439 display concentrations of RDX above the standard.

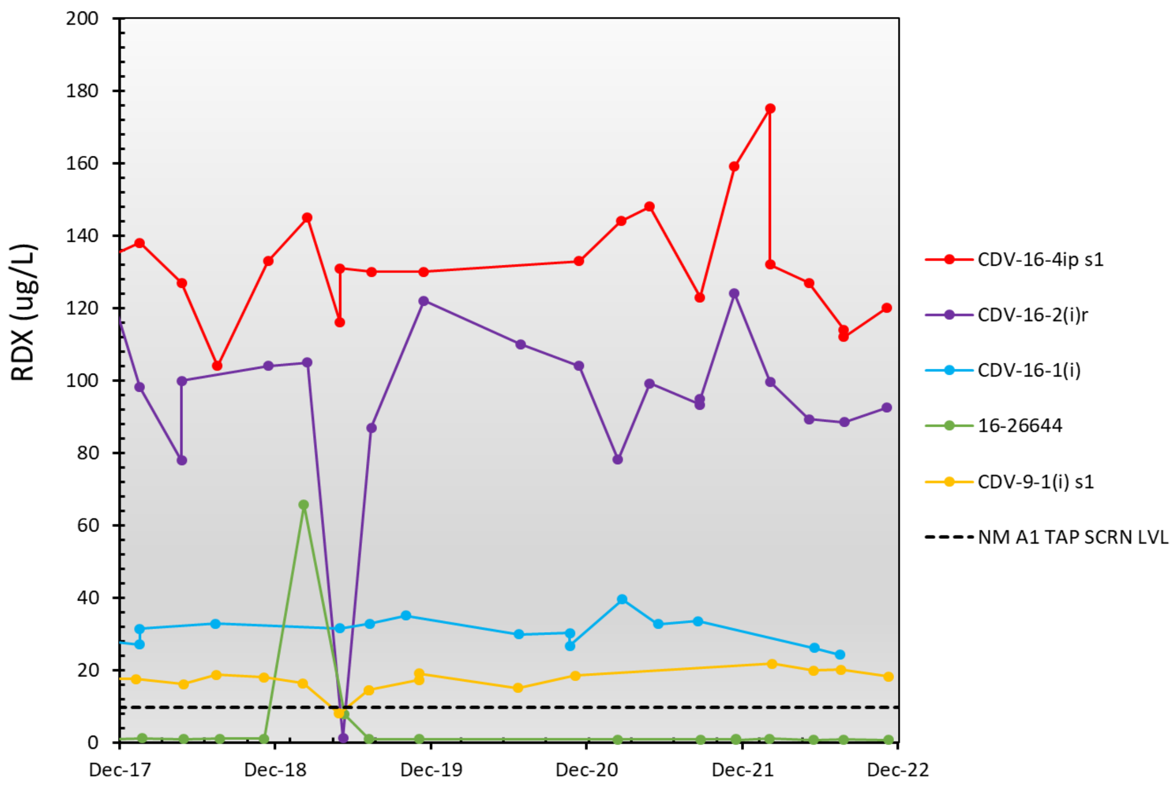


Figure 5-23. RDX concentrations in perched-intermediate groundwater wells in Technical Area 16. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for RDX is 9.66 micrograms per liter.

In May 2020, we submitted a report on fate and transport modeling and risk assessment for RDX in groundwater to the New Mexico Environment Department. Based on the Department's comments, we submitted a revised risk assessment to the New Mexico Environment Department in September 2022. Consistent with the initial risk assessment, the revision to the risk assessment concluded that there is no risk to human health over the next 200 years.

Material Disposal Area AB Monitoring Group

The Material Disposal Area AB monitoring group is located in Technical Area 49. Also known as the Frijoles Mesa Site, Technical Area 49 is located on a mesa near the western end of Ancho Canyon. Part of the area drains into Water Canyon. The canyons in the Ancho Canyon watershed are mainly dry, with no known persistent alluvial groundwater zones and no known perched-intermediate groundwater.

LANL used the site of Material Disposal Area AB to test nuclear weapons components from 1959 to 1961 (Purtymun and Stoker 1987, LANL 1988). The testing involved isotopes of uranium and plutonium; lead and beryllium; explosives such as TNT, RDX, and HMX; and barium nitrate. Some of this material remains in shafts on the mesa top. Further information about activities, solid waste management units, and areas of concern at Technical Area 49 can be found in earlier Laboratory reports (LANL 2010a, 2010b).

In 2022, we found no constituents in Material Disposal Area AB monitoring group wells at concentrations above standards or screening levels.

White Rock Canyon Monitoring Group

The springs that flow along and near the Rio Grande in White Rock Canyon mostly discharge regional aquifer groundwater (Purtymun et al. 1980). A few springs appear to discharge perched-intermediate groundwater. Some other springs may discharge a mixture of regional aquifer groundwater, perched-intermediate groundwater, and percolation of recent precipitation (Longmire et al. 2007). The White Rock Canyon springs serve as important monitoring points for evaluating the Laboratory's potential to impact the Rio Grande (see Figure 5-7).

Six constituents (iron, aluminum, manganese, arsenic, benzo(a)anthracene, and dibenz(a,h)anthracene) were detected above applicable groundwater standards or screening levels for this monitoring group in 2022. We saw exceedances at two baseflow sampling locations and two springs. Table 5-2 shows the date, location, constituent, sample result, and sample purpose for each recorded exceedance.

Table 5-2. Results that exceeded applicable standards or screening levels in spring and perennial base flow samples in White Rock Canyon in 2022

Location	Sample Date	Constituent Name	Sample Result (micrograms per liter)	Standard or Screening Level (microgram per liter)	Sample Purpose
Rio Grande at Frijoles	10/04/2022	Aluminum	11100, 13000	5000	REG[a], FD[b]
Rio Grande at Frijoles	10/04/2022	Iron	7320, 8560	1000	REG, REG
Rio Grande at Frijoles	10/04/2022	Manganese	206, 230	200	REG, REG
Rio Grande at Otowi Bridge	10/11/2022	Aluminum	5,040	5,000	REG
Rio Grande at Otowi Bridge	04/13/2022	Iron	3,170	1,000	REG
Rio Grande at Otowi Bridge	10/11/2022	Iron	4,050	1,000	REG
Spring 2	04/20/2022	Arsenic	10.0	10	FD
Spring 4	10/13/2022	Benzo(a)anthracene	0.384 J[c]	0.12	REG
Spring 4	10/13/2022	Dibenz(a,h)anthracene	0.355 J	0.0343	FD

[a] REG = regular investigative sample.
[b] FD = field duplicate sample for quality assurance purposes.
[c] The analyte is classified as detected, but the reported concentration value is expected to be more uncertain than usual.

General Surveillance Monitoring

Los Alamos and Pueblo Canyon

Alluvial wells LAO-3a and LAUZ-1 in Los Alamos Canyon (see Figure 5-6) continue to show strontium-90 concentrations above or near the U.S. Environmental Protection Agency's 8 picocuries per liter maximum contaminant level (see Figure 5-24). Both locations show a steady declining trend for strontium-90. We have sampled alluvial well LAUZ-1 only periodically since 2011; it was sampled in 2018, 2019, 2021, and 2022. The concentration of strontium-90 in well LAUZ-1 was 64.5 picocuries per liter in 2011, 18.6 picocuries per liter in 2019, 17.1 picocuries per liter in 2021, and 6.01 picocuries per liter in 2022. The source of the strontium-90 is Solid Waste Management Unit 21-011(k), which was an outfall from industrial waste treatment at Technical Area 21. Strontium-90 is persistent at this location and in several downgradient alluvial wells near the confluence of DP Canyon with Los Alamos Canyon, but it has not been migrating to alluvial locations farther down Los Alamos Canyon (LANL 2004).

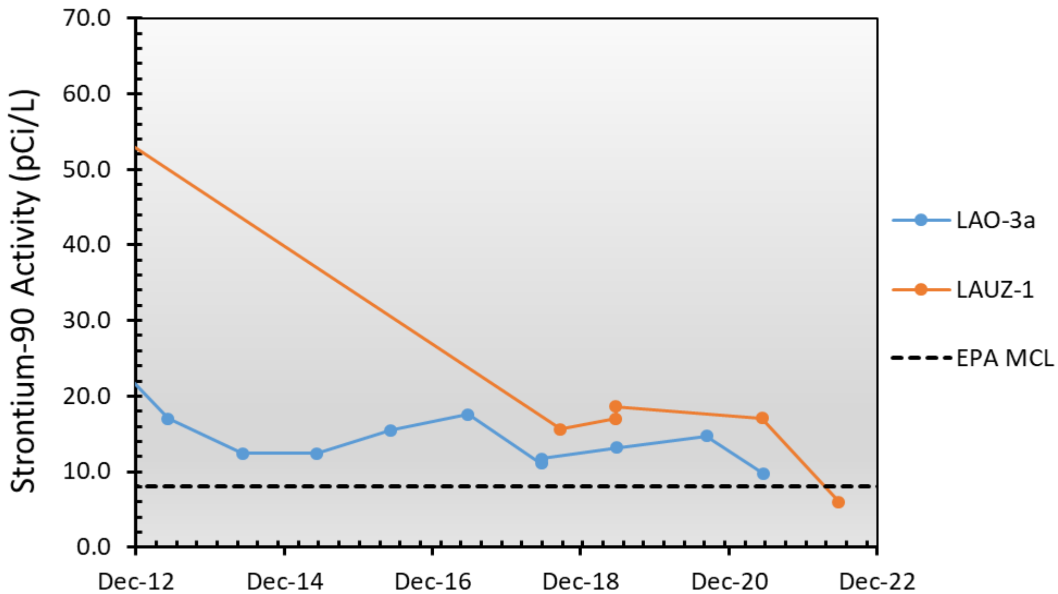


Figure 5-24. Strontium-90 levels at alluvial monitoring wells LAO-3a and LAUZ-1 in Los Alamos Canyon. The U.S. Environmental Protection Agency maximum contaminant level (EPA MCL) for strontium-90 in drinking water value is 8 picocuries per liter.

Alluvial wells PAO-5n and LAUZ-1 and intermediate wells POI-4 and R-3i in Pueblo Canyon showed results above the New Mexico Environment Department tap water screening level of 70 nanograms per liter for PFAS in 2022; respectively, the results were 195.9, 339.6, 136.7, and 86.4 nanograms per liter. As a new emerging contaminant, this was the third sampling event for PFAS. We will continue to monitor for PFAS at these locations.

Lower Los Alamos Canyon

Vine Tree Spring on Pueblo de San Ildefonso land discharges perched-intermediate groundwater. Sampling at Vine Tree Spring began as a replacement for nearby Basalt Spring, which we had sampled since the 1950s until it dried up around 2010. The perchlorate concentration in Vine Tree Spring for 2022 is consistent with prior years' data (see Figure 5-25). The perchlorate contamination could be associated with historical Laboratory operations. For context, the perchlorate values are below the risk-based screening level of 13.8 micrograms per liter. The screening level for perchlorate is determined according to a hierarchical data-screening process required under the 2016 Consent Order.

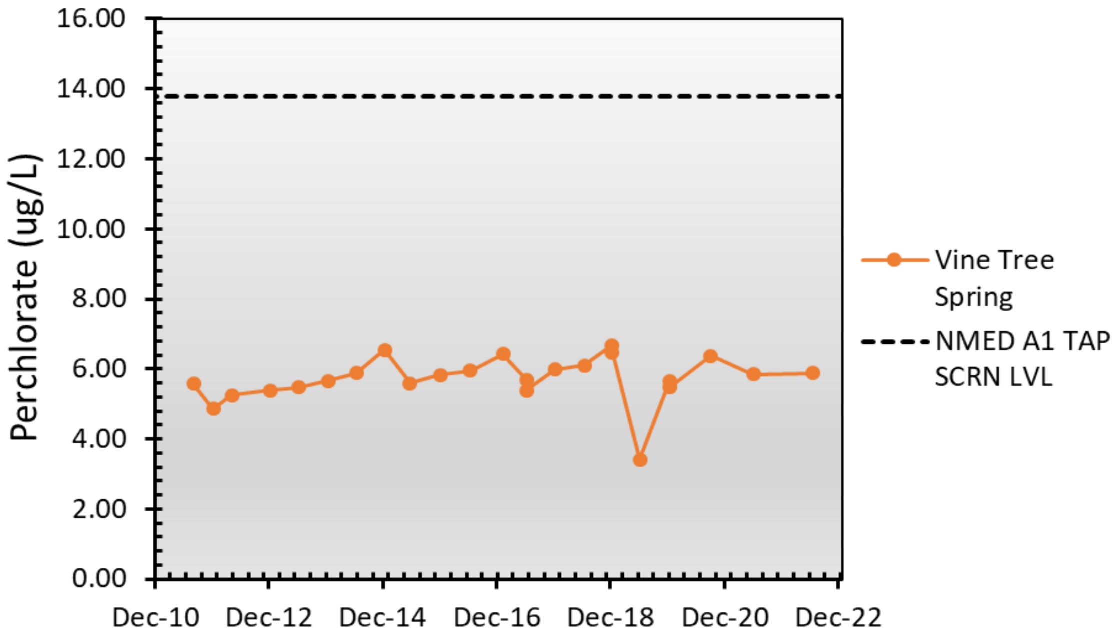


Figure 5-25. Perchlorate concentrations at Vine Tree Spring in Lower Los Alamos Canyon. The New Mexico tap water screening level (NM A1 TAP SCRN LVL), a risk-based screening level for perchlorate, is 13.8 micrograms per liter.

Sandia Canyon

The wells located in Sandia Canyon that are not part of the Chromium Investigation monitoring group include regional aquifer wells R-10 and R-10a and perched-intermediate well R-12. Wells R-10 and R-10a are located on Pueblo de San Ildefonso land. We measured no constituents near or above standards or screening levels in these wells during 2022.

Mortandad Canyon

Several regional aquifer wells in Mortandad Canyon are part of the General Surveillance monitoring group. No constituents in the regional aquifer during 2022 were measured above their respective screening values for these wells.

Under the groundwater discharge permit DP-1132 for the Technical Area 50 Radioactive Liquid Waste Treatment Facility outfall, we collect quarterly and annual samples from seven alluvial, perched-intermediate, and regional aquifer wells to monitor groundwater impacts from discharges to Mortandad Canyon, as discussed in Chapter 2 and later in this chapter.

Historically, we have detected perchlorate in alluvial monitoring wells MCO-4B, MCO-6, and MCO-7 (see Figure 5-26). Due to insufficient water, we have not sampled MCO-4B since 2017. MCO-6 has recently shown results much higher than the New Mexico tap water screening level for perchlorate. In 2022, we were unable to sample MCO-4B, MCO-6, and MCO-7.

Nitrate, fluoride, and total dissolved solids are far below applicable standards in these alluvial wells.

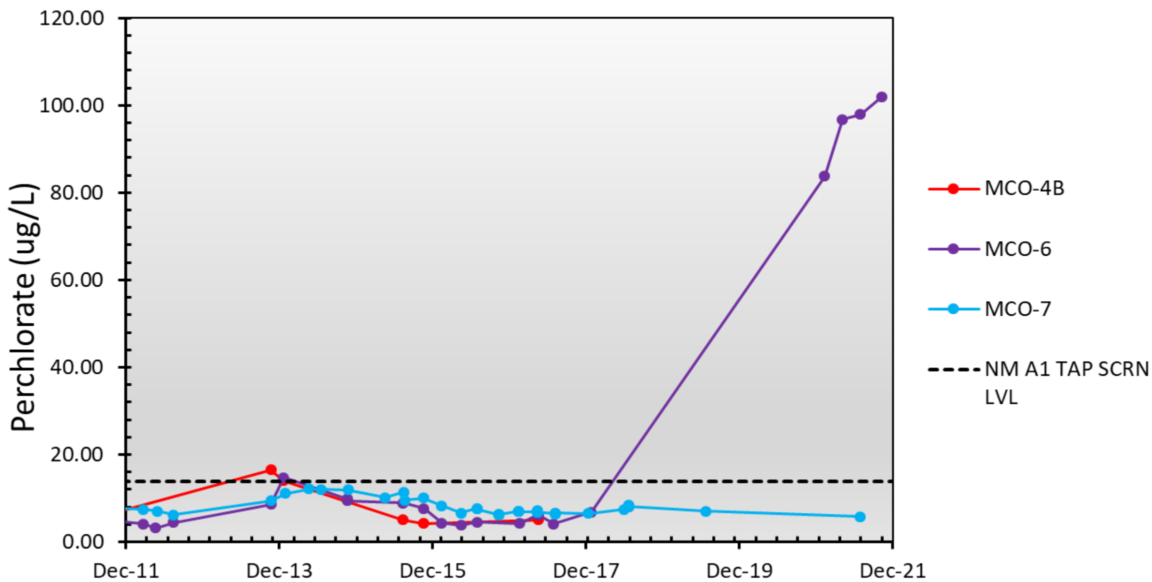


Figure 5-26. Perchlorate concentrations at General Surveillance monitoring group wells MCO-4B, MCO-6, and MCO-7 in Mortandad Canyon alluvial groundwater. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for perchlorate is 13.8 micrograms per liter.

Cañada del Buey

Alluvial well CDBO-6 in Cañada del Buey was dry in 2022, and therefore not sampled.

Pajarito Canyon

The Pajarito Canyon watershed begins in the Sierra de los Valles, west of the Laboratory. Twomile and Threemile Canyons at the Laboratory are tributaries of Pajarito Canyon. Saturated alluvium is present in portions of Pajarito Canyon—including a reach in lower Pajarito Canyon—but does not extend beyond the Laboratory's eastern boundary. In the past, the Laboratory released small amounts of wastewater into tributaries of Pajarito Canyon from several high-explosives-processing sites at Technical Area 09. A nuclear materials experimental facility occupied the floor of Pajarito Canyon at Technical Area 18. Waste management areas at Technical Area 54 occupy the mesa north of the lower part of the canyon.

Solid Waste Management Unit 03-010(a) is the outfall area from a former vacuum repair shop behind a warehouse at Technical Area 03. The outfall area is located on a small tributary to Twomile Canyon. A small zone of shallow perched-intermediate groundwater is present, apparently recharged by runoff from adjacent parking lots and building roofs. We sample this perched groundwater at a depth of approximately 21 feet via well 03-B-13. In 2021, samples from this well contained 1,1,1-trichloroethane at concentrations below the New Mexico groundwater standard (see Figure 5-27). Due to our scheduled sampling frequency, 03-B-13 does not have data for 1,1,1-trichloreothane in 2022. In 2022 03-B-13 contained aluminum at 3,970 micrograms per liter, up from 1,130 micrograms per liter in 2021, and iron at 2,170 micrograms per liter, up from 727 micrograms per liter in 2021. The New Mexico groundwater standard for aluminum is 5,000 micrograms per liter and for iron is 1,000 micrograms per liter. We detected 1,4-dioxane at 3.2 micrograms per liter in 03-B-13, below the 4.59 microgram per liter New Mexico groundwater standard (see Figure 5-28).

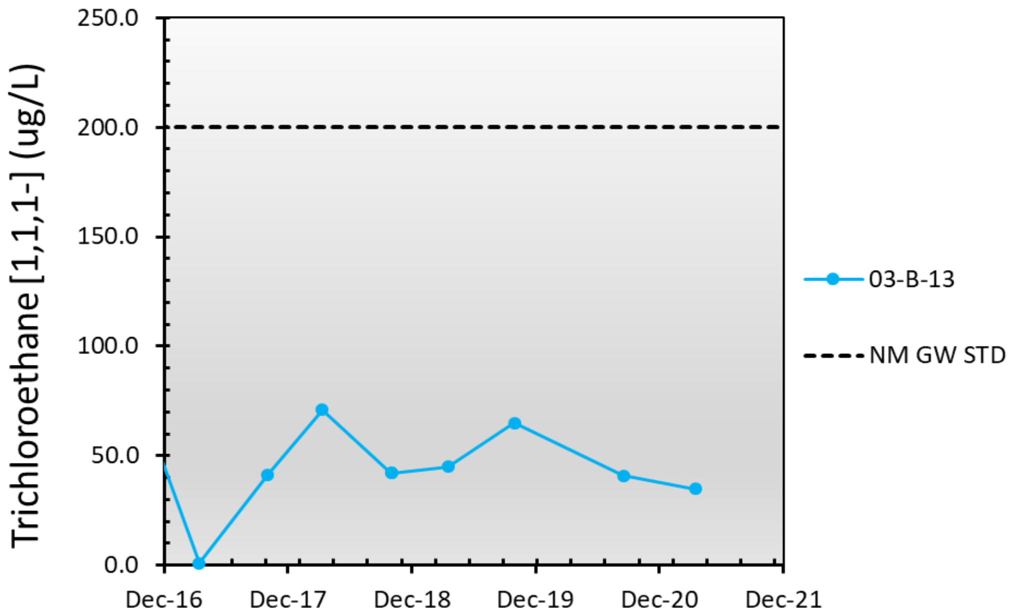


Figure 5-27. Concentrations of 1,1,1-trichloroethane in Pajarito Canyon perched-intermediate groundwater at General Surveillance monitoring group well 03-B-13. The New Mexico groundwater standard (NM GW STD) for 1,1,1-trichloroethane is 200 micrograms per liter.

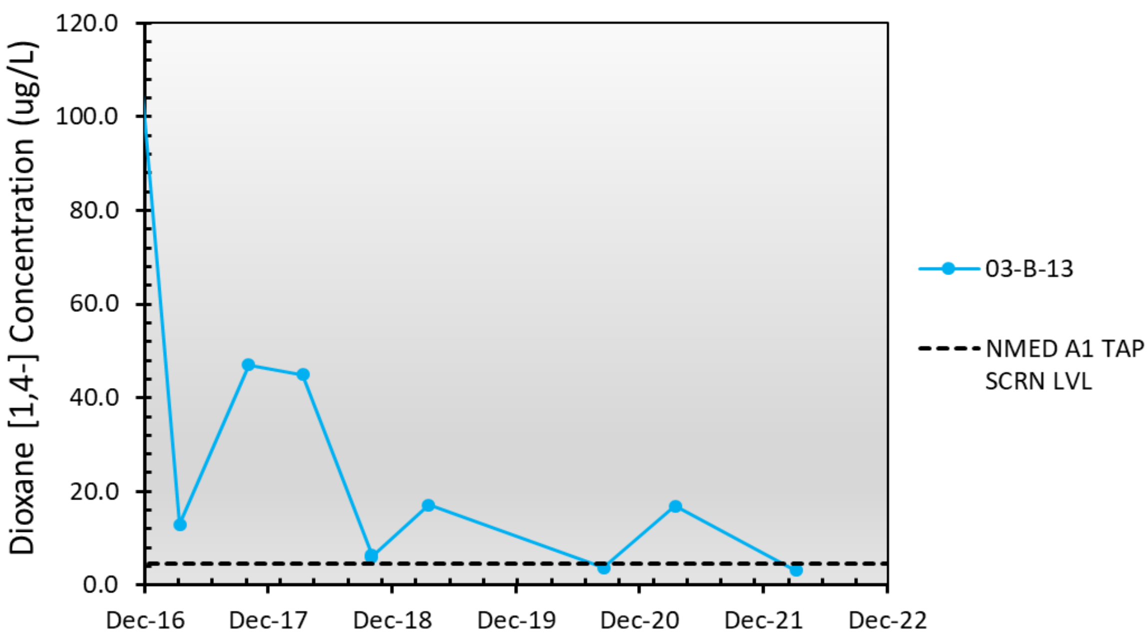


Figure 5-28. Concentrations of 1,4-dioxane in Pajarito Canyon watershed perched-intermediate groundwater at General Surveillance monitoring group well 03-B-13. The New Mexico tap water screening level (NM A1 TAP SCRN LVL) for 1,4-dioxane is 4.59 micrograms per liter.

Several other alluvial and perched-intermediate groundwater and regional aquifer wells in Pajarito Canyon are part of the General Surveillance monitoring group. At alluvial well 18-MW-18, we measured chloride at 346 milligrams per liter, above the New Mexico groundwater standard of 250 milligrams per liter.

Water Canyon has only one General Surveillance monitoring group location: alluvial well WCO-1r. We canceled the 2022 sampling event because of insufficient water during the time of sampling. During the previous sampling event in 2019, we detected iron at 1,560 micrograms per liter, which is above the 1,000 micrograms per liter New Mexico groundwater standard.

Groundwater Discharge Permit Monitoring

In samples collected in support of groundwater discharge permits (from wells MCA-RLW-1, MCA-RLW-2, MCOI-6, SCA-3, SCI-1, R-1, R-14 screen 1, R-46, and R-60), constituents identified in the groundwater discharge permits were measured above applicable standards or screening levels in 2022. Alluvial wells MCA-RLW-1 and SCA-3 were dry during the monitoring period. Several constituents not identified in the groundwater discharge permits related to historical operations were detected in perched/intermediate aquifer well MCOI-6; some of these constituents measured above applicable standards or screening levels, as presented in the Chromium Investigation Monitoring Group portion of this report.

Summary—PFAS Monitoring Results

PFAS are manufactured compounds used for a variety of purposes in various industrial, commercial, and consumer applications. As of December 2018, three PFAS compounds are identified as toxic pollutants under Ground and Surface Water Protection, Title 20, Chapter 6, Part 2 of the New Mexico Administrative Code: perfluorohexanesulfonic acid, perfluorooctanoic acid, and perfluorooctanesulfonic acid. During 2020 and 2021, we sampled for these three PFAS compounds at all Interim Facility-Wide Groundwater Monitoring locations. Beginning in 2022, we sampled only for PFAS compounds at locations where two rounds of PFAS sampling were not completed or where a regulatory standard was exceeded.

Before June 2022, the New Mexico regulatory standard for PFAS in groundwater was 70 nanograms per liter for the combined total concentration of the three PFAS compounds. As of June 2022, the regulatory standards for the PFAS compounds in groundwater are 401 nanograms per liter for perfluorohexanesulfonic acid, 60 nanograms per liter for perfluorooctanoic acid, and 60 nanograms per liter for perfluorooctanesulfonic acid. Table 5-3 provides our 2022 results for these three PFAS compounds in sampled locations in groundwater and perennial base flow.

Because of the potential for cross-contamination when sampling for PFAS compounds, a task group that consists of the New Mexico Environment Department, N3B, and DOE personnel was established before sampling in 2020 to determine best practices for collecting these samples. A standard operating procedure developed by the California State Water Boards (referenced in the N3B Groundwater Sampling SOP N3B-SOP-ER-3003, R0) is used by sampling personnel when collecting PFAS samples.

Table 5-3. PFAS Results for 2022 in Groundwater and Perennial Base Flow

Canyon	Location (well, spring, or perennial base flow sampling site)	Water Source	Sample Date	Perfluorooctanesulfonic acid (nanograms per liter)	Perfluorooctanoic acid (nanograms per liter)	Perfluorohexanesulfonic acid (nanograms per liter)	Sample Purpose
Technical Area 21 Monitoring Group							
Los Alamos	R-9i S1	Intermediate depth groundwater	9/20/2022	9.56	4.86	18.5	REG[a]
Chromium Investigation Monitoring Group							
Mortandad	MCOI-6	Intermediate depth groundwater	11/7/2022	ND[b]	0.979 J[c]	ND	REG
Technical Area 16 Monitoring Group							
Pajarito	Pajarito below S-N Ancho E Basin Confluence	Perennial base flow	03/08/2022	2.82	0.993 J	ND	REG
Water	CDV-16-02659	Alluvial groundwater	3/7/2022	ND	10.4	ND	REG
General Surveillance Monitoring Group							
Water	LAUZ-1	Alluvial groundwater	06/23/2022	135	81.6	123	REG
Pueblo	PAO-5n	Intermediate depth groundwater	6/24/2022	143	39.5	13.4	REG
Pueblo	POI-4	Intermediate depth groundwater	6/20/2022	79.4	40.7	16.6	REG
Pueblo	R-3i	Alluvial groundwater	6/27/2022	21.5	46.2	18.7	REG
Mortandad	MCO-5	Alluvial groundwater	7/21/2022	12.8	7.81	3.37	REG

[a] REG = regular investigative sample.
[b] ND = constituent not detected in the sample.
[c] The constituent is classified as detected, but the reported concentration value is expected to be more uncertain than usual.

Conclusion

The Laboratory has been monitoring groundwater for many years. As described in this chapter, only two areas are showing groundwater contaminants of sufficient concentration and extent to warrant an action such as interim measures, further characterization, and potential remediation under the 2016 Consent Order: RDX contamination in the vicinity of Technical Area 16 and chromium contamination beneath Sandia and Mortandad Canyons. Further characterization work and studies to evaluate groundwater risks and potential remediation strategies are ongoing in both areas.

Quality Assurance

The 2022 Interim Facility-Wide Groundwater Monitoring Plan (N3B 2021) documents all methods and procedures used to perform the field activities associated with these data.

Sampling and data validation were conducted using standard operating procedures that are part of a comprehensive quality assurance program. For a comprehensive list of these standard operating procedures, refer to Appendix B of the 2022 Interim Facility-Wide Groundwater Monitoring Plan (N3B 2021).

Analytical results meet the N3B minimum data quality objectives as outlined in N3B-PLN-SDM-1000, "Sample and Data Management Plan." N3B-PLN-SDM-1000 sets the validation frequency criteria at 100% Level 1 examination and Level 2 verification of data and at 10% minimum Level 3 validation of data.

- A Level 1 examination assesses the completeness of the data as delivered from the analytical laboratory, identifies any reporting errors, and checks the usability of the data based on the analytical laboratory's evaluation of the data.
- A Level 2 verification evaluates the data to determine the extent to which the laboratory met the analytical method and the contract-specific quality control and reporting requirements.
- A Level 3 validation includes Levels 1 and 2 criteria and determines the effect of potential anomalies encountered during analysis and possible effects on data quality and usability. A Level 3 validation is performed manually with method-specific data validation procedures.

N3B personnel validate laboratory analytical data as outlined in N3B-PLN-SDM-1000, ; N3B-AP-SDM-3000, "General Guidelines for Data Validation"; N3B-AP-SDM-3014, "Examination and Verification of Analytical Data"; and additional method-specific analytical data validation procedures. All associated validation procedures have been developed, where applicable, from the U.S. Environmental Protection Agency document EPA QA/G-8, "Guidance on Environmental Data Verification and Data Validation," the "Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories," the U.S. Environmental Protection Agency "National Functional Guidelines for Data Validation," and the American National Standards Institute/American Nuclear Society 41.5-2012 (R2018), "Verification and Validation of Radiological Data for Use in Waste Management and Environmental Remediation."

References

Buddemeier et al. 2000: R. W. Buddemeier, P. A. Macfarlane, and G. Misgna. "Aquifer Types and Terminology," Kansas Geological Survey atlas website http://www.kgs.ku.edu/HighPlains/atlas/aptyp.htm, revised November 21, 2000; accessed January 13, 2020.

Emelity 1996: L. A. Emelity. 1996. "A History of Radioactive Liquid Waste Management at Los Alamos," Los Alamos National Laboratory report LA-UR-96-1283.

LANL 1973: "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972," Los Alamos National Laboratory report LA-5184.

LANL 1988: "Environmental Surveillance at Los Alamos during 1987," Los Alamos National Laboratory report LA-11306-MS.

LANL 1998: "RFI Report for Potential Release Site 16-021(c)," Los Alamos National Laboratory report LA-UR-98-4101.

LANL 2003: "Corrective Measures Study Report for Solid Waste Management Unit 16-021(c)-99," Los Alamos National Laboratory report LA-UR-03-7627.

LANL 2004: "Los Alamos and Pueblo Canyons Investigation Report," Los Alamos National Laboratory report LA-UR-04-2714.

LANL 2005a: "Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau: A Synthesis of Hydrogeologic Workplan Activities (1998–2004)," Los Alamos National Laboratory report LA-14263-MS.

LANL 2005b: "Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54," Los Alamos National Laboratory report LA-UR-05-6398.

LANL 2006: "Investigation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54, Revision 1," Los Alamos National Laboratory report LA-UR-06-1564.

LANL 2007: "Addendum to the Investigation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54," Los Alamos National Laboratory report LA-UR-07-3214.

LANL 2009: "Investigation Report for Sandia Canyon," 2009, Los Alamos National Laboratory report LA-UR-09-6450.

LANL 2010a: "Investigation Report for Sites at Technical Area 49 Outside the Nuclear Environmental Site Boundary," Los Alamos National Laboratory report LA-UR-10-3095.

LANL 2010b: "Investigation Report for Sites at Technical Area 49 Inside the Nuclear Environmental Site Boundary," Los Alamos National Laboratory report LA-UR-10-3304.

LANL 2011a: "Phase III Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50," Los Alamos National Laboratory report LA-UR-11-3429.

LANL 2011b: "Investigation Report for Water Canyon/Cañon de Valle," Los Alamos National Laboratory report LA-UR-11-5478.

LANL 2012: "Phase II Investigation Report for Sandia Canyon," Los Alamos National Laboratory report LA-UR-12-24593.

LANL 2015: "Interim Measures Work Plan for Chromium Plume Control," Los Alamos National Laboratory report LA-UR-15-23126.

LANL 2017: "Completion Report for Groundwater Extraction Well CrEX-2," Los Alamos National Laboratory report LA-UR-17-27466.

N3B 2021: "Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year, October 2021–September 2022, Revision 1" N3B document EM2021-0535.

N3B 2022: "Interim Facility-Wide Groundwater Monitoring Plan for the 2023 Monitoring Year, October 2022–September 2023, Revision 1" N3B document EM2022-0656.

New Mexico Environment Department 2022: "Risk Assessment Guidance for Site Investigations and Remediation: Volume I, Soil Screening Guidance for Human Health Risk Assessments," released November 2022. https://www.env.nm.gov/hazardous-waste/wp-content/uploads/sites/10/2022/11/NMED_SSG_VOL_I_Nov_2022.pdf

LANL 2018a: "Compendium of Technical Reports Conducted Under the Work Plan for Chromium Plume Center Characterization," Los Alamos National Laboratory report LA-UR-18-21450.

LANL 2018b: "Completion Report for Groundwater Extraction Well CrEX-4," Los Alamos National Laboratory report LA-UR-18-23083.

Longmire et al. 2007: P. Longmire, M. Dale, D. Counce, A. Manning, T. Larson, K. Granzow, R. Gray, and B. Newman. 2007. "Radiogenic and Stable Isotope and Hydrogeochemical Investigation of Groundwater, Pajarito Plateau and Surrounding Areas, New Mexico," Los Alamos National Laboratory report LA-14333.

Purtymun and Stoker 1987: W. D. Purtymun, and A. K. Stoker. 1987. "Environmental Status of Technical Area 49, Los Alamos, New Mexico," Los Alamos National Laboratory report LA-11135-MS.

Purtymun et al. 1980: W. D. Purtymun, R. J. Peters, and J. W. Owens. 1980. "Geohydrology of White Rock Canyon from Otowi to Frijoles Canyon," Los Alamos Scientific Laboratory report LA-8635-MS.

Rogers 2001: D. B. Rogers. 2001. "Impact of Sr-90 on Surface Water and Groundwater at Los Alamos National Laboratory through 2000," Los Alamos National Laboratory report LA-13855-MS.

Chapter 6: Watershed Quality

Los Alamos National Laboratory (LANL or the Laboratory) collects and analyzes storm water runoff to check for a variety of substances and characteristics, such as chemical and radionuclide levels, the volume and duration of flow, and the total amount of suspended sediment. We compare these sampling results with New Mexico water quality standards, target action levels, and radiological dose guidelines. The State of New Mexico uses our surface water data in updating its determinations of impaired waters on and near the Laboratory every 2 years.

We also analyze newly deposited sediment samples each year for chemical and radionuclide levels. We compare sediment sampling results with human and ecological health screening criteria. We have found that over time, at any given sampling location, storm-water-related transport of sediment generally results in similar or lower levels of Laboratory-released chemicals and radionuclides at that location than previously existed because of the deposition of new sediment. The New Mexico Environment Department has identified several impaired stream reaches on Laboratory property. Laboratory industrial outfalls are regulated to help minimize these impairments.

Introduction

Unregulated liquid discharges that contained radionuclides, inorganic chemicals, and organic chemicals were released into canyons around the Laboratory during the early years of its operation. Treatments to reduce contaminants in these effluents began in the 1950s. Effluent discharges at the Laboratory have been conducted under permits from regulatory agencies since 1978; however, not all chemicals in local storm water runoff and sediment come from the Laboratory. Other sources of chemicals and radionuclides include the natural composition of rocks and soils, substances associated with trees burned during forest fires, atmospheric deposition of radionuclides and chemicals such as polychlorinated biphenyls (PCBs), and effluent releases and emissions from townsites on the Pajarito Plateau. All of these natural and manufactured sources contribute to the measured levels of chemicals and radionuclides in surface water and sediment across the Pajarito Plateau.

We monitor chemical and radionuclide levels in surface water and sediment in and around the Laboratory to document the water quality in streams within and downstream of the Laboratory and to evaluate risks to human and ecosystem health. Sampling results are compared with New Mexico water quality standards, target action levels from LANL's Storm Water Individual Permit, radiological dose guidelines, and human and ecosystem health screening criteria. The Storm Water Individual Permit is LANL's authorization to discharge (from solid waste management units and areas of concern) under the National Pollutant Discharge Elimination System. (See Chapter 2 for more information about the permit.)

The data presented in this chapter are compiled from three Laboratory programs:

- Annual environmental surveillance sampling of storm water runoff and sediment (N3B 2022a, N3B 2023a, N3B 2023b)
- Implementation of the annual Interim Facility-Wide Groundwater Monitoring Plans (N3B 2021, N3B 2022b), which includes sampling of persistent surface water in streams

- Storm water runoff monitoring associated with the Storm Water Individual Permit (N3B 2023c)

In April 2018, the legacy waste cleanup contractor Newport News Nuclear BWXT-Los Alamos (N3B) assumed responsibility for implementing the Laboratory's surface water and sediment surveillance program, the groundwater protection program, and the Storm Water Individual Permit. The managing and operating contractor, Triad, manages Clean Water Act compliance for current operations, including compliance with outfall permit limits and implementation of storm water pollution prevention plans and low-impact development controls. Triad has also installed engineered structures for watershed enhancement.

At the Laboratory, we consider any soil that is either suspended in water or that has been deposited by surface water flows as sediment. Many of our sediment samples are collected from dry stream channels or adjacent floodplains and not from aquatic habitats.

Hydrologic Setting

Laboratory lands contain all or parts of seven watersheds that drain into the Rio Grande basin (see Figure 6-1). The watersheds are named after the major canyon in each watershed. Listed from north to south, the major canyons are Los Alamos, Sandia, Mortandad, Pajarito, Water, Ancho, and Chaquehui. The watershed headwaters for Los Alamos, Pajarito, and Water canyons are located west of the Laboratory in the eastern Jemez Mountains, mostly within the Santa Fe National Forest. The remainder of the watersheds have their headwaters on the Pajarito Plateau. Only the Ancho Canyon watershed is located entirely on Laboratory land. Pueblo Canyon, which is north of Los Alamos Canyon but not on Laboratory land, is also monitored because of historical Laboratory activities in the area.

Figure 6-2 shows the precipitation amounts and storm water runoff volume for the Laboratory for the monsoonal period of June through October during the years 1995 to 2022. In 2022, snowmelt runoff crossed the downstream (eastern) boundary of the Laboratory at gaging stations in Chaquehui, Mortandad, Pajarito, Pueblo, Sandia, and Water canyons. Total snowmelt runoff for 2022 measured at these stations is estimated at 16 acre-feet, with most of the runoff occurring in Pajarito Canyon. Total storm water flow off the Laboratory for June to October 2022—measured at the downstream Laboratory boundary—is estimated at 92 acre-feet. Most of this runoff occurred in Ancho and Chaquehui canyons; minimal runoff (less than 2.2 acre-feet) occurred in Los Alamos and Sandia canyons; Pajarito, Potrillo, Pueblo, Mortandad, and Water canyons, and Cañada del Buey recorded runoff less than 1 acre-foot. No effluent from the Los Alamos County Waste Water Treatment Facility reached gaging station E060.1 in lower Pueblo Canyon during storm events in 2022, as evidenced by gaging station records that show that storm flow

Terms related to surface water

Base flow – the portion of a perennial stream's flow that is sustained between precipitation events

Effluent – water resulting from industrial processes that is discharged to the environment

Floodplain – an area of land adjacent to a stream that may receive water when the stream floods

Storm water – water that comes as runoff from rain and snowmelt events

Stream reach – a section of a stream or river along which similar hydrologic conditions exist, such as discharge, depth, area, geology, and slope

Surface water – water on the surface of a continent, such as in a river, lake, or wetland recorded at gaging station E059.5 (directly below the facility) did not reach the downstream gaging station E060.1.

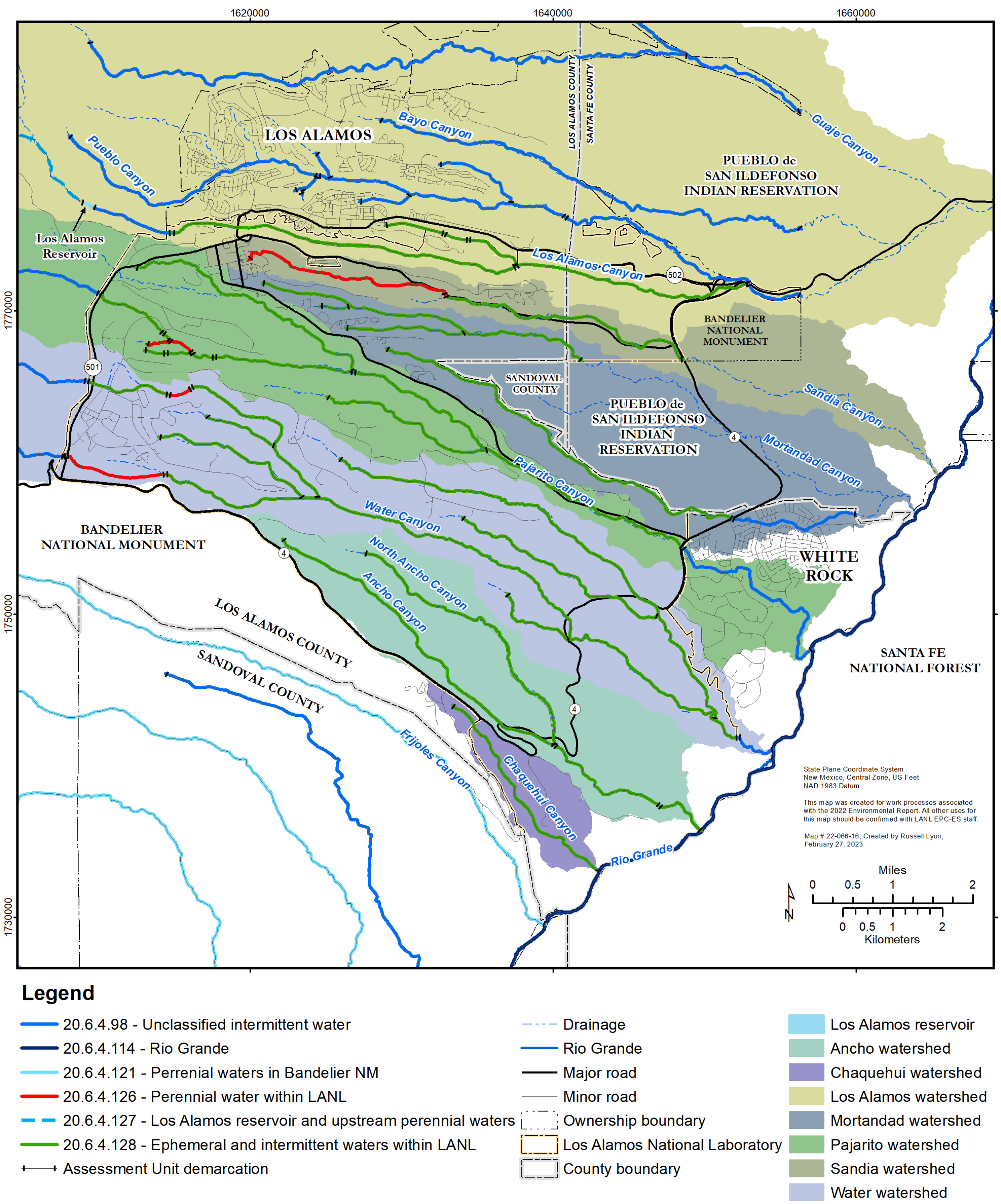


Figure 6-1. Stream reaches and watersheds within and around the Laboratory. Map shows the classifications of streams from Standards for Interstate and Intrastate Surface Waters, Title 20, Chapter 6, Part 4, of the New Mexico Administrative Code.

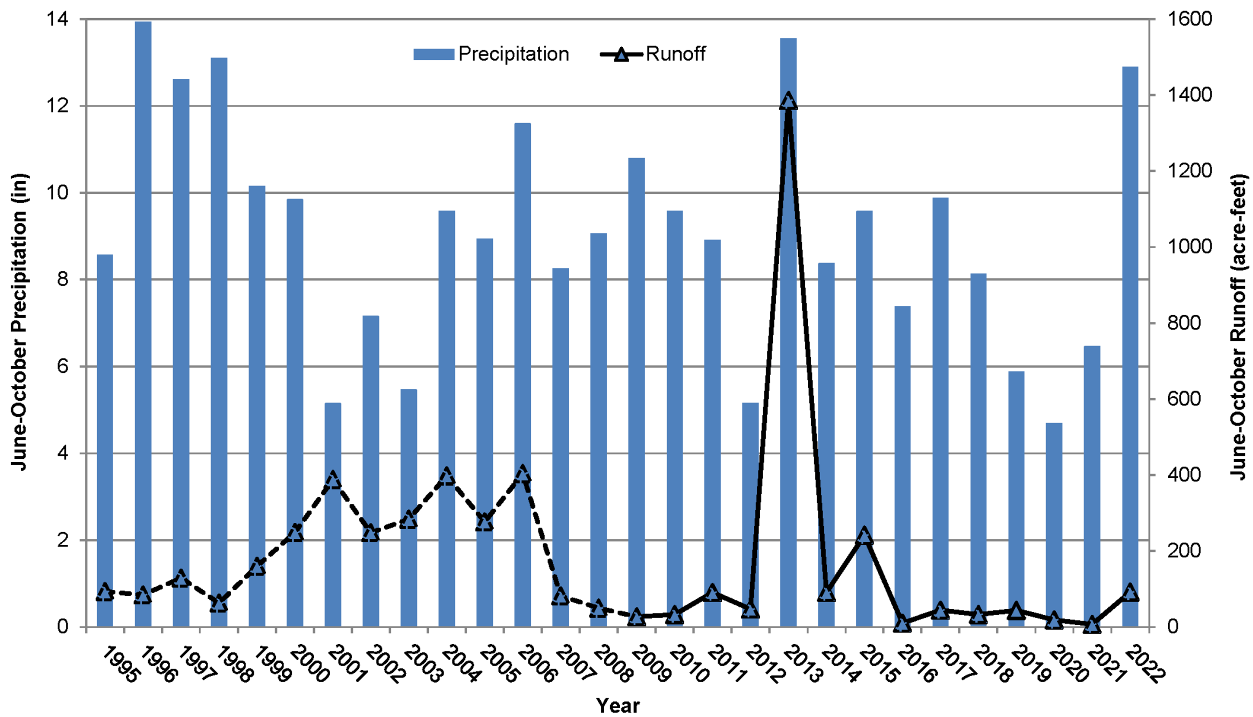


Figure 6-2. Total June–October precipitation from 1995 to 2022 averaged across the Laboratory's meteorological tower network (Technical Area 06, Technical Area 49, Technical Area 53, Technical Area 54, and northern community) and estimated June–October storm water runoff volume in Laboratory canyons from 1995 to 2022. Dashed line indicates data with potential quality issues.

Standards, Screening Levels, and Designated Uses for Stream Reaches

Surface Water Standards and Screening Levels

The New Mexico Water Quality Control Commission establishes surface water quality standards for New Mexico in Standards for Interstate and Intrastate Surface Waters, Title 20, Chapter 6, Part 4, of the New Mexico Administrative Code. New Mexico's water quality standards designate uses for surface waters and set criteria to protect those uses. Therefore, the standard(s) applied to a particular surface water (such as the livestock watering standard or the limited aquatic life standard) depend on the codified designated use(s) of that surface water. The standards used for our evaluations in this chapter were approved by the U.S. Environmental Protection Agency on January 20, 2023, and can be found online at https://www.env.nm.gov/surface-water-quality/wqs/. We use a protocol published by the New Mexico Environment Department to assess attainment of surface water quality standards (New Mexico Environment Department 2021). Hardness-dependent aquatic life criteria for metals are calculated using water hardness values of concurrent samples (U.S. Environmental Protection Agency 2006a, Water Quality Control Commission 2022).

U.S. Department of Energy (DOE) Order 458.1 Chg 4, Radiation Protection of the Public and the Environment, sets total dose limits for radioactivity released during Laboratory operations. Limits apply to members of the public, plants, and animals; therefore, our radiological assessment of surface water evaluates the potential exposures of aquatic organisms as well as animals living on land (collectively called "biota"). We compare radionuclide activities in surface water with the DOE biota concentration guides (DOE 2019) and with site-specific modifications by McNaughton et al. (2013). Biota concentration guides for aquatic, riparian, or terrestrial animals are used for evaluation depending on how often surface water is present at the location. Both perennial reaches and intermittent reaches are screened using aquatic, terrestrial, and riparian animal biota concentration guides; ephemeral reaches are screened using terrestrial animal biota concentration guides. Biota dose results are provided in Chapter 7.

We compare surface water results for gross alpha radioactivity and isotopes of radium with the New Mexico water quality standards. The gross alpha standard does not apply to source, special nuclear, or byproduct material regulated by DOE under the Atomic Energy Act of 1954. The gross alpha radioactivity data discussed in this chapter were not adjusted to remove these sources of radioactivity.

We compare surface water results from the Storm Water Individual Permit site monitoring areas with the target action levels specified in the permit. Additional details for site monitoring area results are provided in the 2022 Update to the Site Discharge Pollution Prevention Plan (N3B 2023c).

Sediment Screening Levels

We compare analytical results for chemicals in sediment to the New Mexico Environment Department's risk-based soil screening levels (New Mexico Environment Department 2022a) and radionuclides in sediment to the Laboratory's risk-based screening action levels (LANL 2015). If no New Mexico soil screening levels exist for a particular chemical, the U.S. Environmental Protection Agency's regional screening levels are used (U.S. Environmental Protection Agency 2020). The soil screening levels for inorganic and organic chemicals and the screening action levels for radionuclides are levels considered safe for human industrial, construction worker, or residential exposure scenarios. If concentrations of substances are below screening action levels or soil screening levels, then adverse human health effects are highly unlikely. In addition, we use sediment background values from Ryti et al. (1998) for reference. (Note: The New Mexico surface water quality standards address only total PCBs and not individual PCB congeners, whereas the soil screening levels address individual PCB congeners and not total PCBs).

These various screening levels provide a high level of confidence in determining a low probability of risk to human health. They are not designed or intended to provide definitive estimates of actual risk and might not represent the current land use (U.S. Environmental Protection Agency 2001). For example, onsite data are compared with residential screening levels, although no residences are nearby. We evaluate human health risks from exposure to storm water in Chapter 8, Public Dose and Risk Assessment.

For evaluating risks to biota, we compare radionuclide activities in sediment with the DOE biota concentration guides (DOE 2019) and with site-specific modifications by McNaughton et al. (2013). Biota concentration guides for riparian and terrestrial animals are used for the evaluation.

State of New Mexico Assessments of Stream Reaches

The New Mexico Environment Department Surface Water Quality Bureau uses surface water sampling results to evaluate impairment of the state's stream reaches under Section 303(d) of the Clean Water Act. They update the list of impaired stream reaches, including those on Laboratory property, every 2 years (New Mexico Environment Department 2022b).

Stream reaches are divided into assessment units. Each assessment unit is assigned one or more of the following designated uses based on its characteristics: cold water aquatic life, marginal warm water aquatic life, limited aquatic life, livestock watering, wildlife habitat, primary (human) contact, secondary (human) contact, and human health-organism only. An assessment unit is considered impaired when one or more of the New Mexico surface water quality standards based on its designated use(s) are not met.

The locations of assessment units on and around the Laboratory are shown in Figure 6-1. The current status of each designated use (supported, not supported, or not assessed) for each assessment unit and the identified cause of impairment, if any, are listed in Table 6-1. The New Mexico Environment Department's 2022–2024 report added selenium and removed mercury as impairment causes in Los Alamos Canyon (New Mexico Route 4 to DP Canyon) and removed mercury as impairment causes in Mortandad Canyon (within LANL) (New Mexico Environment Department 2022b).

What is the Human Health Organism-Only Designated Use and Surface Water Quality Standard?

One designated use of a water body can be people catching and eating fish or other aquatic wildlife (such as crayfish) that live there. The intent of the human health organism-only water quality standard is to protect the health of humans who eat fish or other aquatic wildlife that live in a lake, river, or stream.

Table 6-1. LANL Assessment Units, Impairment Cause, and Designated Use(s) Supported, Not Supported, or Not Assessed during 2022–2024

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Acid Canyon (Pueblo Canyon to headwaters)	Gross alpha,[a] aluminum, PCBs,[b] copper	None	Wildlife habitat, livestock watering, marginal warm water aquatic life	Primary contact
Ancho Canyon (Above Ancho Springs to North Fork Ancho)	PCBs, mercury	Livestock watering	Limited aquatic life, wildlife habitat	Secondary contact
Ancho Canyon (North Fork to headwaters)	PCBs	Wildlife habitat	Limited aquatic life	Secondary contact, livestock watering
Ancho Canyon (Rio Grande to Ancho Springs	PCBs, mercury	Livestock watering	Limited aquatic life, wildlife habitat	Secondary contact
Arroyo de la Delfe (above Kieling Spring to headwaters)	Copper, PCBs, aluminum, gross alpha	None	Limited aquatic life, livestock watering, wildlife habitat	Secondary contact
Arroyo de la Delfe (Pajarito Canyon to Kieling Spring)	Copper, PCBs, aluminum, gross alpha	None	Limited aquatic life, livestock watering, wildlife habitat	Secondary contact
Cañada del Buey (within LANL)	PCBs, gross alpha	None	Limited aquatic life, livestock watering	Secondary contact, wildlife habitat
Cañon de Valle (below LANL gage E256)	Gross alpha	Wildlife habitat, limited aquatic life	Livestock watering	Secondary contact
Cañon de Valle (LANL gage E256 to Burning Ground Spring)	PCBs	Livestock watering	Cold water aquatic life, wildlife habitat	Secondary contact
Cañon de Valle (upper LANL boundary to headwaters)	Gross alpha, PCBs	Wildlife habitat	Marginal warm water aquatic life, livestock watering	Primary contact
Cañon de Valle (within LANL above Burning Ground Spring)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Chaquehui Canyon (within LANL)	PCBs	Wildlife habitat, livestock watering	Limited aquatic life	Secondary contact

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
DP Canyon (100 meters downstream of grade control to 400 meters upstream of grade control)	Copper, PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
DP Canyon (400 meters upstream of grade control to upper LANL boundary)	Copper, PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
DP Canyon (Los Alamos Canyon to 100 meters downstream of grade control)	PCBs, aluminum, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Fence Canyon (above Potrillo Canyon)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Graduation Canyon (Pueblo Canyon to headwaters)	Copper, PCBs	Livestock watering	Wildlife habitat, marginal warm water aquatic life	Primary contact
Indio Canyon (above Water Canyon)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Kwage Canyon (Pueblo Canyon to headwaters)	Not assessed	Not applicable	Not applicable	Primary contact, wildlife habitat, livestock watering, marginal warm water aquatic life
Los Alamos Canyon (DP Canyon to upper LANL boundary)	PCBs, cyanide, selenium, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Los Alamos Canyon (New Mexico Route 4 to DP Canyon)	Aluminum, PCBs, cyanide, radium, gross alpha, selenium	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Mortandad Canyon (within LANL)	Copper, gross alpha, PCBs	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
North Fork Ancho Canyon (Ancho Canyon to headwaters)	Gross alpha, PCBs	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Pajarito Canyon (Arroyo de La Delfe to Starmers Spring)	None	Livestock watering, cold water aquatic life wildlife habitat	None	Secondary contact
Pajarito Canyon (lower LANL boundary to Twomile Canyon)	Aluminum, PCBs, copper, gross alpha, cyanide	Wildlife habitat, limited aquatic life, livestock watering	None	Secondary contact
Pajarito Canyon (Twomile Canyon to Arroyo de La Delfe)	PCBs, silver, copper, gross alpha	Wildlife habitat	Livestock watering, limited aquatic life	Secondary contact
Pajarito Canyon (upper LANL boundary to headwaters)	Gross alpha, cyanide, PCBs, aluminum, mercury	None	Warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Pajarito Canyon (within LANL above Starmers Gulch)	Aluminum, gross alpha	Wildlife habitat	Livestock watering, limited aquatic life	Secondary contact
Potrillo Canyon (above Water Canyon)	Gross alpha	Limited aquatic life, wildlife habitat	Livestock watering	Secondary contact
Pueblo Canyon (Acid Canyon to headwaters)	Gross alpha, PCBs, copper, aluminum	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Pueblo Canyon (Los Alamos Canyon to Los Alamos Waste Water Treatment Plant)	Gross alpha, aluminum, PCBs, selenium	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Pueblo Canyon (Los Alamos Waste Water Treatment Plant to Acid Canyon)	Gross alpha, PCBs	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Sandia Canyon (Sigma Canyon to National Pollutant Discharge Elimination System Outfall 001)	PCBs, aluminum,[c] copper,[c] temperature	Livestock watering	Wildlife habitat, cold water aquatic life	Secondary contact

Assessment Unit Name	Impairment Cause	Designated Use Supported	Designated Use Not Supported	Designated Use Not Assessed
Sandia Canyon (within LANL below Sigma Canyon)	PCBs, aluminum,[c] gross alpha, mercury,[c] copper[c]	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
South Fork Acid Canyon (Acid Canyon to headwaters)	Gross alpha, copper, PCBs	None	Marginal warm water aquatic life, livestock watering, wildlife habitat	Primary contact
Ten Site Canyon (Mortandad Canyon to headwaters)	PCBs, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Three-Mile Canyon (Pajarito Canyon to headwaters)	Gross alpha	Limited aquatic life, wildlife habitat	Livestock watering	Secondary contact
Twomile Canyon (Pajarito Canyon to headwaters)	PCBs, aluminum, copper, gross alpha	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact
Walnut Canyon (Pueblo Canyon to headwaters)	PCBs, copper	Livestock watering, wildlife habitat	Marginal warm water aquatic life	Primary contact
Water Canyon (Area A Canyon to New Mexico Route 501)	None	Cold water aquatic life, livestock watering, wildlife habitat	None	Secondary contact
Water Canyon (within LANL above New Mexico Route 501)	Not assessed	Not applicable	Not applicable	Livestock watering, limited aquatic life, wildlife habitat, secondary contact
Water Canyon (within LANL below Area A Canyon)	PCBs, aluminum, gross alpha, mercury	None	Livestock watering, limited aquatic life, wildlife habitat	Secondary contact

[a] Gross alpha levels in surface water samples are currently not adjusted to remove sources of radioactivity from source, special nuclear, or byproduct material regulated by DOE under the Atomic Energy Act of 1954.

[b] PCBs are total PCBs in the water column.

[c] LANL submitted a third-party IR Category 4b demonstration titled, "Sandia Canyon Assessment Unit NM-9000.A_047 and NM-128.A_11 Dissolved Copper, Mercury and Total Recoverable Aluminum 4B Demonstration" (https://www.env.nm.gov/surface-water-quality/303d-305b/). Accordingly, the associated aluminum and copper listings in this assessment unit are noted as IR Category 4B.

Surface Water and Sediment Sampling

Surface Water Sampling Locations and Methods

We maintain 38 stream gaging stations on and near the Laboratory, 36 of which are equipped with automated samplers that activate at the start of storm water runoff events. Storm water samples are also collected at eight additional stream channel locations. The sampling locations are chosen to monitor surface water flow onto and off Laboratory and former Laboratory lands and at the confluence of canyons.

The number of gaging stations and stream channel sampling locations remains fairly constant over time; however, not all gaging stations or channel sampling locations experience storm water flow in any given year, so the number of locations with samples varies widely from year to year.

The automated samplers at gaging stations are programmed to start collecting water 10 minutes after the peak flow during a runoff event, referred to as "Peak + 10." The year 2022 was the twelfth year that the Peak + 10 sampling method was employed at the gaging stations. We implemented this method based on comments from the New Mexico Environment Department that water samples collected before the peak of the storm flow were highly variable and therefore not ideal for monitoring contaminant and sediment transport. Previously, from 2004–2010, samples were collected at the peak of the runoff event. As a result, current storm water sampling results are not directly comparable to data collected before 2011.

To meet monitoring requirements under the Storm Water Individual Permit, we have samplers in 239 site monitoring areas to sample storm water runoff directly from 397 solid waste management units and areas of concern. These samplers do not remain in operation during months with freezing temperatures. Because rainstorms on the Pajarito Plateau are frequently very localized and not all rainfall events produce storm water runoff, not all active Storm Water Individual Permit sampling locations collect samples each year.

Water from springs is regulated under groundwater standards and is discussed in Chapter 5. Water discharged from springs that has infiltrated and resurfaced is base flow that is regulated under surface water standards. We collected grab samples of base flow at locations identified in the "Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year, October 2021–September 2022" and the "Interim Facility-Wide Groundwater Monitoring Plan for the 2023 Monitoring Year, October 2022–September 2023" (N3B 2021, N3B 2022b).

Figure 6-3 shows locations where samples were collected in 2022 for storm water at stream gaging stations, at sediment-detention basins, and for base flow. Figure 6-4 shows Storm Water Individual Permit site monitoring areas where compliance samples were collected in 2022. We collected 21 samples from 20 Storm Water Individual Permit site monitoring areas in 2022.

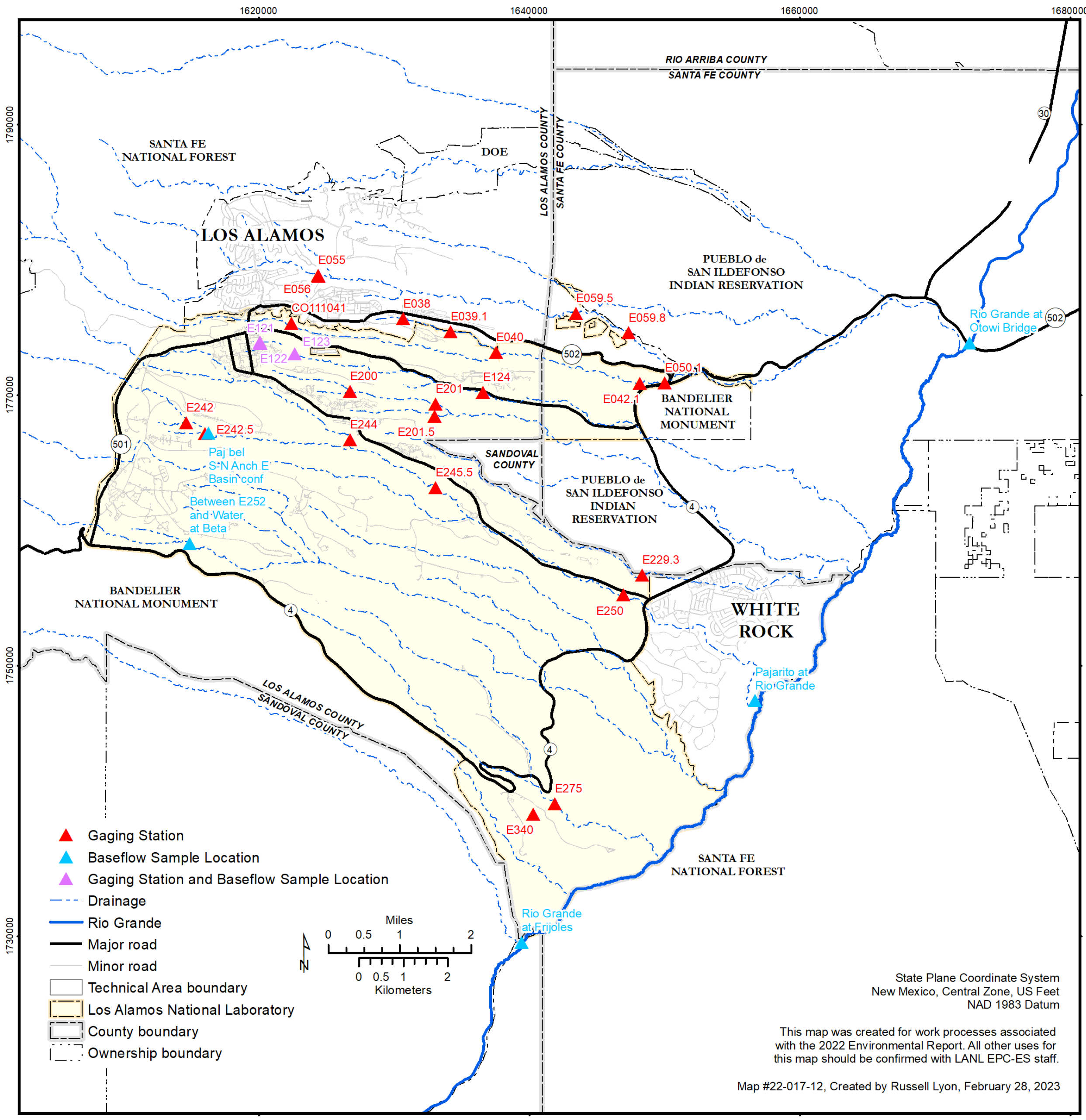


Figure 6-3. Locations sampled for storm water in 2022 at stream gaging stations and for base flow.

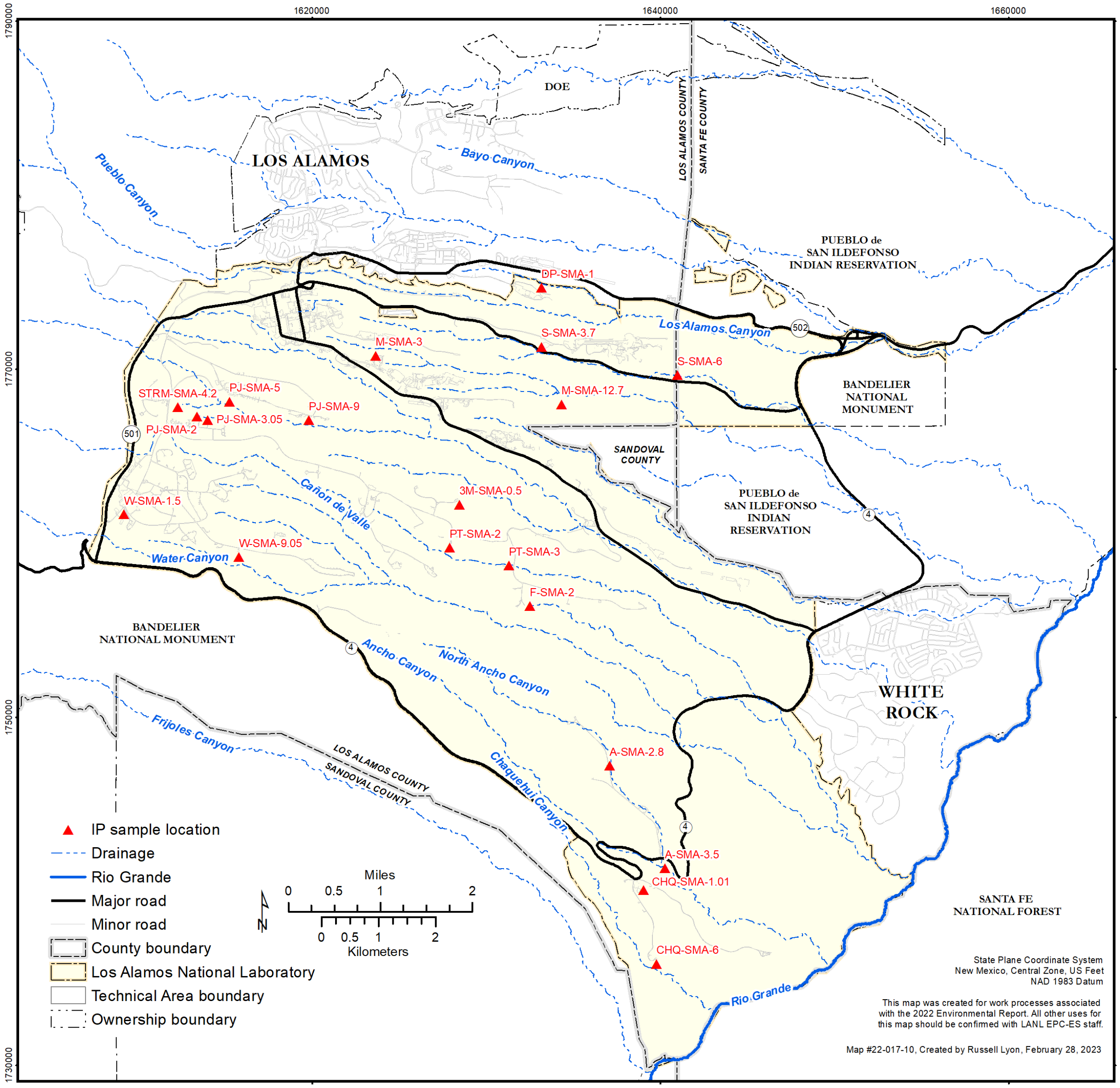


Figure 6-4. Storm Water Individual Permit (IP) site monitoring areas where automated samplers collected storm water samples in 2022.

Sediment Sampling Locations and Methods

Figure 6-5 shows locations sampled for sediment in 2022 as part of the annual environmental surveillance program. Sediment samples were collected at a depth of between 0 and 6 inches, depending on the thickness of the uppermost sediment layer. We collected samples from stream channels and floodplains where new sediment was deposited during 2022. For streams with flowing water, sediment samples were collected near the edge of the main channel adjacent to, but not in, the water. During 2022, storm water runoff flowed in every canyon on Laboratory property; therefore, sediment samples were collected from all major watersheds.

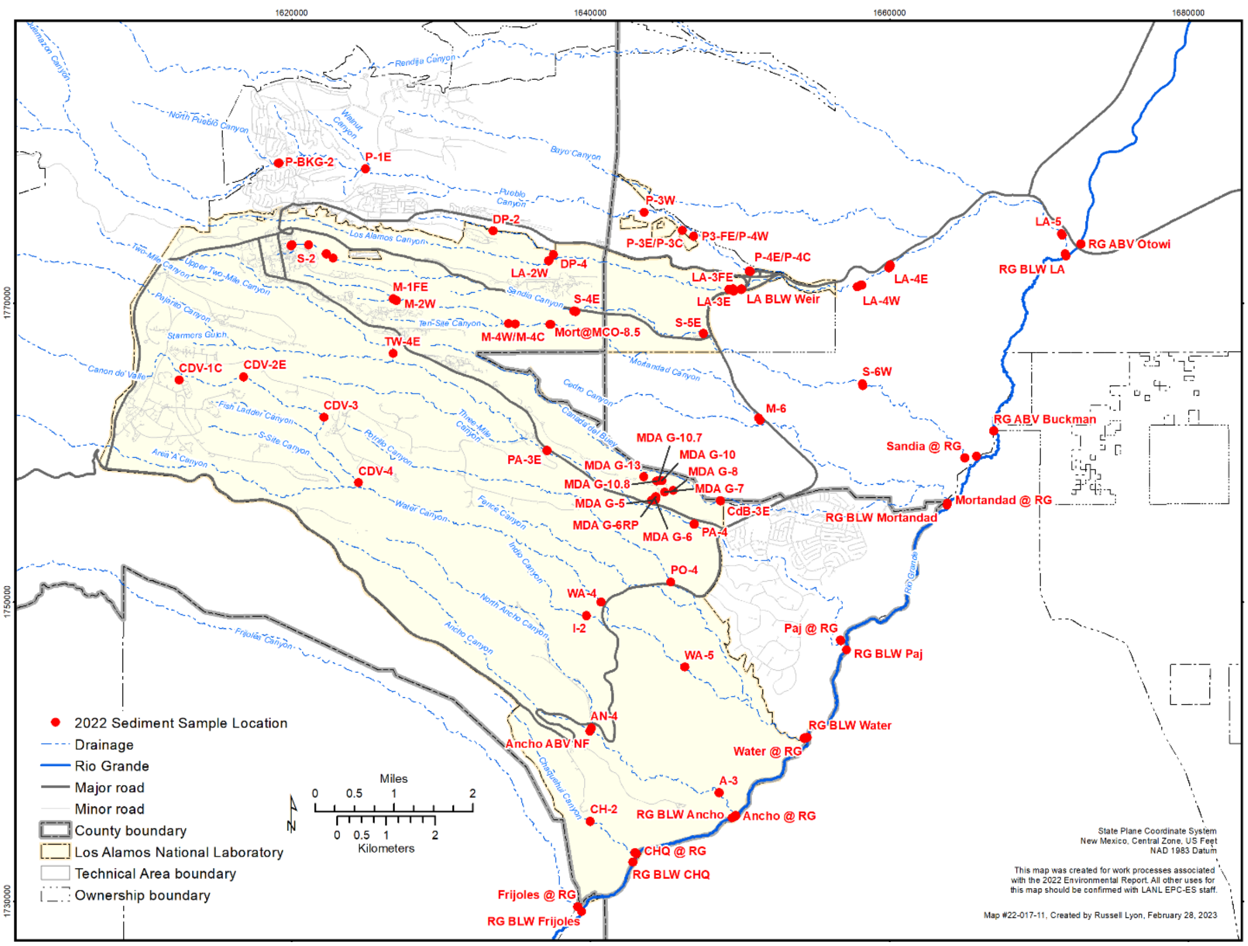


Figure 6-5. Locations sampled in 2022 for sediment as part of the annual environmental surveillance program.

Results

Table 6-2 summarizes inorganic chemical results for 2022 storm water and base flow samples, and Table 6-3 summarizes organic chemical and radionuclide results for 2022 storm water and base flow samples. We collected storm water from 25 locations and base flow samples from 8 locations in 2022. For inorganic chemicals, five locations had no exceedances, five had one inorganic element exceed an applicable New Mexico water quality standard (all for total aluminum), seven had two inorganic elements exceed (total aluminum plus one other inorganic element), and the remainder had more than two inorganic elements exceed an applicable New Mexico water quality standard. For organic chemicals and radionuclides, five locations had no exceedances, six had one chemical or radioactivity measure exceed an applicable New Mexico water quality standard (either gross alpha or total PCBs), seven had two chemicals or radioactivity measures exceed (typically total PCBs and one other), and the remainder had more than two organic chemicals or radioactivity measures exceed an applicable New Mexico water quality standard. The surface water monitoring data for 2022 and previous years are available through the Intellus New Mexico website (https://intellusnm.com).

Table 6-4 summarizes chemical results for 2022 sediment samples at locations that exceeded screening levels for at least one chemical. Minimal exceedances of screening levels for sediment samples collected occurred in 2022; of 97 sediment samples collected, only 10 had exceedances. Plots showing the number of sediment samples taken and the number of samples that exceeded screening levels between 2011 and 2022 are provided in Figure 6-6 for the four chemicals with exceedances in 2022. All radionuclide concentrations in sediment samples collected in 2022 were below screening action levels and the DOE biota concentration guides, so there were no exceedances to report.

Results from compliance sampling for the Storm Water Individual Permit are not presented in the following tables but are discussed in the text and included in the figures in the Discussion and Trends section. Tables of the Storm Water Individual Permit sampling results for 2022 are available in the 2022 Update to the Site Discharge Pollution Prevention Plan (N3B 2023c). Analyses are not performed for every substance in every Storm Water Individual Permit sample; the analyses that are requested each year vary depending on the chemicals or radionuclides that have previously been detected in the solid waste management units and areas of concern within a site monitoring area.

Table 6-2. 2022 Storm Water and Base Flow Results for Inorganic Chemicals. Gray highlighting indicates that a chemical exceeded its screening level in at least one sample from a given location.

Location Description	Stream Gage Number	Total Aluminum[a]			Dissolved Copper			Total Iron			Dissolved Lead			Total Mercury			Total Selenium			Dissolved Silver			Dissolved Zinc		
		Analyses[b]	Detects[c]	Exceedances[d]	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Acid Canyon above Pueblo Canyon	E056	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	0
Ancho Canyon below NM-4	E275	2	2	2	2	2	0	–	–	–	2	1	0	2	2	1	2	2	2	2	0	0	2	0	0
Between E252 and Water Canyon at Beta[e]	NA	2	2	0	2	0	0	–	–	–	2	0	0	2	0	0	2	0	0	2	0	0	2	1	0
Canada del Buey above NM-4	E229.3	3	3	3	3	2	0	–	–	–	3	1	0	3	3	1	3	2	2	3	0	0	3	1	0
Chaquehui Canyon tributary at TA-33	E340	1	1	1	1	1	0	–	–	–	1	0	0	1	1	0	1	1	1	1	0	0	1	0	0
DP Canyon above Los Alamos Canyon	E040	1	1	1	1	1	0	–	–	–	1	1	0	1	0	0	1	1	0	1	0	0	1	1	0
DP Canyon above TA-21	E038	2	2	2	2	2	1	–	–	–	2	0	0	2	2	0	2	2	0	2	0	0	2	1	0
DP Canyon below grade control structure	E039.1	4	4	4	4	4	0	–	–	–	4	2	0	4	2	0	4	1	0	4	0	0	4	3	0
Pueblo Canyon below LAC WWTF[f]	E059.5	5	4	3	5	5	3	5	5	3	5	3	3	5	1	0	5	2	0	5	0	0	5	5	0
Pueblo Canyon below wetlands	E059.8	1	1	1	1	1	0	1	1	1	1	0	0	1	0	0	1	0	0	1	0	0	1	1	0
La Delfe Gulch above Pajarito Canyon	E242.5	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	1	1	0
Los Alamos Canyon above low-head weir	E042.1	1	1	1	1	1	0	–	–	–	1	0	0	1	1	0	1	1	1	1	0	0	1	1	0
Los Alamos Canyon below low-head weir	E050.1	2	2	2	2	2	0	–	–	–	2	2	0	2	1	0	2	2	1	2	0	0	2	2	0
Mortandad Canyon above Ten Site Canyon	E201	2	2	2	2	2	2	–	–	–	2	1	0	2	2	0	2	1	1	2	0	0	2	2	0
Mortandad Canyon below Effluent Canyon	E200	5	5	2	5	5	4	–	–	–	5	1	0	5	1	0	5	1	1	5	0	0	5	5	0

Location Description	Stream Gage Number	Total Aluminum[a]			Dissolved Copper			Total Iron			Dissolved Lead			Total Mercury			Total Selenium			Dissolved Silver			Dissolved Zinc		
		Analyses[b]	Detects[c]	Exceedances[d]	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Pajarito Canyon below S-N Ancho E Basin confluence[e]	NA	2	2	2	2	0	0	2	2	1	2	1	1	2	0	0	2	0	0	2	0	0	2	1	0
Pajarito Canyon above NM-4	E250	2	2	2	2	2	0	–	–	–	2	1	0	2	0	0	2	2	0	2	0	0	2	2	0
Pajarito Canyon above Threemile Canyon	E245.5	1	1	1	1	1	0	–	–	–	1	1	0	1	1	0	1	0	0	1	0	0	1	1	0
Pajarito Canyon at Rio Grande[e]	NA	1	1	0	1	0	0	1	1	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Pueblo Canyon above Acid Canyon	E055	2	2	2	2	2	1	2	2	2	2	2	2	2	1	0	2	1	1	2	0	0	2	2	0
Rio Grande at Frijoles Canyon[e]	NA	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	1	0	0	1	0	0	1	1	0
Rio Grande at Otowi Bridge[e]	NA	2	2	2	2	0	0	2	2	2	2	0	0	2	0	0	2	0	0	2	0	0	2	1	0
Sandia Canyon above Firing Range	E124	3	3	2	3	3	2	–	–	–	3	3	0	3	3	0	3	3	2	3	0	0	3	3	0
Sandia Canyon below Wetlands[e]	E123	4	1	0	5	1	0	4	4	0	5	1	0	5	0	0	4	0	0	5	0	0	5	5	0
Sandia Canyon below Wetlands	E123	4	4	3	4	4	4	4	4	4	4	4	2	4	2	0	4	1	0	4	0	0	4	4	1
Sandia left fork at Asphalt Plant	E122	6	6	6	6	6	5	6	6	6	6	4	4	6	2	0	6	2	2	6	0	0	6	6	3
Sandia right fork at Power Plant§	E121	4	0	0	5	3	0	4	4	0	5	0	0	5	0	0	4	0	0	5	0	0	5	5	0
Sandia right fork at Power Plant	E121	4	4	4	4	4	4	4	4	4	4	2	1	4	2	0	4	1	0	4	0	0	4	4	1
South Fork of Sandia at E122[e]	E122	4	2	0	4	3	0	4	4	0	4	0	0	4	0	0	4	0	0	4	0	0	4	4	0
Starmers Gulch above Pajarito Canyon	E242	3	3	3	3	3	2	3	3	3	3	1	1	3	3	0	3	2	1	3	1	1	3	3	0
Ten Site Canyon above Mortandad Canyon	E201.5	1	1	1	1	1	1	–	–	–	1	0	0	1	1	0	1	1	1	1	0	0	1	1	0
Twomile Canyon above Pajarito Canyon	E244	1	1	1	1	1	1	–	–	–	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0

Table 6-2 Notes:
[a] Unfiltered aluminum is used for base flow samples, and aluminum filtered to 10 µm is used for storm water samples.
[b] Analyses are the number of samples analyzed for that constituent.
[c] Detects are the number of samples in which that constituent was detected.
[d] Exceedances are the number of results that were detected above the screening level.
[e] Indicates base flow sampling locations; all other locations are storm flow sampling locations (note some locations have both storm flow and base flow samples).
[f] LAC WWTF = Los Alamos County Wastewater Treatment Facility
– Data for iron are presented only for locations where the chronic aquatic life criteria apply.

Table 6-3. 2022 Storm Water and Base Flow Results for Organic Chemicals and Radionuclides. Gray highlighting indicates that a chemical exceeded its screening level in at least one sample from a given location.

Location Description	Stream Gage Number	Benzo(a)anthracene			Benzo(a)pyrene			Benzo(b)fluoranthene			Benzo(k)fluoranthene			Dibenz(a,h)anthracene			Dioxins[a]			Gross alpha			Indeno(1,2,3-cd)pyrene			Total PCB		
		Analyses[b]	Detects[c]	Exceedances[d]	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Acid Canyon above Pueblo Canyon	E056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Ancho Canyon below NM-4	E275	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	0	0	0	2	2	2
Between E252 and Water Canyon at Beta[e]	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Canada del Buey above NM-4	E229.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	3	2	0	0	0	3	1	0
Chaquehui Canyon tributary at TA-33	E340	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	1	0	0	0	2	2	2
Above Los Alamos Sediment Basin 1	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
DP Canyon above Los Alamos Canyon	E040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	2	2	0	0	0	2	2	2
DP Canyon above TA-21	E038	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	0	0	0	2	2	2
DP Canyon below grade control structure	E039.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	1	4	4	2	0	0	0	4	4	4
Pueblo below LAC WWTF[a]	E059.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	5	3	2	0	0	0	5	5	3

Location Description	Stream Gage Number	Benzo(a)anthracene			Benzo(a)pyrene			Benzo(b)fluoranthene			Benzo(k)fluoranthene			Dibenz(a,h) anthracene			Dioxins[a]			Gross alpha			Indeno(1,2,3-cd)pyrene			Total PCB		
		Analyses[b]	Detects[c]	Exceedances[d]	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Pueblo Canyon Below Wetlands	E059.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	1	1	1
La Delfe Gulch above Pajarito Canyon	E242.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Los Alamos Canyon above low-head weir	E042.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	1	1	1	0	0	0	1	1	1
Los Alamos Canyon below low-head weir	E050.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3	0	0	0	1	1	1
Mortandad Canyon above Ten Site Canyon	E201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	1	0	0	0	2	2	2
Mortandad Canyon below Effluent Canyon	E200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	5	5	0	0	0	0	5	5	5
Pajarito Canyon below S-N Ancho E Basin confluence[e]	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Pajarito Canyon above NM-4	E250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2	0	0	0	2	2	2
Pajarito Canyon above Threemile Canyon	E245.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Pajarito Canyon at Rio Grande[e]	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0
Pueblo Canyon above Acid Canyon	E055	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	1	1	0	0	0	2	2	2
Rio Grande at Frijoles[e]	NA	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0
Rio Grande at Otowi Bridge[e]	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0
Sandia Canyon above Firing Range	E124	3	1	1	3	1	1	3	1	1	3	1	1	3	1	1	3	3	3	3	3	2	3	1	1	3	3	3
Sandia Canyon below Wetlands[e]	E123	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	4	3	0	1	0	0	5	0	0	4	4	4

Location Description	Stream Gage Number	Benzo(a)anthracene			Benzo(a)pyrene			Benzo(b)fluoranthene			Benzo(k)fluoranthene			Dibenz(a,h)anthracene			Dioxins[a]			Gross alpha			Indeno(1,2,3-cd)pyrene			Total PCB		
		Analyses[b]	Detects[c]	Exceedances[d]	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances	Analyses	Detects	Exceedances
Sandia Canyon below Wetlands	E123	4	0	0	4	0	0	4	0	0	4	0	0	4	1	1	4	4	4	4	3	1	4	1	1	4	4	4
Sandia Canyon left fork at Asphalt Plant	E122	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	5	5	6	4	0	5	0	0	5	5	5
Sandia Canyon right fork at Power Plant[e]	E121	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	4	4	0	1	0	0	5	0	0	4	4	4
Sandia Canyon right fork at Power Plant	E121	4	0	0	4	0	0	4	0	0	4	0	0	4	0	0	4	4	4	4	3	0	4	0	0	4	4	4
South Fork of Sandia Canyon[e]	E122	4	0	0	4	0	0	4	0	0	4	0	0	4	0	0	4	4	0	0	0	0	4	0	0	4	4	4
Starmers Gulch above Pajarito Canyon	E242	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	3	3	2	0	0	0	3	3	3
Ten Site Canyon above Mortandad Canyon	E201.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Twomile Canyon above Pajarito Canyon	E244	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1

[a] The dioxin criteria apply to the sum of the dioxin toxicity equivalents expressed as tetrachlorodibenzo-p-dioxin(2,3,7,8-).
[b] Analyses are the number of samples analyzed for that constituent.
[c] Detects are the number of samples in which that constituent was detected.
[d] Exceedances are the number of results that were detected above the screening level.
[e] Indicates base flow sampling locations; all other locations are storm flow sampling locations (note some locations have both storm flow and base flow samples).

Table 6-4. 2022 Sediment Sampling Locations where Sample Result Exceeded at Least One Screening Level. Gray highlighting indicates that a particular soil screening level was exceeded by a given chemical.

Canyon	Stream Reach	Location ID	Chemical	Result (milligrams per kilogram)	Residential Soil Cancer Screening Level (milligrams per kilogram)	Residential Soil Non-Cancer Screening Level (milligrams per kilogram)	Industrial Soil Cancer Screening Level (milligrams per kilogram)	Industrial Soil Non-Cancer Screening Level (milligrams per kilogram)	Construction Worker Soil Cancer Screening Level (milligrams per kilogram)	Construction Worker Soil Non-Cancer Screening Level (milligrams per kilogram)
Ancho	ANCHO @ RG	AN-61358	Manganese	520	–	10548	–	160183	–	464
Chaquehui	CHQ @ RG	CH-61334	Manganese	513	–	10548	–	160183	–	464
Cañon de Valle	CDV-2E	CV-61551	PCB-170	0.401	0.374589	0.397719	1.76580	5.73889	13.1184	1.71780
Pajarito	PA-4	PA-61576	Manganese	948	–	10548	–	160183	–	464
		PA-61577	Manganese	802	–	10548	–	160183	–	464
Potrillo	PO-4	PO-61509	Manganese	484	–	10548	–	160183	–	464
Sandia	S-2	SA-61654	Chromium	300	97	45183	505	313931	468	134
			Manganese	1040	–	10548	–	160183	–	464
			PCB-126	0.000461	0.000375	0.000398	0.001719	0.005739	0.013118	0.001718
		SA-61655	Manganese	1180	–	10548	–	160183	–	464
	S-6W	SA-61661	Manganese	701	–	10548	–	160183	–	464
Water	WA-4	WA-61565	Manganese	476	–	10548	–	160183	–	464

A dash (–) indicates that no screening level exists for a given chemical.

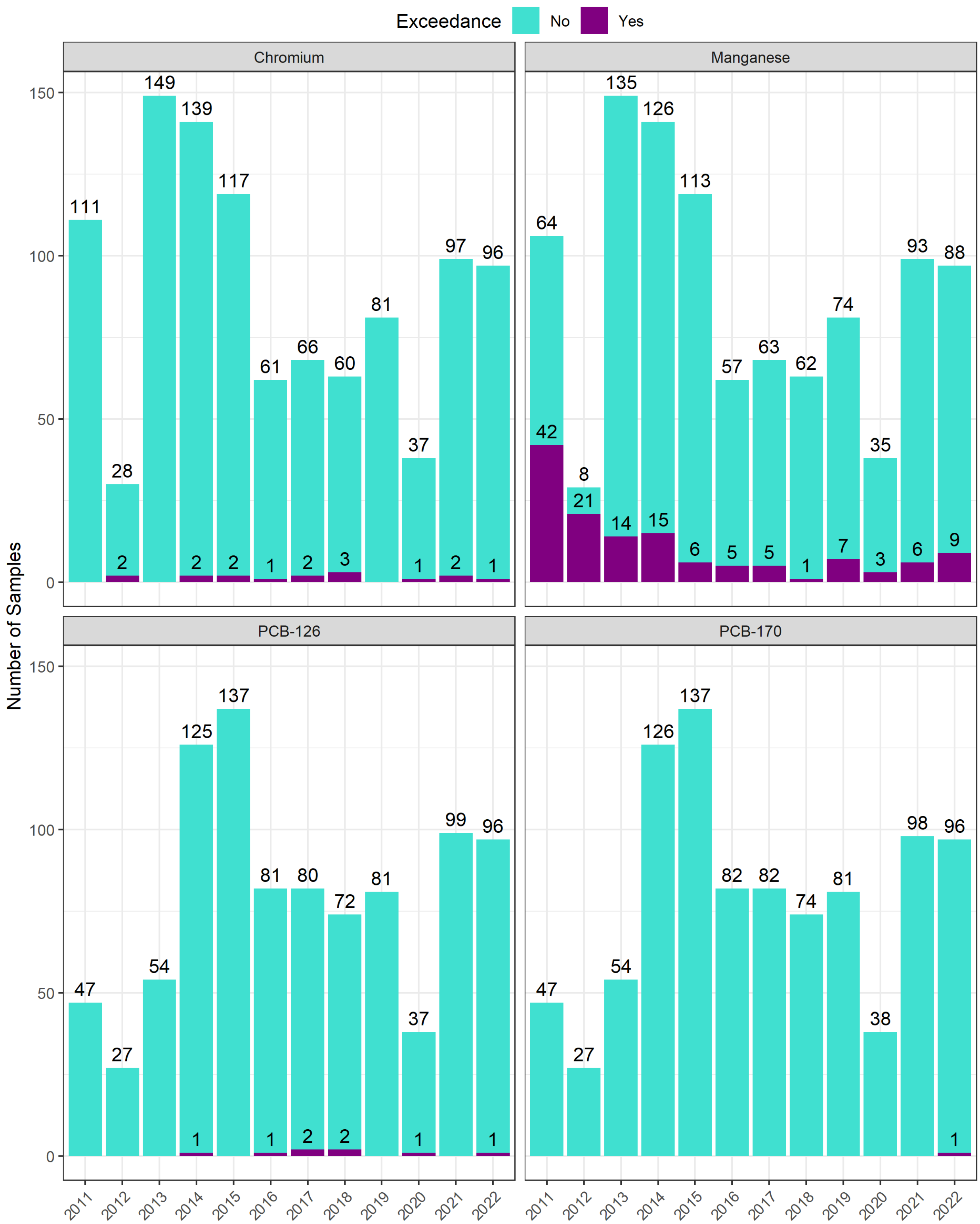


Figure 6-6. Numbers of sediment samples collected and numbers of samples that exceeded screening levels each year for 2011 through 2022 for the four chemicals that exceeded screening levels in sediment in 2022.

Table 6-5 summarizes surface water exceedances in 2022 by providing the total number of exceedances per chemical or radioactive constituent and the percent of all locations analyzed for that chemical or radioactive constituent with an exceedance. Exceedances are categorized by the applicable New Mexico water quality standard.

Table 6-5. Number of Locations (Percent of Locations Analyzed) where Storm Water and Base Flow Results Exceeded New Mexico Water Quality Standards in 2022 for Chemicals or Radioactive Constituents with at Least One Exceedance

Chemical or Radioactive Constituent	Irrigation and Irrigation Storage	Livestock Watering	Wildlife Habitat	Acute Aquatic Life	Chronic Aquatic Life	Human Health Organism Only
Total Aluminum	–[a]	–	–	27 (93%)	12 (41%)	–
Dissolved Copper	0	0	–	13 (45%)	8 (28%)	–
Total Iron	–	–	–	–	12 (41%)	–
Dissolved Lead	0	0	–	0	8 (28%)	–
Total Mercury	–	0	4 (14%)	–	–	–
Total Selenium	–	–	13 (45%)	5 (17%)	3 (10%)	–
Dissolved Silver	–	–	–	1 (3%)	–	–
Dissolved Zinc	0	0	–	3 (10%)	3 (10%)	0
Gross alpha	–	20 (67%)	–	–	–	–
Total PCB	–	–	19 (79%)	2 (8%)	6 (25%)	23 (96%)
Dioxin[a]	–	–	–	–	–	18 (67%)
Benzo(a)anthracene	–	–	–	–	–	1 (13%)
Benzo(a)pyrene	–	–	–	–	–	1 (13%)
Benzo(b)fluoranthene	–	–	–	–	–	1 (13%)
Benzo(k)fluoranthene	–	–	–	–	–	1 (13%)
Dibenzo(a,h)anthracene	–	–	–	–	–	2 (25%)
Indeno(1,2,3-cd)pyrene	–	–	–	–	–	2 (25%)

A dash (–) indicates that no standard for this chemical or radionuclide exists for this category.
The percentage in parentheses represents the percentage of locations that have an exceedance for that analyte.
[a] The dioxin criteria apply to the sum of the dioxin toxicity equivalents expressed as tetrachlorodibenzo-p-dioxin(2,3,7,8-).

Discussion and Trends

The following sections discuss in detail the 2022 storm water and sediment results, broken out by whether a chemical is related primarily to background sources (either natural or manufactured) or related to Laboratory operations.

The storm water and base flow results from 2022 fall within the ranges observed between 2011 and 2021. Several of the figures show results for substances in surface water that exceeded screening levels in 2022. For these figures, the colored circles in the top panel show the locations of samples collected at stream gaging stations, sediment detention basins, base flow sampling locations, and Storm Water Individual Permit site monitoring areas. The color of a circle indicates how the maximum concentration for that substance at that location ranked relative to the maximum concentration of that substance at other locations in the same watershed during 2011 through 2022. For example, blue indicates that the concentration was in the lowest 10 percent of maximum concentrations, and orange indicates that it was in the highest 10 percent of maximum concentrations. The range in concentrations represented by each color is provided at the top of the figure. The graphs in the bottom panel(s) show the storm water and base flow results for the chemical in the watershed for 2011 through 2022, with different colors for Storm Water Individual Permit samples and stream gaging station samples.

Constituents Related to Natural and Manufactured Background Sources

Chemicals that are primarily naturally occurring or derived from sources other than the Laboratory are discussed in the following paragraphs.

Aluminum

Storm water samples collected on the Pajarito Plateau commonly contain aluminum concentrations above New Mexico water quality standards. Most or all of this aluminum is likely naturally occurring (Reneau et al. 2010, Ryan et al. 2019). Aluminum (in the form of aluminosilicates) is a natural component of soil and Bandelier Tuff, and aluminum is not known to be produced from Laboratory operations in any significant quantity. The New Mexico Environment Department Surface Water Quality Bureau has stated that “Natural conditions may contribute to high aluminum concentrations in the Jemez Mountains” (New Mexico Environment Department 2022b).

In 2022, total aluminum concentrations in storm water and base flow samples exceeded the acute aquatic life standard at 27 sampling locations (93 percent of locations) and the chronic aquatic life standard at 12 sampling locations (41 percent of locations). Of 15 Storm Water Individual Permit compliance samples collected in 2022 that were analyzed for aluminum, 5 samples exceeded the target action level for dissolved aluminum concentrations. Of the 42 assessment units on Laboratory or former Laboratory lands, 16 are listed in Table 6-1 as impaired for aluminum.

In 2022, no sediment samples exceeded soil screening levels for aluminum.

Arsenic

Arsenic has both natural and manufactured sources. Coal-fired power plants emit gaseous arsenic. Although the Four Corners Generating Station coal-fired power plant has contributed to arsenic contamination, the Laboratory also operated coal-fired power plants historically. Arsenic is also found naturally in the local volcanic rocks.

In 2022, none of the filtered gaging station storm water or base flow results exceeded the surface water quality standards for arsenic. The 13 Storm Water Individual Permit compliance samples from 2022 that were analyzed for arsenic did not exceed the target action level. None of the 42 assessment units—or stream reaches—on Laboratory or former Laboratory lands are listed as impaired for arsenic, as shown in Table 6-1. In 2022, no sediment samples exceeded soil screening levels for arsenic.

Copper

Copper is naturally occurring, and it is also associated with explosives firing sites, forest fires, and developed areas such as buildings and parking lots. Copper sources in developed landscapes include brake pad abrasion and building materials, such as flashing, plumbing pipes, and electrical components (TDC Environmental 2004, Göbel et al. 2007). Historically, every watershed across the Laboratory has recorded elevated copper concentrations in storm water at some time, including all of the gaging stations located along the Laboratory's upstream boundary.

In 2022, copper concentrations in filtered storm water and base flow samples were detected above the acute aquatic life standard at 13 sampling locations (45 percent of locations) and above the chronic aquatic life standard at 8 sampling locations (28 percent of locations). Of the 42 assessment units on Laboratory or former Laboratory lands, 15 units are listed as impaired for copper (see Table 6-1). In 2022, 16 of 21 Storm Water Individual Permit compliance samples that were analyzed for copper exceeded the target action level. Figure 6-7 through Figure 6-10 show copper concentrations in filtered storm water and base flow for the Ancho and Chaquehui canyons watershed, Los Alamos and Pueblo canyons watershed, the Pajarito canyon watershed, and Sandia and Mortandad canyons watershed, respectively. Concentrations measured in 2022 were similar to those measured in previous years.

In 2022, no sediment samples exceeded soil screening levels for copper.

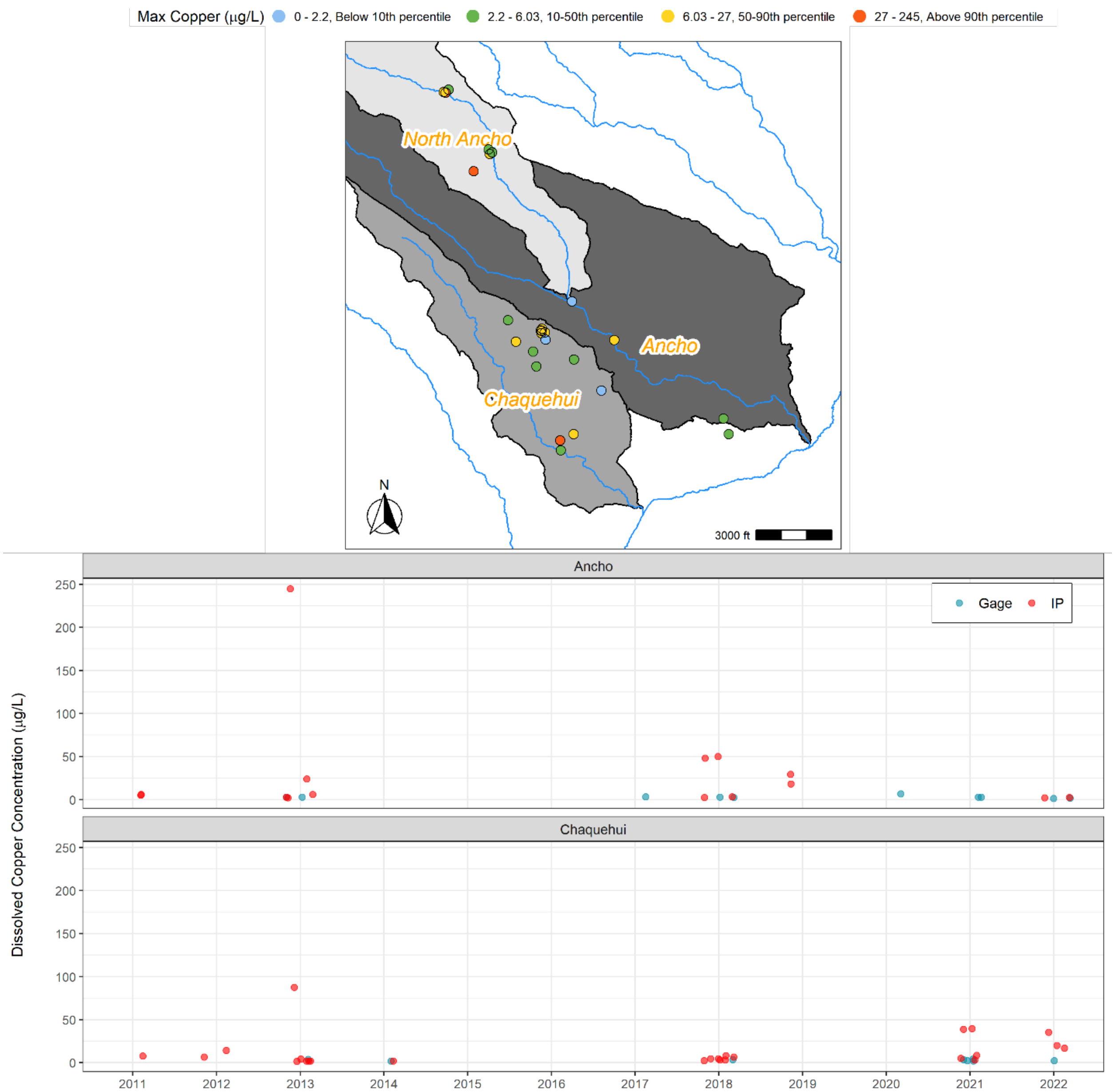


Figure 6-7. Ancho and Chaquehui canyons watershed copper concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2022. Bottom panels: dissolved copper concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

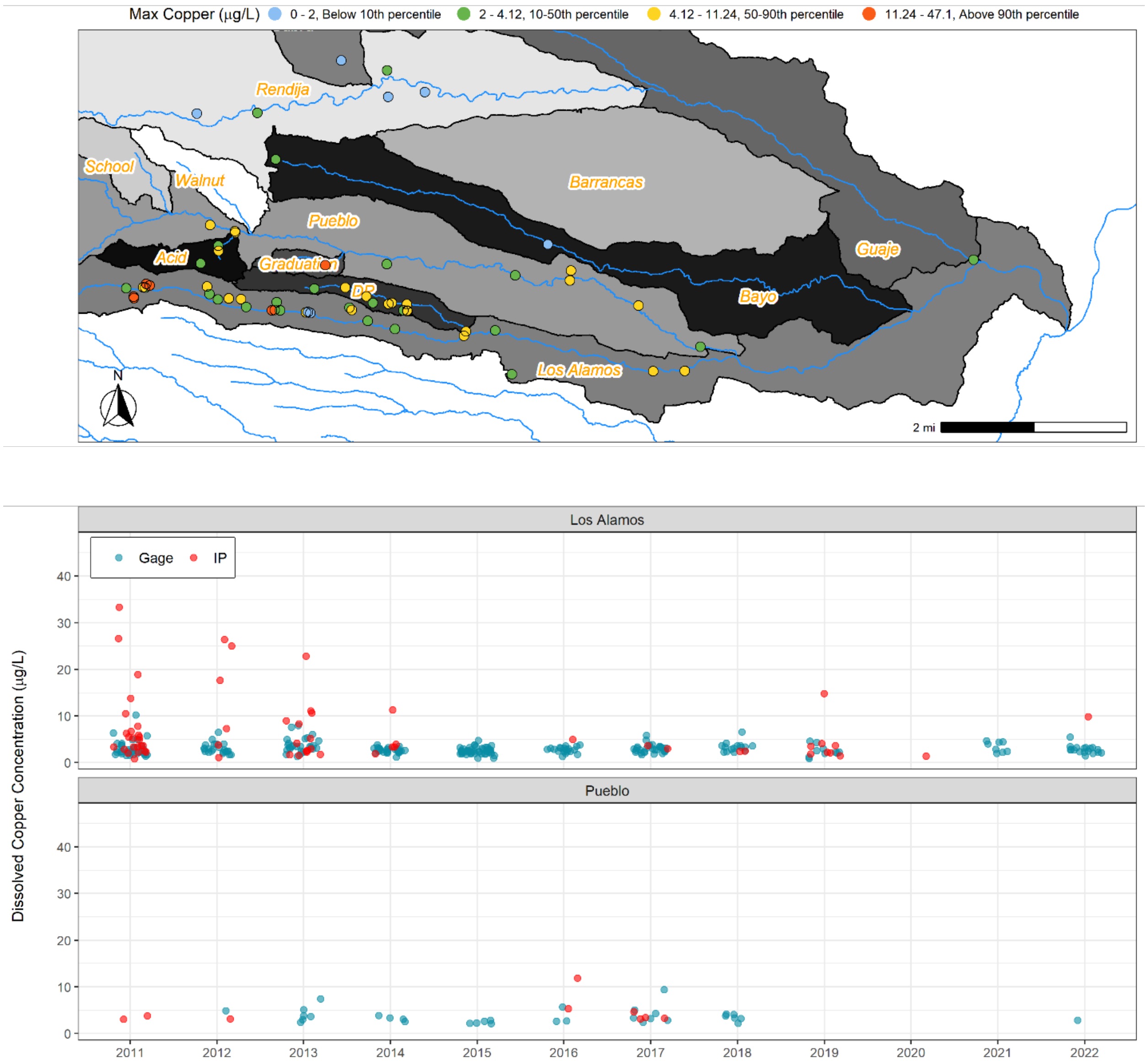


Figure 6-8. Los Alamos and Pueblo canyons watershed copper concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2022. Bottom panels: dissolved copper concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

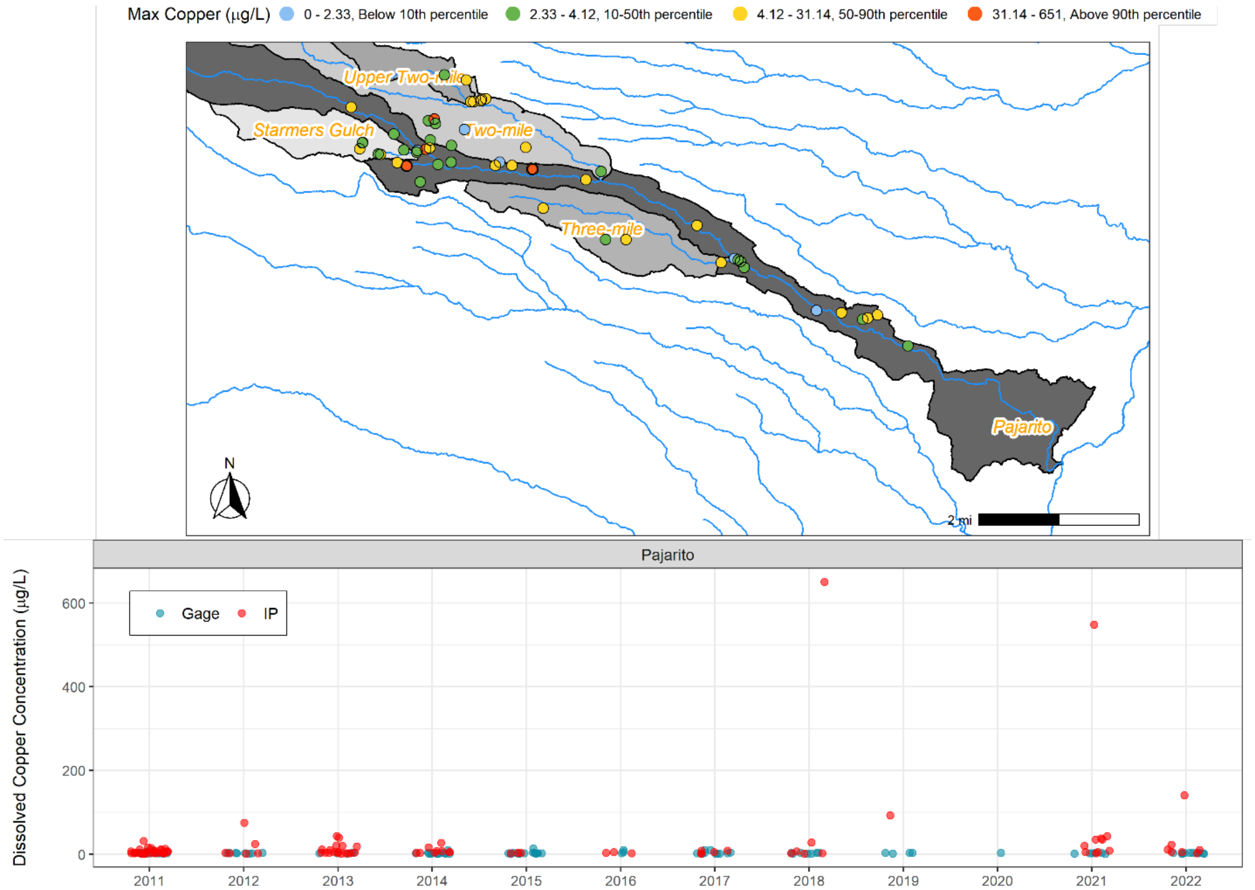


Figure 6-9. Pajarito Canyon watershed copper concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2022. Bottom panels: dissolved copper concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

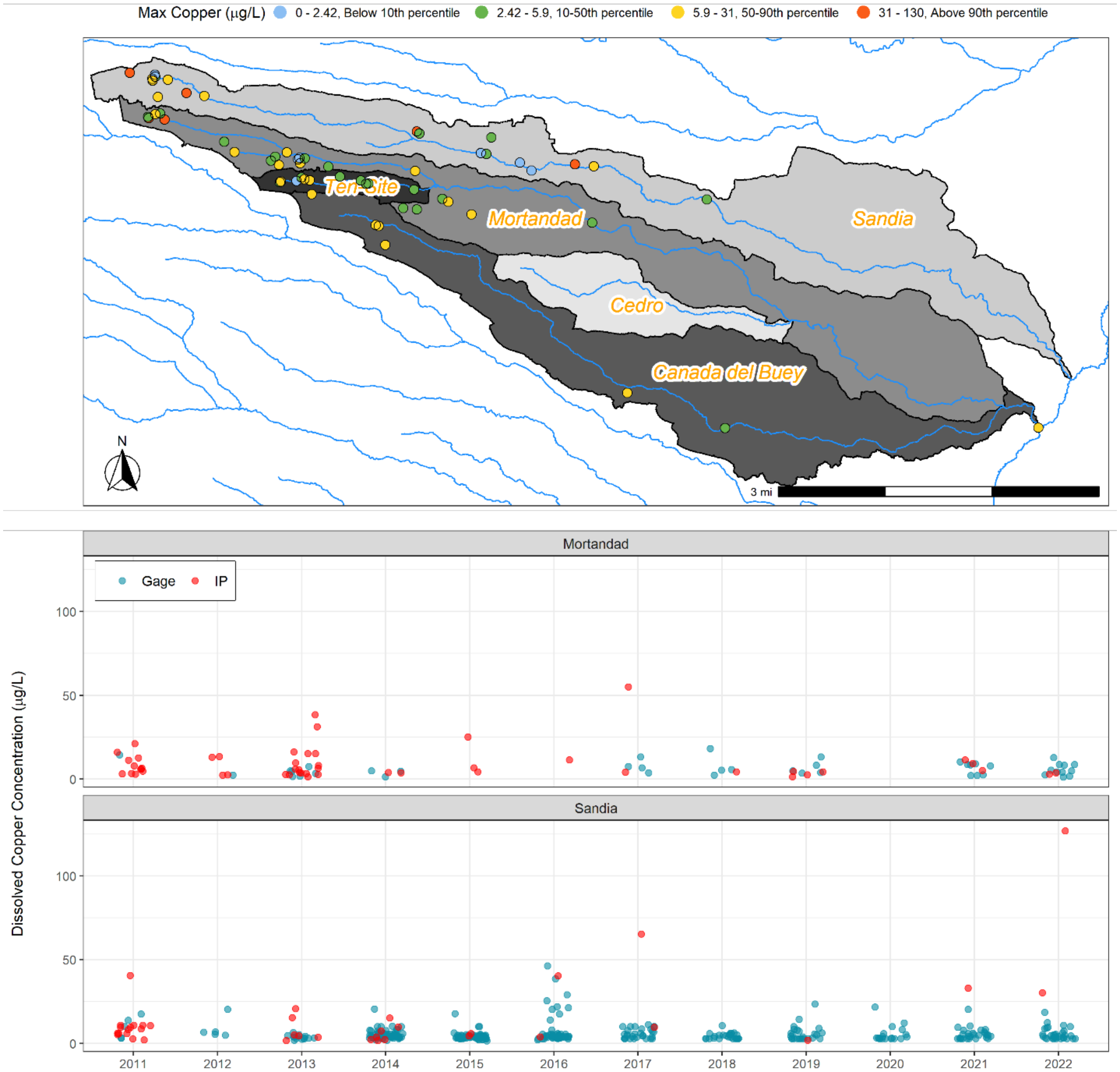


Figure 6-10. Sandia and Mortandad canyons watershed copper concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water copper values for each sampling location from 2011 to 2022. Bottom panels: dissolved copper concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

Iron

Iron is naturally occurring, and it is also associated with explosives firing sites. The water quality standard for total iron became effective in 2022. Iron concentrations in storm water and base flow in 2022 were detected above the chronic aquatic life standard at 12 sampling locations (41 percent of locations). Figure 6-11 through Figure 6-13 show iron concentrations in storm water and base flow for the Los Alamos and Pueblo canyons watershed, Pajarito canyon watershed, and Sandia and Mortandad canyons watershed, respectively. None of the 42 assessment units on

Laboratory or former Laboratory lands are listed as impaired for iron as shown in Table 6-1. There is no target action level for iron for Storm Water Individual Permit samples.

In 2022, no sediment samples exceeded soil screening levels for iron.

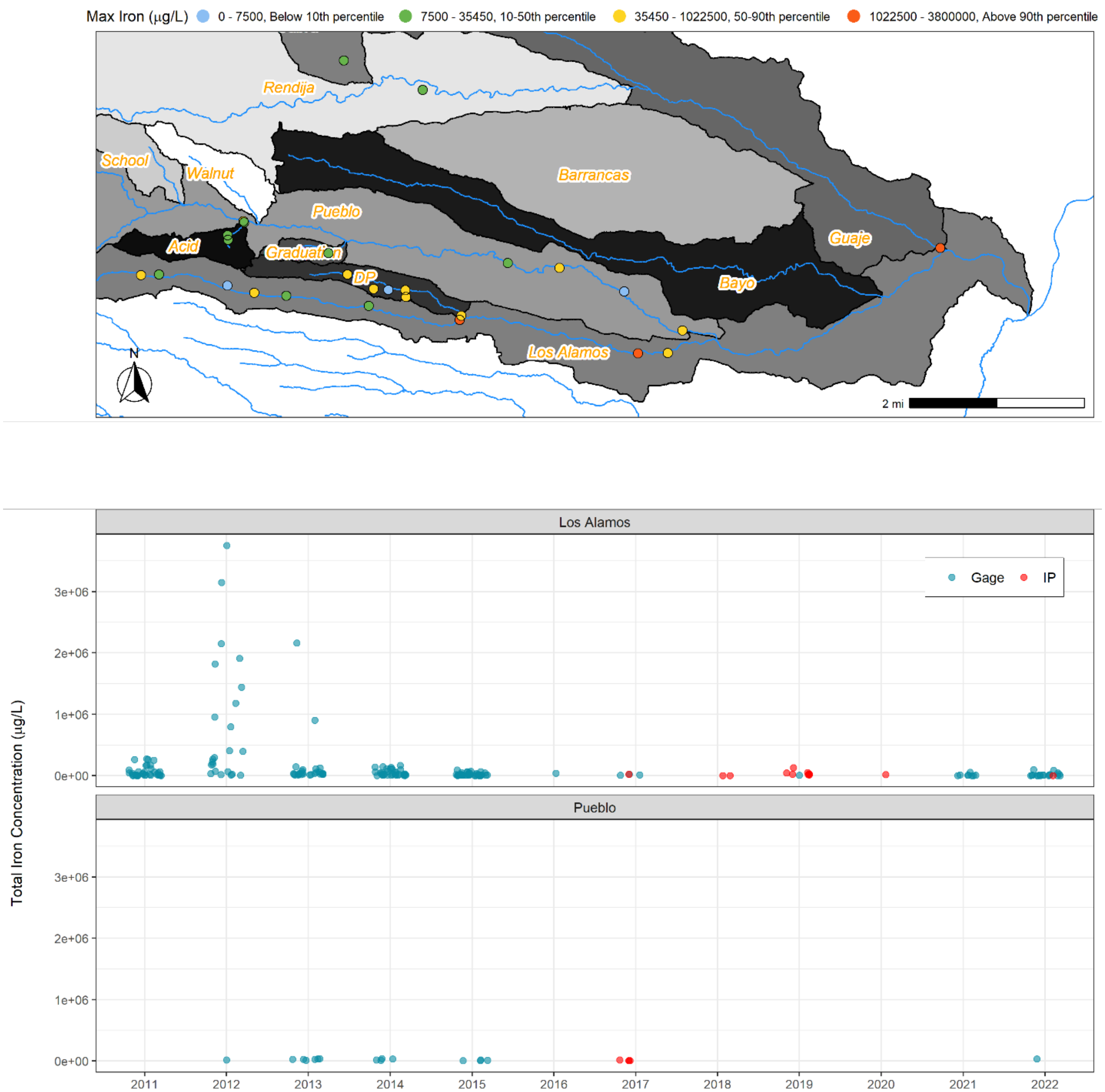


Figure 6-11. Los Alamos and Pueblo canyons watershed iron concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water iron values for each sampling location from 2011 to 2022. Bottom panels: total iron concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

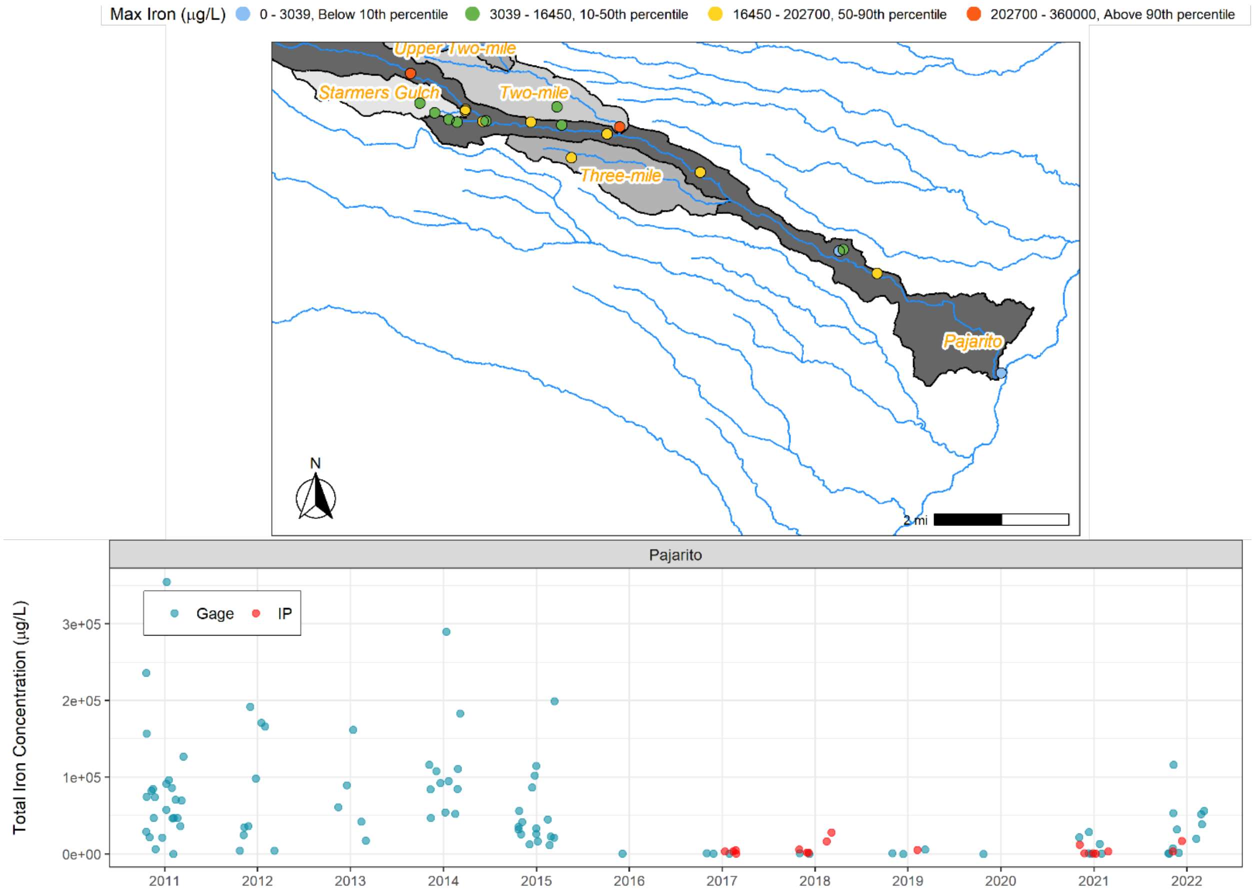


Figure 6-12. Pajarito canyon watershed iron concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water iron values for each sampling location from 2011 to 2022. Bottom panels: total iron concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

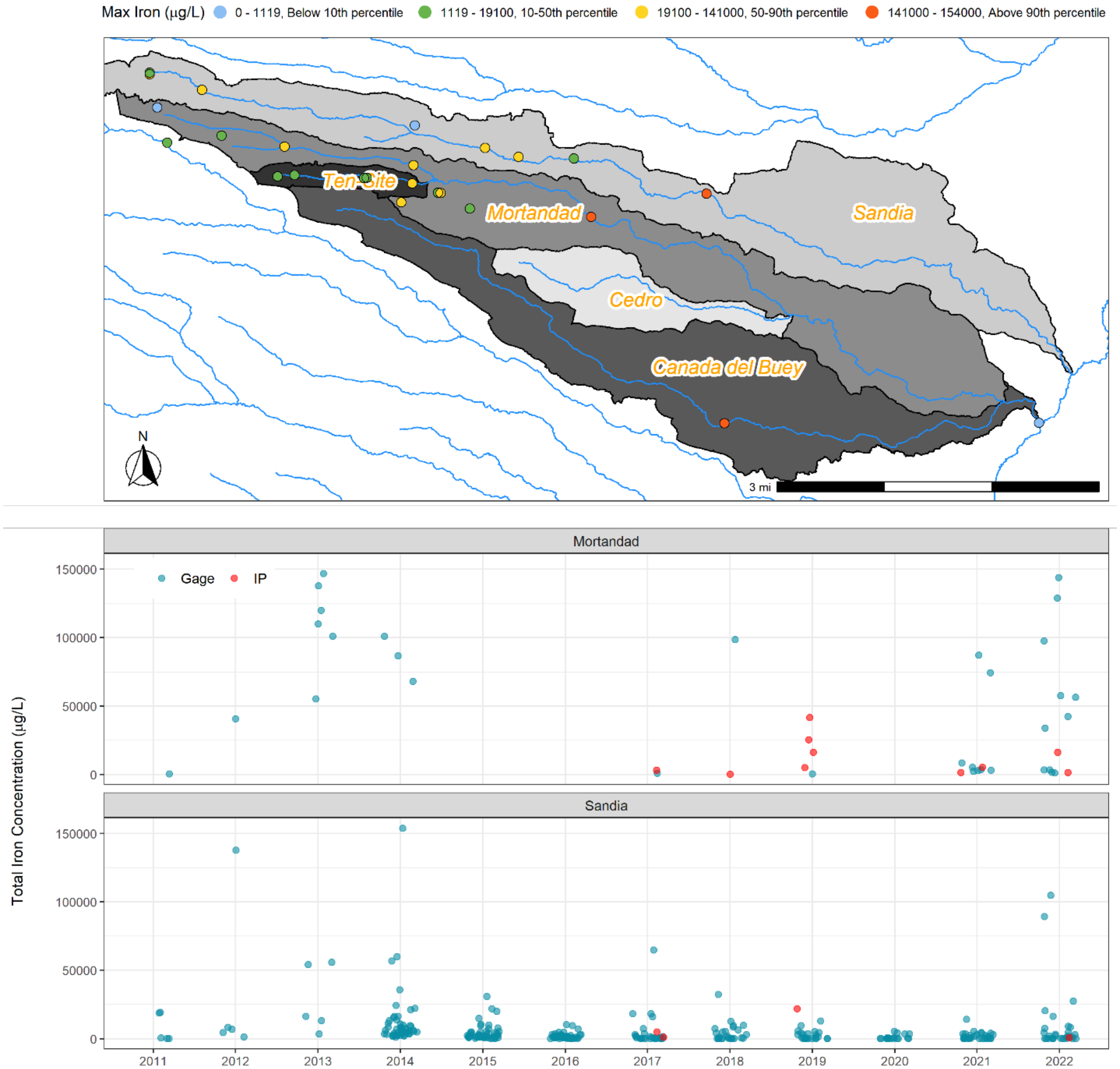


Figure 6-13. Sandia and Mortandad canyons watershed iron concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water iron values for each sampling location from 2011 to 2022. Bottom panels: total iron concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

Lead

Lead is associated with explosives firing sites, as well as developed areas such as buildings and parking lots (Göbel et al. 2007). The major lead sources in developed landscapes are lead-based paints, building sidings, and the operation of automobiles (Davis and Burns 1999).

Lead concentrations in filtered storm water and base flow in 2022 were detected above the chronic aquatic life standard at eight sampling locations (28 percent of locations). None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for lead, as shown in Table 6-1. In 2022, 1 of 14 Storm Water Individual Permit compliance samples that were analyzed for lead exceeded the target action level. Figure 6-14 shows lead concentrations in filtered storm water and base flow for Los Alamos and Pueblo canyons watershed, and Figure 6-15 shows lead concentrations in filtered storm water and base flow for the Sandia and Mortandad canyons watershed.

In 2022, no sediment samples exceeded soil screening levels for lead.

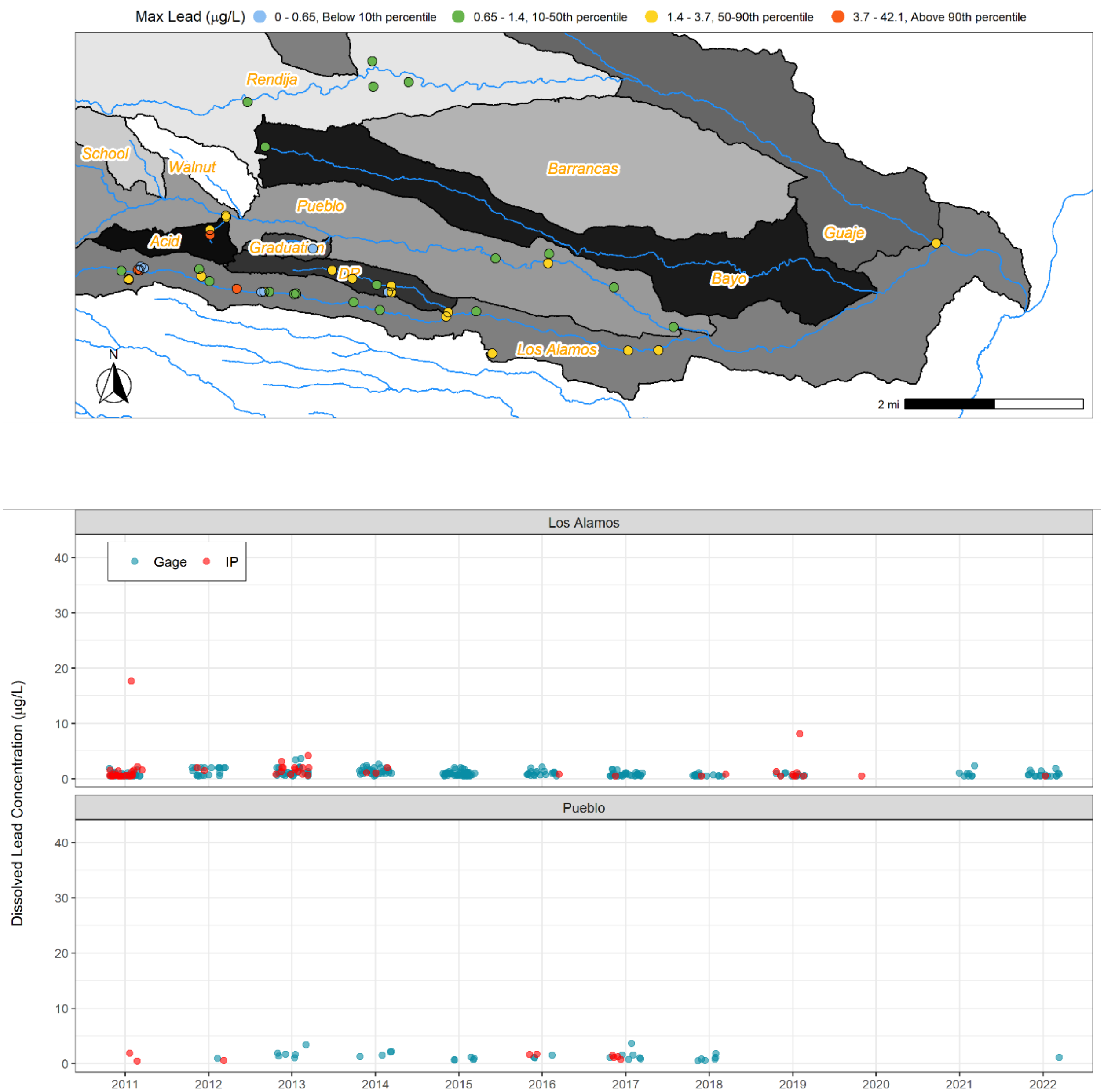


Figure 6-14. Los Alamos and Pueblo canyons watershed lead concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water lead values for each sampling location from 2011 to 2022. Bottom panels: dissolved lead concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

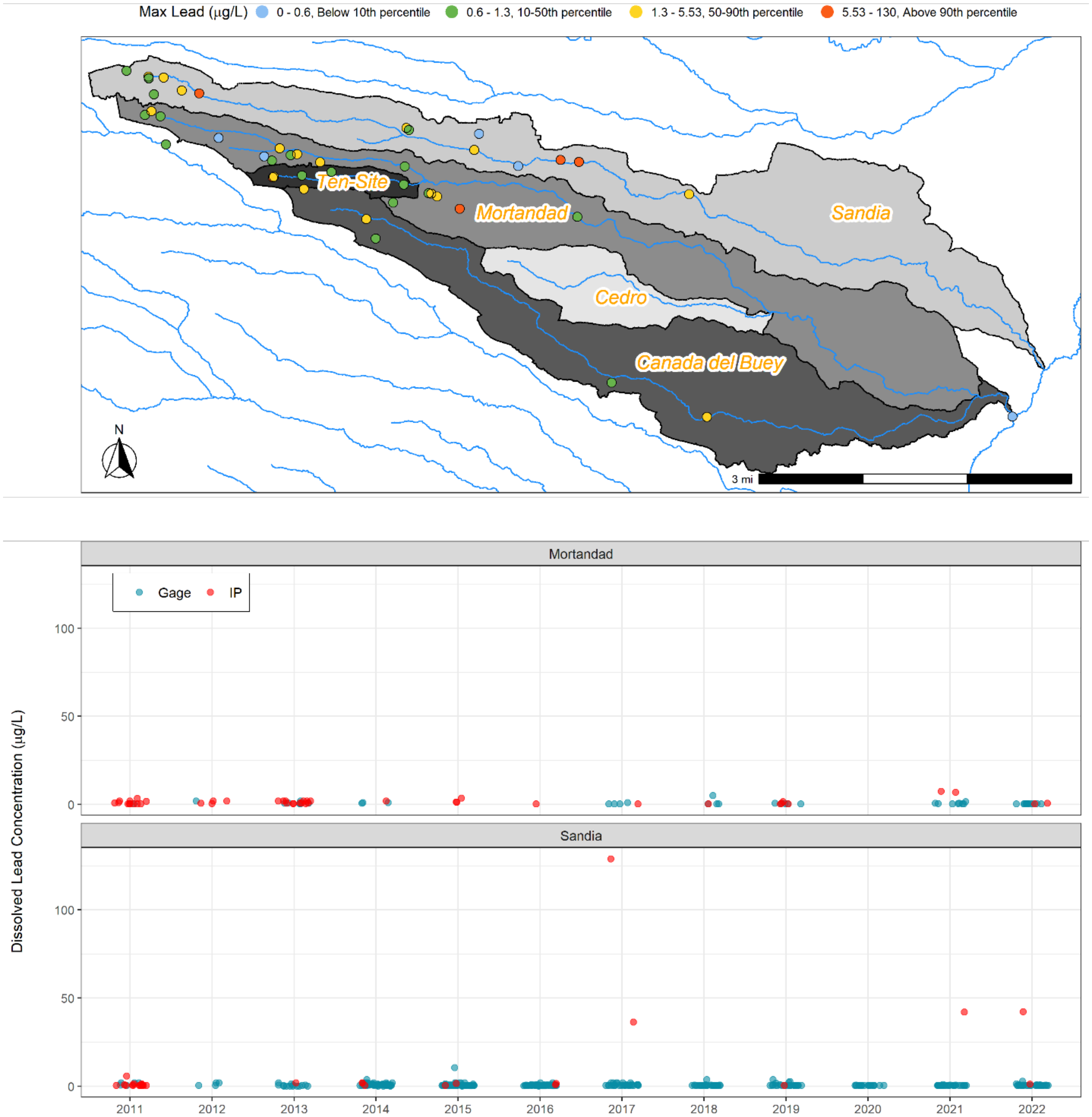


Figure 6-15. Sandia and Mortandad canyons watershed lead concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water lead values for each sampling location from 2011 to 2022. Bottom panels: dissolved lead concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

Manganese

Manganese is naturally occurring on the Pajarito Plateau. Laboratory operations have not generated significant quantities of manganese. Dissolved manganese concentrations were elevated following the Cerro Grande fire and then decreased quickly in subsequent years (Gallaher and Koch 2004, 2005).

No manganese exceedances occurred in storm water and base flow in 2022, and no target action level exists for manganese for Storm Water Individual Permit samples. None of the 42 assessment units—also called stream reaches—on Laboratory or former Laboratory lands are listed as impaired for manganese, as shown in Table 6-1.

In 2022, manganese concentrations in sediment exceeded the construction worker non-cancer soil screening level in nine samples. Figure 6-16 shows manganese concentrations in sediment samples in Pajarito Canyon, and Figure 6-17 shows manganese concentrations in sediment samples in Sandia Canyon.

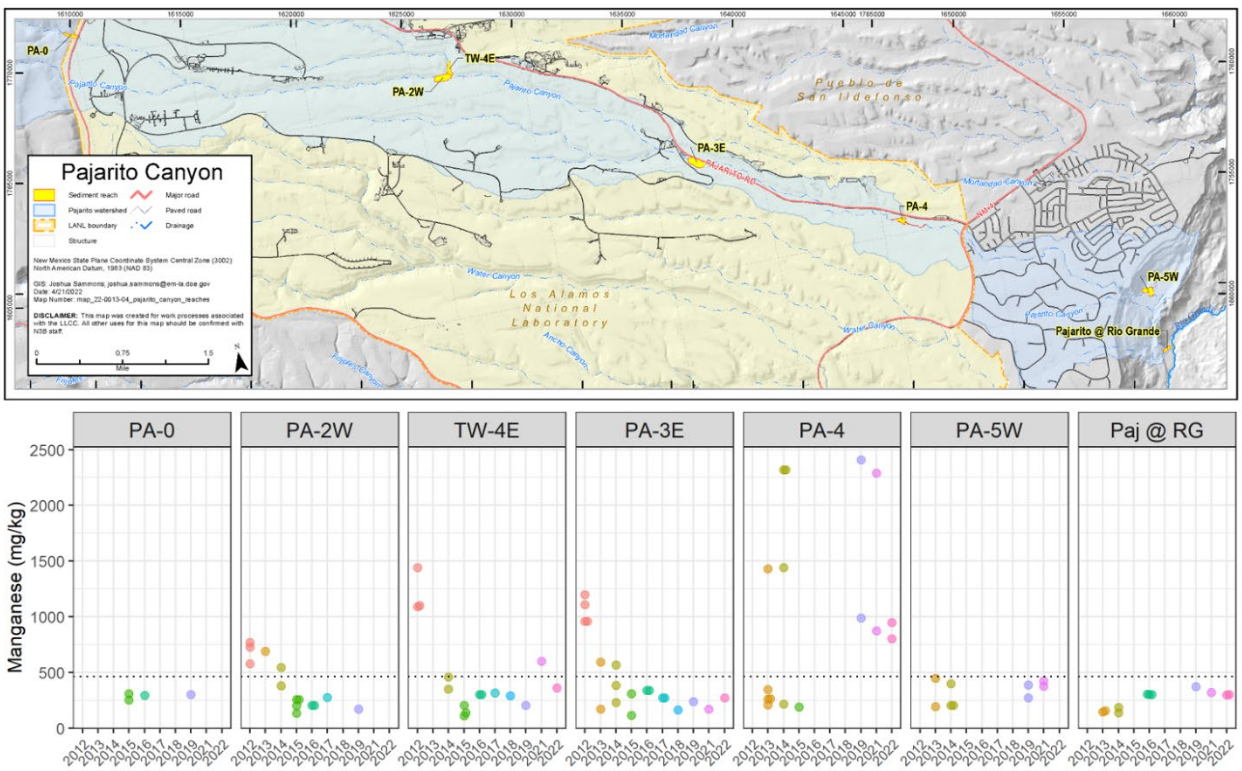


Figure 6-16. Manganese concentrations in sediment samples in Pajarito Canyon from 2012 to 2022. The Construction Worker Non-Cancer Soil Screening Level for manganese is 464 milligrams per kilogram (mg/kg). The locations of reaches are shown in the top panel. Twomile Canyon (reach TW-4E) flows into Pajarito Canyon.

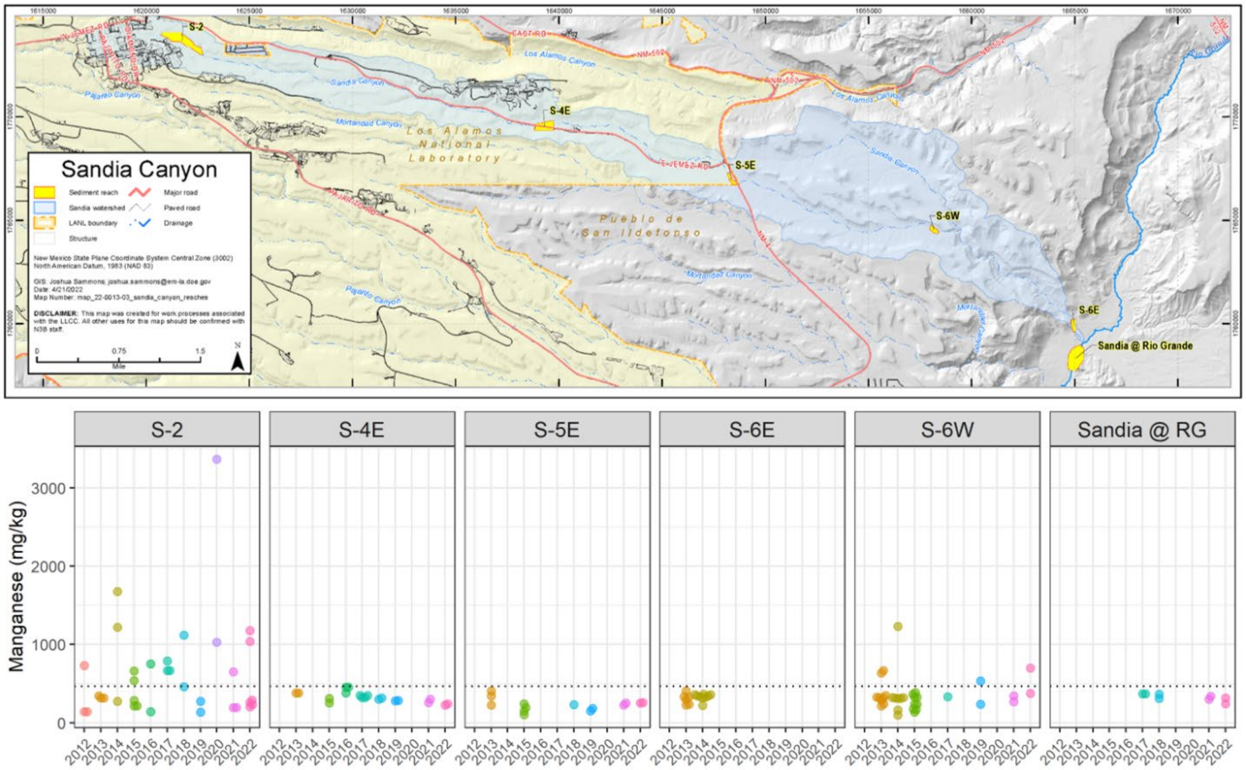


Figure 6-17. Manganese concentrations in sediment samples in Sandia Canyon from 2012 to 2022. The Construction Worker Non-Cancer Soil Screening Level for manganese is 464 milligrams per kilogram (mg/kg). The locations of reaches are shown in the top panel.

Selenium

Selenium is naturally occurring on the Pajarito Plateau. Laboratory operations have not generated significant quantities of selenium. Total selenium concentrations were elevated following the Cerro Grande fire and then decreased quickly in subsequent years (Gallaher and Koch 2004, 2005).

In 2022, total selenium concentrations in storm water and base flow were detected above the wildlife habitat standard at 13 sampling locations (45 percent of locations), above the acute aquatic life standard at 5 sampling locations (17 percent of locations), and above the chronic aquatic life standard at 3 sampling locations (10 percent of locations). Of the 42 assessment units on Laboratory or former Laboratory lands, 3 are listed as impaired for selenium as shown in Table 6-1. In 2022, 3 of 13 Storm Water Individual Permit compliance samples that were analyzed for selenium exceeded the target action level.

In 2022, no sediment samples exceeded soil screening levels for selenium.

Zinc

Although naturally occurring, zinc also can be associated with developed areas. Zinc sources include automobile tires, galvanized materials, motor oil, and hydraulic fluid (Rose et al. 2001, Councell et al. 2004, Washington State Department of Ecology 2006).

In 2022, filtered zinc concentrations in storm water and base flow samples were detected above the acute aquatic life standard at three sampling locations (10 percent of locations) and above the chronic aquatic life standard at three sampling locations (10 percent of locations). None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for zinc, as shown in Table 6-1. In 2022, 3 of 13 Storm Water Individual Permit compliance samples that were analyzed for zinc exceeded the target action level. Figure 6-18 shows zinc concentrations in filtered storm water and base flow for Sandia and Mortandad canyons. Zinc concentrations in 2022 were similar to those measured in 2021, with the exception of a high zinc result from Storm Water Individual Permit location S-SMA-3.7.

In 2022, no sediment samples exceeded soil screening levels for zinc.

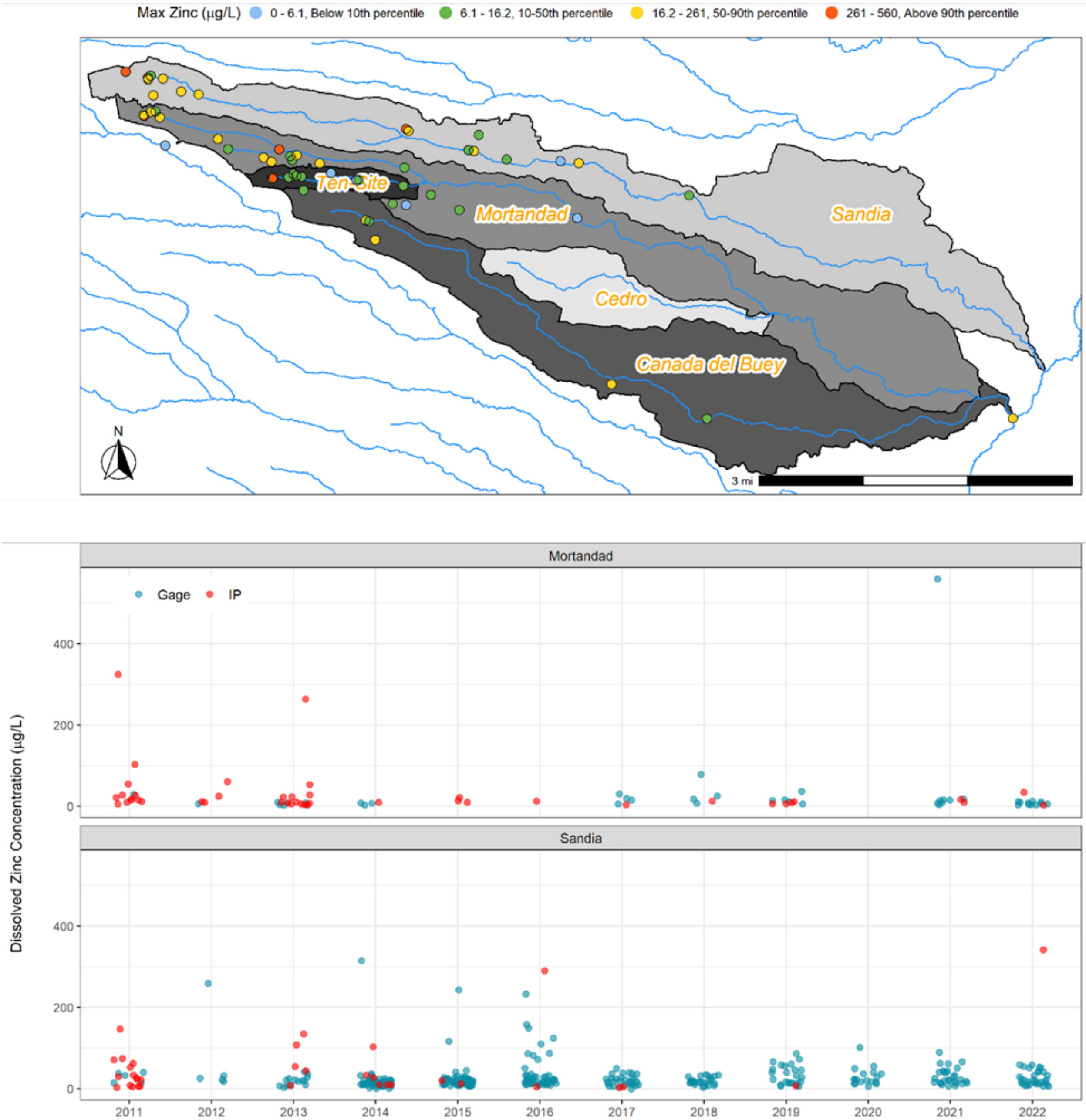


Figure 6-18. Sandia and Mortandad canyons watershed zinc concentrations in filtered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water zinc values for each sampling location from 2011 to 2022. Bottom panels: dissolved zinc concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

Gross Alpha

The gross alpha activity is the sum of the radioactivity from alpha particle emissions from radioactive materials. Alpha particles are released by many naturally occurring radionuclides, such as isotopes of radium, thorium, and uranium, and their decay products. In 2011, 2012, and

2013, the highest gross alpha activities in storm water were measured in samples that contained ash and sediment from the 2011 Las Conchas fire. Gross alpha activities were also particularly high in runoff samples from the large September 2013 flood event.

In 2022, 20 sampling locations (67 percent of locations) had gross alpha activities above the livestock watering standard. Of the 42 assessment units on Laboratory or former Laboratory lands, 27 units are listed as impaired for gross alpha radioactivity, as shown in Table 6-1. In 2022, 12 of 18 Storm Water Individual Permit compliance samples that were analyzed for gross alpha exceeded the target action level. The analytical results from 2022 support earlier conclusions that most of the alpha radioactivity in storm water on the Pajarito Plateau is from the decay of naturally occurring isotopes in sediment and soil and that Laboratory impacts are relatively small (for example, see Gallaher 2007).

Sediment is not analyzed for gross alpha levels because sediment analysis is targeted to specific radionuclides of concern at a particular location.

Radium-226 and Radium-228

Radium is a naturally occurring radioactive element formed by the decay of uranium and thorium in the environment. It occurs at trace levels in virtually all rock, soil, water, plants, and animals. Some regions have higher concentrations due to local geology (U.S. Environmental Protection Agency 2022).

The 13 Storm Water Individual Permit compliance samples from 2022 that were analyzed for radium-226 and radium-228 did not exceed the target action level. Of the 42 assessment units on Laboratory or former Laboratory lands, one unit is listed as impaired for radium, as shown in Table 6-1. The analytical results from 2022 support earlier conclusions that the majority of the radium-226 and radium-228 found in storm water on the Pajarito Plateau is from the decay of naturally occurring isotopes in sediment and soil (Gallaher 2007).

Constituents Related to Los Alamos National Laboratory Operations

Several constituents that were known to be released during historical Laboratory operations were measured in water and sediment. The nature and extent of the constituents in sediment are described in detail in the canyons' investigation reports (LANL 2004, 2005, 2006, 2009a, 2009b, 2009c, 2009d, 2011a, 2011b, 2011c).

The following sections describe the occurrences of key Laboratory-related constituents in 2022 storm water, base flow, and sediment samples. Results for constituents that exceeded screening levels or standards more than once in 2022 at a particular sample location for storm water and base flow are shown in the figures associated with each chemical below.

Cadmium

Cadmium is associated with combustion of fossil fuel; industrial use such as refinement for nickel-cadmium batteries, metal plating, pigments, and plastics; and activities such as sewage sludge disposal and application of phosphate fertilizers (Agency for Toxic Substances and Disease Registry 2012).

In 2022, no cadmium exceedances existed in filtered storm water or base flow samples. No exceedances of the target action level existed for filtered cadmium concentrations in the 13

Storm Water Individual Permit compliance samples in 2022 that were analyzed for cadmium. None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for cadmium (see Table 6-1).

In 2022, no sediment results exceeded soil screening levels for cadmium.

Chromium

Chromium is associated with potassium dichromate that was used as a corrosion inhibitor in the cooling system at the Technical Area 3 power plant (LANL 1973) and was discharged through outfall 001 from 1956 to 1972. Filtered storm water and base flow results did not exceed surface water quality standards in 2022 for either total chromium or hexavalent chromium. No exceedances occurred of the target action levels for filtered chromium concentrations in the 13 Storm Water Individual Permit compliance samples in 2022 that were analyzed for chromium. None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for chromium (see Table 6-1).

In 2022, one sediment sample exceeded both the residential cancer and the construction worker non-cancer soil screening levels for chromium. This sample was from Sandia Canyon, where chromium was known to have been released (see Figure 6-19).

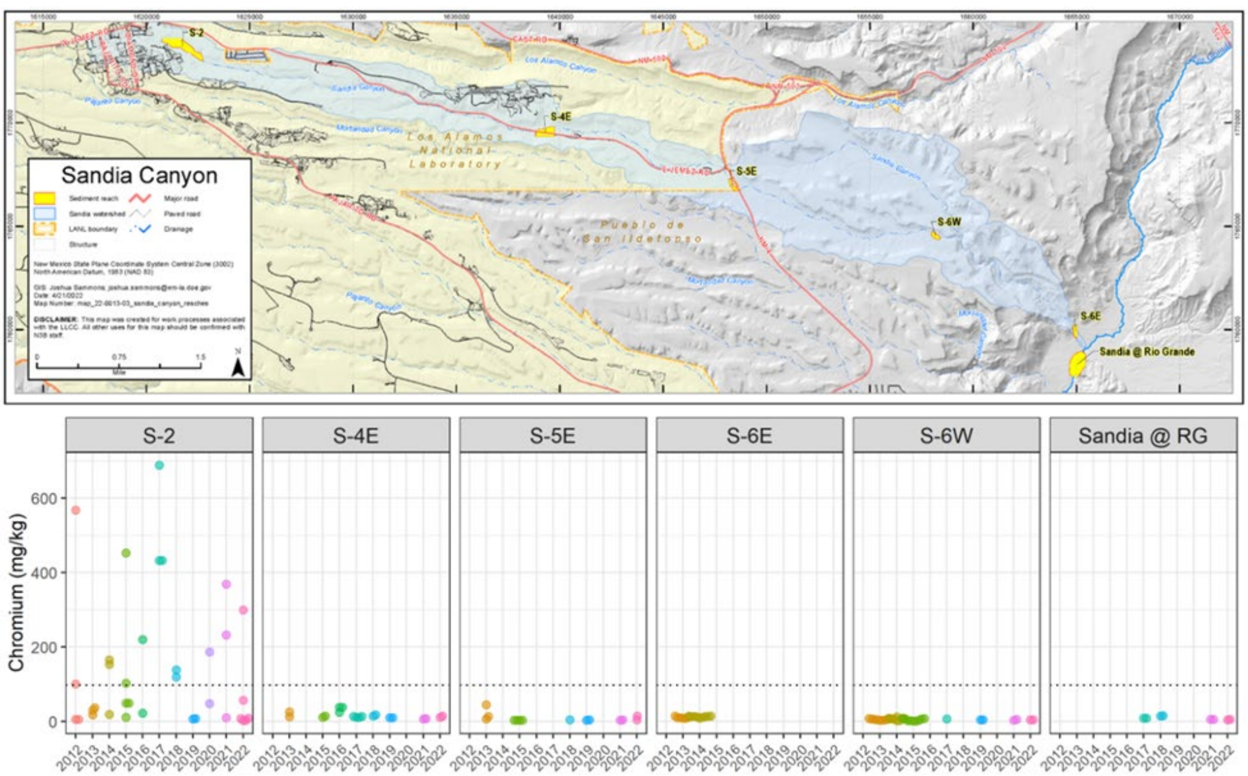


Figure 6-19. Chromium concentrations in sediment samples in Sandia Canyon from 2012 to 2022. The Residential Cancer Soil Screening Level for chromium is 97 milligrams per kilogram (mg/kg). The locations of reaches are shown in the top panel.

Dioxins and Furans

Dioxins and furans are associated with the incineration of medical, industrial, municipal, and private wastes; municipal wastewater treatment sludge; coal-fired boilers; and diesel fuel emissions (U.S. Environmental Protection Agency 2006b). Forest fires are also a major, natural source of dioxins (Gullett and Touati 2003). Toxic equivalents are used to report the toxicity-weighted masses of mixtures of dioxins and furans, which is more meaningful than reporting the number of grams of dioxins or furans because toxic equivalents provide information on toxicity (U.S. Environmental Protection Agency 2010). In addition, surface water quality standards are established for a total dioxin toxic equivalent, but there are no standards for individual dioxins or furans.

In 2022, dioxin concentrations in storm water and base flow samples exceeded the human health organism-only standard at 18 sampling locations (67 percent of locations). No Storm Water Individual Permit compliance samples were analyzed for 2,3,7,8-tetrachlorodibenzodioxin in 2022 because no samples were collected in sample management areas where that compound is identified as a chemical of concern. None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for dioxins or furans (see Table 6-1). Figure 6-20 shows dioxin concentrations in storm water and base flow for the Los Alamos and Pueblo canyons watershed. The dioxin results for the other watersheds are mainly driven by PCB concentrations because certain PCB congeners are included in the total for dioxin toxic equivalents.

In 2022, no sediment samples exceeded soil screening levels for dioxins or furans.

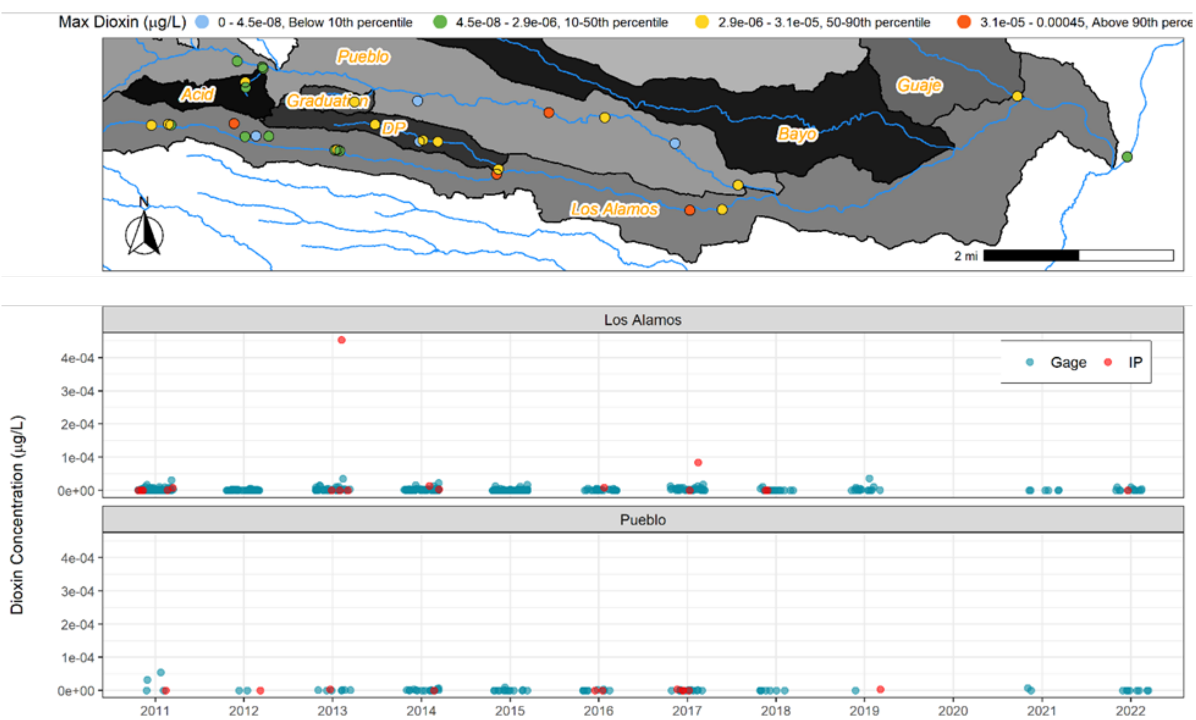


Figure 6-20. Los Alamos and Pueblo canyons watershed dioxin concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water dioxin values for each sampling location from 2011 to 2022. Bottom panels: dioxin concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

Mercury

Sources of mercury include forest fires and fossil fuels, such as coal and petroleum. Human activities, such as mining and fossil fuel combustion, have led to widespread global mercury pollution. Although the Four Corners Generating Station coal-fired power plant has contributed to mercury contamination in the surrounding areas, the Laboratory also operated coal-fired power plants historically.

In 2022, total mercury concentrations in storm water and base flow were detected above the wildlife habitat standard at four sampling locations (14 percent of locations). In 2022, 2 of 13 Storm Water Individual Permit compliance samples that were analyzed for mercury exceeded the target action level. Of the 42 assessment units on Laboratory or former Laboratory lands, 6 units are listed as impaired for mercury (see Table 6-1).

In 2022, no sediment samples exceeded soil screening levels for mercury.

Polychlorinated biphenyls (PCBs)

PCBs are stable, persistent organic compounds that break down slowly in the environment. They were commonly used as plastic and paint stabilizers and coolants in electrical appliances before they were banned in the United States in 1979. Many older construction materials used PCBs, including caulking, paints, window putty, and electrical components (Durell and Lizotte 1998, Kakareka and Kukharchyk 2006). As these building components weather and deteriorate, PCBs accumulate on the landscape and are redistributed. PCBs are remobilized and distributed throughout the globe, including through atmospheric deposition (Chevreuil et al. 1996, Duinker and Bouchertall 1989, Grainer et al. 1990, LANL 2012). PCBs are associated with materials used historically by the Laboratory, including transformers; oils, solvents, and paints used in industrial activities; and a former asphalt batch plant in Sandia Canyon.

In 2022, 23 sampling locations (96 percent of locations) had PCB concentrations above the human health organism-only standard, 2 sampling locations (8 percent of locations) had concentrations above the acute aquatic life standard, 6 sampling locations (25 percent of locations) had concentrations above the chronic aquatic life standard, and 19 sampling locations (79 percent of locations) had concentrations above the wildlife standard. For sampling under the Storm Water Individual Permit in 2022, PCB concentrations were above the target action level in four of six compliance samples that were analyzed for PCBs. Of the 42 assessment units on Laboratory or former Laboratory lands, 31 units are listed as impaired for PCBs (see Table 6-1). Figure 6-21 through Figure 6-24 show total PCB concentrations in unfiltered storm water and base flow for the Ancho and Chaquehui canyons watershed, Los Alamos and Pueblo canyons watershed, Pajarito canyon watershed, and Sandia and Mortandad canyons watershed, respectively.

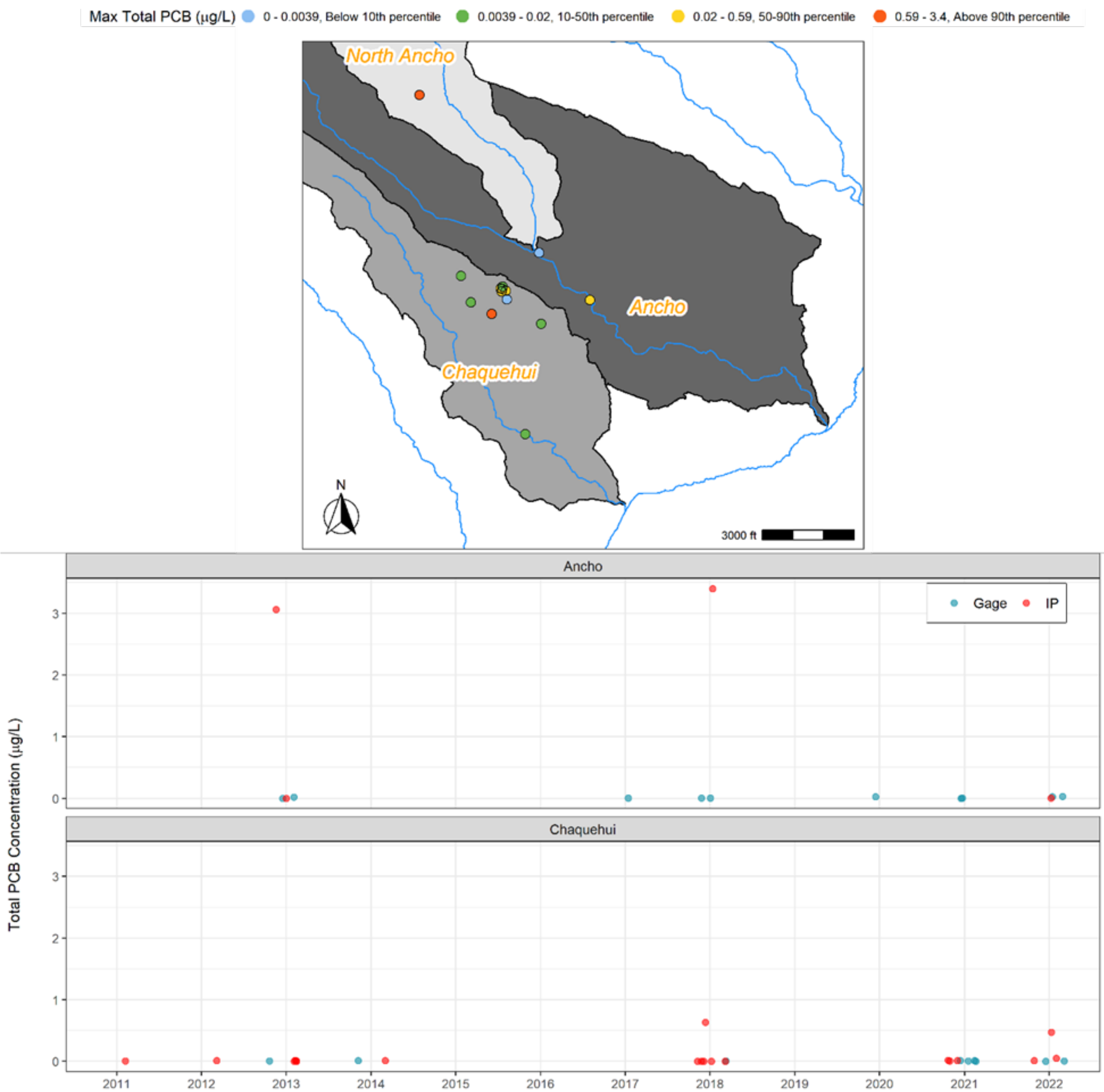


Figure 6-21. Ancho and Chaquehui canyons watershed total PCB concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2022. Bottom panels: total PCB concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

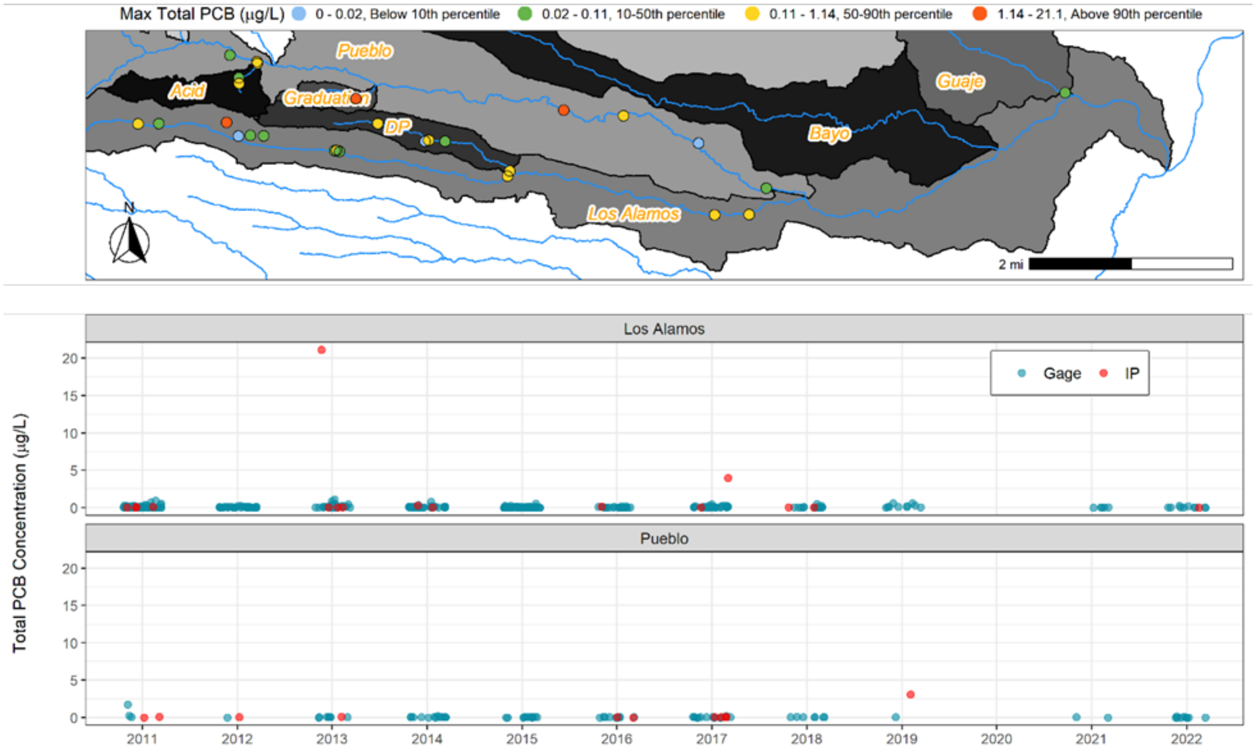


Figure 6-22. Los Alamos and Pueblo canyons watershed total PCB concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2022. Bottom panels: total PCB concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

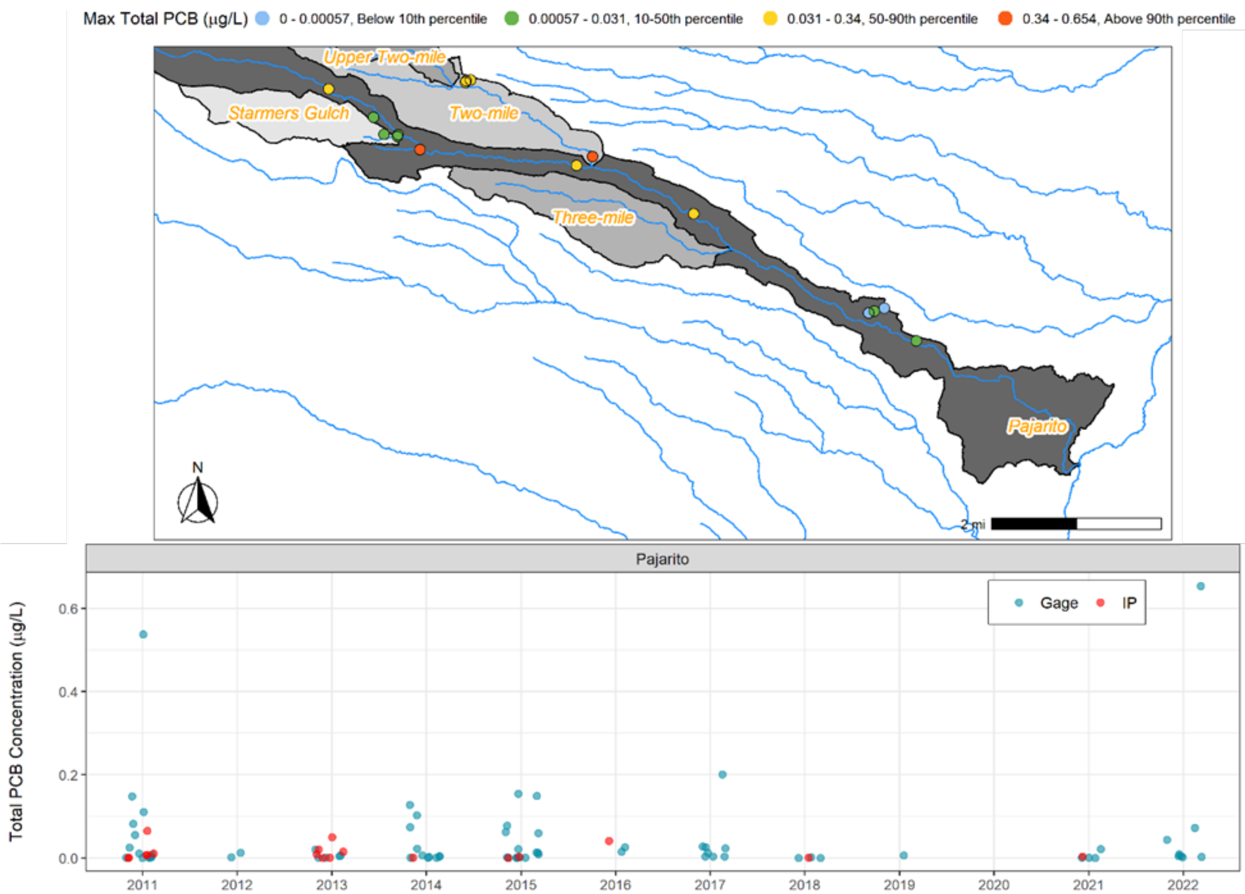


Figure 6-23. Pajarito Canyon watershed total PCB concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2022. Bottom panels: total PCB concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. (µg/L = micrograms per liter)

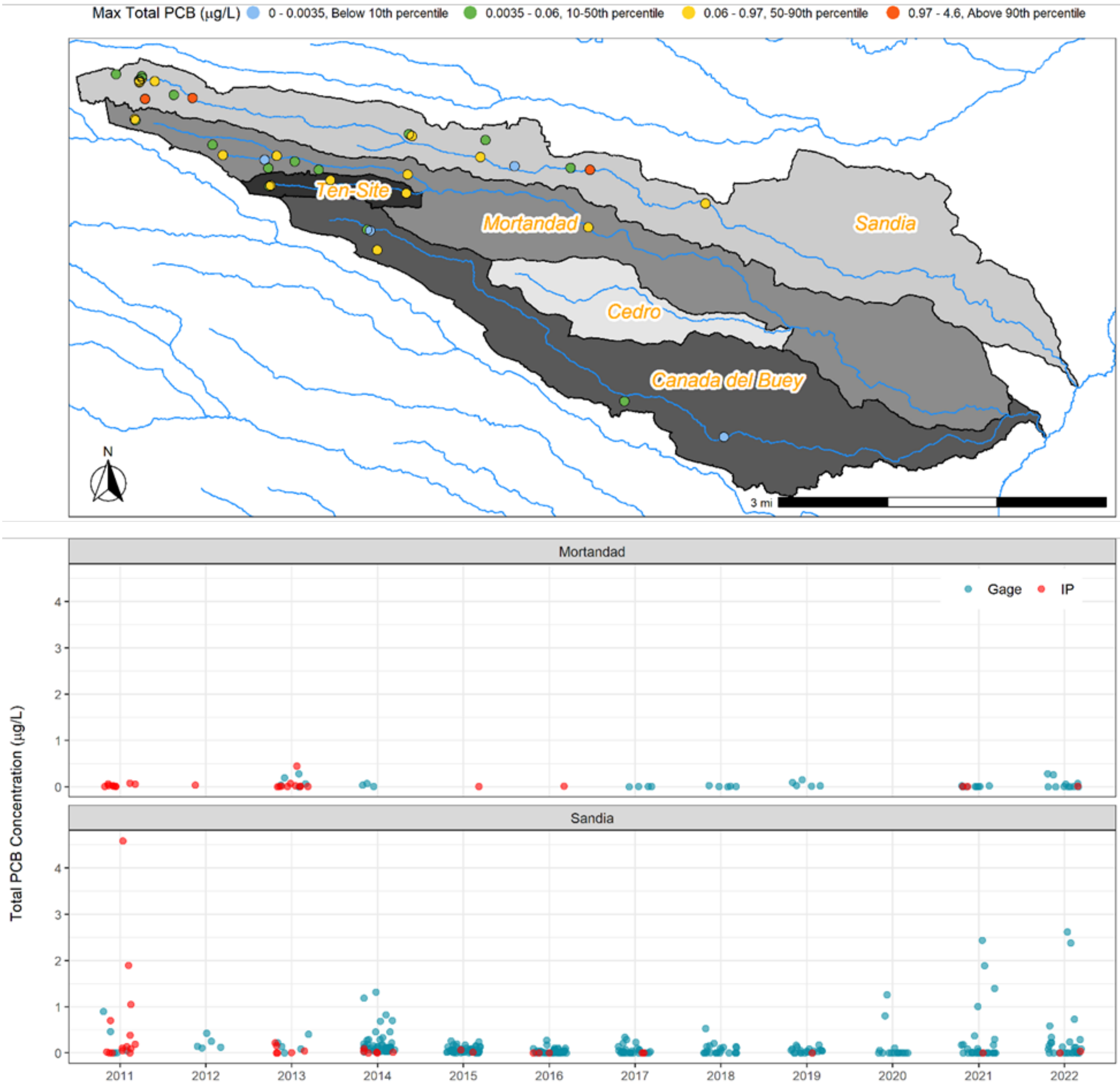


Figure 6-24. Sandia and Mortandad canyons watershed total PCB concentrations in unfiltered storm water from Storm Water Individual Permit samplers and gaging stations and base flow from 2011 to 2022. Top Panel: maximum storm water total PCB concentrations for each sampling location from 2011 to 2022. Bottom panels: total PCB concentrations from Storm Water Individual Permit and gaging station samples from 2011 to 2022. µg/L = micrograms per liter

In 2022, a sediment sample from Cañon de Valle exceeded the residential soil cancer and residential soil non-cancer screening levels for PCB-170. A sediment sample from Sandia Canyon exceeded the residential soil cancer and residential soil non-cancer screening level for PCB-126. The trend of total PCBs in sediment in Los Alamos Canyon is shown in Figure 6-25.

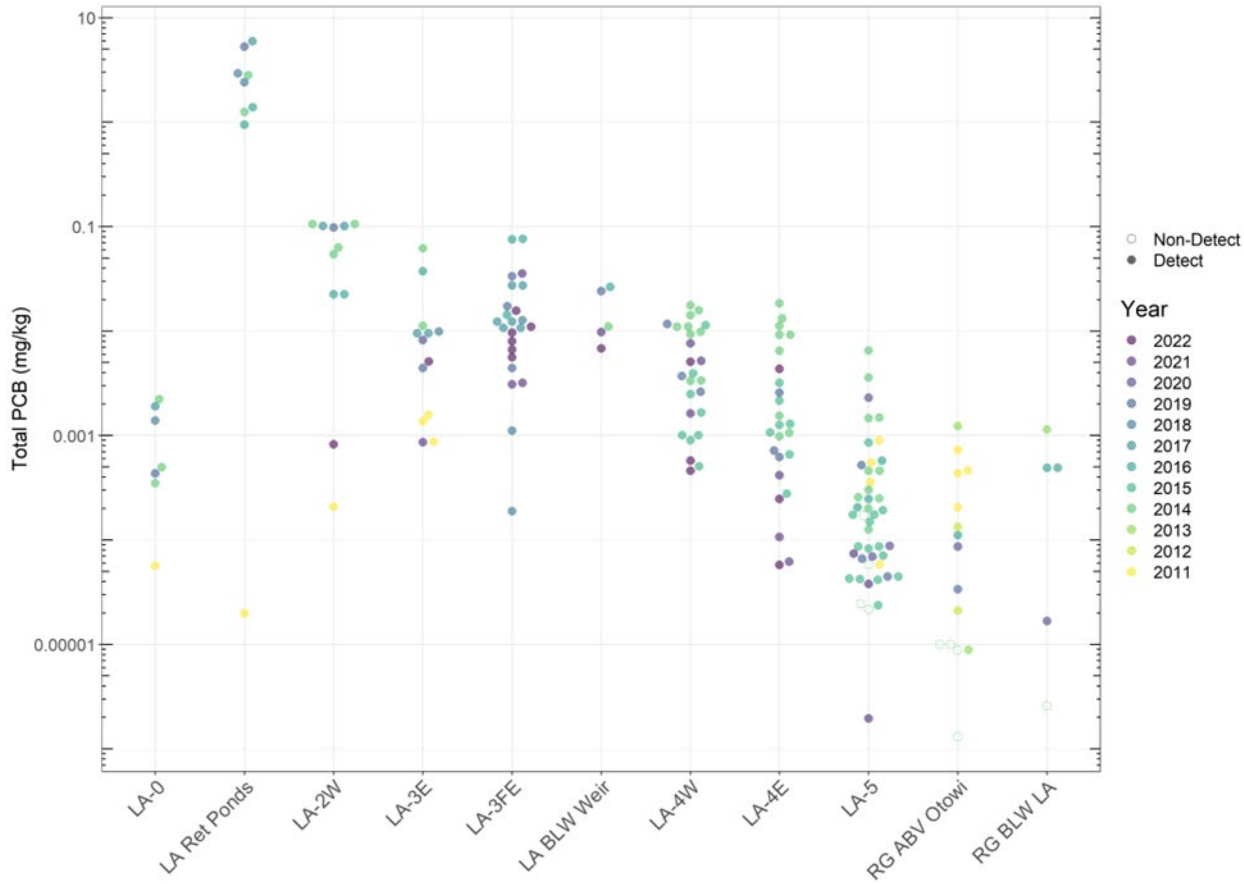


Figure 6-25. Total PCB concentrations in sediment samples in Los Alamos Canyon and the Rio Grande from 2011 to 2022. (mg/kg = milligrams per kilogram)

Polycyclic Aromatic Hydrocarbons

Asphalt is prepared using petroleum products that contain polycyclic aromatic hydrocarbons. Operations at a former asphalt batch plant in Sandia Canyon released effluent to the canyon.

In 2022, one sampling location (13 percent of locations) exceeded the human health organism-only standard for 4 of the 19 polycyclic aromatic hydrocarbons with water quality standards: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene. Two locations (25 percent of locations) exceeded the human health organism-only standard for dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene. Of three compliance samples in 2022, no Storm Water Individual Permit–related exceedances occurred of polycyclic aromatic hydrocarbons. None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for polycyclic aromatic hydrocarbons (see Table 6-1).

In 2022, no sediment samples exceeded screening levels for polycyclic aromatic hydrocarbons.

Radionuclides

Radionuclides are associated with Laboratory activities. In 2022, no storm water or sediment exceedances occurred for radionuclides. The trends of americium-241, cesium-137, plutonium-239/240, and strontium-90 in sediment in Los Alamos Canyon are shown in Figure 6-26 through Figure 6-29, respectively.

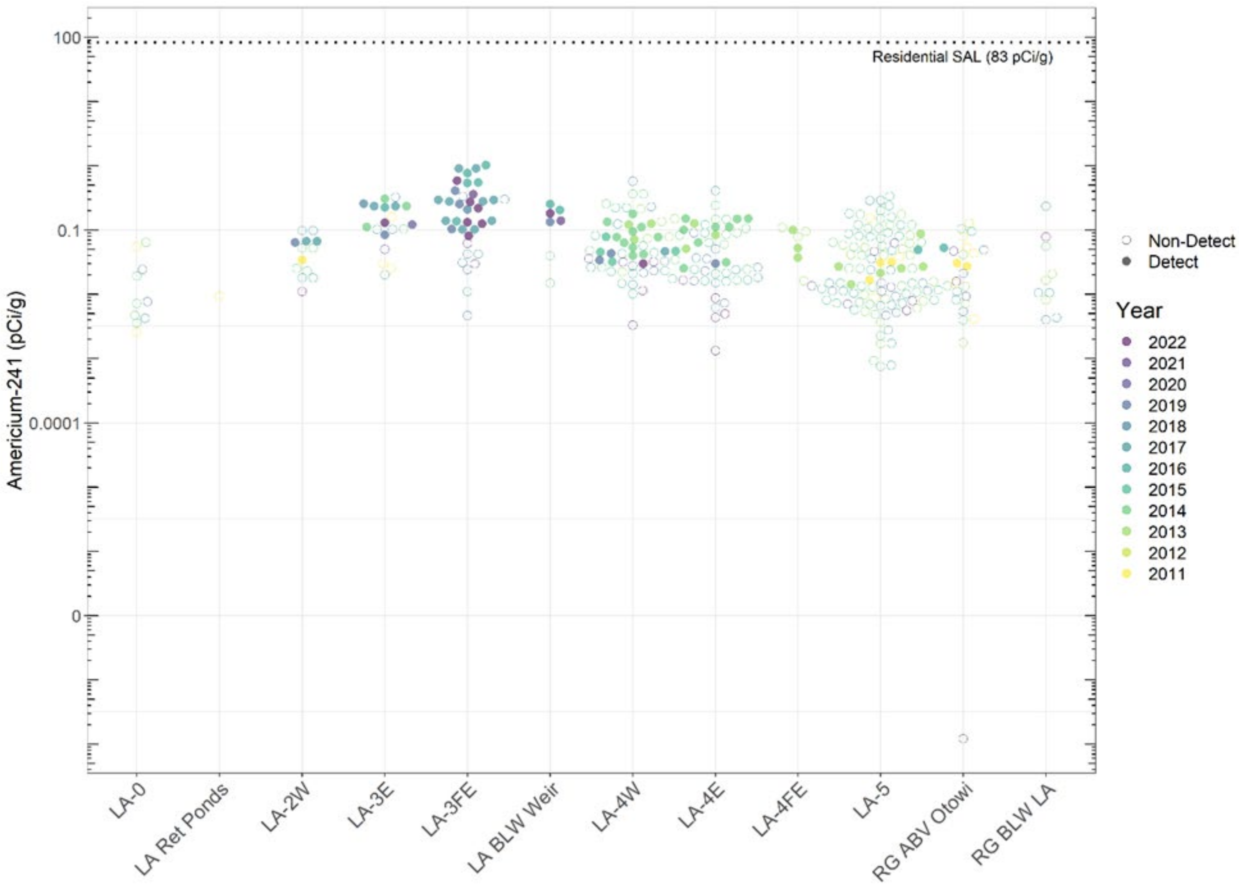


Figure 6-26. Americium-241 concentrations in sediment samples in Los Alamos Canyon and the Rio Grande from 2011 to 2022. The screening action level (SAL) is 83 picocuries per gram (pCi/g).

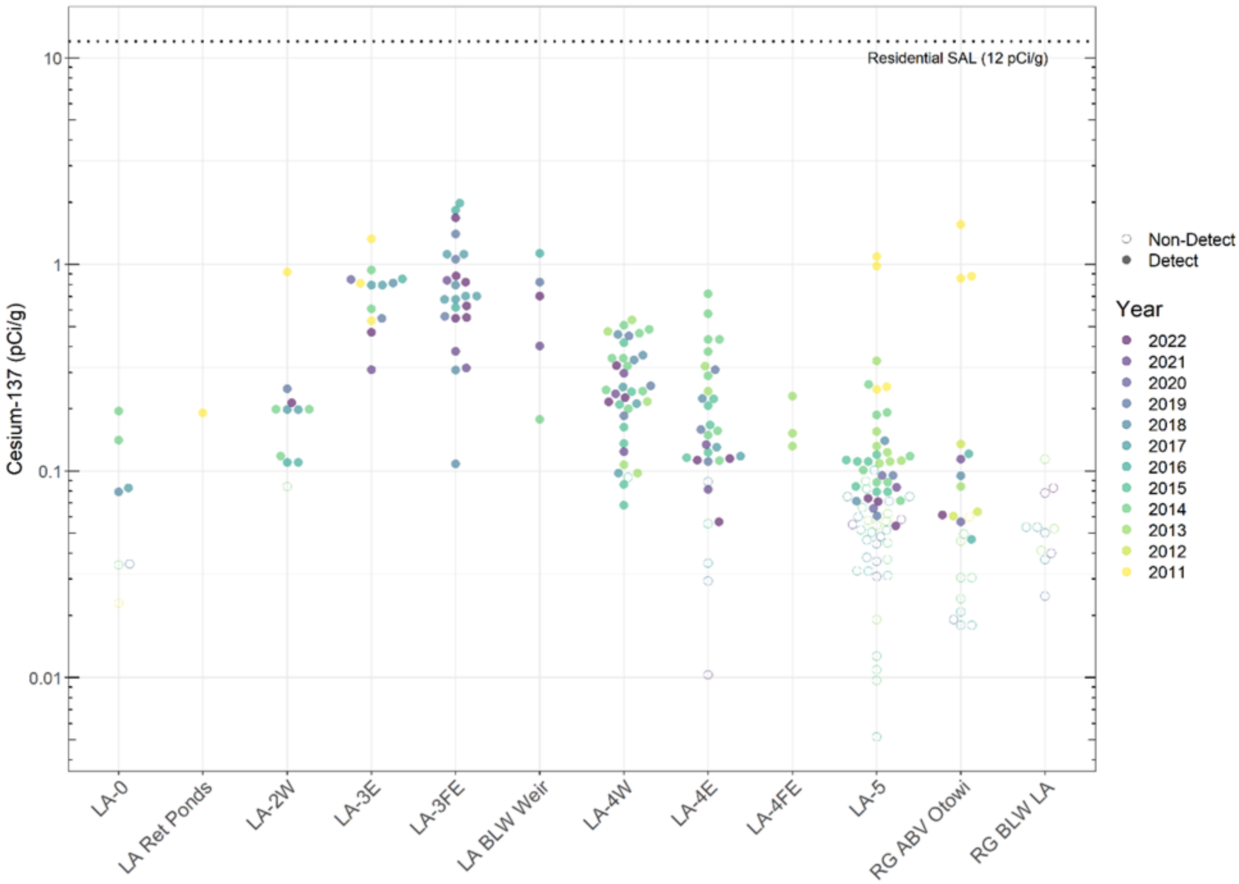


Figure 6-27. Cesium-137 concentrations in sediment samples in Los Alamos Canyon and the Rio Grande from 2011 to 2022. The screening action level (SAL) is 12 picocuries per gram (pCi/g).

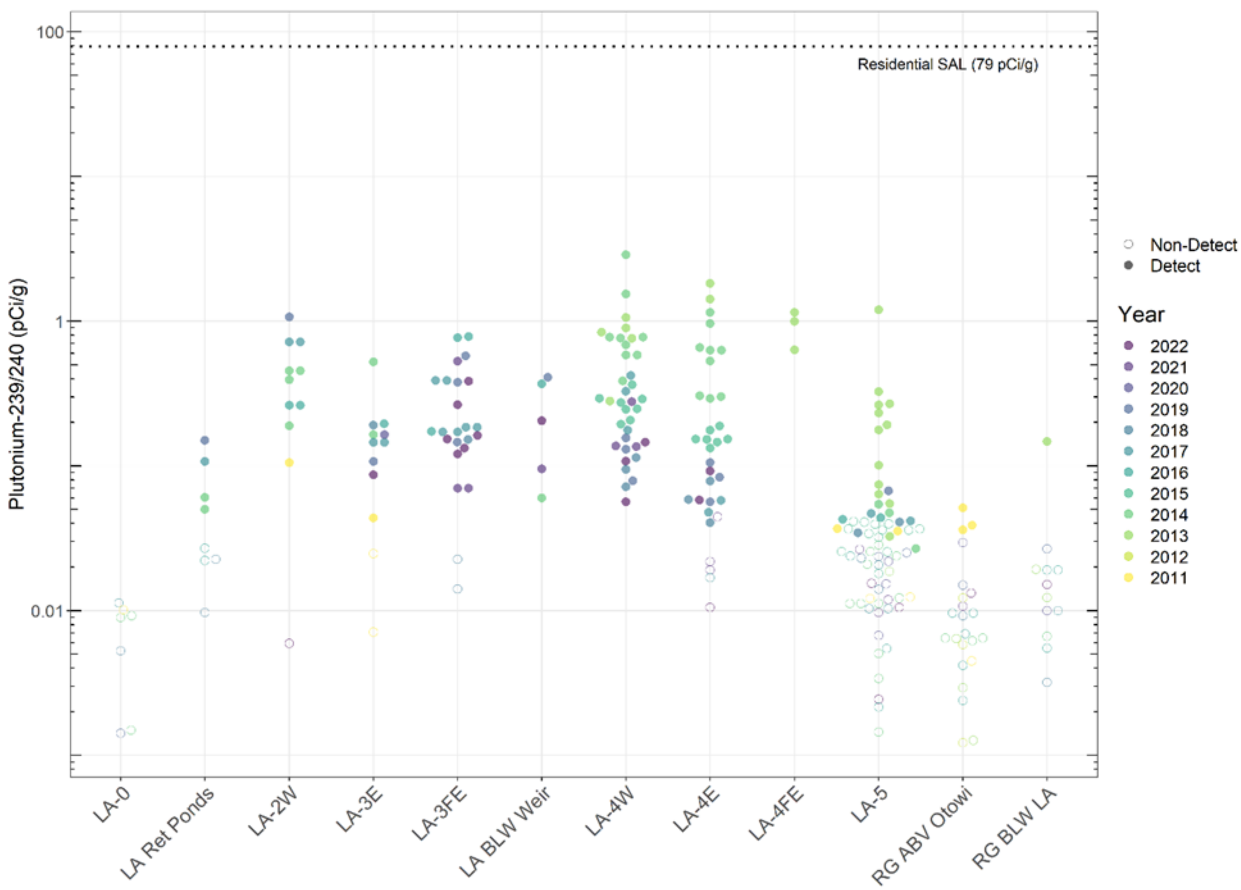


Figure 6-28. Plutonium-239/240 concentrations in sediment samples in Los Alamos Canyon and the Rio Grande from 2011 to 2022. The screening action level (SAL) is 79 picocuries per gram (pCi/g).

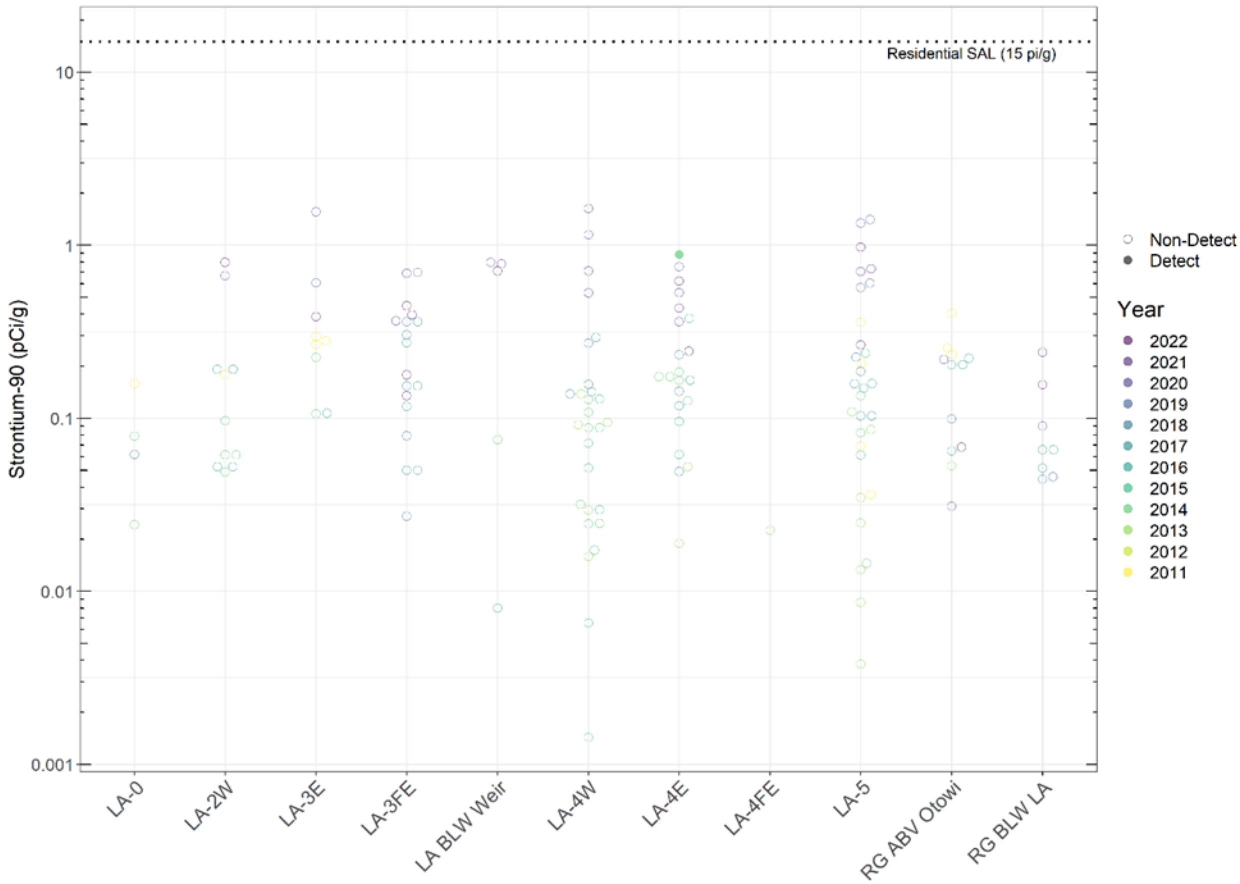


Figure 6-29. Strontium-90 concentrations in sediment samples in Los Alamos Canyon and the Rio Grande from 2011 to 2022. The screening action level (SAL) is 15 picocuries per gram (pCi/g).

Silver

Silver is associated with Laboratory activities in Pajarito Canyon and Cañon de Valle (LANL 2009a, LANL 2011c). Of 14 compliance samples in 2022, no Storm Water Individual Permit–related exceedances occurred of silver. Of the 42 assessment units on Laboratory or former Laboratory lands, 1 unit is listed as impaired for silver (see Table 6-1).

In 2022, no sediment results exceeded soil screening levels for silver.

Thallium

Gaseous emissions from cement factories and coal-fired power plants have contained thallium. Although the Four Corners Generating Station coal-fired power plant has contributed to thallium contamination in the surrounding areas, the Laboratory also operated coal-fired power plants historically.

In 2022, none of the filtered gaging station storm water or base flow results exceeded the surface water quality standards for thallium. Of 13 compliance samples in 2022, no Storm Water Individual Permit–related exceedances occurred for thallium. None of the 42 assessment units on Laboratory or former Laboratory lands are listed as impaired for thallium (see Table 6-1).

In 2022, no sediment samples exceeded soil screening levels for thallium.

Watershed Protection Measures

The Laboratory, in consultation with its regulators and stakeholders, has constructed engineered controls to prevent or minimize the migration of sediment and contaminants. Throughout the Laboratory, storm water control structures have been installed in response to regulatory requirements, site conditions, post-fire flooding threats, and general best management practices. These controls are an integral component of storm water management at LANL.

Consent Order and Storm Water Individual Permit Surface Water Controls

Refer to the 2020 Annual Site Environmental Report Watershed Quality chapter for details on current controls managed by N3B. No new controls were installed by N3B in 2022.

Institutional Surface Water Controls for Enduring Stewardship

Triad manages the storm water control structures at the Laboratory that are not associated with Consent Order or Storm Water Individual Permit activities. LANL infrastructure and property face perennial exposure to the risk of damage from erosion and flooding. Storm water controls are frequently built in conjunction with new facilities to maintain pre-development levels of runoff. Other control structures, situated within canyon bottoms or at road crossings, are designed to mitigate risk to downstream facilities and infrastructure.

Close to 200 engineered storm water management features have been installed at LANL to mitigate the negative effects of storm water runoff and sediment transport. Although some controls were constructed to meet regulatory requirements, an all-encompassing permit or regulation that governs maintenance and functionality of these control features does not exist. The institutional need to ensure that these controls can perform their designed function is fully recognized. We have recently integrated management of storm water infrastructure into existing LANL systems to facilitate a dynamic approach to long-term management and care of controls.

In 2020, Triad initiated a project to locate and document historical institutional storm water controls. On-going efforts to document these controls evolved during 2022 and included new digital means of assessment, allowing an inspection-focused and spatially oriented approach to structure characterization and documentation. Inspection records are stored as fully searchable datasets that facilitate a thorough understanding of issues, developing trends, and required maintenance/repair of infrastructure. We will continue assessment, monitoring, and inspection efforts related to institutionally maintained storm water controls.

Summary – PFAS Monitoring Results

Monitoring of per- and polyfluoroalkyl substances in storm water and sediment was conducted at 15 Storm Water Individual Permit locations in 2022. Samples were collected at three locations, M-SMA-3, PJ-SMA-2, and S-SMA-3.7 (Figure 6-4), but because of data-quality issues during the laboratory analysis, these locations will be re-sampled. Further information is available in the “2022 Annual Data Report for Per- and Polyfluoroalkyl Substances in Stormwater” (N3B 2023d).

Conclusion

We examine our monitoring data to determine if the following conceptual model is still accurate: sediment transported by storm water runoff in Laboratory canyons generally results in the same or lower levels of LANL-released substances in new sediment deposits than previously existed in each reach. Through the surveillance program, we track the movement and concentration of contaminants in sediment over time and can take appropriate action to mitigate or slow sediment transport where needed.

The results of the storm water, base flow, and sediment data from samples collected in 2022 verify this conceptual model. The results also support the finding that the risk assessments presented in the canyons investigation reports (LANL 2004, 2005, 2006, 2009a, 2009b, 2009c, 2009d, 2011a, 2011b, 2011c) represent an upper bound of potential human and ecological health risks in the canyons for the foreseeable future.

The concentrations of chemicals in storm flow and base flow samples in 2022 are within or below the ranges recorded in previous years. Total PCB concentrations in Sandia Canyon in 2022 tended to be higher than in recent years, although still within range of those previously observed. This area will continue to be monitored closely to detect any upward trends.

We continued to observe very few sediment exceedances in 2022. These exceedances included chromium, manganese, and PCBs. Sediment results are tracked over multiple years and compared with nearby surface water results to detect spatial patterns or trends.

Through the human health risk assessments in the canyons' investigation reports, the biota dose assessment (Chapter 7), and human health risk assessment (Chapter 8) in this report, we have concluded that levels of chemicals and radionuclides present in storm water, base flow, and sediment are below levels that would impact human or biota health.

The Laboratory's continued maintenance and construction of watershed-scale engineered controls have been effective in minimizing the migration of contaminated sediment downstream to the Rio Grande.

Quality Assurance

Sampling of storm flow, base flow, and sediment, as well as measuring stream flow, is performed according to written quality assurance and quality control procedures and protocols. Current versions of all procedures and guides are listed at https://eprr.em-la.doe.gov/. These procedures ensure that the collection, processing, and chemical analysis of samples and the validation and verification of analytical data are consistent from year to year.

Analytical results meet the N3B minimum data quality objectives as outlined in N3B-PLN-SDM-1000, "Sample and Data Management Plan." This plan sets the validation frequency criteria at 100 percent Level 1 examination and Level 2 verification of data and at 10 percent minimum Level 3 validation of data. A Level 1 examination assesses the completeness of the data as delivered from the analytical laboratory, identifies any reporting errors, and checks the usability of the data based on the analytical laboratory's evaluation of the data. A Level 2 verification evaluates the data to determine the extent to which the laboratory met the analytical method and the contract-specific quality control and reporting requirements. A Level 3 validation includes Levels 1 and 2 criteria and determines the effect of potential anomalies encountered during analysis and possible effects on data quality and usability. A Level 3 validation is performed manually with method-specific data validation procedures. Laboratory analytical data are validated by N3B personnel as outlined in N3B-PLN-SDM-1000; N3B-AP-SDM-3000, "General Guidelines for Data Validation"; N3B-AP-SDM-3014, "Examination and Verification of Analytical Data"; and additional method-specific analytical data validation procedures. All associated validation procedures have been developed, where applicable, from the U.S. Environmental Protection Agency QA/G-8 Guidance on Environmental Data Verification and Data Validation, the Department of Defense/Department of Energy Consolidated Quality Systems Manual for Environmental Laboratories, the U.S. Environmental Protection Agency National Functional Guidelines for Data Validation, and the American National Standards Institute/American Nuclear Society 41.5: Verification and Validation of Radiological Data.

References

Agency for Toxic Substances and Disease Registry 2012: "Toxicological Profile for Cadmium, Agency for Toxic Substances and Disease Registry," U.S. Department of Human and Health Services, https://www.atsdr.cdc.gov/toxprofiles/tp5-c6.pdf (September 2012).

Chevreuil et al. 1996: M. Chevreuil, M. Garmouma, M. J. Teil, and A. Chesterikoff. 1996. "Occurrence of Organochlorines (PCBs, pesticides) and Herbicides (triazines, phenylureas) in the Atmosphere and in the Fallout from Urban and Rural Stations of the Paris Area," *The Science of the Total Environment* 182 (1):25–37.

Councell et al. 2004: T. B. Councell, K. U. Duckenfield, E. R. Landa, and E. Callender. 2004. "Tire-Wear Particles as a Source of Zinc to the Environment," *Environmental Science and Technology* 38 (15):4206–4214.

Davis and Burns 1999: A. P. Davis and M. Burns. 1999. "Evaluation of Lead Concentrations in Runoff from Painted Structures," *Water Research* 33 (13):2949–2958.

DOE 2019: Department of Energy. 2019. "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," U.S. Department of Energy report DOE-STD-1153-2019.

Duinker and Bouchertall 1989: J. C. Duinker and F. Bouchertall. 1989. "On the Distribution of Atmospheric Polychlorinated Biphenyl Congeners between Vapor Phase, Aerosols, and Rain," *Environmental Science & Technology* 23 (1):57–62.

Durell and Lizotte 1998: G. S. Durell and R. D. Lizotte 1998. "PCB Levels at 26 New York City and New Jersey WPCPs That Discharge to the New York/New Jersey Harbor Estuary," *Environmental Science & Technology* 32 (8):1022–1031.

Gallaher 2007: B. M. Gallaher. 2007. "Watershed Monitoring," in Environmental Surveillance at Los Alamos During 2006, Los Alamos National Laboratory report LA-14341-ENV, 195–230.

Gallaher and Koch 2004: B. M. Gallaher and R. J. Koch. 2004. "Cerro Grande Fire Impacts to Water Quality and Stream Flow near Los Alamos National Laboratory: Results of Four Years of Monitoring," Los Alamos National Laboratory report LA-14177.

Gallaher and Koch 2005: B. M. Gallaher and R. J. Koch. 2005. "Water Quality and Stream Flow After the Cerro Grande Fire: A Summary," Los Alamos National Laboratory report LALP-05-009.

Göbel et al. 2007: P. Göbel, C. Dierkis, and W. G. Coldewey. 2007. "Storm Water Runoff Concentration Matrix for Urban Areas," *Journal of Contaminant Hydrology* 91 (1):26–42.

Grainer et al. 1990: L. Granier, M. Chevreuil, A. -M. Carru, and R. Létolle. 1990. "Urban Runoff Pollution by Organochlorines (Polychlorinated Biphenyls and Lindane) and Heavy Metals (Lead, Zinc and Chromium)," *Chemosphere* 21 (9):1101–1107.

Gullett and Touati 2003: B. K. Gullett and A. Touati. 2003. "PCDD/F Emissions from Forest Fire Simulations," *Atmospheric Environment* 37 (6):803–813.

Kakareka and Kukharchyk 2006: S. Kakareka and T. Kukharchyk. 2006. "Sources of Polychlorinated Biphenyl Emission," in Atmospheric Emission Inventory Guidebook, EMEP/CORINAIR Emission Inventory Guidebook, Part B General Methodology Chapters, https://www.eea.europa.eu/publications/EMEPCORINAIR4/page001.html.

LANL 1973: "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972," Los Alamos National Laboratory report LA-5184.

LANL 2004: "Los Alamos and Pueblo Canyons Investigation Report," Los Alamos National Laboratory report LA-UR-04-2714.

LANL 2005: "Los Alamos and Pueblo Canyons Supplemental Investigation Report," Los Alamos National Laboratory report LA-UR-05-9230.

LANL 2006: "Mortandad Canyon Investigation Report," Los Alamos National Laboratory report LA-UR-06-6752.

LANL 2009a: "Pajarito Canyon Investigation Report, Revision 1," Los Alamos National Laboratory report LA-UR-09-4670.

LANL 2009b: "Investigation Report for Sandia Canyon Aggregate Area," Los Alamos National Laboratory report LA-UR-09-6450.

LANL 2009c: "Investigation Report for North Canyons, Revision 1," Los Alamos National Laboratory report LA-UR-09-6794.

LANL 2009d: "Cañada del Buey Investigation Report, Revision 1," Los Alamos National Laboratory report LA-UR-09-7317.

LANL 2011a: "Investigation Report for Potrillo and Fence Canyons, Revision 1," Los Alamos National Laboratory report LA-UR-11-1820.

LANL 2011b: "Investigation Report for Ancho, Chaquehui, and Indio Canyons, Revision 1," Los Alamos National Laboratory report LA-UR-11-3305.

LANL 2011c: "Investigation Report for Water Canyon/Cañon de Valle," Los Alamos National Laboratory report LA-UR-11-5478.

LANL 2012: "Polychlorinated Biphenyls in Precipitation and Stormwater within the Upper Rio Grande Watershed," Los Alamos National Laboratory report LA-UR-12-1081.

LANL 2015: "Derivation and Use of Radionuclide Screening Action Levels, Revision 4," Los Alamos National Laboratory report LA-UR-15-24859.

McNaughton et al. 2013: M. P. McNaughton, P. Fresquez, and B. Eisele. 2013. "Site-Representative Biota Concentration Guides at Los Alamos," Los Alamos National Laboratory report LA-UR-13-20095.

N3B 2021: "Interim Facility-Wide Groundwater Monitoring Plan for the 2022 Monitoring Year, October 2021 – September 2022," N3B document EM2021-0535.

N3B 2022a: "2022 Annual Periodic Monitoring Report for the General Surveillance Monitoring Group," N3B document EM2022-0747.

N3B 2022b: "Interim Facility-Wide Groundwater Monitoring Plan for the 2023 Monitoring Year, October 2022 – September 2023, Revision 1," N3B document EM2022-0656.

N3B 2023a: "2022 Sandia Wetland Performance Report," N3B document EM2023-0037.

N3B 2023b: "2022 Monitoring Report and 2023 Monitoring Plan for Los Alamos/Pueblo Watershed Sediment Transport Mitigation Project," N3B document EM2023-0142.

N3B 2023c: "2022 Update to the Site Discharge Pollution Prevention Plan; Overview," N3B document EM2023-0001.

N3B 2023d: "2022 Annual Data Report for Per- and Polyfluoroalkyl Substances in Stormwater," N3B document EM2023-0025.

New Mexico Environment Department 2021: "Comprehensive Assessment and Listing Methodology (CALM): Procedures for Assessing Water Quality Standards Attainment for the State of New Mexico CWA §303(d)/§305(b) Integrated Report," New Mexico Environment Department, Surface Water Quality Bureau (effective August 18, 2021), https://www.env.nm.gov/surface-water-quality/wp-content/uploads/sites/18/2021/09/CALM_2021-FINAL_with_appendices.pdf.

New Mexico Environment Department 2022a: "New Mexico Environment Department Risk Assessment Guidance for Site Investigations and Remediation – Volume I, Soil Screening Guidance for Human Health Risk Assessments, November 2022," New Mexico Environment Department, Hazardous Waste Bureau, https://www.env.nm.gov/hazardous-waste/wp-content/uploads/sites/10/2022/11/NMED_SSG_VOL_I_Nov_2022.pdf.

New Mexico Environment Department 2022b: "2022–2024 State of New Mexico Clean Water Act Section 303(d) / Section 305(b) Integrated Report," New Mexico Environment Department, Surface Water Quality Bureau, https://www.env.nm.gov/surface-water-quality/303d-305b/.

Reneau et al. 2010: S. L. Reneau, P. G. Drakos, A. R. Groffman, J. Linville, R. T. Ryti, K. B. Schilling, E. S. Schultz-Fellenz, W. L. Swanson, and S. J. Veenis, "Watershed Monitoring," in Environmental Surveillance at Los Alamos During 2009, Los Alamos National Laboratory report LA-14427-ENV, 207–252.

Rose et al. 2001: S. Rose, M. S. Crean, D. K. Sheheen, and A. M. Ghazi, "Comparative Zinc Dynamics in Atlanta Metropolitan Region Stream and Street Runoff," *Environmental Geology* 40 (8):983–992.

Ryan et al. 2019: A. C. Ryan, R. C. Santore, S. Tobiason, G. WoldeGabriel and A. R. Groffman, "Total Recoverable Aluminum: Not Totally Relevant for Water Quality Standards," *Integrated Environmental Assessment and Management* 15 (6):974–987.

Ryti et al. 1998: R. T. Ryti, P. A. Longmire, D. E. Broxton, S. L. Reneau, and E. V. McDonald, "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-98-4847.

TDC Environmental 2004: "Copper Sources in Urban Runoff and Shoreline Activities," Information Update, Prepared for the Clean Estuary Partnership, TDC Environmental, LLC, San Mateo, CA.

U.S. Environmental Protection Agency 2001: "The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments," U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, https://www.epa.gov/sites/production/files/2015-09/documents/slera0601.pdf.

U.S. Environmental Protection Agency 2006a: "National Recommended Water Quality Criteria," U.S. Environmental Protection Agency, Office of Water, https://www.epa.gov/wqc.

U.S. Environmental Protection Agency 2006b: "An Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the U.S. for the Years 1987, 1995, and 2000," U.S. Environmental Protection Agency, National Center for Environmental Assessment, http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=159286.

U.S. Environmental Protection Agency 2010: "Recommended Toxicity Equivalence Factors (TEFs) for Human Health Risk Assessments of 2,3,7,8-Tetrachlorodibenzo-p-dioxin and Dioxin-Like Compounds," U.S. Environmental Protection Agency, Office of Science Advisor, Risk Assessment Forum, https://www.epa.gov/sites/production/files/2013-09/documents/tefs-for-dioxin-epa-00-r-10-005-final.pdf.

U.S. Environmental Protection Agency 2020: "Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites," U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (accessed April 2021).

U.S. Environmental Protection Agency 2022: "Radionuclide Basics: Radium," U.S. Environmental Protection Agency, https://www.epa.gov/radiation/radionuclide-basics-radium (accessed 12/19/2022).

Washington State Department of Ecology 2006: "A Survey of Zinc Concentrations in Industrial Stormwater Runoff," Washington State Department of Ecology Publication No. 06-03-009.

Water Quality Control Commission 2022: "State of New Mexico Standards for Interstate and Intrastate Surface Waters," New Mexico Water Quality Control Commission, 20.6.4 New Mexico Administrative Code (effective September 2022), https://www.env.nm.gov/surface-water-quality/wqs/.

Chapter 7: Ecosystem Health

Our objectives are to determine whether operations at Los Alamos National Laboratory (LANL or the Laboratory) affect plant or animal populations (collectively called "biota"); to meet federal and state regulatory requirements; to reduce the potential for harm from wildland fire; and to increase forest and habitat resilience to climate-related disturbances.

To monitor levels of radionuclides and other chemicals, we collect samples of soil, sediment, plants, and animals on Laboratory property, around the perimeter of the Laboratory, and from more-distant locations that provide background comparisons. We test samples for radionuclides, inorganic elements (such as metals), and organic chemicals (such as polychlorinated biphenyls [PCBs], per- and polyfluoroalkyl substances [PFAS], dioxins, furans, and high explosives). We also assess radiation dose for plants and animals living around Laboratory facilities and around sediment-retention structures in canyon bottoms. The calculated doses are compared with background levels of radiation, screening levels, and federal standards for plants and animals.

We collected the following samples during 2022:

- *Soil and vegetation samples around the perimeter of Material Disposal Area G at Technical Area 54*
- *Soil, sediment, vegetation, and bird egg samples around the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15*
- *Bird egg and nestling samples at two open-detonation sites and at the open-burn site*
- *Small mammal and vegetation samples in Los Alamos and Pajarito canyons on Laboratory property*
- *Small mammal samples in a Sandia canyon effluent-fed wetland*
- *Deceased animals (primarily from animal-vehicle collisions) from various sites on and off the Laboratory*

In most soil, sediment, plant, and animal samples from onsite and perimeter locations, radionuclides and chemicals were either not detected, had levels similar to background, or had levels below the screening levels that could be harmful to biota. Biota dose assessments indicate that the radiation doses are far below the levels that have adverse effects on plants and animals. Endangered species surveys in 2022 confirmed that two Mexican spotted owl habitats on Laboratory property were again inhabited by adult owls. We conducted pre- and post-treatment monitoring of forested areas that we thinned to see if we met our goals for wildland fire risk reduction.

Introduction

An ecosystem includes living organisms such as plants, animals, and bacteria; nonliving elements such as soil, air, and water; and the interactions among these components (Smith and Smith 2012). The relative health and functioning of an ecosystem can be affected by disturbances, including wildfire, flooding, drought, invasive species, climate shifts, chemical spills, construction projects, vegetation removal, and other events (Rapport 1998). Los Alamos National Laboratory (LANL or the Laboratory) encompasses habitat for many species of plants and animals (collectively called "biota"). To evaluate and support the health of our local ecosystems, we monitor and, where needed, manage

- levels of radionuclides and other chemicals in soil, sediment, plants, and animals;
- federally listed threatened or endangered species;
- populations of migratory bird species and other species of concern; and
- forest conditions.

Biota Dose and Risk Assessment Methods

We monitor chemical and radionuclide levels at specific Laboratory facilities and for the entire institution. We collect a variety of environmental samples including soil, sediments, native vegetation, honey, small mammals, bird eggs, crayfish, fish, and other animals. Institutional monitoring occurs on Laboratory property, around the perimeter of the Laboratory, and at regional background locations. We use these results to calculate radioactive dose and chemical risk for wildlife, plants, and humans (see Chapter 8). Some of the samples collected for institutional monitoring rotate on a 3-year cycle: terrestrial soil and vegetation, foodstuffs (results are reported in Chapter 8), and samples from the Rio Grande and nearby reservoirs. In 2022, we collected foodstuffs samples.

Both institutional and facility-specific results are used to assess the effects of Laboratory-released chemicals and radionuclides on ecosystem health. We perform the assessment by the following:

- measuring levels of radionuclides and other chemicals in soil, plants, and animals from areas on Laboratory property and near the perimeter of the Laboratory and then comparing these levels with
  - levels measured from background locations not affected by Laboratory operations;
  - levels that scientists have determined should trigger further investigation, such as screening levels; and
  - levels that may cause adverse health effects;
- evaluating trends in radionuclide and chemical levels in soil, plants, and animals over time;
- assessing population parameters and species diversity of animals in areas potentially affected by Laboratory operations; and
- estimating radiation dose and chemical risk to biota using the monitoring results.

Soil and Sediment

Soil and sediment receive chemicals that are released into the air and that are attached to particles transported by wind and water. Monitoring soil over time directly measures long-term trends of radionuclide and other chemical concentrations around nuclear facilities (DOE 2015).

Levels of radionuclides and other chemicals (constituents) in soil and sediment samples from the Laboratory are compared with regional statistical reference levels. A regional statistical reference level is calculated using results from all the soil or sediment samples collected at regional background locations during the previous 10 years. It is the level below which precisely 99 percent of the results from regional background soil or sediment samples fall. As required by the U.S. Department of Energy (DOE), all background locations are at a similar elevation to the Laboratory, more than 9.3 miles away from the Laboratory, and beyond the range of potential influence from normal Laboratory operations (DOE 2015). Constituents in soil or sediment collected from regional background locations come from naturally occurring sources and manufactured sources other than the Laboratory, including past testing of atomic weapons, power plant emissions, and automobile emissions.

Levels of constituents in soil and sediment are also compared with ecological soil screening levels. One type of ecological soil screening level is the highest level of a radionuclide or chemical in the soil that is known to not affect selected animals or plants (the no-effect ecological screening level). Another type is the lowest level in the soil known to be associated with an adverse effect on selected animals or plants (the low-effect ecological screening level). Soil concentrations of chemicals and radionuclides below these ecological soil screening levels are unlikely to harm plants or animals.

The Laboratory has estimated no-effect and low-effect ecological screening levels based on published research for a series of plants and animals that could occur at the Laboratory and that represent different trophic levels and feeding habits (LANL 2020). We compare our soil results to ecological soil screening levels for the following terrestrial plants or animals:

- generic plant; earthworm—representing soil-dwelling invertebrates;
- desert cottontail (*Sylvilagus audubonii*)—representing mammalian herbivores;
- deer mouse (*Peromyscus maniculatus*)—representing mammalian omnivores;
- montane shrew (*Sorex monticolus*)—representing mammalian terrestrial insectivores;
- Botta's pocket gopher (*Thomomys bottae*)—representing burrowing mammals;
- gray fox (*Urocyon cinereoargenteus*)—representing mammalian carnivores;
- occult little brown bat (*Myotis lucifugus occultus*)—representing mammalian aerial insectivores;
- American robin (*Turdus migratorius*)—representing avian omnivores, herbivores, and insectivores;
- violet-green swallow (*Tachycineta thalassina*)—representing avian aerial insectivores; and
- American kestrel (*Falco sparverius*)—representing avian carnivores (LANL 2020).

Ecological sediment screening levels have also been developed for the following aquatic plants and animals:

- algae—representing aquatic autotrophs,
- aquatic snails—representing aquatic herbivore/grazer,
- daphnids—representing aquatic omnivore/herbivore,
- fish—representing aquatic intermediate carnivore, and
- aquatic community organisms (LANL 2020).

Plant and Animal Tissues

Small mammals, such as wild mice, are well suited for monitoring chemical and radionuclide exposures and uptake in biological systems because of their close contact with soil, burrowing behavior, and omnivorous diets (Smith et al. 2002, Talmage and Walton 1991).

Bird eggs and nestlings are useful for monitoring chemical and radionuclide exposures and uptake in biological systems because different bird species occupy different trophic levels. Additionally, the collection of nonviable eggs and/or nestlings that die of natural causes is noninvasive and nondestructive to wild populations. Wild bird eggs have been shown to reflect chemical exposures from the location where a female bird feeds during egg formation (Dauwe et al. 2005); however, chemicals from the female's previous exposures, such as on migration routes or wintering grounds, can also be deposited into eggs (Bustnes et al. 2010). Nestlings tend to reflect chemical exposures from local sources due to their limited mobility. Birds can be exposed through several routes, including food items, ingestion of soil, drinking water, and inhalation.

Levels of chemicals in plant and animal tissues are compared with lowest observable adverse effect levels in tissues, when available. A lowest observable adverse effect level in tissues is the lowest concentration measured in a plant or animal's tissues that has been associated with an adverse effect (U.S. Environmental Protection Agency 2014). Levels of radionuclides in tissues are compared with biota dose screening levels, which are set at 10 percent of the DOE limit for radiation doses to biota (DOE 2019, McNaughton 2021).

Estimated Doses to Plants and Animals

The dose to biota is calculated using RESRAD-BIOTA software (version 1.8) (http://resrad.evs.anl.gov/codes/resrad-biota/), which is DOE's methodology for evaluating radiation doses to aquatic and terrestrial biota. This calculated dose is compared with DOE limits: 1 rad per day for terrestrial plants and aquatic animals and 0.1 rad per day for terrestrial animals (DOE 2019).

Comparisons among Sites and over Time

We perform statistical tests to evaluate differences in constituents among sites and to examine trends in constituent levels over time. Examples of these tests include t-tests, analysis of variance, Kruskal-Wallis tests, Kendall's Tau tests, linear regressions, and generalized linear models. Statistical analyses are not conducted on datasets where 80 percent or more of the results for a specific chemical or radionuclide are "not detected" (Helsel 2012). Samples collected within approximately the past 10 years are used to study trends over time. These samples are directly comparable because they were analyzed with similar analytical methods and instruments and have similar detection limits. We test a null hypothesis of no effect for each set of data. For each test, we select a probability level, or p-value, of the null hypothesis being correct, and then we accept or reject the null hypothesis. A p-value of less than 5 percent ($p < 0.05$) is used as our threshold to reject the null hypothesis of no difference between locations or no trend over time. If the p-value is greater than 5 percent ($p > 0.05$), we accept the null hypothesis of no difference or no trend.

Results of Facility-Specific Monitoring for Radionuclides and Chemicals

Area G at Technical Area 54

Area G was established in 1957 and is the Laboratory's primary low-level radioactive solid waste burial and storage site (DOE 1979, Martinez 2006; see Figure 7-1). Tritium, plutonium, americium, and uranium are the main radionuclides in waste materials at Area G (Mayfield and Hansen 1983). The Laboratory has conducted soil, vegetation, and small mammal monitoring at Area G since 1980 to monitor whether radionuclides are migrating beyond the waste burial area (LANL 1981, Mayfield and Hansen 1983).

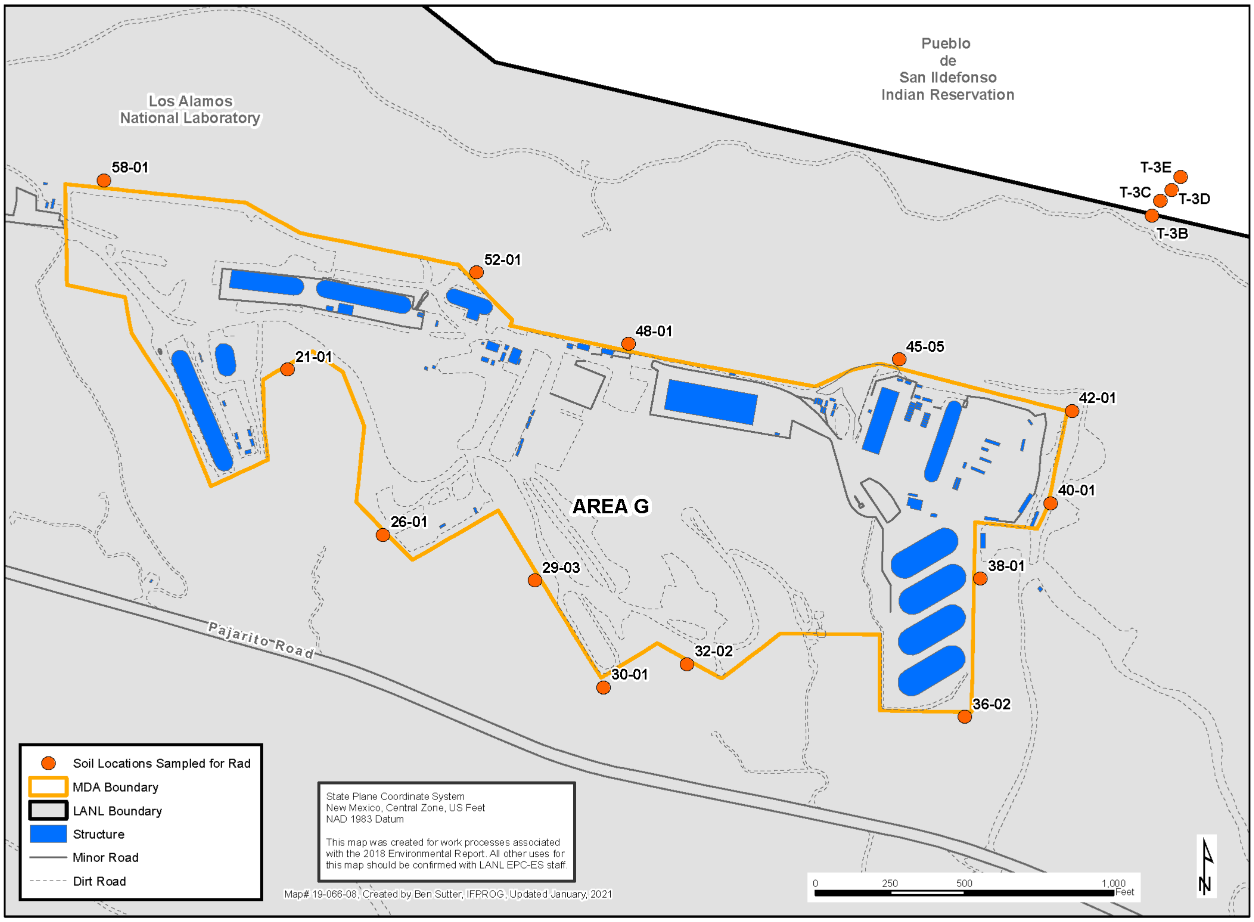


Figure 7-1. Locations of soil and vegetation samples collected around Area G and near the Laboratory and Pueblo de San Ildefonso boundary in 2022. (MDA = Material Disposal Area)

We collect surface soil and vegetation at Area G each year for testing. Surface soil grab samples (0 to 6 inches deep) and composite tree samples, primarily of one-seed juniper (*Juniperus monosperma*), were collected in June 2022 at 13 designated locations around the perimeter of Area G. Four soil and one composite tree sample were collected at the bottom of Cañada del Buey, near the boundary between the Laboratory and the Pueblo de San Ildefonso (see Figure 7-1). All samples were analyzed for tritium, americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235/236, and uranium-238.

Soil Results

The 2022 soil results at Area G are summarized as follows (see Supplemental Table S7-1 for individual results):

- Tritium and strontium-90 were not detected in soil around Area G.
- Cesium-137 activities were below the regional statistical reference level.
- Uranium-234, uranium-235/236, and uranium-238 activity were similar to or below the regional statistical reference levels.
- Americium-241, plutonium-238, and plutonium-239/240 activities were above the regional statistical reference levels in several locations.
- All radionuclide levels are far below their soil ecological screening levels.

Americium-241, plutonium-238, and plutonium-239/240 in soil samples collected on the north, northeastern, and eastern side of Area G were above their regional statistical reference levels. These concentrations are similar to previous years and most radionuclide levels are not increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-2); however, americium-241 is increasing at location 48-01. This location will continue to be monitored.

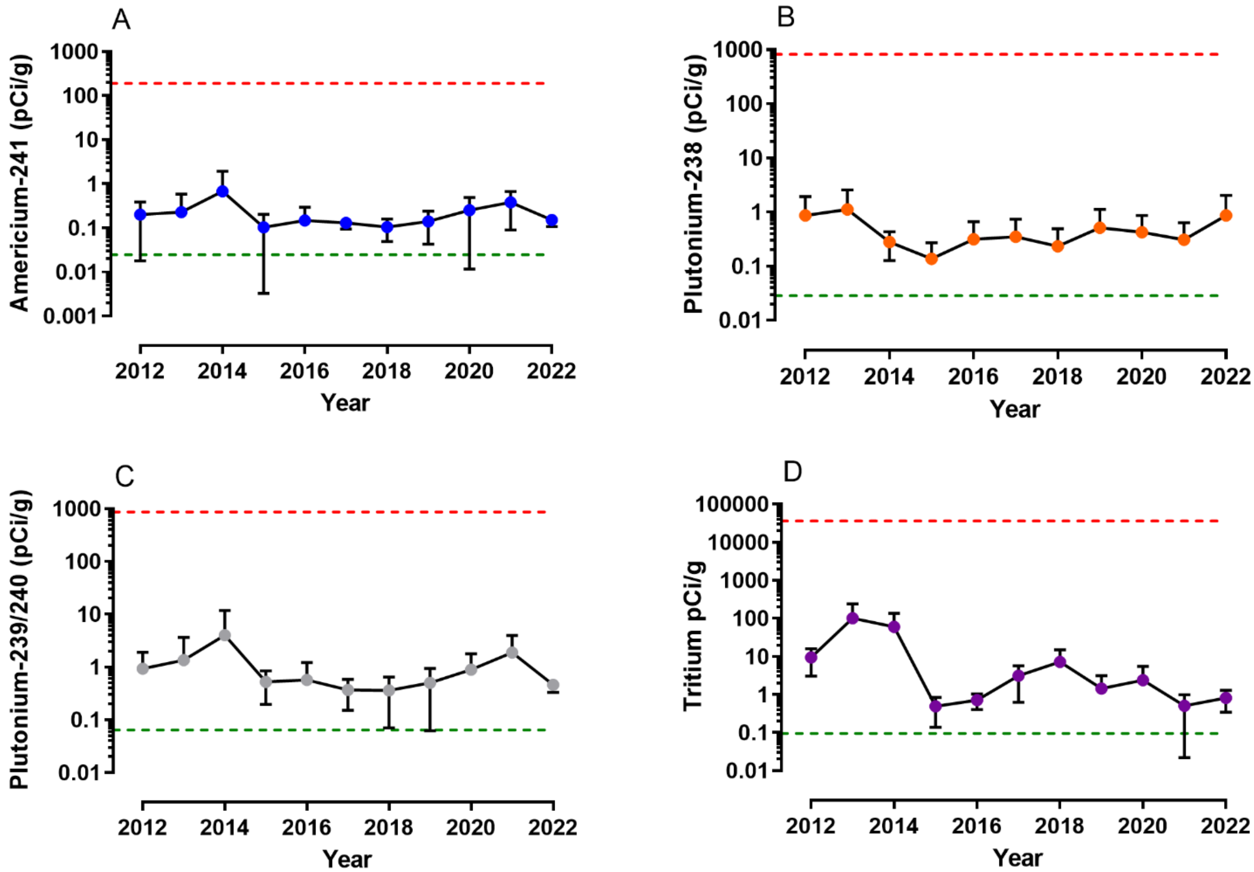


Figure 7-2. (A) Americium-241; (B) plutonium-238; (C) plutonium-239/240 activities in surface soil samples collected from five locations on the northern, northeastern, and eastern side (locations 38-01, 40-01, 42-01, 45-05 and 48-01); and (D) tritium activities in surface soil samples collected from two locations on the southern side (locations 29-03 and 30-01) of Area G at Technical Area 54 from 2012 to 2022. Data are compared with the regional statistical reference level (green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis. Points represent mean, and error bars represent standard deviation. Bottom error bars are absent on some points because the error would have been a negative value; however, negative values cannot be shown on a logarithmic axis. Note: pCi/g = picocuries per gram.

Vegetation Results

Tree samples were collected at the same general locations as the soil samples (see Figure 7-1); however, because of a firebreak along the fence line, some of the trees were located more than 30 feet away from the fence around Area G, particularly on the northern and eastern sides. Levels of radionuclides in native tree samples (primarily one-seed juniper) can be caused by root uptake and by deposition of radionuclides on the surfaces of leaves and branches.

In 2022, the vegetation samples collected around the perimeter of Area G were analyzed on a dry basis for radionuclides. In contrast, vegetation samples from previous years were analyzed on an ash basis. This change in analysis method was associated with a change in analytical laboratories (see the section on Analytical Laboratory Quality Assessment near the end of this chapter). The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, the 2022 native tree results at Area G are summarized as follows (see Supplemental Table S7-2 for individual results):

- Most radionuclides in overstory vegetation samples were not detected.
- All activities were below the biota dose screening level for terrestrial plants.

Similar with previous years, tritium in overstory vegetation was highest (up to 9,040 picocuries per gram dry basis) in trees growing in the southern sections near the tritium disposal shafts. The levels of plant tritium are highly variable from year to year, which could be a result of any (or a combination) of the following: soil moisture, depth of roots, time of sampling, distance from the perimeter fence, temperature, or barometric pressure.

Laboratory/Pueblo de San Ildefonso Boundary in Cañada del Buey

In 2022, a duplicate-split soil sample (where soil is thoroughly mixed in a bag and then split into two sample containers) was collected at location T-3B on Laboratory property near the Technical Area 54 and Pueblo de San Ildefonso boundary (see Figure 7-1). This location has been sampled from 2016 through 2022. An additional three soil samples were collected on Pueblo de San Ildefonso property at locations T-3C, T-3D, and T-3E near the Laboratory and the Pueblo de San Ildefonso boundary (see Figure 7-1).

The 2022 results at the Laboratory/Pueblo de San Ildefonso Boundary in Cañada del Buey are summarized as follows (see Supplemental Table S7-1 for individual results):

- Most radionuclide activities in soil were not detected or were below the regional statistical reference level.
- Soil activity of americium-241 was above the regional statistical reference level in one of the duplicate soil samples collected at T-3B.
- Soil activities of plutonium-238 at T-3B and plutonium-239/240 at T-3B and T-3D were above the regional statistical reference levels.
- Soil activities of uranium isotopes were above the regional statistical reference levels at locations T-3D and T-3E.
- All soil radionuclide activities were below all ecological soil screening levels.
- No radionuclides were detected in overstory vegetation at T-3B or T-3D.

Soil Results

Tritium, strontium-90, and uranium-235/236 were not detected in any of the soil samples collected near the boundary of Technical Area 54 and Pueblo de San Ildefonso.

Americium-241 was detected in one of the duplicate soil samples at T-3B—with an activity of 0.044 picocuries per gram—and exceeded the regional statistical reference level of 0.025 picocuries per gram; the other duplicate soil sample from this location did not contain detectable activities of americium-241 (Table S7-1).

Plutonium-238 was detected in both duplicate soil samples at T-3B—with activities of 0.058 and 0.059 picocuries per gram—and exceeded the regional statistical reference level of 0.029 picocuries per gram. Plutonium-238 activities were detected in soil collected from T-3C and

T-3E—with activities of 0.021 and 0.023 picocuries per gram, respectively, and were below the regional statistical reference level. Plutonium-238 was not detected in the soil sample collected at T-3D (see Table S7-1).

Plutonium-239/240 was detected in both duplicate soil samples at T-3B—with activities of 0.083 and 0.167 picocuries per gram—and exceeded the regional statistical reference level of 0.064 picocuries per gram. Plutonium-239/240 activities were also detected at T-3C and T-3E—with activities of 0.042 and 0.037 picocuries per gram, respectively, and were below the regional statistical reference level. Plutonium-239/240 soil activity at T-3D was 0.071 picocuries per gram and slightly exceeded the regional statistical reference level of 0.064 picocuries per gram (see Table S7-1).

All of these observations are well below the most sensitive, no-effect ecological soil screening levels for americium-241, plutonium-238, and plutonium-239/240 of 190, 820, and 870 picocuries per gram, respectively. Radionuclide activities are not changing over time in soil near the Technical Area 54 and Pueblo de San Ildefonso boundary (Kendall's Tau, $p > 0.05$; see Figure 7-3).

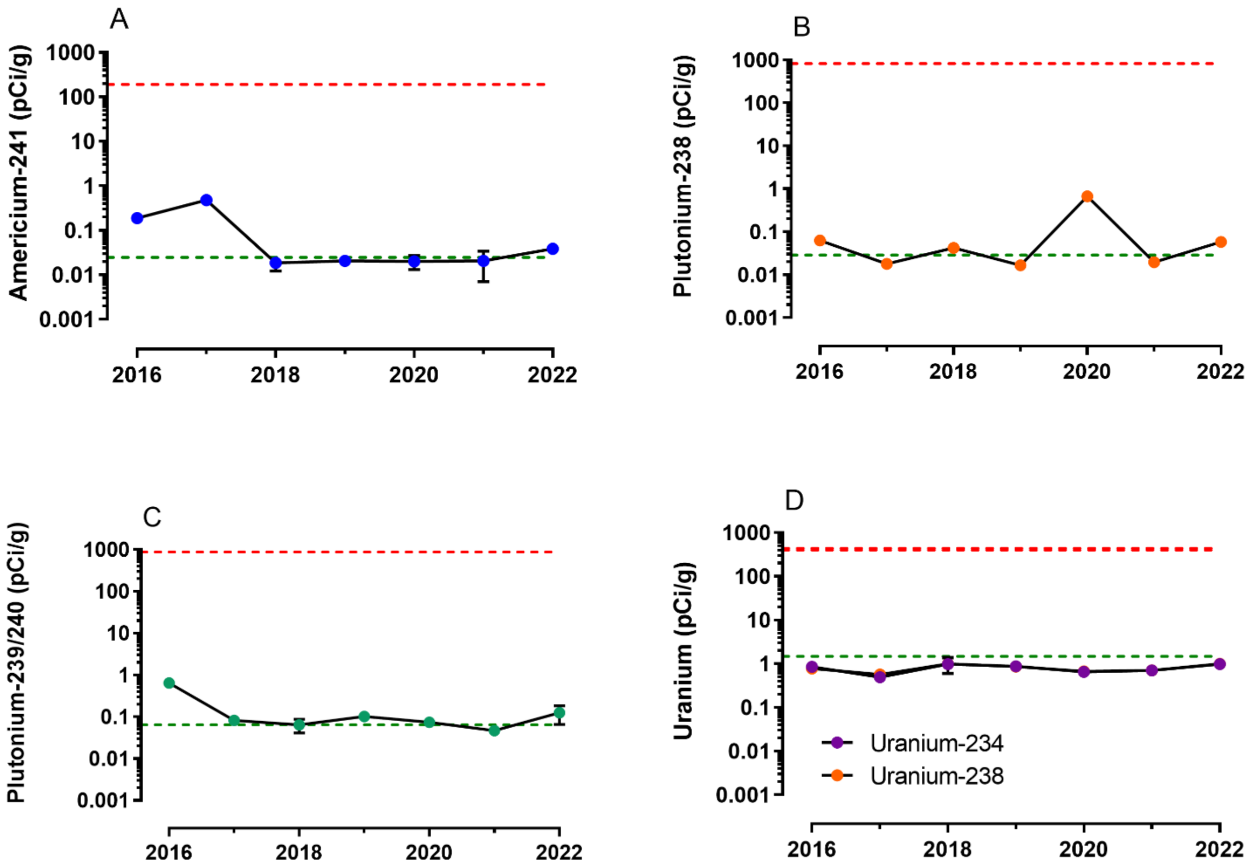


Figure 7-3. (A) Americium-241, (B) plutonium-238, (C) plutonium-239/240, and (D) uranium-234 and uranium-238 activities in soil collected near the Technical Area 54 and Pueblo de San Ildefonso border from 2016 through 2022 at the T-3B location on Laboratory property. Results from 2018 through 2022 are the average of duplicated samples. Data are compared with the regional statistical reference level (green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis. Points represent true values (between 2016 and 2017, n = 1 each) or represent mean values (between 2018 and 2022, n = 2 each), and error bars represent standard deviation. Error bars may appear absent on some points because standard deviations are too small to plot. (pCi/g = picocuries per gram)

All three uranium isotopes were detected in all soil samples collected near Technical Area 54 and the Pueblo de San Ildefonso boundary. Most observations were below their regional statistical reference level (Table S7-1); however, at T3-D and T-3E, uranium-234 and uranium-238 were detected and were slightly above the regional statistical reference level (Table S7-1), which is similar to previous years. The near 1:1 ratio of uranium-234 to uranium-238 activities indicates that these uranium activities are from naturally occurring sources (U.S. Nuclear Regulatory Commission 2019), and the concentrations observed here are similar to Laboratory background concentrations (Ryti et al. 1998).

Vegetation Results

In 2022, the vegetation samples collected near the Technical Area 54 and Pueblo de San Ildefonso boundary were analyzed on a dry basis for radionuclides. In contrast, vegetation samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, no radionuclides were detected in overstory vegetation samples collected near Technical Area 54 and the Pueblo de San Ildefonso boundary (Table S7-2).

Other Samples Collected from Pueblo de San Ildefonso

In June 2022, we collected duplicate soil samples from two locations at Pueblo de San Ildefonso. One was collected on Pueblo de San Ildefonso Sacred Area lands on the north side of the fence line across from Area G; the other was collected further north near Tsankawi. Several radionuclides were not detected in the soil samples. All detected radionuclides were below their regional statistical reference level and were well below the most sensitive no-effect ecological soil screening levels (Table S7-3). The level of cesium-137, although below the regional statistical reference level, is increasing over time in soil collected from the Sacred Area (Kendall's Tau, $p < 0.05$). This trend will continue to be monitored in future sampling. No other radionuclides are increasing over time (Kendall's Tau, $p > 0.05$).

Most inorganic elements were detected in soil samples from Pueblo de San Ildefonso, and all concentrations were below their regional statistical reference levels; however, similar to previous years, manganese, selenium, thallium, and vanadium exceeded no-effect ecological soil screening levels in one or both of the soil sample locations (Table S7-4). As a note, the regional statistical reference levels of these elements are also above no-effect ecological soil screening levels (Table S7-4). No inorganic elements were increasing over time in soil collected from Pueblo de San Ildefonso (Kendall's Tau, $p > 0.05$).

Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15

The purpose of the Dual-Axis Radiographic Hydrodynamic Test Facility is to study properties of the explosives used to trigger nuclear weapons. Soil, sediment from local drainages, plants, and animals are monitored to determine if constituents released from the facility could be affecting plants or animals and if the observed levels are consistent with our expectations of radionuclide and chemical uptake. This environmental monitoring has occurred annually since 1996. The Dual-Axis Radiographic Hydrodynamic Test Facility began firing-site operations in 2000, with the following timeline for methods of mitigating releases from detonations:

- 2000–2002; open-air detonations
- 2003–2006; detonations using foam mitigation
- 2007–2020; detonations within closed steel containment vessels
- 2021–2022; detonations within closed steel containment vessels inside of a weather enclosure

We monitor radionuclides; inorganic elements; organic chemicals such as high explosives, dioxins and furans; and PFAS chemicals in soil and sediment. Biota or products of biota collected around the Dual-Axis Radiographic Hydrodynamic Test Facility have included overstory vegetation, small mammals, honeybees, honey, bird eggs, and nestlings. Samples of soil, sediment, and one type of biota or biota product (honey) are collected annually. Typically, the collection of vegetation, honey, and small mammals is rotated so that each is sampled once in a 3-year period. Bird samples are collected opportunistically when abandoned or infertile eggs or deceased nestlings are found in local nest boxes. In 2022, we collected soil, sediment, overstory vegetation, and bird egg samples at the facility. A honey sample was also collected, and its results are reported in Chapter 8. All sample locations are shown in Figure 7-4.

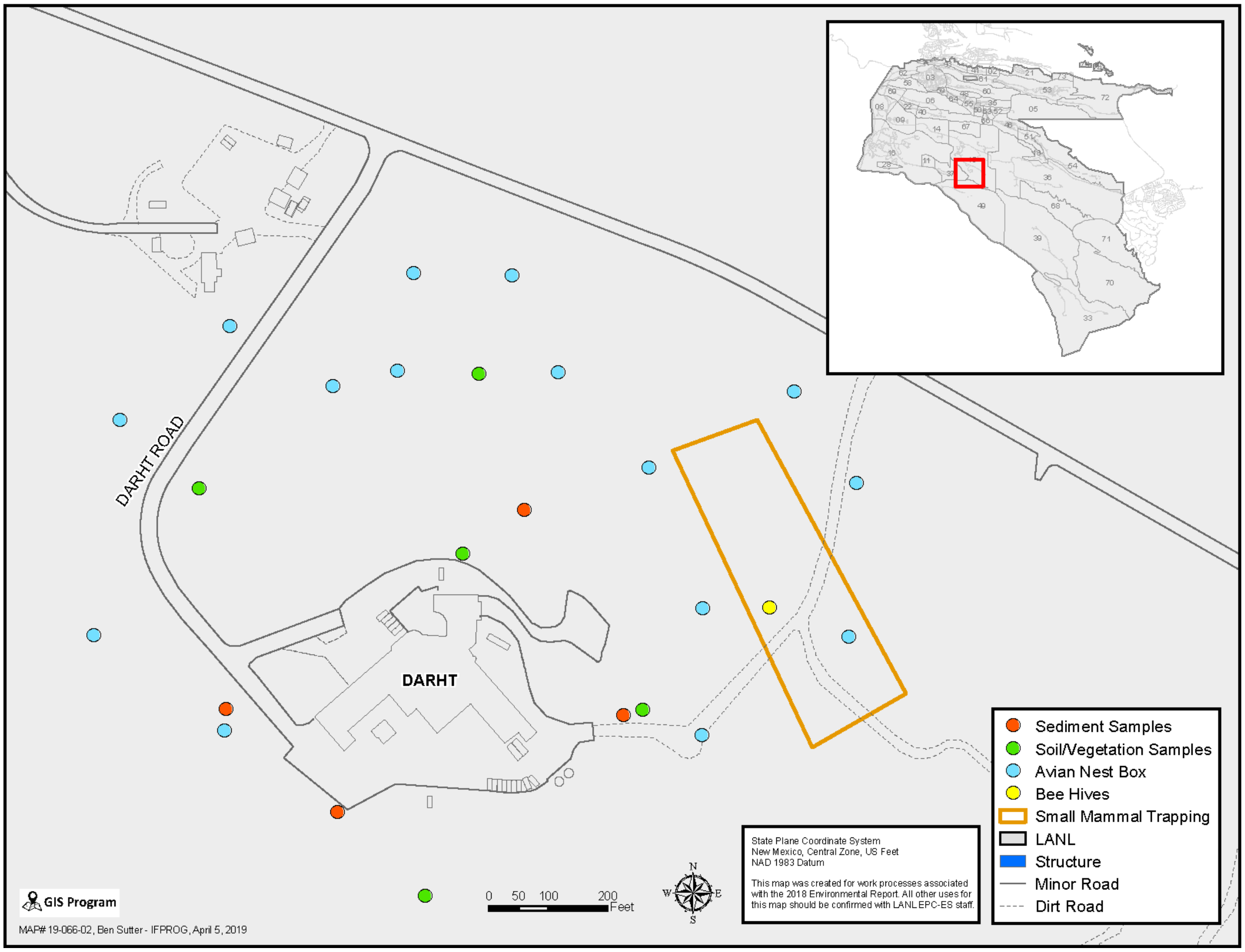


Figure 7-4. Soil, sediment, and biota sample locations at the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) at Technical Area 15.

For soil samples, we collect five surface soil subsamples at a depth from 0 to 2 inches and mix them to prepare a composite soil sample at each location. The soil samples were collected in June 2022 along the fenceline on the north, east, south, and west sides of the Dual-Axis Radiographic Hydrodynamic Test Facility. An additional composite soil sample was collected about 75 feet north of the firing point next to the protective berm. We collected sediment grab samples at depths from 0 to 6 inches on the north, east, south, and southwest sides within drainages around the facility. All soil and sediment samples were analyzed for the following:

- the radionuclides americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, uranium-234, uranium-235/236, and uranium-238;
- inorganic elements including aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc;

- PFAS compounds; and
- high explosives.

A duplicate of the sample nearest to the firing point was analyzed for dioxins and furans.

In 2022, we collected four overstory vegetation samples at the same locations as the perimeter soil samples. These samples were analyzed for radionuclides, inorganic elements, and PFAS chemicals as listed above. Eggs that did not hatch were collected from nest boxes that surrounded the Dual-Axis Radiographic Hydrodynamic Test Facility and were analyzed. Two samples, each consisting of an individual western bluebird (*Sialia mexicana*) egg, were analyzed for inorganic elements, and one composite sample of five western bluebird eggs was analyzed for PFAS compounds.

Constituent results in soil and sediment samples are compared with the baseline statistical reference levels for the Dual-Axis Radiographic Hydrodynamic Test Facility. The baseline statistical reference levels were calculated from samples collected at the facility during 1996 to 1999, before the beginning of firing-site operations. The baseline level for each constituent is the precise level below which the results from 99 percent of samples from this time occurred (Nyhan et al. 2001). In cases where there are no baseline statistical reference levels (mostly inorganic elements such as aluminum, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, vanadium, and zinc), the soil and biota chemical results are compared with regional statistical reference levels.

Soil and Sediment Radionuclide Results

The 2022 soil and sediment results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Table S7-5 for individual results):

- Soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility did not contain detectable levels of americium-241, plutonium-238, plutonium239/240, strontium-90, or tritium.
- Most detectable levels of cesium-137 were below the baseline statistical reference level, and all were below the regional statistical reference level.
- Some samples had levels of uranium isotopes above the baseline statistical reference levels.
- All activities were far below all ecological soil screening levels.

In 2022, soil and sediment samples contained all three isotopes of uranium. This observation is consistent with previous years. Several samples contained activities of uranium that were higher than the regional statistical reference levels and the baseline statistical reference levels. The relative isotopic abundance of uranium-234, uranium-235, and uranium-238 activities indicate that the uranium in these samples is depleted uranium from testing activities rather than natural uranium (U.S. Nuclear Regulatory Commission 2019). The levels of uranium are far below all ecological screening levels.

Operations at the Dual-Axis Radiographic Hydrodynamic Test Facility have changed since 2007 to include the use of closed-containment vessels. Since 2008, uranium-238 activity near the firing point has mostly been similar to the baseline statistical reference level (see Figure 7-5).

Levels of radionuclides in soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility are not increasing over time (Kendall's Tau, $p > 0.05$).

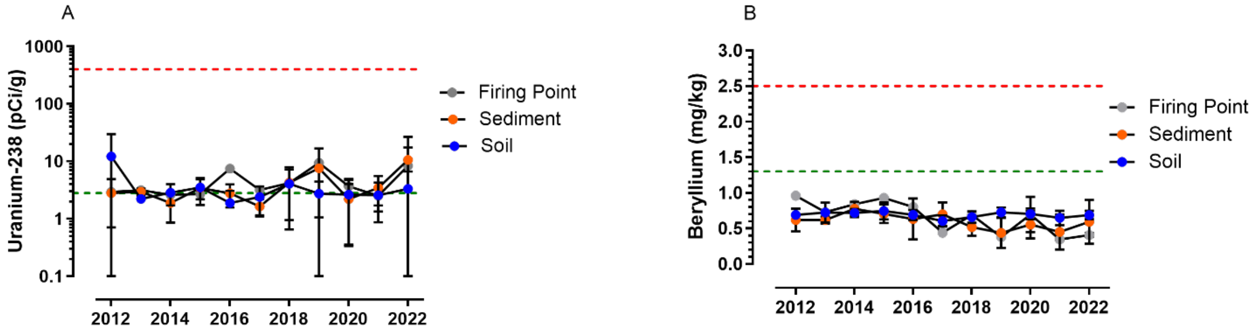


Figure 7-5. (A) Uranium-238 activities and (B) beryllium concentrations in surface soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility and in the firing point soil sample from 2012 to 2022 compared with the baseline statistical reference level (mean plus three standard deviations of soil uranium-238 pre-operations; green dashed line) and the lowest no-effect ecological screening level (red dashed line). Note the logarithmic scale on the vertical axis for uranium-238 and the linear scale for beryllium. Points represent true values (firing point 2012–2019) or represent means (sediment, and soil samples and the firing point in 2020–2022), and error bars represent standard deviation. Bottom error bars are absent on some uranium-238 points because the error would have been a negative value; however, negative values cannot be shown on a logarithmic axis. (pCi/g = picocuries per gram; mg/kg = milligrams per kilogram)

Soil and Sediment Inorganic Element Results

The 2022 soil and sediment inorganic element results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see Table S7-6 for individual results):

- Most inorganic elements were found at detectable concentrations in all soil and sediment samples collected in 2022.
- Concentrations of most inorganic elements (aluminum, arsenic, beryllium, cadmium, calcium, chromium, cobalt, iron, magnesium, nickel, and potassium) were below all reference and screening levels.
- Concentrations of eight inorganic elements (barium, lead, manganese, mercury, selenium, thallium, vanadium, and zinc) exceeded the no-effect ecological soil screening level for the plant, montane shrew, or American robin and/or the low-effect soil ecological screening level for the American robin in some samples.
- The number of locations with concentrations potentially associated with adverse effects at an individual level are minimal, and no impacts to populations or communities of plants and animals are expected.

Consistent with observations in previous years, some soil and sediment samples contained concentrations of barium, lead, manganese, mercury, selenium, thallium, vanadium, and zinc that exceeded the no-effect ecological soil screening level for the plant, montane shrew, or American robin (Table 7-1 and Table S7-6). All concentrations of barium, lead, manganese, mercury, thallium, and vanadium were below the regional statistical reference levels and the baseline statistical reference levels (when available). Note: The regional statistical reference level of these elements is also above the no-effect ecological soil screening level.

Table 7-1. Percent of soil and sediment samples from the Dual-Axis Radiographic Hydrodynamic Facility in 2022 (n = 10) that exceeded an inorganic element screening level or reference level or that had an increasing trend over time

Inorganic Element	Exceedance				Percent of locations with increasing trend over time	Locations of exceedance and/or increasing trend
	No-effect ecological screening level[a]	Low-effect ecological screening level[b]	Baseline statistical reference level	Regional statistical reference level		
Antimony	0%	0%	20%	30%	0%	Soil – W, E, and S sides
Barium	30%	0%	0%	0%	10%	Sediment – SW side; Soil – N and W sides
Beryllium	0%	0%	0%	0%	10%	Soil – W side
Cadmium	0%	0%	0%	0%	30%	Soil – W and N side; Sediment – E side
Calcium	–	–	–	0%	20%	Soil – S and firing point
Chromium	0%	0%	0%	0%	10%	Sediment – E side
Cobalt	0%	0%	–	0%	10%	Soil – W side
Copper	0%	0%	0%	0%	30%	Soil – firing point; Sediment – E and S sides
Lead	20%	0%	0%	0%	0%	Soil – N and W sides
Magnesium	–	–	–	0%	10%	Soil – S side
Manganese	70%	0%	–	0%	10%	Sediment – N, S, and SW sides; Soil – N, E, S, and W sides
Mercury	20%	0%	0%	0%	0%	Sediment – S side; Soil – N side
Potassium	–	–	–	0%	10%	Soil – W side
Selenium	100%	20%	60%	0%	0%	All
Silver	0%	0%	0%	70%	30%	Soil – E, S, and W sides and firing point; Sediment – S, E, and SW sides
Sodium	–	–	–	20%	20%	Sediment – E and S sides
Thallium	50%	0%	0%	0%	0%	Sediment – SW, and S sides; Soil – N, E, and W sides
Vanadium	100%	100%	–	0%	0%	All
Zinc	20%	0%	–	20%	50%	Soil – N and firing point; Sediment – E, S, and SW sides

[a] Plant, montane shrew, or American robin
[b] American robin
A dash (–) indicates that no ecological screening level or baseline statistical reference level is available.
N = north, W = west, E = east, S = south, and SW = southwest

Of the inorganic elements that exceeded a screening level or reference level, barium and manganese are increasing in soil collected from the west side. Consistent with previous years, sodium concentrations are increasing over time in sediment samples collected from the east and south sides; silver concentrations are also increasing over time in sediment samples collected on the east, soil samples collected from the west, and at the firing point of the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall's Tau, $p < 0.05$). Zinc continues to increase over time in sediment collected from the south and southwest side of the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall's Tau, $p < 0.05$). Zinc was also increasing in sediment on the east side, at the firing point, and in soil collected from the north side. Some of these results are consistent with observations in previous years, and these trends will continue to be monitored in future sampling.

Beryllium, listed as a chemical of potential concern before the start-up of operations at the facility (DOE 1995), was not detected above the baseline statistical reference level (1.3 milligrams per kilogram) in any of the soil or sediment samples during 2022. Beryllium concentrations in all soil and sediment samples from 2012 to 2022 have been below the baseline statistical reference level and are not increasing over time (Kendall's Tau, $p > 0.05$; see Figure 7-5). All beryllium concentrations observed in soil and sediment samples collected around the Dual-Axis Radiographic Hydrodynamic Test Facility are well below the lowest no-effect ecological soil screening level of 2.5 milligrams per gram (Table S7-6).

Soil and Sediment Organic Compound Results

The 2022 soil and sediment organic compound results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows:

- No high explosives were detected in any of the soil or sediment samples.
- Most dioxin and furans were not detected, and those that were detectable were either below the no-effect or low-effect ecological soil screening levels.
- PFAS chemicals were detected at concentrations below ecological soil screening levels.

Dioxins and furans were evaluated in the duplicate soil samples collected at the firing point. Most furans and dioxins were not detected. The detected dioxin congeners were TCDD at concentrations of 0.000864 and 0.000844 nanograms per gram, 1,2,3,4,6,7,8-heptachlorodibenzodioxin at concentrations of 0.00089 and 0.000858 nanograms per gram, 1,2,3,4,6,7,8,9-octachlorodibenzodioxin at concentrations of 0.00703 and 0.00818 nanograms per gram, and 1,2,3,4,6,7,8,9-octachlorodibenzofuran at 0.000995 and 0.000998 nanograms per gram.

TCDD had not been detected in soil at the firing point before 2022. The levels that were observed exceeded the no-effect ecological soil screening level for the montane shrew (0.00029 nanograms per gram) but were below the low-effect ecological soil screening level of 0.0019 nanograms per gram. Because TCDD has rarely been detected, and the detected levels are below the most sensitive mammal low-effect ecological soil screening level, we do not anticipate adverse effects to populations of small mammals. We will continue monitoring at this location.

No ecological soil screening levels exist for 1,2,3,4,6,7,8-heptachlorodibenzodioxin, 1,2,3,4,6,7,8,9-octachlorodibenzodioxin, or 1,2,3,4,6,7,8,9-octachlorodibenzofuran; however, toxic equivalent factors can be used to calculate the TCDD toxic equivalent for dioxin-like compounds. The toxic equivalent factor is 0.01 for 1,2,3,4,6,7,8-heptachlorodibenzodioxin, 0.0003 for 1,2,3,4,6,7,8,9-octachlorodibenzodioxin, and 0.0003 1,2,3,4,6,7,8,9-octachlorodibenzofuran (Van den Berg et al. 2006). Multiplying the detectable concentrations of these congeners by their respective toxic equivalent factors yields values that are orders of magnitude less than the montane shrew no-effect ecological soil screening level for TCDD (0.00029 nanograms per gram).

In 2022, we had the 10 soil and sediment samples collected at the Dual-Axis Radiographic Hydrodynamic Test Facility analyzed for 37 PFAS compounds. Of the 37 compounds analyzed in the 10 soil samples (which yielded 370 results), the majority (86%) were not detected. Most locations contained detectable concentrations of at least one PFAS compound. No PFAS were observed in the sediment sample collected on the southwest side, and similar to previous years, no PFAS compounds were detected in the soil samples collected at the firing point.

Perfluorooctanesulfonic acid was the most frequently detected PFAS compound, occurring in seven of the soil samples with a range of 0.19 to 6.8 nanograms per gram. Perfluorooctanesulfonic acid was the only PFAS compound detected in soil from the west side (0.276 nanograms per gram) and sediment from the north side (0.204 nanograms per gram) of the facility; both values were below the regional statistical reference level of 0.697 nanograms per gram. Soil collected on the north side contained detectable levels of three PFAS compounds, including perfluorooctanesulfonic acid, perfluorobutanoic acid, and perfluorooctanoic acid at 0.190, 0.209, and 0.186 nanograms per gram, respectively. All were below their regional statistical reference levels (Table S7-7).

Similar to last year, detectable concentrations of PFAS compounds were mostly observed on the east and south sides of the facility. The sediment sample collected on the south side and the soil sample collected on the east side contained detectable concentrations of 12 PFAS compounds, whereas 7 PFAS compounds were observed in the soil sample on the south side (Table S7-7).

The sediment sample collected on the east side had the highest concentrations and the greatest number of PFAS chemicals detected (17 of the 37 PFAS compounds analyzed). The highest PFAS compound concentration was 16.7 nanograms per gram of 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (Table S7-7). Perfluorooctanesulfonic acid concentrations from the four samples collected on the east and south sides of the Dual-Axis Radiographic Hydrodynamic Test Facility exceeded the regional statistical reference level of 0.697 nanograms per gram; however, all concentrations were far below the most sensitive ecological soil screening level for perfluorooctanesulfonic acid of 1,800 nanograms per gram. Additionally, all concentrations of detected PFAS compounds in soil and sediment collected around the Dual-Axis Radiographic Hydrodynamic Test Facility were at least one order of magnitude below the Environmental Protection Agency's Regional Screening Levels for both residential and industrial uses (U.S. Environmental Protection Agency 2022). In 2022, some concentrations of PFAS compounds near the Dual-Axis Radiographic Hydrodynamic Test Facility exceeded their regional statistical reference levels; however, they all were below available ecological soil screening levels. Most concentrations of PFAS compounds observed here are within the range of global observations of concentrations in soil collected from non-polluted sites (Brusseau et al. 2020).

Overstory Vegetation Results

The 2022 overstory vegetation results at the Dual-Axis Radiographic Hydrodynamic Test Facility are summarized as follows (see supplemental tables S7-8 and S7-9 for individual results):

- No radionuclide activities were detected in overstory vegetation.
- Most concentrations of inorganic elements in overstory vegetation were below their baseline statistical reference level and the regional statistical reference level.
- Only one PFAS compound was detected in one overstory vegetation sample collected around the perimeter of the Dual-Axis Radiographic Hydrodynamic Test Facility.

In 2022, the vegetation samples collected at the Dual-Axis Radiographic Hydrodynamic Test Facility were analyzed on a dry basis for radionuclides. In contrast, vegetation samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the baseline and regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, no radionuclides were detected in overstory vegetation samples collected at the Dual-Axis Radiographic Hydrodynamic Test Facility.

Several inorganic elements were not detected in overstory vegetation collected around the Dual-Axis Radiographic Hydrodynamic Test Facility. All but two detected concentrations of silver were below their regional statistical reference level. Silver in the overstory vegetation samples collected on the south (0.122 milligrams per kilogram) and north (0.112 milligrams per kilogram) sides of the Dual-Axis Radiographic Hydrodynamic Test Facility exceeded the regional statistical reference level of 0.027 milligram per gram; however, the observed levels were about an order of magnitude less than the baseline statistical reference level of 1.2 milligrams per gram.

Contrary to observations in soil and sediment, antimony increased over time in the overstory vegetation samples collected on the north, west, and south sides of the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall’s Tau, $p < 0.05$). Selenium in vegetation increased over time on the east and south sides (Kendall’s Tau, $p < 0.05$). Manganese and silver were increasing in overstory vegetation collected on the south side; nickel increased in vegetation on the north side, and silver increased in vegetation on the east side (Kendall’s Tau, $p < 0.05$). Samples where a specific inorganic element was not detected ranged from 0 to 50 percent and could be influencing these results. Because all observed levels were below the baseline statistical reference level and all but the two concentrations of silver were below the regional statistical reference level, these trends are not of ecological concern. These trends will be monitored in future sampling. No other elements are increasing over time around the Dual-Axis Radiographic Hydrodynamic Test Facility (Kendall’s Tau, $p > 0.05$).

Most PFAS compounds were not detected. A total of 37 PFAS compounds were evaluated in each of the four vegetation samples; three samples did not contain any detectable PFAS compounds. The overstory vegetation sample collected on the east side of the Dual-Axis Radiographic Hydrodynamic Test Facility contained 4.62 nanograms per gram of perfluoropentanoic acid, which was below the regional statistical reference level of 5.94 nanograms per gram. Perfluoropentanoic acid (used in many consumer products) is a common PFAS chemical observed in the environment (Ghisi et al. 2019).

Bird Egg Results

Levels of chemicals in bird egg samples were consistent with previous years. Several inorganic elements were not detected, including aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and vanadium. All detectable concentrations of elements were below their regional statistical reference levels and below the lowest observable adverse effect levels in tissues, when available (Table S7-10).

No PFAS compounds were detected in the western bluebird composite samples collected from the Dual-Axis Radiographic Hydrodynamic Test Facility in 2022.

Open-Detonation and Open-Burn Firing Sites

Avian nest boxes have been placed at two open-detonation firing sites: Minie (located at Technical Area 36) and Technical Area 39 Point 6; and at the open-burn site located at Technical Area 16. Inorganic elements (mostly metals), dioxins, and furans are substances of interest at these locations (Fresquez 2011). Nonviable eggs and nestlings that died from natural causes are collected and submitted for chemical analyses. In 2022, we collected 4 nonviable eggs and 1 deceased western bluebird nestling on Laboratory property and 11 nonviable eggs and 2 deceased western bluebird nestlings in background areas located at Bandelier National Monument.

Results from eggs collected from the Laboratory were compared with regional statistical reference levels calculated from the nonviable eggs of western bluebirds and ash-throated flycatchers (*Myiarchus cinerascens*) collected from the background locations in 2021 and 2022 (n = 20 samples). Owing to limited sample mass, most nonviable egg samples were evaluated for inorganic elements, and one sample was evaluated for PFAS. In previous years, egg samples have been analyzed on a dry weight basis; however, in 2021 and 2022, they were all on a wet weight basis.

PFAS results from one nestling were compared with the regional statistical reference levels calculated from deceased nestlings of western bluebirds and ash-throated flycatchers from background locations (n = 2 samples). Nonviable egg and nestling results were also compared with the lowest observable adverse effect levels in tissues from peer-reviewed literature when available.

Bird Egg Results

The one ash-throated flycatcher egg sample collected from Technical Area 39 Point 6 and the two western bluebird egg samples collected from Technical Area 16 did not have detectable levels of several elements. The inorganic elements that were detected were below their regional statistical reference levels (Table S7-11). Selenium concentrations in the eggs were well below the lowest observable adverse effect level in eggs of 2.6 milligrams per gram (Ohlendorf and Heinz 2011). A lowest observable adverse effect level is available for mercury, but mercury was not detected in any of the egg samples. No other lowest observable adverse effect levels in eggs are available. The overall results indicate that the levels of inorganic elements in western bluebird and ash-throated flycatcher eggs at the open-detonation firing site and at the open-burn site are not likely to cause adverse effects in breeding bird populations; however, more data are needed to make robust assessments and to evaluate trends over time.

One western bluebird composite egg sample (four eggs total) collected from a nest box at Technical Area 16 burn site was tested for 37 PFAS compounds. Four compounds were detected at low levels, including perfluoroundecanoic acid, perfluorononanoic acid, perfluorotetradeconoic acid, and perfluorotridecanoic acid at 0.307, 0.317, 0.733, and 1.02 nanograms per grams, respectively. Regional statistical reference levels for PFAS compounds in passerine eggs have not yet been calculated because only one egg sample from Bandelier National Monument has been analyzed for PFAS compounds.

The four detected PFAS compounds are not as well-studied as other PFAS compounds such as perfluorooctanesulfonic acid. A lowest observable adverse effect level in tissues for perfluorooctanesulfonic acid in avian eggs has been reported as 92.4 nanograms per gram (Dennis et al. 2021). The observed concentrations of the detected PFAS compounds in the western bluebird egg sample at Technical Area 16 were two orders of magnitude below this perfluorooctanesulfonic acid lowest observable adverse effect level in eggs. 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. 2004).

Bird Nestling Results

One deceased western bluebird nestling was obtained at the Laboratory in 2022 from Technical Area 36. This nestling was analyzed for 37 PFAS compounds and did not contain any detectable levels. Similarly, no PFAS compounds were detected in nestling samples collected from Bandelier National Monument. More data are needed, including additional nestling samples from firing sites, to make robust assessments and to evaluate trends over time.

Sediment and Flood-Retention Structures

Many chemicals and radionuclides released into the environment adhere to soil and sediment particles. Storm water flows can transport these soil and sediment particles downstream in canyon bottoms. The Laboratory has constructed flood- and sediment-retention structures to reduce flood risks and to stop or slow the movement of sediments and associated chemicals and radionuclides off Laboratory property.

The Los Alamos Canyon weir and the Pajarito Canyon flood-retention structure were built following the Cerro Grande fire in 2000. As part of an environmental analysis of actions taken in response to the Cerro Grande fire, DOE identified various measures to minimize impacts that resulted from the fire (DOE 2000). One of the measures is monitoring soil, surface water, groundwater, and biota upstream of flood-control structures, within sediment-retention basins, and within sediment traps to determine if constituent concentrations in these areas adversely affect plants or animals.

To address monitoring requirements, we collect native grasses, forbs, and wild mice in the retention basins of the Los Alamos Canyon weir and the Pajarito Canyon flood-retention structure on an annual basis.

We attempt to collect the following samples from each location annually:

- a composite understory vegetation sample for radionuclide, inorganic element, and PFAS analyses;
- a composite sample of approximately 100 grams of whole-body mice for radionuclide analyses;
- three individual mice for inorganic elements analyses;
- three individual mice for PCB analysis; and
- three individual mice for PFAS analysis.

The following two sections report the 2022 results of this monitoring.

Los Alamos Canyon Weir

The Los Alamos Canyon weir is made of rock-filled wire cages called "gabions" and is designed to slow water flow and reduce the movement of sediment off Laboratory property. The weir was built in Los Alamos Canyon near the northeastern boundary of the Laboratory. The retention basin upstream of the weir covers more than 1 acre. Accumulated sediment was excavated from the retention basin in 2009, 2011, 2013, and 2014. Sediment excavated in 2009 was placed on the west side of the basin and stabilized, whereas sediment excavated in 2011, 2013, and 2014 was analyzed, placed on a plastic liner, contained within a berm, compacted, and seeded approximately 0.5 miles west of the weir in Los Alamos Canyon.

Vegetation Results

We collected one composite understory vegetation sample within the retention basin and submitted it in July 2022 for radionuclide, inorganic element, and PFAS analyses. Plants collected included curly dock (*Rumex crispus*), kochia (*Bassia scoparia*), wild buckwheats (*Eriogonum spp.*), and dragon sagewort (*Artemisia dracunculus*).

The 2022 understory vegetation results within the Los Alamos Canyon retention basin are summarized as follows (see supplemental tables S7-12 and S7-13 for individual results):

- Most radionuclides in the composite vegetation sample were not detected.
- Some inorganic element concentrations in the composite vegetation sample were detected, and all were below the regional statistical reference levels.
- Most PFAS chemical concentrations in the composite vegetation sample were not detected; concentrations of detected PFAS compounds in understory vegetation exceeded their regional statistical reference levels.

In 2022, the vegetation sample collected from the Los Alamos Canyon retention basin was analyzed on a dry basis for radionuclides. In contrast, vegetation samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, most radionuclides were not detected in the composite vegetation sample (Table S7-12). Strontium-90 was the only radionuclide detected—at 0.974 picocuries per gram—well below the biota dose screening level of 5,375 picocuries per gram.

Approximately 50 percent of inorganic elements were detected in the understory vegetation sample, and all detected concentrations were below their regional statistical reference levels

(Table S7-13). Like previous years, antimony and silver were increasing over time (Kendall's Tau, $p < 0.05$). Lead was also increasing in the understory vegetation sample (Kendall's Tau, $p < 0.05$). However, the percentages of nondetects range from 27 to 64 percent in antimony, lead, and silver and could be influencing these trends. Additionally, all concentrations of antimony, lead, and silver are below their regional statistical reference levels and are not of ecological concern.

A total of 37 PFAS compounds were evaluated in the composite vegetation sample, and 32 were not detected. Perfluorobutanoic acid, perfluoroheptanoic acid, perfluorohexanoic acid, perfluorooctanesulfonic acid, and perfluoropentanoic acid were detected at 1.43, 0.219, 0.679, 0.499, and 10.3 nanograms per gram, respectively. Perfluorobutanoic acid, perfluoroheptanoic acid, perfluorooctanesulfonic acid, and perfluoropentanoic acid exceeded their regional statistical reference levels at 0.772, 0.166, 0.201, and 5.95 nanograms per gram, respectively. Perfluorobutanoic acid (used in synthetic chemistry), perfluorohexanoic acid and perfluoropentanoic acid (used in many consumer products), and perfluorooctanesulfonic acid (used in textiles and firefighting foam) are common PFAS compounds observed in the environment (Ghisi et al. 2019). The literature lacks reports of PFAS levels and effects in non-agricultural plants, so we do not know the ecological significance of these observed levels.

Small Mammal Results

Small mammals were collected from the retention basin in July 2022 using Sherman live traps. All animal-handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We collected one Mexican woodrat (*Neotoma mexicana*) for radionuclide analyses, one western harvest mouse (*Reithrodontomys megalotis*) and two silky pocket mice (*Perognathus flavus*) for inorganic element analyses, two deer mice (*Peromyscus maniculatis*) and one pinyon mouse (*Peromyscus truei*) for PCB analyses, and two western harvest mice and one silky pocket mouse for PFAS analyses.

The 2022 small mammal results at the Los Alamos Canyon Weir are summarized as follows (see Tables S7-14 through S7-16 for individual results):

- Most radionuclides in the woodrat sample were not detected, and all were below the biota dose screening levels.
- Most inorganic elements in small mammal samples were detected and were below their regional statistical reference levels.
- Beryllium, magnesium, and silver in small mammals are increasing over time.
- PCBs in small mammal samples were detected but were below the regional statistical reference levels and the lowest observable adverse effect level in tissues.
- PCBs in small mammals are not changing over time.
- Most PFAS compounds were not detected. The concentrations of detected PFAS chemicals were within the range of observations in published literature for mammals collected from non-polluted sites.

In 2022, the small mammal samples collected from the Los Alamos Canyon retention basin were analyzed on a dry basis for radionuclides. In contrast, small mammal samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, most radionuclides were not detected in the woodrat (Table S7-14). Only cesium-137 and strontium-90 were detected. Cesium-137 was detected at 0.276 picocuries per gram and was well below the biota dose screening level of 800 picocuries per gram. Strontium-90 was detected at 0.387 picocuries per gram and was well below the biota dose screening level of 593 picocuries per gram.

Many inorganic elements were detected in individual small mammal samples, and most were below their regional statistical reference levels (Table S7-15). Antimony exceeded the regional statistical reference level in one mouse, and cadmium and magnesium exceeded their regional statistical reference levels in all three mice. Antimony was detected at 2.46 milligrams per kilogram and exceeded the regional statistical reference level of 0.102 milligrams per kilogram. Cadmium was detected at 0.114, 0.140, and 0.169 milligrams per kilogram and exceeded the regional statistical reference level of 0.041 milligrams per kilogram. Magnesium was detected at 479, 493, and 565 milligrams per kilogram and exceeded the regional statistical reference level of 473 milligrams per kilogram.

In our analysis of trends in inorganic element concentrations over time, most inorganic elements in small mammals are not changing; however, concentrations of beryllium, magnesium, and silver are increasing (Kendall's Tau, $p < 0.05$). Including all small mammal samples from the past 3 years collected from the Los Alamos Canyon weir, 74 percent of beryllium results and 23 percent of silver results were not detected. These high levels of nondetects could be influencing these trends. Most observed levels of beryllium and silver are below the regional statistical reference levels and are not of ecological concern. Magnesium was detected in all small mammals; however, because magnesium is an essential mineral and because the majority (89 percent) of levels during the past 11 years are below the regional statistical reference level, this observation is not of concern to small mammal populations. These trends will continue to be monitored.

PCBs were detected in all individual small mammal samples and were below the regional statistical reference level (Table S7-16). Measured PCB concentrations were 0.006, 0.006, and 0.001 milligrams per kilogram, below the regional statistical reference level of 0.053 milligrams per kilogram. All observed concentrations are two orders of magnitude below the lowest observable adverse effect level in tissues observed in mice (2.5 milligrams per kilogram) reported from PCB-contaminated sites where wild mouse populations were negatively affected (Batty et al. 1990). The levels of PCBs in small mammals collected from the retention basin are not changing over time (Kendall's Tau, $p > 0.05$, Figure 7-6). The variability in PCB concentrations may be related to the removals of sediment from the basin between 2009 and 2014 and accumulation of sediment since that time.

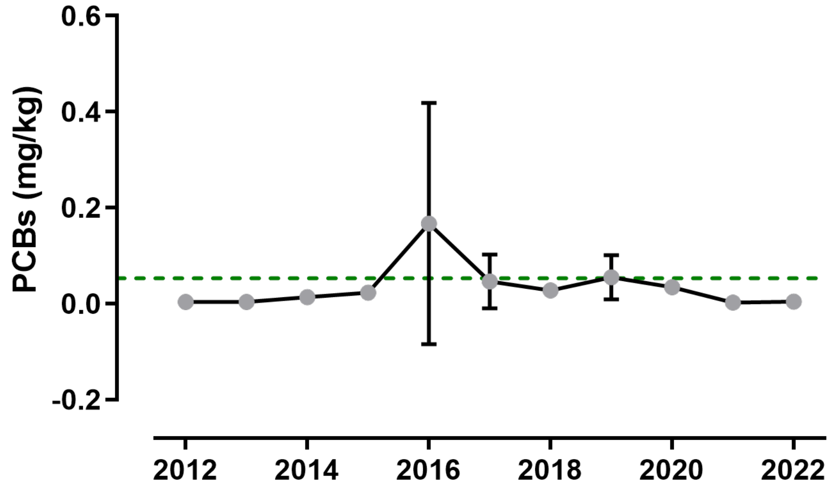


Figure 7-6. PCB concentrations in individual whole-body mice samples collected upstream (in the retention basin) of the Los Alamos Canyon weir from 2012 to 2022 compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations: green dashed line). Note the linear scale on the vertical axis. Points represent true values or the mean when multiple results were available; error bars represent standard deviation. Error bars may appear absent on some points because standard deviations are too small to plot. Note: mg/kg = milligrams per kilogram.

A total of 37 PFAS compounds were evaluated in each individual small mammal, and the majority (99 percent) of PFAS chemicals were not detected. Similar to previous years, perfluoroundecanoic acid was detected in two mice at 1.28 and 0.372 nanograms per gram, which exceeded the regional statistical reference level of 0.155 nanograms per gram. Perfluoroundecanoic acid is a longer chain PFAS compound and has a greater propensity to bioaccumulate in animal tissues because these molecules are difficult to metabolize. Concentrations of PFAS compounds observed here are within the range of observations reported in the published literature for mammals collected from non-polluted sites (Aas et al. 2014; Bossi et al. 2015).

Pajarito Canyon Flood-Retention Structure

The Pajarito Canyon flood-retention structure is located upstream of Technical Area 18. The structure extends 390 feet across the canyon and is about 70 feet high. The bottom of the retention structure is equipped with one 42-inch-diameter drainage culvert, which allows storm water to drain. Accumulated water is retained behind the retention structure no longer than 96 hours; water drains into the existing streambed.

Vegetation Results

In July 2022, one composite understory vegetation sample was collected on the upstream side of the Pajarito Canyon flood-retention structure and analyzed for radionuclides, inorganic elements, and PFAS compounds. Plants collected included curly dock, lamb's ear (*Stachys byzantina*), lamb's quarter (*Chenopodium album*), rubber rabbitbrush (*Ericameria nauseosa*), white yarrow (*Achillea millefolium*), and dragon sagewort (*Artemisia dracunculus*).

The 2022 understory vegetation results within the Pajarito Canyon flood-retention basin are summarized as follows (see supplemental tables S7-17 and S7-18 for individual results):

- No radionuclides were detected in the composite vegetation sample.
- Some inorganic element concentrations in the composite vegetation sample were detected, and all were below the regional statistical reference levels except for thallium.
- Perfluoropentanoic acid was the only PFAS chemical detected in the understory vegetation sample and was below the regional statistical reference level.

In 2022, the vegetation samples collected from the Pajarito Canyon flood-retention structure were analyzed on a dry basis for radionuclides. In contrast, vegetation samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, no radionuclides were detected in the composite vegetation sample (Table S7-17).

Approximately 40 percent of inorganic elements were detected in the composite vegetation sample, and most elements were below their regional statistical reference level (Table S7-18). Thallium was detected at 0.151 milligrams per gram, which exceeded the regional statistical reference level of 0.091 milligrams per gram. Antimony is increasing in vegetation over time (Kendall's Tau, $p < 0.05$); however, 40 percent of the results are nondetects. Additionally, all detectable concentrations of antimony are below the regional statistical reference level and therefore, this trend is not of ecological concern. No other inorganic elements are increasing over time (Kendall's Tau, $p > 0.05$).

A total of 37 PFAS compounds were evaluated in the composite vegetation samples, and perfluoropentanoic acid was the only PFAS compound detected at 1.37 nanograms per gram, below the regional statistical reference level of 5.95 nanograms per gram.

Small Mammal Results

Small mammals were captured upstream of the Pajarito Canyon flood-retention structure in July 2022 using Sherman live traps. All animal-handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We collected a composite sample of one brush mouse (*Peromyscus boylii*), three deer mice, and two western harvest mice for radionuclide analyses; three individual western harvest mice for inorganic element analyses; one brush mouse, one pinyon mouse, and one deer mouse for PCB analyses; and one brush mouse and two individual deer mice for PFAS compounds.

The 2022 small mammal results at the Pajarito Canyon flood-retention structure are summarized as follows (see Tables S7-19 through S7-21 for individual results):

- No radionuclides were detected in the composite small mammal sample.
- Several inorganic elements were detected in small mammal samples, and the majority were below their regional statistical reference levels.
- PCBs were detected in small mammal samples at levels below both the regional statistical reference level and the lowest observable adverse effect level in tissues.
- Inorganic elements and PCBs are not increasing in small mammals over time.
- The majority of PFAS chemicals were not detected in small mammal samples, but some detected concentrations exceeded regional statistical reference levels.

In 2022, the small mammal samples collected from the Pajarito Canyon flood-retention structure were analyzed for radionuclides on a dry basis. In contrast, samples from previous years were analyzed on an ash basis. The difference in basis prevents direct comparison with the regional statistical reference levels and prevents incorporating the 2022 results into the trend analyses; however, no radionuclides were detected in the small mammal composite sample (Table S7-19).

Several inorganic element concentrations in small mammal samples were detected, and the majority were below their regional statistical reference levels (Table S7-20). Magnesium was detected in one western harvest mouse at 500 milligrams per kilogram, which exceeded the regional statistical reference level of 473 milligrams per kilogram. Silver was detected in two mice at 0.152 and 0.158 milligrams per kilogram, which exceeded the regional statistical reference level of 0.005 milligrams per kilogram. All remaining concentrations of elements were below their regional statistical reference levels. Inorganic elements in small mammals were not increasing over time (Kendall's Tau, $p > 0.05$).

PCBs were detected in all three mice at 0.001, 0.003, and 0.005 milligrams per kilogram, which are all below the regional statistical reference level of 0.053 milligrams per kilogram (Table S7-21). All PCB concentrations are at least three orders of magnitude below the lowest observable adverse effect level in tissues observed in mice (2.5 milligrams per kilogram) reported from PCB-contaminated sites where wild mouse populations were negatively affected (Batty et al. 1990). PCB concentrations in whole-body wild mice collected upstream of the Pajarito Canyon flood-retention structure are not changing over time (Kendall's Tau, $p > 0.05$; Figure 7-7).

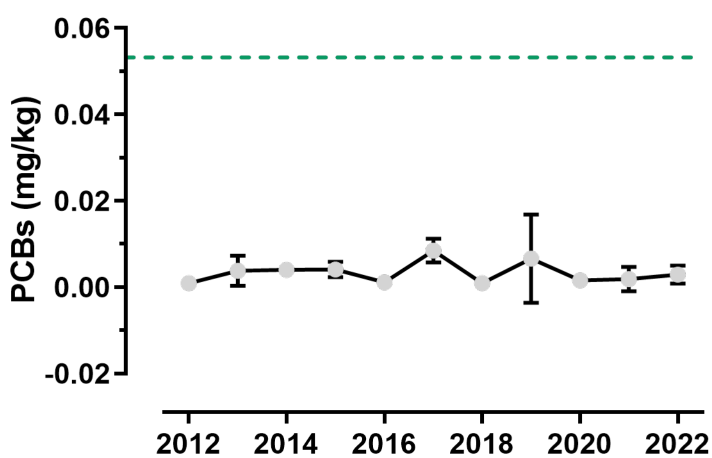


Figure 7-7. PCB concentrations in individual whole-body mouse samples collected upstream (in the retention basin) of the Pajarito Canyon flood-retention structure from 2012 to 2022 compared with the regional statistical reference level (mean plus three standard deviations of small mammals collected from background locations: green dashed line). Note the linear scale on the vertical axis. Points represent the mean, and error bars represent standard deviation. Error bars may appear absent on some points because standard deviations are too small to plot. (mg/kg = milligrams per kilogram)

A total of 37 PFAS compounds were evaluated in the individual mice, and 88 percent were not detected. One brush mouse contained three PFAS compounds: methyl perfluorooctane sulfonamidoethanol[N-], perfluorooctanesulfonic acid, and perfluoropentanoic acid, at 1.42, 0.40, and 0.85 nanograms per gram, respectively. The methyl perfluorooctane sulfonamidoethanol[N-] exceeded its regional statistical reference level of 0.37 nanograms per gram. One deer mouse contained two PFAS compounds: perfluorododecanoic acid and perfluorooctanesulfonic acid, at 0.23 and 13.4 nanograms per gram, respectively, which also exceeded their regional statistical reference levels (perfluorododecanoic acid = 0.15 nanograms per gram; perfluorooctanesulfonic acid = 1.80 nanograms per gram). The other deer mouse had the highest concentrations and the greatest number of PFAS compounds detected (9 of the 37 types of PFAS compounds analyzed). The highest detectable PFAS compound was 13.5 nanograms per gram of perfluorooctanesulfonic acid; six of the nine detected PFAS compounds exceeded their respective regional statistical reference levels. Because PFAS are recently emerging chemicals of concern, little is known about wildlife tissue concentrations and their relation to adverse effects. We are exploring potential sources for some of the PFAS chemicals detected at LANL. Anticipated sources are atmospheric deposition and historical use of PFAS-containing materials.

Special Assessment – PFAS in Small Mammals at Sandia Canyon

In 2022, we conducted a special assessment of PFAS concentrations in small mammals collected from the Sandia Canyon wetland. The Sandia Canyon wetland receives water from multiple outfalls but primarily from National Pollutant Discharge Elimination System–permitted outfall 001. Sources of water into the wetland include effluent from the sanitary wastewater system plant, water from the sanitary effluent reclamation facility, and wastewater discharged from industrial equipment, such as cooling towers (LANL 2008, LANL 2016). The Sandia Canyon wetland is also located directly south of the Los Alamos County Eco Station, which receives municipal waste (Figure 7-8). Wastewater treatment plants and landfills are known sources of PFAS (Banzhaf et al. 2017, Dalahmeh et al. 2018, Bai and Son 2021).

Small mammals were collected in July 2022 using Sherman live traps. All animal-handling procedures were approved by LANL's Institutional Animal Care and Use Committee. We collected five deer mice and five western harvest mice for PFAS analyses. We graphed the PFAS results to visually inspect the data using the package vegan (Galili et al. 2017) in the R statistical software version 4.2.2 (R Core Team 2023).

Of the 37 compounds analyzed in the 10 small mammals (which yielded 370 results), the majority (83 percent) were not detected. Fifteen PFAS compounds were detected in at least one small mammal collected from the Sandia Canyon wetland (Figure 7-9). All small mammals contained both perfluorodecane sulfonate (range 0.142 to 19.1 nanograms per gram) and perfluorooctanesulfonic acid (range 5.36 to 33.2 nanograms per gram; Figure 7-9 and Table S7-22). These two PFAS compounds are frequently detected in treated wastewater and in sediments in urban watersheds (Bai and Son 2021; Dalahmeh et al. 2018). The total number of PFAS compounds observed in individuals ranged from 3 to 10 (Table S7-22). The maximum concentration of a PFAS chemical was perfluorooctanesulfonic acid at 33.2 nanograms per gram in a deer mouse (Figure 7-9 and Table S7-22). The majority of PFAS compounds that were detected had tissue concentrations below 2 nanograms per gram.

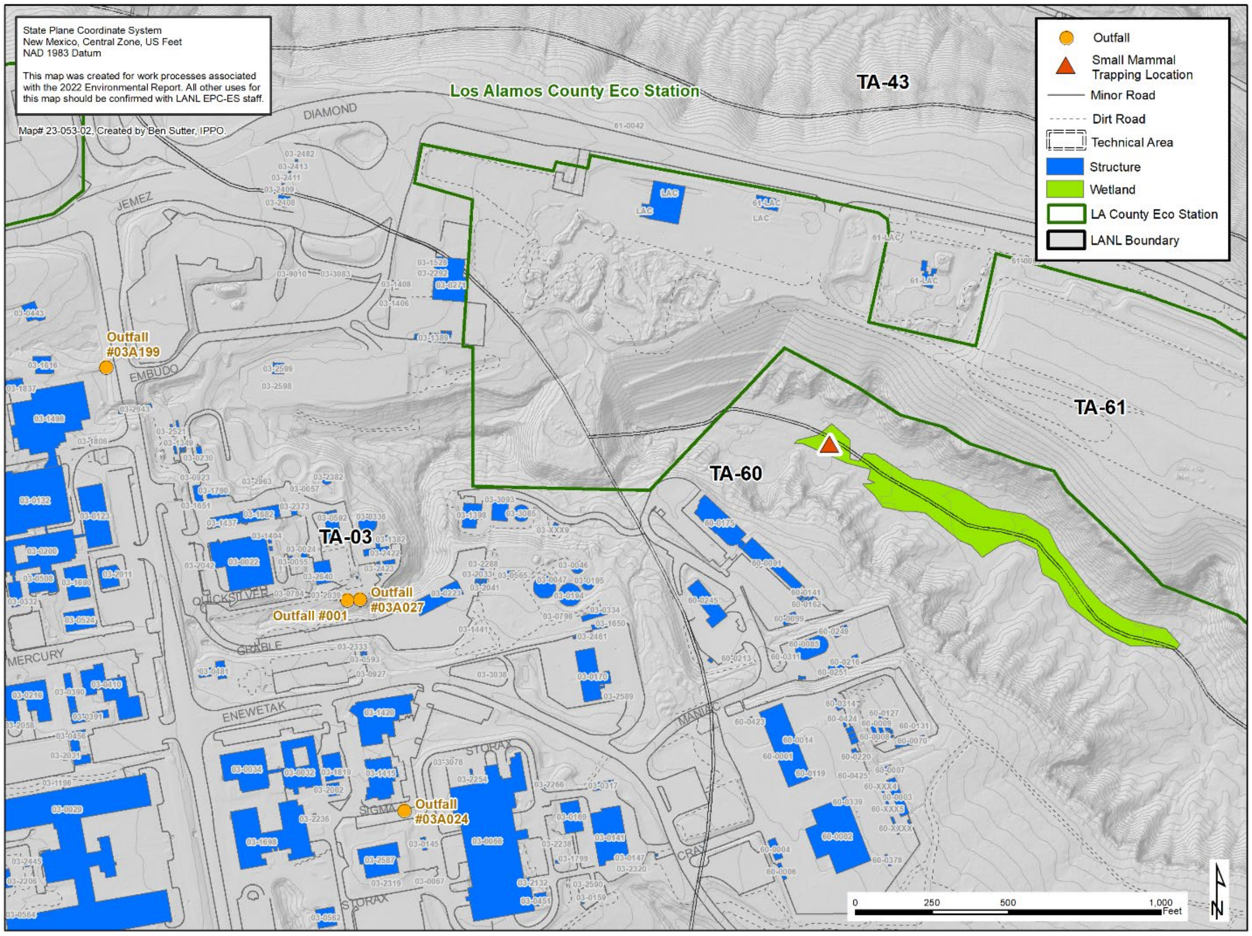


Figure 7-8. Location of small mammal samples collected from the Sandia Canyon wetland in 2022.

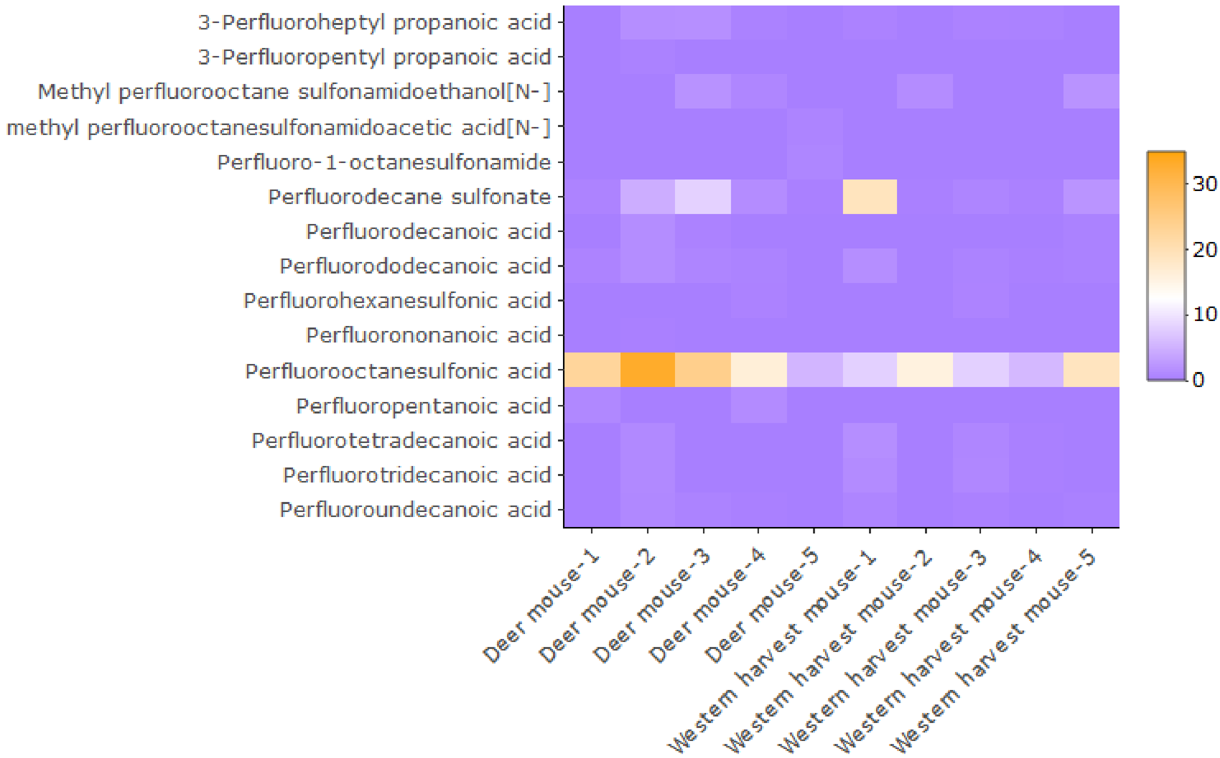


Figure 7-9. Detection frequencies of PFAS compounds (15 compounds total) that were detected in at least one individual small mammal collected from Sandia Canyon wetland in 2022.

We have regional statistical reference levels for some PFAS compounds developed from sampling animals that live in dry habitats; however, because PFAS compounds are often strongly associated with water, it is not appropriate to compare these levels to the results from the Sandia Canyon wetland. Because PFAS compounds are recently emerging chemicals of concern, little is known about wildlife tissue concentrations and their relation to adverse effects. A lowest observable adverse effect level in tissues for mice has not yet been determined. In a recent study by Murphy et al. (2023), small mammal density was 178 percent higher in the Sandia Canyon wetland when compared with neighboring study sites; thus, we do not currently have evidence of negative effects. More data from similar habitats are needed to make robust comparisons.

Institutional Monitoring for Radionuclides and Chemicals

Large Animal Monitoring Methods

Monitoring Network

We have opportunistically collected road-killed mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*) from onsite, perimeter, and background locations since the 1970s (Los Alamos Scientific Laboratory 1973). To date, we have collected and analyzed approximately 69 deer and 63 elk.

In 2015, we began collecting other species, including mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), great horned owl (*Bubo virginianus*), western screech-owl (*Megascops kennicottii*), red-tailed hawk (*Buteo jamaiciensis*), gopher snake (*Pituophis catenifer*), and additional species killed by vehicles or by other accidents.

Here we report results from six mule deer, two elk, three great horned owls, two raven (*Corvus corax*), one coyote, and one western garter snake (*Thamnophis elegans*) from onsite and perimeter locations (see Figure 7-10). Most animals collected were casualties of vehicle strikes.

Animal tissue samples were analyzed for radionuclides, inorganic elements, PCBs, and/or PFAS compounds. Leg bone and muscle were harvested from the deer, elk, and coyote. Bone was analyzed for radionuclides, and muscle was analyzed for radionuclides, inorganic elements, PCBs, and/or PFAS. Muscle samples were harvested from the great horned owls and one of the common ravens. The samples were analyzed for PCBs and PFAS, and the remaining bodies (feathers included and unwashed) were analyzed for radionuclides and inorganic elements. Due to limited sample mass, the western garter snake was analyzed only for PCBs. We collected liver samples from seven animals for PFAS analysis.

We statistically tested the results from deer analyses from 2009 through 2022. Generalized linear models were used to assess the effects of year, location (onsite or perimeter), and the interaction of year by location on concentrations of radionuclides, inorganic elements, and PCBs. The models did not include deer from background because of small sample size. Models were not run when 80 percent or more of the results for a specific radionuclide or chemical were nondetects (Helsel 2012).

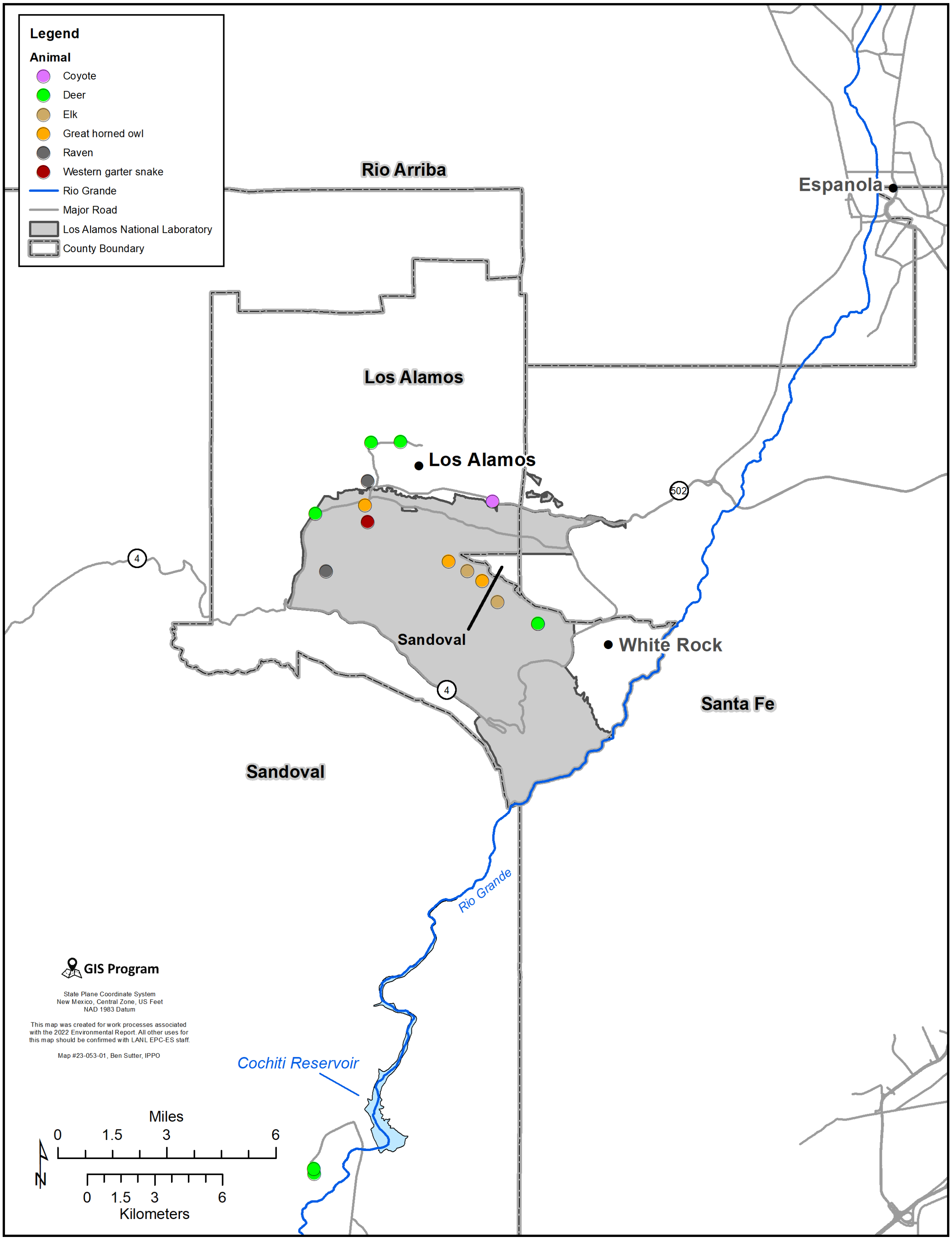


Figure 7-10. Locations of animals collected opportunistically from within and around the Laboratory in late 2021 through 2022.

Large Animal Monitoring Results

Large animal monitoring results are summarized as follows (see Table S7-23 through Table S7-29 for individual results):

- Most radionuclides were not detected, were below regional statistical reference levels, and/or were below the biota dose screening levels.
- Most inorganic element concentrations were below their regional statistical reference levels.
- PCBs were detected in most samples. All deer and elk PCB values were below the U.S. Food and Drug Administration red meat consumption guidelines.
- Most PFAS compounds were not detected. Most levels that were detected are within the range of concentrations reported in the published literature for animal tissues collected from non-polluted sites.

Radionuclide Results in Large Animals

Most radionuclides were either not detected or below their regional statistical reference levels (Table S7-23) in deer and elk. One muscle sample from a deer and one bone sample from an elk contained uranium-234 activities (0.685 and 0.010 picocuries per gram, respectively) that were above the regional statistical reference level of 0.217 and 0.009 picocuries per gram, respectively. Strontium-90 in bone of two deer (0.915 and 1.460 picocuries per gram) exceeded the regional statistical reference level of 0.769 picocuries per gram (Table S7-23). All activities were far below the biota dose screening levels that are protective of biota.

In our analysis of results from deer, between 2009 and 2022, a significant decreasing trend occurred in bone strontium-90 levels over time, consistent for both onsite and perimeter deer (Generalized Linear Model, $p < 0.0001$).

In the coyote, common ravens, and great horned owls, most radionuclides were either not detected or were below their regional statistical reference levels (Table S7-24). Most radionuclides were not detected in the coyote collected from a perimeter location; however, the activity of cesium-137 at 6.18 picocuries per gram in the muscle sample was above the regional statistical reference level of 2.17 picocuries per gram. In one great horned owl and in two common ravens, uranium-238 was the only radionuclide detected above the regional statistical reference level, and the level was far below the biota dose screening level (Table S7-24). More data from background locations are needed to make robust assessments; however, levels of radionuclides observed in all animals were well below the biota dose screening levels.

Inorganic Element Results in Large Animals

Most inorganic elements in deer and elk were below their regional statistical reference levels. Barium, calcium, copper, lead, magnesium, manganese, nickel, potassium, sodium, and zinc were higher than the regional statistical reference in one or more of the deer and elk samples (Table S7-25).

Most concentrations of inorganic elements in the muscle of deer collected on site did not differ from concentrations in deer collected from perimeter sites. Arsenic was higher in perimeter deer (Generalized Linear Model, $p < 0.001$). Arsenic is also increasing over time in both onsite and perimeter deer (Generalized Linear Model, $p < 0.0001$), though there was a significant interaction of year by location (Generalized Linear Model, $p < 0.0001$), indicating that the rate of increase differed between onsite and perimeter locations. Deer muscle antimony concentrations were also increasing over time (Generalized Linear Model, $p < 0.001$), but there was no difference between onsite and perimeter deer muscle samples (Generalized Linear Model, $p > 0.05$). There was a significant interaction of year by location (Generalized Linear Model, $p < 0.05$) in deer antimony concentrations, indicating that the rate of increase differed between onsite and perimeter locations. Deer muscle cadmium, lead, nickel, and thallium concentrations are increasing over time, consistent in both onsite and perimeter deer muscle samples (Generalized Linear Model, $p < 0.05$). The percentage of nondetects in these datasets ranged from 34 percent to 78 percent and could be influencing these observations. Because most deer samples contained antimony, arsenic, cadmium, lead, nickel, and thallium concentrations below the regional statistical reference level, these trends are not of ecological concern. Trends in these inorganic element concentrations will continue to be monitored.

In the great horned owls and common ravens, most inorganic elements were detected but were below their regional statistical reference levels (Table S7-26). One great horned owl had iron concentrations detected (180 milligrams per kilogram) above the regional statistical reference level of 136 milligrams per kilogram (Table S7-26). The common raven collected from Technical Area 16 contained antimony, cadmium, and iron concentrations of 0.475, 0.031, and 202 milligrams per kilogram, respectively, which are higher than their respective regional statistical reference levels (Table S7-26). The coyote, collected from a perimeter location, contained 0.393 milligrams per kilogram of nickel, which was slightly higher than the regional statistical reference level of 0.364 milligrams per kilogram (Table S7-26). As previously mentioned, the regional statistical reference levels for these groups of animals are based on small sample sizes, and more data are needed to make robust assessments.

PCB Results in Large Animals

PCBs were analyzed in five of the six deer and both elk (note that PCBs were not analyzed in one of the deer samples; see description under the Analytical Laboratory Quality Assessment section). PCBs were detected in two deer and two elk; three deer had no detections. PCB concentrations in the two elk were 0.00011 and 0.00005 milligrams per kilogram and exceeded the regional statical reference level of 0.00002 milligrams per kilogram (Table S7-27). PCB concentrations in deer were low and did not exceed the regional statistical reference level of 0.0001 milligrams per kilogram (Table S7-27). Our observations for both deer and elk are well below the U.S. Food and Drug Administration standard of 3 milligrams per kilogram for red meat consumption by humans (U.S. Food and Drug Administration 1987). There were no differences in total PCBs in deer on site when compared with perimeter deer, nor were there changes over time between the sites (Generalized Linear Model, $p > 0.05$).

PCBs were detected in the western garter snake all three great horned owls, a common raven, and the coyote. Concentrations ranged from 0.0050 to 0.2120 milligrams per kilogram (Table S7-28). The western garter snake, two of the three great horned owls, and the coyote contained PCB levels that were above their respective regional statistical reference levels (Table S7-28).

The lowest observable adverse effect level of PCBs in tissues is between 1 and 30 milligrams per kilogram in avian eggs and 2 to 4 milligrams per kilograms in avian adult plasma (Harris and Elliott 2011). The levels observed are well below the lowest observable adverse effect level in tissues for birds. Whereas no specific lowest observable adverse effect levels in tissues for PCBs in deer, elk, snakes and coyotes exist, adverse effects in other animals are not observed until concentrations are above 1 milligram per kilogram (Batty et al. 1990, Harris and Elliott 2011).

PFAS Results in Large Animals

We submitted samples from four deer, two elk, one coyote, one common raven, and three great horned owls to be tested for 37 PFAS compounds. A muscle sample was collected from all animals, and a corresponding liver sample was collected from seven of those animals.

No PFAS compounds were observed in the four deer muscle samples, whereas PFAS compounds were observed in the two deer liver samples we submitted. (Note: We did not collect liver samples for the other two deer.) One deer liver contained perfluoroundecanoic acid at 0.316 nanograms per gram, and the other deer liver contained perfluorononanoic acid, perfluorooctanesulfonic acid, and perfluoroundecanoic acid at 0.466, 3.31, and 0.335 nanograms per gram, respectively (Table S7-29).

Three PFAS compounds were detected in an elk muscle sample collected from Pajarito Road; ethyl perfluorooctane sulfonamidoethanol [N-], 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid, and ethylperfluoro-1-octanesulfonamide [N-] at 1.85, 0.865, and 0.800 nanograms per gram, respectively. A liver sample was not collected from this animal (Table S7-29). In the other elk, similar to the deer, the muscle sample did not contain detectable PFAS compounds but the liver contained perfluoroheptanoic acid, perfluorononanoic acid, and perfluorooctanesulfonic acid at 0.337, 0.552, and 4.76 nanograms per gram, respectively (Table S7-29).

The coyote muscle sample contained two detectable PFAS chemicals: perfluorohexanesulfonic acid and perfluorooctanesulfonic acid, at 0.278 and 1.39 nanograms per gram, respectively. The liver sample from this coyote also contained perfluorohexanesulfonic acid at 1.49 nanograms per gram in addition to eight other PFAS chemicals (Table S7-29). The highest concentration in the coyote liver was 3.75 nanograms per gram of perfluorodecanoic acid.

The muscle and liver sample from the common raven did not contain any detectable PFAS.

Two of the three great horned muscle samples and both great horned owl liver samples that were analyzed had PFAS chemicals. The great horned owl collected from Pajarito Road, which did not contain detectable PFAS in muscle, contained 0.557 nanograms per gram of perfluorooctanesulfonic acid in the liver (Table S7-29). The great horned owl collected from Technical Area 03 contained detectable concentrations of five PFAS compounds in muscle and the same five chemicals as well as an additional two compounds detected in its liver. For the chemicals that were observed in both muscle and liver, the liver contained higher concentrations (Table S7-29). The great horned owl from Technical Area 46 that had only a muscle sample analyzed contained eight PFAS compounds, including perfluorooctanesulfonic acid with the highest concentration of 14.3 nanograms per gram (Table S7-29).

No regional statistical reference levels for PFAS compounds are available for any of these species.

Perfluorooctanesulfonic acid and perfluoroundecanoic acid were the most frequently detected compounds. These two compounds are longer-chain PFAS compounds and have a greater propensity to bioaccumulate in animal tissues because these molecules are difficult to metabolize. Most of our observations are within the ranges of PFAS concentrations observed in animal tissues from published studies that occurred away from point-source pollution and in the Antarctic, where global fallout is the primary source of PFAS in the environment (Aas et al. 2014, Bossi et al. 2015). When liver and muscle samples were taken from the same animal, PFAS detections were more frequent and had higher concentrations in liver samples, which is similar to findings in published studies (Robuck et al. 2021). Our results also suggest that lower concentrations are found in herbivores, such as deer and elk, compared with other trophic levels; however, our sample sizes are still quite small, and we cannot draw robust conclusions at this time. Because PFAS are recently emerging chemicals of concern, little is known about wildlife tissue concentrations and their relation to adverse effects.

Summary—PFAS Monitoring Results

Per- and polyfluoroalkyl substances (PFAS) are synthetic compounds found in many manufactured items such as cookware, food packaging, stain repellents, and fire-fighting foams. The several thousand types of PFAS compounds repel oil, stains, grease, and water and are fire resistant. The widespread use of PFAS and their persistence in the environment means that the past and current uses of PFAS compounds can result in elevated PFAS levels in the environment and the accumulation of PFAS in animal tissues over time. PFAS also have possible impacts on human health.

In 2022, we tested 55 samples for PFAS compounds, including 6 soil samples, 4 sediment samples, 6 vegetation samples, 3 avian nestling samples, 3 avian egg samples, 16 small mammal samples, and 17 road-killed animal samples (10 muscle samples and 7 liver samples) from on and off the Laboratory. All samples were analyzed for a suite of 37 PFAS compounds.

We evaluated PFAS compounds in soil and sediment around the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15. Like previous years, no PFAS compounds were detected in the soil samples collected at the firing point. Detectable concentrations of PFAS compounds were mostly observed on the east and south sides of the facility. We reported 12 PFAS compounds in the sediment sample and 7 PFAS compounds in the soil sample collected on the south side and 12 PFAS compounds in the soil sample collected on the east side. The highest PFAS compound concentration in soil or sediment was 16.7 nanograms per gram of 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid. Perfluorooctanesulfonic acid was the most frequently detected compound, occurring in seven of the soil and sediment samples with a range of 0.19 to 6.8 nanograms per gram. Some of these values exceeded the regional statistical reference level for perfluorooctanesulfonic acid, but all were well below the ecological soil screening level and the Environmental Protection Agency’s Regional Screening Levels. Concentrations of PFAS observed here are within the range of global observations of concentrations in soil collected from non-polluted sites (Brusseau et al. 2020).

We evaluated PFAS compounds in vegetation from the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15, the flood retention structure in Pajarito Canyon, and the weir in Los Alamos Canyon. Perfluoropentanoic acid was detected in one of the four overstory vegetation samples collected at the Dual-Axis Radiographic Hydrodynamic Test Facility at

Technical Area 15 (on the east side) and in the understory vegetation sample collected in Pajarito Canyon. The understory vegetation sample collected from Los Alamos Canyon contained five PFAS compounds, including perfluoropentanoic acid.

Of three avian nestling samples and three avian egg samples collected, PFAS compounds were observed in only one western bluebird composite egg sample collected from a nest box at the Technical Area 16 burn site. Four compounds were detected in this sample, including perfluoroundecanoic acid, perfluorononanoic acid, perfluorotetradeconoic acid, and perfluorotridecanoic acid at 0.307, 0.317, 0.733, and 1.02 nanograms per gram, respectively. All observed concentrations of PFAS compounds in this sample were two orders of magnitude below the perfluorooctanesulfonic acid lowest observable adverse effect level in tissue (Dennis et al. 2021).

We collected 16 small mammals for PFAS analyses from three onsite locations: 3 at the Los Alamos Canyon Weir, 3 at the Pajarito Canyon flood retention structure, and 10 from an effluent-fed wetland in Sandia Canyon. Commonly detected PFAS compounds in small mammals included perfluoroundecanoic acid in Los Alamos Canyon, perfluorooctanesulfonic acid in Pajarito Canyon, and perfluorodecane sulfonate and perfluorooctanesulfonic acid in Sandia Canyon. Some of the PFAS chemicals detected in small mammals were at levels above their respective regional statistical reference levels. In general, small mammals from Los Alamos Canyon have the lowest number and level of PFAS compounds, and small mammals from the Sandia Canyon wetland have the highest number and level of PFAS compounds.

Four deer, two elk, one coyote, one common raven, and three great horned owls were collected opportunistically (mostly as roadkill) and were analyzed for PFAS compounds. We collected a muscle sample from each animal and a corresponding liver sample from seven of the animals. No PFAS compounds were observed in deer or elk muscle; however, some PFAS compounds were detected in livers collected from the same animal. The coyote and great horned owls also had more detections and higher levels of PFAS compounds in liver tissue compared with muscle tissue. The great horned owls contained higher concentrations of PFAS compounds compared with other taxa. Perfluorooctanesulfonic acid and perfluoroundecanoic acid were the most frequently detected compounds. The majority of detected PFAS concentration was within the ranges observed in animal tissues from published studies, including studies that occurred away from point-source pollution and in the Antarctic, where global fallout is the primary source of PFAS in the environment (Aas et al. 2014, Bossi et al. 2015).

Overall, most PFAS chemicals were not detected in soil, sediment, vegetation, or small and large animals. We observed more PFAS chemicals in soil than in vegetation. No consistent patterns of PFAS distributions or detections exist between soil and vegetation at a site. Perfluorooctanesulfonic acid was the most common PFAS chemical in soil, whereas perfluoropentanoic acid was the most common PFAS chemical in vegetation. Perfluoroundecanoic acid and perfluorooctanesulfonic acid were the most common PFAS chemicals in small and large mammals. Perfluorodecane sulfonate was also detected in all small mammals collected from the effluent-fed wetland in Sandia Canyon. Perfluoroundecanoic acid and perfluorooctanesulfonic acid are longer-chain PFAS compounds and have a greater propensity to bioaccumulate in animal tissues because these molecules are difficult to metabolize.

The concentrations of detected PFAS chemicals were generally within the range of global observations of concentrations in soil and animals collected from non-polluted sites (Aas et al. 2014, Bossi et al. 2015, Brusseau et al. 2020). For most of our samples, the PFAS concentrations observed are suspected to be due to a non-point source such as atmospheric deposition. We are exploring potential sources for some of the PFAS chemicals detected in the different media. Anticipated sources are atmospheric deposition and historical Laboratory use of PFAS-containing materials.

Please see the following sections for more detailed descriptions of PFAS results:

- Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15
- Open-Detonation and Open-Burn Firing Sites
- Sediment and Flood-Retention Structures
- Small Mammal Monitoring at Sandia Canyon Effluent-fed Wetland
- Large Animal Monitoring

Biota Radiation Dose Assessment

Introduction

The purpose of the biota dose assessment is to ensure that plant and animal populations are protected from the effects of Laboratory radioactive materials, as required by DOE Order 458.1. This assessment follows the guidance of the DOE standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019), and uses the standard DOE dose calculation program, RESRAD-BIOTA version 1.8.

Previous biota dose assessments were reported in the Annual Site Environmental Reports and concluded that biota doses for populations at the Laboratory are well below the DOE limits of 1 rad per day for terrestrial plants and aquatic animals and 0.1 rad per day for terrestrial animals (DOE 2019).

Plants and animals receive doses from external radiation. Plants receive internal doses from radionuclides taken up through their roots if the roots penetrate material buried in material disposal areas. Animals receive internal doses when they eat the plants. When a predator eats its prey, there is a possibility for bioaccumulation as the ingested material passes up the food chain. Bioaccumulation is accounted for by introducing “bioaccumulation factors” or “concentration ratios,” which are the ratios of the radionuclides in living tissue to the concentrations in the underlying soil and water.

Published concentration ratios provide the option of calculating the concentrations in living tissue from the concentrations in soil. Alternatively, the concentration ratios can be used to calculate the soil concentration from measured concentrations in biota tissue. The comparison of these two methods shows that, in most cases, the concentration ratios are conservative overestimates.

The biota doses reported in the following paragraphs are calculated using site-representative values as described in Appendix F of DOE-STD-1153-2019 (DOE 2019). Whenever the data allow alternative calculations of the dose from either soil or tissue data, the largest dose is reported as follows.

The material that potentially contributes to the biota doses at the Laboratory is legacy waste material. Ongoing remediation and radioactive decay result in decreasing concentrations, so a generally decreasing trend in biota dose is expected; however, ongoing operations and movement of soil or sediment may cause an accumulation of radioactive material, so key locations are reassessed annually.

Mesa-Top Facilities

Area G

This chapter reports new measurements of soil and vegetation around material disposal area G, known as "Area G." The results are generally comparable with previous years, though there is some year-to-year variation depending on the exact locations sampled. This year-to-year variation can be seen in the trend graphs of this chapter.

As recommended by the DOE standard (DOE 2019), this assessment uses the highest measured concentrations, and the resulting doses are reported in Table 7-2 and Table 7-3.

Table 7-2. Dose Rate to Terrestrial Animals at Area G for 2022 DOE Limit: 0.1 rad per day (rad/day) for terrestrial animals. Values are given in scientific notation.

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Am-241	8.4E–10	8.4E–06	1.4E–07	3.3E–05	4.1E–05
Cs-137	2.3E–08	2.3E–05	3.0E–09	1.5E–06	2.5E–05
H-3	1.3E–03	2.7E–03	2.6E–03	2.6E–03	9.2E–03
Pu-238	3.7E–10	1.5E–06	3.8E–07	2.7E–05	2.9E–05
Pu-239	4.7E–11	1.9E–07	8.2E–08	5.3E–06	5.6E–06
Sr-90	3.8E–07	2.3E–05	3.1E–06	9.1E–05	1.2E–04
U-234	1.2E–08	1.2E–06	4.6E–06	1.8E–05	2.4E–05
U-235	2.2E–08	2.2E–06	2.8E–07	1.1E–06	3.6E–06
U-238	8.2E–07	8.2E–05	4.0E–06	1.5E–05	1.0E–04
Medium Total	1.3E–03	2.8E–03	2.6E–03	2.8E–03	Overall Dose Rate 9.6E–03

Table 7-3. Dose Rate to Terrestrial Plants at Area G for 2022 DOE Limit: 1.0 rad per day (rad/day) for terrestrial plants. Values are given in scientific notation.

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	8.4E–10	8.4E–06	6.2E–05	7.1E–05
Cs-137	2.3E–08	2.3E–05	1.5E–06	2.5E–05
H-3	1.3E–03	2.7E–03	2.8E–03	6.8E–03
Pu-238	3.7E–10	1.5E–06	8.2E–05	8.4E–05

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Pu-239	4.7E–11	1.9E–07	2.6E–05	2.6E–05
Sr-90	3.8E–07	2.3E–05	9.1E–05	1.2E–04
U-234	1.2E–08	1.2E–06	1.8E–05	1.9E–05
U-235	2.2E–08	2.2E–06	1.1E–06	3.3E–06
U-238	8.2E–07	8.2E–05	1.5E–05	9.8E–05
Medium Total	1.7E–04	4.7E–04	1.1E–03	Overall Dose Rate 7.2E–03

At Area G, the largest dose contribution is from tritium, which is mostly concentrated near the southern edge of Area G at locations 29-03 and 30-1 (Figure 7-1).

The results in Table 7-2 show that the biota doses at Area G are well below the DOE limits of 0.1 rad per day for animals, and Table 7-3 shows that the doses are also below the limit of 1 rad per day for plants. Overall, there are no expected impacts to biota health.

Dual-Axis Radiographic Hydrodynamic Test Facility

The Dual-Axis Radiographic Hydrodynamic Test Facility biota dose assessment uses the same methods described in the previous section. The largest doses were calculated from the soil data, indicating that the tissue-to-soil concentration ratios are overestimates, as discussed in the introduction to this section on page 7-37. The largest soil activities were entered into RESRAD-BIOTA, and the results are reported in Table 7-4 and Table 7-5.

Table 7-4. Dose Rate to Terrestrial Animals at the Dual-Axis Radiographic Hydrodynamic Test Facility for 2022 DOE Limit: 0.1 rad per day (rad/day) for terrestrial animals. Values are given in scientific notation.

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Am-241	3.2E–12	3.2E–08	5.3E–10	1.2E–07	1.6E–07
Cs-137	1.6E–08	1.6E–05	2.0E–09	1.0E–06	1.7E–05
H-3	6.0E–08	1.2E–07	1.2E–07	1.2E–07	4.1E–07
Pu-238	1.8E–12	7.1E–09	1.9E–09	1.3E–07	1.4E–07
Pu-239	1.5E–12	6.0E–09	2.6E–09	1.7E–07	1.8E–07
Sr-90	3.7E–07	2.2E–05	3.0E–06	8.8E–05	1.1E–04
U-234	3.5E–08	3.5E–06	1.3E–05	5.0E–05	6.6E–05
U-235	1.1E–07	1.1E–05	1.4E–06	5.1E–06	1.8E–05
U-238	1.6E–05	1.6E–03	7.9E–05	3.0E–04	2.0E–03
Medium Total	1.7E–05	1.7E–03	9.7E–05	4.4E–04	Overall Dose Rate 2.2E–03

Table 7-5. Dose Rate to Terrestrial Plants at the Dual-Axis Radiographic Hydrodynamic Test Facility for 2022 DOE Limit: 1.0 rad per day (rad/day) for terrestrial plants. Values are given in scientific notation.

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	3.2E–12	3.2E–08	2.4E–07	2.7E–07
Cs-137	1.6E–08	1.6E–05	1.0E–06	1.7E–05
H-3	6.0E–08	1.2E–07	1.3E–07	3.0E–07
Pu-238	1.8E–12	7.1E–09	4.0E–07	4.1E–07
Pu-239	1.5E–12	6.0E–09	8.2E–07	8.3E–07
Sr-90	3.7E–07	2.2E–05	8.8E–05	1.1E–04
U-234	3.5E–08	3.5E–06	4.9E–05	5.3E–05
U-235	1.1E–07	1.1E–05	5.2E–06	1.6E–05
U-238	1.6E–05	1.6E–03	3.0E–04	1.9E–03
Medium Total	1.7E–05	1.7E–03	4.5E–04	Overall Dose Rate 2.1E–03

The largest dose contribution is from uranium, most of which is the result of Laboratory operations. The activities of the other radionuclides are consistent with natural background and global fallout.

Table 7-4 and Table 7-5 show that the biota doses are well below the DOE limits of 0.1 rad per day for animals and 1 rad per day for plants. No impacts are expected to biota health.

Sediment-Retention Sites in Canyons

Los Alamos Canyon Weir

The Los Alamos Canyon weir receives drainage from former Technical Areas 01, 02, and 21. The soil and sediment trapped by the weir include slightly elevated activities of fission products (cesium-137 and strontium-90) and transuranic radionuclides (americium and plutonium).

As shown in Table 7-6 and Table 7-7, the doses are all less than 1 percent of the DOE limits.

Table 7-6. Dose to Terrestrial Animals in Los Alamos Canyon Weir for 2022 DOE Limit: 0.1 rad per day (rad/day) for terrestrial animals. Values are given in scientific notation.

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
Am-241	1.7E–10	1.7E–06	2.9E–08	6.7E–06	8.5E–06
Cs-137	6.8E–08	6.8E–05	8.8E–09	4.4E–06	7.3E–05
Pu-238	7.8E–11	3.1E–08	8.1E–09	5.7E–07	6.1E–07
Pu-239	2.7E–11	1.1E–07	4.8E–08	3.1E–06	3.3E–06
Sr-90	9.4E–07	5.7E–05	7.5E–06	2.3E–04	2.9E–04

Nuclide	External		Internal		Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Water (rad/day)	Soil (rad/day)	
U-234	2.1E–08	2.1E–06	7.8E–06	3.0E–05	3.9E–05
U-235	2.7E–08	2.7E–06	3.5E–07	1.3E–06	4.4E–06
U-238	1.5E–06	1.5E–04	7.2E–06	2.7E–05	1.8E–04
Medium Total	2.5E–06	2.8E–04	2.3E–05	3.0E–04	Overall Dose Rate 6.0E–04

Table 7-7. Dose Rate to Terrestrial Plants in Los Alamos Canyon Weir for 2022 DOE Limit: 1 rad per day (rad/day) for terrestrial plants. Values are given in scientific notation.

Nuclide	External		Internal	Nuclide Total (rad/day)
	Water (rad/day)	Soil (rad/day)	Soil (rad/day)	
Am-241	1.7E–10	1.7E–06	1.3E–05	1.5E–05
Cs-137	6.8E–08	6.8E–05	4.4E–06	7.3E–05
Pu-238	7.8E–11	3.1E–08	1.8E–06	1.8E–06
Pu-239	2.7E–11	1.1E–07	1.5E–05	1.5E–05
Sr-90	9.4E–07	5.7E–05	2.3E–04	2.8E–04
U-234	2.1E–08	2.1E–06	2.9E–05	3.2E–05
U-235	2.7E–08	2.7E–06	1.3E–06	4.1E–06
U-238	1.5E–06	1.5E–04	2.7E–05	1.8E–04
Medium Total	2.5E–06	2.8E–04	3.2E–04	Overall Dose Rate 6.0E–04

Pajarito Canyon Flood-Retention Structure

The Pajarito Canyon flood-retention structure does not receive significant quantities of LANL radionuclides. During 2022, any contribution from DOE operations was indistinguishable from background. The total biota dose in Pajarito Canyon is less than 1% of the DOE limits and has no expected impact on biota health.

Roadkill Animals

Whenever possible, samples from animals killed on the roads are analyzed for levels of radionuclides and chemicals. This year, four deer, two elk, three owls, two common ravens, and a coyote were sampled and analyzed.

Sample number SFB-23-265502 was a deer killed on Pajarito Road near Area G. The independent analytical laboratory reported 0.685 picocuries per gram of uranium-234, with no detectable uranium-235 or uranium-238 (Table S7-23), which is an unlikely isotopic mixture; the analytical laboratory agreed that uranium-233 was another possibility. For either of these possibilities, the dose to the deer would be less than 4×10^{-5} rad per day, and the possible dose to a person who eats the venison would be less than 0.1 millirem. These doses are extremely small and do not indicate a significant concern.

The only road-killed animal that contained a clear indication of LANL radioactive material was the coyote. It was killed in December 2022 on East Road near the Los Alamos Cooperative Market, and analysis showed that it contained 6.18 picocuries per gram of cesium-137 (Table S7-24). This concentration is consistent with the expected uptake from soil that contains 1 picocurie of cesium-137 per gram of soil, which is slightly higher than global fallout but is consistent with the concentrations in the nearby DP Canyon and Technical Area 21. This very small amount of cesium-137 would not be expected to cause any significant effects on the coyote (4.3E−05 rad/day), nor does it indicate any significant effect that might affect humans.

Conclusion

Previous biota dose assessments have shown that biota doses at LANL are far below the DOE limits. This 2022 assessment confirms the previous assessments and shows that there are no expected harmful effects to the health of biota populations from Laboratory radioactive materials.

Biological Resources Management Program

We monitor federally listed, threatened, or endangered species and migratory bird species; provide guidelines and requirements for Laboratory operations to minimize impacts to sensitive species and their habitats; and ensure that all Laboratory operations comply with federal and state regulatory requirements.

Threatened and Endangered Species Surveys

In 2022, we completed surveys for four species protected under the Endangered Species Act: the Mexican spotted owl (*Strix occidentalis lucida*), the Southwestern willow flycatcher (*Empidonax traillii extimus*), the Jemez Mountains salamander (*Plethodon neomexicanus*), and the western distinct population of the Yellow-billed cuckoo (*Coccyzus americanus*).

Mexican spotted owl

The Mexican spotted owl generally inhabits mixed conifer, ponderosa pine (*Pinus ponderosa*), and gambel oak (*Quercus gambelii*) forests in mountains and canyons (U.S. Fish and Wildlife Service 2012). Mexican spotted owls in the Jemez Mountains of northern New Mexico prefer cliff faces in canyons for their nest sites (Johnson and Johnson 1985).

Under the Laboratory’s Threatened and Endangered Species Habitat Management Plan, Mexican spotted owl habitat has been identified based on a combination of cliff habitat and forest characteristics (LANL 2022a). At LANL, habitats of threatened and endangered species are called “areas of environmental interest.” Currently, five Mexican spotted owl areas of environmental interest span seven canyons at the Laboratory.

Surveys for breeding Mexican spotted owls are conducted every year in areas of environmental interest. In 2022, we detected Mexican spotted owls in the Mortandad and Threemile canyon areas of environmental interest. We confirmed occupancy of both sites by breeding pairs, but they did not successfully fledge any young—likely due to lower-than-average precipitation during the 2021 monsoon and winter seasons that limited the availability of food in early 2022 (Yang et al. 2021, Stanek et al. 2022). Mexican spotted owls have occupied these two sites in previous years (Thompson et al. 2021).

Southwestern willow flycatcher

The Southwestern willow flycatcher is found in close association with dense stands of willows (*Salix spp.*), arrowweed (*Pluchea sp.*), buttonbush (*Cephalanthus occidentalis*), tamarisk (*Tamarix sp.*), Russian olive (*Elaeagnus angustifolia*), and other riparian vegetation, often with a scattered overstory of cottonwood (*Populus sp.*; U.S. Fish and Wildlife Service 2002).

Under the Laboratory's Threatened and Endangered Species Habitat Management Plan, Southwestern willow flycatcher habitat has been identified based on the presence of riparian habitat with suitable wetland vegetation (LANL 2022a). Only one area of environmental interest for the southwestern willow flycatcher exists at the Laboratory—in the bottom of Pajarito Canyon. There were no detections in 2022.

Jemez Mountains salamander

The Jemez Mountains salamander occurs predominantly at elevations between 7,000 and 11,000 feet in mixed-conifer and spruce-fir forests that consist primarily of Douglas fir (*Pseudotsuga menziesii*), blue spruce (*Picea pungens*), Engelmann spruce (*Picea Engelmannii*), white fir (*Abies concolor*), limber pine (*Pinus flexilis*), ponderosa pine (*Pinus ponderosa*), Rocky Mountain maple (*Acer glabrum*), and aspen (*Populus tremuloides*; Degenhardt et al. 1996).

Under the Laboratory's Threatened and Endangered Species Habitat Management Plan, Jemez Mountains salamander habitat has been identified based on a geographical information systems analysis and a field-validated inspection of suitable habitat components (LANL 2022a). Currently, five Jemez Mountains salamander areas of environmental interest exist at the Laboratory in four canyons. We conduct surveys in these areas where there is a specific project need and when suitable environmental conditions are met. There were six surveys completed in 2022 in the Los Alamos Canyon area of environmental interest, and no salamanders were detected.

Yellow-billed cuckoo

The yellow-billed cuckoo is a riparian obligate species, and it nests almost exclusively in low- to mid-elevation riparian habitat dominated by cottonwoods and willows (Halterman et al. 2015). Potential habitat on Laboratory property for this species is located along the Rio Grande; there are no current Laboratory operations in this area. No breeding habitat is identified for the species under the Laboratory's Threatened and Endangered Species Habitat Management Plan.

We do not conduct surveys every year, but we review any LANL work activities that might affect habitat for this species (Keller 2015). Several planned utility projects will require river crossings in this area. In 2022, a cuckoo was detected once along one of two transects surveyed but was not detected during subsequent surveys. The cuckoo may have been using the area as stopover habitat during migration. We will continue to perform these surveys in subsequent years to support future planned projects.

Migratory Bird Monitoring

Breeding Season Bird Banding at the Sandia Wetlands

We have been operating a bird banding station in the Sandia Canyon wetland since 2014. This wetland contains primarily broadleaf cattail (*Typha latifolia*), lanceleaf cottonwood (*Populus acuminata*), narrowleaf willow (*Salix exigua*), and Russian olive (*Elaeagnus angustifolia*; N3B

2019). The Sandia Canyon wetland attracts numerous species of breeding birds, including many species of conservation concern. The purpose of this project is to monitor the species, age classes, breeding status, and return rates of songbirds that use the area around the wetland.

Beginning in May each year, we operate the bird banding station during the bird breeding season using a protocol called Monitoring Avian Productivity and Survivorship (DeSante et al. 2021), administered by The Institute for Bird Populations. Use of the Monitoring Avian Productivity and Survivorship protocol is a continent-wide collaborative effort among public agencies, non-governmental groups, and individuals. By following a standard protocol, we produce data that can be compared among sites.

During banding sessions, we deploy 12 mist nets that are 12 meters long and made of 30-millimeter mesh. A standard U.S. Geological Survey uniquely numbered aluminum band is put on each captured bird. All birds are identified, aged, sexed, weighed, measured, fat scored, and checked for signs of molting feathers. We use the aging and sexing criteria provided in the Identification Guide to North American Birds (Pyle 2022).

A total of 1,905 birds that represent 74 species have been captured during the breeding seasons of 2014 through 2022. In 2022, we captured 154 birds that represented 35 species. The most common newly captured species in 2022 was the pygmy nuthatch (*Sitta pygmaea*), and the most common recaptured species was the song sparrow (*Melospiza melodia*).

Fall Migration Bird Banding at Pajarito Wetlands

Biologists at the Laboratory also monitor birds on Laboratory property during fall migration. During the fall of 2022, we completed the thirteenth year of monitoring birds during fall migration. Birds were captured at a mist-netting station located in a wetland and riparian complex in Technical Area 36 on the north side of Pajarito Road.

The fall banding station uses 14 mist nets that are 12 meters long and made of 30-millimeter mesh. A uniquely numbered aluminum band is put on each bird. All birds are identified, aged, sexed, weighed, measured, fat scored, and checked for signs of molting feathers. The aging and sexing criteria are based on the Identification Guide to North American Birds (Pyle 2022).

Since 2010, when the fall banding station was established, 5,604 birds have been captured. During the fall of 2019, we captured the highest number of birds, totaling 1,375 birds; the following year (2020), we captured the lowest overall number at 193 birds. In 2022, we captured 596 birds that represented 52 species. The two most commonly captured bird species at this site in 2022 were the house finch (*Haemorhous mexicanus*) and the chipping sparrow (*Spizella passerina*). The chipping sparrow was also the most recaptured bird species in 2022 at the fall station.

Bird Monitoring at Open-Detonation and Open-Burn Firing Sites

We began bird population monitoring in 2013 for two open-detonation sites and at the open-burn site as part of a Resource Conservation and Recovery Act permitting process. Open-detonation sites are locations at the Laboratory where explosives are set off. The open-burn site is a facility where materials are ignited for self-sustained combustion (for example, to remove residues of high explosives). The two open-detonation sites included in the permitting process are Minie site at Technical Area 36 and Point 6 at Technical Area 39; the open-burn site is in Technical

Area 16. Together these are referred to as the treatment sites and hereafter referred to as Minie, Technical Area 39, and the Burn Site. The objective of the ongoing population monitoring is to determine whether Laboratory operations at these sites impact bird species richness (the number of different species present), species diversity (a combination of the number of species present and their relative abundance), or composition (the presence or absence of each individual species).

Point-Count Surveys

We conduct point counts surveys for birds along transects at the three treatment sites and compare the results to surveys conducted in control sites (areas of similar habitat but less developed). The habitat type at Minie and Technical Area 39 is a two-needle pinyon pine (*Pinus edulis*) and one-seed juniper woodland habitat referred to as pinyon-juniper. The habitat type at the Burn Site is a forested ponderosa pine habitat referred to as ponderosa pine. Surveys reported here are conducted in the summer during the bird breeding season.

A total of 1,182 birds that represent 58 species were recorded at the three treatment sites combined in 2022 (Gadek et al. 2023). The species diversity at Minie, Technical Area 39, and the Burn Site were statistically higher than their associated controls. This outcome is consistent with previous years, likely due to subtle habitat differences between treatment and control sites. Annual diversity at treatment sites in 2022 remains stable relative to past years. Overall diversity remains high across all treatment sites relative to the control sites. The results from 2022 continue to suggest that operations at the treatment sites are not negatively impacting bird populations. This long-term project will continue to monitor for any changes over time.

Avian Nest Box Use and Success

The Laboratory's avian nest box network, including at the three treatment sites described previously, had 365 monitored nest boxes in 2022. Of those, 134 contained active nests, and 58 of those nests fledged young successfully, resulting in an overall occupancy rate of 36 percent with a 43 percent success rate for active nests.

During the 2022 nesting season, 15 nest boxes at each treatment site were actively monitored. The occupancy rates at Minie, the Burn Site, and Technical Area 39 were 33 percent, 93 percent, and 13 percent, respectively. Occupancy rates at TA-39 are routinely low compared with the other treatment sites and the overall network, whereas occupancy at the Burn Site is high. TA-39 is the lowest-elevation treatment site, and occupancy has been decreasing over time at both this site and other areas of the avian nest box network at a similar elevation. Wysner et al. (2019) found that western bluebirds, one of the target species of the network, are nesting at progressively higher elevations over time, which may be affecting our observations of nest box occupancy at lower-elevation sites. Occupancy and success rates at the other two treatment sites seem to be fluctuating in the same manner as the overall network and have not displayed a decreasing trend over time.

The results from 2022 continue to indicate that operations at the three treatment sites are not negatively affecting their local bird populations.

Wildland Fire and Forest Management Program

The Wildland Fire and Forest Management Program prepares for wildland fire with fuel mitigation and forest management projects. We plan and implement treatments, including forest thinning, to reduce the potential for harm from wildland fire and to increase forest and habitat resilience to climate-related disturbances. We track the locations of our thinning projects, monitor the forest conditions before and after treatment, and document the ecological response of forests to treatments to determine whether the treatments were implemented as designed and to provide information for adaptive management during future forest management activities. Monitoring allows us to assess our effectiveness at reducing fuels, improving forest resiliency, and protecting threatened and endangered species habitat (LANL 2019).

In 2022, we developed an official procedure for documenting and monitoring forest thinning treatments (LANL 2023), and we collected data from 52 pre-treatment monitoring plots in three project areas. Thinning treatments were implemented on 28 acres in one of these project areas during the year, so we also collected post-treatment monitoring (see the "Technical Area 16 Open Space Thinning Project" section that follows). In May 2022, we conducted photo monitoring of emergency fuels mitigation activities performed during the Cerro Pelado Fire.

Monitoring and Documentation of Forest Management Activities

The LANL Wildland Fire Mitigation and Forest Health Plan (LANL 2019) presents treatment standards for LANL property to meet the following goals:

- Restore and maintain landscapes: LANL landscapes are resilient to disturbances.
- Develop a fire-adapted community: LANL workforce, neighbors, and infrastructure can withstand a wildland fire without loss of life and property.
- Ensure wildland fire mitigation implementation: All wildland fire mitigation working group organizations participate in making and implementing safe, effective, and efficient risk-based wildland fire management decisions.

Our monitoring procedure establishes sampling design and data collection methods for evaluating the outcome of treatments. The results allow assessment and adaptive management for the following Wildland Fire and Forest Management objectives:

- Implement treatments to manage vegetative communities for resilience, including fire-related disturbances
- Protect habitat for federally listed threatened or endangered species
- Minimize soil erosion and offsite sediment transport
- Assess effectiveness of fuel treatments
- Increase forest resilience to drought and fire (in other words, achieve more water available to individual trees and shrubs by establishing lower tree densities, increased water infiltration, and slower water runoff)
- Establish a mosaic forest structure in both space and time (for example, treatments will be implemented over several years, with spatial gaps between heavily treated areas)
- Increase adequate forest gaps and openings to increase available light to and diversity of understory herbaceous vegetation

- Avoid and arrest the spread of invasive plant species, including Siberian elm (*Ulmus pumila*), teasel (*Dipsacus spp.*), and invasive thistles (*Cirsium spp.*)
- Preserve the oldest ponderosa pine individuals for their genetic and habitat importance
- Limit the spread of damaging insects
- Improve riparian ecosystem function (for example, increase cover of native riparian vegetation and reduce channel downcutting, thereby improving access of water to floodplain)
- Preserve seed sources by collecting cones from any large individuals that are removed (to be used in regional restoration efforts in severely burned areas)

Table 7-8 provides an overview of the types of forest stand measurements that are identified in the monitoring procedure. Standard forest inventory methods are used to measure stand density and other variables. We place approximately one variable radius plot every 3 acres.

Table 7-8. Forest health objectives and associated forest stand measurements

Forest Health Objective	Forest Stand Measurements
Vegetative community resilience	Stand density, line-point intercept, erosion metrics
Threatened and Endangered species habitat	1,000-hour fuel loading, snag density, canopy cover
Soil erosion	Soil erosion assessment, photos
Fuel treatment effectiveness	Stand density, fuel loading
Forest structure	Stand density and species composition, tree size distribution
Gaps/openings	Stand density, drones, line-point intercept, photos
Invasives spread	Line-point intercept, invasives early detection
Forest insects	Stand inventory and health metrics
Riparian function	Erosion monitoring, photos, stream gauge data, line-point intercept, riparian mapping
Seed source	Tree life stage

Technical Area 16 Open Space Thinning Project

In 2022, we collected data on stand density and structure in the Technical Area 16 open space thinning project area. This project had the primary objective of reducing fuels and stand density near facilities in the southwest corner of the Laboratory (Figure 7-11). Because this thinning was conducted during the Cerro Pelado wildfire emergency, time allowed only four plots in two units for collecting data on forest structure before treatment. Photos of the two units before and after thinning are shown in Figure 7-12.

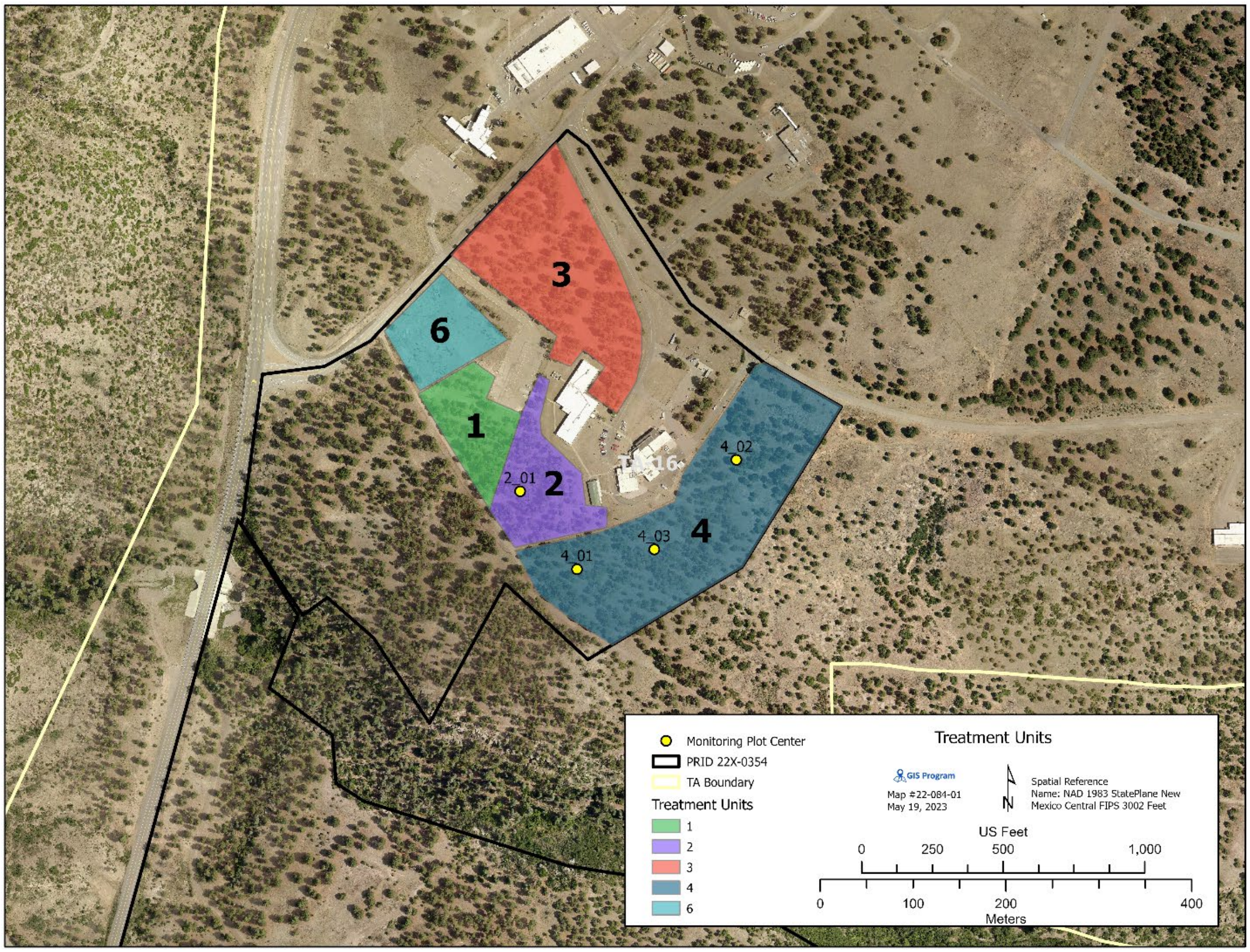


Figure 7-11. Map of the Technical Area 16 Open Space Thinning Project extent with treatment Units 1, 2, 3, 4, and 6 shown in different colors. Yellow points indicate locations of forest health monitoring plots, with one plot in Unit 2 and three plots in Unit 4.

Unit 2 - Pre-treatment - May 2, 2022

Unit 2 - Post-treatment - July 27, 2022

Unit 4 - Pre-treatment - May 4, 2022

Unit 4 - Post-treatment - July 28, 2022

Figure 7-12. Four photos taken in Unit 2 (top) and Unit 4 (bottom) of the Technical Area 16 thinning project, two before the treatment (left side) and two after the treatment (right side). Dates of the photos are below each image.

Basal area per acre (the sum of the cross-sectional area of tree trunks at 4.5 feet high) and the number of trees per acre are common but different ways to describe the density of a stand of trees. Using a wedge prism tool, we could collect data on basal area more quickly than on the number of trees per acre, so we collected basal area estimates in all units before the emergency thinning operations. Basal area and trees per acre (before and after thinning) are presented in Table 7-9. Stand structure measurements before and after thinning are presented in Table 7-10 (LANL 2022b).

Table 7-9. The acreage of each treatment unit and the average basal area per acre for those treatment units before and after treatment (pre- and post-treatment, respectively)

Unit	Acres	Stand Density – Trees per acre		Stand Density - Average Basal Area per acre (square feet per acre)	
		Pre-Treatment[a]	Post-Treatment[b]	Pre-Treatment[a]	Post-Treatment[b]
1[c]	1.8	–	–	120	80
2	2.4	72	34	110	70
3[c]	6.9	–	–	145	103
4	6.2	60	40	83	67

[a] Pre-treatment: Summary of plot data collected before the thinning treatment.
[b] Post-treatment: Summary of plot data for trees remaining after the thinning treatment.
[c] Treatments were about to begin, so no trees per acre measurements were collected in Units 1 and 3, only the basal area.

Table 7-10. Summary of forest stand data before and after treatment in Units 2 and 4

Unit	Plot[a]	Average DBH[b] per acre (inches)		Average Tree Height (feet)		Basal Area (square feet per acre)		Trees per acre		Coarse Woody Debris[c] (tons per acre)	
		Pre[d]	Post[e]	Pre	Post	Pre	Post	Pre	Post	Pre	Post[f]
2	2_01	17.2	19.3	64	69	130	70	72	34	5.1	1.0
4	4_01	14.8	16.0	54	55	130	90	106	63	3.0	7.3
4	4_02	20.7	20.7	51	51	40	40	17	17	–[g]	1.3
4	4_03	15.7	18.5	51	62	80	40	57	40	15.6	8.5
	Average	17.1	18.4	52	54	83	67	60	40	9.3	5.7

[a] Plot: Unit number_plot number.
[b] DBH = Diameter at breast height, measured at 4.5 ft on a tree.
[c] Coarse woody debris includes logs, sticks, branches, needles, and masticated biomass.
[d] Pre: Summary of plot data collected before the thinning treatment.
[e] Post: Summary of plot data for trees remaining after the thinning treatment.
[f] Coarse woody debris includes biomass from trees that were masticated on site for Unit 4.
[g] Plot 4_02 did not have pre-treatment coarse woody debris data collected.

The monitoring results for Unit 2 and Unit 4 indicated that the thinning treatment resulted in post-treatment tree densities between 10 and 125 trees per acre, in accordance with the LANL Wildland Fire Mitigation and Forest Health Plan standards.

Coarse woody debris on the forest floor ranged from 3 to 16 tons per acre pre-treatment to 1 to 9 tons per acre post-treatment (Table 7-10). A value of 7 to 13 tons per acre of coarse woody debris maintains soil productivity in the Rocky Mountains region (Graham et al. 1994). The diameter distribution (Figure 7-13) following the treatment contained fewer small trees but a similar overall distribution.

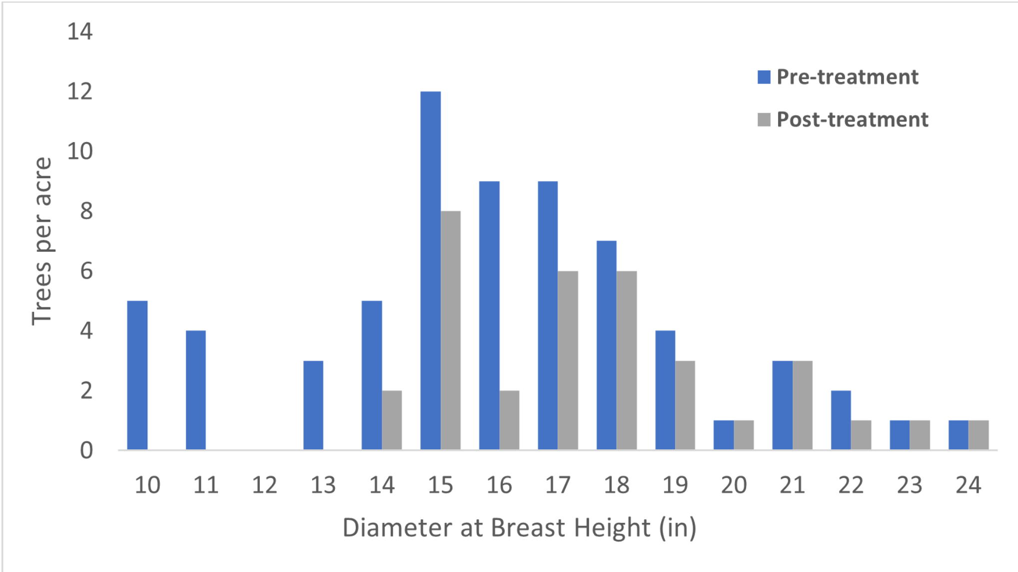


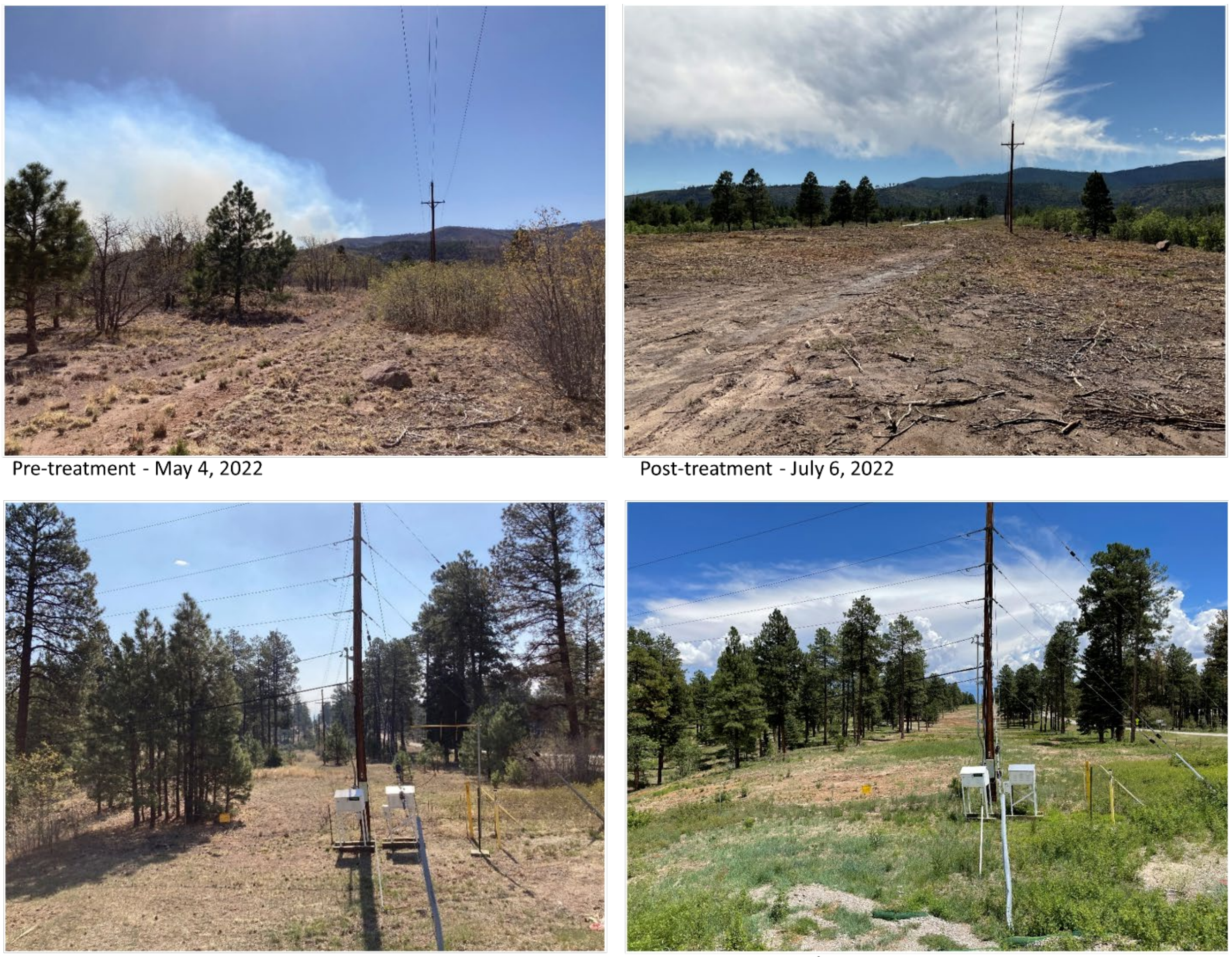
Figure 7-13. The distribution of trees by diameter at breast height (inches) before and after a thinning treatment in Technical Area 16. Blue indicates pre-treatment, and grey indicates post-treatment. The horizontal axis is diameter at breast height (inches) for trees measured in the variable-area forest health monitoring plots, and the vertical axis is the count of those measured trees expanded to trees per acre.

Emergency Fuels Mitigation Activities for the Cerro Pelado Fire

The Cerro Pelado Fire began on Friday, April 22, 2022, approximately 7 miles east of Jemez Springs, New Mexico. Ultimately burning 45,605 acres, the fire came within 3 miles of Los Alamos National Laboratory's southwest boundary. The fire was declared 100 percent contained on June 14, 2022.

In response to the risk of fire spread, we undertook a series of emergency treatments along West Jemez Road and New Mexico State Highway 4 on the western and southern LANL property lines. These emergency treatments consisted of brush and tree removal and mastication to reduce fuel and establish a firebreak.

Before and after photo-monitoring (Figure 7-12, Figure 7-14, and Figure 7-15) and global positioning system surveys of treatment boundaries (Figure 7-16) were used to document and assess these treatments. Soil stability was monitored as part of an emergency storm water pollution prevention plan (LANL 2022c).



Pre-treatment - May 4, 2022 | Post-treatment - July 6, 2022

Pre-treatment - May 4, 2022 | Post-treatment - July 6, 2022

Figure 7-14. Photos taken in the fuel break and utility corridor treatment (top) and fuel break (bottom) along State Route 4, before the treatment (left side) and two after the treatment (right side). Dates of the photos are below each image.

Pre-treatment - May 12, 2022

Post-treatment - July 6, 2022

Pre-treatment - May 11, 2022

Post-treatment - May 14, 2022

Figure 7-15. Photos taken in the utility corridor treatment (top) and evacuation route (bottom) before the treatment (left side) and after the treatment (right side). Dates of the photos are below each image.

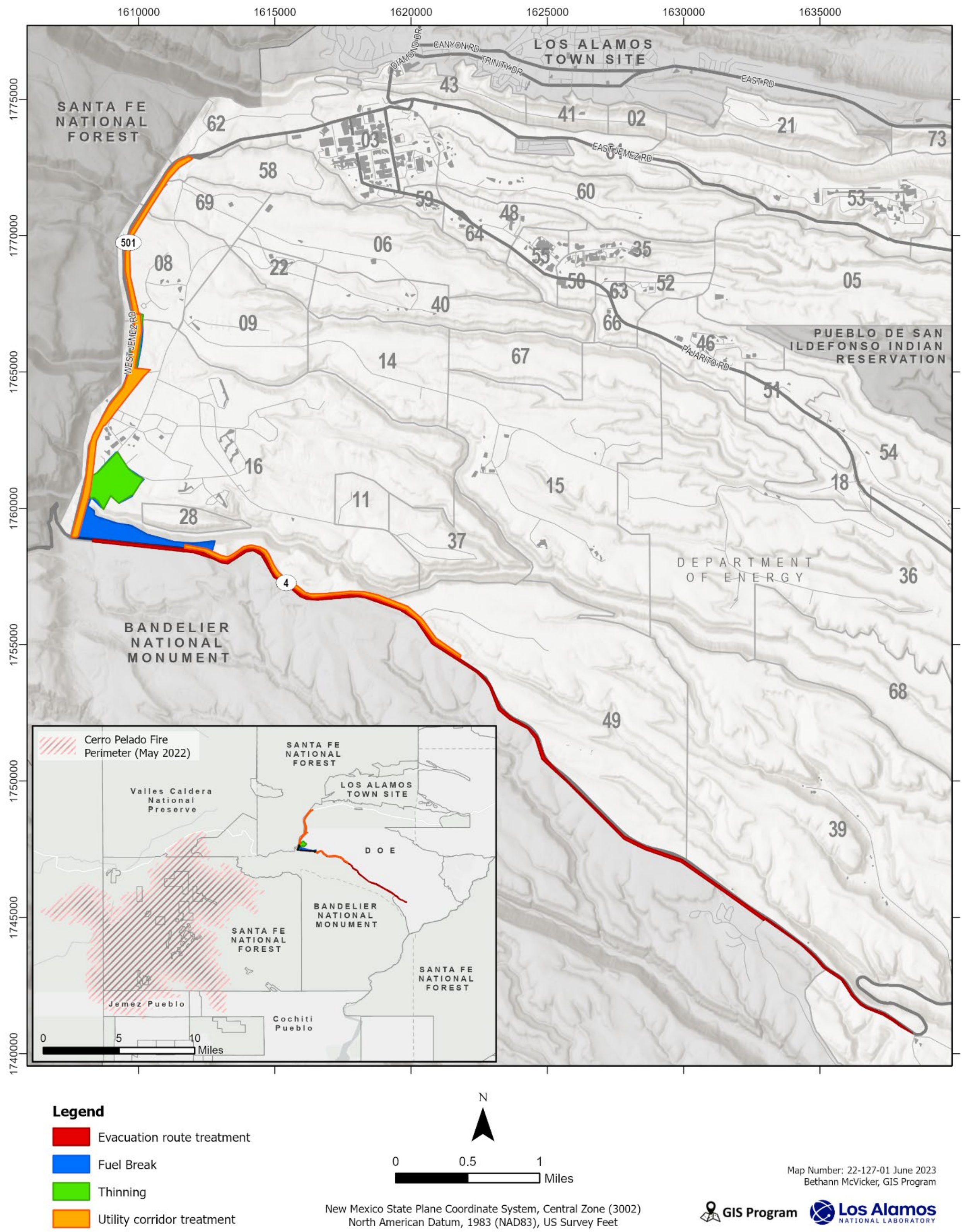


Figure 7-16. Map of the different treatments that occurred in response to the encroaching Cerro Pelado fire, with the fire boundary in the inset. Treatments are divided into the following categories: utility corridor treatment, fuel break, evacuation route treatment, and thinning.

Quality Assurance

The Soil, Foodstuffs, and Biota Program collects samples according to written, standard quality assurance and quality control procedures and protocols. These procedures and protocols are identified in the Laboratory's Implementation of the *Soil, Foodstuffs, and Biota Program, Quality Assurance Project Plan* (EPC-ES-QAPP-001) and in the following Laboratory procedures:

- EPC-ES-GUIDE-015, *General PFAS Sampling Guidance for the Soil, Foodstuffs, and Biota Program*
- EPC-ES-TP-003, *Soil and Vegetation Sampling for the Environmental Surveillance Program*
- EPC-ES-TP-004, *Produce Sampling*
- EPC-ES-TP-005, *Fish Sampling*
- EPC-ES-TP-006, *Soil and Vegetation Sampling at Facility Sites*
- EPC-ES-TP-007, *Road Kill Sampling*
- EPC-ES-TP-008, *Crayfish Sampling*
- EPC-ES-TP-013, *Benthic Macroinvertebrate Sampling*
- EPC-ES-TP-017, *Soil Sampling for Land Transfer and Conveyance and Other Special Projects*
- EPC-ES-TP-035, *Sediment Sampling in Reservoirs and Rivers*
- EPC-ES-TP-201, *Live Trapping of Small Mammals*
- EPC-ES-TP-219, *Managing and Sampling Honeybee Hives*

The Soil, Foodstuffs, and Biota program collects biological samples under approved New Mexico Game and Fish Scientific Collection Permits as well as approved Institutional Animal Care and Use Committee protocols.

These procedures ensure that the collection, processing, and chemical analysis of samples; the validation and verification of data; and the tabulation of analytical results are conducted in a consistent manner from year to year. Locations and samples have unique identifiers to provide chain-of-custody control from the time of collection through analysis and reporting.

The Health Physics program calculates dose to nonhuman biota according to a written quality control procedure: *Calculating Dose to Nonhuman Biota* (EPC-ES-TP-001).

In addition, procedures and protocols for biota dose assessment can be found in the *Technical Project Plan for Biota Dose Assessment* (EPC-ES-TPP-002).

The Biological Resources program collects field data according to written quality control procedures:

- EPC-ES-AP-014, *Institutional Animal Care and Use Committee Operations*
- EPC-ES-TP-203, *Threatened and Endangered Species Surveys*
- EPC-ES-TP-205, *Avian Monitoring*

In addition to these procedures, some parts of our work require the following federal and state permits. These permits are individual permits and not institutional. Personnel who work as wildlife biologists at LANL must have the training and background to be able to obtain such permits. Surveys for federally listed species follow specific protocols set forth by the U.S. Fish and Wildlife Service, and training to these protocols is a prerequisite to obtaining a permit.

- Federal bird banding permits issued by the U.S. Geological Survey's bird banding laboratory
- Federal recovery permits to survey or handle federally listed species issued by the U.S. Fish and Wildlife Service
- State permits for scientific research issued by the New Mexico Department of Game and Fish

The Wildland Fire and Forest Health Program collects and quality checks monitoring data using the following procedure: *Monitoring and Documentation of Forest Management Activities for Los Alamos National Laboratory* (LANL 2023).

Field Sampling Quality Assurance

Overall, quality of field sampling is maintained through the rigorous use of carefully documented procedures, listed in the Quality Assurance section, that govern all aspects of the sample collection program.

Samples are collected under full chain-of-custody procedures to minimize the chance of data transcription errors. Once collected, samples are hand-delivered to the Laboratory's Sample Management Office, where staff ship the samples via express mail directly to an external analytical laboratory under full chain-of-custody control. Sample Management Office personnel track all samples. Upon receipt of data from the analytical laboratory (electronically and hard copy), the completeness of the field sample process and other variables are assessed. A quality assessment document is created, attached to the data packet, and provided in the data package. Field data completeness for sample collection in 2022 was 100 percent.

Water blanks are commonly used within analytical studies to determine whether contamination has been inadvertently introduced into a sample set. In our investigation, water blanks were used to determine whether PFAS contamination was introduced into field samples through carryover from contaminated equipment or experimental procedure. Water blanks for PFAS detection are typically collected during each sampling event. In 2022, a total of seven water blanks for PFAS were collected. One PFAS-free water blank was collected alongside environmental samples at the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15, firing sites, the Los Alamos Canyon weir, the Pajarito Canyon flood-retention structure, and Sandia Canyon; and two PFAS-free water blanks were collected alongside roadkill samples.

Two PFAS-free water blank samples contained detectable PFAS concentrations. In the water blank collected alongside environmental samples at the Dual-Axis Radiographic Hydrodynamic Test Facility at Technical Area 15, perfluorobutanoic acid and perfluoropentanoic acid were observed at 1.73 and 0.681 parts per trillion, respectively. Perfluorobutanoic acid was detected in five soil samples, ranging in concentrations from 0.206 to 0.556 parts per billion. Perfluoropentanoic acid was detected within three soil samples, ranging in concentrations from

0.363 to 0.967 parts per billion, and in one vegetation sample at a concentration of 4.62 parts per billion. Because the compounds observed in the water blank sample are two to three orders of magnitude below the observations in the environmental samples, it is unlikely that the contamination observed in the water blanks would have significantly contributed to the observed concentrations in environmental samples. The other PFAS water blank that contained detectable PFAS was from Pajarito Canyon: 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid was observed at 10.9 parts per trillion; however, 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid was not observed in any of the environmental samples collected from this location.

No PFAS compounds were detected in the water blank samples collected from the firing sites, from Sandia Canyon, or from the two blanks collected alongside the roadkill samples. The PFAS-free water blank sample collected alongside environmental samples at Los Alamos Canyon weir was not analyzed (see description in the Analytical Laboratory Quality Assessment section).

Analytical Laboratory Quality Assessment

In 2022, ALS in Fort Collins, Colorado, closed, and the Soil, Foodstuffs, and Biota program began sending samples to GEL Laboratories LLC in Charleston, South Carolina, for radionuclide and total analyte list analyses.

Vegetation samples from Area G and the Dual-Axis Radiographic Hydrodynamic Test Facility and both vegetation and small mammal samples from the Los Alamos Canyon weir and the Pajarito Canyon flood-retention structure were analyzed for radionuclides on a dry weight basis by GEL. In previous years, ALS analyzed these sample types for radionuclides on an ash weight basis. The difference in basis prevented direct comparison with the regional statistical reference levels and prevented incorporating the 2022 results into trend analyses.

Two samples never arrived at the designated analytical laboratory and were considered lost. The lost samples consisted of a whole-body owl that was targeted for radionuclide and total analyte list analyses at GEL and one deer muscle sample that was targeted for PCB analyses at Cape Fear Analytical LLC in Cape Fear, North Carolina.

One quality control sample of a PFAS-free water blank was not properly logged in when it arrived at GEL. The sample exceeded the turnaround time before it could be analyzed and therefore, no data were received on this sample.

Therefore, in total, we lost analytical results from two environmental samples and one quality control sample in 2022.

References

Aas et al. 2014: C. B. Aas, E. Fuglei, D. Herzke, N. G. Yoccoz, and H. Routti. 2014. "Effects of Body Condition on Tissue Distribution of Perfluoroalkyl Substances (PFASs) in Arctic Fox (Vulpes lagopus)," *Environmental Science and Technology* 48 (19):11654–11661.

Bai and Son 2021: X. Bai and Y. Son. 2021. "Perfluoroalkyl substance (PFAS) in surface water and sediments from two urban watersheds in Nevada, USA," *Science of the Total Environment* 751: https://doi.org/10.1016/j.scitotenv.2020.141622

Banzhaf et al. 2017. S. Banzhaf, M. Filipovic, J. Lewis, C. J. Sparrenbom, and R. Barthel. 2017. “A review of contamination of surface-, ground-, and drinking water in Sweden by perfluoroalkyl and polyfluoroalkyl substances (PFASs),” *Ambio* 46:335–346.

Batty et al. 1990: J. Batty, R. A. Leavitt, N. Biondo, 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 (2):283–290.

Bossi et al. 2015: R. Bossi, M. Dam, and F. Riget. 2015. “Perfluorinated alkyl substances (PFAS) in terrestrial environments in Greenland and Faroe Islands,” *Chemosphere* 129:164–169.

Brusseau et al. 2020: M. L. Brusseau, R. H. Anderson, and B. Guo. 2020. “PFAS concentrations in soils: Background levels versus contaminated sites,” *Science of the Total Environment* 740:140017. https://doi.org/10.1016/j.scitotenv.2020.140017

Bustnes et al. 2010: J. O. Bustnes, B. Moe, D. Herzke, S. Hanssen, and D. Nordstad. 2010. “Strongly increasing blood concentrations of lipid-soluble organochlorines in high arctic common eiders during incubation fast,” *Chemosphere* 79 (3):320–325.

Dalahmeh et al. 2018: D. Dalahmeh, S. Tirgani, A. J. Komakech, C. B., Niwagaba, and L. Ahrens. 2018. “Per- and polyfluoroalkyl substances (PFASs) in water, soil and plants in wetlands and agricultural areas in Kampala, Uganda. *Science of the Total Environment* 2018:660–667.

Dauwe et al. 2005: T. Dauwe, E. Janssens, L. Bervoets, R. Blust, and M. Eens. 2005. “Heavy-metal concentrations in female laying great tits (Parus major) and their clutches,” *Archives of Environmental Contamination and Toxicology*, 49 (2):249–256.

Degenhardt et al. 1996: W. G. Degenhardt, C. W. Painter, and A. H. Price. 1996. *Amphibians and Reptiles of New Mexico*. University of New Mexico Press, Albuquerque, NM.

Dennis et al. 2021: N. M. Dennis, 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.

DeSante et al. 2021: D. F. DeSante, K. M. Burton, D. R. Kaschube, P. Velez, D. Froehlich, and S. Albert. 2021. *MAPS Manual: 2021 Protocol*. The Institute for Bird Populations, Point Reyes Station, CA.

DOE 1979: Department of Energy. 1979. “Final Environmental Impact Statement: Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico,” U.S. Department of Energy, DOE/EIS-0018.

DOE 1995: Department of Energy. 1995. “Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement,” U.S. Department of Energy, DOE/EIS-0228.

DOE 2000: Department of Energy. 2000. “Special Environmental Analysis for the Department of Energy, National Nuclear Security Administration, Actions Taken in Response to the Cerro Grande Fire at Los Alamos National Laboratory,” U.S. Department of Energy Los Alamos Area Office, DOE/SEA-03.DOE 2015: Department of Energy. 2015. “DOE Handbook: Environmental Radiological Effluent Monitoring and Environmental Surveillance,” U.S. Department of Energy handbook DOE-HDBK-1216-2015.

DOE 2015: Department of Energy. 2015. “DOE Handbook: Environmental Radiological Effluent Monitoring and Environmental Surveillance,” U.S. Department of Energy handbook DOE-HDBK-1216-2015.

DOE 2019: Department of Energy. 2019. “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota,” U.S. Department of Energy, DOE-STD-1153-2019.

Fresquez 2011: P. Fresquez. 2011. “Chemical Concentrations in Field Mice 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.

Gadek et al. 2023: C. D. Gadek, M. S. Velardi, E. J. Abeyta. 2023. “2022 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-23-30407.

Galili et al. 2017: T. Galili, A. O‘Callaghan, J. Sidi, and C. Sievert. 2017. “heatmaply: an R package for creating interactive cluster heatmaps for online publishing.” Bioinformatics. doi:10.1093/bioinformatics/btx657.

Ghisi et al. 2019: R. Ghisi, T. Vamerali, and S. Manzetti. 2019: “Accumulation of perfluorinated alkyl substances (PFAS) in agricultural plants: A review,” *Environmental Research*, 169:326–341.

Graham et al. 1994: R. T. Graham, A. E. Harvey, M. F. Jurgensen, T. B. Jain, J. R. Tonn, and D. S. Page-Dumroese. 1994. “Managing coarse woody debris in forests of the Rocky Mountains.” Res. Pap. INT-RP-477. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 13 pp.

Halterman et al. 2015: M. D. Halterman, M. J. Johnson, J. A. Holmes, S. A. Laymon. 2015. “A Natural History Summary and Survey Protocol for the Western Distinct Population Segment of the Yellow-billed Cuckoo: U.S. Fish and Wildlife Techniques and Methods,” 45 pp.

Harris and Elliott 2011: M. L. Harris, and J. E. Elliott. 2011. “Effects of Polychlorinated Biphenyls, Dibenzo-p-Dioxins, and Dibenzofurans, and Polybrominated Diphenyl Ethers in Wild Birds,” in *Environmental Contaminants in Biota Interpreting Tissue Concentrations*, 2nd Edition, Beyer W. N. and J. P. Meador (eds.), CRC Press Boca Raton, FL, 477–528.

Helsel 2012: D. Helsel. 2012. “Comparing Two Groups,” in *Statistics for Censored Environmental Data Using Minitab and R*, 2nd Edition. D. Helsel (ed.), Wiley, Hoboken, NJ, 153–193.

Johnson and Johnson 1985: J. A. Johnson and T. H. Johnson. 1985. "Timber Type Model of Spotted Owl Habitat in Northern New Mexico," New Mexico Department of Game and Fish report, Santa Fe, NM.

Kannan et al. 2002: K. Kannan, S. Corsolini, J. Falandysz, G. Oehme, S. Focardi, and J. Giesy. 2002. "Perflurooctanesulfonate and related fluorinated hydrocarbons in marine mammals, fishes, and birds from coasts of the Baltic and the Mediterranean Seas," *Environmental Science and Technology* 36:3210–3216.

Keller 2015: D. C. Keller. 2015. "Biological assessment for the addition of the western distinct population segment of the Yellow-billed Cuckoo and the New Mexico Meadow Jumping Mouse to the Los Alamos National Laboratory Habitat Management Plan," Los Alamos National Laboratory report LA-UR 15-23445.

LANL 1981: "Environmental Surveillance at Los Alamos during 1980," Los Alamos National Laboratory report LA-8810-ENV.

LANL 2008. "Historical Investigation Report for Upper Sandia Canyon Aggregate Area," Los Alamos National Laboratory report LA-UR-08-1851.

LANL 2016: "2016 Sandia Wetland Performance Report," Los Alamos National Laboratory report LA-UR-17-23076.

LANL 2019: "LANL Wildland Fire Mitigation and Forest Health Plan," Los Alamos National Laboratory report EMD-PLAN-200, Revision 0, LA-UR-19-25122.

LANL 2020: "ECORISK Database," Release 4.2, Los Alamos National Laboratory database, https://www.intellusnm.com/documents/documents.cfm (accessed May 2023).

LANL 2022a: "Threatened and Endangered Species Habitat Management Plan for Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-22-20556.

LANL 2022b: "Forest Monitoring Data Summary for the 2022 Weapons Engineering Tritium Facility (WETF) Area Thinning Project," Los Alamos National Laboratory report LA-UR-22-32466.

LANL 2022c: "Fuels Mitigation NEPA Review: Cerro Pelado," Los Alamos National Laboratory report LA-CP-22-20806.

LANL 2023: "Monitoring and Documentation of Forest Management Activities for Los Alamos National Laboratory," Los Alamos National Laboratory report EPC-TP-01-2022, LA-UR-23-23433.

Los Alamos Scientific Laboratory 1973: "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972," Los Alamos Scientific Laboratory report LA-5184.

Martin et al. 2004: J. W. Martin, 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* 38:373–380.

Martinez 2006: S. Martinez. 2006. "Information Sheet: Material Disposal Area G," Los Alamos National Laboratory report LALP-06-133.

Mayfield and Hansen 1983: D. Mayfield and W. R. Hansen. 1983. “Surface Reconnaissance through 1980 for Radioactivity at Radioactive Waste Disposal Area G at the Los Alamos National Laboratory,” Los Alamos National Laboratory report LA-9556-MS.

McNaughton 2021: M. McNaughton. 2021. “Calculating Dose to Non-Human Biota,” Los Alamos National Laboratory Environmental Stewardship Group procedure EPC-ES-TP-001, R2.

Murphy et al. 2023: S. Murphy, C. Hathcock, T. Espinoza, P. Fresquez, J. Berryhill, J. Stanek, B. Sutter, and S. Gaukler. 2023. “Comparative spatially explicit approach for testing effects of soil chemicals on terrestrial wildlife bioindicator demographics,” Environmental Pollution, 316 https://doi.org/10.1016/j.envpol.2022.120541

N3B 2019: Newport News Nuclear BWXT-Los Alamos (N3B). “2018 Sandia Wetland Performance Report,” Newport News Nuclear BWXT-Los Alamos report EM2019-0091.

Nyhan et al. 2001: J. W. Nyhan, P. R. Fresquez, K. D. Bennett, J. R. Biggs, T. K. Haarmann, D. C. Keller, and H. T. Haagenstad. 2001. “Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999),” Los Alamos National Laboratory report LA-13808-MS.

Ohlendorf and Heinz 2011: H. M. Ohlendorf and G. H. Heinz. 2011. “Selenium in Birds,” in *Beyer, W., and Meador, J. eds. Environmental Contaminants in Biota: Interpreting Tissue Concentrations*, 2nd Edition, W. Beyer and J. Meador (eds.), CRC Press Boca Raton, Florida, 669–701.

Pyle 2022: P. Pyle. 2022. *Identification Guide to North American Birds*, Part 1, 2nd Edition. Slate Creek Press, Forest Knolls, California. 698 pp.

R Core Team 2023: R Core Team. 2023. “R: A language and environment for statistical computing. R Foundation for Statistical Computing,” Vienna, Austria.

Rapport 1998: D. Rapport. 1998. “Defining Ecosystem Health,” in *Ecosystem Health: Principles and Practice*, D. Rapport, R. Costanza, P. R. Epstein, C. Gaudet, and R. Levins (eds.), Blackwell Science, Oxford, England, 18–33.

Robuck et al. 2021: A. R. Robuck, J. P. McCord, M. J. Strynar, M. G. Cantwell, D. N. Wiley, and R. Lohmann. “Tissue-specific distribution of legacy and novel per- and polyfluoroalkyl substances in juvenile seabirds,” *Environmental Science and Technology Letters*, 8:457–462.

Ryti et al. 1998: R. P. Ryti, P. Longmire, D. Broxton, S. Reneau, and E. McDonald. 1998. “Inorganic and Radionuclide Background Date for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory,” Los Alamos National Laboratory report LA-UR-98-4847.

Smith et al. 2002: P. N. Smith, G. P. Cobb, F. M. Harper, B. M. Adair, and S. T. McMurry. 2002. “Comparison of white-footed mice and rice rats as biomonitors of polychlorinated biphenyl and metal contamination,” *Environmental Pollution* 119 (2):261–268. https://doi.org/10.1016/S0269-7491(01)00306-2

Smith and Smith 2012: T. M. Smith and R. L. Smith. 2012. *Elements of Ecology*, 8th Edition, Benjamin Cummings Boston, MA.

Stanek et al. 2022: J. E. Stanek, B. E. Thompson, S. E. Milligan, K. A. Tranquillo, S. M. Fettig, and C. D. Hathcock. 2022. "Does Age, Residency, or Feeding Guild Coupled with a Drought Index Predict Avian Health during Fall Migration?" *Animals*, 12 (4):454. https://doi.org/10.3390/ani12040454

Talmage and Walton 1991: S. S. Talmage and B. T. Walton. 1991. "Small Mammals as Monitors of Environmental Contaminants," in *Reviews of Environmental Contamination and Toxicology: Continuation of Residue Reviews*, G. W. Ware (ed.), Springer New York, NY, 47–145. https://doi.org/10.1007/978-1-4612-3078-6_2

Thompson et al. 2021: B. E. Thompson, J. E. Stanek, C. D. Hathcock, A. A. Sanchez, J. T. Berryhill, and M. A. Wright. 2021. "Status of Federally Listed Threatened and Endangered Species at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-21-30846.

U. S. Environmental Protection Agency 2014: "U.S. Environmental Protection Agency Glossary from the Risk Assessment Portal," http://www.epa.gov/risk_assessment/glossary.htm (accessed May 2015).

U.S. Environmental Protection Agency 2022: "Regional Screening Levels (RSLs) – Generic Tables, Tables as of November," https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables (accessed 13 April 2023).

U.S. Fish and Wildlife Service 2002: "Southwestern willow flycatcher recovery plan," i–ix + 210 pp., Appendices A–O. Albuquerque, NM.

U.S. Fish and Wildlife Service 2012: "Final Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*)," First Revision. U.S. Fish and Wildlife Service. Albuquerque, NM. 413 pp.

U.S. Food and Drug Administration 1987: "CPG Sec. 565.200 Red Meat Adulterated with PCBs," https://www.fda.gov/ICECI/ComplianceManuals/CompliancePolicyGuidanceManual/ucm074589.htm (accessed May 2020).

U.S. Nuclear Regulatory Commission 2019: "Natural Uranium," https://www.nrc.gov/reading-rm/basic-ref/glossary/natural-uranium.html (accessed March 2019).

Van den Berg et al. 2006: M. Van den Berg, 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.

Wysner et al. 2019: T. E. Wysner, 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://doi.org/10.1007/s00114-019-1650-9

Yang et al. 2021: D. Yang, A. Yang, J. Yang, R. Xu, and H. Qiu. (2021). "Unprecedented migratory bird die-off: A citizen-based analysis on the spatiotemporal patterns of mass mortality events in the western United States," *GeoHealth* 5 (4), e2021GH000395. https://doi.org/10.1029/2021GH000395

Chapter 8: Public Dose and Risk Assessment

U.S. Department of Energy regulations limit the total annual radiological dose to any member of the public from Los Alamos National Laboratory (LANL or the Laboratory) operations to 100 millirem. Furthermore, doses must be as low as reasonably achievable. The annual dose received by any member of the public from airborne emissions of radionuclides is limited by Clean Air Act regulations to 10 millirem.

The objective of this chapter is to use environmental sampling data collected from air, water, soil, and foodstuffs to answer the question, "What are the potential doses and risks to the public from the Laboratory's operations?" All known radionuclides released in significant quantities from LANL are reported and used in dose calculations. The assessments show that during 2022 all doses to the public were far below all regulatory limits and guidance and that the public is well protected. Radiological doses to the public from Laboratory operations are less than 1 millirem per year, and health risks are indistinguishable from zero.

Introduction

In this chapter, dose and risk from radiological and chemical sources are assessed to ensure that the public is protected and to demonstrate compliance with federal regulations and U.S. Department of Energy (DOE) orders. The data reported here and in the previous chapters are considered in the context of public exposure, using standard methods to calculate the potential effects of radiological dose and risk. These methods do not include tribal-specific exposure scenarios. The results are compared with regulatory limits and international standards.

Radiological Materials

Overview of Radiological Dose

Radiological dose is the primary measure of harm from radiation. We calculate doses using the standard DOE and U.S. Environmental Protection Agency methods (DOE 2020, DOE 2022, U.S. Environmental Protection Agency 2020). In this chapter, we assess doses to the public. Doses to plants and animals are assessed in Chapter 7.

DOE regulations limit the total annual dose to any member of the public from Laboratory operations to 100 millirem. Furthermore, doses must be as low as reasonably achievable (LANL 2020). The annual dose received by any member of the public from airborne emissions of radionuclides is limited to 10 millirem by the National Emission Standards for Hazardous Air Pollutants Other Than Radon From Department of Energy Facilities, Title 40, Part 61, Subpart H, of the Code of Federal Regulations. The annual dose from community drinking water supplies is limited under the Safe Drinking Water Act to 4 millirem (National Primary Drinking Water Regulations, Title 40 Part 141 of the Code of Federal Regulations).

To contextualize these limits, the dose from natural background and from medical and dental procedures is about 800 millirem per year (see Figure 8-1). In contrast, doses from Laboratory operations are typically less than 1 millirem per year. The origins and reasons for the Los Alamos County background dose are discussed briefly in the section Dose from Naturally Occurring Radiation and in detail in the paper by Gillis et al. (2014).

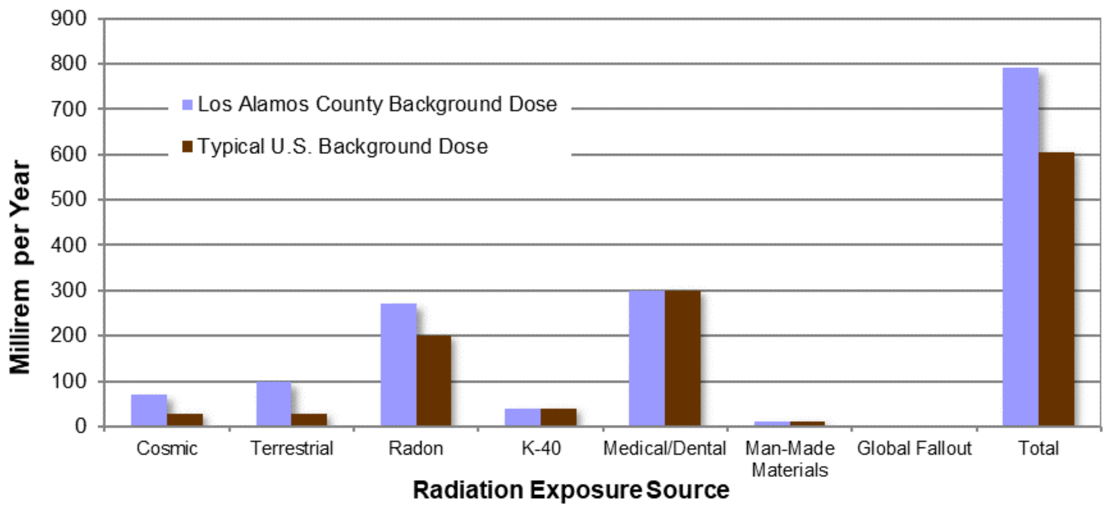


Figure 8-1. The average Los Alamos County radiation background dose compared with average U.S. radiation background dose (Gillis et al. 2014). (K-40 = Potassium-40)

Overview of Exposure Pathways

Potential doses to the public from radionuclides associated with Laboratory operations are calculated by evaluating all exposure pathways. Total dose is the sum of three principal exposure pathways: direct-penetrating (photon or neutron) radiation, inhalation of airborne radioactive particles, and ingestion of radionuclides in water or food.

Direct-Penetrating Radiation

We monitor direct-penetrating radiation from photons and neutrons at 85 locations in and around the Laboratory (see Chapter 4). Direct-penetrating radiation from Laboratory sources contributes to a measurable dose only within about 1 kilometer of the source. At distances of more than 1 kilometer, dispersion, scattering, and absorption of the photons and neutrons attenuate the dose to much less than 0.1 millirem per year, which cannot be distinguished from natural background radiation. The only measurable above-background doses from direct-penetrating radiation come from Technical Area 53 and Technical Area 54, as reported in Chapter 4.

Inhalation

At distances of more than 1 kilometer from Laboratory sources, any dose related to current Laboratory operations is almost entirely from people who inhale airborne radioactive emissions. Whenever possible, we calculate doses using the airborne radioactivity levels measured by the environmental air-sampling network reported in Chapter 4 (the Ambient Air Sampling for Radionuclides section). Where local levels of airborne radioactivity are too small to measure or cannot be measured by the environmental air-monitoring station methods, doses are calculated using a model called Clean Air Act Assessment Package-1988, PC Version 4.1 (CAP88) (U.S. Environmental Protection Agency 2013, 2020). CAP88 is an atmospheric-dispersion and dose-calculation computer code that combines stack emissions data with meteorological data to calculate dose.

Some of the radionuclide emissions from Technical Area 53 are short-lived and cannot be measured by the environmental air-monitoring stations. These emissions are measured at the stacks as reported in Chapter 4, Exhaust Stack Sampling for Radionuclides, and the resulting estimated doses are calculated with CAP88.

The air-pathway dose assessment is described in detail in an annual air emissions report (Fuehne and Lattin 2023) and in Chapter 4.

Ingestion

Exposure through ingestion occurs when people consume liquids and food that contain radionuclides. The ingestion pathway includes drinking local water or beverages prepared with local water, eating locally grown food, and eating meat from either domesticated or hunted animals that eat local vegetation or drink local water. Measurements from groundwater are reported in Chapter 5, measurements from surface water and sediment are reported in Chapter 6, and measurements from soil, plants, and animals are reported in Chapter 7 and here.

Dose from Naturally Occurring Radiation

In Los Alamos County, naturally occurring sources of radioactivity include cosmic rays, direct-penetrating radiation from terrestrial sources, radon gas, and elements that occur naturally inside the human body, such as potassium-40 (see Figure 8-1). Annual doses from cosmic radiation range from 50 millirem at lower elevations near the Rio Grande to about 90 millirem in the higher elevations west of Los Alamos (Bouville and Lowder 1988, Gillis et al. 2014). Annual background doses from external gamma radiation (from natural terrestrial sources such as uranium and thorium and their decay products) range from about 50 millirem to 150 millirem (DOE 2012).

The inhalation of naturally occurring radon and its decay products constitutes a large proportion of the annual dose for members of the public. Nationwide, the average annual dose from radon is about 200 millirem to 300 millirem (National Council on Radiation Protection 1987). In Los Alamos County, the average residential radon concentration results in an annual dose of about 300 millirem (Whicker 2009).

An additional 30 millirem per year results from naturally occurring radioactive materials in the body, such as potassium-40, which is present in all food and living cells.

Human-made sources of radiation also raise the total average annual background dose (Gillis et al. 2014). Members of the U.S. population receive an average annual dose of 300 millirem from medical and dental uses of radiation (National Council on Radiation Protection 2009). Another 10 millirem per year comes from manufactured products, such as stone or adobe walls.

In total, the average annual dose from sources other than Laboratory operations is about 800 millirem for a typical Los Alamos County resident. Figure 8-1 compares the average radiation background in Los Alamos County with the average background dose in the United States.

Generally, any additional dose of less than 0.1 millirem per year cannot be distinguished from the dose generated by background levels of radiation.

Dose from Water

We report measurements from water in Chapters 5 and 6. Local drinking water contains no measurable radioactivity from current or historical Laboratory operations. For further information regarding Los Alamos County drinking water quality, refer to the Los Alamos Department of Public Utilities 2022 Annual Drinking Water Quality Report (Los Alamos County 2023). Furthermore, dose from water does not include surface water because it is not a source of drinking water in Los Alamos County. The dose pathway from surface water to humans is through foodstuffs, which are discussed in the following sections.

Dose from Foodstuffs

Monitoring Network

The Soil, Foodstuffs, and Biota program monitors constituents in a wide variety of foodstuffs to determine whether Laboratory operations are affecting human health via the food chain. We collect foodstuffs samples once every 3 years and most recently in 2022. We define foodstuffs as all types of material that people may consume, including cultivated or native fruits and vegetables and animal products such as eggs, milk, honey, meat from domestic or wild animals, and fish. We use the word “crops” to refer to cultivated or native vegetative material.

In general, we collect foodstuffs from sites on the Laboratory, from communities surrounding the Laboratory (perimeter locations), from areas downstream of the Laboratory that are irrigated with Rio Grande water, and from background locations that are more than 9 miles from the Laboratory and represent worldwide fallout or natural levels. In 2022, we collected 50 crop samples, which included 24 different commodities (apples—both ordinary and crab, apricots, cherries, corn, cucumbers, grapes, green chile, lamb’s quarter, manzanita, onions, peaches, pears, pie cherries, pinto beans, plums, pumpkins, purslane, rhubarb, shuputah, tomatoes, watermelons, yellow squash, and zucchini). Samples were collected from the Laboratory; from gardens and farms located in Los Alamos townsite, White Rock/Pajarito Acres, Pueblo de San Ildefonso (perimeter locations), Pueblo de Cochiti (downstream of LANL); and from regional background locations (Figure 8-2). We collected chicken eggs from various background locations; from Cochiti Pueblo (downstream of LANL); and from perimeter locations, such as Los Alamos townsite, White Rock townsite, and Pueblo de San Ildefonso. We also collected milk, honey, and tea from select locations. Additionally, we collected deer and elk samples on an annual basis, primarily as roadkill or hunter donations; detailed results regarding deer and elk samples can be found in Chapter 7.

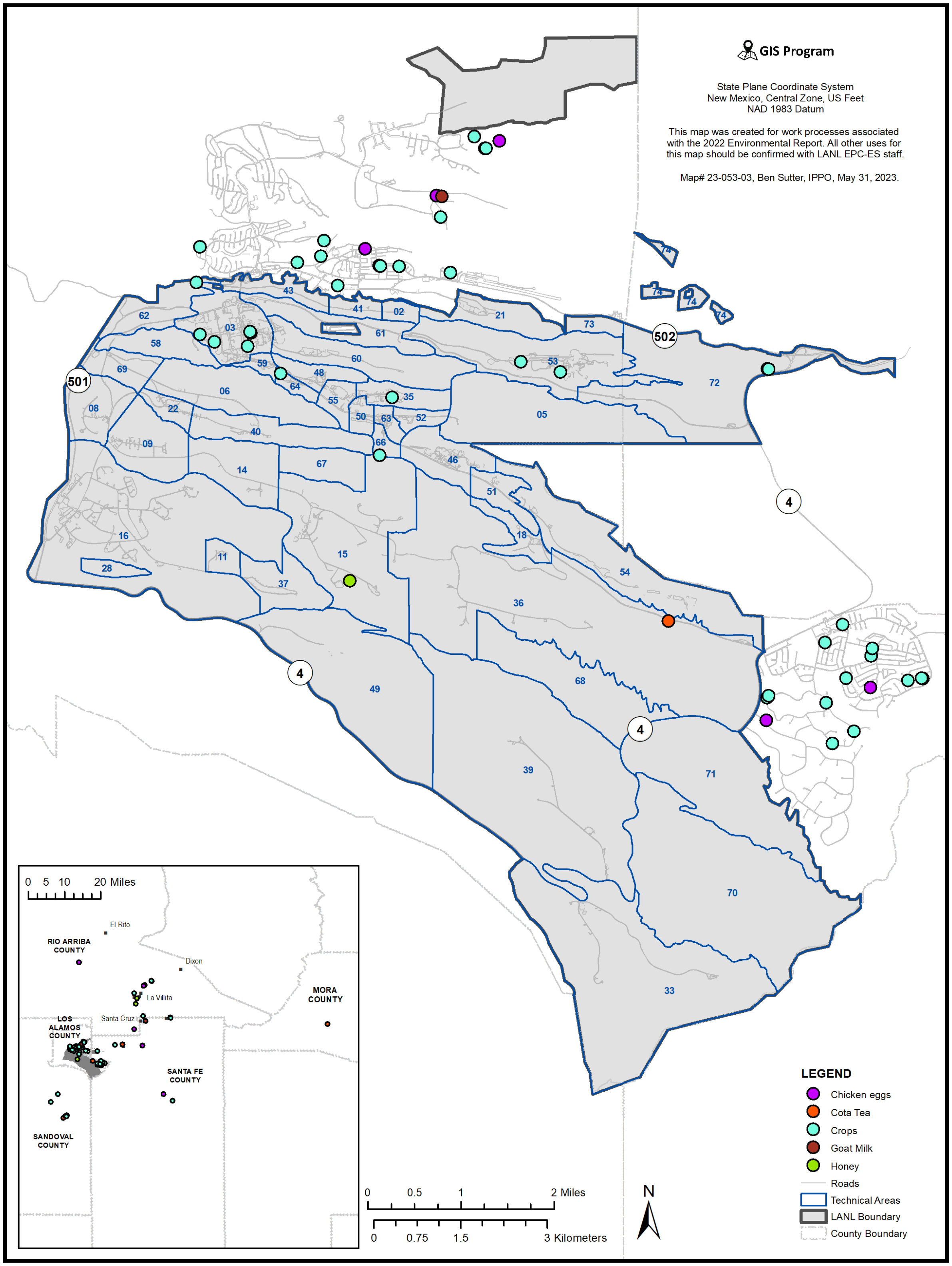


Figure 8-2. Locations of foodstuffs samples collected around Los Alamos National Laboratory, from surrounding communities, and from background locations in 2022.

Methods and Analyses

We collected approximately 2–3 pounds of crops per sample and rinsed them thoroughly with municipal tap water. We placed crop samples into a zippered plastic bag, and eggs, milk, honey, and brewed tea samples into amber-colored glass jars and polyethylene sample bottles. The samples were labeled, sealed with chain-of-custody tape, placed on ice, and submitted to the Laboratory's Sample Management Office. All samples were shipped under full chain of custody to ALS Laboratory, Fort Collins, Colorado, or GEL Laboratories, Charleston, South Carolina, for analyses. Samples were analyzed for radionuclides (americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, tritium, uranium-234, uranium-235/236, and uranium-238), inorganic elements (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc) and per- and polyfluoroalkyl substances (PFAS). Milk and eggs were also analyzed for polychlorinated biphenyls (PCBs) congeners at Cape Fear Laboratory, Wilmington, North Carolina.

Sample results for radionuclides, inorganic elements, PFAS compounds, or PCBs in foodstuffs were compared with the regional statistical reference level for that constituent. The regional statistical reference level is the level below which 99 percent of the results fell for samples collected at regional background locations during the past 10 years (calculated from the mean plus three standard deviations). For crops, the regional statistical reference level for a constituent is calculated using all crops combined, not on a crop-specific basis. Total PCB concentrations in milk and eggs were also compared with U.S. Food and Drug Administration's Tolerances for Polychlorinated Biphenyls (PCBs), Title 21 Part 190 Section 109.30 of the Code of Federal Regulations.

Radionuclide Monitoring in Foodstuffs

Most radionuclide activities in crops were either below the minimum detectable activity or below the regional statistical reference level (Table S8-1). Cesium-137 was detected slightly above the crop regional statistical reference level of 0.716 picocuries per gram for ashed samples in purslane from LANL and in apples from White Rock at 1.06 and 0.958 picocuries per gram, respectively (Table S8-1). Additionally, strontium-90 was detected above the crop regional statistical reference level of 2.76 picocuries per gram in ashed samples in purslane from LANL and in onions from White Rock at 4.84 and 3.98 picocuries per gram, respectively (Table S8-1). When these data are adjusted for the ratios of ash-to-fresh weight and plant-to-soil concentrations, they are consistent with activities expected from global fallout and would cause ingestion doses of less than 0.01 mrem/year.

The majority of radionuclides in chicken eggs was not detected. Tritium was detected in an egg sample collected from Los Alamos townsite. The detected level was below the regional statistical reference level for tritium (Table S8-2). The goat milk sample collected from Los Alamos townsite did not contain detectable radionuclides (Table S8-2). The dose that would result from ingesting these foodstuffs is less than 0.001 mrem/year.

The honey sample collected at the Dual Axis Radiographic Hydrodynamic Test Facility at LANL did not contain detectable levels of americium-241, cesium-137, plutonium-238, plutonium-239/240, or strontium-90 (Table S8-3). Tritium was detected at 0.62 picocuries per milliliter, which is below the regional statistical reference level. Uranium-234, uranium-235, and uranium-238 were detected at 1.09, 0.06, and 1.82 picocuries per gram for ashed samples, respectively (Table S8-3). These isotopic ratios indicate that the uranium in the honey was depleted uranium from Laboratory operations. This honey is not available to the public; however, if it were ingested, the dose would be 0.01 mrem per kilogram.

Cota, a native plant that can be used to make tea, was collected from LANL, Cochiti Pueblo, Pueblo de San Ildefonso, and background locations. Samples of tea made from cota did not contain detectable levels of americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, or tritium. The cota collected from LANL, Cochiti Pueblo, and background locations was brewed with municipal water from White Rock, New Mexico, to make tea, whereas local well water was used to brew tea at Pueblo de San Ildefonso. The activities of uranium isotopes were higher in tea brewed at Pueblo de San Ildefonso (Table S8-3). Uranium activities observed in this tea are within the ranges of uranium activities observed between 2011 and 2022 in water samples from the Black Mesa monitoring well. The source of the uranium in the groundwater at the Black Mesa well is underground uranium deposits in the Espanola basin (McLemore et al. 2011) and not from Laboratory operations.

Dose from Food

DOE Standard 1196 (DOE 2022) is used to calculate the dose from ingestion of locally grown food.

Overall, the data for foodstuffs demonstrate that the individual dose from eating local or regional foodstuffs, including crops, eggs, milk, tea, deer, and elk, is less than 0.01 millirem per year. Radionuclide concentrations in publicly available food are consistent with global fallout or naturally occurring material, and any contributions from the Laboratory are too small to measure. Therefore, the conclusion is that the ingestion dose from LANL operations is generally less than 0.01 millirem per year and is consistent with zero.

Dose from Soil

Radioactive materials in soil can contribute to dose by any of the exposure pathways discussed above. The potential doses are calculated using the RESRAD family of codes (https://resrad.evs.anl.gov/).

In 2021, soil and vegetation samples were collected from 36 locations (LANL 2022). The results, which are similar to previous years, are reported in Chapter 7. The only offsite location with radionuclide concentrations above background was in Acid Canyon, where americium-241, plutonium-239, and strontium-90 concentrations exceeded the regional statistical reference levels. Potential doses in Acid Canyon are less than 0.1 millirem per year (McNaughton et al. 2018).

All-Pathway Radiological Dose Results

The objective of this section is to calculate the all-pathway doses to the public from Laboratory operations.

As required by DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, we calculated doses from the Laboratory to the following members of the public: total human population within 80 kilometers (50 miles) of the Laboratory and hypothetical "maximally exposed individual."

To identify the location of and the total dose to the hypothetical maximally exposed individual, we considered air-pathway dose, onsite dose at publicly accessible locations, other publicly accessible locations with measurable doses, and offsite dose.

Collective Dose to the Population within 80 Kilometers

The collective population dose from Laboratory operations is the sum of the doses for each member of the public within an 80-kilometer radius of the Laboratory (DOE 2020). Outside of Los Alamos County, the doses are too small to measure directly, so the collective dose is calculated by modeling the transport of radioactive air emissions using CAP88. As discussed in the sections "Dose from Water" and "Dose from Soil and Foodstuffs," the dose from the other pathways is consistent with zero.

The 2022 collective population dose to people who live within 80 kilometers of the Laboratory was 0.12 person-rem—approximately 70 percent from tritium, presumed to be oxidized—and 30 percent from short-lived activation products (Fuehne and Lattin 2023). This dose is less than 0.001 millirem per person and is much less than the background doses shown in Figure 8-1.

Collective population doses for recent years are shown in Figure 8-3. The trend line for the past 10 years shows a general decrease, which is the result of improved engineering controls at the Los Alamos Neutron Science Center and the tritium facilities.

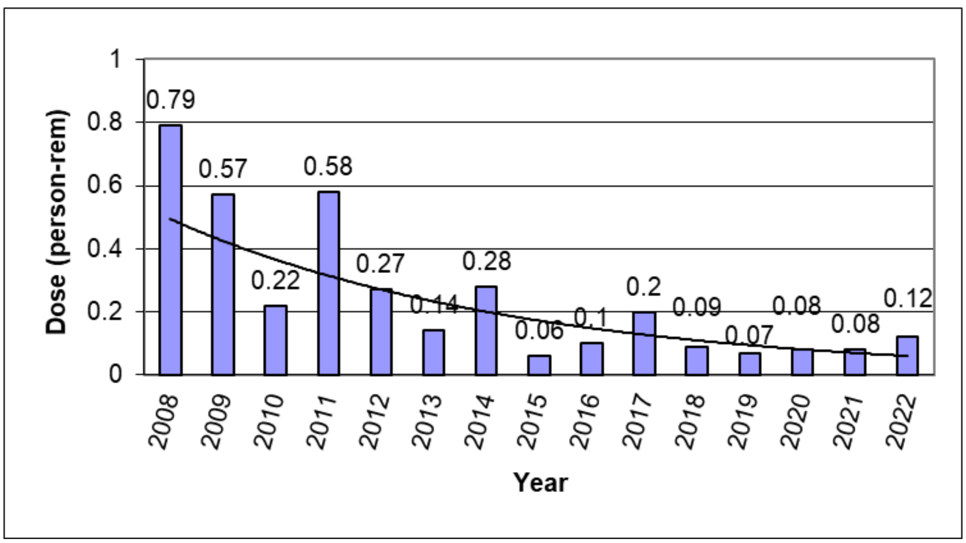


Figure 8-3. Annual collective dose (person-rem) to the population within 80 kilometers of the Laboratory.

Dose to the Maximally Exposed Individual

The "maximally exposed individual" is a hypothetical member of the public who receives the greatest possible dose from Laboratory operations (DOE 2020). We consider all exposure pathways that could cause a dose and all publicly accessible locations, both within the Laboratory boundary (on site) and outside the boundary (off site).

Maximally Exposed Individual Offsite Dose

The air-pathway dose calculations are described in the annual air emissions report (Fuehne and Lattin 2023). In 2022, the offsite location of the hypothetical maximally exposed individual was at 95 Entrada Drive, close to environmental air-monitoring station 396 (Chapter 4, Figure 4-1). The total offsite dose for the maximally exposed individual during 2022 was 0.45 millirem (Fuehne and Lattin 2023).

Contributions to this annual dose were from short-lived activation products from the Los Alamos Neutron Science Center (0.05 millirem), other stack emissions (0.002 millirem), environmental measurements at the environmental air-monitoring station (0.10 millirem), and the potential dose contribution from unmonitored stacks (0.29 millirem).

Comparison with Previous Years

The annual maximally exposed individual doses are shown in Figure 8-4. The general downward trend is the result of improved engineering controls.

As described in previous annual site environmental reports, the 6.46-millirem dose in 2005 resulted from a leak at Technical Area 53, and the 3.53-millirem dose in 2011 was from the remediation of Material Disposal Area B.

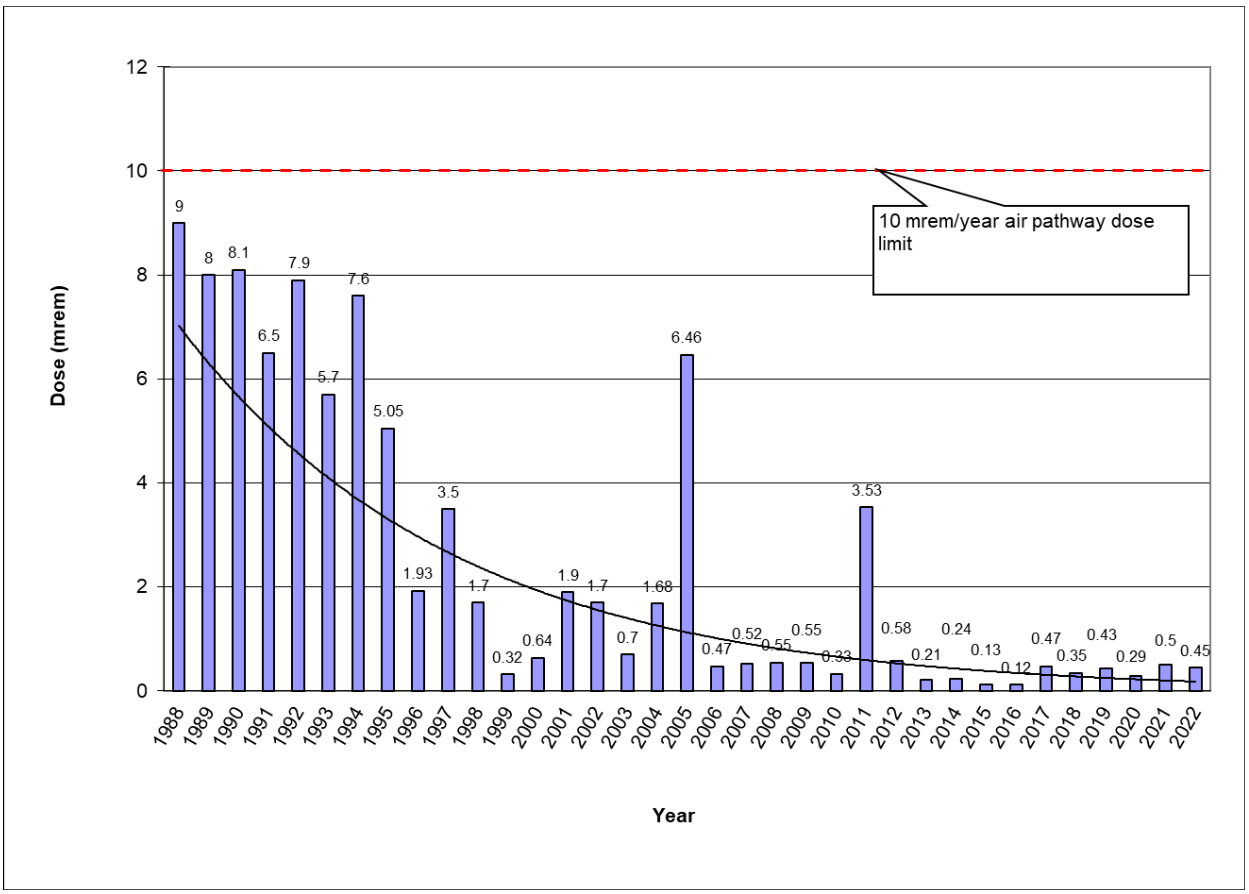


Figure 8-4. Annual maximally exposed individual dose.

Maximally Exposed Individual Onsite Dose

The onsite locations where a member of the public could receive a measurable dose are on or near publicly accessible roads (McNaughton et al. 2013). The only location with a measurable Laboratory-generated dose is at East Jemez Road near Technical Area 53. As reported in Chapter 4 (the Monitoring for Gamma and Neutron Direct-Penetrating Radiation section), at this location in 2022, the neutron dose was 0.64 millirem, and the gamma dose was 0.036 millirem, for a total of approximately 0.7 millirem. The contribution from stack emissions was less than 0.01 millirem. These doses would be received by a hypothetical individual who stayed at this location 24 hours per day for 365 days per year. However, members of the public, such as joggers, bus drivers, or cyclists, spend no more than 1/40 of their time at this location (National Council on Radiation Protection 2005). Therefore, the onsite dose for a maximally exposed individual is 0.7/40 ≈ 0.02 millirem, which is less than the offsite dose for a maximally exposed individual described in the previous section.

Other Locations with Measurable Dose

As reported in Chapter 4, neutron dose was measured in Cañada del Buey, north of Technical Area 54, Area G, and near the Pueblo de San Ildefonso boundary. Transuranic waste at Area G emits neutrons while awaiting shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. After subtracting background, the measured neutron dose in Cañada del Buey in 2022 was 4 millirem. After applying the standard factor of 1/20 for occasional occupancy (National Council on Radiation Protection 2005), the individual neutron dose in 2022 was 4/20 ≈ 0.2 millirem. The contribution from Laboratory stack emissions was less than 0.001 millirem. Within the boundaries of Area G, the average air concentrations of plutonium and americium were each approximately 1 attocurie per cubic meter (Chapter 4, Table 4-4), and the average uranium-234, -235, and -238 concentrations were 13, 1, and 12 attocuries per cubic meter, respectively (Chapter 4, Table 4-5). Using the dose conversion factors from DOE Standard 1196 (DOE 2022) and assuming 1/20 occupancy, the annual dose near Area G was less than 0.01 millirem from inhalation of LANL radioactive material. Thus, in 2022, the total dose in Cañada del Buey from Laboratory operations at Area G was 0.2 millirem.

Maximally Exposed Individual Summary

At the offsite location for the maximally exposed individual, 95 Entrada Drive, the direct-penetrating radiation and ingestion doses are consistent with zero, so the largest all-pathway dose for 2022 was the same as the air-pathway dose of 0.45 millirem.

The dose of 0.45 millirem in 2022 is far below the 10 millirem annual air-pathway limit in the National Emission Standards for Hazardous Air Pollutants Other Than Radon From Department of Energy Facilities, Title 40, Part 61, Subpart H of the Code of Federal Regulations, and the 100 millirem all pathway DOE limit (DOE 2020). The dose for the maximally exposed individual is less than 0.1 percent of the average U.S. background radiation dose shown in Figure 8-1.

Conclusion

The doses to the public from Laboratory operations are summarized in Table 8-1. Doses are below all regulations and standards.

Table 8-1. LANL Radiological Doses for Calendar Year 2022

Pathway	Dose to Maximally Exposed Individual (millirems per year)	Percentage of DOE 100-millirem-per-year Limit	Estimated Population Dose (person-rem)	Number of People within 80 kilometers	Estimated Background Population Dose (person-rem)
Air	0.45	0.45%	0.12	n/a[a]	n/a
Water	<0.1	<0.1%	0	n/a	n/a
Other pathways (foodstuffs, soil, etc.)	<0.1	<0.1%	0	n/a	n/a
All pathways	0.45	0.45%	0.12	~343,000	~268,000[b]

[a] n/a = Not applicable. Background population dose is not calculated for individual exposure pathways.
[b] Background population dose is equal to the number of people multiplied by the dose per person based on 780 millirem per person, as shown in Figure 8-1.

Nonradiological Materials

This section summarizes the potential human health risk from nonradiological materials released from the Laboratory in 2022. Air emissions are reported in Chapters 2 and 4; groundwater is reported in Chapter 5; surface water and sediment are reported in Chapter 6; and soil, plants, and animals are reported in Chapter 7. Foodstuffs are reported earlier in this chapter and in the following sections. Please see the monitoring network and methods and analyses descriptions for foodstuffs monitoring in the section "Dose from Foodstuffs" earlier in this chapter. The results from all chapters are summarized as follows.

Results Summary

Air

The data reported in Chapters 2 and 4 show that in general, the Los Alamos County air quality is good and meets all applicable state and federal air quality standards. The Laboratory's emissions of regulated pollutants are below the amounts allowed in LANL's Title V Operating Permit. There are no measurable health effects to the public from Laboratory air emissions.

Groundwater

Groundwater data are reported in Chapter 5.

Los Alamos County monitors its water supply in compliance with the Safe Drinking Water Act. We analyzed additional samples from Los Alamos County water supply wells in 2022. No water supply wells showed detections of Laboratory-related constituents above drinking water standards. The drinking water supply meets New Mexico Environment Department and U.S. Environmental Protection Agency drinking water standards (Los Alamos County 2023).

Additional supplemental water sampling was conducted in the City of Santa Fe's Buckman Well Field. No Laboratory-related constituents were detected.

Within Laboratory boundaries, hexavalent chromium from the Laboratory has been detected above the New Mexico groundwater standard (50 micrograms per liter) in the regional aquifer below Mortandad Canyon. As described in Chapter 5, the Laboratory has begun interim measures to control migration of this chromium plume.

Los Alamos County drinking water contains 5 micrograms per liter of naturally occurring chromium unrelated to the Laboratory (Los Alamos County 2023).

Surface Water and Sediment

The concentrations of chemicals in surface water and sediment are reported in Chapter 6. The sediment data verify the conceptual model that, compared with previous deposits, movement and addition of sediment from repeated flood events results in lower concentrations of Laboratory-related constituents in newer sediment deposits. The data also show that the human health risk assessments in the canyon investigation reports (see Chapter 6) represent an upper bound of potential risks. Human exposure scenarios were discussed in the investigation reports. The conclusions in the investigation reports—that there were no human health risks—remain accurate because the constituent concentrations are decreasing with time.

In Chapter 6, we compared unfiltered storm water concentrations with drinking water standards as screening levels. However, storm water is not a drinking water source and, therefore, is not a significant pathway to human exposure. The plant and animal measurements reported in Chapters 7 and 8 confirm no significant uptake into the food chain.

Chapter 6 presents data for polychlorinated biphenyls (PCBs) in the surface water of the Pajarito Plateau. The foodstuffs that could use this water are primarily terrestrial animals, such as deer and elk. The data reported in Chapter 7 show that the concentrations of PCBs in deer and elk are far below the human health screening values and are not associated with adverse human-health effects.

The only aquatic animals that may be influenced by surface water runoff from the Laboratory and that are eaten by people are in the Rio Grande and in the Cochiti Reservoir. In the Rio Grande, PCB concentrations in aquatic animals are similar upstream and downstream of LANL influence (LANL 2022). There is no detectable contribution from the Laboratory to PCB concentrations in aquatic animals in the Rio Grande.

We conclude that there is no measurable risk to the public from exposure to surface water and sediment that results from either current or legacy Laboratory operations.

Inorganic Element Monitoring in Foodstuffs

The majority of inorganic element concentrations in crops was below the regional statistical reference levels. Two samples (pie cherries from Los Alamos and White Rock townsites) were analyzed for inorganic elements on a dry-weight basis by GEL, whereas the remaining samples were analyzed on fresh-weight basis. The difference in basis prevented direct comparisons of the pie-cherry results with the regional statistical reference levels; see Table S8-4 for sample results.

Of the remaining 48 crop samples examined in 2022, 7 samples had concentrations of one or more of the examined elements (antimony, chromium, cobalt, copper, lead, nickel, or zinc) that exceeded the regional statistical reference level. Concentrations above the regional statistical reference levels were observed in apples (both ordinary and crab), apricots, corn, peaches, and pinto beans (Table S8-4).

Antimony was above the regional statistical reference level in six of the seven samples, with concentrations that ranged from 1.64 to 4.68 milligrams per kilogram (Table S8-4). Antimony is a metalloid naturally found within the earth's crust primarily as the mineral stibnite and is used in multiple industrial and commercial settings, including in semiconductors, tracer bullets, cable sheathing, and lead-antimony batteries (Ashley et al. 2003, Anderson 2012, Ettler et al. 2010). The regional statistical reference level for antimony is 1.49 milligrams per kilogram.

Of 11 apricot trees sampled in 2022, 4 were located on LANL property. Of these, one tree (located at Technical Area 35) had levels of chromium, cobalt, copper, lead, nickel, and zinc at 82, 17, 720, 84, 700, and 1,500 milligrams per kilogram, respectively, which exceeded their respective regional statistical reference level (Table S8-4). Regional statistical levels for these elements are as follows (represented as milligrams per kilogram): chromium 1.14, cobalt 0.664, copper 26.4, lead 2.07, nickel 4.48, and zinc 105.

Chromium, cobalt, copper, nickel, and zinc are all trace elements required by the human body; however, trace elements can become hazardous if ingested at sufficiently high concentrations. The ingestion of lead is not recommended at any level (Angelova et al. 2014, National Research Council 1989). According to Goldhaber (2003), the highest recommended rates for daily copper and zinc intake that pose no risk to almost all individuals are copper at 10 milligrams per day and zinc at 40 milligrams per day.

Apricot trees acquire water through their roots and may uptake minerals and metals that are contained in this water. These elements can then be partitioned into growing tissue, including fruits (Amer et al. 2019, Baltrėnaitė et al. 2012, Mawari et al. 2022). Apricot trees usually have shallow root systems reaching a depth of no more than seven feet and extending no more than 40 feet, which may suggest that the tree is accumulating the minerals and metals from relatively shallow soil depths in the area (Ruiz-Sánchez et al. 2005, Ziton 2021). The location of the apricot tree at Technical Area 35 was visually examined for surface soil contamination, and no anomalies were noted. However, it was noted that the tree was in a drainage ditch that funnels water from multiple buildings and parking lots over the tree's root system.

The majority of inorganic elements observed in chicken eggs was not detected, and all detectable concentrations were below regional statistical reference levels (Table S8-5). In goat milk collected from Los Alamos townsite, the majority of inorganic elements was observed below the regional statistical reference level. Antimony, selenium, and zinc were observed at 33.1, 26.4, and 6,360 micrograms per liter, which exceeded the regional statistical reference levels of 22.3, 21.5, and 5,275 micrograms per liter, respectively (Table S8-5). The regional statistical reference levels for goat milk are based on two samples, and thus more data are needed for robust comparisons.

The majority of inorganic elements observed in honey were not detected, and all detectable concentrations were below regional statistical reference levels (Table S8-6). Several inorganic elements were not detected in cota tea (Table S8-6). Because only one background sample has been collected, regional statistical reference levels could not be calculated; however, the detection patterns and concentrations of elements were similar in cota tea across locations (Table S8-6). Additionally, inorganic element levels were well below the drinking water standards in the National Primary Drinking Water Regulations, Title 40, Part 141 of the Code of Federal Regulations.

PCB Monitoring in Foodstuffs

PCBs were analyzed in animal products, including chicken eggs and goat milk. PCBs were not detected in chicken eggs collected from Pueblo de San Ildefonso, Cochiti Pueblo, or from one of the Los Alamos townsite locations (Table S8-7). PCBs were detected in seven perimeter egg samples, with the highest observation of 0.307 milligram per kilogram, which exceeded the regional statistical reference level of 0.019 milligram per kilogram and slightly exceeded the PCB tolerance value in eggs of 0.300 milligram per kilogram (from Tolerances for Polychlorinated Biphenyls (PCBs), Title 21, Part 109, Section 109.30 of the Code of Federal Regulations). PCBs in the remaining six egg samples ranged from 0.000024 to 0.011 milligram per kilogram and were below the regional statistical reference levels and well below the PCB tolerance value in egg (Table S8-7).

Goat milk from Los Alamos townsite contained detectable levels of PCBs of 0.274 micrograms per liter (Table S8-7). PCB levels in goat milk from Los Alamos townsite exceeded the regional statistical reference level of 0.015 micrograms per liter but were well below the PCB tolerance value in milk of 1,500 micrograms per liter (from Tolerances for Polychlorinated Biphenyls (PCBs), Title 21, Part 109, Section 109.30 of the Code of Federal Regulations).

PFAS Monitoring in Foodstuffs

The majority of PFAS chemicals were not detected in crop samples collected in 2022. Only five PFAS compounds were observed in crops, and they were observed in crop samples from all types of locations (perimeter, downstream of LANL, LANL, and background).

Perfluorobutanoic acid was the most commonly detected PFAS compound. It was detected in 11 crop samples, mostly within a range 0.17 to 3.9 nanograms per gram. Some of these observations exceeded the regional statistical reference level of 2.05 nanograms per gram. One sample of plums collected in White Rock had 22.8 nanograms per gram. Perfluoropentanoic acid was detected in seven samples, mostly within a range of 0.17 to 1.07 nanograms per gram. Some of these observations exceeded the regional statistical reference level of 0.22 nanograms per gram. The plums from White Rock had 7.39 nanograms per gram. Perfluorobutanoic acid and perfluoropentanoic acid are short chain PFAS chemicals and have been frequently observed in crops (Bao et al. 2019, Li et al. 2019).

Perfluorobutanesulfonic acid was observed in two crop samples at 0.18 and 0.55 nanograms per gram. The regional statistical reference level is 0.18 nanograms per gram. Perfluorohexanoic acid was observed only in the plums from White Rock, at 0.26 nanograms per gram, and perfluorooctanesulfonic acid was observed only in pears collected from Pueblo de San Ildefonso, at 2.23 nanograms per gram. Both of these exceeded their regional statistical reference levels of 0.22 and 0.22 nanograms per gram, respectively.

The White Rock plums were collected from trees that were located in a parking lot and next to an office building. These plum trees received water runoff from the building and the roof.

Overall, the majority of our observations of PFAS in crops are below levels reported in fruits and vegetables that were collected near PFAS-contaminated sites (Bao et al. 2019, Li et al. 2019). Currently, the United States does not have regulatory limits for PFAS compounds in food items.

The majority of PFAS chemical were not detected in egg samples collected in 2022 (Figure 8-5). Perfluorobutanoic acid was the most frequently detected PFAS compound in chicken eggs, with a range of 0.206 to 0.378 nanograms per gram—below the regional statistical reference level of 0.627 nanograms per gram. Egg samples from two perimeter locations had notably higher values of perfluorooctanesulfonic acid (179 nanograms per gram and 31.9 nanograms per gram), and the sample from one of these locations had multiple PFAS compounds detected (11 of the 37, Table S8-8). To investigate this anomaly, we collected additional samples from both of these perimeter locations (Table S8-8). We also created an egg-sampling questionnaire for egg donators to identify potential sources of PFAS for their backyard chicken flocks. Based on answers on the questionnaires, we collected samples from various brands of mealworms given to chickens by their owners because mealworms were one of our main suspected exposure routes. The majority of PFAS were not detected in mealworms, and those that were detected were all below 1 nanogram per gram. We also collected additional egg samples from the two perimeter locations later in the year and in the spring of 2023. Both locations had reduced PFAS detections over time; PFAS results in the spring of 2023 were below the regional statistical reference levels (Table S8-8, Figure 8-6). One study from Belgium that focused on home-produced chicken eggs found that perfluorooctanesulfonic acid was detected at similarly high values. The authors of the study suggested that the backyard foraging habitats of chickens may cause exposure—eating worms, leftover kitchen scraps, and other prey items and drinking rainwater (Lasters et al. 2022).

The honey sample collected from the northeastern side of Dual-Axis Radiographic Hydrodynamic Test Facility contained perfluorobutanoic acid and perfluoropentanoic acid at 2.10 and 0.568 nanograms per gram, respectively. We currently have PFAS results from only one honey sample collected from a background location and, therefore, a regional statistical reference level cannot be calculated; however, no PFAS compounds were detected in the honey sample collected from a background location. Both perfluorobutanoic acid and perfluoropentanoic acid are common PFAS compounds detected in the environment (Ghisi et al. 2019). More data are needed to make robust comparisons.

The majority of PFAS chemicals were not detected in cota tea samples. Only one PFAS compound was detected in cota tea from each of the following locations: Pueblo de San Ildefonso (perfluoropentanoic acid at 1.25 nanograms per liter), LANL (perfluorobutanoic acid at 19.3 nanograms per liter), and Mora (background location; perfluoropentanoic acid at 0.67 nanograms per liter). Cota tea from Cochiti Pueblo contained four detectable PFAS concentrations: perfluorobutanesulfonic acid, perfluorobutanoic acid, perfluorooctanesulfonic acid, and perfluoropentanoic acid at 0.98, 28.5, 0.89, and 11.8 nanograms per liter, respectively. We collected the cota plants from LANL and Cochiti Pueblo alongside a paved road. PFAS compounds have been observed in road dust, including perfluorobutanoic acid and perfluorooctanesulfonic acid (Murakami and Takada 2008, Li et al. 2023); therefore, the proximity to the road could be influencing the PFAS observations in the cota tea samples. Due to small sample size, no regional statistical reference level exists for comparisons.

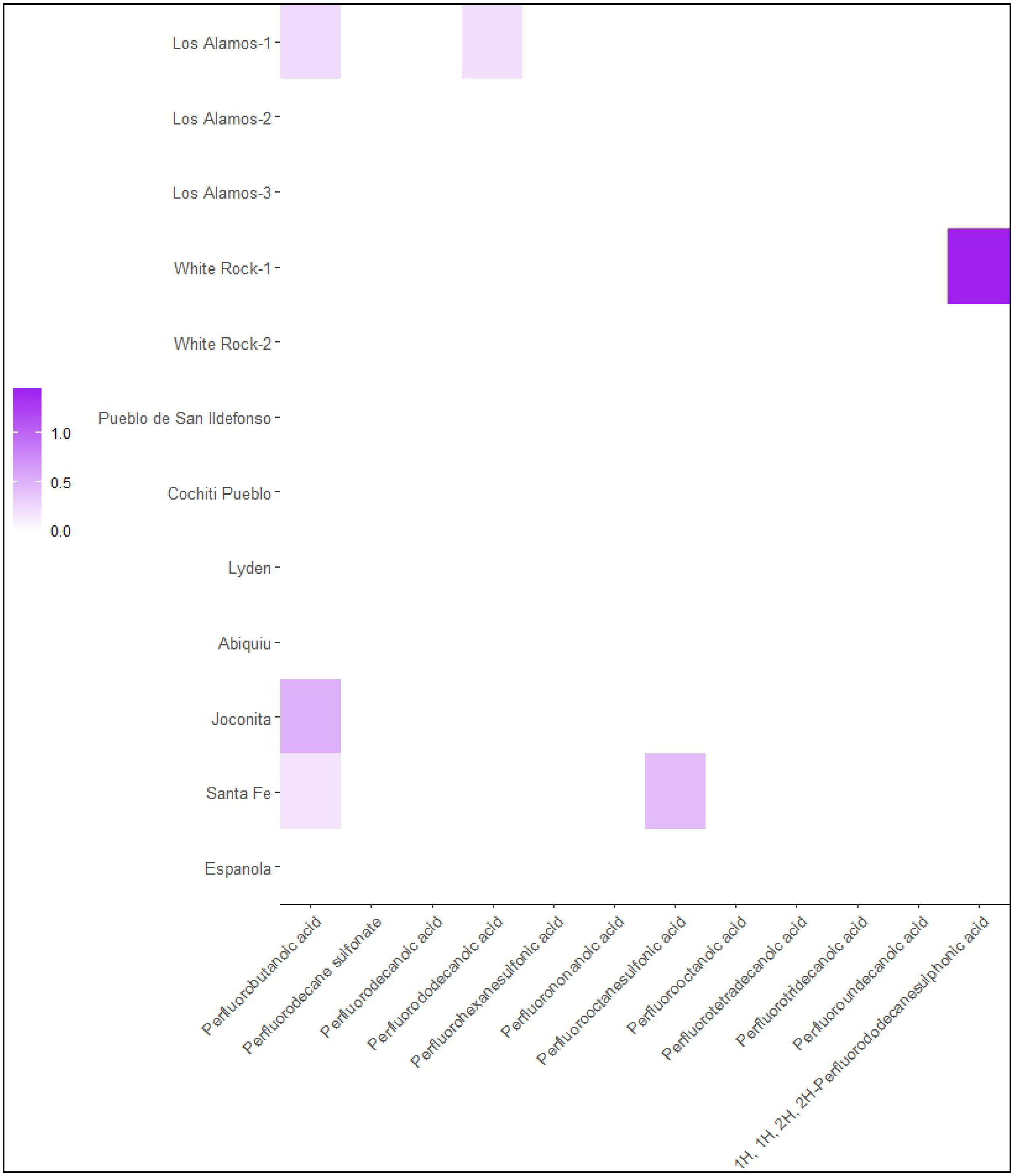


Figure 8-5. PFAS detections (nanograms per gram) in chicken egg samples collected from surrounding communities and from background locations in 2022.

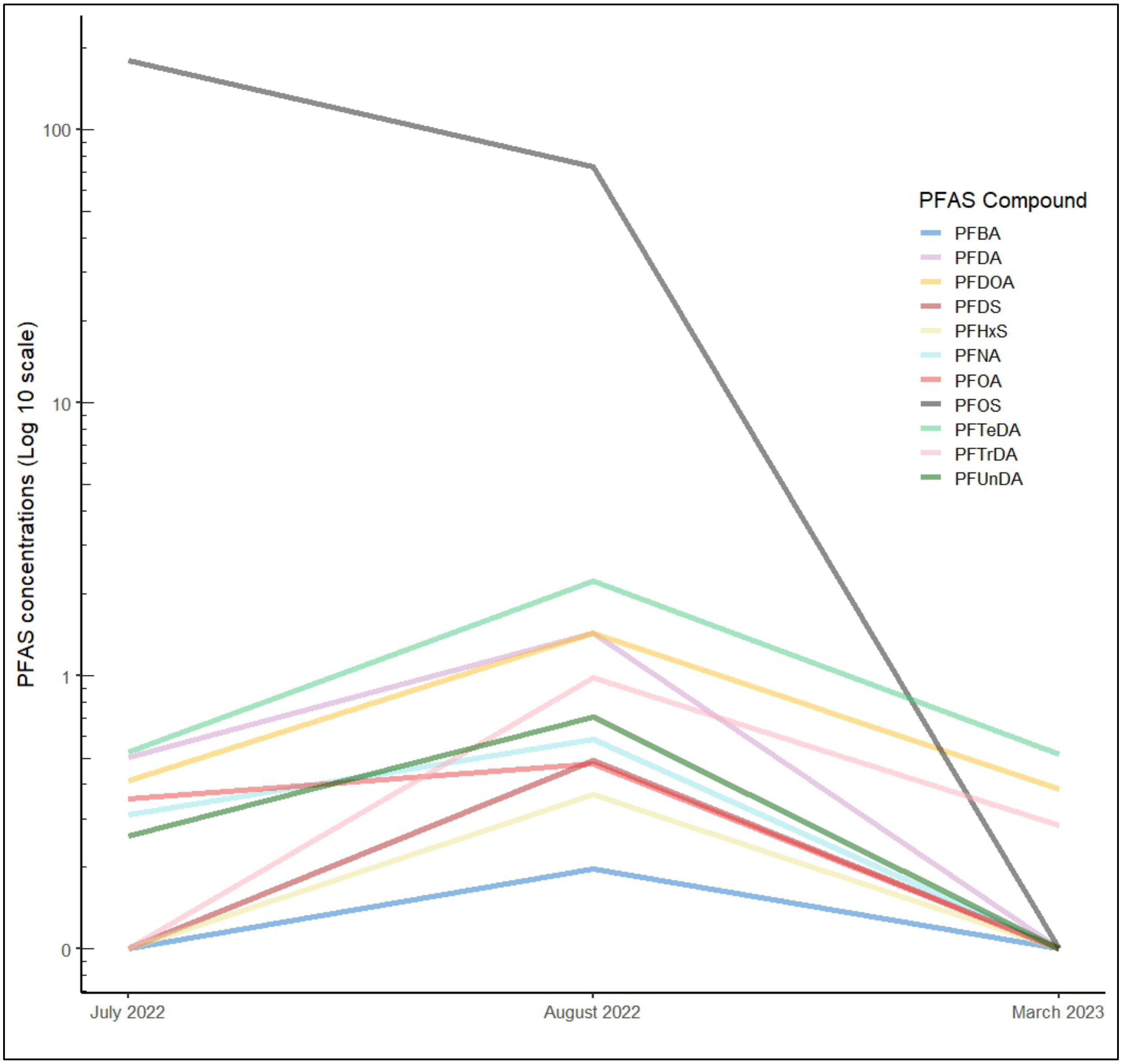


Figure 8-6. PFAS detections (nanograms per gram) in chicken egg samples from one perimeter location in July 2022, August 2022, and March 2023. Note the log scale on the Y axis. (PFDS = perfluorodecane sulfonate, PFBA = perfluorobutanoic acid, PFDA = perfluorodecanoic acid, PFDOA = perfluorododecanoic acid, PFHxS = perfluorohexanesulfonic acid, PFNA = perfluorononanoic acid, PFOA = perfluorooctanoic acid, PFOS = perfluorooctanesulfonic acid, PFTeDA = perfluorotetradecanoic acid, PFTrDA = perfluorotridecanoic acid, PFUnDA = perfluoroundecanoic acid)

Goat milk from Los Alamos townsite contained only perfluorobutanoic acid at 4.02 nanograms per liter. No regional statistical reference is available for goat milk; however, no PFAS chemicals were detected in the one goat milk sample from a background location. Perfluorobutanoic acid is commonly detected in the environment (Ghisi et al. 2019). More data are needed to make robust comparisons.

Summary—PFAS Monitoring Results

PFAS compounds were analyzed in crops, chicken eggs, goat milk, honey, and cota tea. Overall, the majority of PFAS compounds were not detected. Perfluorobutanoic acid and perfluoropentanoic acid were the most commonly detected PFAS chemicals observed in foodstuffs. Perfluorobutanoic acid was observed in crops, chicken eggs, goat milk, honey, and cota tea, whereas perfluoropentanoic acid was observed in crops, honey, and cota tea. Plums from White Rock and cota tea from LANL and Cochiti Pueblo had higher levels of perfluorobutanoic acid relative to other foodstuffs samples. These observations may be explained by the proximity to roads as perfluorobutanoic acid has been detected in road dust (Li et al 2023). One chicken egg sample from a perimeter location contained detectable levels of 11 of the 37 PFAS compounds analyzed as well as the highest level of perfluorooctanesulfonic acid. Eggs from this property were re-analyzed at two later time points, and perfluorooctane-sulfonic acid concentrations in eggs from the most recent analyses were below the regional statistical reference level. For most of our samples, the PFAS concentrations observed are suspected to be due to a non-point source, i.e., atmospheric deposition. Please see the PFAS Monitoring in Foodstuffs section for more detailed descriptions of PFAS results.

Quality Assurance

Quality assurance for the dose calculations is described in procedure EPC-ES-TPP-006, *Environmental Human Dose Assessment*.

The Soil, Foodstuffs, and Biota program collects samples according to written, standard quality assurance and quality control procedures and protocols. These procedures and protocols are identified in the Laboratory's *Implementation of the Soil, Foodstuffs, and Biota Program, Quality Assurance Project Plan* (EPC-ES-QAPP-001) and in the following Laboratory procedures pertaining to foodstuffs collections:

- EPC-ES-TP-004, *Produce Sampling*
- EPC-ES-TP-007, *Road Kill Sampling*
- EPC-ES-TP-008, *Crayfish Sampling*
- EPC-ES-TP-005, *Fish Sampling*
- EPC-ES-TP-219, *Managing and Sampling Honeybee Hives*
- EPC-ES-GUIDE-015, *General PFAS Sampling Guidance for the Soil, Foodstuffs, and Biota Program*.

The Soil, Foodstuffs, and Biota program collects biological samples under approved New Mexico Game and Fish Scientific Collection Permits, as well as approved Institutional Animal Care and Use Committee protocols.

These procedures ensure that the collection, processing, and chemical analysis of samples; the validation and verification of data; and the tabulation of analytical results are conducted in a consistent manner from year to year. Locations and samples have unique identifiers to provide chain-of-custody control from the time of collection through analysis and reporting.

Field Sampling Quality Assurance

Overall, quality of field sampling is maintained through the rigorous use of carefully documented procedures, listed in the previous section, that govern all aspects of the sample collection program. Samples are collected under full chain-of-custody procedures to minimize the chance of data transcription errors. Once collected, samples are hand-delivered to the Laboratory's Sample Management Office, where staff ship the samples via express mail directly to an external analytical laboratory under full chain-of-custody control. Sample Management Office personnel track all samples. Upon receipt of data from the analytical laboratory (electronically and in hard copy), the completeness of the field sample process and other variables is assessed. A quality assessment document is created, attached to the data packet, and provided in the data package.

Due to drought- and wildfire-related causes, only three foodstuffs samples were collected from Pueblo de San Ildefonso; therefore, field data completeness for sample collection in 2022 was 93 percent.

Water blanks are commonly used within analytical studies to determine whether contamination has been inadvertently introduced into a sample set. In our investigation, water blanks were used to determine whether PFAS contamination was introduced into field samples through carryover from contaminated equipment or experimental procedure. Water blanks for PFAS detection are typically collected during each sampling event. In 2022, a total of 13 water blanks for PFAS were collected.

Two water samples contained a detectable PFAS compound on two separate occasions. 1H, 1H, 2H, 2H-perfluorooctane sulfonic acid was observed in one water blank at 6.93 nanograms per liter but was not observed in any of the five foodstuffs samples that were collected on the same day. Perfluorobutanoic acid was detected in a water blank at 2.45 nanograms per liter, and it was also observed in goat milk at 4.02 nanograms per liter.

Analytical Laboratory Quality Assessment

In 2022, ALS in Fort Collins, Colorado, closed, and the Soil, Foodstuffs, and Biota program began sending samples to GEL in Charleston, South Carolina, for radionuclide and total analyte list analyses.

Two foodstuffs samples were analyzed for radionuclides on a dry-weight basis by GEL, whereas the remaining samples were analyzed on an ash-weight basis. The difference in basis prevented the direct comparisons with the regional statistical reference levels.

One apple sample collected from LANL property in August was not analyzed for tritium because the entire sample was dried before taking an aliquot for tritium (dried samples cannot be analyzed for tritium). Therefore, in total, we lost one analytical result from one environmental sample in 2022.

Conclusion

The environmental data collected in 2022 show that, currently, there is no measurable risk to the public from materials released from the Laboratory. The public doses and risks from LANL operations are smaller than the regulatory limits and the naturally occurring background levels.

References

Amer et al. 2019: M. M. Amer, B. A. Sabry, D. A. Marrez, A. S. Hathout, A. S. Fouzy. 2019. "Exposure assessment of heavy metal residues in some Egyptian fruits," Toxicology Reports 6:538–543.

Anderson 2012: C. G. Anderson. 2012. "The metallurgy of antimony," Geochemistry 72:3–8.

Angelova et al. 2014: M. G. Angelova, T. V. Petkova-Marinova, M. V. Pogorielov, A. N. Loboda, V. N. Nedkova-Kolarova, A. N. Bozhinova. 2014. "Trace element status (iron, zinc, copper, chromium, cobalt, and nickel) in iron-deficiency anaemia of children under 3 years," Anemia, http://dx.doi.org/10.1155/2014/71808

Ashley et al. 2003: P. M. Ashley, D. Craw, B. P. Graham, D. A Chappell. 2003. "Environmental mobility of antimony around mesothermal stibnite deposits, New South Wales, Australia and Southern New Zealand," Journal of Geochemical Exploration 77(1):1–4.

Baltrėnaitė et al. 2012: E. Baltrėnaitė, A. Lietuvninkas, P. Baltrėnas. 2012. "Use of dynamic factors to assess metal uptake and transfer in plants—example of trees," Water, Air & Soil Pollution, 223:4297–4306.

Bao et al. 2019: J. Bao, W. J. Yu, Y. Liu, X. Wang, Y. H Jin, G. H. Dong. 2019. "Perfluoroalkyl substances in groundwater and home-produced vegetables and eggs around a fluorochemical industrial park in China," Ecotoxicology and Environmental Safety 171:199–205.

Bouville and Lowder 1988: A. Bouville and W. M. Lowder, "Human Population Exposure to Cosmic Radiation," Radiation Protection Dosimetry 24:293–299.

DOE 2012: *An Aerial Radiological Survey of Los Alamos National Laboratory and Surrounding Communities*, U.S. Department of Energy report DOE/NV/25946--1619.

DOE 2020: *Radiation Protection of the Public and the Environment*, U.S. Department of Energy Order 458.1 Chg 4.

DOE 2022: *Derived Concentration Technical Standard*, U.S. Department of Energy Standard DOE-STD-1196-2022.

Ettler et al. 2010: V. Ettler, V. Tejnecký, M. Mihaljevič, O. Šebek, M. Zuna, A. Vaněk. 2010. "Antimony mobility in lead smelter-polluted soils," *Geoderma* 155(3–4):409–418.

Fuehne and Lattin 2023: D. P. Fuehne and R. R. Lattin. "2022 LANL Radionuclide Air Emissions Report," Los Alamos National Laboratory report LA-UR-23-25741.

Ghisi et al. 2019: R. Ghisi, T. Vamerali, and S. Manzetti. 2019: "Accumulation of perfluorinated alkyl substances (PFAS) in agricultural plants: A review," *Environmental Research*, 169:326–341.

Gillis et al. 2014: J. M. Gillis, J. J. Whicker, M. McNaughton, and W. Eisele. "Comparison of Background Radiation Effective Dose Rates for Residents in the Vicinity of a Research and Nuclear Weapons Laboratory (Los Alamos County, USA) with National Averages," Los Alamos National Laboratory report LA-UR-14-28732.

Goldhaber 2003: S. B. Goldhaber. 2003. "Trace element risk assessment: essentiality vs. toxicity. *Regulatory Toxicology and Pharmacology* 38(2):232–242.

LANL 2020: "Los Alamos National Laboratory Environmental ALARA Program," Los Alamos National Laboratory Functional Series Document EPC-ES-FSD-003.

LANL 2022: "Los Alamos National Laboratory 2020 Annual Site Environmental Report," Los Alamos National Laboratory report LA-UR-21-28555.

Lasters et al. 2022: R. Lasters, T. Groffen, M. Eens, D. Coertjens, W. A. Gebbink, J. Hofman, L. Bervoets. 2022. "Home produced eggs: An important human exposure pathway of perfluoroalkylated substances (PFAS)," Chemosphere 308:136283.

Li et al. 2019: P. Li, X. Oyang, Y. Zhao, T. Tu, X. Tian, L. Li, Y. Zhao, J. Li, Z. Xiao. 2019. "Occurrence of perfluorinated compounds in agricultural environment, vegetables, and fruits in regions influenced by a fluorine-chemical industrial park in China," Chemosphere 225:659–667.

Li et al. 2023: P. F. Li, Y. Wang, C. Yang, Y. L. Shi, J. S. Cui. 2023. "Pollution Characteristics and Health Risk Assessment of Per- and Polyfluoroalkyl Substances and Emerging Alternatives in Road Dust, Shijiazhuang," *Huan Jing ke Xue Huanjing Kexue*, 44(3):1593–1601.

Los Alamos County 2023: "2022 Annual Drinking Water Quality Report," Los Alamos Department of Public Utilities, https://www.losalamosnm.us/common/pages/DisplayFile.aspx?itemId=18583904

Mawari et al. 2022: G. Mawari, N. Kumar, S. Sarkar, M. K. Daga, M. M. Singh, T. K. Joshi, N. A Khan. 2022. "Heavy metal accumulation in fruits and vegetables and human health risk assessment: findings from Maharashtra, India," *Environmental Health Insights* 16: DOI:11786302221119151.

McLemore et al. 2011: V. Mclemore, D. Vaniman, D. McQuillan, and P. Longmire. 2011. "Uranium Deposits in the Espanola Basin, Santa Fe County, New Mexico," *New Mexico Geological Society Guidebook*, 62nd Field Conference, *Geology of the Tusas Mountains – Ojo Cliente, 2011*, 399–408.

McNaughton et al. 2013: M. W. McNaughton, B. R. Brock, W. F. Eisele, and J. J. Whicker. "On-site Measurements and Calculations of the Maximally Exposed Individual (MEI) at LANL," Los Alamos National Laboratory report LA-UR-13-25871.

McNaughton et al. 2018: M. W. McNaughton, C. A. Bullock, M. J. Chastenet, D. P. Fuehne, B. G. Harcek, D. Katzman, C. L. Rodriguez, R. T. Ryti, and J. J. Whicker. "Acid Canyon Dose," Los Alamos National Laboratory report LA-UR-18-29981.

Murakami and Takada 2008: M. Murakami, H. Takada. 2008. "Perfluorinated surfactants (PFSs) in size-fractionated street dust in Tokyo," *Chemosphere* 73(8):1172–7.

National Council on Radiation Protection 1987: "Exposure of the Population in the United States and Canada from Natural Background Radiation," National Council on Radiation Protection and Measurements Report 94.

National Council on Radiation Protection 2005: "Structural Shielding Design and Evaluation for Megavoltage X- and Gamma Ray Radiotherapy Facilities," National Council on Radiation Protection and Measurements Report 151.

National Council on Radiation Protection 2009: "Ionizing Radiation Exposure of the Population of the United States," National Council on Radiation Protection and Measurements Report 160.

National Research Council 1989: National Research Council. 1989. "Diet and health: implications for reducing chronic disease risk," National Academies Press (U.S.), DOI: 10.17226/1222

Ruiz-Sánchez et al. 2005: M. C. Ruiz-Sánchez, V. Plana, M. F. Ortuño, L. M. Tapia, J. M. Abrisqueta. 2005. "Spatial root distribution of apricot trees in different soil tillage practices," Plant and Soil 272:211–221.

U.S. Environmental Protection Agency 2013: "CAP88-PC User Guide," Trinity Engineering Associates, Inc., prepared for the U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency 2020: Federal Register 85 FR 12917 (2020). U.S. Environmental Protection Agency https://www.federalregister.gov/documents/2020/03/05/2020-04546/national-emission-standards-for-hazardous-air-pollutants-radionuclides-availability-of-updated

Whicker 2009: J. J. Whicker. "Work to Save Dose: Contrasting Effective Dose Rates from Radon Exposure in Workplaces and Residences Against the Backdrop of Public and Occupational Regulatory Limits," Health Physics 97:248–256.

Ziton 2021: T. Ziton. 2021. "Are Apricot Tree Roots Invasive? What You Should Know," https://couchtohomestead.com/are-apricot-tree-roots-invasive/ (accessed June 2023).

Appendix A: Standards and Screening Levels for Radionuclides and Other Chemicals in Environmental Samples

General Formation of a Standard or Screening Level

A standard is a reference value designed to protect a target group from a harmful level of exposure to a chemical. It may be used as a regulatory limit. Regulatory agencies, such as the U.S. Environmental Protection Agency, typically define standards.

In developing standards, agencies consider

- pathways of exposure to target groups,
- exposure scenarios, and
- the length of time target groups are exposed.

A target group may refer to, for example, the general public, animals, or a sensitive population such as children. Possible pathways of exposure include inhalation of air or ingestion of water, soil, animals, or plants. Exposure scenarios describe the activities of a target group at a site that influence both the likelihood and length of exposures. Examples of exposure scenarios include resident (someone living on a site) and worker (someone disturbing soil during construction activities at a site).

A screening level is a chemical concentration that, when exceeded in a sample, indicates that the sampled location might warrant further investigation or action. Screening levels may be calculated by a regulatory agency or by another party.

Throughout this Annual Site Environmental Report, levels of radioactive and chemical constituents in air, water, soil, and sediment samples are compared with standards or other guidance established by regulations of federal and state agencies. For environmental samples and chemicals that do not have standards or guidance, levels are compared with screening levels.

Table A-1. DOE Public Dose Limits for External and Internal Exposures

Exposure Pathway	Dose Equivalent at Point of Maximum Probable Exposure
All pathways	100 millirem per year
Air pathway only*	10 millirem per year
Drinking water	4 millirem per year

*Defined by U.S. Environmental Protection Agency's regulations issued under the Clean Air Act (Code of Federal Regulations Title 40, Part 61, Subpart H).

Appendix A Standards and Screening Levels for Radionuclides and Other Chemicals in Environmental Samples

DOE Radiation Dose Limits

DOE Order 458.1 Chg 4, *Radiation Protection of the Public and the Environment*, describes radiation protection standards for the public, referred to as public dose limits (See Table A-1). DOE's public dose limits apply to the effective dose that a member of the public receives from DOE operations. For all exposure pathways combined, the total limit is 100 millirem per year.

For water, radionuclide levels are compared with DOE's derived concentration standards (DOE 2021; See Table A-2) to evaluate the potential for impacts to members of the public. The derived concentration standards for water (in picocuries per liter) are the concentrations that would result in a dose of 100 millirem per year if a Reference Person (as defined in the standard) consumed the water.

Hydrogen-3	2,600,000
Beryllium-7	2,500,000
Strontium-89	39,000
Strontium-90	1700
Cesium-137	4100
Uranium-234	1200
Uranium-235	1300
Uranium-238	1400
Plutonium-238	430
Plutonium-239	400
Plutonium-240	400
Americium-241	740

The DOE has also defined biota dose limits that apply to populations of animals and plants. For details, refer to DOE Standard 1153 (DOE 2019).

Clean Air Act Radiation Dose Limits for DOE Facilities

For air emissions, in addition to the DOE standards, in 1985 and 1989 the U.S. Environmental Protection Agency established the "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities," in Title 40, Part 61, Subpart H of the Code of Federal Regulations. This Clean Air Act regulation states that emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose of 10 millirem per year. DOE has adopted this as a dose limit (See Table A-1). The regulation requires monitoring of all release points that can produce a dose of 0.1 millirem per year to a member of the public.

Appendix A Standards and Screening Levels for Radionuclides and Other Chemicals in Environmental Samples

National Pollutant Discharge Elimination System Permits

The types of monitoring required under the National Pollutant Discharge Elimination System and the limits established for sanitary and industrial outfalls can be found at http://water.epa.gov/polwaste/npdes.

Drinking Water Standards

For chemical constituents in drinking water, the U.S. Environmental Protection Agency issued regulations and standards under the federal Safe Drinking Water Act, which the New Mexico Environment Department adopted.

Radioactivity in drinking water is regulated by U.S. Environmental Protection Agency regulations contained in Title 40, Part 141, of the Code of Federal Regulations and by the New Mexico Drinking Water Regulations, Sections 206 and 207. These regulations stipulate that combined radium-226 and radium-228 activity in drinking water may not exceed 5 picocuries per liter. Gross-alpha activity (including radium-226 but excluding radon and uranium) may not exceed 15 picocuries per liter.

For manufactured beta- and photon-emitting radionuclides, U.S. Environmental Protection Agency drinking water standards are limited to levels that would result in doses not exceeding 4 millirem per year.

Surface Water Standards

Levels of radionuclides in surface water samples may be compared with either the DOE-derived concentration standards (DOE 2021) or the New Mexico Water Quality Control Commission stream standards. The concentrations of nonradioactive constituents may be compared with the New Mexico Water Quality Control Commission stream standards, which are available at https://www.env.nm.gov/surface-water-quality/wqs/. The New Mexico Water Quality Control Commission groundwater standards can also be applied in cases where discharges could affect groundwater.

Soils and Sediment Screening Levels

If chemical or radionuclide levels in soil exceed regional statistical reference levels (regional background levels), the levels are then compared with screening levels. The human health screening levels for soil from publicly accessible locations are the levels that would produce (1) a dose of 15 millirem or greater to an individual for radionuclides, (2) an estimated excess cancer risk of 1×10^{-5} for cancer-causing chemicals, or (3) a hazard quotient greater than 1 for hazardous chemicals that do not cause cancer. The screening levels differ for different exposure scenarios. Soil and sediment screening levels are mostly used in evaluating sites for remediation. Screening levels for radionuclides are found in a Laboratory document (LANL 2015); screening levels for nonradionuclides are found in a New Mexico Environment Department document (NMED 2021).

Foodstuffs Standards and Screening Levels

Federal standards exist for radionuclides and selected nonradionuclides (for example, mercury and polychlorinated biphenyls [PCBs]) in foodstuffs. The Laboratory has established screening levels for radionuclides. If levels in foodstuffs exceed regional statistical reference levels, they are then compared with screening levels and existing standards. The Laboratory has established a screening level of 1 millirem per year for activities of individual radionuclides in individual foodstuffs (for example, fish and crops), assuming a residential scenario. The U.S. Environmental Protection Agency has established screening levels for mercury and PCBs in fish (EPA 2018).

Biota (Wild Animals and Plants) Standards and Screening Levels

If radionuclide or chemical levels in biota exceed regional statistical reference levels, the levels are then compared with screening levels. For radionuclides in biota, the Laboratory sets screening levels at 0.1 rad per day for terrestrial plants and aquatic biota and 0.01 rad per day for terrestrial animals, which is 10 percent of the DOE standard (DOE 2019). If a chemical in biota tissue exceeds the regional statistical reference level, detected concentrations in the tissue are compared with lowest observed adverse effect levels reported in published literature, if available, and concentrations in the soil at the place of collection are compared with ecological screening levels (LANL 2020).

References

DOE 2019: "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," U.S. Department of Energy Standard DOE-STD-1153-2019 (2019).

DOE 2021: "Derived Concentration Technical Standard," U.S. Department of Energy Standard DOE-STD-1196-2021 (July 2021).

EPA 2018: "Fish Tissue Data Collected by EPA," U.S. Environmental Protection Agency accessed May 2018, https://www.epa.gov/fish-tech/fish-tissue-data-collected-epa

LANL 2015: "Derivation and Use of Radionuclide Screening Action Levels, Revision 4," Los Alamos National Laboratory document LA-UR-15-24859 (September 2015).

LANL 2020: "ECORISK Database," Release 4.2, Los Alamos National Laboratory, available at https://www.intellusnm.com (November 2020).

NMED 2021: "Risk Assessment Guidance for Site Investigations and Remediation," New Mexico Environment Department report (November 2021).

Appendix B: Units of Measurement

Throughout the "Annual Site Environmental Report," the U.S. customary (English) system of measurement has generally been used. For units of radiation activity, exposure, and dose, U.S. customary units (curie, roentgen, rad, and rem) are retained as the primary measurement because current standards are written in terms of these units. The equivalent units from the International System of Units are the becquerel, coulomb per kilogram, gray, and sievert, respectively. Table B-1 presents factors for converting U.S. customary units into units from the International System of Units (metric).

Table B-1. Approximate Conversion Factors for Selected U.S. Customary Units

Multiply U.S. Customary (English) Unit	by	to Obtain International System of Units (Metric) Unit
degrees Fahrenheit	5/9 (first subtract 32)	degrees Celsius
inches	2.54	centimeters
cubic feet	0.028	cubic meters
acres	0.4047	hectares
ounces	28.3	grams
pounds	0.453	kilograms
miles	1.61	kilometers
gallons	3.785	liters
feet	0.305	meters
parts per million	1	micrograms per gram
parts per million	1	milligrams per liter
square miles	2.59	square kilometers
picocuries	37	millibecquerel
rad	0.01	gray
millirem	0.01	millisievert

Table B-2 presents prefixes used in this report to define fractions or multiples of the base units of measurements. Scientific notation is used in this report to express very large or very small numbers. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2.0×10^3, the decimal point should be moved three numbers (insert zeros if no numbers are given) to the right of its present location. The number would then read 2000. If the value given is 2.0×10^{-5}, the decimal point should be moved five numbers to the left of its present location. The result would be 0.00002.

Table B-2. Prefixes Used with International System of Units (Metric) Units

Prefix	Factor	Symbol
mega	1,000,000 or 10^{6}	M
kilo	1000 or 10^{3}	k
centi	0.01 or 10^{-2}	c
milli	0.001 or 10^{-3}	m
micro	0.000001 or 10^{-6}	µ
nano	0.000000001 or 10^{-9}	n
pico	0.000000000001 or 10^{-12}	p
femto	0.000000000000001 or 10^{-15}	f
atto	0.000000000000000001 or 10^{-18}	a

Data Handling of Radiochemical Samples

Measurements of radioactivity in samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique, and results for individual measurements can be negative numbers. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values are included in the population calculations (Gilbert 1975).

For individual measurements, uncertainties are reported as one standard deviation. The standard deviation is estimated from the propagated sources of analytical error.

Standard deviations for the ambient air monitoring network station and group (offsite regional, offsite perimeter, and onsite) means are calculated using the standard equation

$$s = (\Sigma(c_i - \quad)^2/(N - 1))^{1/2}$$

where

c_i = sample i,

$\overline{c}$ = mean of samples from a given station or group, and

N = number of samples in the station or group.

This value is reported as one standard deviation for the station and group means.

Reference

Gilbert 1975: R. O. Gilbert, “Recommendations Concerning the Computation and Reporting of Counting Statistics for the Nevada Applied Ecology Group,” Battelle Pacific Northwest Laboratories report BNWL-B-368 (September 1975).

Appendix C: Descriptions of Technical Areas and Their Associated Programs

Locations of the technical areas operated by Los Alamos National Laboratory (LANL or the Laboratory) in Los Alamos County are shown in Figure 1-3 in Chapter 1. There are also some offsite facilities in Los Alamos, Santa Fe, and Rio Arriba counties. The main programs conducted at each of the areas are listed in this appendix.

Technical Area	Location and Activities
00 (offsite facilities)	The Technical Area 00 designation is assigned to structures leased by the U.S. Department of Energy outside the Laboratory's boundaries in Los Alamos County.
02 (Omega Site or Omega West Reactor)	Omega West Reactor, an 8-megawatt nuclear research reactor, was located at Technical Area 02. The reactor was decontaminated and decommissioned in 2002. Technical Area 02 is now the location of the Omega West Monument and interpretive panels. The monument commemorates the historic reactors and other historical events that took place at Technical Area 02.
03 (Core Area or South Mesa Site)	Technical Area 03 is the Laboratory's core scientific and administrative area and contains approximately half of the Laboratory's employees and total floor space. It is the location of many key Laboratory facilities, including the Chemistry and Metallurgy Research Building, the Sigma Complex, the machine shops, the Material Sciences Laboratory, and the Nicholas C. Metropolis Center for Modeling and Simulation.
05 (Beta Site)	Between East Jemez Road and the Pueblo de San Ildefonso, Technical Area 05 contains physical support facilities and an electrical substation. It is also the site of the Laboratory's interim measure to control chromium plume migration in the regional aquifer.
06 (Twomile Mesa Site)	Technical Area 06 is sited in the northwestern part of the Laboratory and is mostly open land. It contains a meteorological tower, gas-cylinder-staging buildings, the Western Technical Area Substation, and buildings awaiting demolition. There are also properties listed for the Manhattan Project National Historical Park located in this technical area.
08 (GT Site or Anchor Site West)	Located along West Jemez Road, Technical Area 08 is a testing site where nondestructive dynamic testing techniques are used to ensure the quality of materials in items ranging from test weapons components to high-pressure dies and molds. Techniques used include radiography, radioisotope techniques, ultrasonic and penetrant testing, and electromagnetic test methods. The Manhattan Project National Historical Park also hosts the historic Gun Site properties in this technical area.

Technical Area	Location and Activities
09 (Anchor Site East)	Technical Area 09 is located on the western edge of the Laboratory. Fabrication feasibility and the physical properties of explosives are explored at this technical area, and new organic compounds are investigated for possible use as explosives.
11 (K-Site)	Technical Area 11 is used for testing explosives components and systems, including vibration analysis and drop-testing materials and components under a variety of extreme physical environments. Facilities are arranged so that testing can be controlled and observed remotely, allowing devices that contain explosives, radioactive materials, and nonhazardous materials to be safely tested and observed. Properties listed for the Manhattan Project National Historical park are also located in this technical area.
14 (Q-Site)	Technical Area 14 is located in the northwestern part of the Laboratory and is one of 14 firing areas. Most operations are remotely controlled and involve detonations, certain types of high-explosives machining, and permitted burning. Properties listed for the Manhattan Project National Historic Park are also located in this technical area.
15 (R-Site)	Technical Area 15 is located in the central portion of the Laboratory; it is used for high-explosives research, development, and testing, mainly through hydrodynamic testing and dynamic experimentation. It contains two firing sites: the Dual-Axis Radiographic Hydrodynamic Test Facility, which has an intense high-resolution, dual-machine radiographic capability; and Building 306, a multipurpose facility where primary diagnostics are performed.
16 (S-Site)	Technical Area 16 lies in the western part of the Laboratory and includes the Weapons Engineering Tritium Facility. It is also the location of high-explosives research, development, and testing. The Manhattan Project National Historical Park also hosts the V-Site property in this technical area.
18 (Pajarito Site)	Technical Area 18 is sited in Pajarito Canyon and was the location of the Los Alamos Critical Experiment Facility, a general-purpose nuclear experiments facility. All operations here have ceased. The technical area, including the Pond Cabin and the Slotin Building, is now part of the Manhattan Project National Historical Park.
21 (DP Site)	Technical Area 21 is located on the northern border of the Laboratory, next to the Los Alamos townsite. The former radioactive materials (including plutonium) processing facility was in the western part of Technical Area 21. The Tritium Systems Test Assembly and the Tritium Science and Fabrication Facility were in the eastern part. Operations from these facilities have been transferred, and demolition was completed in 2010.

Technical Area	Location and Activities
22 (TD Site)	Technical Area 22 is located in the northwestern portion of the Laboratory and houses the Detonator Production Facility. Research, development, and fabrication of high-energy detonators and related devices are conducted at this facility. Properties listed for the Manhattan Project National Historic Park are also located in this technical area.
28 (Magazine Area A)	Technical Area 28 is sited near the southern edge of the Laboratory and was an explosives storage area. It contains five empty storage magazines that are being decontaminated and decommissioned.
33 (HP Site)	Technical Area 33 is a remotely located technical area at the southeastern boundary of the Laboratory. Activities at this site include programs intended to protect, deter, and respond to weapons of mass destruction. Laboratories and testbeds include additive manufacturing, machining, pulsed power, laser interaction, power delivery and response, chemical compatibility, cryogenics, biological measurements, and radiological material detection and effects. The National Radioastronomy Observatory's Very Long Baseline Array telescope is here. A portion of the White Rock Canyon Reserve is also located here.
35 (Ten Site)	Technical Area 35 is located in the north-central portion of the Laboratory. The Target Fabrication Facility, located here, houses activities related to weapons production and laser fusion research. High-energy density physics tests are conducted here.
36 (Kappa Site)	Technical Area 36 is a remotely located area in the eastern portion of the Laboratory; it has four active firing sites that support explosives testing. The sites are used for a wide variety of nonnuclear ordnance tests.
37 (Magazine Area C)	Technical Area 37, used as an explosives storage area, is sited along the eastern perimeter of Technical Area 16.
39 (Ancho Canyon Site)	Technical Area 39, at the bottom of Ancho Canyon, is used to study the behavior of nonnuclear weapons (primarily by photographic techniques) and various phenomenological aspects of explosives.
40 (DF Site)	Technical Area 40 is centrally located within the Laboratory and is used for general testing of explosives or other materials and development of special detonators for initiating high-explosives systems.
41 (W-Site)	Technical Area 41 is located in Los Alamos Canyon; it is no longer actively used. Many buildings have been decontaminated and decommissioned; the remaining structures include historic properties.

Technical Area	Location and Activities
43 (Bioscience Facilities)	Technical Area 43 lies adjacent to the Los Alamos Medical Center at the northern border of the Laboratory; it is the location of the Bioscience Facilities (formerly called the Health Research Laboratory). The Bioscience Facilities house Biosafety Level 1 and 2 laboratories and are the focal point of bioscience and biotechnology at LANL. Research performed at the Bioscience Facilities includes structural, molecular, and cellular radiobiology; biophysics; radiobiology; biochemistry; and genetics.
46 (WA Site)	Technical Area 46 is sited between Pajarito Road and the Pueblo de San Ildefonso. It is one of the Laboratory's basic research sites. Activities have focused on applied photochemistry operations and have included development of technologies for laser isotope separation and laser enhancement of chemical processes. The Sanitary Wastewater Systems Plant is also here.
47 (offsite facilities)	Technical Area 47 contains leased office and warehouse space in Santa Fe.
48 (Radiochemistry Site)	Technical Area 48 is located in the north-central portion of the Laboratory. It supports research and development in nuclear and radiochemistry, geochemistry, production of medical radioisotopes, and chemical synthesis. Hot cells are used to produce medical radioisotopes.
49 (Frijoles Mesa Site)	Technical Area 49 is located near Bandelier National Monument. It is used as a training area and for outdoor tests on materials and equipment components that involve generating and receiving short bursts of high-energy, broad-spectrum microwaves. The National Park Service operates the Interagency Wildfire Center and helipad near the entrance to the technical area.
50 (Waste Management Site)	Technical Area 50 is located near the center of the Laboratory. It is the location of waste management facilities, including the Radioactive Liquid Waste Treatment Facility and the Waste Characterization, Reduction, and Repackaging Facility. The Actinide Research and Technology Instruction Center is also here.
51 (Environmental Research Site)	Technical Area 51 is located on Pajarito Road in the eastern portion of the Laboratory; it is used for research and experimental studies on the long-term impacts of radioactive materials on the environment. Various types of waste storage and coverings are studied here.
52 (Reactor Development Site)	Technical Area 52 is located in the north-central portion of the Laboratory. A wide variety of theoretical and computational research and development activities related to nuclear reactor performance and safety, as well as to several environmental, safety, and health activities, are carried out here.

Technical Area	Location and Activities
53 (Los Alamos Neutron Science Center)	Technical Area 53 is located in the northern portion of the Laboratory and includes the Los Alamos Neutron Science Center. This facility houses one of the largest research linear accelerators in the world and supports basic and applied research programs. Basic research includes studies of subatomic and particle physics, atomic physics, neutrinos, and the chemistry of subatomic interactions. Applied research includes materials science studies that use neutron spallation and contribute to defense programs. The facility also irradiates targets for medical isotope production.
54 (Waste Disposal Site)	Technical Area 54 is located on the eastern border of the Laboratory and is one of the largest technical areas at the Laboratory. Its primary function is management of solid radioactive and hazardous chemical wastes, including storage, treatment, decontamination, and disposal operations.
55 (Plutonium Facility Complex Site)	Technical Area 55 is located in the center of the Laboratory along Pajarito Road and includes the Plutonium Facility Complex and the Radiological Laboratory Utility Office Building. The manufacture of plutonium pits and parts, fabrication of samples for research and development activities, and pit surveillance takes place here. Other activities include chemistry and metallurgy research, actinide chemistry, and materials characterization.
57 (Fenton Hill Site)	Technical Area 57 is located about 20 miles west of the Laboratory on land administered by the U.S. Forest Service. The Laboratory has used this site since 1974, and the site is subject to an interagency agreement between the U.S. Department of Energy and the U.S. Forest Service. The site was originally developed for the Hot Dry Rock geothermal energy program, which was terminated in 1995, and subsequently used for astronomical studies. In 2012, the Laboratory demolished and removed several small structures, trailers, equipment pads, and equipment and implemented site stabilization. Some astronomy activities may continue.
58 (Twomile North Site)	Technical Area 58 is located near the Laboratory's northwest border on Twomile Mesa North; it is forested area reserved for future use because of its proximity to Technical Area 03. The technical area houses the protective force running track, a few Laboratory-owned storage trailers, and a temporary storage area.
59 (Occupational Health Site)	Technical Area 59 is located on the south side of Pajarito Road adjacent to Technical Area 03. Facilities provide LANL support services in the areas of health physics, risk management, industrial hygiene and safety, policy and program analysis, air quality, water quality and hydrology, hazardous and solid waste analysis, and radiation protection.

Technical Area	Location and Activities
60 (Sigma Mesa)	Technical Area 60 is sited southeast of Technical Area 03 and is primarily used for physical support and infrastructure activities. The historic buildings for the Nevada Test Site Test Fabrication Facility and a test tower are also sited here. This facility is used as a waste storage area.
61 (East Jemez Site)	Technical Area 61 is located in the northern portion of the Laboratory. It contains physical support and infrastructure facilities. It also hosts a 1-megawatt solar power plant and the Los Alamos County Eco Transfer Station that are operated by Los Alamos County. This technical area is the former site of the Los Alamos County landfill, which is now closed and capped.
62 (Northwest Site)	Next to Technical Area 03 and West Jemez Road in the northwest corner of the Laboratory; Technical Area 62 serves as a forested buffer zone. This technical area is reserved for future use.
63 (Pajarito Service Area)	Technical Area 63 lies in the north-central portion of the Laboratory; it contains physical support and infrastructure facilities and the Transuranic Waste Facility.
64 (Central Guard Site)	Technical Area 64 is located in the north-central portion of the Laboratory and provides offices and storage space.
66 (Central Technical Support Site)	Technical Area 66 is on the southeast side of Pajarito Road in the center of the Laboratory. The Nonproliferation And National Security Center and Advanced Technology Assessment Center, the only facility at this technical area, provides office and technical space for technology transfer and other industrial partnership activities.
67 (Pajarito Mesa Site)	Technical Area 67 is a forested buffer zone in the north-central portion of the Laboratory and has no operations or facilities.
68 (Water Canyon Site)	In the southern portion of the Laboratory, Technical Area 68 contains environmental study areas.
69 (Anchor North Site)	In the northwestern corner of the Laboratory, Technical Area 69 serves as a forested buffer zone. The Emergency Operations Center is located here.
70 (Rio Grande Site)	Technical Area 70 is located on the southeastern boundary of the Laboratory. It is an undeveloped technical area that serves as a buffer zone and includes part of the White Rock Canyon Reserve.
71 (Southeast Site)	Technical Area 71 is located on the southeastern boundary of the Laboratory and is adjacent to White Rock to the northeast. It is an undeveloped technical area that serves as a buffer zone for the High Explosives Test Area. A portion of the White Rock Canyon Reserve is here.
72 (East Entry Site)	Technical Area 72 is located along East Jemez Road on the northeastern boundary of the Laboratory and used by protective force personnel for required firearms training and practice purposes.

Appendix D: Related Websites

For more information on environmental topics at Los Alamos National Laboratory (LANL or the Laboratory), visit the following websites.

Current and past environmental reports and supplemental data tables	*https://environment.lanl.gov/resources/annual-site-environmental-reports/*
The Laboratory's website	*https://www.lanl.gov*
U.S. Department of Energy/National Nuclear Security Administration Los Alamos Field Office	*https://www.energy.gov/nnsa/locations* *https://www.energy.gov/contact-us/mailing-addresses-and-information-numbers-operations-field-and-site-offices*
U.S. Department of Energy Environmental Management Los Alamos Field Office	*https://energy.gov/em-la/environmental-management-los-alamos-field-office*
U.S. Department of Energy website	*https://www.energy.gov*
The Laboratory's environmental stewardship pages	*https://environment.lanl.gov/*
N3B – Los Alamos Legacy Cleanup Contract website	*https://n3b-la.com*
The Laboratory's Electronic Public Reading Room website	*https://eprr.lanl.gov*
Los Alamos Legacy Cleanup Contract Electronic Public Reading Room website	*https://ext.em-la.doe.gov/EPRR*
The Laboratory's environmental database	*https://www.intellusnm.com*

The following Los Alamos National Laboratory organizations performed environmental surveillance, ensured environmental compliance, and provided environmental data for this report:

- Associate Directorate for Environment, Safety, Health, and Quality
- Environmental Protection and Compliance Division
- N3B Los Alamos
- Environmental Remediation Program

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LA-UR-19-28565	LA-13775-ENV	LA-14369-ENV
LA-UR-17-27987	LA-13861-ENV	LA-14407-ENV
LA-UR-16-26788	LA-13979-ENV	LA-14427-ENV
LA-UR-15-27513	LA-14162-ENV	LA-14445-ENV
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Technical coordination:
Leslie Hansen
Environmental Protection and Compliance Division-Environmental Stewardship Group

Additional coordination assistance:
Sonja Salzman
Nuclear Process Infrastructure Division-Hazardous Materials Management Group

Technical editing and layout:
Tamara Hawman
Communications and External Affairs Division-Technical Editing and Communications Group

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