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EXECUTIVE SUMMARY

This investigation report for Sandia Canyon presents the results of studies conducted to investigate contamination in sediment, surface water, shallow perched alluvial groundwater, the vadose zone, perched-intermediate groundwater, and regional groundwater potentially impacted by solid waste management units (SWMUs) and areas of concern (AOCs) located within the Sandia watershed. The investigations were conducted to fulfill the requirements of several New Mexico Environment Department– (NMED-) approved work plans and reports prepared by Los Alamos National Laboratory (the Laboratory). The Sandia Canyon investigation includes characterization activities for chromium contamination found in regional groundwater beneath Mortandad Canyon at concentrations exceeding the New Mexico groundwater standard of 50 µg/L. An important driver for this investigation was the identification of chromium at approximately 400 µg/L in the regional aquifer at well R-28 in late 2005. Since then, chromium concentrations of 800 µg/L to 900 µg/L have been identified in the regional aquifer at well R-42 and at 500 µg/L to 600 µg/L at perched-intermediate well SCI-2.

This report integrates the investigations conducted to date for chromium and other contaminants originating from Sandia Canyon. Data from beneath Los Alamos and Mortandad Canyons are included in the development of the conceptual model because of complex lateral hydrologic and contaminant pathways in the subsurface. Data collected during the investigations included in this report are used to (1) define the nature and extent of contamination; (2) update the conceptual model for contaminant distribution and transport; (3) assess potential present-day human health and ecological risk from contaminants; (4) set up the available remedial actions, if needed, that may be appropriate to achieve or maintain site conditions at an acceptable risk level; and (5) provide support for decisions at SWMUs and AOCs. The assessments in this report are primarily conducted using data the Laboratory collected since 2003 to evaluate environmental conditions. Data from previous investigations and from environmental surveillance sampling are used, when available, along with current data to help identify temporal trends in contamination.

The sediment investigations presented in this report focused on characterizing the nature, extent, and inventory of contaminants in post-1942 sediment deposits for 12 reaches in Sandia Canyon. Data from these reaches are used to evaluate potential human health and ecological risks and to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentrations and inventories at increasing distances from source areas and temporal trends in contamination. Sediment characterization was also conducted to support the biota investigations, according to the approved study plan presented in the Sandia Canyon biota investigation work plan, to provide additional data to support the assessment of potential ecological effects as presented in this report.

The water investigations presented in this report focus on watershed-scale characterization of surface-water base-flow, springs, alluvial groundwater, vadose-zone pore water, perched-intermediate groundwater, and regional groundwater within and beneath Sandia Canyon. Groundwater information from beneath adjacent watersheds (primarily Mortandad and Los Alamos Canyons) is also considered in this report because, in the Sandia Canyon area, contaminants have been transported laterally across watershed boundaries in the subsurface. These data are used to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentrations at increasing distances from the source areas and as a function of time since contaminant releases were halted. This work involved sampling persistent surface water and springs, drilling and installing monitoring wells, sampling new and preexisting groundwater monitoring wells, and measuring water-level variations in all groundwater sources.

Additional studies conducted as part of this investigation include (1) a study of vadose zone contaminant pathways using deionized-water leach and acid digestion of core, (2) a surface water balance using

stream gage data and alluvial-well water level data to constrain the location and amount of surface water and alluvial groundwater loss in Sandia Canyon, (3) an investigation of water table elevations for the regional aquifer beneath the site and to define hydraulic gradients and water level responses to water-supply pumping, (4) a continuous pumping and time-series sampling test to evaluate whether residual drilling fluid effects are present at regional aquifer well R-28 that could potentially impact reliability and representativeness of groundwater-quality data, (5) a surface-based geophysical survey using electrical methods to delineate zones of subsurface saturation and identify where localized infiltration and shallow perching horizons may be present, (6) a laboratory study to assess the impact of wetland drying on chromium stability and migration, (7) a laboratory study to assess chromium attenuation mechanisms using batch and column adsorption experiments and synchrotron X-ray absorption near-edge spectroscopy to determine the speciation of trivalent chromium [Cr(III)] versus Cr(VI) on site-specific hydrogeologic material, (8) implementation of site-scale groundwater-flow and contaminant-transport models to model distributions of the historic chromium source in Sandia Canyon, and (9) biological investigations to assess the potential for adverse effects of contaminants from post-1942 sediment deposits and surface water on terrestrial and aquatic ecological receptors.

Investigations of sediments, surface water and groundwater have identified the nature and extent of contaminants released into Sandia Canyon. Chemicals of potential concern (COPCs) in Sandia Canyon include inorganic, organic, and radionuclide constituents at concentrations above screening levels and federal and/or state groundwater standards. These COPCs are derived from several sources, including Laboratory SWMUs and AOCs, runoff from developed areas, and natural sources such as noncontaminated soils, sediments, and bedrock. Important source areas for Laboratory-derived COPCs in Technical Area 03 (TA-03) include the former outfall for the power plant cooling towers in upper Sandia Canyon [SWMU 03-012(b)] and a former transformer storage area [SWMU 03-056(c)] along the south fork of Sandia Canyon, and the former asphalt batch plant [Consolidated Unit 03-009(a)-00] along the north fork of Sandia Canyon. The impacts of additional Laboratory sources such as TA-53 and the Protective Force firing range at TA-72 are minor compared to the TA-03 sources. Much of the contamination related to Laboratory releases is associated with effluent discharges from TA-03 in the upper part of Sandia Canyon. The contamination has been dispersed downcanyon in sediments, surface water, and alluvial groundwater from release sites. Subsequently, waterborne constituents have percolated into the subsurface and are observed in vadose-zone pore water, intermediate-perched groundwater, and regional groundwater.

Contaminants in sediment that were originally released from TA-03 extend for approximately 10 to 12 km (6 to 7 mi) downcanyon from the sources. Stormwater runoff and surface-water flow from daily effluent releases generally infiltrate into alluvium in the middle portion of Sandia Canyon, resulting in the deposition of contaminated sediment in that area. This finding is consistent with the lack of evidence of past transport of Laboratory-derived contaminants from Sandia Canyon to the Rio Grande. The most important sediment deposition area is in the upper canyon where a broad wetland exists (reach S-2). This area contains approximately 80% to 90% of the inventory of chromium and PCBs within Sandia Canyon sediment deposits. Chromium is detected at low concentrations above the background value (BV) at the eastern Laboratory boundary (reach S-5E), and is below the BV farther downcanyon on Pueblo de San Ildefonso land. Similarly, polychlorinated biphenyls (PCBs) have been detected at low concentrations in reach S-5E but not farther downcanyon. Therefore, there is no evidence of recognizable transport of Laboratory-derived contaminants from Sandia Canyon into the Rio Grande. Polycyclic aromatic hydrocarbons (PAHs) are another important COPC and are detected in sediments primarily in reaches S-1N and S-2.

Investigations of surface water and groundwater have identified the nature and extent of contaminants released into Sandia Canyon. However, the investigation also identified a possible data gap in extent of

chromium to the south of well R-28, which will be addressed by the installation of a new regional monitoring well, R-50. The COPCs in surface water and alluvial groundwater relate closely to those identified for sediment but generally extend for a shorter distance downcanyon from the source than do the sediment COPCs. A group of COPCs, including PCBs and several adsorbing and precipitating trace metals, are limited to surface water and alluvial groundwater within Sandia Canyon as predicted by their geochemical behavior. Other more mobile COPCs are found in the underlying vadose zone, perched-intermediate groundwater, and regional groundwater. The conceptual model of fate and transport developed for this investigation suggests that surface water and alluvial groundwater infiltrate bedrock units predominantly along a spatially limited infiltration window in the middle portion of Sandia Canyon near TA-53. COPCs along the groundwater pathway, particularly chromium and nitrate, are found in various phases. These include pore water collected from unsaturated core, perched groundwater on top of and within the Cerros del Rio basalt, and, in the case of chromium, as an adsorbed or reduced solid phase fixed on bedrock units extending from the base of alluvium to the base of the basalts. Dissolved phase chromium is present within the regional aquifer as Cr(VI) at concentrations exceeding the 50 µg/L New Mexico groundwater standard (for filtered groundwater, NMGSF). Nitrate (as nitrogen) is also present in the regional aquifer at concentrations approximately one-half the NMGSF of 10 mg/L. The footprint of breakthrough locations from the vadose zone into the regional aquifer is estimated based on groundwater data and a calibrated groundwater model used to support the conceptual model. Chemical and hydrologic data from groundwater monitoring wells and the groundwater model enable definition of extent of chromium contamination at concentrations in the regional groundwater.

A mass balance for chromium is used to reconcile the estimated chromium mass released from the TA-03 power plant cooling tower outfall from 1956 to 1972 with the mass found in the principal environmental reservoirs of anthropogenic chromium, including surface sediment, vadose zone rocks, perched intermediate groundwater, and regional groundwater. The mass-balance estimate suggests that the majority of the chromium mass released from the original source is contained as Cr(III) in the reach S-2 sediments and as adsorbed and reduced phases in the vadose zone. Data from geochemical studies presented in this report indicate that the adsorbed and reduced chromium in the sediments and in the vadose zone are predominantly geochemically stable, indicating that the Cr(III) inventory is not likely to act as secondary sources for Cr(VI) under current hydrogeochemical conditions. A continued source of Cr(VI) to the regional aquifer might be present as perched-intermediate groundwater and in pore water within the vadose zone. However, measured chromium concentrations in perched-intermediate groundwater and vadose-zone pore water beneath Sandia Canyon are currently less than maximum observed concentrations in the regional aquifer. This finding indicates continuing recharge of the regional aquifer may result in decreasing chromium concentrations over time in the regional aquifer, although short-term variability, including slight increases, might be expected.

The site-specific human health risk assessment uses a recreational exposure scenario to represent the present-day and reasonably foreseeable future land use in Sandia Canyon. The assessment results indicate that for the recreational scenario, no areas in Sandia Canyon have contaminant concentrations greater than levels acceptable for noncarcinogens (hazard index of 1) or radionuclides (target dose limit of 15 mrem/yr in sediment and 4 mrem/yr in water). However, potential carcinogenic risk is twice the target risk level (incremental cancer risk criterion of 1×10^{-5}) in reach S-1N, primarily from PAHs concentrated in sediment. These PAHs may originate from the former asphalt batch plant located near the reach and/or runoff from developed areas at the head of the watershed.

A baseline ecological risk assessment indicates exposures to chemicals of potential ecological concern (COPECs) may cause potential adverse effects to terrestrial and aquatic receptors in the upper part of Sandia Canyon, including the Sandia wetland. For the terrestrial environment, the main COPECs of concern are PCBs for which there is the potential for adverse effects through the food web for shrews and

other wildlife, particularly in reach S-2. For the aquatic environment, both the field macroinvertebrate surveys and the chironomid bioassay point toward potential ecological impacts that could be related to contaminants from Laboratory operations or other sources. However, other non-COPEC factors related to habitat quality also correlate to decreased growth or survival from the bioassay measures and may be the cause of the findings.

In summary, chromium is the most important groundwater COPC identified for Sandia Canyon because it exceeds the NMGSF. The uncertainty in the southern extent of chromium contamination in the regional aquifer will be further refined with the installation of regional aquifer well R-50, which is planned for installation beginning in the fall of 2009. The results of this investigation also indicate that human health risks are acceptable for present-day and foreseeable future land use, although adverse ecological effects were observed within terrestrial and aquatic systems in upper Sandia Canyon. Groundwater will continue to be monitored as part of the annual Interim Facility-Wide Groundwater Monitoring Plan for potential changes in concentrations or distribution of contaminants for each of the zones, particularly with respect to chromium and nitrate in perched intermediate and regional groundwater. An assessment of remedial alternatives may be appropriate in the future and, if necessary, will address all pertinent issues in the watershed in an integrated manner.

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1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or the Laboratory) is a multidisciplinary research facility operated by the U.S. Department of Energy (DOE). The Laboratory is located in north-central New Mexico, approximately 90 km (60 mi) northeast of Albuquerque and 30 km (20 mi) northwest of Santa Fe. The Laboratory consists of a 103 km^2 (40 mi^2) area, mostly on the Pajarito Plateau, which is a series of mesas separated by eastward-draining canyons. It also includes part of White Rock Canyon along the Rio Grande to the east. The Laboratory is currently investigating sites potentially contaminated by past operations, both inside and outside the current Laboratory boundary, to ensure that contaminants do not threaten human health or the environment. The sites under investigation are designated as solid waste management units (SWMUs), areas of concern (AOCs), and consolidated units. Contamination in canyon bottoms and in groundwater is being investigated on a watershed basis between the possible sources and the Rio Grande, the master drainage in the region, in addition to investigations at SWMUs and AOCs.

1.1 Purpose and Scope

This investigation report presents the results of studies conducted from 1998 to 2009 to assess contamination in affected media in, beneath, and surrounding Sandia Canyon. The area encompassed by this investigation is shown in Figure 1.1-1. The investigation reported herein addresses sediment, surface water, shallow perched alluvial groundwater, perched-intermediate groundwater, and regional groundwater potentially impacted by SWMUs and AOCs located within the watershed. These media are collectively referred to as canyons media in this report.

The investigations were conducted to fulfill the requirements of several documents. The “Work Plan for Sandia Canyon and Cañada del Buey” (hereafter called “the work plan”) (LANL 1999, 064617) describes work scope and regulatory requirements for characterizing Sandia Canyon. The work plan contains a background review of SWMUs and AOCs in the watershed, the history of releases, and a review of contaminant data collected before the work plan was prepared. The New Mexico Environment Department (NMED) approved the work plan in 2005 following the Laboratory’s responses to a request for supplemental information (RSI), a subsequent notice of disapproval (NOD), and an addendum to the work plan (LANL 2003, 081597; NMED 2003, 076014; LANL 2005, 091542; NMED 2005, 091689; NMED 2005, 089312; LANL 2007, 095060). The requirement to implement the work plan was also included by reference in Section IV.B.5.b.i of the March 1, 2005, Compliance Order on Consent (the Consent Order).

Substantial work in and surrounding Sandia Canyon was also conducted pursuant to a letter from NMED (2005, 091683) requiring that the Laboratory submit an interim measures work plan to investigate the chromium contamination found in the regional groundwater beneath Mortandad Canyon (LANL 2006, 091987). An additional work plan, “Drilling Work Plan for Nature and Extent of Chromium Contamination in Groundwater Investigations” (LANL 2008, 101643) was prepared by the Laboratory for drilling and geochemistry studies of chromium and other contaminants related to releases in Sandia Canyon and observed in the regional aquifer near R-28 in Mortandad Canyon.

The investigations conducted under the work plan also followed the technical strategy presented in the “Core Document for Canyons Investigations” (hereafter “the canyons core document”) (LANL 1997, 055622). The canyons core document was prepared after a pilot study in Los Alamos and Pueblo Canyons was implemented in 1996, with the goal of standardizing the technical strategy for work in canyons. In 1998, NMED approved the core document (LANL 1998, 057666; NMED 1998, 058638).

This report represents the integration of all of the investigations conducted to date for chromium and other contaminants originating from Sandia Canyon. The domain of the discussions contained in this report is

larger than the area encompassed by and beneath the Sandia Canyon watershed. Data from and beneath adjacent watersheds are incorporated into the conceptual model as a result of hydrologic and contaminant pathways identified during the investigations. Data collected during the investigations included in this report are used to (1) define the nature and extent of contamination; (2) update the conceptual model for contaminant distribution and transport; (3) assess potential present-day human health and ecological risk from contaminants; (4) determine and recommend potential remedial actions, if needed, that may be appropriate to achieve or maintain site conditions at an acceptable risk level; and (5) provide support for decisions at SWMUs and AOCs. The assessments in this report are primarily conducted using data the Laboratory collected since 1998 to evaluate environmental conditions. Data from previous investigations and from environmental surveillance sampling are used, when available, along with current data to help identify any temporal trends in contamination.

This report addresses characterization and risk assessment on the spatial scale of an entire canyon system, encompassing a large area downcanyon and downgradient of SWMUs and AOCs. The characterization and assessment approach used in this investigation provides an integrating perspective on historical and current contaminant releases to the canyon floor and subsequent contaminant redistribution resulting from various transport processes. This approach facilitates the development of conceptual models that describe expected spatial and temporal trends in contaminant concentrations, thus supporting recommendations for long-term monitoring. The results also support the Laboratory's watershed approach by providing information on the extent of contamination associated with SWMUs, AOCs and aggregate areas in the Sandia Canyon watershed and by helping identify and prioritize remedial activities within the watershed. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with DOE policy.

1.2 Organization of Investigation Report

This investigation report has the following sections, following the outline used in the NMED-approved "Mortandad Canyon Investigation Report" (LANL 2006, 094161; NMED 2007, 095109). Section 1 is an introduction to the report and to the Sandia watershed. Section 2 provides background information on the sources and history of contaminant releases, previous investigations of canyons media, and remediation activities that have occurred in the watershed. Section 3 describes the scope of activities in this investigation. Section 4 introduces the field investigations. Section 5 describes the regulatory context of this investigation. Section 6 presents screening level (SL) assessments that identify chemicals of potential concern (COPCs) and that help focus subsequent sections on the subset of the most important COPCs for evaluating potential human health risk. Section 7 presents a physical system conceptual model, including discussions of the nature, sources, extent, fate, and transport of select COPCs that are most relevant for evaluating potential human health and ecological risk and contaminant distributions. Section 8 presents ecological risk screening assessments and human health risk screening assessments and results. Section 9 presents conclusions and recommendations. Acknowledgements of those who contributed to this report are listed in section 10. Section 11 presents the references cited in this report.

This report includes the following appendixes. Appendix A presents a list of acronyms and abbreviations, a table showing conversion of metric units to U.S. customary units, and data qualifier definitions. Appendix B presents field-investigation methods and results. Appendix C presents analytical results from sediment and water samples and summarizes data quality. Data packages are included as Attachment C-1 on DVDs. Appendix D presents supporting information on spatial contaminant trends. Appendix E presents supporting information on risk and statistical analyses. Supplemental tables for Appendixes B through E are provided on CD in Attachment 1. Appendix F presents an alluvial water-level study. Appendix G provides an updated map of the water table beneath the Laboratory based on new

wells and an analysis of transient, regional water levels. Appendix H presents results from the chromium isotope investigation. Appendix I describes analyses of attenuation mechanisms for chromium in the subsurface based on field observations and laboratory analysis. Appendix J presents the results of laboratory drying experiments of wetland sediments. Appendix K summarizes a plant uptake investigation. Appendix L describes numerical simulations of chromium transport in the regional aquifer. Appendix M provides the results of a low-flow pump test at regional well R-28. Finally, Appendix N presents geologic cross-sections along and perpendicular to Sandia Canyon.

1.3 Watershed Description

Sandia Canyon heads on the Pajarito Plateau in Technical Area 03 (TA-03), has a maximum elevation of approximately 2320 m (7600 ft) above sea level (asl), and extends approximately 17.6 km (10.9 mi) to the Rio Grande at an elevation of approximately 1660 m (5445 ft) asl (Figure 1.1-1). The watershed has a drainage area of 14.2 km^2 (5.5 mi^2), of which 45% is on Laboratory land, 39% is on Pueblo de San Ildefonso land, 15% is within Bandelier National Monument, and 1% is on private land. The part of the watershed upcanyon from state highway NM 4 and White Rock, the primary focus of this investigation, has a drainage area of 6.7 km^2 (2.6 mi^2), of which 96% is on Laboratory land, 3% is on Pueblo de San Ildefonso land, and 1% is on private land.

Bedrock geologic units exposed within the Sandia Canyon watershed consist largely of the Tshirege Member of the Bandelier Tuff and basaltic rocks of the Cerros del Rio volcanic field (Griggs and Hem 1964, 092516; Smith et al. 1970, 009752; Dethier 1997, 049843). Geologic units within this watershed are discussed in more detail in section 7 of this report.

A comprehensive overview of the biological setting of the Sandia Canyon watershed is provided in the "Sandia Canyon Biota Investigation Work Plan" (LANL 2007, 099152). Details about the hydrology of the watershed are provided in section 7 and Appendix B of this report.

1.4 Current Land Use

The portion of the Sandia Canyon watershed downcanyon from SWMUs and AOCs is located on DOE land, private land at the Royal Crest trailer park, Bandelier National Monument land, and Pueblo de San Ildefonso land. Laboratory activities in the canyon bottom are largely restricted to environmental work, such as sediment and water sampling, except for the Protective Force firing range in TA-72. Currently, some public access to the watershed is available on Laboratory land downcanyon from SWMUs and AOCs, east of the firing range, and other parts of the canyon may be used by Laboratory personnel for recreational activities, such as hiking. The Pueblo land supports various traditional uses.

2.0 BACKGROUND

Inorganic chemicals, organic chemicals, and radionuclides have been released into Sandia Canyon from a variety of sources, primarily Laboratory operations and Laboratory physical support in several TAs, probably since the Laboratory began operation in 1943. This section summarizes known releases of inorganic chemicals, organic chemicals, and radionuclides that have contributed to contamination in the Sandia watershed. The primary Laboratory use of Sandia Canyon has been for the discharge of liquid waste from industrial and sanitary systems. The canyon was also the location of a brief operation of a small-charge implosion and initiator experiment site in the 1940s and in recent years has served as the location of the Laboratory's security force firing range. These operations, conducted in and next to Sandia Canyon, might have discharged to Sandia Canyon and its tributaries. Discharges are associated with

outfalls, surface runoff, and firing site activities located at TA-03, which is the current location of the Laboratory administration complex, and former TA-20, which briefly operated in the 1940s as a firing site. Additional discharges began with the continued expansion of Laboratory operations to include accelerator technology research and a firing range in the 1960s, specifically at TA-53 and TA-72.

Much of the contamination related to Laboratory releases is associated with effluent discharges. The contamination has been dispersed into the watershed in sediments, surface water, and alluvial groundwater from release sites. Subsequently, waterborne constituents have percolated into the subsurface and are observed in vadose-zone pore water. Hexavalent chromium is present in intermediate-perched water and in regional groundwater. SWMUs and AOCs that may contribute contaminants to the Sandia watershed are described in various work plans and historical investigation reports (LANL 1999, 064617; LANL 2008, 100692; LANL 2008, 100693; LANL 2009, 105079; LANL 2009, 105078). In addition, releases associated with the TA-03 Power Plant cooling towers are discussed in documents related to the chromium investigations (LANL 2006, 091987; LANL 2006, 094431; LANL 2007, 098938; LANL 2008, 102996). The following sections provide an overview of the sources and history of contaminant releases in the watershed as well as investigations that address contaminant distribution and concentrations in canyons media. Remediation activities implemented to reduce contamination in the canyon bottom or in source areas are also discussed.

2.1 Sources and History of Contaminant Releases

2.1.1 TA-03

Sandia Canyon heads within TA-03 (Plate 1). TA-03 contains most of the Laboratory's administrative buildings and public and corporate access facilities. In addition, this area houses several Laboratory activities such as experimental sciences, special nuclear materials, theoretical/computations, and physical support operations (LANL 2008, 100693). The SWMUs and AOCs located at TA-03 and within the Sandia watershed will be investigated as part of the Upper Sandia Canyon Aggregate Area investigation (LANL 2008, 100692).

2.1.1.1 Effluent Releases

Liquid effluents have been released from TA-03 to Sandia Canyon since the early 1950s and continue today. The highest volume releases include treated sanitary wastewater, steam plant effluent, and cooling tower blowdown from the TA-03 power plant (building 03-0022, Plate 1). From 1951 to 1985, treated effluent generated by the TA-03 waste water treatment plant (WWTP) [Consolidated Unit 03-014(a)-99, discussed in section 2.1.1.4] was recycled and used for cooling at the TA-03 power plant (LANL 2008, 100692). The water was further treated before it was used as cooling water, and the history of water treatment chemicals used at the power plant is provided in the "Interim Measures Report for Chromium Contamination" (LANL 2006, 094431). In particular, potassium dichromate usage from 1956 to 1972 resulted in an estimated total release of approximately 31,000 to 72,000 kg (69,000 to 160,000 lb) of hexavalent chromium [Cr(VI)] into the south fork of upper Sandia Canyon [SWMU 03-012(b)] (LANL 2007, 098938). Phosphate, zinc, and sulfuric acid were other common additives used during this time period. Since 1985, the Laboratory uses the Los Alamos County power grid for its electrical power needs, and the TA-03 power plant is used only for backup or emergency power, at most a few times a month. Municipal water rather than recycled waste water is used for cooling. Chlorine, bromine, sodium molybdate, zinc chloride, other inorganic salts, and acrylate polymers have been used as cooling water additives during this period of low power generation (LANL 2006, 094431).

In 1976 and 1977, a monitoring program detected tritium in effluent from sanitary sewage treatment facilities at the Laboratory (Stoker 1977, 037377). The study noted that there was apparently routine tritium contamination entering the TA-03 treatment facility in upper Sandia Canyon. Effluent tritium concentrations measured approximately monthly from June 1976 to January 1977 ranged between 4200 pCi/L and 38,500 pCi/L.

Currently, three National Pollutant Discharge Elimination System (NPDES) outfalls release to upper Sandia Canyon in the TA-03 area (EPA 2007, 099009). NPDES Outfall 001 (formerly designated as NPDES Outfall 01A001 and shown on Plate 1 with this designation) discharges effluent, predominantly from the Laboratory's TA-46 Sanitary Wastewater Systems Consolidation (SWSC) plant and the TA-03 steam plant boilers. Effluent for infrequent cooling of the TA-03 power plant is also discharged here. Outfall 001 is the main effluent source of water to Sandia Canyon, and average discharges approach 290,000 gal./d. NPDES outfalls 03A027 and 03A199 (Plate 1), associated with facility cooling of the Strategic Computing Complex (SCC) and the Laboratory Data Communications Center (LDCC), also discharge to upper Sandia Canyon. These two outfalls contribute less than 100,000 gal./d of cooling water effluent to the canyon. Together these three outfalls (001, 03A027, and 03A199) provide sufficient water to mobilize contaminants within the watershed. Appendix F of this report shows the daily outfall volumes recorded for the three NPDES outfalls from October 2006 to June 2009. Effluent at the outfall points is monitored in compliance with the NPDES permits.

Lesser volumes of effluent from other outfalls, as well as floor, roof and storm drains, have also released to the upper Sandia watershed from TA-03. Sources associated with other small outfalls include treated cooling water, and caustic wash and rinse water from cleaning gas cylinders. Materials associated with floor drains include Stoddard solvents, dry acid, caustic materials, spent paint solvents, cutting oils contaminated with machined beryllium particles, welding torch wastewater, diesel fuel, hydraulic and compressor oils, residual oil from vehicle maintenance bays, organic solvents, and potential releases from electrochemical and depleted uranium (DU) processing facilities (LANL 2008, 100693). By 1987, most floor drains were routed to the Laboratory's sanitary sewer line and no longer discharge to outfalls.

2.1.1.2 Former Asphalt Batch Plant

Consolidated Unit 03-009(a)-00 includes several SWMUs and AOCs related to the former asphalt batch plant (building 03-0073) that began operations in 1961 and was decommissioned in 2002. This consolidated unit consists of disposal sites associated with normal construction and infrastructure maintenance at the former plant. These disposal sites contained items such as concrete, cured asphalt, and soil. Components of these materials include asphalt, petroleum hydrocarbons (including oils, kerosene, and diesel fuel), and light distillates (LANL 2008, 100693). SWMUs and AOCs include former surface storage sites, a former settling pond, several former asphalt and asphalt emulsion storage and product tanks, a former asphalt landfill, a former storm drain, a former oil cleanout bin, former diesel oil storage tanks, and a former outfall. Many of these areas have been remediated and are discussed further in section 2.3.2. Soil contamination occurred at several of these SWMUs and AOCs and will be investigated further (LANL 2008, 100692).

2.1.1.3 Polychlorinated Biphenyl Sites

Several AOCs and one SWMU within TA-03 are the locations of former polychlorinated biphenyl- (PCB-) containing transformers, former transformer or capacitor bank storage areas, or former PCB spills (LANL 2008, 100693). PCB-containing transformers and capacitors have either been removed or replaced with non-PCB equipment. At SWMU 03-056(c), an inactive outdoor storage area located on the north side of a utilities shop (building 03-0233), PCB soil contamination spread beyond the SWMU boundary. Several

cleanup activities and a voluntary corrective action (VCA) were performed at this SWMU, as discussed in section 2.3.1 (LANL 2001, 071259; LANL 2008, 100693). PCB-containing fluids and solvents are potentially associated with releases from these sites.

2.1.1.4 Former TA-03 Waste Water Treatment Plant

Thirty SWMUs and AOCs were assigned to the components and outfalls of the former WWTP that operated at TA-03 from 1951 until 1992, when the Laboratory's SWSC plant became active (LANL 1993, 020947, p. 5-46). The WWTP (building 03-0223) is located on the southern rim (near the head) of Sandia Canyon (LANL 2008, 100693) and primarily served TA-03, TA-43, TA-59, and TA-60 and the trailer park on East Jemez Road. The WWTP had two parallel systems, the north and south plants. Each system consisted of entrance works, Imhoff tanks, sludge-drying beds, settling/digestion tanks, dosing siphons, a chlorination system, trickling filters, final clarifying tanks, lift systems, and an outfall (SSS01S). From the late 1950s to the late 1970s, dried sludge was added to the soil around the entrance works as a soil amendment (LANL 1993, 020947). Soil contamination occurred at several SWMUs and AOCs and will be investigated further (LANL 2008, 100692). Chemicals that enter a WWTP can become concentrated in sewage sludge and may become potential soil contaminants. Some metals (e.g., chromium, copper, lead, mercury, silver, zinc), organic chemicals, PCBs (Aroclor-1260), and radionuclides were detected in soil samples at SWMUs and AOCs associated with the former WWTP.

2.1.1.5 Other SWMUs and AOCs

Several lesser SWMUs and AOCs within TA-03 are the locations of former equipment storage areas, container storage areas, surface disposal sites or operational releases (LANL 2008, 100693). Contaminants potentially released at these sites include pesticides, herbicides, hydraulic and vacuum pump oil, waste solvents, small amounts of electroplating wastewater, inorganic chemicals, and DU.

2.1.2 TA-60

TA-60, also known as Sigma Site, was created from the eastern portion of TA-03 and lies on Sigma Mesa between Sandia and Mortandad Canyons (Plate 1). All the buildings at TA-60 are located on the western end of the mesa and contain Laboratory support and maintenance operations and contractor service facilities. The Nevada Test Site (NTS) test fabrication facility (building 60-0017), the NTS test tower (building 60-0018), several small abandoned experimental areas, including a solar pond and a test drill hole, a new asphalt batch plant, and storage sites for pesticides, topsoil, and tuff are also located at TA-60 (LANL 1999, 064617, p. 2-25).

Several SWMUs and AOCs are former storage or staging areas for debris (e.g., concrete, wood, asphalt, and pipes); containers of diesel sludge and petroleum products; drilling equipment; and new products (containers of solvents, antifreeze, motor oil, transmission fluid and window-washing fluid) (LANL 2008, 100693).

SWMU 60-006(a) is an abandoned septic system that served building 60-0017, the NTS test rack facility, and building 60-0018, a test tower. The septic system consists of a septic tank and an associated seepage pit. The septic system received wastewater from facility bathrooms and seven floor drains, including one in a paint booth. It was constructed in 1986 and abandoned in place in 1989 when the facility was connected to the sanitary sewer system and to the TA-03 WWTP (LANL 2008, 100693). The contents of the tank were not removed before abandonment. Potential contaminants include inorganic and organic chemicals. Both the septic tank and the seepage pit will be removed as part of the Upper Sandia Canyon Aggregate Area investigation (LANL 2008, 100692).

2.1.3 TA-61

TA-61 was created from a portion of TA-03 in 1989. The area contains the Los Alamos County municipal landfill, a residential trailer park, a private concrete batch plant, and a Laboratory-operated asphalt batch plant. The landfill, established in 1974, dominates the site and is designated as SWMU 61-005. Large trenches and disposal areas have been excavated from the north wall of Sandia Canyon to accommodate the landfill, which accepts waste from the county and the Laboratory. TA-61 is bounded on the north by Los Alamos Canyon and on the south by Sandia Canyon (Plate 1). SWMUs and AOCs located within TA-61 are being investigated as part of the Upper Sandia Canyon Aggregate Area investigation (LANL 2008, 100692).

SWMU 61-002 is a former storage area at TA-61, east of the Radio Repair Shop (building 61-0023, formerly building 03-0282) on East Jemez Road (Figure 4.3-1). Historically, the area was used to store capacitors and transformers. In addition, the storage area contained several oil-filled containers and unmarked containers. Before 1985, containers of PCB-contaminated oil were stored in this area and were known to have leaked. In 1986, elevated PCB concentrations were detected in soil samples. The area was subsequently excavated, backfilled with clean soil, and paved over with asphalt. After the 1986 remediation, the east side of the storage area was used to store electrical equipment, some of which contained PCBs (LANL 1993, 020947, p. 5-101). All storage operations were discontinued in 1992. Further corrective actions were performed in 2005, including removal of two underground product lines and 424 yd^3 of soil.

Potential contaminants that may have run off from TA-61 include PCBs, petroleum hydrocarbons, and possibly lead (LANL 1996, 052930; LANL 2008, 100692).

2.1.4 TA-53

The Los Alamos Neutron Science Center (LANSCE) (previously called the Los Alamos Meson Physics Facility or the Clinton P. Anderson Meson Facility) consists of a 0.5-mi- (0.8-km-) long linear proton accelerator and associated experimental research areas, offices, laboratories, and shops. The accelerator is used to produce subatomic particles for basic research, isotope production, radiochemistry, solid state physics research, and accelerator technology development (LANL 1994, 034756, p. 2-5). The Sandia Canyon work plan discusses the facility, which has been operational since 1970 (LANL 1999, 064617). The main activity at TA-53 currently centers around LANSCE and associated experimental areas.

The former TA-53 surface impoundments [Consolidated Unit 53-002(a)-99] may have contributed some contaminants to Sandia Canyon. These surface impoundments received treated sanitary and radioactive waste from TA-53 facilities. Details are included in the work plan (LANL 1999, 064617). These impoundments have been remediated and since 2006 their status is “corrective action complete with controls” (NMED 2006, 095421); they are no longer a potential source of contamination to the watershed.

Several SWMUs and AOCs are former storage areas for spent solvents, acidic wastes and scintillation oil; an inactive waste disposal pit that may have received solvent wastes (trichloroethene and Freon), PCBs, and radioactive activation products; former underground storage tanks (with associated drain lines) that were used to temporarily store radioactive liquid waste (RLW); and an inactive aboveground neutralization tank for neutralized RLW, that may also have contained mercury.

AOC 53-012(e) is a drainline and former outfall that discharged cooling tower water and floor drains to Sandia Canyon starting in approximately 1968. Several former NPDES outfalls discharged from TA-53

into Sandia Canyon; most were removed from the NPDES permit between 1995 and 1998 (LANL 1999, 064617). Historically, cooling tower additives included sodium molybdate, phosphate, and zinc.

Runoff and effluent from TA-53 may have carried contaminants into Sandia Canyon. The Lower Sandia Canyon Aggregate Area historical investigation report (LANL 2009, 105078) lists potential low-level soil contamination from metals (including lead shot), organic chemicals, PCBs and radionuclides.

2.1.5 Former TA-20

Former TA-20 was used during the Manhattan Project to test initiators (devices that generate neutrons to initiate nuclear explosions). Later, this TA was used briefly for other types of implosion tests. The site consisted of a series of firing areas that were spaced along a small road heading west from NM 4 (LANL 1994, 034756, p. 2-1). Former TA-20 is now located partly within TA-53 and partly within TA-72 (LANL 2009, 105078).

SWMUs and AOCs in former TA-20 primarily include former landfills and former firing sites (LANL 2008, 105078). Two former septic systems are also AOCs in former TA-20. Most of these sites were removed or partly removed in 1948. As part of the 1995 Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) soil sampling, total uranium was measured above soil BVs in most samples at most of these sites. Other contaminants observed, but at lower frequency and at fewer sites, include beryllium, cadmium, chromium, copper, lead, mercury, silver, thallium, cesium-137, europium-152 and strontium-90 and uranium isotopes.

2.1.6 TA-72

TA-72 is currently used as a small-arms firing range by the Laboratory's security force and has been operational since 1966. Lead is known to be present in the firing range; bullets are scattered around the base of the berms and cliffs. Lead shot from skeet shooting is visible on the ground surface (LANL 2009, 105078).

Two Los Alamos County water-supply wells, PM-1 and PM-3 (Plate 1), each with associated facilities (chlorinator and pump station), are also located within TA-72 (LANL 1994, 034756, p. 2-9).

2.1.7 Runoff from Developed Areas

The Sandia watershed includes developed areas within the Laboratory, the Los Alamos County municipal landfill, a residential trailer park, and a private concrete batch plant. Near the head of the watershed, several large paved parking lots and roads drain into the canyon. Runoff from developed areas can transport various contaminants into the canyon. Contaminants commonly found below developed areas include constituents in motor oil, gasoline, diesel fuel, asphalt, road salt, PCBs, heavy metals, and pesticides. Polycyclic aromatic hydrocarbons (PAHs), frequently associated with vehicle usage and asphalt, are a common class of contaminants associated with developed areas (Edwards 1983, 082302; Lopes and Dionne 1998, 082309; Van Metre et al. 2000, 082262). Metals associated with runoff from roads include cadmium, chromium, copper, lead, nickel, and zinc (Walker et al. 1999, 082308; Breault and Granato 2000, 082310, p. 49). Consistent with studies in other regions, investigations in canyons in and near the Laboratory have identified various inorganic and organic COPCs as being associated with runoff from developed areas (LANL 2004, 087390, pp. 7-14, 7-16).

2.1.8 Cerro Grande Fire

In May 2000, the Cerro Grande fire burned part of the Sandia watershed. Approximately 1.6 km^2 (0.6 mi^2) of the watershed was within the burn perimeter area (BAER 2000, 072659), comprising 24% of its area above NM 4. All of the burn area within the burn perimeter was classified as low burn severity or not burned, and effects of the fire in this watershed were relatively minor. Various naturally occurring inorganic chemicals (e.g., barium, cobalt, and manganese) and anthropogenically created fallout radionuclides (e.g., cesium-137, plutonium-239/240, and strontium-90) were concentrated in Cerro Grande ash at levels exceeding that of background sediments before the fire, and the transport of ash has resulted in elevated levels of these analytes in postfire sediment deposits in some canyons (Katzman et al. 2001, 072660; Kraig et al. 2002, 085536; LANL 2004, 087390). Elevated levels of inorganic chemicals and radionuclides attributed to the transport of ash have also been found in stormwater samples in some canyons (Gallaher and Koch 2004, 088747).

2.2 Contamination in Canyons Media

Contamination in sediment, surface water, and groundwater in Sandia Canyon has been evaluated in several studies before this report, dating back to 1971 (Purtymun 1971, 004795). This previous work documented the presence of elevated levels of inorganic chemicals, organic chemicals, and radionuclides in canyon media and has evaluated the potential effects of contaminants on biota. Some key studies, summarized below, provide background and supplemental data for the investigations presented in this report. Relevant information from these studies is also included in subsequent sections of this report.

2.2.1 Environmental Surveillance Program

The Laboratory's Environmental Surveillance Program (ESP) has sampled and analyzed sediments and surface water in Sandia Canyon since approximately 1970. This work, reported in annual Environmental Surveillance reports (e.g., LANL 2008, 105241), and in other reports (e.g., Purtymun 1971, 004795; Purtymun 1973, 004971; Purtymun 1975, 011787; Gallaher and Koch 2004, 088747) supports the evaluation of long-term trends in contamination in different media and an understanding of the role of stormwater transport.

2.2.2 Ecology and Environmental Sciences Groups

The Laboratory's Ecology and Environmental Sciences Groups have conducted studies on the potential uptake of contaminants by biota in Sandia Canyon. This includes studies of the potential uptake of contaminants by mammals (Bennett et al. 1999, 082652) and birds (Fair and Sommer 2002, 098047; Fair and Colestock 2003, 098046; Fair et al. 2004, 085524; Fair and Heikoop 2006, 098045).

2.2.3 Resource Conservation and Recovery Act and Consent Order Investigations

Since 1998, detailed studies of canyons media in Sandia Canyon have been conducted by the Laboratory as part of RCRA and Consent Order investigations. Summaries of results of sediment investigations through 2007 have been presented previously (Katzman 2000, 064349; LANL 2007, 098127). Supplemental data on contamination in canyons media are available through other Laboratory reports (e.g., LANL 1996, 054466; LANL 1996, 054467; LANL 1997, 056660.4). The work presented in this investigation report builds on these previous studies.

2.2.4 NMED and EPA

NMED and the U.S. Environmental Protection Agency (EPA) or their subcontractors have collected and analyzed samples from canyons media and conducted aquatic macroinvertebrate studies in Sandia Canyon as part of oversight activities (NMED 1997, 057582; NMED 1998, 057583; EPA 2001, 070669). These data provide supplemental information about contamination in the watershed.

2.3 Remediation Activities

Several remediation activities in the Sandia watershed have reduced the potential for transport of contaminants from SWMUs or AOCs into the canyon bottoms. The activities most relevant to this investigation are summarized below.

2.3.1 PCB Cleanup

PCB cleanup has occurred at the PCB sites discussed in sections 2.1.1.3 and 2.1.3. In 1995, an expedited cleanup was conducted at SWMU 03-056(c), and PCB-contaminated soil was excavated from an area approximately 60 ft long by 70 ft wide. A VCA was also conducted in 2000 when approximately 2400 yd^3 of contaminated soil was excavated from the SWMU (LANL 2001, 071259). In addition, PCB-containing transformers and capacitors have been removed, and sites showing evidence of leaks were sampled and cleaned up in accordance with Toxic Substances Control Act (TSCA) requirement (40 Code of Federal Regulations [CFR] 761) (LANL 2008, 100693).

2.3.2 Remediation at the Former TA-03 Asphalt Batch Plant

The TA-03 asphalt batch plant (former structure 03-0073) was decommissioned in 2002 and dismantled in 2003. The tanks associated with the plant were cleaned out, removed and disposed of at the Los Alamos County landfill in 2003 or earlier. In 2003, sediment and water were removed from the settling pond, and the pond was filled with clean fill. The storm drain is now closed and locked. Much of the former plant's footprint was paved with asphalt for use as a parking lot in 2003 (LANL 2008, 099214).

2.3.3 Remediation at Former TA-20

Remediation activities at former TA-20 are described in the historical investigation report for the Lower Sandia Canyon Aggregate Area (LANL 2009, 105078). In 1946, an intensive radiation monitoring and cleanup effort was performed at TA-20. Soil contaminated with polonium was removed from firing areas, from a cave where radioactive materials had been stored, and from disposal pits. Polonium-210 was used in initiator tests but has only a 138-d half-life and would no longer be present at the site. Some structures were also removed. Beginning in 1948, TA-20 was largely decommissioned so East Jemez Rd could be built in Sandia Canyon. Decommissioning activities included removal of structures, cleanup of high explosives (HE) and removal of landfill materials. Additional structures were removed in the 1960s and in 1985 (mostly underground structures including manholes, pull boxes, and footings) (LANL 1994, 034756)(LANL 1994, 034756). In 1995, a VCA was conducted at AOC 20-003(c), a former U.S. Navy Gun Site (LANL 1996, 053775).

2.3.4 Planting of Cottonwoods and Willows in Sandia Canyon

Cottonwood and willow stems were planted in upper Sandia Canyon (reach S-2) in March and April 2007 to help stabilize contaminated sediment deposits, slow floodwaters, enhance the deposition of sediment and associated contaminants, and improve habitat. Sixty cottonwood stems were planted in a transition

area west of the primary cattail wetland and approximately 100-200 m east of the landfill bridge culvert. In this area inset, abandoned channel surfaces widen and the channel meanders. The cottonwood planting was designed to help maintain or enhance the meandering. Seven hundred willow stems were also planted in this area and farther east, extending to the primary cattail wetland. In addition, 300 willow stems were planted immediately east of the headcut at the east end of the wetland to help stabilize that area.

3.0 SCOPE OF ACTIVITIES

The scope of activities in this report include investigations of sediment, surface water, groundwater, geochemistry, and biota in the Sandia watershed, as presented in the work plan and subsequent documents (LANL 1999, 064617; LANL 2003, 081597; LANL 2005, 091542; LANL 2006, 091987; LANL 2006, 093388; LANL 2006, 094129; LANL 2007, 095060; LANL 2007, 095454; LANL 2007, 098127; LANL 2007, 099152). Data from these studies are used to evaluate spatial and temporal trends in contamination within the Sandia watershed and across watershed boundaries, including variations in contaminant concentrations at increasing distances from the source areas and as a function of time. Groundwater investigations in the adjacent watersheds of Los Alamos and Mortandad Canyons are also included because they are important to understand the subsurface transport of contaminants originating from Sandia Canyon. These investigations are discussed below.

3.1 Sediment Investigations

The sediment investigations presented in this report focused on characterizing the nature, extent, concentrations, and inventory of contaminants in post-1942 sediment deposits in a series of reaches in Sandia Canyon. Data from these reaches are used to evaluate potential human health and ecological risks and to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentrations and inventories at increasing distances from source areas and temporal trends in contamination. The investigation methods are discussed in section 4.1 and Appendix B, section B-1, of this report; in the approved work plan and subsequent related documents (LANL 1999, 064617; LANL 2003, 081597; LANL 2005, 091542); and in the canyons core document (LANL 1997, 055622; LANL 1998, 057666).

The scope of this investigation included 12 reaches in Sandia Canyon, including the areas presented in section 7.1.2 of the work plan (LANL 1999, 064617; pp. 7-9 to 7-14), as modified in an addendum to the work plan (LANL 2007, 095060) and a Phase 1 summary report (LANL 2007, 098127). One reach specified in the work plan that had been previously characterized in 1998 (reach S-1, Sandia Canyon above the landfill bridge), was subsequently subdivided into three reaches (S-1 North, S-1 South, and S-2 West). Table 3.1-1 lists the sediment investigation reaches and the years in which samples were collected in each reach. Table 3.1-1 also provides abbreviations for reach names included in this report and the approximate length and distance of each reach from the Rio Grande, as well as additional information on the reaches. Figure 3.1-1 and Plate 1 show the location of the investigation reaches within Sandia Canyon.

Sediment characterization was also conducted to support the biota investigations according to the approved study plan presented in the “Sandia Canyon Biota Investigation Work Plan” (LANL 2007, 099152). This sampling was conducted to provide additional data to support the assessment of potential ecological effects from sediment contamination. This characterization included resampling previously sampled sediment layers in some reaches and collecting samples at new locations in other reaches. Details of the methodology are presented in section B-3 of Appendix B.

3.2 Surface-Water and Groundwater Investigations

The water investigations presented in this report focus on watershed-scale characterization of surface-water base-flow, springs, alluvial groundwater, intermediate perched groundwater, and regional groundwater within and beneath the Sandia watershed to satisfy the requirements in several documents (LANL 1998, 059599; LANL 1999, 064617; LANL 2006, 091987; NMED 2006, 092543; LANL 2007, 095454; NMED 2007, 095832; LANL 2007, 098938; LANL 2007, 099607; NMED 2008, 100964). Surface water and groundwater information from adjacent watersheds (primarily Mortandad and Los Alamos Canyons) is also considered in this report because contaminants have been transported across watershed boundaries in the subsurface. Data from these components of the hydrogeologic system are used to evaluate potential human health and ecological risk as well as to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentrations at increasing distances from the source areas and as a function of time since contaminant releases were halted. This work involved sampling persistent surface water and springs, drilling and installing monitoring wells, sampling new and preexisting groundwater wells, and measuring water-level variations in all groundwater sources. Figure 3.2-1 and Plate 1 show the locations of surface-water and groundwater sites sampled as part of this investigation. The investigation methods are discussed in Appendix B of this report.

3.2.1 Alluvial Well Installations

Five alluvial monitoring wells, wells SCA-1 through SCA-5, were installed in 2006 to fulfill the requirements of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). SCA-1 was installed in upper Sandia Canyon in the wetland and the remaining four wells, SCA-2, SCA-3, SCA-4 and SCA-5, were installed in the middle part of Sandia Canyon near East Jemez Road (Figure 3.2-1 and Plate 1). The goal of the five alluvial wells was to constrain the extent of alluvial saturation, determine the nature and extent of contamination (with particular emphasis on chromium) within alluvial groundwater, and collect data to calculate chromium inventories. Details about well completions and hydrogeologic conditions encountered in these wells are provided in the "Interim Measures Investigation Report for Chromium Contamination in Groundwater" (LANL 2006, 094431) and "Final Completion Report for Sandia Canyon Drilling Program 2006" (Kleinfelder 2006, 095121).

Alluvial monitoring wells SCO-1 and SCO-2 were installed in the middle part of Sandia Canyon, west of NM 4, in 1990 to satisfy special permit conditions in the Hazardous and Solid Waste Amendments (HSWA) Module VIII portion of the Laboratory's RCRA operating permit (EPA 1990, 001585). These alluvial wells were installed near the eastern Laboratory boundary to investigate the nature and extent of alluvial groundwater (Figure 3.2-1 and Plate 1). Both wells were dry at the time of installation (Purtymun and Stoker 1990, 007508) and periodic attempts to sample these wells as part of the Laboratory's annual environmental surveillance activities have failed from lack of water.

3.2.2 Piezometer Installations

Five piezometers (SCP-1a, SCP-1b, SCP-1c, SCP-2a, and SCP-2b; Plate 1) were installed as part of two piezometer nests in 2006 to fulfill the requirements of the chromium interim measures work plan (LANL 2006, 091987). Piezometers SCP-1a, SCP-1b, and SCP-1c were installed in a single borehole approximately 6 ft west of alluvial well SCA-4. Piezometers SCP-2a and SCP-2b were constructed in separate boreholes approximately 5 and 10 ft east, respectively, of alluvial well SCA-3. The nested piezometers were installed to provide data regarding infiltration rates and vertical hydraulic gradients. Details about piezometer completions and hydrogeologic conditions in these piezometers are provided in the "Interim Measures Investigation Report for Chromium Contamination in Groundwater" (LANL 2006,

094431) and “Final Completion Report for Sandia Canyon Drilling Program 2006” (Kleinfelder 2006, 095121).

3.2.3 Vadose-Zone Characterization Core Holes

Six core holes, SCC-1 through SCC-6 (Figure 3.2-1 and Plate 1), were drilled in the middle part of Sandia Canyon near East Jemez Road in 2006 to fulfill the requirements of the chromium interim measures work plan (LANL 2006, 091987). The purpose of the core holes was to determine the nature and extent of chromium in the upper vadose zone and to collect data to calculate chromium inventories. The core holes were 259.5 to 400 ft deep and targeted geologic units above the Cerros del Rio basalt. Details about the hydrogeologic conditions encountered in these core holes are provided in the “Interim Measures Investigation Report for Chromium Contamination in Groundwater” (LANL 2006, 094431) and “Final Completion Report for Sandia Canyon Drilling Program 2006” (Kleinfelder 2006, 095121).

Five core holes, SC1 through SC5 (Plate 1), were drilled in 2002 to characterize the geotechnical properties of alluvium and tuff units beneath the middle part of Sandia Canyon to support preconceptual design studies of a proposed Advanced Hydrotest Facility (AHF) at TA-53. In addition to geotechnical information, these core holes provided useful information about the thickness and extent of alluvium and alluvial saturation. Samples from these core holes were used to augment investigations of nature and extent of chromium in the upper vadose zone. Details about the hydrogeologic conditions encountered in these core holes are provided in the “Report of Pre-conceptual Geotechnical Investigations, Advanced Hydrotest Facility Project, TA-53” (Kleinfelder 2002, 091687).

Core hole SCOI-3 (Plate 1) was drilled to fulfill the requirements of the “Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon” (LANL 1995, 050290). Core hole SCOI-3 was intended as an intermediate-depth well to sample perched groundwater identified at a depth of 450 ft during installation of water supply well PM-1 in 1964 (Cooper et al. 1965, 008582). The purpose of SCOI-3 was reevaluated during development of the Laboratory’s Hydrogeologic Work Plan (LANL 1998, 059599), and the borehole was abandoned after reaching a depth of 132.5 ft so a new well (R-12) designed to characterize perched zones and the regional aquifer could be installed at this location. Instead of deepening core hole SCOI-3, well R-12 was started as a new well so larger casing could be used to ensure that a well of adequate diameter was installed to the regional aquifer.

3.2.4 Perched-Intermediate Monitoring Well Installations

Perched-intermediate groundwater monitoring well SCI-1 (Figure 3.2-1 and Plate 1) was installed in 2006 to fulfill the requirements of the “Interim Measures Work Plan for Chromium Contamination in Groundwater” (LANL 2006, 091987). The SCI-1 well was installed in the core hole SCC-1 after perched-intermediate water was found in the Puye Formation above Cerros del Rio basalt. Details about well completion and hydrogeologic conditions encountered at SCI-1 are provided in the “Interim Measures Investigation Report for Chromium Contamination in Groundwater” (LANL 2006, 094431) and “Final Completion Report for Sandia Canyon Drilling Program 2006” (Kleinfelder 2006, 095121).

Perched-intermediate groundwater monitoring well SCI-2 (Figure 3.2-1 and Plate 1) was installed in 2008 as recommended by the “Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon” (LANL 2007, 098938). Well installation was implemented according to the “Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon” (LANL 2007, 099607). The work plan was modified by the NMED letters dated March 18, 2008, “Investigation of Chromium Contamination in Regional Groundwater” (NMED 2008, 100964) and May 8, 2008, “Approval with Modification Drilling Work Plan for Nature and Extent of Chromium

Contamination in Groundwater Investigations" (NMED 2008, 101638). The SCI-2 core hole was drilled to a total depth (TD) of 890.0 ft to collect core samples of hydrostratigraphic units beneath Sandia Canyon to investigate the stratigraphy and geochemistry of these units. A polyvinylchloride (PVC) well was installed in the SCI-2 core hole after perched-intermediate water was found in the Cerros del Rio basalt. Details about well completion and hydrogeologic conditions encountered at SCI-2 are provided in the "Completion Report for Wells R-43 and SCI-2" (LANL 2009, 105296).

3.2.5 Regional Aquifer Monitoring Well Installations

Regional groundwater monitoring well R-12 was installed in 2000 near the eastern Laboratory boundary in Sandia Canyon (Figure 3.2-1 and Plate 1) as part of the implementation of the "Work Plan for Sandia Canyon and Cañada del Buey" (LANL 1999, 064617) and "Hydrogeologic Workplan" (LANL 1998, 059599). R-12 was installed with three well screens and a Westbay sampling system to provide water-quality and water-level data for intermediate-depth perched zones and for the regional aquifer downgradient of contaminant release sites in the upper Sandia Canyon, Los Alamos Canyon, and Mortandad Canyon watersheds. R-12 is also sited to provide early warning of potential contaminants approaching supply well PM-1 and to provide hydrologic and geologic data that contribute to understanding the vadose zone and regional aquifer in this part of the Laboratory. Details about well completion and hydrogeologic conditions encountered at R-12 are provided in the "Characterization Well R-12 Completion Report" (Broxton et al. 2001, 071252). The representativeness of groundwater data from all three screens at R-12 was compromised because of geochemical effects caused by the use of organic additives during drilling (LANL 2005, 091121). Rehabilitation of the well screens in R-12 is described in section 3.2.6.

Well R-11 was installed in 2004 along East Jemez Road in Sandia Canyon, immediately southwest of the Protective Force firing range at TA-72 (Figure 3.2-1 and Plate 1), as part of the implementation of the "Work Plan for Sandia Canyon and Cañada del Buey" (LANL 1999, 064617) and the "Hydrogeologic Workplan" (LANL 1998, 059599). R-11 was installed with a single well screen and a submersible pump sampling system to provide water-quality and water-level data for the regional aquifer downgradient of contaminant release sites in Sandia Canyon. A companion core hole was drilled in 2003 to a TD of 296.5 ft bgs to determine the nature and extent of potential contaminants in the upper vadose zone. Details about the well completion and hydrogeologic conditions encountered in R-11 are provided in the "Final Completion Report, Characterization Well R-11" (Kleinfelder 2005, 090044).

Wells R-35a and R-35b were installed in Sandia Canyon in 2007 to satisfy a requirement by NMED to evaluate migration of chromium contamination in the regional aquifer (NMED 2006, 092543). The two single-screen wells at the R-35 location (Figure 3.2-1 and Plate 1) are set at different depths in the regional aquifer to measure water quality and pumping effects from production wells in the vicinity, especially PM-3. Well R-35a is the deeper of the two wells and was completed with a well screen in the depth interval corresponding to the top of the well screen in PM-3. Well R-35b was completed with a screen near the top of the regional aquifer. The paired-well configuration is intended to determine if chromium contamination is present in regional groundwater near PM-3 and to evaluate if chromium concentrations vary with depth. The R-35 wells also serve as sentry wells for PM-3. Details about the well completion and hydrogeologic conditions encountered in the two wells are provided in "Completion Report for Regional Aquifer Wells R-35a and R-35b" (LANL 2007, 098129).

Well R-36 was installed in Sandia Canyon in 2008 on the south side of East Jemez Road within TA-72 to satisfy a requirement by NMED (2007, 095832). R-36 is a single screen well that provides groundwater monitoring near the eastern Laboratory boundary, replacing the function of the regional aquifer well screen at R-12 that was plugged and abandoned because of unreliable water quality data and

unrepresentative aquifer conditions in Miocene basalt. R-36 was located between wells R-12 and R-35 (Figure 3.2-1 and Plate 1) to act as a Laboratory boundary well in the uppermost regional aquifer within sediments above the Miocene basalt. R-36 was also designed to assess whether chromium and other possible contaminants are present in the regional aquifer east of an area of known chromium contamination at well R-28 and to monitor water levels within the regional aquifer. Details about the well completion and hydrogeologic conditions encountered in R-36 are provided in "Completion Report for Regional Aquifer Well R-36" (LANL 2008, 102185).

Well R-42 was installed in 2008 during implementation of the "Drilling Work Plan for Nature and Extent of Chromium Contamination in Groundwater Investigations" (LANL 2008, 101643) as approved in NMED letter dated May 8, 2008, "Approval with Modification Drilling Work Plan for Nature and Extent of Chromium Contamination in Groundwater Investigations" (NMED 2008, 101638) to investigate the extent of chromium contamination in the vicinity of R-28. R-42 is a single-screen well that was installed in Mortandad Canyon west of R-28 (Figure 3.2-1 and Plate 1). Details about the well completion and hydrogeologic conditions encountered in R-42 are provided in "Completion Report for Regional Aquifer Well R-42" (LANL 2009, 105026).

Well R-43 was installed in 2008 as recommended by the "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon" (LANL 2007, 098938). The well was installed according to the "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607). The work plan was modified according to the NMED letters dated March 18, 2008, "Investigation of Chromium Contamination in Regional Groundwater" (NMED 2008, 100964) and May 8, 2008, "Approval with Modification Drilling Work Plan for Nature and Extent of Chromium Contamination in Groundwater Investigations" (NMED 2008, 101638). R-43 is a dual-screen regional well that was installed near intermediate well SCI-2 in Sandia Canyon (Figure 3.2-1 and Plate 1) to define the nature and extent of contamination and address key uncertainties in the conceptual model for contaminant fate and transport of contaminants, with particular emphasis on chromium. Details about well completion and hydrogeologic conditions encountered at R-43 are provided in the "Completion Report for Wells R-43 and SCI-2" (LANL 2009, 105296).

Well R-44 was installed in 2009 to satisfy a requirement in the NMED letter dated March 18, 2008, "Investigation of Chromium Contamination in Regional Groundwater" (NMED 2008, 100964) to investigate the lateral and vertical extent of chromium contamination in the vicinity of R-28. R-44 is a dual-screen well in the uppermost part of the regional groundwater system that was installed in a small tributary of Mortandad Canyon southeast of R-28 (Figure 3.2-1 and Plate 1). Details about the well completion and hydrogeologic conditions encountered in R-44 are provided in "Completion Report for Regional Aquifer Well R-44" (LANL 2009, 106418).

Well R-45 was installed in 2009 to satisfy a requirement in the NMED letter dated March 18, 2008, "Investigation of Chromium Contamination in Regional Groundwater" (NMED 2008, 100964) to investigate the lateral and vertical extent of chromium contamination in the vicinity of R-28. R-45 is a dual-screen well in the uppermost part of the regional groundwater system that was installed in Mortandad Canyon east of R-28 (Figure 3.2-1 and Plate 1). Details about the well completion and hydrogeologic conditions encountered in R-45 are provided in "Completion Report for Regional Aquifer Well R-45" (LANL 2009, 106427).

3.2.6 Well Rehabilitation

Groundwater data from the three screens at R-12 were considered nonrepresentative because of geochemical effects caused by the use of organic additives during drilling (LANL 2005, 091121). This well

was equipped with a Westbay multilevel sampling system and had two well screens in perched-intermediate groundwater (screens 1 and 2) and one screen (screen 3) in the regional aquifer. R-12 is considered an important monitoring site because of its location along the eastern Laboratory boundary, its proximity to supply well PM-1, and its position potentially downgradient of chromium contamination within the regional aquifer (e.g., R-11 and R-28). The well was rated as fair in its ability to produce reliable and representative water-quality samples for the regional aquifer screen, and the well was rated as poor for the upper perched-zone screen (LANL 2005, 091121). The lower perched-zone screen was not evaluated because of a lack of water-quality data.

A pilot study for rehabilitation of the well screens was conducted in 2006 in accordance with requirements in the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987) and the Laboratory's "Workplan for R-Well Rehabilitation and Replacement" (LANL 2006, 092535). Rehabilitation activities consisted of removing the Westbay sampling system, video logging the well interior, conducting specific capacity tests on all three screened intervals, monitoring water-quality parameters during the tests, and collecting groundwater samples for geochemical analyses. Water-quality parameters were within acceptable limits after pumping of isolated screens during the specific capacity tests, and further development was not considered necessary. Well rehabilitation results were documented in the "Final Well Rehabilitation Report for Characterization Well R-12" (Kleinfelder 2006, 095044) and "Pilot Well Rehabilitation Study Summary Report" (LANL 2007, 095889).

Following rehabilitation, more than 600,000 gal. of water from screens 1 and 2 flowed into screen 3 in R 12 before the Westbay system could be reinstalled. As a result, NMED required screen 3 be plugged and abandoned (NMED 2007, 095832). Well R-12 was converted to a dual-screen perched-intermediate monitoring well in 2007 with the Westbay equipment replaced by a Baski sampling system. Before the Westbay with the Baski sampling system was replaced, additional specific-capacity tests were performed and high-velocity jetting, swabbing and pumping were conducted at screen 1 to further improve its groundwater quality. The resulting water quality was rated as good, an average score improvement of 20% over water quality before rehabilitation (LANL 2008, 100352). Abandonment procedures for screen 3 and reconfiguration of R-12 are documented in "Well R-12 Rehabilitation and Conversion Summary Report, Revision 1" (LANL 2008, 100352). Well R-36, drilled about 3000 ft west of R-12, replaces the abandoned screen 3 at R-12.

3.2.7 Surface Water and Groundwater Sampling

This investigation included sampling of surface water, alluvial groundwater, springs, perched-intermediate groundwater, and regional groundwater to provide snapshots of water quality throughout the hydrological system. Water-quality data from this sampling provides information about constituents that can be used to fingerprint potential sources and pathways, leading to improved conceptual models of processes controlling chromium mobility and transport and to subsequent remedy selection. Table 3.2-1 lists the sites that were sampled, and Figure 3.2-1 shows the sampling locations. Both filtered and nonfiltered water samples were collected, and the suite of analytes included general inorganic constituents, metals (including total and hexavalent chromium), stable isotopes of hydrogen, nitrogen, and oxygen, perchlorate, volatile organic compounds (VOCs), HE compounds, total organic carbon (TOC), and tritium as described in the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). The field parameters for groundwater samples include temperature, conductivity, pH, alkalinity, dissolved oxygen, and turbidity. Analytical results for the metals and general chemistry are presented in Attachment C-1 of Appendix C (on DVD).

In response to a requirement by NMED (2005, 091683), a group of intermediate and regional groundwater wells (including water-supply wells) surrounding R-28 was sampled in late January and early

February 2006 for an analytical suite intended to help characterize the chromium contamination and define potential sources. Results of that initial investigation were incorporated into the design of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987), and the analytical data are presented in Appendix C of that work plan.

3.2.8 Water Balance Investigation

A surface water balance investigation was conducted to constrain the location and amount of surface water and alluvial groundwater loss in Sandia Canyon between surface-water gaging stations E123 and E124 (LANL 2006, 091987; NMED 2006, 092543; LANL 2007, 095454). Two new temporary stream gages were installed in the narrow bedrock-dominated portion of Sandia Canyon between gage E123 and E124. Together with discharge data from outfalls and flow data from existing stream gages, the new stream gages allowed division of upper Sandia Canyon into three or four stream segments, providing better delineation of the areas of surface-water loss. Streambed infiltration losses were determined by comparing surface-water flow between gages.

Automated water-level data are collected with transducers at alluvial monitoring wells SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5, piezometers SCP-2a,b and SCP-1a,b,c and intermediate wells SCI-1 and SCI-2. These data are used to study the spatial and temporal water level responses in the canyon.

3.2.9 Regional Groundwater-Level Measurements

Automated groundwater-level data are collected with transducers in regional wells throughout the Sandia, Mortandad and Los Alamos watersheds. These data are used to define the elevation of the water table beneath the site and to study groundwater level responses to water-supply pumping.

3.2.10 Sampling Test at Regional Aquifer Well R-28

A continuous pumping and time-series sampling test was conducted at R-28 on November 28 and 29, 2007 to evaluate whether residual drilling fluid effects are present at R-28 that could impact reliability and representativeness of groundwater-quality data. The concept behind the test is that prolonged pumping will draw groundwater into the well screen from a distance that is greater than the near-borehole environment that was potentially affected by organic additives during drilling. If residual drilling fluids are present, prolonged pumping should produce measurable changes in key chemical indicators as groundwater is drawn from progressively greater distances from the well. The study had particular focus on chromium because it is the most prevalent contaminant in the regional aquifer at this location. Well R-28 was pumped at a rate that varied from approximately 2.50 to 4.25 gallons per minute (gpm) using the dedicated pump installed for sampling. Automated water-level records were also obtained throughout the test from a dedicated pressure transducer located within the well. Samples were collected in a time series throughout the test so data would be available to evaluate changes.

3.2.11 Surface Geophysics

Surface geophysics using electrical methods can be useful in delineating zones of subsurface saturation, especially where localized infiltration and shallow perching horizons may be present. To test this capability, the Laboratory contracted with Geophex, Ltd., in 2004 to collect direct current (DC) resistivity profiles along portions of Pueblo, DP, Los Alamos, Sandia, Twomile, and Pajarito Canyons. The goal of this study was to test the utility of this technique for guiding subsequent drilling to intersect likely infiltration pathways or perching zones. The method used involves placement of electrodes in wetted soil at approximately 20-ft spacing along the line of investigation, applying DC current, and measuring

electrode response in a dipole-dipole geometry. Resistivity profiles were collected along the canyon axes over zones where infiltration was suspected and canyon conditions allowed.

3.3 Geochemical Investigations

Several geochemical investigations were designed for obtaining a quantitative assessment of site-specific processes that affect accumulation, release, and migration of chromium at the Laboratory. These investigations included the collection of core from six boreholes drilled to the top of Cerros del Rio lavas (SCC-1 to SCC-6) for deionized (DI) water and EPA 3050 acid leach analysis of chromium and other analytes; collection of core through the Cerros del Rio lavas (SCI-2) and into underlying Puye Formation and Miocene sediments for DI and EPA 3050 leach analysis; analysis of potential background sources of natural chromium in groundwater; an assessment of the impact of wetland drying on chromium migration; and laboratory studies directed at defining chromium attenuation mechanisms in site-specific lithologies. The laboratory studies included optical, X-ray diffraction (XRD), and scanning electron microscope (SEM) analysis of samples selected from core and cuttings, batch and column sorption experiments using these samples, and synchrotron X-ray absorption near-edge spectroscopy (XANES) to determine the speciation of trivalent chromium [Cr(III)] versus Cr(VI) on sample surfaces.

These geochemical investigations address requirements set forth in the “Interim Measures Work Plan for Chromium Contamination in Groundwater” (LANL 2006, 091987); “Approval with Modifications for the Interim Measures Work Plan for Chromium Contamination in Groundwater” (NMED 2006, 092543); “Addendum to the Work Plan for Sandia Canyon and Cañada del Buey, Revision 1” (LANL 2007, 095454); “Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon” (LANL 2007, 098938); “Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon” (LANL 2007, 099607); and “Investigation of Chromium Contamination in Regional Groundwater” (NMED 2008, 100964). The investigation results are discussed in detail in Appendices H, I, and J of this report.

3.3.1 Chemistry of Archival Vadose-Zone Core Samples

Selected archival core samples from Los Alamos, Sandia, Mortandad, and Ten Site Canyons were analyzed to determine the nature and extent of chromium contamination in the upper vadose zone, to identify infiltration pathways, and to provide information for estimates of contaminant inventories. The investigation of archival cores was performed as part of the “Interim Measures Work Plan for Chromium Contamination in Groundwater” (LANL 2006, 091987). Core samples were analyzed for moisture content and chromium and other constituents using both DI water leaching and the EPA 3050 digestion method, which is referred to as the acid-soluble (digested) fraction. Archival cores were selected from 6 core holes in Los Alamos Canyon [LAOI(A)-1.1, LADP-3, LAOI3.2/3.2A,R-8, LAOI-7, and R-9]; 6 core holes in Sandia Canyon (SC2-AHF, SC3-AHF, SC4-AHF, R-11, SC5-AHF, and R-12); 12 core holes in Mortandad Canyon (MCB-2, MCB-5, R-1, MCOI-8, MCB-14, MCOI-6, MCB-12, MC1-AHF, MC2-AHF, MC3-AHF, R-28, and MCB-16); and 3 core holes in Ten Site Canyon (35-2028, R-14, MCB-15). These data supplement new core data (SCC-1 through SCC-6) (described in section 3.2.3 of this report) and provide information to evaluate chromium distributions beneath Los Alamos and Mortandad Canyons. Core samples were selected for analysis at nominal 20-ft intervals in each core hole. Results of archival core analyses are presented in section 5.5.1.2, Plate 1, and Appendix C-4 of the “Interim Measures Investigation Report for Chromium Contamination in Groundwater” (LANL 2006, 094431).

3.3.2 Chromium Background Study

The use of DI and EPA 3050 leach methods on core samples is effective in producing concentration data for chromium and other analytes, but all rock units at the Laboratory contain some chromium, and it is important to constrain the extent to which natural chromium may be leached along with anthropogenic chromium. To constrain the possible contribution of natural sources of chromium to groundwater, leaching experiments were designed using samples of uncontaminated Cerros del Rio lavas. Samples of this lithology were selected because they have the highest chromium content of all rock units at the Laboratory, and they are a major component of vadose zone groundwater migration and perching along chromium-migration pathways. The chromium background study focused on 10 samples of Cerros del Rio lavas. Eight of these were selected from unaltered flow material, one was selected from a soil-zone flow top, and one was selected from fracture material in a perched zone. All 10 samples were used to produce two splits: 1 crushed for DI leach in the Laboratory's EES-14 groundwater analysis laboratory and 1 supplied as coarse material to an external laboratory for EPA 3050 acid leach. For the eight samples of unaltered flow material, fine powders were prepared for whole-rock chemical analysis by the Laboratory's EES-14 X-ray fluorescence (XRF) laboratory.

3.3.3 Wetland Drying Experiments

The wetland in upper Sandia Canyon contains a significant inventory of the anthropogenic chromium (an estimated 21% to 49% of total chromium released, 5700 to 27,000 kg) released from power plant cooling towers at TA-03 (LANL 2008, 102996). Available data indicate that chemical retention of chromium in the wetland is facilitated by the thriving wetland biota and the poorly crystalline inorganic media associated with the wetland plant root zone. The Laboratory is considering water conservation measures in the wetland that may include restricting or cutting off inflow of water. The impact of such measures on the wetland chromium inventory with drying out and loss of the wetland plant community is not known, but there is concern that part of the anthropogenic inventory of chromium, arsenic, and other chemicals may be transported downcanyon and introduced into the groundwater system. To better understand geochemical processes that may be involved, a set of drying and leaching experiments were selected using wetland samples of plants and associated soil along the length of the wetland. These samples were dried out in the laboratory to simulate wetland desiccation. Samples were then leached using DI water and SWSC effluent. The leached chemical concentrations were analyzed in the EES-14 groundwater chemistry laboratory.

3.3.4 Chromium Attenuation Mechanisms

Studies of chromium attenuation mechanisms in the subsurface were planned using natural samples that represent major hydrostratigraphic units beneath Sandia and Mortandad Canyons. These units include the Guaje Pumice Bed of the Otowi Member, Bandelier Tuff; Cerros del Rio basaltic lavas; the Puye Formation; and Santa Fe Group sediment. These studies are discussed in detail in Appendix I, and included XRD and SEM examination of core samples, batch sorption and column experiments, XANES analyses, and geochemical modeling.

3.3.5 Simulations of Contaminant Transport

Site-scale groundwater-flow and contaminant-transport models were developed to model the fate and transport of the historical chromium source in Sandia Canyon (NMED 2006, 092543; LANL 2007, 095454). The models are based on the existing understanding of flow and transport in the vadose zone and the regional aquifer and include all available hydrogeological data. Models are used to synthesize available data, test the conceptual site model, estimate locations of the chromium arrival at the top of the

regional aquifer, and estimate the current and potential past distribution (mass balance) of chromium in different surface and subsurface media. Model results are compared to available monitoring data to refine the conceptual site model and have been presented in two previous reports (LANL 2007, 098938; LANL 2008, 102996) and in Appendix L of this report.

3.4 Biological Investigations

The biological investigations presented in this report focused on characterizing the potential for adverse effects of contaminants from post-1942 sediment deposits and surface water on terrestrial and aquatic ecological receptors. These investigations build upon the results obtained from sediment and surface water characterization, and the basis for the investigation approach is documented in the "Sandia Canyon Biota Investigation Work Plan" (LANL 2007, 099152). The investigation methods are discussed in section 4.4 and in Appendix B of this report.

3.5 Deviations from Planned Activities

The "Sandia Canyon Biota Investigation Work Plan" (LANL 2007, 099152) called for analyzing the chironomid bioassay test water midway through the 10-day test to quantify the concentration of hexavalent chromium during the test. Hexavalent chromium sampling results were not obtained because samples were not correctly preserved for chemical analysis. The impact of not having these data is discussed in section 8.1.4.2, the ecological risk assessment uncertainty analysis.

Zonal sampling of municipal water supply well PM-3 was proposed in the "Addendum to the Work Plan for Sandia Canyon and Cañada del Buey, Revision 1" (LANL 2007, 095454) to determine if there were depth-dependent variations in the quality of water entering the well screen at PM-3. The Laboratory could not obtain permission to access PM-3 from the Los Alamos Utilities Department because it was being used to provide drinking water for the county during the period of the investigation.

4.0 FIELD AND LABORATORY INVESTIGATIONS

Field investigations in the Sandia watershed included investigations of sediment, surface water, groundwater, and biota. The approaches and methods of these investigations are briefly discussed in the following sections. A more detailed discussion of the methods and of the field investigation results are presented in Appendixes B, F, and G. The methods and laboratory investigation results are discussed further in Appendixes H, I, J, and K.

4.1 Sediment

Sediment investigations in Sandia Canyon included detailed geomorphic characterization and sediment sampling in a series of discrete reaches, following the general process described in the work plan and canyons core document (LANL 1997, 055622; LANL 1998, 057666; LANL 1999, 064617). The geomorphic characterization in most reaches included preparing a detailed geomorphic map delineating the horizontal extent of geomorphic units with varying physical characteristics, contaminant concentrations, and/or age. These maps are presented in Plates 2 to 5. Field XRF screening measurements were used to help delineate geomorphic units in reaches where the level of chromium contamination in post-1942 sediment was higher than in nearby pre-1943 sediment. The geomorphic characterization also included measuring the thicknesses of potentially contaminated post-1942 sediment deposits to estimate the volume of contaminated sediment and the contaminant inventory in each reach. Several methods were used to identify the bottom of post-1942 sediment deposits, including determining

the depth of burial of trees associated buried soils, and noting the presence or absence of materials imported to the watershed after 1942 (e.g., quartzite gravel, plastic).

Field data on the volume and chromium concentrations in the different geomorphic units in reaches were used to help allocate samples for analysis at off-site laboratories. In some reaches, samples were collected in two or more phases, and analytical results from initial sampling phases were used to help guide subsequent sampling. Section B-1 of Appendix B includes more detailed discussion of the investigation methods. All analytical results of the sediment sampling incorporated in this investigation report are presented in Attachment C-2 in Appendix C (on DVD).

Plates 2 to 5 present geomorphic maps for reaches in Sandia Canyon and sampling locations, field XRF measurement locations, and stratigraphic description locations within these reaches. The horizontal extent of contaminated or potentially contaminated sediment deposits in each reach is delineated by the extent of the channel ("c") and floodplain ("f") units in these maps. Section B-1 of Appendix B presents field-investigation results, including sediment thickness measurements and field XRF-screening results.

4.2 Surface Water and Groundwater

The surface water and groundwater investigations in the Sandia Canyon watershed were designed to define the nature and extent of contamination, to identify the physical and chemical processes controlling contaminant distributions, and to identify the transport pathways that could result in potential human health and ecological risk. This work includes sampling persistent surface water, drilling and installing monitoring wells and piezometers, sampling new and preexisting groundwater wells, and measuring water level variations in all groundwater sources. In addition, core was collected to characterize the distribution contaminants and moisture in rock units of the upper vadose zone. The investigation methods are discussed in Appendix B of this report.

4.2.1 Alluvial Well Installations

Five alluvial monitoring wells, SCA-1 through SCA-5, were installed in 2006 to fulfill the requirements of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). Details about the field investigations associated with the installation of these wells are provided in the "Final Completion Report for Sandia Canyon Drilling Program 2006" (Kleinfelder 2006, 095121).

Two alluvial monitoring wells, SCO-1 and SCO-2, were installed in lower Sandia Canyon in 1990 to satisfy special permit conditions in the HSWA Module VIII portion of the Laboratory's RCRA operating permit (EPA 1990, 001585). Details about well completions and hydrogeologic conditions encountered in these wells are provided in (Purtymun and Stoker 1990, 007508).

4.2.2 Piezometer Installations

Five piezometers (SCP-1a, SCP-1b, SCP-1c, SCP-2a, and SCP-2b) were installed as part of two piezometer nests in 2006 to fulfill the requirements of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). The nested piezometers were installed to provide data regarding infiltration rates and vertical hydraulic gradients. Details about the field investigations associated with the installation of these piezometers are provided in the "Final Completion Report for Sandia Canyon Drilling Program 2006" (Kleinfelder 2006, 095121).

4.2.3 Vadose-Zone Characterization Core holes

Five core holes, SC1 through SC5, were drilled in 2002 to characterize the geotechnical properties of alluvium and tuff units beneath the middle part of Sandia Canyon to support preconceptual design studies of the proposed AHF at TA-53. Details about the field investigations associated with the installation of these core holes are provided in.

Six core holes, SCC-1 through SCC-6, were drilled in lower Sandia Canyon in 2006 to fulfill the requirements of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). These holes were drilled to collect core from surface to the top of the Cerros del Rio lavas. Details about the field investigations associated with the installation of these core holes are provided in the "Final Completion Report for Sandia Canyon Drilling Program 2006" (Kleinfelder 2006, 095121).

4.2.4 Perched-Intermediate Monitoring Well Installations

Perched-intermediate groundwater monitoring well SCI-1 was installed in 2006 to fulfill the requirements of the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). Details about the field investigations associated with the installation of SCI-1 are provided in the "Final Completion Report for Sandia Canyon Drilling Program 2006" (Kleinfelder 2006, 095121).

Perched-intermediate groundwater monitoring well SCI-2 was installed in 2008 as recommended by the "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon" (LANL 2007, 098938) and implemented by the "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607). Details about the field investigations associated with the installation of SCI-2 and R-43 are provided in the "Completion Report for Wells R-43 and SCI-2" (LANL 2009, 105296).

4.2.5 Regional-Aquifer Monitoring Well Installations

Nine regional wells were installed in Sandia and Mortandad Canyons to fulfill the requirements of a variety of documents (LANL 1998, 059599; LANL 1999, 064617; LANL 2006, 091987; LANL 2007, 099607; NMED 2008, 100964). Detailed well completion reports describe the investigation methods, well completion diagrams, geologic logs, and borehole geophysical logs for these wells. These well completion reports are described in section 3.2.1 of this investigation report.

4.2.6 Well Rehabilitation

A pilot study for rehabilitation of the R-12 well screens was conducted in 2006 in accordance with requirements in the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987) and the Laboratory's "Work Plan for R-Well Rehabilitation and Replacement" (LANL 2006, 092535). Field methods and well rehabilitation results are documented in the "Final Well Rehabilitation Report for Characterization Well R-12" (Kleinfelder 2006, 095044) and "Pilot Well Rehabilitation Study Summary Report" (LANL 2007, 095889).

R-12 was converted to a dual-screen perched-intermediate monitoring well in 2007 with the Westbay equipment replaced by a Baski sampling system. Before replacing the Westbay with the Baski sampling system, additional tests and development were conducted at screen 1 to further improve its groundwater quality. Abandonment procedures for screen 3 and reconfiguration of R-12 are documented in "Well R-12 Rehabilitation and Conversion Summary Report, Revision 1" (LANL 2008, 100352).

4.2.7 Surface Water and Groundwater Sampling

As described in section 3.2.7, this investigation included sampling of surface water, alluvial groundwater, springs, perched-intermediate groundwater, and regional groundwater. Table 3.1-1 lists the sites that were sampled, and Figure 3.2-1 and Plate 1 show the sampling locations. Water-quality field parameters, including pH, specific conductance, temperature, and turbidity, were measured for each surface and groundwater sample collected. Ongoing sampling of surface water under base flow conditions, springs, and regional groundwater is conducted as part of the "Interim Facility-Wide Groundwater Monitoring Plan" (LANL 2009, 106115) and field and analytical procedures are described in that document.

4.2.8 Water Balance Investigation

A water balance investigation was conducted for Sandia Canyon that examined surface water and alluvial groundwater losses in upper and middle Sandia Canyon, west of NM 4. Three temporary gages, D123, D123.5 (later named D123.8) and D123.6, were installed between gages E123 and E124 as part of this investigation to better delineate surface water losses in the bedrock portion of the canyon (Plate 1). Detailed outfall records from NPDES outfalls 01A001 and 03A027 were used to constrain the input water volume entering the wetland area in the upper watershed. The study used outfall data and data from the stream gages from October 2005 through June 2008. Results are presented in three reports (LANL 2006, 094431; LANL 2007, 098938; LANL 2008, 102996).

Continuous water-level data were collected in alluvial monitoring wells SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5, piezometers SCP-2a,b and SCP-1a,b,c and intermediate wells SCI-1 and SCI-2. Data from October 2006 to June 2009 were used to qualitatively describe spatial and temporal trends in alluvial and perched-intermediate water levels beneath the canyon, and to estimate alluvial water losses and ranges in infiltration rates to underlying bedrock (LANL 2006, 094431; LANL 2008, 102996; Appendix F of this report). Both mean-daily and hourly data were used in the analyses.

4.2.9 Regional Water-Level Measurements

Historical and new water-level data were compiled for regional wells in the Los Alamos, Mortandad, and Sandia watersheds. These data, which included both manual and automated measurements, allow hydraulic interconnections between wells to be assessed by comparing water-level responses with pumping records at municipal supply wells. Water-level data were also collected to determine hydraulic gradients within groundwater bodies and to assess hydraulic conductivity. Details of the field methodology and results are presented by Koch and Schmeer (2009, 105181). Further results are presented in the fate and transport update report (LANL 2008, 102996) and in Appendix G of this report.

4.2.10 Sampling Test at Regional Aquifer Well R-28

A continuous pumping and time-series sampling test was conducted at R-28 on November 28 and 29, 2007, as described in section 3.2.10. Results from this study are presented in Appendix M.

4.2.11 Surface Geophysics

A DC resistivity profile was collected in Sandia Canyon by Geophex, Ltd., in December 2005. This profile extends west to east from approximately SCA-2 to R-11, although R-11 was the only well installed in this section of the canyon at the time the resistivity profile was collected. A detailed discussion of this profile is provided in Appendix B of the "Interim Measures Investigation Report for Chromium Contamination in Groundwater" (LANL 2006, 094431).

4.3 Geochemical Investigations

Geochemical investigations provided data on DI leach and EPA 3050 acid leach analyses of core samples; data on sources of natural chromium in groundwater; data on the impact of wetland drying on chromium release and migration; and laboratory derived K_d values for chromium sorption on site specific lithologies. The laboratory data include optical, XRD, and SEM analyses as well as XANES determination of the speciation of Cr(III,IV) on representative lithologies. The geochemical investigations also include modeling results of chromium speciation and saturation evaluations based on representative perched and regional groundwaters. Details of geochemical studies and results are provided in Appendixes H, I, and J.

4.3.1 Chemistry of Archival Vadose-Zone Core Samples

Selected archival core samples were analyzed for chromium and other constituents using both DI water leaching and the EPA 3050 digestion method. The scope of this work is discussed in section 3.3.1, and results are presented in the "Interim Measures Investigation Report for Chromium Contamination in Groundwater" (LANL 2006, 094431). The DI and EPA Method 3050 leach data for SCI-2 are provided in Appendix C of this report and are discussed in Appendix I.

4.3.2 Chromium Background Study

Leaching experiments for the chromium background study were performed as described in section 3.3.2. Results from this study are presented in Appendix I.

4.3.3 Wetland Drying Experiments

Wetland drying experiments for the chromium background study were performed as described in section 3.3.3 and are discussed in detail in Appendix J.

4.3.4 Chromium Attenuation Mechanisms

Studies of chromium attenuation mechanisms in the subsurface were performed as described in section 3.3.4. Results are presented in Appendix I.

4.4 Biota

Biological data were collected to evaluate the potential for adverse ecological effects from contaminants in sediment and surface water. Biota investigations in Sandia Canyon included a range of activities, as presented in the "Sandia Canyon Biota Investigation Work Plan" (LANL 2007, 099152). Field investigations included studies of bird nest boxes and aquatic macroinvertebrates, collection of sediment samples for earthworm toxicity tests, seedling germination tests, and aquatic toxicity tests, and collection of water samples for the aquatic toxicity tests. The nest box study included adding nest boxes to an existing network, collecting data on occupancy, and collecting samples of eggs and insects for laboratory analyses. These activities are discussed in more detail in section 8.1 and section B-3.0 of Appendix B.

5.0 REGULATORY CRITERIA

This section provides information on the regulatory context, human health SLs, ecological screening levels (ESLs), applicable water-quality standards, and other SLs for the Sandia Canyon investigation.

5.1 Regulatory Context

Regulatory requirements governing the canyons investigations are discussed in section 1.4 of the NMED-approved canyons core document (LANL 1997, 055622; LANL 1998, 057666; NMED 1998, 058638; LANL 2007, 096665). In particular, these investigations address requirements of the Consent Order. Corrective actions at the Laboratory are subject to the Consent Order, which contains general requirements and those specific to Sandia Canyon (Section IV.B.5, "Sandia Canyon Watershed"). The Consent Order was issued pursuant to the New Mexico Hazardous Waste Act (NMHWA), New Mexico Statutes Annotated (NMSA) 1978 § 74-4-10 and the New Mexico Solid Waste Act 1978, § 74-9-36(D). RCRA and NMHWA regulate releases of hazardous wastes and hazardous waste constituents. DOE Order 5400.1, "General Environmental Protection Program," establishes requirements for managing residual radioactivity at DOE facilities.

As a result of the operational history of sites within the Sandia Canyon watershed, this investigation addresses both radioactive and hazardous components. NMED has authority under the NMHWA over the cleanup of hazardous wastes and hazardous constituents, while DOE has authority over the cleanup of radioactive contamination. Radionuclides are regulated under DOE Order 5400.5, "Radiation Protection of the Public and the Environment," and DOE Order 435.1, "Radioactive Waste Management."

Three types of water samples are considered in this report. Groundwater samples may be collected from alluvial, intermediate, or regional aquifers. Two types of surface water samples are evaluated in the report. Stormwater is transient and exists for some period of time directly in response to precipitation events. All other surface water samples are referred to as nonstorm-related surface water.

Surface-water discharges are subject to a permit under Section 402 of the federal Clean Water Act (CWA), including stormwater discharges, and are not regulated under the Consent Order. Stormwater discharges from certain SWMUs and AOCs are regulated by an Individual Permit (IP) issued by EPA Region 6, pursuant to the NPDES permit program (Authorization to Discharge under the National Pollutant Discharge Elimination System, NPDES Permit No. NM0030759, February 13, 2009). The Laboratory's IP became effective on April 1, 2009, and covers stormwater runoff from sites with significant industrial activity [see 40 Code of Federal Regulations 122.26(b)(14)].

The assessments in this report are primarily risk-based for all media and contaminants. Concentrations of chemicals and radionuclides in sediment are compared with various risk-based SLs described in sections 5.2 and 5.3. Surface-water and groundwater standards are used to support the assessment of nature and extent of contamination. Applicable water-quality standards are discussed in section 5.4. Stormwater comparison values are discussed in section 5.5.

5.2 Human Health Screening Levels

Human health SLs for sediment are soil screening levels (SSLs) for inorganic and organic chemicals and screening action levels (SALs) for radionuclides. These are media-specific concentrations derived for residential exposure. If environmental concentrations of contaminants are below SALs or SSLs, then the potential for adverse human health effects is highly unlikely. For sediment COPCs with carcinogen or noncarcinogen endpoints, SSLs from NMED guidance (NMED 2009, 106420) were used, if available. If values were not available from NMED, then the residential screening value from the EPA regional SL tables http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm was used as the SSL (adjusted to 10^{-5} risk to conform with NMED SSLs). The SSLs for noncarcinogens are based on a hazard quotient (HQ) of 1.0. The SSLs for carcinogens are based on a cancer risk level of 10^{-5}. For nonradionuclide COPCs without NMED SSLs, approved surrogate chemicals were used (NMED 2003, 081172), where applicable. SALs for radionuclides were obtained from Laboratory guidance (LANL 2005, 088493). The radionuclide

SALs have a target dose limit of 15 millirem per year (mrem/yr), which is consistent with DOE guidance (DOE 2000, 067489).

Human health SLs for nonstorm-related surface water are NMED tap water screening values (NMED 2009, 106420) for carcinogens and noncarcinogens. If values were not available from NMED, then the EPA regional tap water screening levels were used for carcinogens and noncarcinogens (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm). The DOE Derived Concentration Guidelines (DCGs) were used for radionuclides. Comparisons to these screening values are provided in section 8.2. The SLs for carcinogens and noncarcinogens in water are based on the same HQ and cancer risk levels as the SSLs. The SLs for radionuclides in nonstorm-related surface water were calculated based on a target dose limit of 4 mrem/yr, which is the radiation dose limit for a public drinking water supply in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

The initial screening comparisons of sediment and water data to residential SLs are provided in section 6. Additional information regarding the potential for human health risks from COPCs in affected media in Sandia Canyon is provided in section 8.2.

5.3 Ecological Screening Levels

ESLs are used to determine chemicals of potential ecological concern (COPECs) for sediment. The document, "Screening Level Ecological Risk Assessment Methods, Revision 2" (LANL 2004, 087630), contains information about how ESLs are derived. ESLs are developed for a suite of receptors designed to represent individual feeding guilds. Receptors such as the robin and kestrel are modeled with multiple diets to represent multiple feeding guilds. Concentrations of each COPC in sediment and nonstorm-related surface water were compared with ESLs from the ECORISK Database Version 2.3 (LANL 2008, 103352); these comparisons are provided in section 6. Additional information regarding the potential for ecological risks from COPCs in affected media in Sandia Canyon is provided in section 8.1.

5.4 Water Quality Standards and Screening Levels

COPCs are identified by comparing concentrations in water with applicable water-quality standards and screening values. The New Mexico Water Quality Control Commission (NMWQCC) establishes surface-water standards in the State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 New Mexico Administrative Code [NMAC]). Certain watercourses may be "classified" and have segment-specific designated uses. A designated use may be an attainable or an existing use (e.g., livestock watering) for surface water. Nonclassified surface waters are described as ephemeral, intermittent, or perennial, each of which also has corresponding designated uses described in 20.6.4.97–99 NMAC. The designated uses for surface water are associated with use-specific water-quality criteria (WQC), including numeric criteria.

Sandia Canyon from "Sigma Canyon" (between reaches S-3E and S-4W; Plate 1) upstream to NPDES Outfall 001 at the Laboratory is classified as perennial (20.6.4.4.126 NMAC) and has designated uses of cold-water aquatic life habitat, livestock watering, wildlife habitat, and secondary contact. The remaining segments in Sandia Canyon are ephemeral (20.6.4.97 NMAC), with designated uses of limited aquatic life, livestock watering, wildlife habitat, and secondary contact.

The numeric WQC for livestock watering (20.6.4.900[F] and 20.4.6.900[J] NMAC); wildlife habitat (20.4.6.900[G] and 20.4.6.900[J] NMAC); acute aquatic life (20.6.4.900[H], 20.4.6.900[I], and 20.4.6.900[J] NMAC); human health (persistent) (20.6.4.11[G] and 20.4.6.900[J] NMAC); and secondary contact (20.6.4.900[E] NMAC) apply to nonstorm-related surface water for all of the watercourse

classifications. For classified ephemeral/intermittent segments, the WQC for acute total ammonia (20.6.4.900[K] NMAC) also applies. The New Mexico Environment Improvement Board (NMEIB) Standards for Protection Against Radiation (20.3.4.461 [D], 20.3.4.461 [E] NMAC) are applicable to nonstorm-related surface water.

Concentrations of radionuclides in nonstorm-related surface water were compared with the lowest of the following values to identify COPCs:

- NMEIB Standards for Protection Against Radiation (20.3.4.461 [D], 20.3.4.461 [E] NMAC)
- DOE Biota Concentration Guides (BCGs) for protection of ecological receptors (DOE 2002, 085637)

If none of the above standards exist for an analyte, the following values were compared with concentrations in nonstorm-related surface water to identify COPCs:

- DCGs based on 4 mrem/yr

To identify COPCs in groundwater, comparisons to the lowest of the following standards were performed:

- human health (20.6.2.3103[A] New Mexico Administrative Code [NMAC]: Human health standards)
- other standards for domestic water (20.6.2.3103[B] NMAC: Other standards for domestic water supply)
- EPA maximum contaminant levels (MCLs)
- New Mexico Environment Improvement Board Standards for Protection Against Radiation (20.3.4.461 [D], 20.3.4.461 [E] NMAC)

If none of the above standards exist for an analyte, the following values were compared with concentrations in groundwater to identify COPCs:

- DOE DCGs based on 4 mrem/yr
- EPA regional tap water SLs

Comparisons of groundwater concentrations to applicable standards are summarized in section 6. Comparisons to NMED tap water screening values (NMED 2009, 106420) for carcinogens and noncarcinogens are also provided in section 6.

5.5 Stormwater Comparison Values

Stormwater discharges are regulated under the CWA, and no applicable standards for stormwater are available. Stormwater monitoring data for Sandia Canyon are evaluated relative to the following values from the State of New Mexico Standards for Interstate and Intrastate Surface Waters (§ 20.6.4 NMAC):

- livestock watering (20.6.4.900[F] and 20.4.6.900[J] NMAC)
- wildlife habitat (20.4.6.900[G] and 20.4.6.900[J] NMAC)
- acute aquatic life (20.6.4.900[H], 20.4.6.900[I], and 20.4.6.900[J] NMAC)
- human health (persistent) (20.6.4.11[G] NMAC)

Stormwater concentrations are compared with these values in section 6.

6.0 CANYONS CONTAMINATION

This section describes the methodology and results of screening assessments conducted to identify COPCs in sediment, nonstorm-related surface water, and groundwater samples collected in Sandia Canyon. The screening process for stormwater data is also described. Identifying COPCs forms the basis for evaluating contamination in canyons media. COPCs identified in this section are evaluated in the human health risk assessment in section 8.2 and have been considered in developing the measures evaluated in the baseline ecological risk assessment in section 8.1. A subset of these COPCs is discussed as part of the conceptual model development in section 7. Section 6.1 briefly describes how the data were prepared for the screening processes. Section 6.2 presents the screen for sediment, Section 6.3 presents the screens for nonstorm-related surface water and groundwater, and section 6.4 presents the stormwater evaluation. The term “sediment” includes all post-1942 sediment deposits in the canyon bottoms, including deposits in abandoned channels and floodplains as well as in active stream channels; therefore, sediment includes alluvial soil as defined in some other studies.

6.1 Data Preparation

Data packages for the analytical data for all media are presented in Attachment C-1 in Appendix C. The data used in the assessments were obtained from the Sample Management Database and the Water Quality Database and are presented in Attachment C-2 in Appendix C. Samples collected, analytical methods, and data quality issues are summarized in Appendix C, and data qualifiers are defined in Appendix A. Sample locations may be referred to by more than one name, and a crosswalk showing synonyms for location names is presented in Table 6.1-1.

Results used in the screens and subsequent risk assessments are populated with "Y" in the COPC_HH_screen field included on the data CD in Attachment C-2 in Appendix C. Certain analytical results were not evaluated in the COPC screens for the following reasons:

- Results from the less sensitive method when two results exist for a sample/analyte combination—For example, semivolatile organic compound (SVOC) results from samples that were also analyzed by a VOC, PAH, or HE analytical method. The results from the SVOC method are excluded from the screen because the VOC, PAH, and HE analytical methods provide lower detection limits.
- Results from subsequent sampling events that overlap earlier analyses—When a location was resampled to enlarge the suite of compounds analyzed, only the first set of results was retained for those analytes analyzed in both instances.
- Sediment samples collected for biota studies—These samples are composite samples and/or resamples of locations already characterized and were collected for use in biota studies. These sampling results are evaluated in the ecological risk assessment (section 8.1).
- Sediment PCB congener results—These data were collected in only one reach (S-2) and so are not comparable across reaches. PCB congener results are discussed in sections 7.1, 8.1 and 8.2. Aroclor results are included in the screens.
- Field duplicate results—These results were excluded from the screen because they are for samples obtained for quality assurance/quality control (QA/QC) purposes and not as primary characterization data.

- Results from water samples collected before 2003—Results from samples collected in 2003 and later are used in the COPC screens because these data are most representative of current site conditions.
- Water data from locations not included in Table 6.1-1—These data are discussed in section 7 as part of the conceptual model only. Locations included in the water screens are noted in Table 6.1-1.

There was a short-duration, rain-on-snow event in January 2008 with 15 h of total flow. This event was more similar to typical stormwater events than snowmelt runoff, which provides persistent flow in other canyons. Samples from this event were included as part of the stormwater screen in section 6.4.

6.2 Sediment COPCs

This section presents the process for screening analytical results obtained from sediment samples collected in Sandia Canyon. Samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-1 in Appendix C. Sample locations are presented in Plates 2 and 3. Analytical results were screened to develop a list of COPCs, as presented in section 6.2.1. Because reach S-2W consists of only one location, it is included with other sediment sampling results from reach S-2 in the screens below.

6.2.1 Identification of Sediment COPCs

Inorganic and radionuclide COPCs in sediment are identified by a screening process that includes comparing the maximum concentrations by reach with Laboratory-specific sediment background values (BVs) (LANL 1998, 059730). Analytes are retained as COPCs using rules specific to the class of analyte. This process is discussed below.

For inorganic chemicals, an analyte is retained as a COPC in a reach if

- the analyte has a BV and a detected or nondetected result in the reach exceeds the BV, or
- the analyte does not have a BV but has at least one detected result in the reach.

For radionuclides, an analyte is retained as a COPC in a reach if

- the analyte has a BV and at least one detected result in the reach exceeds the BV, or
- the analyte does not have a BV but has at least one detected result in the reach.

No BVs are available for organic chemicals, and retaining an organic chemical as a COPC is based on detection status. For organic chemicals, an analyte is retained as a COPC in a reach if there is at least one detected result in the reach.

A total of 31 inorganic chemicals, 50 organic chemicals, and 11 radionuclides were retained as COPCs in sediment in Sandia Canyon. Maximum sampling results in each reach (including detection limits for some inorganic chemicals) for these COPCs are presented in Tables 6.2-1, 6.2-2, and 6.2-3 for inorganic chemicals, organic chemicals, and radionuclides, respectively. The ESLs and residential SSLs and SALs are included in the tables for comparison purposes. The assessment of the potential for adverse ecological risks, including the screen against ESLs, is presented in section 8.1. The assessment of the potential for adverse effects on human health, including the screen against residential SSLs and SALs, is presented in section 8.2.

6.2.2 Comparison of Sediment COPC Concentrations to Residential SSLs and SALs

Maximum concentrations (including detection limits for inorganic chemicals) of sediment COPCs in each reach were compared with residential SSLs for inorganic and organic chemicals or residential SALs for radionuclides to identify which COPCs are most important for evaluating potential human health risk. Matching residential SLs and analytes is straightforward for most analytes by name, Chemical Abstract Service (CAS) identification (ID), or by appropriate surrogates. However, the measured forms of chromium and mercury require additional explanation. Sampling results for chromium in sediment indicate the chromium is predominantly Cr(III) with a small fraction of Cr(VI). The EPA regional screening level (RSL) for total chromium assumes a 1:6 ratio Cr(VI):Cr(III) and is used as the chromium SSL. Cr(VI) was also measured in sediments, and the hexavalent chromium residential SSL from NMED was used. The EPA RSL for mercury inorganic salts is used as the mercury SSL because it represents all forms of mercury present in sediment (inorganic, organic, and elemental). Methyl mercury was also measured in sediment and the mercury (methyl) residential SSL from NMED was used.

Three inorganic COPCs (arsenic, chromium, and lead) have maximum concentrations exceeding residential SSLs and are highlighted in gray in Table 6.2-1. Six organic COPCs (Aroclor-1254, Aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and total petroleum hydrocarbon (TPH) diesel range organics (DRO) have maximum concentrations exceeding residential SSLs and are highlighted in gray in Table 6.2-2. One radionuclide COPC, thorium-228, has maximum concentrations exceeding the residential SAL and is highlighted in gray in Table 6.2-3.

6.3 Surface-Water and Groundwater COPCs

This section presents the process for screening nonstorm-related surface-water and groundwater sampling results from Sandia Canyon. Water samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-2 in Appendix C. Sampling locations are presented in Table 3.2-1, Figure 3.2-1, and Plate 1. Analytical results from nonstorm-related surface-water and groundwater samples were screened to develop a list of COPCs, as presented in section 6.3.1. Spring samples were screened both as nonstorm-related surface-water and as groundwater.

6.3.1 Identification of Surface-Water and Groundwater COPCs

There are no BVs for surface-water, and retaining an analyte as a COPC is based on detection status. This process is performed for groups of data defined by field preparation (filtered or nonfiltered samples) and analyte type (inorganic chemicals, organic chemicals, and radionuclides). An analyte is retained as a COPC for a surface-water location if at least one result was detected at that location.

Groundwater COPCs are identified by a screening process that includes comparing the maximum detected concentrations with Laboratory groundwater BVs (LANL 2009, 106115) for filtered and nonfiltered samples.

For inorganic chemicals and radionuclides, an analyte is retained as a COPC for a location if

- the analyte has a BV and a detected result at that location exceeds the BV, or
- the analyte does not have a BV but has at least one detected result at that location.

No groundwater BVs are available for organic chemicals, and retaining an organic chemical as a COPC is based on detection status. For organic chemicals, an analyte is retained as a COPC for a location if at least one result was detected at that location.

A total of 43 inorganic chemicals in filtered and nonfiltered samples, 49 organic chemicals in nonfiltered samples, and 16 radionuclides in filtered and nonfiltered samples were retained as COPCs in water in Sandia Canyon. Maximum sampling results for nonstorm-related surface water and groundwater are presented in Tables 6.3-1 to 6.3-28.

6.3.2 Comparison of Water COPC Concentrations to Standards

Maximum detected concentrations of water COPCs in filtered and nonfiltered samples were compared with applicable water-quality standards, as discussed in section 5, to identify which COPCs are most important from a regulatory perspective. Matching SLs and analytes is straightforward for most analytes by the name, CAS ID, or by use of appropriate surrogates. However, the measured forms of chromium and mercury require additional explanation. For chromium in filtered water, the NMED tap water SL for Cr(VI) is used as one of the comparison values because it is assumed that most chromium in filtered water is the Cr(VI) form. Chromium in nonfiltered water is a combination of both Cr(III) and Cr(VI) and thus has no directly comparable NMED tap water SL. Cr(VI) was also measured in water and the hexavalent chromium tap water screening value from NMED is used. The NMED tap water SL for mercury (elemental) is included in the tables for comparison to mercury because there is no tap water value for total mercury.

Twelve inorganic COPCs and five organic COPCs have maximum concentrations above a water-quality standard. These COPCs are highlighted in gray, as applicable, in Tables 6.3-1 to 6.3-28. Radionuclide COPCs do not have maximum concentrations above a water-quality standard.

6.4 Stormwater

This section presents the process for evaluating analytical results obtained from stormwater samples collected in Sandia Canyon. Stormwater samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-2 in Appendix C.

6.4.1 Stormwater Screen against Comparison Values

The first step in the stormwater screen (Table 6.4-1) is an evaluation of detected analyte concentrations in filtered and nonfiltered stormwater samples using the lowest comparison value applicable for that field preparation from the State of New Mexico Standards for Interstate and Intrastate Surface Waters (§20.6.4 NMAC), as described in section 5.5. These stormwater comparison values are presented in Table 6.4-2 and include values for livestock watering, wildlife habitat, human health persistent, and acute aquatic life. Table 6.4-1 presents the results of the stormwater evaluation grouped by location, field preparation, and analyte type.

Eight inorganic chemicals (aluminum, arsenic, cadmium, chromium, copper, lead, silver, and zinc) in filtered samples and two inorganic chemicals (cyanide-amenable to chlorination and mercury) in nonfiltered samples were greater than stormwater comparison values. Five organic chemicals (Aroclor-1242, Aroclor-1254, Aroclor-1269, benzo(a)pyrene, and hexachlorobenzene) in nonfiltered samples were greater than stormwater comparison values. Stormwater gross-alpha radiation in nonfiltered samples was greater than its comparison value. Table 6.4-3 summarizes the number of stormwater results by analyte exceeding the lowest comparison value and the basis for the comparison value.

6.4.2 Comparison of Stormwater Concentrations to Acute Exposure Benchmarks

Analytes with concentrations greater than comparison values were evaluated further relative to the potential for acute exposure to human health or the environment. The acute exposure benchmarks for the protection of ecological receptors are a subset of the comparison values discussed in section 6.4.1. Specifically, the comparison values associated with acute aquatic life address the protection of ecological receptors to acute exposures; these benchmark comparisons are discussed in section 6.4.2.1. Human health benchmarks were calculated for those analytes greater than persistent human health comparison values; the comparisons to acute human health benchmarks and their derivation are discussed in sections 6.4.2.2 and 6.4.2.3. Wildlife habitat values are protective of the potential for adverse effect based on chronic exposures and therefore do not pertain to effects associated with acute exposures. Analytes exceeding these values (cyanide-amenable to chlorination, mercury, and gross-alpha radiation) are not evaluated further.

6.4.2.1 Acute Ecological Comparisons

The maximum detected concentrations of seven analytes (aluminum, cadmium, chromium, copper, lead, silver, and zinc) are greater than stormwater comparison values based on acute aquatic life criteria. Because the stormwater comparison values are based on an acute exposure, the acute aquatic life standards are also used as the benchmarks for acute ecological exposures. Table 6.4-4 summarizes the maximum detected concentrations of the analytes exceeding an acute benchmark, and these exceedances are discussed in section 8.1.

6.4.2.2 Acute Human Health Comparisons

The maximum detected concentrations of six analytes (Aroclor-1242, Aroclor-1254, Aroclor-1260, arsenic, benzo(a)pyrene, and hexachlorobenzene) were greater than stormwater comparison values based on human health persistent criteria. Because human health persistent values do not represent acute exposures, human health acute exposure benchmarks were developed. The method for calculating acute human health exposure benchmarks is described in section 6.4.2.3. As shown in Table 6.4-5, the maximum detected concentrations do not exceed the benchmarks, so these analytes in stormwater are not an issue as a potential acute human health concern in Sandia Canyon.

6.4.2.3 Acute Human Health Stormwater SLs

Data on concentrations of contaminants are not typically evaluated for acute toxicity in human health risk assessments. Consequently, compilations of acute toxicity values are not typically available nor are media-specific screening values based upon acute toxicity data. To evaluate the acute toxicity from short-term exposure to stormwater in Sandia Canyon, the following hierarchy of acute oral toxicity values was used (in order of descending priority):

1. Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) for hazardous substances) (http://www.atsdr.cdc.gov/mrls/)
    a. acute
    b. subchronic or intermediate

2. The Risk Assessment Information System Chemical-Specific Toxicity Values (http://rais.ornl.gov/tox/tox_values.shtml)

    a. acute

    b. short-term

    c. subchronic

3. ATSDR oral toxicity values from chemical-specific toxicity profiles modified by uncertainty and modifying factors (http://www.atsdr.cdc.gov/toxpro2.html)

    a. lowest acute nonlethal dose

    b. lowest acute lethal dose

    c. lowest subchronic dose

The selected dose (in mg/kg-d) from the above hierarchy of sources is converted to a stormwater SL according to the following equation:

SL (µg/L) = [dose (mg/kg-d) × body weight (BW) (31 kg)/water ingested (0.2 L/d)] × (1000 µg/mg)

In these calculations it is assumed that the most sensitive receptor will be the recreational child (BW = 31 kg) ingesting 0.2 L of water per day during an exposure event. This is consistent with the derivation of surface-water SLs in section 8.2.

For example, the MRL for Aroclor-1254 is 3E-05 mg/kg-d (the ATSDR intermediate oral MRL for Aroclor-1254 is used); therefore, the SL for Aroclor-1254 is

SL Aroclor-1254 (µg/L) = (3E-05 × 31/0.2) × 1000 = 4.65 µg/L.

6.5 Summary

Table 6.5-1 presents a summary of the COPCs in sediment, nonstorm-related surface water, groundwater, and detected analytes in stormwater in Sandia Canyon. Table 6.5-1 indicates which COPCs with maximum results that exceed residential SSLs and SALs for sediment and water-quality standards for nonstorm-related surface water and groundwater. Table 6.5-1 also presents stormwater analytes with maximum detected concentrations that exceed acute exposure benchmark values.

7.0 PHYSICAL SYSTEM CONCEPTUAL MODEL

This section discusses aspects of the physical system conceptual model that are relevant for understanding the nature, sources, extent, fate, and transport of contaminants in the Sandia watershed. The discussion of contaminants focuses on COPCs that are shown to be most important for evaluating potential present-day human health risk based on the comparisons with SALs, SSLs, and standards in sections 6 and 8.2 and that represent known contaminant releases into the watershed. These COPCs are included in evaluations of potential human health risk in section 8.2. This section also includes discussion of other COPCs identified as study design COPECs and are relevant for evaluating potential present-day ecological risk in section 8.1. Some additional COPCs relevant for understanding contaminant transport are also discussed. As used in this section, “contaminants” refers to COPCs known to represent releases from Laboratory SWMUs or AOCs or other anthropogenic sources, whereas “COPC” is a more general term that also includes analytes identified in section 6 that may or may not represent such releases.

The following discussion is divided into three sections. Section 7.1 discusses COPCs in sediments and the fluvial processes controlling their distributions. Section 7.2 describes the hydrology of the watershed, including descriptions of surface water, alluvial groundwater, pore water, intermediate-perched groundwater, and regional groundwater and summarizes spatial and temporal trends for contaminants in these media. Together, the data presented in sections 7.1 and 7.2 are used to identify contaminant sources and to understand contaminant transport away from the source areas. The sections present a summary of the physical system conceptual model based on the combined contaminant and pathways data. Key aspects of the physical system conceptual model are shown in Figure 7.0-1. Supporting information about trends in hydrologic conditions, contaminant distributions, and geochemistry that support the conceptual model is presented in Appendices D, F, G, H, I, J, and L.

7.1 Contaminants in Sediments

This section discusses general aspects of contaminants associated with sediment in Sandia Canyon, including how the distribution and concentration of contaminants are affected by fluvial processes acting over decadal time periods after releases. Subsequent sections discuss details of the distribution and concentration of specific COPCs in sediment deposits in Sandia Canyon that are important for evaluating potential human health or ecological risk or the downcanyon transport of contaminants in floods. In this section the term “contaminant” is used to refer to COPCs known to represent releases from Laboratory SWMUs or AOCs or other anthropogenic sources, whereas “COPC” is a more general term that also includes analytes identified in section 6 that may or may not represent such releases. For example, some COPCs identified by comparison with BVs or detection limits may represent naturally elevated concentrations, as discussed below.

Most contaminants in sediment in Sandia Canyon that were derived from Laboratory sources were originally released in cooling water from outfalls or as sanitary wastewater releases and surface spills near the head of the canyon in TA-03, as discussed in section 2. The cooling water flowed for varying distances downcanyon, interacting with sediment and organic matter in the channel and in a broad cattail wetland in reach S-2 that at one time extended from approximately 0.5 to 1.1 km (0.3 to 0.7 mi) downcanyon from the outfall. The size of the wetland has changed over time, being small in the early years of the Laboratory and growing until the 1980s or 1990s associated with the deposition of large amounts of sediment and saturation of the alluvium from the releases of cooling water and sanitary wastewater. Hand-auger holes in S-2 penetrated up to 4.7 m (15 ft) of post-1942 alluvium containing quartzite gravel overlying Bandelier Tuff bedrock, and this alluvium was derived from erosion of soil and fill material at TA-03 and other developed areas in the headwaters of Sandia Canyon. The erosion in the headwaters and subsequent downcanyon sediment deposition in S-2 was probably greatest when TA-03 and adjacent areas were being developed, reducing over time as the extent of building and paved areas increased and fill slopes stabilized. In recent years, the size of the wetland has decreased as the stream channel has progressively incised in the western part of S-2. The stream channel is currently incised below the original upper elevation of the wetland (c3 unit) for 300 m downcanyon from the culvert at the west end of S-2, and has a maximum depth of 2.8 m below the c3 surface in a 1-m deep scour hole immediately east of the lip of the culvert and 1.8 m a short distance downstream. This incision probably began because of a combination of reduced sediment supply from the headwaters and increased stormwater runoff from pavement and buildings. To a lesser extent, the size of the wetland has also been decreasing because of the upcanyon migration of a headcut that began near the eastern end of S-2. Between 1998 and March 2007, the headcut migrated upcanyon about 14 m, and between March 2007 and August 2009, it migrated an additional 5 m.

Figure 7.1-1 shows a longitudinal profile through reach S-2, indicating the stream channel elevation in August 2009 (surveyed with a global-positioning system [GPS] instrument), the elevation of bedrock beneath the post-1942 alluvium (as determined from hand auger holes), and the elevation of geomorphic units that represent former stream channel positions. The c3 unit represents the maximum extent of alluviation and wetland development, and its height decreases from 1.8 m above the channel near the west end of S-2 to 0.3 m 250 m downcanyon. The c2 units (c2a and c2b) represent intermediate channel elevations during the period of incision, which is still ongoing during large runoff events. The sediment eroded from the west part of S-2 has been largely deposited in the active cattail wetland in the east part of S-2 (the c1ct unit), such that this area continues to aggrade. Figure 7.1-1 also shows the position of the headcut in 1998, 2007, and 2009. The elevation of the former cattail wetland east of the headcut, abandoned following incision and headcut migration, is indicated by the c2cr unit.

Figure 7.1-2 shows a series of cross-sections from west to east in S-2, indicating the varying elevation and width of geomorphic units and the thickness of alluvium through S-2. The width of post-1942 geomorphic units varies from about 15 m (50 ft) at the west end of S-2, reaches a maximum of about 70 m (230 ft) about 200 m downcanyon, and decreases to approximately 10 m (33 ft) at the east end of S-2. The main cattail wetland (c1ct) has a maximum width of about 50 m (165 ft) and a total length of 350 m (1150 ft), although cattails also extend in a narrower strip along the channel (c1 unit) to the west part of S-2. The stream bed is on bedrock in the eastern part of S-2 (c1br unit), and the stream is completely incised into bedrock a short distance downstream.

Reach S-2 is the most important part of Sandia Canyon in the context of sediment contamination because of the proximity to contaminant sources, the large volume of sediment deposited during the period of active contaminant releases, the presence of high concentrations of organic matter in the wetland, and the deposition of large amounts of silt and clay. Dissolved contaminants commonly adsorb to sediment particles or organic matter because of the geochemical behavior of most metals and organic chemicals that are of concern in this investigation (Watters et al. 1983, 011888; Salomons and Forstner 1984, 082304; Lopes and Dionne 1998, 082309). Contaminants will preferentially bind to smaller particles because of their larger ratio of surface area to mass and greater electrostatic attractions, and Nyhan et al. (1976, 011747) have documented a general inverse relation between contaminant concentration and particle size of stream bed sediment on the Pajarito Plateau. Preferential adsorption to finer particles and organic matter also occurs when spilled contaminants infiltrate into soils on hillslopes. Because of the general inverse correlation of contaminant concentrations with sediment particle size, concentrations can be an order of magnitude higher in the finest grained sediment deposits, which contain up to 80% or more silt and clay, than in coarse-grained sediment deposits that contain < 5% silt and clay (LANL 2004, 087390; Reneau et al. 2004, 093174; LANL 2006, 094161). The fine facies sediment in S-2 has a higher silt and clay content than the other reaches, contributing to higher contaminant concentrations (average of 60% silt and clay in S-2 fine facies samples, compared to averages of 30% to 43% in other reaches in the western part of Sandia Canyon). The organic matter and saturated alluvium also produce geochemically reducing conditions for converting Cr(VI) released in cooling water to Cr(III). As discussed in subsequent sections, S-2 therefore has both the highest concentrations of chromium and other contaminants and the highest contaminant inventory (contaminant mass) in Sandia Canyon.

In addition to the geomorphic variations along the length of reach S-2 resulting from sediment aggradation and incision, geomorphic variations elsewhere along Sandia Canyon are important in controlling the distribution of contaminants. Figure 7.1-3 shows a longitudinal profile along the length of Sandia Canyon and variations in the average width of post-1942 geomorphic units and the volume of post-1942 sediment in the different sediment investigation reaches. Small volumes of sediment are associated with narrow areas of post-1942 sediment west of S-2, in reaches S-1N and S-1S, and east of S-2, in reaches S-3W and S-3E. These are also relatively steep reaches incised into the Bandelier Tuff,

where the stream channel locally directly overlies bedrock. Cross-sections through these reaches showing the heights, thicknesses, and widths of different geomorphic units are shown in Figure 7.1-4.

Downcanyon, the area of post-1942 sediment widens and the volume increases where the stream channel gradient decreases (Figure 7.1-3). The post-1942 sediment volume is largest in reach S-4E, an actively aggrading area upcanyon from the Protective Force firing range, and the width of post-1942 geomorphic units is largest downcanyon in reach S-5C in an area of broad floodplains. Cross-sections through these reaches are shown in Figure 7.1-5.

Reach S-4W is in a transitional area where, unlike the aggradation occurring in S-4E, the stream channel has been actively incising through alluvium, stranding former post-1942 stream channel deposits at progressively higher elevations above the channel. In S-4W, the upper surface of the c4 unit is approximately 2.9 to 3.6 m above the channel, the upper surface of the c3 unit is approximately 1.5 to 1.8 m above the channel, and the upper surface of the c2 unit is approximately 0.5 to 1.0 m above the channel (Figure 7.1-6). Tree-ring dating (dendrochronology) indicates that the c4 surface was abandoned before 1969 and the c3 surface before 1980 by channel incision (Figure 7.1-6). The incision that has occurred through this part of Sandia Canyon was probably aided by the increased stormwater runoff from developed areas in the headwaters that was discussed previously. The incision extends upcanyon through reach S-3E, where the highest post-1942 channel deposits (c3 unit) are approximately 2 m above the channel (Figure 7.1-4). Sediment eroded from this incising area has contributed to the aggradation downcanyon in S-4E.

Reach S-4W is also in the part of Sandia Canyon where surface water discharged from TA-03 infiltrates into the stream bed. The stream flows continuously upcanyon in S-3E, supplied by anthropogenic releases, and is ephemeral downcanyon in S-4E, supplied by stormwater runoff. Surface flow is currently intermittent in S-4W on a daily cycle, with the channel being dry in the morning and flowing in the afternoon in response to effluent releases from TA-03 several hours earlier. In this area, contaminants dissolved in surface water can interact with the stream bed, adsorbing onto sediment particles. Downcanyon, contaminants are entirely associated with sediment that has been remobilized by erosion of the channel bed and stream banks during storm runoff events.

Downcanyon from reach S-5C, the width of post-1942 geomorphic units and the volume of post-1942 sediment decreases significantly (Figure 7.1-3). A cross section through reach S-5E is shown in Figure 7.1-5, illustrating the narrower width and smaller thicknesses of the post-1942 geomorphic units. These changes are associated with the progressive downcanyon infiltration of stormwater runoff and reduced flood frequency and magnitude.

Once adsorbed to sediment particles in the stream bed, contaminants can subsequently be redistributed by floods that scour the stream bed and mobilize the bed sediment. Contaminants in the stream bed that originated as solid particles will behave similarly to those originally released as dissolved components in wastewater. Contaminants associated with coarse size fractions (coarse sand and coarser; >0.5 mm [0.02 in.]) are generally transported as bed load along the stream bed, whereas contaminants associated with fine size fractions (fine sand and finer; <0.25 mm [0.01 in.]) are generally transported in suspension (Malmon 2002, 076038, pp. 108–114; Malmon et al. 2004, 093018). Contaminants associated with medium sand (0.25–0.5 mm [0.01–0.02 in.]) can be either transported as bed load or as suspended load. The coarse sediment fractions typically travel shorter distances during a flood than fine fractions, because of their interactions with other sediment particles on the stream bed, and are usually redeposited within the channel during waning stages of a flood. In areas where the channel is aggrading (raising its elevation through sediment deposition) and where no stream banks exist or where banks are low, coarse sediment can be deposited over adjacent floodplains. In floods that overtop stream banks or where no stream

banks exist, some of the fine particles and associated contaminants carried in suspension are also deposited on adjacent abandoned channels or floodplains as flow depth and velocity decreases relative to the main channel. In large flood events, contaminants can be distributed across the entire width of floodplains in canyon bottoms. In reaches where transmission losses into the stream bed exceed discharge, all sediment is deposited. Additional fine particles are deposited on or infiltrate into the stream bed during waning stages of flow, to be potentially scoured and resuspended in subsequent events.

During floods, sediment from a variety of sources is mixed, changing contaminant concentrations longitudinally along a channel. Where runoff from tributaries draining noncontaminated or less-contaminated areas enters the main channel, contaminant concentrations are reduced. Some of the sediment transported in floods is eroded from the bed and banks of the channel, and this erosion can also change contaminant concentrations in a flood. When a flood draining contaminated areas erodes noncontaminated or less-contaminated material along the channel, concentrations in transported sediment decrease. The net result is a general downcanyon decrease in contaminant concentrations in sediment with distance from a contaminant source area (e.g., Marcus 1987, 082301; Graf 1996, 055537; Reneau et al. 2004, 093174; LANL 2006, 094161), and an increase in contaminant concentrations along main channels where significant amounts of contaminants are provided from tributaries (LANL 2004, 087390).

Contaminant concentrations in sediment carried in floods also change over time in relation to the history of contaminant releases. Concentrations are generally highest during the period of peak contaminant releases and decrease over time as a result of the mixing processes discussed above. Such decreases over time have been documented in other canyons at the Laboratory (Malmon 2002, 076038, pp. 315–322; LANL 2004, 087390, pp. 7–8; Reneau et al. 2004, 093174, pp. 1216–1217; LANL 2006, 094161, pp. pp. 37–39), as well as in other regions (Lewin et al. 1977, 082306, p. 357; Rowan et al. 1995, 082303, p. 61).

Multiple floods occurring over decadal time periods result in sediment deposits in each reach that have a range in age and particle size distribution and hence in contaminant concentration. Schematic cross-sections illustrating the distribution of coarse and fine sediment in reaches in Sandia Canyon are shown in Figures 7.1-2 and 7.1-4 to 7.1-6. The term “coarse facies” refers to sediment with median particle size in the less than 2 mm (0.08 in.) fraction of medium to very coarse sand, and these deposits commonly have a high gravel content. The term “fine facies” refers to sediment with median particle size of silt to medium sand. The active channel (c1 geomorphic unit) is typically dominated by relatively young coarse facies sediment deposits. In reach S-2, a cattail wetland occurs along the active channel (c1ct and c2ct units), and fine facies sediment is commonly deposited in the wetland and other areas where floodwaters spread and energy drops. Abandoned channels (c2, c3, and c4 units), which are areas occupied by the channel sometime after 1942 but subsequently abandoned following channel migration and/or channel incision, typically include fine facies sediment overlying older coarse facies sediment. Abandoned channels can also include coarse deposits as the uppermost, youngest layer. Post-1942 floodplains (f1 unit) typically include thinner layers of post-1942 fine facies sediment which bury pre-1943 sediments or soils. (Section B-1 of Appendix B presents additional discussion of sediment facies and geomorphic units.)

As shown in Figures 7.1-2 and 7.1-4 to 7.1-6, the layers with the highest contaminant concentrations in a reach are often at depth, buried by younger sediment layers with lower concentrations, although they can also occur at the surface. These figures also show how the relation of sediment layers to trees provides one means of estimating the thickness and age of different sediment layers (tree age determined from tree-ring dating [dendrochronology]; see section B-1 for more discussion of field-investigation methods). Plates 2 through 5 show the distribution of geomorphic units in the investigation reaches.

Most of the contaminants in Sandia Canyon sediments occur in areas of post-1942 sediment deposition outside the active stream channels, as also seen in other canyons at the Laboratory (LANL 2003, 077965; LANL 2004, 087390; Reneau et al. 2004, 093174; Reid et al. 2005, 091247; LANL 2006, 094161; LANL 2009, 106771). At present, these deposits probably constitute the primary source for contaminants carried by floods, as observed in other regions (e.g., Rowan et al. 1995, 082303, pp. 63–64), with active channels and erosion from hillslopes constituting lesser sources. The concentration and inventory (amount) of contaminants in deposits outside the active channel vary longitudinally within the canyons. Concentrations are typically highest in fine sediment deposits near the sources that date to the period of contaminant releases and decrease in younger deposits, in coarser deposits, and downcanyon. Contaminant inventories display more irregular patterns than contaminant concentrations and are related to longitudinal variations in the volume, grain size, and age of sediment deposits within a canyon. Subsequent sections provide examples of the variations in contaminant concentration and inventory in sediment deposits within Sandia Canyon.

Variations in background concentrations of some analytes in sediment can complicate the identification and evaluation of contaminants related to Laboratory releases. For example, background concentrations of fallout radionuclides in sediments have been shown to vary between regional rivers and reservoirs (McLin and Lyons 2002, 082305) and between these settings and canyons on the Pajarito Plateau (LANL 1998, 059730; McDonald et al. 2003, 076084). Background concentrations of some inorganic chemicals in sediments have also been shown to vary between different areas on the Pajarito Plateau as a result of local variations in soils or bedrock (Drakos et al. 2000, 068739; LANL 2009, 106506; LANL 2009, 106790; LANL 2009, 106771). Because soils on the Pajarito Plateau have higher concentrations of many inorganic chemicals than sediments (LANL 1998, 059730), deposition of sediment derived from locally eroded soils provides a possible source for elevated concentrations of inorganic chemicals in sediments.

Mineralogic variations within naturally occurring sediment can also contribute to background variations, for example the higher concentrations of many metals in black magnetite-rich sands on the Pajarito Plateau, such as iron, manganese, nickel, thallium, vanadium, and zinc (Reneau et al. 1998, 062050, pp. 12–14). Concentrations of various inorganic and organic chemicals in sediment may also be elevated near urbanized or industrial areas as a result of runoff from roads and other developed areas (Edwards 1983, 082302; Lopes and Dionne 1998, 082309; Walker et al. 1999, 082308; Breault and Granato 2000, 082310; Van Metre et al. 2000, 082262), further complicating the identification and evaluation of contaminants related to Laboratory releases. The topics of variations in background concentration and contributions from developed areas as they relate to key contaminants in Sandia Canyon are discussed in subsequent sections.

The following sections first use spatial variations in concentrations of sediment COPCs in Sandia Canyon to identify sources, in part distinguishing COPCs that are present because of releases from Laboratory SWMUs or AOCs from COPCs derived from other sources, such as natural background variations. Because of mixing of sediment from various sources during transport, contaminant concentrations are generally highest near the point of release and decrease downcanyon (e.g., Marcus 1987, 082301; Graf 1996, 055537; LANL 2004, 087390; Reneau et al. 2004, 093174; LANL 2006, 094161). Therefore, the spatial distribution of contaminants can directly indicate their source or sources. Figures D-1.1-1, D-1.1-2, and D-1.1-3 in Appendix D show all sampling results for all COPCs plotted against distance from the Rio Grande, which help to identify sources and possible outliers in the data set.

7.1.1 Inorganic Chemicals in Sediments

Eleven inorganic COPCs in Sandia Canyon sediment (aluminum, arsenic, cadmium, chromium, cobalt, iron, lead, mercury, molybdenum, silver, and thallium) have been identified as being important for assessing potential human health risk, and are included in the risk assessment in section 8.2. Additional inorganic chemicals detected in sediment samples are important for assessing potential ecological risk [barium, Cr(VI), copper, cyanide, methyl mercury, nickel, perchlorate, selenium, and zinc; LANL 2007, 099152, and section 8.1)]. The spatial distribution of these inorganic chemicals (discussed below) indicates they are derived from a variety of sources, including Laboratory SWMUs or AOCs and naturally occurring soils and bedrock. Once in the canyon bottom, most of these inorganic chemicals adsorb to sediment particles and organic matter (Salomons and Forstner 1984, 082304) and can be remobilized by floods that scour the stream bed or erode banks, being transported varying distances downcanyon.

This section focuses on spatial variations in inorganic chemicals in Sandia Canyon. Supporting information is included in Appendix D. Table D-1.2-1 presents average concentrations in each reach for inorganic chemicals discussed in this section, substituting one-half of the detection limit for nondetected sampling results. Table D-1.2-1 presents the upper and lower bounds on these averages using either the detection limit (upper bound) or zero (lower bound) for nondetects, which indicate uncertainties in the average values. This table shows that average concentrations of these inorganic chemicals are generally lower in coarse facies sediment than in fine facies sediment, as found in other canyons (LANL 2004, 087390; LANL 2006, 094161; LANL 2009, 106771; LANL 2009, 106790). Figure 7.1-7 and the following discussions focus on data from fine facies sediment. Figure 7.1-7 and Table D-1.2-1 also show the uncertainty in the average concentration of some inorganic chemicals that exists in some reaches because of elevated detection limits and/or detected concentrations close to detection limits.

The plots in Figure 7.1-7 include both the sediment BV for each inorganic chemical, which is an estimate of the upper level of background concentrations, and the average value from the background sediment data set, where available (averages from McDonald et al. 2003, 076084, Table 10, pp. 49-50). The background averages are included to be consistent with the presentation of averages from potentially contaminated samples, although averages for fine facies sediment are expected to be higher than the entire background data set, which also includes coarse facies samples. For reaches where an inorganic chemical is not a COPC, the average background concentration is plotted in Figure 7.1-7.

Aluminum is a COPC in one investigation reach, S-2, where it is included in the evaluation of potential human health risk in section 8.2. The maximum aluminum concentration in S-2, 20,000 mg/kg, is only 30% higher than the sediment BV of 15,400 mg/kg (Table 6.2-1). The average aluminum concentration in fine facies sediment in S-2, 9000 mg/kg, is also well below the BV (Figure 7.1-7 and Table D-1.2-1). The BV is exceeded in only 5% of the S-2 samples (four samples), all of which were collected in 1998 from the cattail wetland. These data suggest the elevated aluminum is associated with unique geochemical conditions in the wetland, although the high values from 1998 were not reproduced in more recent samples from the wetland in 2007 and 2008. Differences in analytical laboratories between 1998 and 2007–2008 may contribute to the higher concentrations in 1998. These results, in combination with the absence of aluminum above the BV closer to sources, indicate that the elevated aluminum in S-2 is not the result of anthropogenic releases.

Arsenic is an important inorganic chemical for evaluating potential human risk in Sandia Canyon, with maximum concentrations being greater than the sediment BV of 3.98 mg/kg in four investigation reaches (S-1N, S-1S, S-2, and S-3W). The highest concentrations are from the current and former cattail wetland in S-2. The elevated concentrations in S-1N and S-1S and downcanyon decreases from S-2 to S-3W

suggest releases of arsenic from TA-03 into both forks of upper Sandia Canyon (Figure 7.1-7 and Table D-1.2-1).

Barium was identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (section 8.1). It has maximum concentrations above the sediment BV of 127 mg/kg in 3 of the 11 investigation reaches (S-1S, S-2, and S-3W), and the highest concentration is in reach S-1S (1060 mg/kg; Table 6.2-1). Only a single sample from S-1S had barium above the BV, indicating limited releases. The highest concentrations in S-2 are from current or former cattail areas (c1ct and c2cr units). The spatial variations in barium concentration indicate releases into the south fork of Sandia Canyon from TA-03 and downcanyon transport (Figure 7.1-7 and Table D-1.2-1).

Cadmium is included in the human health risk assessment in section 8.2 in one investigation reach, S-2, and was also identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152, and section 8.1). It was detected above the sediment BV of 0.4 mg/kg in two investigation reaches (S-2 and S-3W) and is also considered to be a COPC in seven other reaches because of detection limits above the BV. The highest concentrations are from the current and former cattail wetland in S-2. Average concentrations in fine facies sediment are also highest in S-2, decreasing downcanyon to S-3W (Figure 7.1-7 and Table D-1.2-1). The similarity in spatial relations for cadmium as exists for chromium and other inorganic COPCs, as discussed below, indicates releases of cadmium from one or more sites in TA-03.

Chromium is an important inorganic chemical for evaluating potential human health risk in Sandia Canyon (section 8.2), with maximum concentrations being greater than the sediment BV of 10.5 mg/kg in 9 of the 11 reaches (Table 6.2-1), all except reaches S-6W and S-6E downcanyon from the eastern Laboratory boundary. It was also identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1), and is of concern for impacts to groundwater (e.g., LANL 2006, 094431; LANL 2007, 098938; section 7.2). The highest concentration, 3740 mg/kg, was measured in fine-grained, former cattail wetland sediments in the east part of reach S-2. The predominant source of chromium in the watershed is NPDES Outfall 001, which discharged cooling water containing chromate from the TA-03 power plant into the south fork of Sandia Canyon. Elevated chromium in S-1N indicates additional, smaller releases into the north fork. The much higher concentrations in S-2 than in S-1S closer to the primary source are consistent with the greater interaction between the cooling water and sediments and associated organic matter in the cattail wetland than along the steeper, narrower channel in the south fork. Downcanyon from S-2, concentrations progressively decrease associated with the mixing of contaminated and noncontaminated sediment. Concentrations are slightly above background levels in reach S-5E, immediately above NM 4, and below the BV in reaches closer to the Rio Grande. These relations indicate minimal transport of chromium released from TA-03 into the Rio Grande.

Hexavalent chromium was identified as an important COPC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1) and is of concern for impacts to the regional aquifer (e.g., LANL 2006, 094431; LANL 2007, 098938; section 7.2). It has been detected at low concentrations in all reaches where Cr(VI) analyses were conducted, with a maximum of 2.53 mg/kg in reach S-4E (Table 6.2-1). In the area of the highest chromium concentrations, reach S-2, Cr VI concentrations average <0.1% of the total chromium concentrations where measured in the same samples (0.3 mg/kg vs. 638 mg/kg, respectively). This indicates that the vast majority of the chromium in Sandia Canyon sediment is Cr(III).

Cobalt is included in the human health risk assessment in section 8.2 in one investigation reach (S-2) and has detected results above the sediment BV of 4.73 mg/kg in six samples from two investigation reaches (S-2 and S-4E; Table 6.2-1). Except for one anomalous result from S-4E, a coarse-grained subsurface

sample (CASA-07-3602, 68- to 110-cm deep), all results above the BV are from silt and clay rich samples from the active cattail wetland in S-2 (c1ct unit). The average concentration in fine facies sediment in S-2 (2.59 mg/kg; Figure 7.1-7 and Table D-1.2-1) is very close to the average of the background data set (2.35 mg/kg; McDonald et al. 2003, 076084). The similarity of cobalt concentrations in S-2 to background concentrations, combined with the finer average particle size in S-2, indicates that the cobalt in Sandia Canyon represents natural background variability, as was also found in other canyons at the Laboratory (e.g., LANL 2009, 106790).

Copper was identified as an important COPC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It has maximum concentrations above the sediment BV of 11.2 mg/kg in 8 of the 11 investigation reaches and the highest concentration in reach S-2 (223 mg/kg; Table 6.2-1). As with other COPCs, the highest concentrations in S-2 are from current or former cattail areas. The spatial variations in copper concentration are very similar to those for chromium, indicating primary releases from TA-03 into the south fork of Sandia Canyon and downcanyon transport (Figure 7.1-7 and Table D-1.2-1).

Cyanide was identified as an important COPC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It has maximum concentrations above the sediment BV of 0.82 mg/kg in four investigation reaches (S-1N, S-1S, S-2, and S-3E), and the highest concentration in reach S-2 (11.6 mg/kg; Table 6.2-1). As with other COPCs, the highest concentrations in S-2 are from current or former cattail areas. Highest average concentrations are in S-2, and the next highest are in S-1S (Figure 7.1-7 and Table D-1.2-1). These spatial variations in cyanide concentration indicate releases from TA-03 into the south fork of Sandia Canyon and downcanyon transport.

Iron is included in the human health risk assessment in section 8.2 in two investigation reaches (S-1N and S-2) and has results above the sediment BV of 13,800 mg/kg in five reaches (S-1N, S-2, S-3W, S-4E, and S-5C). The highest concentration was measured in a coarse-grained active channel sample from S-1N (29,500 mg/kg; Table 6.2-1). All other samples from S-1N have iron concentrations below the BV, indicating this sample may have included a fragment of metal in the stream bed. Average concentrations in fine facies sediment in all reaches are all below the BV, and the spatial variations in iron concentration show no pattern to indicate significant releases (Figure 7.1-7 and Table D-1.2-1). Instead, the iron in Sandia Canyon sediment probably largely records natural background variability, as was found in other canyons at the Laboratory (e.g., LANL 2009, 106790).

Lead is an important COPEC for evaluating potential human risk in Sandia Canyon (section 8.2) and was also identified as an important COPC for evaluating potential ecological risk (LANL 2007 099152; section 8.1). Lead has maximum concentrations above the sediment BV of 19.7 mg/kg in 9 of the 11 reaches, all except S-6W and S-6E downcanyon from the eastern Laboratory boundary (Table 6.2-1). The highest concentration was measured in the western part of S-2 (reach S-2W), from a coarse-grained subsurface sample collected in 1998 (690 mg/kg, sample RESA-98-0057, 44- to 50-cm deep). The highest average concentrations of lead in fine facies sediment are from S-1S and S-1N (Figure 7.1-7 and Table D-1.2-1), indicating multiple sources in the upper part of the Sandia Canyon watershed. Lead is a common contaminant found below roads and other developed areas, and one source is the past use of leaded gasoline (Walker et al. 1999, 082308, p. 364; Breault and Granato 2000, 082310, p. 48; Callender and Rice 2000, 082307, p. 232). Releases from Laboratory SWMUs or AOCs may constitute other sources. For example, although concentrations generally decrease downcanyon from S-1S and S-1N, lead concentrations increase in reach S-5C, indicating releases from either TA-53 or the Protective Force firing range in TA-72 (Figure 7.1-7 and Table D-1.2-1).

Mercury is included in the human health risk assessment in section 8.2 in one investigation reach, S-2, and was also identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It has detected results above the sediment BV of 0.1 mg/kg in six investigation reaches (S-1S, S-2, S-3W, S-3E, S-4E, and S-5C). The highest concentrations are from the current and former cattail wetland in S-2. The highest average concentrations in fine facies sediment are in S-1S (Figure 7.1-7 and Table D-1.2-1), indicating primary releases from TA-03 into the south fork of Sandia Canyon.

Methyl mercury analyses were obtained from six samples in reach S-2 to evaluate the chemical form of the mercury and possible variations between saturated and desiccated sediments. In S-2, methyl mercury concentrations average 0.5% of the total mercury concentrations in these six samples (0.0016 mg/kg vs. 0.98 mg/kg, respectively). The highest percentage of methyl mercury (1.8%) was from a saturated subsurface sample in the active cattail wetland (c1ct unit), whereas the lowest percentage (0.01%) was from a desiccated former cattail wetland (c2cr unit). The three saturated samples averaged 0.7% methyl mercury, and the three unsaturated samples averaged 0.3% methyl mercury. These differences indicate the chemical form of the mercury is influenced by the degree of saturation and reducing conditions below the water table, as expected, although only a small part of the total mercury is methylated.

Molybdenum is included in the human health risk assessment in section 8.2 in one investigation reach (S-2). Molybdenum has no BV and is considered a COPC in 9 of the 11 reaches based on detection status (no data are available from the other two reaches, S-1N and S-1S). Molybdenum was used at the TA-03 power plant as a corrosion inhibitor as a replacement for chromate, and released into the south fork of Sandia Canyon from NPDES Outfall 001. The maximum concentration was measured in S-2 from former cattail wetland sediment (c2cr unit; 44.4 mg/kg). Average concentrations in fine facies sediment are also highest in S-2 and decrease rapidly downcanyon (Figure 7.1-7 and Table D-1.2-1).

Nickel was identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (section 8.1). It has maximum concentrations above the sediment BV of 9.38 mg/kg in 3 of the 11 investigation reaches (S-2, S-3W, and S-6E), with the highest concentration in reach S-2 (69.3 mg/kg; Table 6.2-1). The highest concentrations in S-2 are from the current cattail wetland (c1ct unit). The spatial variations in nickel concentration indicate releases from TA-03 and downcanyon transport as far as S-3W (Figure 7.1-7 and Table D-1.2-1). The two results from S-6E above the BV (9.5 and 10.7 mg/kg) are probably derived from elevated local background associated with different bedrock units in White Rock Canyon than the background sample sites on the Pajarito Plateau, indicated by the absence of nickel above the BV in upcanyon reaches (S-3E to S-6W).

Perchlorate is identified as an uncertainty for evaluating potential ecological risk because of the absence of an ESL (LANL 2007, 099152; section 8.1). It also has no BV and is considered to be a COPC in a reach based solely on detection status. Perchlorate was detected in all reaches except S-3W, where no perchlorate analyses were obtained. It has an overall low detection frequency in Sandia Canyon sediment samples (24% detects) and an average detection limit for nondetects (0.00299 mg/kg) that is more than twice the average detected value (0.00114 mg/kg). Average perchlorate concentrations in the investigation reaches are shown in Figure 7.1-7 and Table D-1.2-1 and show no spatial variations that would indicate releases from specific Laboratory sites. These results indicate the detected perchlorate represents natural background and not Laboratory releases, a conclusion also reached in other watersheds at the Laboratory (e.g., LANL 2009, 106771; LANL 2009, 106790).

Selenium was identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It has maximum detected concentrations above the sediment BV of 0.3 mg/kg in 9 of the 11 investigation reaches and is considered to be a COPC in the other 2 reaches

(S-6W and S-6E) based on detection limits above the BV. Selenium has an unusual distribution in that the highest concentration was measured in reach S-3W (5.07 mg/kg; Table 6.2-1), higher than in reaches closer to Laboratory sites. The highest average concentrations in fine faces sediment were measured in reaches S-1N and S-1S, and averages are very similar in these two reaches (2.32 mg/kg and 2.28 mg/kg, respectively; Figure 7.1-7 and Table D-1.2-1), indicating either dispersed releases from Laboratory sites or an elevated local background. The relatively low concentrations in S-2 are also anomalous in that other sediment COPCs in Sandia Canyon that have clear sources at Laboratory sites have higher concentrations in S-2 than in S-3W. Therefore, the source of the selenium in Sandia Canyon is uncertain.

Silver is included in the human health risk assessment in section 8.2 in one investigation reach, S-2, and was also identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It was detected above the sediment BV of 1.0 mg/kg in 7 of the 11 reaches. The highest concentrations are from the current and former cattail wetland in S-2. The average concentration of silver in fine facies sediment is also highest in S-2, and the spatial distribution indicates releases into the south fork of Sandia Canyon (reach S-1S) and decreasing concentrations downcanyon from S-2 (Figure 7.1-7 and Table D-1.2-1).

Thallium is included in the evaluation of potential human health risk in section 8.2 in one reach, S-2, the only reach where thallium is a COPC. Thallium is above the BV of 0.73 mg/kg in two samples from S-2 (3% of all S-2 samples), at 0.886 and 1.06 mg/kg. The average concentration in fine facies sediment in S-2 is less than half the BV and is similar to the average detected concentration in other Sandia Canyon sediment samples (Figure 7.1-7; Table D-1.2-1). These relations indicate that the thallium in Sandia Canyon sediment is largely or entirely naturally occurring, which is a conclusion also reached in other canyons at the Laboratory (Drakos et al. 2000, 068739; LANL 2009, 106790).

Zinc was identified as an important COPEC for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). It has maximum detected concentrations above the sediment BV of 60.2 mg/kg in 8 of the 11 investigation reaches and has its maximum concentration in the active cattail wetland in S-2 (1140 mg/kg; Table 6.2-1). Its spatial distribution indicates releases into both the north and south forks of Sandia Canyon and downcanyon transport at least as far as reach S-5C (Figure 7.1-7; Table D-1.2-1).

7.1.2 Organic Chemicals in Sediments

This section focuses on spatial variations in select organic chemicals in Sandia Canyon. Seven organic chemicals in Sandia Canyon sediments have been identified as being important for assessing potential human health risk and are evaluated in section 8.2, including four PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, and indeno[1,2,3-cd]pyrene), two PCBs (Aroclor-1254 and Aroclor-1260), and one pesticide (dieldrin). Another organic chemical TPH-DRO, has maximum concentrations greater than a screening guideline. Three additional organic chemicals (Aroclor-1242, Aroclor-1248, and 4,4'-DDD) have been identified as important for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1).

7.1.2.1 PCBs

PCBs were detected in every Sandia Canyon investigation reach except the two easternmost reaches, S-6W and S-6E (Table 6.2-2). PCBs have low solubilities and a strong affinity for organic material and sediment particles (Chou and Griffin 1986, 083419). PCBs were widely used in electric transformers and other industrial applications (e.g., Walker et al. 1999, 082308, pp. 364-365), and their widespread use is

consistent with their spatial distribution in sediments in Sandia Canyon. The highest concentrations were measured in sediment below a former transformer storage area at TA-03, SWMU 03-056(c), although the sediment data indicate that PCBs were also derived from other sources in the watershed, as discussed below.

Five PCBs were detected in Sandia Canyon sediment samples using the Aroclor method: Aroclor-1016, Aroclor-1242, Arolcor-1248, Aroclor-1254, and Aroclor-1260. One of these, Aroclor-1016, was detected only in a single sample collected in 1998 and is not discussed further in this section. Average concentrations for the other Arolcors in fine and coarse facies sediment in each reach are shown in Table D-1.2-2, substituting one-half the detection limit for nondetected sampling results. This table also presents the upper and lower bounds on these averages, using either the detection limit (upper bound) or zero (lower bound) for nondetects. Table-D-1.2-2 indicates that average concentrations of PCBs are generally lower in coarse facies sediment than in fine facies sediment, and the discussions and figures in this section focus on data from fine facies sediment. Table-D-1.2-2 also indicates the uncertainty that exists in the average concentration of PCBs in some reaches because of elevated detection limits and/or a high frequency of nondetects.

Aroclor-1242 was detected in one sample from reach S-2, a depth-integrated sample through the entire thickness of alluvium in the active cattail wetland, which was also the maximum detected concentration in Sandia Canyon (c1ct unit; 0.366 mg/kg; 0- to 207-cm depth; Table 6.2-2). This is a detection frequency of 1% in S-2 (1 of 88 samples). Downcanyon in reach S-5C it was detected in one coarse-grained sample (6% detection frequency), and in S-5E it was detected in two samples (20% detection frequency), which indicates the possibility of releases from TA-53 or the Protective Force firing range in TA-72. However, considerable uncertainty exists in average Aroclor-1242 concentrations in these reaches because of the high frequency of nondetects (Figure 7.1-8 and Table D-1.2-2).

Aroclor-1248 was detected in three samples in reach S-1N (27% detection frequency) and two samples in reach S-2 (2% detection frequency). The spatial distribution indicates releases from TA-03 into the north fork of Sandia Canyon, although there is uncertainty in average concentrations because of the high frequency of nondetects (Figure 7.1-8 and Table D-1.2-2).

Aroclor-1254 was detected in all reaches except S-6W and S-6E, east of NM 4 and the eastern Laboratory boundary. The highest concentration (2.53 mg/kg; Table 6.2-2) was measured from a depth-integrated sample (CASA-07-3956, location ID SA-600899; 0 to 2.08 m deep) from an auger hole through the c2b unit in the middle of reach S-2. The spatial distribution of Aroclor-1254 indicates releases from TA-03 into both the north and south forks of Sandia Canyon, and average concentrations are similar in both reaches (Figure 7.1-8 and Table D-1.2-2). Concentrations generally decrease downcanyon from S-2, with a small increase in average Aroclor-1254 concentration in reach S-4E that suggests the possibility of releases from the western part of TA-53. However, the sediment samples were typically finer grained in S-4E than in the steeper upcanyon reaches, and this increase may be from the higher silt and clay content instead of releases from TA-53. Fine-facies samples from S-4E have an average of 57% silt and clay, whereas S-3W, S-3E, and S-4W have averages of 30-43% silt and clay.

Aroclor-1260 shows a spatial distribution similar to Aroclor-1254, with multiple sources in upper Sandia Canyon and a general downcanyon decrease below the sources (Figure 7.1-8 and Table D-1.2-2). The maximum detected concentration (11 mg/kg) was from a subsurface layer in reach S-1S in 1998 downcanyon from SWMU 03-056(c) (11 mg/kg, RESA-98-0070, 52- to 62-cm deep). The highest concentration in S-2 (2.08 mg/kg; Table 6.2-2) was measured from the former cattail wetland east of the headcut (CASA-07-639, location ID SA-600155, c2cr unit).

PCB congener data were collected from six previously sampled locations in reach S-2 to evaluate the congener signatures and compare Aroclor and congener results. In most of these samples (5 out of 6), total PCB concentrations reported by the congener method were higher than reported by the Aroclor method, and the average concentration in these six samples was 73% higher using the congener method. Figure 7.1-9 summarizes PCB congener homologs for these samples, expressed as percent of total in each sample. Figure 7.1-9a presents the results for each sample, and Figure 7.1-9b compares the averages in these samples to those in Aroclor samples (Frame et al. 1996, 106797). Consistent with the Aroclor analyses, the congener data indicate that the Sandia Canyon PCBs are mostly a mixture of Aroclor-1254 and Aroclor-1260. There are no systematic differences between the congener signature in saturated sediment and desiccated sediment in these data, indicating that drying has not significantly affected the congener percentages. For example, CASA-08-13548 is in the saturated part of the active cattail wetland, at the headcut (c1ct unit), and CASA-08-13553 is from the desiccated, abandoned former wetland area 20 m east (c2cr unit), and congener signatures in these samples are very similar.

7.1.2.2 PAHs

Four PAHs have been identified as being most important for evaluating potential human health risk in section 8.2: benzo(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; and indeno(1,2,3-cd)pyrene. These PAHs have similar spatial distributions, with the highest average concentrations in S-1N, generally lower but elevated concentrations in S-1S and S-2, and much lower concentrations downcanyon (Figure 7.1-10 and Table D-1.2-3). Detected results for benzo(a)anthracene and benzo(a)pyrene in reach S-5C indicate an additional source in the eastern part of TA-53 and/or the Protective Force firing range at TA-72, although there is large uncertainty in the average concentrations in S-5C because of elevated detection limits for analyses obtained in 2000 by the SVOC method (SW-846:8270; most results in this data set were obtained with the PAH method, SW-846:8310). A former asphalt batch plant next to the north fork of Sandia Canyon is a possible source for the elevated concentrations in S-1N, but this area also receives runoff from large areas of pavements and other development, which are additional sources of PAHs. Similar elevated concentrations of PAHs have been found in sediment downcanyon from urbanized areas in the Los Alamos townsite (LANL 2004, 087390) and in other regions (Edwards 1983, 082302; Lopes and Dionne 1998, 082309; Walker et al. 1999, 082308; van Metre 2000, 082262). The maximum result for these PAHs in Sandia Canyon, which influence the average concentrations shown in Figure 7.1-10 and Table D-1.2-3, were in the same S-1N sample (CASA-08-8764). It is possible that this sample included a fragment of asphalt, which is the inferred source for unusually high PAHs found in other sediment samples at the Laboratory downgradient of developed areas (LANL 2009, 106771).

7.1.2.3 Pesticides

One pesticide, dieldrin, is included in the human health risk assessment in section 8.2. Dieldrin and 4,4'-DDD have also been identified as important COPECs for evaluating potential ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1).

The pesticide 4,4'-DDD (dichlorodiphenyldichloroethane) was detected in one sample from Sandia Canyon, collected from reach S-2 in 1998 (0.036 mg/kg, RESA-98-0026). This represents a detection frequency of less than 1% for the complete data set. The detected S-2 concentration is close to the average detection limit for nondetects from S-2 (0.027 mg/kg). The low frequency of detects and similarity of detected concentrations to detection limits results in large uncertainty in average concentrations of 4,4'-DDD in S-2 (Table D-1.2-4) and prevents identification of any specific sources for 4,4'-DDD in the watershed.

Dieldrin was detected in two samples from Sandia Canyon: one collected from reach S-2 in 1998 (0.037 mg/kg, RESA-98-0026) and one collected from reach S-5E in 2007 (0.00274 mg/kg, CASA-07-3712). This represents a detection frequency of 1% for the complete data set. The detected S-5E concentration is less than the average detection limit for nondetects from that reach (0.00450 mg/kg), and the detected S-2 concentration is close to the average detection limit for nondetects from S-2 (0.027 mg/kg). The low frequency of detects and similarity of detected concentrations to detection limits results in large uncertainty in average concentrations of dieldrin in these reaches (Table D-1.2-4), and the scattered occurrence of the detects prevents identification of any specific sources for dieldrin in the watershed.

7.1.2.4 TPH-DRO

TPH-DRO was detected in every investigation reach in Sandia Canyon. Detected TPH-DRO concentrations are above the NMED screening guideline of 520 mg/kg in 10 samples from 2 reaches (S-1N and S-1S). In S-1N, average concentrations in both fine and coarse facies sediment are above the screening guideline, and in S-1S the average concentration in fine facies sediment is above the guideline (Figure 7.1-11 and Table D-1.2-4). Concentrations are much lower in downcanyon reaches. The sample with the maximum concentration (2700 mg/kg, CASA-08-8766) was collected from the active stream channel (c1 unit) in S-1N, indicating recent releases into the channel.

Although TPH-DRO concentrations are lower downcanyon in reach S-2, field observations and analytical data indicate relatively high concentrations at depth. Specifically, diesel odors and blackish layers were noted in multiple holes in the western half of S-2 while hand augering, and the location where the odors were the strongest and the depth with the blackest sediment was sampled for TPH-DRO and other organic chemicals. This sample provided the highest TPH-DRO concentration in S-2 (470 mg/kg, CASA-07-3948, 1.54-1.98 m deep in the c3 unit). This sample also had relatively high chromium concentration (1300 mg/kg), and the S-2 sample with the next highest TPH-DRO concentration (250 mg/kg, CASA-07-639, c2cr unit) also had high chromium (3740 mg/kg). This general collocation of high TPH-DRO and high chromium concentrations suggest the timing of their releases were similar. Chromium was released in cooling water from the TA-03 power plant from 1956 to 1972, suggesting that sediment 1.5 to 2 m deep in the c3 unit dates to sometime during this period.

Relatively low concentrations of TPH-DRO were detected in the reaches downcanyon from S-2, with slight increases seen in reaches S-5C and S-5E (Figure 7.1-11 and Table D-1.2-4). This increase suggests some releases from the eastern part of TA-53 and/or the Protective Force firing range in TA-72. Detected TPH-DRO in reaches S-6W and S-6E indicates possible transport from Laboratory sites to the Rio Grande, but this diesel could also be associated with runoff from major roads (East Jemez Road and NM 4), and other Laboratory-derived contaminants have not been identified that far downcanyon.

7.1.3 Radionuclides in Sediment

Two radionuclides in Sandia Canyon sediment are included in the evaluation of potential human health risk in section 8.2: thorium-228 and thorium-232. No radionuclides have been identified as important for evaluating ecological risk in Sandia Canyon (LANL 2007, 099152; section 8.1). Thorium-228 has one result above the sediment BV of 2.28 pCi/g in one sample each in reaches S-4W and S-5E, with the maximum concentration being less than 10% above the BV (2.47 pCi/g in S-4W; Table 6.2-3). Thorium-232 has only one sample that is less than 2% above the BV of 2.33 pCi/g (2.37 pCi/g; Table 6.2-3). Average concentrations are well below the BVs (Table D-1.2-5). Reaches S-4W and S-5E are incised into Bandelier Tuff unit Qbt 1g, which has relatively high BVs for thorium-228 and thorium-232

(4.90 pCi/g for both) (LANL 1998, 059730), indicating that the thorium-228 and thorium-232 at this site are probably naturally occurring and derived from the local rock unit. This same conclusion has been reached in other canyons at the Laboratory (LANL 2009, 106771).

7.1.4 Summary of Sources and Distribution of Key Sediment COPCs

The data discussed in the previous sections indicate the sediment COPCs in Sandia Canyon have a variety of sources, including Laboratory TAs and associated SWMUs or AOCs and natural background. Table 7.1-1 summarizes the inferred primary sources of the sediment COPCs discussed above and also the inferred downcanyon extent of COPCs that are or may be derived from Laboratory sources. Sources and downcanyon extent for these COPCs are discussed further below.

7.1.4.1 TA-03

TA-03 is the primary source for most COPCs in Sandia Canyon sediment. Sediment data, combined with historical records, indicate releases of inorganic and organic chemicals from multiple sites into both the north fork and south fork of Sandia Canyon. Identified sources include discharges of cooling water from the TA-03 power plant at NPDES Outfall 001 and PCB spills from SWMU 03-056(c), a former transformer storage area. COPCs released from TA-03, as shown by sediment data, include the inorganic chemicals arsenic, barium, cadmium, chromium, copper, cyanide, lead, mercury, molybdenum, nickel, silver, and zinc, various PAHs, PCBs, and pesticides, and TPH-DRO. These chemicals are identified as COPCs for varying distances downcanyon, with several extending as far as NM 4 (e.g., chromium, lead, molybdenum, Aroclor-1254, and Aroclor-1260).

7.1.4.2 TA-53 and/or TA-72

The sediment data indicate that several COPCs were or may have been released from either the eastern part of TA-53 or the Protective Force firing range in TA-72, including lead, Aroclor-1242, and possibly some PAHs and TPH-DRO. These COPCs are mixed with contaminants derived from TA-03 and can be traced relatively short distances downcanyon.

7.1.4.3 Natural Background Variability

Sediment data from different canyons indicate that natural background concentrations for many inorganic chemicals and radionuclides are more variable than found in the original sediment background data set used to develop BVs for the Laboratory (LANL 1998, 059730; McDonald et al. 2003, 076084). As a result, sediment concentrations can be elevated above BVs even where no Laboratory releases occurred (e.g., LANL 2009, 106506). In the Sandia Canyon sediment data set, the spatial distribution of some inorganic COPCs (Figure 7.1-7) indicates they are dominantly or entirely derived from naturally occurring materials, representing locally elevated background levels. These include aluminum, cobalt, iron, and thallium (Table 7.1-1). Isolated occurrences of nickel above the BV close to the Rio Grande also indicate natural background variability. One inorganic COPC with no BV, perchlorate, also has a spatial distribution that suggests it largely or entirely represents naturally occurring material and not releases from Laboratory sites.

7.1.5 Contaminant Inventory

Data collected in this investigation allow determining geographic variations in the amount, or inventory, of contaminants contained in sediment deposits in different parts of Sandia Canyon. Inventories have been

estimated for select COPCs in Sandia Canyon that have been derived from Laboratory sites and that may warrant remedial actions because of impacts on water quality, specifically chromium and four PCBs (Aroclor-1242, Aroclor-1248, Aroclor-1254, and Aroclor-1260). Supporting data for these inventory estimates are presented in section D-1.4 of Appendix D.

Figure 7.1-12 summarizes the geographic distribution of chromium in sediment deposits in Sandia Canyon, which updates estimates presented in a previous report (LANL 2007, 098127). No inventories are estimated for reaches where chromium is not a COPC (S-6W and S-6E), which would largely or entirely represent inventories associated with background concentrations. The total inventory of anthropogenic chromium in post-1942 sediment deposits in Sandia Canyon is estimated at approximately 18,000 kg (40,000 lb) (Table D-1.4-2). Approximately 70% of the total is contained within fine facies sediment. In Figure 7.1-12 the chromium inventory is plotted both as a normalized inventory in each reach per km of channel ([a] units of kg/km), and as cumulative amounts from the TA-03 Outfall 001 to the Rio Grande ([b] units of kg). The cumulative plot extrapolates between sampled reaches. An estimated 84% of the total is contained within reach S-2, where concentrations are highest and where a large volume of post-1942 sediment exists. Approximately 5% of the chromium is contained along the next 4 km of channel, between S-2 and the east end of S-4W, where storm runoff is confined to a relatively narrow band along the channel. Approximately 11% occurs in the next 5 km, on Laboratory land east of NM 4, and less than 0.5% farther downcanyon.

Estimated inventories of PCBs in Sandia Canyon sediment deposits range from approximately 3 kg (7 lb) for Aroclor-1248 to 35 kg (78 lb) for Aroclor-1254 (Table D-1.4-2). As with chromium, most of the mass is contained within reach S-2, ranging from an estimated 79% for Aroclor-1260 to 99.6% for Aroclor-1248. Most of the PCBs are also associated with fine facies sediment, ranging from an estimated 68% for Aroclor-1242 to 75% for Aroclor-1260. Figure 7.1-13 summarizes the geographic distribution of Aroclor-1254 in sediment deposits in Sandia Canyon as an example of the distribution of PCBs. Approximately 0.1% is contained west of the landfill bridge, mostly in reach S-1S below SWMU 03-056(c), the former transformer storage area. An estimated 88% is contained within S-2, 2% between S-2 and S-4W, 9% between S-4W and the eastern Laboratory boundary, and 1% farther downcanyon. Other COPCs are expected to have similar spatial variations in inventory as chromium and PCBs, with most of their mass occurring in S-2 associated with the large sediment volume and proximity to sources.

7.1.6 Relations between Particle Size and Contaminant Concentration

The particle size distribution of sediment deposits can have a strong influence on contaminant concentrations because of the preferential tendency for contaminants to adsorb onto small particles, although these relations can be obscured because of temporal variations in release history and other factors (Reneau et al. 1998, 065407; LANL 2004, 087390; Reneau et al. 2004, 093174; LANL 2006, 094161). To illustrate these relations, Figure 7.1-14 plots concentrations of chromium in sediment samples from Sandia Canyon against percent silt and clay content (percent in the <2 mm fraction of the sample). In all reaches, chromium concentrations are highest in samples with relatively high silt and clay content, and coarse-grained samples with less than 10% silt and clay have relatively low concentrations. For a given silt and clay content in a reach, chromium concentrations can vary widely because of differences in sediment age (e.g., time since peak chromium releases) and variable mixing with sediment containing lower chromium concentrations. For example, in reach S-2 all samples with greater than 1000 mg/kg chromium have approximately 80% to 90% silt and clay, but other samples with similar silt and clay content have much lower chromium concentrations. Correlations between silt and clay content and chromium concentration are poorest in reaches S-3W and S-3E, which are relatively steep narrow reaches (R^2 = 0.37), and S-4W, an entrenched reach with an abundant supply of pre-1942 sediment

(R^2 = 0.31). Correlations are better in downcanyon reaches that are primarily depositional (S-4E, S-5C, and S-5E, R^2 = 0.62 to 0.71). Figure 7.1-14 also illustrates how, for a given silt and clay content, average chromium concentrations decrease downcanyon because of mixing with other sediment.

7.1.7 Flood Attenuation and Downcanyon Extent of Contamination

Gaging station records of stream discharge (e.g., LANL 2007, 098938; Ortiz et al. 2008, 105250) indicate that floods generated from upper Sandia Canyon significantly attenuate as they move downcanyon, recording transmission losses into the alluvium. For example, during the period October 1, 2004, to July 31, 2009, 22 recorded storm runoff events exceeded 1 cubic foot per second (cfs) at stream gage E124 located between reaches S-3E and S-4W, but only 5 of these events were recorded at gage E125 3.8 km (2.4 mi) downcanyon, near reach S-5E and the eastern Laboratory boundary. The infiltration and loss of surface water upcanyon from E124 is also well documented (LANL 2007, 098938). These observations are consistent with the large volume of post-1942 sediment that has been deposited in the vicinity of reaches S-4E and S-5C (Figure 7.1-2 and Table B-1.0-1).

Analytical data discussed in previous sections demonstrate most of the contaminants associated with sediment released from TA-03 were deposited in reach S-2, close to their sources. A secondary focus of sediment and contaminant deposition is the area around reaches S-4E and S-5C. Only small amounts of Laboratory-derived contaminants are found downcanyon in reach S-5E immediately above the eastern Laboratory boundary and NM 4. For example, the maximum chromium concentration decreases downcanyon from 3740 mg/kg in S-2 to 22.5 mg/kg in S-5E, approximately twice the BV of 10.5 mg/kg, and all samples farther downcanyon have chromium below the BV. The PCBs Aroclor-1254 and Aroclor-1260 show the same spatial distribution, having highest concentrations near sources in TA-03, being detected at low concentrations in S-5E, and not being detected farther downcanyon. The downcanyon extent of recognizable contamination in Sandia Canyon derived from Laboratory sites is therefore between S-5E and S-6W, or between 3.4 and 6.5 km above the Rio Grande.

Detects of one COPC derived from Laboratory sites, TPH-DRO, at low concentrations downcanyon from NM 4 suggest possible transport from Laboratory sites to the Rio Grande. However, this TPH-DRO may also have been derived from runoff from major roads (East Jemez Road and NM 4), and the TPH-DRO data are inconclusive in terms of indicating the downcanyon extent of Laboratory-derived contaminants.

7.1.8 Temporal Trends in Sediment Contamination

Data on sediment contamination in other canyons at the Laboratory indicate that concentrations were highest at the time of peak releases and subsequently decreased over time from mixing of contaminated and noncontaminated sediment (e.g., Malmon 2002, 076038; LANL 2004, 087390; Reneau et al. 2004, 093174; LANL 2006, 094161). These same temporal trends have also been documented in other regions (e.g., Lewin et al. 1977, 082306; Rowan et al. 1995, 082303). Although there are few direct data pertaining to changes in concentrations of contaminants in Sandia Canyon sediment over time, available data indicate that contaminant concentrations here follow the same trends found elsewhere and have decreased over time since peak releases. For example, active channel sediment near the east end of reach S-2 had 50 mg/kg of chromium when sampled in 1998 and 18.5 mg/kg in 2007. In addition, in reaches where the stream channel has been incising and stranding older post-1942 sediment deposits above the channel, the highest concentrations of chromium have been measured in these older, higher deposits. Examples are provided in Figures 7.1-4 and 7.1-6 for reaches S-3E and S-4W, respectively. Similarly, where progressive aggradation has been occurring, the highest concentrations of chromium have been found buried at depth (reach S-4E; Figure 7.1-5). The historical stream incision that has been occurring in the part of Sandia Canyon that includes S-3E and S-4W has supplied large volumes of

noncontaminated pre-1943 sediment to the channel, which mixes with contaminated sediment derived from upcanyon and accelerates the natural downcanyon decreases in concentration. These processes are expected to continue, resulting in similar or lower concentrations of contaminants in the future.

7.1.9 Relation of Sediment Contamination to Stormwater Quality

As presented in section 6.4.1, 10 inorganic chemicals and 5 organic chemicals in stormwater samples from Sandia Canyon have concentrations exceeding stormwater comparison values. All of these, except one organic chemical (hexachlorobenzene), are also COPCs in Sandia Canyon sediment deposits, and with one exception (aluminum), the remainder have confirmed or probable sources at Laboratory sites, as indicated by historical data and sediment analyses. Erosion of contaminated sediment deposits in Sandia Canyon during runoff events provides a dispersed source for these contaminants transported by stormwater, and excavation or stabilization of eroding banks would contribute to improvements in stormwater quality. In particular, continued retreat of the headcut near the east end of reach S-2 constitutes a clear source for contaminants transported in stormwater, and stabilization of the headcut would probably contribute to improvements in stormwater quality at downcanyon stations.

7.2 Conceptual Model for Hydrology and Contaminant Transport in Water

7.2.1 Hydrologic Conceptual Model

7.2.1.1 Surface Water

Sources of surface water in the Sandia watershed are currently dominated by effluent releases. Effluent water releases to Sandia Canyon have occurred since the early 1950s and continue today, with the primary sources being treated sanitary wastewater and cooling tower blowdown, as described in section 2.1.1. Since 1992, the TA-46 SWSC plant has routed effluent to TA-03 and released this effluent, along with the TA-03 steam plant boilers, to upper Sandia Canyon through NPDES Outfall 001 (LANL 2006, 094431). Currently, releases to the canyon are primarily at TA-03, with an average 1100 m^3/d (290,000 gal./d) from Outfall 001 and additional releases from cooling of computing facilities at NPDES Outfalls 03A027 and 03A199 of less than 600 m^3/d (100,000 gal./d) (Appendix F). Data from 2007 and 2008 indicate the NPDES outfalls contribute approximately 75% of the total surface water flow in the canyon, with stormwater runoff and snowmelt contributing the remainder (LANL 2008, 102996, Appendix C). The long-term discharges and runoff support the thriving wetland near the head of Sandia Canyon and have supplied a sufficient water volume to facilitate contaminant transport in the canyon. The wetland contains abundant solid organic matter that serves both as a chemical reductant and as an adsorbent to contaminants that flow through the wetland. This process helps to immobilize some of the contaminants as discussed in Appendix J. Persistent surface flow occurs through the wetland and into the narrow, bedrock portion of the upper canyon, ending near surface water sampling station SCS-2 (Plate 1).

The transport of contaminants by surface water downgradient along the canyon is facilitated where relatively thin alluvium overlies relatively impermeable bedrock in the stream channel, limiting the amount of infiltration along the stream channel and resulting in greater movement of surface water downcanyon (Figure 7.0-1). The downcanyon extent of surface water flow is controlled by discharge from NPDES Outfall 001, runoff from storm events and snowmelt, and moisture content of the alluvium along the channel. The effects of these variables are reflected in changing infiltration patterns deduced from gaging data collected in 2007 and 2008, at permanent gaging stations E121, E122, E123, and E124 and temporary gaging stations D123.6 and D123.8 (Figure 7.0-1) (LANL 2007, 098938, Appendix B; LANL 2008, 102996, Appendix C).

Based on surface water data collected from July 2007 to June 2008, an average water flux of 15,000 m^3/yr (12 acre-ft/yr) is estimated to infiltrate into bedrock beneath the wetland, along an area that includes the Rendija Canyon fault zone [in Figure 7.0-1 surface water segment 1 (SW1)]; LANL 2008, 102996, Appendix C). This volume represents approximately 2% of the surface water (both effluent and runoff) flowing into the canyon during the period of the study and indicates that faults and fractures in this area are probably, at best, secondary pathways for deep infiltration. Virtually no deep infiltration occurred east of the wetland between gage E123 and temporary gage D123.6 (Figure 7.0-1, SW2), where welded Bandelier Tuff with a thin veneer of alluvium lies beneath the canyon floor. It is possible water does not flow into the fractures within welded Bandelier Tuff in SW2 because the fractures are infilled by illuviated silt, clay, and secondary minerals beneath the canyon floor. Also, fractures in the welded portion of the Bandelier Tuff tend to die out in less brittle tuff below.

During the study period, approximately 23% of surface water infiltrated bedrock units between temporary gages D123.6 and D123.8 (SW3 in Figure 7.0-1). This part of the canyon is steep and has a narrow canyon bottom where the stream incises through increasingly less welded tuff in the lower part of Qbt 2 and then through the nonwelded units Qbt 1v and Qbt 1g (Figure 7.0-1). The greatest portion of surface water (>60% of the total) infiltrates into the alluvium between temporary gage D123.8 and gage E124 in an area where the canyon floor broadens and the alluvium thickens (western portion of SW4 in Figure 7.0-1). Surface water flows past gage E124 (eastern portion of SW4 in Figure 7.0-1) only during times of high alluvial groundwater levels a few times per year. Runoff from storm events sometimes causes ephemeral flow and episodic infiltration to occur through the remaining portion of Sandia Canyon on Laboratory property, and possibly as far to the east as the Rio Grande; these events are very infrequent (less than annually) and result in surface-water flows that are of low duration.

7.2.1.2 Alluvial Groundwater

Alluvial groundwater in Sandia Canyon is recharged daily by surface-water flow, largely supplied by effluent from Outfall 001, and periodically by stormwater. This groundwater generally accumulates in the lower part of the alluvial deposits that fill the canyon bottom, most often perching on or within shallow bedrock units. The alluvial groundwater body extends farther downcanyon (roughly more than 1 km [0.6 mi] farther east) than do the daily stream-flow events. Because alluvial groundwater acts as a primary source of infiltrating water into the deeper tuff units, the extent of this groundwater helps define deeper infiltration zones beneath the canyon. Alluvial saturation occurs approximately between stream gage D123.8 and alluvial well SCA-5, with the most persistent perched alluvial groundwater occurring between alluvial wells SCA-2 and SCA-4 (Figure 7.0-1 and Appendix F). Water-level measurements indicate that alluvial groundwater is lost to bedrock units beneath the canyon floor in this area (Appendix F). This interpretation is supported by the results of analyzing transient, alluvial water-level responses to surface flow events. Analyses of the alluvial water-level data indicate that recharge to the alluvium, and flow within the alluvium and to the suballuvium bedrock are both spatially and temporally heterogeneous with infiltration rates potentially as high as a few meters per year (LANL 2008, 102996, Appendix C). Lateral flow within the alluvium and infiltration of alluvial groundwater provide a driving force for subsurface transport of mobile constituents, such as Cr(VI), nitrate, sulfate, molybdenum, tritium, and chloride along the length of the canyon and into the deeper subsurface. The combination of surface water and alluvial groundwater losses in the areas defined by SW3 and SW4 leads to the deep infiltration zones depicted in Figure 7.0-1.

7.2.1.3 Vadose-Zone Hydrology

Percolation of alluvial groundwater results in deeper, unsaturated flow into suballuvial bedrock units. Movement of moisture in the vadose zone is probably dominated by vertical gravity-driven flow through

highly porous Bandelier Tuff and upper Puye Formation sediments, but moisture-gradient-driven flow and spreading along stratigraphic contacts are expected to be important as well. Infiltration through the Cerros del Rio basalt is expected to be dominated by unsaturated flow through fractured basalt matrix and interflow breccias. Infiltration in the lower vadose zone is probably dominated by gravity-driven flow through highly porous sediments of the lower Puye Formation and underlying Miocene pumiceous deposits. Saturated flow occurs in zones of perched-intermediate groundwater like those found at SCI-1 and SCI-2, as described in the following section.

The analysis of available hydrogeological data, including moisture profiles in the SCC boreholes, indicates that most of the deep infiltration along Sandia Canyon occurs in the middle portion of the canyon, approximately between wells SCA-2 and SCA-4 where perched alluvial groundwater is present (Figure 7.0-1) (LANL 2006, 094431). Calibration to moisture data indicates that infiltration rates are on the order of 1 to 6 m/yr in the primary infiltration zone depicted in Figure 7.0-1 (LANL 2008, 102996, Appendix J), resulting in travel times to the regional aquifer of approximately 10 to 50 yr.

Infiltration patterns from the alluvium into bedrock are most likely spatially heterogeneous and transient. For example, deep infiltration probably occurs less frequently and at lower rates between SCC-4 and SCC-6 than west of SCC-4 because perched alluvial groundwater is present less frequently in this downcanyon area. This conclusion is supported by the lower moisture contents measured in core from boreholes SCC-5 and SCC-6, and from well R-11 (Plate 1) (LANL 2006, 094431) and through observations of alluvial groundwater levels, which vary with TA-03 effluent discharges and with stormwater runoff (Appendix F). Based on these observations, the conceptual model for vadose-zone flow in Sandia Canyon is that the primary zone of infiltration is located in middle Sandia Canyon approximately between SCA-2 and SCA-4, and that rapid percolation in this area is driven by a history of nearly continuous daily discharges of effluent to the canyon since the early 1950s. The size of the primary infiltration zone expands and contracts based on fluctuations in the average effluent discharge rate and transient stormwater and snowmelt events. During periods of higher than average surface-water flow, the infiltration zone probably expands along the axis of the canyon to the east, and infiltration rates along the margins of the infiltration zone increase temporarily.

7.2.1.4 Perched-intermediate Groundwater

A zone of perched-intermediate groundwater occurs within the Puye Formation on top of the Cerros del Rio basalt between wells SCI-1 and SCC-4 (Figure 7.0-1, Appendix N), where it was approximately 25-ft to 1-ft thick, respectively, when the wells were drilled. This perched zone is probably recharged by percolation of alluvial groundwater through the underlying bedrock units before perching on top of the basalt. Although the intermediate-zone groundwater levels at well SCI-1 have gradually risen by approximately 7 ft from February 2007 to June 2009 (Appendix F, Figure F-2.0-1), there is no direct correlation of water levels with runoff events or alluvial groundwater fluctuations in Sandia Canyon. However, the temperature of water in intermediate well SCI-1 is similar to the temperature of alluvial groundwater in the canyon, indicating it may be actively recharged from above (Appendix F).

The perching layer for the groundwater at well SCI-1 is the top of the Cerros del Rio basalt. There is a local depression in the upper basalt surface in the vicinity of nearby well SCI-2 (Figure N-1.0), which may control the accumulation of perched water in this area. The top of the Cerros del Rio basalt also acts as a perching horizon at wells MCOI-4 and MCOBT-4.4 in Mortandad Canyon, indicating this contact has favorable characteristics for perching groundwater over a wide area. A structure contour map presented in Appendix H of the “Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon” (LANL 2007, 098938) (Figure H-2) shows that the upper surface of the Cerros del Rio basalt near well SCI-1 generally dips westward towards well R-1 in Mortandad Canyon. Small variations in the

surface of the Cerros del Rio basalt from erosion and the lateral abutment of basalt flows could result in groundwater pathways with slightly different orientations.

A second perched-intermediate zone is penetrated by well SCI-2 within fractured lavas and interflow breccias in the lower part of the Cerros del Rio basalt (Figure 7.0-1, Appendix N). The thickness of the perched zone is uncertain but ranges between 45 and 100 ft. The groundwater level at well SCI-2 occurs at a depth of 533 ft and has fluctuated approximately 1 ft from February 2009 to June 2009 (Appendix F). The SCI-2 water level does not correlate with runoff events or alluvial groundwater fluctuations in Sandia Canyon. However, the relatively short period of groundwater-level data precludes additional analyses at this time. The water temperature at well SCI-2 is approximately 5°C warmer than that of alluvial groundwater in the canyon (Appendix F). This temperature difference coincides with the difference dictated by the local geothermal gradient, indicating the groundwater at well SCI-2 is in thermal equilibrium with the surrounding rock and is not rapidly recharged by alluvial water. Chromium concentrations in well SCI-2 groundwater (593 µg/L) are much greater than those measured for either present-day alluvial groundwater (5-10 µg/L) or SCI-1 perched groundwater (14 µg/L), which supports the interpretation that well SCI-2 perched water represents older groundwater that may have recharged during or soon after the period of chromium release in the canyon (1956 to 1972).

The lava flows hosting the perched groundwater at well SCI-2 were deposited over a south to south-southeast dipping surface that developed on top of the Puye Formation (Appendix N). The nature of the perching horizon at the base of these basalts is poorly understood but may include relatively impermeable sedimentary rock of the Puye Formation and clay altered flow-base volcanic sediment at the base of the Cerros del Rio basalt that occurs at a depth of 629 ft (LANL 2009, 105296). Alternatively, groundwater may be perched above massive lava that contains clay-filled fractures near its top at a depth of 578 ft. The groundwater contained in the lower part of the Cerros del Rio basalt may follow the dip of the basalt towards the south and south-southeast. Lack of perched water in the Cerros del Rio basalt at wells R-28 and R-42 in Mortandad Canyon may indicate that the perched groundwater drained from the basalts and infiltrated into the underlying Puye Formation, eventually reaching the regional aquifer in the area between wells SCI-2 and R-28/R-42. This is supported by the elevated chromium concentrations at wells R-28 and R-42, by predicted current chromium arrival locations in the regional aquifer, many of which are predicted to arrive south of Sandia Canyon (Appendix L, Figure L-5.2-2), by groundwater mixing calculations discussed below, and by vadose-zone modeling results presented in the chromium fate and transport update report (LANL 2008, 102996). Also, a perched groundwater approximately 4 ft thick was encountered in the Puye Formation below the Cerros del Rio basalt when well R-42 was drilled (LANL 2009, 105026).

Geochemical signatures of groundwater also provide hydrologic information about the perched-intermediate zones observed at wells SCI-1 and SCI-2. Figure 7.2-1 presents a cross-section to illustrate a conceptual model for potential mixing of perched-intermediate groundwaters beneath Los Alamos, Sandia, and Mortandad Canyons based on mean values of major ion groundwater chemistry and rock type. Figure 7.2-2 shows the same information in map view. Stiff diagrams illustrate the relative concentrations of major cations (sodium, calcium, magnesium, and potassium) to major anions (chloride, bicarbonate, sulfate, and bromide) at each location (see legend, Figure 7.2-1). The conceptual model figure depicts potential mixing of perched-intermediate groundwater caused by lateral flow along perching layers at the top and base of the Cerros del Rio basalt that dip generally westward and southward, respectively (Appendix N). Groundwater at wells SCI-1 and SCI-2 have much higher major ion concentrations than other intermediate groundwater in the vicinity. High ionic-strength water infiltrating in Sandia Canyon, represented by the alluvial well SCA-2 stiff diagram, may mix with water originating beneath Los Alamos Canyon to produce the water chemistries at wells SCI-1 and SCI-2. This hypothesis is further explored in section D-2.3 with groundwater mixing ratios.

Perched-intermediate groundwater is present within fractured lavas of the Cerros del Rio basalt and sands, silts, and gravels of the underlying Puye Formation at monitoring well R-12 near the eastern Laboratory boundary (Figure 7.0-1 and Plate 1). Substantial infiltration from alluvial groundwater from Sandia Canyon is highly unlikely at this location because of the lack of local saturation in the alluvium. The hydrogeologic setting and elevation of the perched groundwater at well R-12 is similar to perched groundwater found at well R-9 in Los Alamos Canyon; it is thought not to be contiguous with perched groundwater at wells SCI-1 or SCI-2. Koch and Schmeer (2009, 105181) hypothesize the perched-intermediate groundwater at well R-12 may be recharged by surface and alluvial water in Los Alamos Canyon based on delayed R-12 water level responses to snowmelt and storm runoff events in Los Alamos Canyon.

During drilling of well R-10a, intermediate perched groundwater was encountered between 330 and 370 ft depth in silts and arkosic sands sandwiched between thick massive lavas of the Cerros del Rio basalt. The water level in this zone was 304 ft, indicating the groundwater was confined. Well R-10a and its companion well R-10 were completed in the regional aquifer.

Perched-intermediate groundwater was not encountered at regional wells R-11, R-35a, R-35b, R-36, R-28, R-44, or R-45, indicating that the perched zones at wells SCI-1 and SCI-2 are not connected with R-12 and R-10/10a. The inferred connection between the perched-intermediate systems at wells R-10/10a and R-12 is based on their similar settings within the Cerros del Rio basalt, their similar groundwater elevations, and their relatively close proximity.

7.2.1.5 Regional Aquifer Hydrology

The regional aquifer beneath Sandia Canyon and canyons to the north and south can be represented as a complex heterogeneous system that includes confined and unconfined zones. The degree of hydraulic communication between these zones is thought to be spatially variable. The shallow portion of the regional aquifer (near the water table) is predominantly under phreatic (unconfined) conditions and has limited thickness (approximately 30 to 50 m [98 to 164 ft]). Groundwater flow and contaminant transport directions in this zone generally follow the gradient of the regional water table. The regional water-table map is presented in Appendix G (Figure G-1.1-1). This water table map includes new data collected at recently installed regional wells in the vicinity of Pajarito, Mortandad and Sandia Canyons. The ambient regional groundwater flow gradients are relatively high to the west (close to the Pajarito fault zone) and to the east (close to the Rio Grande), varying between 0.0005 and 0.05 m/m. Gradients are relatively low in the area of the chromium contamination; on the order of 0.001 with an uncertainty range from 0.0005 to 0.002. The gradients are computed, based on the water-level contours presented in Figure G-1.1-1.

The infiltration recharge of the regional aquifer originating along Sandia Canyon is expected to be substantial considering the large volumes of effluent discharged. Infiltration is expected to be relatively focused in the central portion of the canyon, as presented in Figure 7.0-1 (section 7.2.1.2). An analysis of the potential impact of this infiltration recharge on the regional aquifer water levels was performed in Appendix I of the chromium fate and transport update report (LANL 2008, 102996). It was concluded that recharge might have caused a mound of the regional water table beneath the canyon of variable width and depth (less than 3 m high) depending on various hydrogeological parameters, such as hydraulic conductivity. The spatial analysis of the regional water table elevations (Appendix G, section G-1) does not provide conclusive observations of a mound at the regional water table; nevertheless, the somewhat elevated water-levels at well R-36 (about 0.1 to 0.5 m higher than levels at wells R-42 R-28, R-45, R-11, R-13, and R-34) and at well R-35b (about 0.4 m higher than the level at well R-45) may be an indication that recharge influences the shape of the regional water table (Appendix G, section G-1). However, it is

also feasible that the water levels at these particular wells are also influenced by infiltration recharge occurring to the north of Sandia Canyon (e.g., Los Alamos Canyon).

The deep portion of the regional aquifer is predominantly under confined conditions, and it is stressed by Pajarito Plateau water supply pumping. The largest fluctuations in the water levels of the deep aquifer zone are observed at well R-35a (~3 m) (Appendix G, section G-2); this well is located close to water-supply well PM-3. However, water levels at well R-35b, which is next to well R-35a and screened in the shallow phreatic zone of the regional aquifer, does not show any discernible impacts of the water-supply pumping (Appendix G, section G-2). Based on analyses provided in Appendix G (section G-2), the pumping wells appear to have only minimal impact on the regional water table near Sandia Canyon. The largest pumping fluctuations at screens located relatively close to the regional water table are observed at well R-15, with a magnitude of about 1 m; the magnitude of fluctuations at wells R-28 and R-11 is about 0.3 m. Compared to well R-35b, the drawdown magnitude is fairly large at wells R-15, R-11, and R-28 considering these wells are much farther from any of the water-supply wells than well R-35b, which is adjacent to well PM-3. This is a result of three-dimensionality in the aquifer heterogeneity and in groundwater flow in this area. As a result, the water-supply pumping of the deep aquifer is expected to have a minor impact on the groundwater flow and transport in the shallow phreatic zone of the regional aquifer. Therefore, it can be expected that contaminant transport follows the shallow, ambient water-table gradients rather than diverting deeper toward the pumping water-supply wells. However, the poor hydraulic communication does not preclude the possibility that some contaminant migration may occur between the shallow and deep aquifer zones. Between the two zones, the hydraulic gradient has a strong downward vertical component because of water supply pumping (water-level difference between wells R-35a and R-35b is about 4 to 5 m), creating the possibility that downward contaminant flow may occur along “hydraulic windows,” although these have not been directly observed.

In the regional aquifer, the advective flow paths of contaminant migration may not be perpendicular to the equipotential water table lines, i.e., parallel to the direction of the hydraulic gradients. Deviations from the flownet conformity rule may occur because of anisotropy and heterogeneity of aquifer materials. Flow- and head-gradient vectors do not coincide in an anisotropic medium when the flow gradient is not coincident with the principal directions of the permeability tensor (Freeze and Cherry 1979, 088742, Chapter 5). As a result, the south-southwest dips of aquifer rock units in this area may influence the flow vectors (Appendix L, Figure L-2.0-2).

The major ion chemistry of regional aquifer groundwaters in shown in map view in Figure 7.2-3; stiff diagrams depict geochemistry as a function of rock type. The groundwaters at wells R-42 and R-28 have distinctly different chemistry, with higher major ion concentrations, than at other nearby regional wells. The groundwaters at these two wells contain elevated levels of anthropogenic Cr(VI) and other contaminants. Therefore, some component of vadose-zone water arriving near these wells mixes with regional water to generate the observed major ion concentrations at wells R-42 and R-28.

7.2.2 COPCs in Water

7.2.2.1 Overview

A variety of contaminants are identified as COPCs in surface water and groundwater within and beneath Sandia Canyon (section 6.3). The following discussion focuses on COPCs that are near or above applicable water-quality standards (section 6.3.5). A limited number of other constituents are included where they provide useful insights for, or corroboration of, COPC distributions, sources, transport processes, or transport rates. COPCs identified in section 6.3 not discussed in this section are generally expected to have similar distributions and behaviors to one or more of the COPCs discussed here.

COPCs with maximum concentrations in water greater than applicable water-quality standards include 11 metals (aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, silver, and zinc), 5 organic chemicals (Aroclor-1254, Aroclor-1260, BHC[delta] (benzene hexachloride), bis[2-ethylhexyl]phthalate, and bromomethane), and chloride (Table 6.5-1). No radionuclide COPCs have maximum concentrations exceeding a water-quality standard. Although molybdenum concentrations are well below water-quality standards, this trace metal is included in the following discussion because concentrations of this COPC exceed its BVs in alluvial groundwater and in perched-intermediate well SCI-1 in the Sandia watershed. Additionally, molybdenum concentrations show an increasing trend in well SCI-1. Although not detected in groundwater or in nonstorm-related surface water, two additional organic chemicals—benzo[a]anthracene and benzo[a]pyrene—are included because they represent a class of COPCs—PAHs—for which maximum concentrations in sediment in upper Sandia Canyon exceed residential SSLs (section 6.2.2).

Not all COPCs with maximum concentrations that exceed applicable water-quality standards are discussed in this section. In particular, beryllium, cadmium, silver, BHC[delta-], and bromomethane are not discussed because these COPCs have low detection rates in water and because exceedances of BVs, ESLs, and applicable standards are generally limited to infrequent detections in water samples from surface and alluvial environments, as summarized below and in Table D-2.1-1 (metal COPCs) and Table D-2.1-3 (organic COPCs):

- The maximum concentration of beryllium in one of 20 nonfiltered samples of alluvial groundwater (4.6 µg/L, SCA-2) exceeds the EPA MCL of 4 µg/L. One other nonfiltered sample of alluvial groundwater (3.3 µg/L, SCA-4) exceeds the alluvial BV of 2.5 µg/L. The single detection of beryllium (0.14 µg/L, SA-603204) among 54 samples of nonfiltered nonstorm-related surface water is less than the ESL of 5.3 µg/L. Beryllium is not detected above BVs or standards in any filtered samples of surface water and alluvial groundwater, and is below detection in all samples of perched-intermediate and regional groundwater (Table 6.5-1).
- The maximum concentration of cadmium in 1 of 58 filtered nonstorm-related surface-water samples (0.104 µg/L, SCS-2) exceeds the aquatic life criterion of 0.1 µg/L for chronic exposure (Table 6.3-22). Cadmium is not detected above BVs or standards in alluvial, perched-intermediate, or regional groundwater (Table 6.5-1).
- The maximum concentration of silver in stormwater (10.1 µg/L) exceeds the acute aquatic life criterion of 0.4 µg/L in one sample (Table 6.4-3) and is discussed in section 8.1. Silver is not detected above the ESL of 0.15 µg/L nor above any standard in nonstorm-related surface water, nor is it detected above BVs or standards in alluvial, perched-intermediate, or regional groundwater (Table 6.5-1).
- Delta-BHC is detected in one sample of nonstorm-related surface water at gage E122 (location WSFS) in the north fork of Sandia Canyon (0.292 µg/L) at a value exceeding the acute aquatic life criterion of 0.17 µg/L (Table 6.3-26). Delta-BHC is below detection in all other water samples (Table 6.5-1).
- Bromomethane is detected in two of 181 regional groundwater samples. Both detections occur at R-36 (14.7 and 23.6 µg/L), in the first two characterization samples collected from this well, and exceed the EPA regional tap-water screening value of 8.7 µg/L. In subsequent samples from R-36, concentrations dropped below detection levels. Bromomethane is not detected in any other water samples (Table 6.5-1).

Section 7.2.2.2 summarizes spatial variations in concentrations of surface water and alluvial groundwater COPCs in Sandia Canyon, as compared with spatial distribution of these COPCs in canyon sediments.

The primary objective of this comparison is to confirm sources, in part distinguishing COPCs present because of releases from Laboratory SWMUs or AOCs from COPCs derived from other sources, such as natural background variations. Spatial variations are depicted in histogram plots of average concentrations in sediments, surface water, and alluvial groundwater. The objective of these plots is to evaluate possible mechanisms by which a COPC is transported from its source and the role of the wetland or sediment during transport. Other data summaries that support the evaluation of COPC distributions include frequency of detection tables (Tables D-2.0-1 through D-2.0-16, Appendix D of this report) and accompanying data plots that show COPC concentrations as a function of time and location (Figures D-2.1-1 through D-2.1-4, Appendix D).

Sections 7.2.2.3 and 7.2.2.4 examine COPC concentrations in borehole samples and in deep groundwater to evaluate the nature and extent of these chemicals in the deep subsurface.

Section 7.2.2.5 evaluates alternative hypotheses of COPC transport using indicator species or tracers, experimental results in appendixes, and lines of evidence that affect contaminant transport such as hydrogeology and water balance studies. Conceptual models that account for the COPC distributions and trends are drawn primarily from discussions in sections 7.1, 7.2.1, and D-2 in Appendix D, Appendixes H, I, and J, and from more detailed discussions in earlier Laboratory investigation reports referenced in this section.

The distribution of key COPCs in water in the Sandia watershed based upon the evaluations in this section are summarized in Table 7.2-1. As presented in the rest of this section, observed distributions are consistent with conceptual models that group COPCs into three categories according to transport characteristics:

- Strongly adsorbing, relatively immobile COPCs predominantly associated with sediment. The distribution of these COPCs is largely limited to surface media and the alluvial groundwater zone. This category includes aluminum, beryllium, cadmium, lead, Aroclor-1254, Aroclor-1260, delta-BHC, TPH-DRO, benzo[a]anthracene, benzo[a]pyrene, and benzo[b]fluoranthene.
- COPCs predominantly associated with clays, iron (oxy)hydroxides, and solid organic matter. The distribution of these COPCs is more extensive than those in the previous category because they have the potential to be transported through porous media as colloids or adsorbed onto colloidal phases. Some COPCs in this category form colloids or adsorb strongly onto colloids phases under some environmental conditions, and desorb under others; or vice versa. Such mechanisms have the potential to enhance or to retard transport. This COPC category includes arsenic, Cr(III), copper, iron, manganese, and zinc.
- Moderately to highly mobile COPCs, which have the greatest potential to be transported to deep groundwater. This COPC category includes chloride, Cr(VI), molybdenum, nitrate, and sulfate.

7.2.2.2 COPC Distributions in Surface Water and Alluvium

In this section, metal COPCs are discussed first, followed by discussions of organic COPCs and lastly other inorganic COPCs. Within each category, COPCs are discussed in alphabetical order. The evaluation of COPC distributions in surface water and alluvial groundwater is supported by data summarized in several histogram plots, for which the following rationales, limitations, and caveats are provided:

- COPC concentrations in surface water and alluvial groundwater can be heavily influenced by the nature and extent of their distributions in canyon sediment. Silt, clay, and soil organic matter in

the sediment in Sandia Canyon reaches (section 7.1) play a key role in determining the mobility of many inorganic and organic COPCs.

- To facilitate the identification of spatial trends and potential correlations among different metal COPCs, Figure 7.2-4 presents histogram plots of average metal concentrations in fine and coarse sediment facies in the reaches, and Figure 7.2-5 presents analogous plots for filtered and nonfiltered samples of surface water and alluvial groundwater in the Sandia watershed. Such representation is useful for providing a high-level summary, but is subject to the following limitations and caveats.
    - ❖ Sediment averages include samples outside the active channel or away from stream banks. These average concentrations thus include COPCs in sediment that may not be currently near or in contact with surface water or alluvial groundwater.
    - ❖ Average concentrations can be heavily biased by infrequent highly elevated sampling results as well as by variable detection limits.
    - ❖ Different protocols are used to calculate average concentrations in sediment and in water. Averages listed for sediment are arithmetic means, using values of one-half the detection limit for nondetected sampling results (section D-1.2), and averages for water are medians (section D-2.3).

Aluminum

Aluminum is a sediment COPC in one investigation reach (S-2), which includes the Sandia wetland and vicinity (section 7.1.1). Maximum concentrations in stormwater exceed the stormwater comparison value based on the acute aquatic life criterion of 750 µg/L at several surface-water locations (Table 6.3-2), and this trace metal is included in the human health risk assessment in section 8.2.

In nonstorm-related surface water, dissolved concentrations of aluminum exceed the aquatic life criterion of 87 µg/L for chronic exposure at three of the 11 surface-water monitoring stations: station WSFS at stream gage E122 in the north fork of upper Sandia Canyon (maximum of three exceedances = 552 µg/L), stream gage E123 below the Sandia wetlands (one exceedance = 100 µg/L), and station WMSC in the middle portion of Sandia Canyon at the terminus of persistent flow (maximum of five exceedances = 250 µg/L). Maximum concentrations in nonfiltered water exceed the ESL of 87 µg/L at 7 of the 11 stations, with 33 of the 38 exceedances occurring at the same 3 locations listed previously: station WSFS (maximum of 11 exceedances = 2420 µg/L), station E123 (maximum of 12 exceedances = 1290 µg/L), and station WMSC (maximum of 10 exceedances = 1010 µg/L).

No filtered alluvial groundwater samples exceed the alluvial BV (15,670 µg/L) or the New Mexico groundwater standard for filtered water (5000 µg/L). The maximum aluminum concentration in one nonfiltered sample from well SCA-2 (40,200 µg/L) exceeds the EPA regional tap water screening level of 37,000 µg/L, and two nonfiltered samples from well SCA-4 (16,100 and 35,800 µg/L) exceed the BV for filtered alluvial groundwater (15,670 µg/L) (Figure D-2.0-1).

On average, surface water and alluvial groundwater have similar concentrations of dissolved aluminum. In nonfiltered alluvial waters, however, average aluminum concentrations are similar to those in surface waters only in the wetland (wells SCA-1 and SCA-1-DP). In nonfiltered samples from saturated alluvium east of the wetland (wells SCA-2, SCA-4, and SCA-5), aluminum concentrations are much higher than in surface waters (Figure 7.2-5a). Most likely, these elevated aluminum concentrations do not result from anthropogenic releases (section 7.1.4.3) but they have significance as indicators of transport of adsorbed COPCs. For example, the distribution of total lead (Figure 7.2-5f) correlates closely with that of total

aluminum (Figure 7.2-5a) in surface water and alluvial groundwater. From this perspective, the most significant feature of the distribution of aluminum in water may be the high concentration of total aluminum (nonfiltered) periodically observed in alluvial groundwater at wells SCA-2, SCA-4, and SCA-5 (average 10,000 to 12,000 µg/L, Figure 7.2-5a). The presence of high aluminum concentrations in nonfiltered water samples indicates that particulate matter (>0.45 µm) is transported into the subsurface to depths of 37 ft (well SCA-4) and 55 ft (well SCA-5) or more. High aluminum concentrations do not persist between sampling events (Figure D-2.0-1), possibly indicating that the aluminum-rich particulate matter is filtered out of solution.

Arsenic

Arsenic is also a sediment COPC in the Sandia watershed, with maximum concentrations exceeding the BV in investigation reaches above, in, and east of the wetland (section 7.1.1). Average concentrations of total arsenic in sediment are also highest in the four uppermost investigation reaches, including the active wetland in reach S-2 (Figure 7.2-4b). In surface water, the maximum arsenic concentration (10.4 µg/L) occurs at station WSFS above the wetland, and exceeds the water-quality criterion of 9 µg/L for human health (for a perennial stream). No other surface-water samples exceed a standard. In alluvial groundwater, the EPA MCL of 10 µg/L is exceeded by four of seven filtered samples at well SCA-4 (maximum = 15.7 µg/L) and by three of seven nonfiltered samples from the same well (maximum = 19.4 µg/L). One of 7 samples at SCA-1 (maximum = 8.7 µg/L) and 2 of 12 samples at SCA-2 (maximum = 8.4 µg/L) exceed the alluvial BV of 5 µg/L.

Relative distributions of total arsenic in surface water and alluvial groundwater differ from that in sediment in the investigation reaches downgradient of the wetland. Whereas average sediment concentrations are highest in reach S-2 (which includes the wetland) and decrease downgradient in the middle part of Sandia Canyon, in alluvial groundwater the lowest average concentrations occur within the wetland (~2 µg/L at well SCA-1) and the highest average concentrations are observed in well SCA-4 (10 µg/L) (Figure 7.2-5b). Negligible differences between average concentrations in filtered (using 0.45-µm filters) and nonfiltered samples at each location indicate that, on average, arsenic concentrations in these waters are dominated by dissolved or colloidal forms.

Relative distributions of arsenic in surface water and alluvial groundwater show some similarities to those of molybdenum (cf., Figure 7.2-5b and 7.2-5h). Both metals occur predominantly as oxyanions (arsenate and molybdate) in most waters. Although these metals adsorb onto metal (oxy)hydroxides, studies have shown that phosphate competes effectively for the same adsorption sites, leading to partial desorption of arsenate (Appendix J) and molybdate. This observation is relevant because high phosphate concentrations were discharged from the TA-03 power-plant outfall (Consolidated Unit 03-012(b)-00) for several decades (LANL 2006, 094431). Evidence for the potential of this mechanism to enhance release of arsenate from the wetland is discussed in Appendix J as part of the wetland drying experiments. A plot of arsenic versus phosphate concentrations in alluvial groundwaters indicates a threshold effect may be present for this release mechanism because elevated arsenic concentrations are observed in well SCA-4 when phosphate concentrations exceed about 3 mg/L (as P); elevated molybdenum concentrations are also associated with these higher phosphate levels (Figure 7.2-6a and b).

Chromium

Chromium is an important inorganic COPC in sediment, surface water, and groundwater in the Sandia watershed primarily as a consequence of the use of potassium dichromate in cooling water for the TA-03 power plant from 1956 to 1972. Discharge of cooling water blowdown from this facility resulted in an estimated total release of approximately 31,000 to 72,000 kg (69,000 to 160,000 lb) of Cr(VI) into the

south fork of Sandia Canyon [SWMU 03-012(b)] (LANL 2007, 098938; section 2.1.1.1). The highest inventory of the released chromium is presently contained in reach S-2, which includes the wetland (section 7.1). Solid organic matter and saturated alluvium in the Sandia wetland produce geochemically reducing conditions for converting soluble Cr(VI) released in cooling water to insoluble Cr(III), which is particularly stable in this environment. Cr(III) concentrations up to 3740 mg/kg occur within organic-rich sediments in S-2, and average chromium concentrations in the fine facies in S-2 (600 mg/kg) greatly exceed those in any facies in any other reach (Figure 7.2-4c). The chromium inventory in S-2 is estimated to be approximately 15,000 kg (section D-1.3 in Appendix D of this report).

Chromium concentrations for filtered samples are low (<10 µg/L) for all surface and alluvial waters. No filtered surface-water samples have chromium concentrations that exceed the aquatic life criterion of 27.6 µg/L for chronic exposure, and neither filtered nor nonfiltered surface-water samples have chromium concentrations that exceed the ESL of 77 µg/L. No filtered alluvial water samples have chromium concentrations that exceed the New Mexico groundwater standard of 50 µg/L. Two nonfiltered alluvial samples at well SCA-2 (222 and 552 µg/L) exceed the EPA MCL of 100 µg/L. At all alluvial locations, the majority of the samples (18 of 24 filtered samples; 19 of 20 nonfiltered samples) exceed the alluvial BV of 5 µg/L.

The relative distributions of chromium concentrations in surface water and alluvial groundwater differ from that in sediment. The highest average chromium concentrations in nonfiltered water samples occur immediately downgradient of the wetland (gage E123, 179 µg/L) and in well SCA-2 (135 µg/L). These comparatively elevated average concentrations are driven primarily by four excursions (226 and 329 µg/L at gage E123 and 222 and 552 µg/L at well SCA-2). Average chromium concentrations for nonfiltered water are lowest (17 µg/L) in alluvial groundwater within the wetland (well SCA-1-DP). The distribution pattern for nonfiltered chromium samples in water is similar to that of nonfiltered iron samples (Figure 7.2-5e), which suggests these two metals share similar transport characteristics in this surface environment.

Several mechanisms can account for the present-day low-level mobilization of chromium from the wetland (Appendix J), which manifests as higher concentrations in alluvial groundwater than in surface waters:

- Cations concentrated in the SWSC treated effluent—including calcium, sodium, and magnesium—may enhance desorption of Cr(III) from wetland sediment through cation exchange reactions.
- Sulfate, phosphate, and total carbonate alkalinity are competing anions for Cr(VI), which limits adsorption of Cr(VI) onto iron (oxy)hydroxides at or above pH 6.
- Complexing of Cr(III) with DOC, in the forms of humate and fulvate ligands (anions), may also enhance desorption of Cr(III) from the organic-rich solids concentrated within the wetland.
- Colloids (smaller than 0.22 µm in size) consisting of $Fe_xCr_{1-x}(OH)_3$ and $Cr(OH)_3$ are mobilized by water moving through the wetland.

Copper

Copper has maximum concentrations above the sediment BV in 8 of the 11 investigation reaches (section 7.1.1). The highest concentrations are in sediment from reach S-2, in current or former wetland areas. Spatial variations in sediment are most similar to those of chromium insofar as the bulk of the inventory resides in the wetland, and concentrations drop off sharply with increasing distance downcanyon (Figure 7.2-4d).

In surface water, half the filtered samples exceed the aquatic life criterion of 3.2 µg/L for chronic exposure. These exceedances occur at 6 of the 11 surface-water monitoring locations, with the two highest concentrations (6.99 and 7.2 µg/L) detected at the westernmost and easternmost reaches in which surface flow occurs in Sandia Canyon: station WSFS (gage E122) in the north fork of Sandia Canyon, and station SCS-2 near the terminus of persistent surface flow (Figure 3.2-1). About 33% of the 58 nonfiltered surface-water samples exceed the ESL of 5 µg/L. The maximum concentration (10.9 µg/L) as well as the largest proportion of exceedances (8 of 13 samples) are detected at gage E123 below the wetlands.

No alluvial samples exceed applicable standards, which include the New Mexico groundwater standard of 1000 µg/L and the EPA MCL of 1300 µg/L for filtered and nonfiltered groundwater, respectively. One filtered sample at SCA-2 (120 µg/L), three nonfiltered samples at SCA-2 (maximum = 66 µg/L), and three nonfiltered samples at SCA-4 (maximum = 43.8 µg/L) exceed the alluvial BV of 5 µg/L.

The distribution pattern for copper in surface water and alluvial groundwater is most similar to those of arsenic and molybdenum with respect to the following characteristics:

- The lowest average copper concentration occurs in alluvial groundwater within the wetland (maximum = 3.7 µg/L in well SCA-1; not detected in well SCA-1-DP).
- The highest average copper concentrations are observed downgradient of the wetland (well SCA-2 for copper; well SCA-4 for arsenic and molybdenum).
- Differences between average filtered and nonfiltered concentrations are negligible at all locations, indicating that, in general, copper concentrations in these waters are dominated by dissolved or colloidal forms.

Iron

Spatial variations of iron concentrations in sediment show no pattern that would indicate significant releases, and probably represent natural background variability (section 7.1.1). However, iron is a dominant constituent controlling transport processes and rates for the majority of the inorganic COPCs.

Although there is no applicable standard for iron in surface water, concentrations in all surface-water samples are less than the New Mexico tap-water screening value of 25,600 µg/L. Total iron concentrations exceed the ESL of 1000 µg/L in one sample each at station WSFS (gage E122) (1610 µg/L) and gage E121 (1270 µg/L) west of the wetland in the north and south forks of Sandia Canyon, respectively, and in three samples at gage E123 east of the wetland (maximum = 1550 µg/L).

In alluvial groundwater, iron concentrations in six of eight filtered samples at well SCA-1 (maximum = 2150 µg/L) exceed the New Mexico groundwater standard of 1000 µg/L. The total iron concentration in one of six nonfiltered samples at well SCA-2 (36,400 µg/L) exceeds the EPA regional tap-water screening level of 26,000 µg/L. None of the 24 filtered alluvial samples exceed the alluvial BV (8270 µg/L). Four of the 20 unfiltered alluvial samples exceed this BV, including 2 samples each at well SCA-2 (maximum = 36,400 µg/L) and SCA-4 (maximum = 16,400 µg/L).

Similar to the distribution of aluminum in sediment, iron has higher concentrations in fine facies sediment than in coarse facies sediment, and average concentrations are more or less constant among the reaches (Figure 7.2-4e). In water, average iron concentrations in filtered water are negligibly low—with the notable exception of up to 2150 µg/L measured in the reducing environment of the wetland at SCA-1. Average nonfiltered concentrations are generally highly elevated (Figure 7.2-5e), indicating iron

concentrations in these waters are dominated by particulate forms. In alluvial groundwater, total iron concentrations are correlated with total aluminum concentrations (Figure 7.2-6a).

Lead

Lead is a COPC for which the maximum concentrations in sediment exceed the BV in 9 of 11 investigation reaches. The highest average concentrations occur in fine facies sediment in reaches above the wetland (Figure 7.2-4f).

In surface water, lead concentrations in filtered samples exceed the aquatic life criterion of 0.66 µg/L for chronic exposure in one sample collected above the wetland (gage WSFS, 0.97 µg/L) and in three samples collected at the present-day terminus of persistent flow in middle part of Sandia Canyon (SCS-2, maximum = 0.97 µg/L; this location has the same location coordinates as the WMSC). Total lead concentrations exceed the ESL of 1.2 µg/L in 6 of 11 samples at gage E123 east of the wetland (maximum = 4.7 µg/L), in 1 of 12 samples collected above the wetland (WSFS, 4 µg/L), and in 1 of 9 samples collected at the terminus of persistent flow (WMSC, 1.3 µg/L).

In alluvial groundwater, none of the 24 filtered samples have lead concentrations that exceed the EPA MCL of 15 µg/L or the alluvial BV (1.88 µg/L). Four of 20 nonfiltered alluvial samples have lead concentrations exceeding the EPA MCL (15 µg/L): well SCA-2 (maximum = 30.1 µg/L) and well SCA-4 (maximum = 38.1 µg/L).

The distribution of lead concentrations in surface water and alluvial groundwater is most similar to that of aluminum (Figure 7.2-5f). Lead concentrations in filtered samples are generally negligibly low compared to those in nonfiltered samples, indicating lead in these waters is predominantly associated with particulates. Secondly, like aluminum, average lead concentrations are by far the highest in nonfiltered alluvial groundwater samples from locations in middle Sandia Canyon (wells SCA-2, SCA-4, and SCA-5).

Manganese

Manganese concentrations in sediment do not exceed the BV, and spatial variations in manganese concentrations show no pattern that indicates releases (Figure 7.2-4g).

There is no applicable standard for manganese in surface water, but all surface-water samples have concentrations less than the New Mexico tap-water screening value of 876 µg/L. Manganese concentrations exceed the ESL of 80 µg/L in six of 24 filtered samples and in six of 20 nonfiltered samples, all from the upper portion of Sandia Canyon. Nine of the 12 exceedances are observed in samples collected at gage E123 east of the wetland (maximum = 224 µg/L). The other three samples are from locations above the wetland (WSFS [gage E122], maximum = 236 µg/L; gage E121, 123 µg/L).

In alluvial groundwater, filtered samples have manganese concentrations that exceed the New Mexico groundwater standard of 200 µg/L at well SCA-1 (maximum = 1380 µg/L) and well SCA-1-DP (maximum = 792 µg/L). Three of 20 nonfiltered alluvial samples exceed the EPA regional tap-water screening level of 880 µg/L: well SCA-1 (maximum = 1460 µg/L) and well SCA-2 (1140 µg/L). Eleven of 23 filtered samples and 14 of 20 nonfiltered samples have manganese concentrations above the alluvial BV (21 µg/L).

The distribution of manganese in sediment and water differs markedly from those of all other metals evaluated in this section. In contrast to the distribution of average iron concentrations in sediment, average manganese concentrations in fine facies sediment are higher (by about a factor of 2) downgradient of the wetland than average concentrations in or above the wetland (Figure 7.2-4g). In

water, average manganese concentrations are highest within the wetland and negligibly low in surface water from locations other than gage E123 east of the wetland (Figure 7.2-5g). At these six monitoring locations, filtered and nonfiltered concentrations of manganese are not significantly different, indicating manganese is dominated by dissolved or colloidal forms. The pattern for these six locations indicates that surface waters above and downgradient of the wetland are generally oxidizing with respect to manganese, and that alluvial groundwater in the wetland is reducing with respect to this metal. Manganese in alluvial wells downgradient of the wetland shows distribution that is similar to chromium and iron. Concentrations of the three metals are significantly higher in nonfiltered samples than in filtered samples in these wells, indicating that manganese in alluvial groundwater may also be dominated by particulate forms in this part of the hydrologic system. As is the case for most other metals in alluvial groundwater at these locations, elevated manganese concentrations in nonfiltered samples do not persist from one event to the next, nor do manganese concentrations show temporal trends of increasing or decreasing concentrations.

Molybdenum

Molybdenum does not have a sediment BV, and is listed as a COPC for the Sandia watershed based solely on its detection status (section 7.1.1). No data are available for molybdenum in sediment from investigation reaches above the wetland. The distribution of molybdenum in sediment is dominated by that associated with the fine facies in reach S-2, which includes the wetland and vicinity (Figure 7.2-4h). Concentrations in sediment decrease rapidly downcanyon. The distribution of molybdenum in sediment is most similar to that of chromium, except that concentrations of molybdenum are considerably lower (maximum = 44.4 mg/kg for molybdenum).

Molybdenum concentrations in surface waters are less than the irrigation standard of 1000 µg/L and the New Mexico tap-water screening value of 183 µg/L. No alluvial samples exceed a standard, which include the New Mexico groundwater standard of 1000 µg/L and the EPA tap-water screening value of 180 µg/L for filtered and nonfiltered groundwater, respectively. Molybdenum concentrations exceed the alluvial BV of 5 µg/L in most samples. Differences between filtered and nonfiltered concentrations are negligible, indicating molybdenum concentrations in these waters are dominated by dissolved or colloidal forms. In contrast to the distribution observed in sediment, average concentrations of molybdenum in water increase steadily with distance downgradient, and all but one of the molybdenum concentrations above 30 µg/L occurs in alluvial groundwater at well SCA-4 (maximum = 67 µg/L) (Figure 7.2-5h). This distribution may reflect a contribution from former outfall discharges at TA-53.

Zinc

Zinc is a COPC for which the maximum concentration in sediment exceeds the BV (60 mg/kg) in eight of the 11 investigation reaches. Average concentrations are highest in fine facies sediment in the wetland (Figure 7.2-4j).

In surface water, zinc concentrations in filtered samples exceed the acute aquatic life criterion of 42 µg/L in 15 of 58 samples. Proceeding from the upper section of Sandia Canyon to the terminus of persistent surface flow, the 15 exceedances occurred in six samples at gage E121 (maximum = 390 µg/L), one sample at station WSFS (gage E122) in the north fork of Sandia Canyon (93.8 µg/L), five samples at gage E123 east of the wetland (maximum = 74.8 µg/L), and three samples collected from middle Sandia Canyon at SCS-2 (maximum = 46.8 µg/L). Total zinc concentrations exceed the ESL of 66 µg/L in six of 55 samples, four of which are in upper Sandia Canyon above the wetland: station WSFS (144 µg/L) and collocated gage E122 (maximum = 76.3 µg/L) and gage E121 (382 µg/L). The other two ESL exceedances occur at gage E123 east of the wetland (maximum = 97.8 µg/L).

No alluvial groundwater samples exceed the New Mexico groundwater standard of 10,000 µg/L for filtered samples or the EPA regional tap-water screening level of 11,000 µg/L for nonfiltered samples. Fourteen of 24 filtered samples and 17 of 20 nonfiltered samples have zinc concentrations above the alluvial BV (10 µg/L). Among these samples, the highest concentrations occur at well SCA-2 (maximum = 195 µg/L) and well SCA-4 (maximum = 214 µg/L).

The distribution of zinc concentrations in surface water and alluvial groundwater shares similarities with, as well as significant differences from, those of chromium, iron, arsenic, manganese, molybdenum, and zinc. Total zinc concentrations are strongly correlated with total iron concentrations (Figure 7.2-6e). Like chromium and iron, average zinc concentrations in nonfiltered samples are heavily skewed by occasional excursions, and the variability in concentrations is greatest at gage E123, well SCA-2, and well SCA-4. Like arsenic, manganese, and molybdenum, differences between filtered and nonfiltered concentrations of zinc in surface water and alluvial groundwater are generally small (although not negligible), indicating that zinc concentrations are dominated by dissolved or colloidal forms. Like arsenic, average zinc concentrations are lowest within the wetland (wells SCA-1 and SCA-1-DP) and in the single sample from SCA-5 for which data are available (October 2006). However, in contrast with the other trace metals, zinc concentrations are consistently higher in surface-water samples collected at gage E121 than those in samples collected at WSFS, suggesting that releases into the south fork of upper Sandia Canyon have been more significant than those into the north fork.

Aroclor-1254 and Aroclor-1260

The bulk of the sediment inventories of Aroclor-1254 and Aroclor-1260 reside in reach S-2, including the wetland, and distributions of these two PCBs in sediment are dispersed downgradient as far as reach S-5E (section 7.1.1 and Figure 7.2-7a). Aroclor-1254 and Aroclor-1260 are consistently detected in surface water immediately downgradient of the wetland (gage E123) at concentrations that exceed the human health criterion for perennial water (0.00064 µg/L). In alluvial groundwater, these two PCBs are detected infrequently at well SCA-1 within the wetland, at concentrations below the EPA MCL of 0.5 µg/L. PCBs are not detected in surface water or groundwater downgradient of gage E123 (Figure 7.2-7b). Absence in downgradient water is expected because PCBs generally remain tightly bound to soil and sediment. Persistence in sediment is particularly characteristic of the more highly chlorinated PCBs that dominate mixtures in Aroclor-1248 and especially in Aroclor-1260. The detection of these two Aroclors in waters in the immediate vicinity of the wetland is likely from the presence of suspended sediment in these samples. Suspended sediment concentrations in nonfiltered samples collected at gage E123 range from 2 to 68 mg/L. In well SCA-1, the suspended sediment concentration is 207 mg/L in the only sample for which this parameter is reported (October 2006).

Benzo[a]anthracene and Benzo[a]pyrene

The highest concentrations of benzo[a]anthracene and benzo[a]pyrene in sediment are in investigation reaches S-1N and S-1S above the wetland (section 7.1.1.2, Figure 7.2-8a). Much smaller concentrations have been measured in reach S-2, which includes the wetland. Downgradient dispersion in sediment is minimal although an additional source term for these PAHs appears to be present that accounts for detected concentrations in investigation reach S-5C (section 7.1.1, Figure 7.2-8a). These PAHs are not detected in surface-water or groundwater samples (Figure 7.2-8b). Absence in downgradient media is consistent with the propensity of these high-molecular-weight PAHs to partition into soil and sediment as a result of their low water solubilities, low vapor pressures, and high octanol-water partition coefficients (K_{ow}), with values in the range of 10^5 to 10^6 (Syracuse Research Corporation 2005, 090573).

Two additional PAHs detected in sediment are benzo(b)fluoranthene and indeno(1,2,3-cd)pyrene (section 7.1.1.1). These two COPCs are also not detected in surface water nor in alluvial groundwater samples. Their absence from water is likewise consistent with their very strong tendencies to partition into soil and sediment.

Bis[2-ethylhexyl]phthalate

Bis[2-ethylhexyl]phthalate is not detected in surface water. This COPC is detected in one of 14 alluvial groundwater samples. The single detection occurs at well SCA-4 (51.2 µg/L), at a concentration which exceeds the EPA MCL of 6 µg/L. Bis(2-ethylhexyl)phthalate is a component of plastics and could be derived from several sources, including sampling equipment, Laboratory discharges and runoff, and analytical laboratories in which water samples come in contact with plastic during analysis.

Chloride

There is no applicable standard for chloride in surface water. Average concentrations of chloride in surface water and alluvial groundwater are provided in Figure 7.2-9a. Chloride concentrations in surface water are less than the ESL of 230 mg/L in all but one of 62 samples. The single ESL exceedance is a chloride concentration of 346 mg/L at gage WSFS in the south fork of upper Sandia Canyon.

One of 26 alluvial groundwater samples (well SCA-2, 266 mg/L) exceeds the New Mexico groundwater standard of 250 mg/L. Eighteen of 26 alluvial samples exceed the alluvial BV (70 mg/L). Maximum values generally show a decreasing trend with distance downgradient: well SCA-1 (197 mg/L), well SCA-1-DP (106 mg/L), well SCA-2 (148 mg/L), and well SCA-4 (123 mg/L).

7.2.2.3 COPC Distributions in the Vadose Zone

Transport of COPCs into the suballuvial vadose zone is generally limited to soluble constituents such as Cr(VI), Mo(VI), chloride, nitrate, phosphate, sulfate, and tritium. This section summarizes concentration profiles measured on core collected from the six core holes SCC-I to SCC-6 and the perched-intermediate well SCI-2 drilled in Sandia Canyon. It describes the present-day vadose-zone distribution of COPCs discharged from the TA-03 power plant cooling towers into Sandia Canyon at SWMU 03-012(b): chromium, molybdenum, phosphate, zinc, nitrate and sulfate. Core samples were analyzed for the metals (chromium, molybdenum, and zinc) using both DI water leaching to determine pore water concentrations and the EPA 3050 digestion method, which is referred to as the acid-soluble (digested) fraction (section 3.3). For the anions (nitrate, phosphate and sulfate), pore water concentrations were determined by DI leaching. Much of the information is summarized from the chromium interim measures report (LANL 2006, 094431).

Chromium

Vadose-zone profiles indicate most of the dissolved chromium in core holes SCC-1 to SCC-3 has been largely flushed out of pore water in the upper 122 m (400 ft) of the vadose zone by low-chromium water following cessation of chromium releases in 1972 (LANL 2006, 094431). Chromium concentrations in pore water from core at SCI-2 from depths of approximately 110 to 240 m (350 to 800 ft) in the Puye Formation and the Cerros del Rio basalt range up to about 300 µg/L, indicating that residual chromium remains in pore water in these deeper units (Plate 6 and Figure I-3.2-2). Core holes SCC-1 to SCC-3 and well SCI-2 are within the primary infiltration zone discussed in section 7.2.1.3 and illustrated in Figure 7.0-1. Further downcanyon at SCC-4 and SCC-5, chromium pore water concentrations between 20 µg/L and 190 µg/L are present within the upper portion of the Bandelier Tuff and concentrations below

that are less than the detection limit. Deep infiltration rates are less here than in the primary infiltration zone to the west. At R-11 and SCC-6, chromium is pore water is below the detection limit, except in the alluvium (Plate 6), indicating virtually no transport of chromium in this portion of the canyon. All of the pore water concentrations measured in the vadose zone are less than those measured at regional wells R-42 and R-28. Pore water chromium concentrations for the lower part of the vadose zone are limited to SCI-2 core samples, and other deep vadose-zone pathways may contain higher chromium concentrations. Nonetheless, with the data available, it appears further migration of vadose-zone pore waters from directly beneath Sandia Canyon to the regional aquifer should not result in increased maximum regional aquifer concentrations in the future.

Acid-soluble chromium concentrations measured by the EPA 3050 method on cores collected from the SCC core holes and from SCI-2 are presented in Figure 5.5-1 of the chromium interim measures report (LANL 2006, 094431) and in Figure I-3.2-2, respectively. The data show that acid-soluble chromium is elevated compared to BVs in the Bandelier Tuff, the Cerro Toledo interval, the upper Puye Formation, and the Cerros del Rio basalt. In section D-2.2 of Appendix D, a mass balance approach was used to estimate the anthropogenic chromium that may be present in the vadose zone beneath Sandia Canyon based on the acid-soluble chromium measured in these cores, which are thought to attenuate chromium through chemical reduction, precipitation and adsorption (Appendix I). The estimated mass balance attributes a mean value of 39,000 kg Cr(VI) attenuated on vadose-zone rocks beneath Sandia Canyon, potentially representing 76% of the mean estimated original Cr(VI) source term. Uncertainty on these values is discussed in Appendix D.

Molybdenum

Molybdenum has migrated into the vadose zone in Sandia Canyon, probably since cooling tower releases containing molybdenum began in the canyon. At the TA-03 power plant, that occurred from 1993 to 2001 (section 2). Acid-soluble molybdenum and pore-water dissolved molybdenum concentrations for SCC-1 to SCC-6 are shown in Figure 5-5.3 in the chromium interim measures report (LANL 2006, 094431). Plate 6 of this report also presents the pore water concentrations, which are elevated into the Bandelier Tuff in core holes SCC-1, SCC-2, SCC-3, and SCC-4 and in the alluvium in SCC-5 and SCC-6. Because molybdenum was used 20 yr or more after chromium at the TA-03 power plant, it trails chromium migration though the vadose zone (i.e., it is generally observed closer to the surface). Pore water and acid-soluble concentrations are correlated, indicating that molybdenum weakly adsorbs onto vadose zone materials.

Zinc

Zinc has migrated into the vadose zone in Sandia Canyon. At the TA-03 power plant cooling towers, zinc was used from 1956 to 1972 and again from 2001 to 2006 (LANL 2006, 094431) but may have been used in the years between these periods as it is a common cooling tower additive. Zinc concentrations as a function of depth for acid-soluble zinc and pore-water dissolved zinc in core holes SCC-1 to SCC-6 are shown in Figure 5-5.5 in the chromium interim measures report (LANL 2006, 094431) for core holes SCC-1 to SCC-6. Zinc was detected in all pore water samples analyzed in these core holes and is elevated over the entire length of the six core holes, possibly reflecting a long discharge history. Acid-soluble zinc concentrations exceed the upper tolerance limit (UTL) in only a few of the samples. However, pore water and acid-soluble concentrations are correlated indicating that zinc weakly adsorbs onto vadose zone materials.

Nitrate and Sulfate

The distribution of pore water nitrate in core from the upper vadose zone in Sandia Canyon is shown in Figure 7.2-10, based on data from core holes SCC-1 to SCC-6. Some of the lowest pore water nitrate concentrations are in portions of Sandia Canyon where significant infiltration is expected, particularly at SCC-2. One interpretation of the low nitrate concentrations in core at SCC-2 is that previously high, but very soluble, nitrate concentrations have been flushed out by later low-nitrate waters percolating through the vadose zone. Surface-water data presented in section D-2.3 show that nitrate concentrations have decreased with time, probably because of better wastewater treatment processes. Highest water fluxes occur at SCC-2 through SCC-4, and these locations have the lowest pore water nitrate concentrations. Conversely, lower infiltration rates or potentially intermittent flow occur at SCC-5 and SCC-6, and these locations are poorly flushed by recent waters and tend to retain their nitrate inventories in the Otowi Member of the Bandelier Tuff. In this scenario, sporadic high nitrate values in the alluvium (e.g., uppermost sample at SCC-3) suggest that pockets of nitrate retention may be retained even above the deeper vadose zone where nitrate has been largely flushed out.

Figure 7.2-11 compares sulfate distributions in the same core holes. Within the Otowi Member, sulfate distributions tend to be fairly high in the four western core holes (SCC-1 to SCC-4) and lower in the eastern holes (SCC-5 and SCC-6). The lowest sulfate concentrations occur in the easternmost core hole, SCC-6. These distributions suggest that either the time frame of sulfate movement is more recent than that of nitrate or that the geochemistry of groundwater interaction for sulfate differs significantly from that of nitrate. Section D-2.3 shows that the time-variant concentrations of nitrate and sulfate in surface water in Sandia Canyon are not correlated.

Phosphate

Phosphate is present in pore water from core holes SCC-1 to SCC-6, as shown in Figure 5-5.4 in the chromium interim measures report (LANL 2006, 094431). Phosphorous-derived cooling water additives were used at the TA-03 power plant from 1951 through 2001. Other cooling towers discharging to Sandia Canyon may have also released effluent with phosphate (e.g., from TA-53). Phosphate was detected in most of the SCC core samples analyzed, and vadose-zone pore water concentrations range from below the detection limit to 35 mg/L. Phosphate is present above its detection limit throughout the depth profiles in SCC-2, SCC-3, SCC-5, and SCC-6, but its concentration drops below its detection limit in the Otowi Member in SCC-1 and SCC-4. Its concentration versus depth profiles for phosphate differ significantly from the infiltration patterns shown by the other mobile analytes discussed in this section.

7.2.2.4 COPC Distributions in Perched-intermediate Groundwater and Regional Groundwater

This section examines the spatial and temporal variations of COPCs detected in deeper groundwater to evaluate the nature and extent in the deep subsurface. For each COPC, its current distribution in water is described and time histories for selected analytes are presented to illustrate the evolution of the COPC in the environment. Plots in Appendix D provide a comprehensive overview of the spatial and temporal trends of COPCs beneath Sandia and Mortandad Canyons.

Information used to support the evaluation of selected COPC distributions in intermediate and regional groundwater is presented in a series of plots provided in a graphical format that integrates concentration data for a given analyte in a watershed onto a single figure that yields both three-dimensional spatial information and temporal trends. These plots are referred to as “subway plots” because of their resemblance to maps of subway systems.

The plot format and their utility are described here. Across the top of each plot is a linearized plan-view map of the Sandia and Mortandad watersheds showing the major canyons and tributaries, and the locations of selected base-flow stations and monitoring wells within the two watersheds. Symbols for the monitoring locations are color-coded to depict the water type sampled: yellow for base flow (surface water), blue for alluvial groundwater, green for perched-intermediate groundwater, and red for groundwater from the regional aquifer. Pointers from this map splay down to the concentration plot below so the reader remains oriented to the respective monitoring location.

Each plot provides analyte concentration data for the time period from January 2003 to July 2009 for a selected set of monitoring locations in the watershed. The color coding that represents water type is maintained so that the sample depth is qualitatively represented. The plot is segmented by monitoring location, with the temporal data plotted from left (January 2003) to right (July 2009) within each segment. Dual-screen wells have two segments on the concentration plot. For constituents with available background concentrations, UTL values are included on the plot for reference for perched-intermediate groundwater and for regional aquifer groundwater.

Chromium

Chromium concentrations exceed the New Mexico groundwater standard of 50 µg/L and the EPA MCL of 100 µg/L in three monitoring wells (SCI-2, R-28, and R-42). These elevated chromium levels are linked to the TA-03 power-plant outfall (Consolidated Unit 03-012(b)-00) at the head of Sandia Canyon. Other potential contributing sources of chromium may include the cooling tower at the Omega West reactor (TA 02) in Los Alamos Canyon and release sites at TA-03, TA-35, and TA-48 in the Mortandad watershed. The total mass of chromium released and effluent discharge volumes in Sandia Canyon were more than an order of magnitude greater than those released in Los Alamos and Mortandad Canyons. Some of the other mobile contaminants collocated with chromium are probably derived from contaminant sources in Los Alamos and Mortandad Canyons, suggesting a commingling of contaminant plumes.

The three monitoring wells at which chromium concentrations exceed the EPA MCL of 100 µg/L lie within a kilometer of one another and include intermediate-perched well SCI-2 (maximum = 658 µg/L) in the middle portion of Sandia Canyon, and regional monitoring wells R-42 and R-28 (maximum = 886 and 490 µg/L, respectively) in Mortandad Canyon (Figures 7.2-12 and 7.2-13). Although available data span less than a year for wells SCI-2 and R-42, concentrations thus far have steadily increased in well SCI-2 (from 489 µg/L in November 2008 to 658 µg/L in May 2009) as well as in well R-42 (from 768 µg/L in November 2008 to 886 µg/L in May 2009) but have not shown any consistent trend in well R-28. Average chromium concentrations in filtered groundwater samples are shown in Figure L-2.0-2, and chromium concentration and water level data for some of the key monitoring wells near Sandia Canyon are plotted versus time in Figure L-4.0-1.

Stiff diagrams of major ion chemistry for regional groundwater are shown in map view in Figure 7.2-3. These diagrams show chromium-bearing groundwater at R-42 and R-28 have distinctly higher major ion concentrations than surrounding regional wells. The spatial association of elevated major ion concentrations with elevated levels of anthropogenic chromium and other contaminants indicate that vadose-zone water mixes with regional water near R-42 and R-28 to generate the observed major ion and contaminant concentrations.

Filtration and analysis of surface water collected below the wetland and filtered through a 0.02-µm filter show chromium concentrations approximately half that of samples filtered through a 0.45-µm filter (Appendix J). This analysis suggests that up to half the chromium detected in surface water at low concentrations may be attributable to colloids. However, at moderate to high concentrations, filtered and

hexavalent chromium concentrations are highly correlated, based on early data collected involving the analysis of filtered samples for total chromium and Cr(VI) at R-1, R-11, and R-28 (LANL 2006, 093175). It is therefore assumed that elevated levels of chromium measured in filtered samples of deep groundwater are predominantly present as Cr(VI).

Chromium is detected below the New Mexico groundwater standard of 50 µg/L, but consistently above BVs of 2.4 µg/L and 5.75 µg/L for intermediate and regional groundwater, respectively, at eight other monitoring wells (Figures 7.2-12 and 7.2-13).

- At perched-intermediate well SCI-1, ~1/4 km northwest of well SCI-2 in Sandia Canyon, total dissolved chromium was detected at a peak concentration of 22 µg/L in August 2007. Values have gradually decreased since then, to current (May 2009) concentrations of 12.6 µg/L and 15.4 µg/L in filtered and nonfiltered samples, respectively.
- At regional well R-11, ~1 km east of well SCI-2 in Sandia Canyon, chromium shows a well-defined increasing trend between 2005 and 2007, reaching peak concentrations of 35.1 µg/L (nonfiltered sample) in February 2007 and 34.8 µg/L (filtered sample) in June 2007. Concentrations remained above 30 µg/L at R-11 for about 1 yr, then decreased steadily after August 2007 to a current value of 17 µg/L (April 2009), about one-half the earlier peak concentration. These trends may parallel trends in the flux of chromium arriving at the regional aquifer from the vadose zone or, alternatively, may reflect spatially varying chromium concentrations migrating through the regional aquifer at R-11. No other monitoring wells in the area observed similar behavior (Figure L-4.0-1).
- At regional well R-15, ~1 km west of well R-42 in Mortandad Canyon, maximum chromium concentrations of 10.5 and 11.3 µg/L (filtered and nonfiltered samples, respectively) occurred in November 2007. Concentrations have remained fairly constant and have not shown a clear trend over the five years that this monitoring well has been in place.
- The upper screens of regional wells R-44 and R-45, ~0.5 km southeast and east-southeast of well R-42, show chromium concentrations above the regional groundwater BV of 5.75 µg/L (filtered): 13.5 µg/L in well R-44 (nonfiltered, February 2009) and 12.4 µg/L in well R-45 (nonfiltered, July 2009).

In addition to these wells, chromium is also detected above background in three perched-intermediate wells in middle Mortandad Canyon: MCOI-4, MCOI-5, and MCOI-6. Upper bounds on the portion of chromium that is attributable to the Sandia source are discussed in section D-2.3.

- At well MCOI-4, maximum concentrations of 29 µg/L and 135 µg/L for filtered and nonfiltered samples, respectively, occur in the first two samples collected from this well (2005). Differences between chromium concentrations in filtered and nonfiltered samples largely disappear after the first year. Chromium concentrations decrease steadily until May 2008, when they reach present-day levels of about 8 µg/L. The trend described for chromium parallels that observed for perchlorate as well as for boron, nitrate, calcium, magnesium, and tritium at this location (section D-2.3).
- At well MCOI-5, maximum concentrations are 4.6 µg/L for filtered samples and 770 µg/L for nonfiltered samples. As with MCOI-4, the peak concentration for nonfiltered samples occurs in the first sample collected from this well (June 2005), dropping sharply in subsequent samples to approach the perched-intermediate BV of 2.4 µg/L by October 2006. Subsequent nonfiltered concentrations fluctuate between 2 and 62 µg/L and do not show a trend. Filtered concentrations fluctuate narrowly around a median value of 3 µg/L throughout the period of record. Thus, in contrast with MCOI-4, filtered and nonfiltered concentrations at MCOI-5 are not closely

correlated. Iron, molybdenum, and zinc follow trends similar to that observed for chromium (e.g., low concentrations in filtered samples throughout the period of record) and elevated concentrations in nonfiltered samples that drop sharply over the first 2 yr. This pattern suggests that the presence of these metals in early samples may have resulted from residual metal fragments of drilling equipment in the borehole (e.g., Appendix I).

- At well MCOI-6, the maximum concentration of 57 µg/L occurs in the second sample collected from this well (September 2005). Differences between chromium concentrations in filtered and nonfiltered samples are relatively small throughout the period of record. Chromium concentrations decrease gradually to a low of 29 µg/L (filtered) in February 2007, after which they increase gradually to present-day levels of about 42 µg/L (nonfiltered) in May 2009. Correlations between chromium and other COPCs may be obscured by the presence of commingling of groundwater from Mortandad and Sandia sources as well as by differences in transport rates through geologic media (section D-2.3).

Evidence for retardation of chromium during transport through geologic media is provided by analytical results for stable isotopes of chromium (δ^{53}Cr) that show various fractions of Cr(VI) have been reduced to the less-mobile species Cr(III) in surface water and groundwater within Sandia and Mortandad Canyons (Appendix H). Ferrous iron [Fe(II)] concentrated in oxide minerals, olivine, pyroxene, and amphibole present in vadose-zone and aquifer material is hypothesized to be the most important naturally occurring reductant for removing Cr(VI) from intermediate and regional groundwater. Reduction of Cr(VI) to Cr(III) occurs as Fe(II) oxidizes to Fe(III), forming ferric hydroxide (FeOOH), a common alteration product of Fe(II)-bearing minerals. The greatest potential for reduction appears to reside in the Fe(II)-rich Cerros del Rio basalt, with the extent of reduction dependent upon contaminant concentration, mineral surface area, porous media groundwater flow, and residence time within the basalt. To a first approximation, the chromium isotope data suggest that roughly one quarter of the main mass of Cr(VI) has been reduced in the vadose zone before it reaches the regional aquifer along the dominant contaminant flowpaths through the vadose zone to the regional aquifer (Appendix H). However, the reduction rate may be higher along other infiltration flowpaths that did not manifest as contaminant pathways to the regional aquifer. Constant δ^{53}Cr values at most contaminated regional aquifer locations may suggest (1) negligible reduction of Cr(VI) to Cr(III) in the regional aquifer, and/or (2) a steady rate of reduction of Cr(VI) to Cr(III) in the vadose zone along the dominant contaminant flowpath.

An analysis presented in the chromium fate and transport update report (LANL, 2008, 102996) suggested the fluctuations in chromium concentration at R-28 are correlated with water-level changes. Figure G-3.0-1 in Appendix G compares transients in the water-level elevation and concentrations of key geochemical constituents observed at R-28 over a longer time frame. The data suggest a correlation exists between the water levels and chromium, nitrate, and tritium concentrations. In addition, chromium, nitrate, and tritium concentration also seem to be spatially correlated with each other, indicating fluctuations of the regional water table affect the contaminant fate and transport. For example, geochemical constituents in the vadose zone just above the regional water table could be mobilized during times of higher water levels. In this way, chromium, nitrate, and tritium mass residing in the vadose zone may be flushed by rising water levels, resulting in a higher measured concentration at the monitoring wells. Conversely, when the water table drops, chromium, nitrate, and tritium come from continuously saturated strata, which potentially results in more dilute concentrations.

Molybdenum

No deep groundwater samples exceed standards for molybdenum, which include the New Mexico groundwater standard of 1000 µg/L for filtered water, the EPA regional tap water screening level of

180 µg/L for nonfiltered water, and the New Mexico tap-water screening value of 183 µg/L for filtered and nonfiltered waters (Table 6.5-1). However, molybdenum concentrations in the perched-intermediate well SCI-1 consistently exceed the BV of 4.3 µg/L (Figure 7.2-14). The maximum molybdenum concentration (77.7 µg/L) in SCI-1 occurs in the most recent sample (May 2009). Concentrations at this well have risen steadily from an initial value of 44.9 µg/L measured in January 2007.

Elevated molybdenum concentrations at well SCI-1 may be derived from the Sandia Canyon TA-03 power-plant outfall [Consolidated Unit 03-012(b)-00]. Molybdenum was released into Sandia Canyon from 1993–2001 (LANL 2006, 094431) and possibly as early as 1991 based on concentrations measured at surface-water stations SCS-1, SCS-2 and SCS-3 (section D-2.3). The present-day composition of groundwater at well SCI-1 thus appears to be dominated by water infiltrating after 1990. The following lines of evidence for this timing are discussed in section D-2.3:

- increasing molybdenum concentrations at well SCI-1, reflecting the continued arrival of this COPC to the perched-intermediate zone at this location (Figures 7.2-14 and D-2.3-8);
- declining tritium activities at well SCI-1, reflecting the decrease in tritium activities in the water discharged to upper Sandia Canyon after 1986 (Figure D-2.3-7 for SCS stations);
- steady low chromium concentrations at well SCI-1, reflecting the absence of significant concentrations of this COPC in water currently arriving at the perched-intermediate zone at this location and/or that most of the mass of chromium has migrated through the Puye Formation at this location (Figure 7.2-13), and
- the presence of low levels of chlorate at well SCI-1 (Table D-2.3-3), a product of the MIOX process implemented in the SWSC facility starting in 2000.

Elevated molybdenum concentrations (77 µg/L) similar to those at well SCI-1 also occur at well TA-53i. However, dissimilar concentrations of other mobile COPCs such as boron, bromide, chloride, nitrate, perchlorate, sulfate, and tritium support the conclusion that molybdenum at well TA-53i is derived from sources in Los Alamos Canyon rather than Sandia Canyon.

With the exception of a couple outliers, molybdenum is not detected above the BV of 4.3 µg/L in perched-intermediate wells MCOI-4 and MCOI-6 in middle Mortandad Canyon, nor is it detected above the BV in MCOI-5, except for the first three samples (June 2005 to January 2006) (Figure D-2.1-1).

Chloride

Chloride is detected below the New Mexico groundwater standard of 250 mg/L but consistently exceeds BVs of 7.78 mg/L and 3.57 mg/L for intermediate and regional groundwater, respectively, in three perched-intermediate wells and seven regional wells in Sandia Canyon and in three regional wells in Mortandad Canyon (Figure 7.2-15). This COPC derives from multiple sources in the Sandia, Los Alamos and Mortandad Canyons.

The highest chloride concentrations in deep groundwater occur in the same wells in which chromium is present above standards, suggesting that chloride in these wells is predominantly derived from Sandia Canyon (section D-2.3):

- Perched-intermediate well SCI-1 had a peak chloride concentration of 98.7 mg/L (June 2007), which decreased to 83.3 mg/L in the most recent sample (May 2009).
- Perched-intermediate well SCI-2 had a peak chloride concentration of 62.1 mg/L (June 2007), with no apparent trend revealed in the first four samples from this well.

- The highest chloride concentrations in the regional aquifer occur at regional wells R-28 and R-42 (31.7 mg/L and 32.5 mg/L, respectively). No temporal trend is evident at either location.

No other deep groundwaters considered in this report have chloride concentrations that approach those observed in the preceding four wells. Other wells in which chloride is consistently above background levels include regional wells R-11, R-10a, and R-15.

- Regional well R-11 in middle Sandia Canyon reached peak chloride concentrations of 4.65 mg/L in February 2007. As with chromium, chloride concentrations remained elevated at well R-11 for about 1 yr, then decreased after August 2007 to a current value of 3.97 mg/L (April 2009), approaching local background levels.
- Regional well R-10a in lower Sandia Canyon had a maximum concentration of 6.29 mg/L in the first sample collected (November 2005). Concentrations at this well have leveled off at a slightly lower value of ~5.9 mg/L.
- Regional well R-15 in middle Mortandad Canyon had a maximum concentration of 4.77 mg/L in June 2004, decreased to 3.96 mg/L in June 2007, then increased slightly to a current value of 4.4 mg/L. Concentration trends may correlate with changes in water levels at this location, indicating at least some portion of chloride is transported to this location via the vadose zone, as discussed previously in section 7.2.1.

In addition to these wells, chloride is also detected above the BV of 7.78 mg/L in three perched-intermediate wells in middle Mortandad Canyon: MCOI-4, MCOI-5, and MCOI-6. Section D-2.3 uses chloride concentrations and trends in MCOI-4 and MCOI-6 to estimate upper bounds on the portion of chromium that is attributable to the Sandia source in this part of the perched-intermediate zone.

- At well MCOI-4, chloride concentrations fall into a relatively narrow range of 18 mg/L to 21 mg/L, with no trend over time.
- At well MCOI-5, chloride concentrations range from 4.9 mg/L to 7.2 mg/L. The maximum concentration occurs in June 2006, and concentrations level off in June 2007 to the current average of 5.1 mg/L ± 0.2 mg/L. Similar decreasing trends are observed for nitrate, perchlorate, sulfate, and tritium at this well.
- In MCOI-6, the maximum chloride concentration of 45 mg/L occurs in the most recent sample (May 2009), increasing gradually from 21.5 mg/L in June 2006.

Nitrate-Nitrite as Nitrogen

Nitrate-nitrite is detected below the New Mexico groundwater standard of 10 mg/L (as N) but consistently exceeds BVs of 2.41 mg/L and 0.89 mg/L for intermediate and regional groundwater, respectively, at two perched-intermediate wells and seven regional wells in Sandia Canyon as well as in three regional wells in Mortandad Canyon (Figure 7.2-16), as summarized below. In some of these wells, nitrate-nitrite derives predominately from sources in the Los Alamos and Mortandad watersheds, and only to a lesser extent to sources in the Sandia watershed, based on geochemical and isotopic data discussed in section D-2.3. Section D-2.3 uses nitrate-nitrite concentrations and trends at selected wells to estimate upper bounds on the portion of chromium that is attributable to Sandia sources at these locations.

Nitrate-nitrite concentrations exceeding one-half the groundwater standard are observed in two perched-intermediate wells (SCI-1 and SCI-2) and four regional wells (R-43, R-11, R-42, and R-28):

- At perched-intermediate well SCI-1 in middle Sandia Canyon, the maximum concentration is 4.99 mg/L (April 2007), which steadily decreases in subsequent samples to its current value of 2.29 mg/L (May 2009).
- At the new perched-intermediate well SCI-2 in middle Sandia Canyon, the maximum concentration is 5.1 mg/L (October 2008), which decreases in subsequent samples to its current value of 4.36 mg/L (May 2009).
- At the new regional well R-43 in middle Sandia Canyon, the nitrate-nitrite concentration is 6.0 mg/L in the upper screen, and slightly lower at 5.4 mg/L in the lower screen.
- At regional well R-11 in middle Sandia Canyon, the maximum nitrate-nitrite concentration is 7.4 mg/L (June 2007). Other than this one sample, concentrations fluctuate around an average concentration of 5.0 (±0.4) mg/L since June 2006.
- At the new regional well R-42 in middle Mortandad Canyon, the maximum nitrate-nitrite concentration of 7.03 mg/L occurs in the most recent of four samples (May 2009), indicating that concentrations may be increasing with time.
- At regional well R-28 in middle Mortandad Canyon, the maximum nitrate-nitrite concentration of 5.39 mg/L occurs in June 2007. Concentrations throughout the period of record fluctuate between 3.1 mg/L and 5.4 mg/L and possibly covary with water-level changes (Appendix G). Covariation suggests that some portion of the nitrate-nitrite arrives at this location via the vadose zone.

Nitrate-nitrite is also elevated above the regional BV in four regional wells in lower Sandia Canyon:

- Well R-36 shows steady concentrations of ~2.3 mg/L.
- Well R-35b concentrations are steady at ~1.2 mg/L.
- Well R-10a concentrations fluctuate between 1.1 and 2.1 mg/L, with no temporal trend apparent.
- Since its rehabilitation and conversion to a dual-screen well, the lower screen in well R-12 has consistently shown nitrate concentrations that fluctuate between 1.1 mg/L and 1.5 mg/L.

Nitrate-nitrite is detected at levels exceeding the New Mexico groundwater standard of 10 mg/L (as N) in perched-intermediate wells MCOI-4 and MCOI-6 in middle Mortandad Canyon, and at one-half the groundwater standard in perched-intermediate well MCOI-5. Section D-2.3 uses nitrate-nitrite concentrations and trends in conjunction with stable nitrogen isotope ratios in nitrate to estimate upper bounds on the portion of chromium that is attributable to mixed Mortandad Canyon and Sandia Canyon sources in this part of the perched-intermediate zone.

- At well MCOI-4, the maximum nitrate-nitrite concentration (17.7 mg/L) occurs in June 2006, after which concentrations decrease to a present-day value of 10.1 mg/L. Based on nitrogen isotope data, this nitrate-nitrite is dominantly derived TA-50 releases of neutralized nitric acid.
- At well MCOI-5, the maximum nitrate-nitrite concentration (5.36 mg/L) occurs in March 2007. Similar to chloride, concentrations level off by November 2007 to the current average of 4.3 (±0.1) mg/L. Based on nitrogen isotope data, this nitrate-nitrite may be derived from past releases of sewage effluent from TA-35 via Ten Site Canyon.
- At well MCOI-6, the maximum nitrate-nitrite concentration of 20.4 mg/L occurs in November 2007, after which concentrations decrease to a current value of 13.6 mg/L (May 2009). Nitrogen isotope

data indicate this nitrate-nitrite is dominantly derived from TA-50 releases of neutralized nitric acid with a component derived from Sandia Canyon based on the presence of chlorate.

Perchlorate

Perchlorate is detected consistently above BVs of 0.18 and 0.46 µg/L for perched-intermediate and regional groundwater, respectively, at four perched-intermediate and eight regional wells in Sandia Canyon as well as in five regional wells in Mortandad Canyon (Figure 7.2-17). In most of these wells, perchlorate is derived predominately from sources in Mortandad Canyon with other possible sources from Los Alamos Canyon, and to a much lesser extent from sources in the Sandia watershed. Past concentrations of perchlorate in effluent discharged into Mortandad Canyon were an order of magnitude greater than perchlorate released in Sandia Canyon.

Among the wells included in the screening assessment in section 6, the highest perchlorate concentrations occur consistently at regional well R-15 (maximum = 7.06 µg/L, February 2009) in middle Mortandad Canyon. Like chloride, perchlorate concentrations at this location appear to fluctuate with water levels (Appendix G), indicating that some portion of perchlorate arrives at the regional aquifer near well R-15 via the vadose zone. Perchlorate at well R-15 probably comes from TA-50 in Mortandad Canyon.

No other deep groundwater wells contain perchlorate levels approaching those in well R-15. In Sandia Canyon low concentrations of perchlorate (approximately 1 to 3 µg/L) are produced from the MIOX process in which aqueous chlorine [Cl(0)] oxidizes to Cl(-I), Cl(2), Cl(3), Cl(5), and Cl(VII) species including chloride, hypochlorite, chlorite, chlorate, and perchlorate. Perchlorate concentrations range from 1.0 to 1.6 µg/L in the four wells with the highest chromium concentrations, suggesting the perchlorate in these four wells may be derived from mixing of multiple canyon sources:

- At perched-intermediate well SCI-1, the maximum peak concentration of 1.58 µg/L occurs in April 2007, and subsequently declines to a current value of 1.17 µg/L (May 2009).
- At the new perched-intermediate well SCI-2, perchlorate concentrations are steady at ~1.0 µg/L.
- At new regional well R-42, perchlorate concentrations are steady at ~1.25 µg/L.
- At regional well R-28, concentrations fluctuate between 0.9 and 1.0 µg/L. As is the case with chloride and chromium, no temporal trend is apparent.

Perchlorate is also slightly elevated above the BV of 0.46 µg/L in four regional wells in middle and lower Sandia Canyon:

- At regional well R-11 in middle Sandia Canyon, perchlorate concentrations fluctuate between 0.69 µg/L and 0.82 µg/L, with no temporal trend apparent.
- At regional well R-36, perchlorate concentrations are steady at ~1.6 µg/L.
- At regional well R-10a, concentrations fluctuate between 0.6 µg/L and 0.82 µg/L, with no temporal trend apparent.
- At perched-intermediate well R-12, perchlorate concentrations in the lower screen have fluctuated between 1.0 µg/L and 1.2 µg/L since February 2008, following the rehabilitation and conversion of R-12 to a dual-screen well. Much lower concentrations (0.19 µg/L to 0.36 µg/L) are measured in samples from the upper screen at R-12.

Perchlorate is detected above the EPA MCL of 15 µg/L in three perched-intermediate wells in middle Mortandad Canyon: MCOI-4, MCOI-5, and MCOI-6. Section D-2.3 uses perchlorate concentrations and trends in MCOI-4 and MCOI-6 to estimate upper bounds on the portion of chromium that is attributable to the Sandia source in this part of the perched-intermediate zone.

- At well MCOI-4, perchlorate concentrations peak at 166 µg/L in January 2006 then decrease steadily to the current value of 61.7 µg/L (May 2009). The source of perchlorate measured at MCOI-4 is TA-50.
- At well MCOI-5, perchlorate concentrations reached a maximum value of 132 µg/L in October 2006. Subsequent concentrations follow an unsteady decreasing trend to the current value of 83.7 µg/L (May 2009). The source of perchlorate measured at MCOI-5 is TA-50.
- In MCOI-6, the maximum perchlorate concentration of 246 µg/L occurs in the second sample collected from this well in September 2005. Subsequent concentrations decrease in a stepwise fashion, with average concentrations of 176 µg/L ± 15 µg/L (January 2006 to February 2008), 142 µg/L ± 22 µg/L (May 2008 to November 2008), and 94 µg/L ± 4 µg/L (February 2009 to May 2009). The source of perchlorate measured at MCOI-6 is TA-50.

Tritium

Tritium is detected at several wells evaluated in this report at activities that are well below the New Mexico livestock watering standard of 20,000 pCi/L but consistently above BVs of 7.54 pCi/L and 11.43 pCi/L for intermediate and regional aquifers, respectively (Figure 7.2-18). Among the wells included in the screening assessment in section 6, the highest tritium activities in deep groundwater are detected in the same wells in which chromium is present above background SLs (SCI-1, SCI-2, R-28, and R-42), suggesting that some portion of the tritium in these four wells might be derived from a Sandia source. However, activities of tritium released into Los Alamos and Mortandad Canyons were several orders of magnitude greater than those released in Sandia Canyon, and it is likely that tritium measured at R-15, R-28, and R-42 is derived from TA-50 that released over 5×10^5 pCi/L since 1963 (Longmire et al. 2007, 096660). The presence of nearly 200 pCi/L at R-28 and R-42 strongly suggests groundwater at these two wells is mixed containing more than one source of contaminants mainly derived from Sandia and Mortandad Canyons.

- At perched-intermediate well SCI-1, the peak tritium activity of 150 pCi/L occurs in January 2007, after which it steadily declines to a current value of 101 pCi/L (May 2009).
- At perched-intermediate well SCI-2, the first four samples show stable tritium activities with an average of 495 pCi/L ± 15 pCi/L.
- At regional well R-28, the average tritium activity is 188 pCi/L ± 17 pCi/L in the 17 samples collected since May 2005. The highest activity (234 pCi/L) occurs in the February 2009 sample, but no temporal trend is apparent at this location. As is the case for nitrate-nitrite at R-28, tritium activities throughout the period of record fluctuate between 152 pCi/L and 234 pCi/L and possibly covary with water-level changes (Appendix G). Covariation suggests that some portion of the tritium arrives at this location via the vadose zone.
- At new regional well R-42, the average tritium activity is 195 ± 12 pCi/L for the three samples collected since November 2008.

Other wells in which tritium is consistently detected above BVs include R-11, R-15, R-12, and R-36:

- At regional well R-11 in middle Sandia Canyon, tritium activities peak at 12 pCi/L in June 2007 and decrease thereafter to a current value of 5.5 pCi/L.
- At regional well R-15 in middle Mortandad Canyon, the maximum activity of 38 pCi/L occurs in the most recent sample (February 2009). Activities fluctuate between 25 pCi/L and 31 pCi/L during the previous 4 yr, with no clear temporal trend.
- At perched-intermediate well R-12 in lower Sandia Canyon, the maximum tritium activity of 149 pCi/L occurs in the uppermost screen prior to rehabilitation of this well and its conversion to a dual-screen well in October 2006. Activities in this screen decreased following the installation of a purgeable sampling system, averaging 79 ± 6 pCi/L in samples collected since February 2008.
- In the lower screen at R-12, tritium activities have remained approximately steady at 53 pCi/L ± 3 pCi/L since February 2008.
- At regional well R-36 in lower Sandia Canyon, tritium activities are approximately steady at 20 pCi/L throughout the first year of sampling at this location, with no clear temporal trend.

In addition to these wells, maximum activities of tritium are more than one-half the New Mexico livestock watering standard of 20,000 pCi/L in perched-intermediate wells MCOI-4 and MCOI-6 in middle Mortandad Canyon, and about one-fourth the groundwater standard in perched-intermediate well MCOI-5. Tritium concentrations measured at MCOI-4, MCOI-5, and MCOI-6 are dominantly derived from TA-50 releases.

- At well MCOI-4, average tritium activities are 12,000 pCi/L ± 640 pCi/L from June 2005 to June 2007, decreasing over the past 2 yr to a present-day value of 7150 pCi/L (February 2009).
- At well MCOI-5, tritium activities were highest in 2006 (5230 pCi/L ± 120 pCi/L), decreasing to 3600 pCi/L± 300 pCi/L in subsequent years. Parallel trends are observed for chloride, nitrate, perchlorate, and sulfate at this well.
- At well MCOI-6, maximum tritium activities of 13,100 pCi/L occur in 2005 and decreasing since then to 9520 pCi/L in February 2009.

Bis[2-ethylhexyl]phthalate

Bis(2-ethylhexyl)phthalate is detected above the EPA MCL of 6 µg/L in one intermediate screen (R-12 screen 1 (25.1 µg/L), and three regional screens (R-36, 59.1 µg/L; R-33 screen 2, 8.2 µg/L; and R-42, 11.7 µg/L. Bis(2-ethylhexyl)phthalate is a component of plastics and could be derived from several sources, including sampling equipment, Laboratory discharges and runoff, and analytical laboratories in which water samples come in contact with plastic during analysis.

8.0 RISK ASSESSMENTS

This section presents the methods used to evaluate the potential for adverse ecological and human health risks from contaminants in sediment and surface water. Risk characterization results, uncertainty analysis, and risk-assessment summary are also provided for each assessment.

8.1 Baseline Ecological Risk Assessment

Biological, sediment, and water data were collected in Sandia Canyon reaches to evaluate the potential for adverse ecological effects from contaminants in sediment and persistent surface water. A biota investigation work plan was developed based on the application of the eight-step EPA Ecological Risk Assessment Guidance for Superfund (ERAGS) (EPA 1997, 059370) to COPECs in sediment and persistent surface water (LANL 2007, 099152).

Steps 1 and 2 of ERAGS include the screening-level ecological risk assessment (SLERA) (LANL 2004, 087630), which identifies COPECs and ecological receptors potentially at risk. Initial ecological screening results based on the comparison of minimum ESLs with available sediment and water data are provided in the biota investigation work plan (LANL 2007, 099152). These screening-level assessments identified COPECs and formed the basis for proceeding to the baseline ecological risk assessment (ERAGS Steps 3 to 8).

Steps 3 and 4 of ERAGS comprise problem formulation and study design, which include refining the list of COPECs, developing a conceptual site exposure model, selecting assessment endpoints, and selecting associated measures of effect and exposure. The study design required for these measures was included in the biota investigation work plan (LANL 2007, 099152). Deviations to the original biota work plan are discussed in section 8.1.2. ERAGS Steps 6 and 7 comprise the implementation of the study design, analysis of ecological exposure and effects, and risk characterization. ERAGS Step 8 is risk management, and the conclusions that may lead to risk management activities are documented in section 9.

8.1.1 Problem Formulation

This section addresses the baseline ecological risk assessment problem formulation, which is Step 3 of ERAGS. Problem formulation includes refinement of the list of COPECs, a literature search on known ecological effects, the conceptual site exposure model, and the selection of assessment endpoints and associated measures. Due to the nature of the primary contamination in Sandia Canyon (metals and PCBs) and the ecological setting (including an expansive wetland area in reach S-2), the assessment endpoints (AEs) and associated ecological measures developed for the Pajarito Canyon investigation (LANL 2006, 093553) were adapted for Sandia Canyon. Problem-formulation elements are summarized in the following sections.

8.1.1.1 Refinement of COPEC List

The third step of the ERAGS process involves refinement of the COPEC list from the screening to focus on those COPECs that have the largest potential for ecological risk. As explained in the SLERA methods document (LANL 2004, 087630, p. 31; LANL 2009, 106771), the criterion for retaining a COPC as a COPEC is a HQ greater than 0.3. The HQ is the ratio of exposure to an adverse effects level. The ESL screening excludes COPCs with an HQ less than or equal to 0.3. To determine whether areas of the canyon may pose a potential risk to ecological receptors, and therefore what areas should be included within the scope of the biota investigation, the criterion of an HQ greater than 3 was used to identify study design COPECs. This criterion of 3 is based on the geometric mean of the ratio between the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL) (Dourson and Stara 1983, 073474). An HQ greater than 3 represents levels that may impact receptors and is therefore appropriate for determining which COPECs should be included in site-specific biota studies in the Sandia Canyon reaches. Concentrations corresponding to LOAELs represent levels where impacts to individuals or populations may occur, and these levels represent a more appropriate criterion for determining which

COPECs should be included in site-specific biota analyses to assess if impacts to ecological receptors have occurred. The same criterion of an HQ greater than 3 was used to refine the list of COPECs for the baseline studies conducted in Los Alamos and Pueblo Canyons (LANL 2004, 087390, p. 8-2), Mortandad Canyon (LANL 2006, 094161, p. 96), and Pajarito Canyon (LANL 2009, 106771, p. 64). Receptors representing threatened and endangered (T&E) species are evaluated versus an HQ greater than 1 to ensure protection of each individual within the population.

The COPECs, exposure pathways, and receptors in Sandia Canyon are similar to those previously investigated in the Los Alamos and Pueblo, Mortandad, and Pajarito watersheds (LANL 2004, 087390; LANL 2005, 089308; LANL 2006, 093553; LANL 2006, 094161; LANL 2008, 104909). Aspects of the study designs and conclusions from biological investigations performed in these watersheds are therefore complementary to the ecological risk assessment process in Sandia Canyon. Contaminant concentrations, risk measures, and results that are less than results from previous studies (or "bounded by" previous studies) can be evaluated against analogous COPEC and media measurements in the Sandia Canyon to interpret potential risks.

As discussed in the Sandia Canyon biota investigation work plan (LANL 2007, 099152, p. 3), study design COPECs are COPCs with an HQ greater than 3 and a maximum detected concentration in Sandia Canyon greater than in the Pajarito Canyon watershed. This assessment approach follows and builds upon those presented in the NMED-approved documentation for the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 089308); "Mortandad Canyon Investigation Report" (LANL 2006, 094161); "Pajarito Canyon Biota Investigation Work Plan" (LANL 2006, 093553); and "Pajarito Canyon Investigation Report" (LANL 2008, 104909). In brief, the assessment approach for these canyons included identifying COPECs for each assessment endpoint entity (e.g., terrestrial plants) and the measures of exposure, effect, and ecosystem characteristics for each assessment endpoint. If COPC concentrations in Sandia Canyon sample media are less than concentrations in the exposure media evaluated in previous canyons investigation reports and these reports concluded there was no unacceptable ecological risk to this assessment endpoint, then Sandia Canyon biota studies are not necessary.

Study design COPECs include metals, PCBs, and pesticides. Some SVOCs had HQs greater than 3, but concentrations of PAHs in Sandia Canyon are less than those reported in Pajarito Canyon and have been detected at similar or greater concentrations in other canyons (e.g., LANL 2004, 087390) and no ecological risks were noted for field studies or bioassays in these previous investigations. PAHs were therefore eliminated as study design COPECs for this study. Phthalates also had HQs greater than 3, but concentrations of these SVOCs are similar in Sandia Canyon and Pajarito Canyon[1], and phthalates were assessed in the NMED-approved Mortandad Canyon investigation report (LANL 2006, 094161; LANL 2007, 098279; NMED 2007, 096394), and no ecological risks were noted for the Mortandad Canyon watershed field studies or bioassays. Thus, additional ecological risk assessment of phthalates is not warranted.

The ecological risk assessment considers the potential for adverse effects based on affected media in Sandia Canyon. The affected media include sediment and surface water; these media were evaluated to determine study design COPECs. There are both terrestrial and aquatic exposures from sediments. Most sediment deposits have well-developed terrestrial ecological communities and only some sediment deposits support aquatic ecological communities (see section 8.1.1.3).

[1] Bis(2-ethylhexyl)phthalate in Sandia Canyon was 1.35 mg/kg compared to 1.27 mg/kg in the Pajarito Canyon watershed. The relative difference was small for di-n-butylphthalate: 0.106 mg/kg in Sandia Canyon compared to 0.104 mg/kg in the Pajarito Canyon watershed.

Selection of study design COPECs for soil was based on comparison of the maximum detected concentrations in all geomorphic units within a reach with the minimum soil ESL. Active channel sediment may have terrestrial exposure pathways because of the transient nature of water flow in the channels in this watershed; therefore, concentrations in active channel geomorphic units (c1 and c1ct) were included in the screening for terrestrial receptors. The 14 study design COPECs for soil identified in the biota investigation work plan are cadmium, chromium, Cr(VI), copper, cyanide (total), lead, mercury, perchlorate, selenium, zinc, Aroclor-1242, Aroclor-1254, Aroclor-1260, and dieldrin (LANL 2007, 099152, Table 5.1-2, p. 32). Additional sediment samples have been collected since the biota investigation work plan was developed and a more recent version of the ECORISK Database (Version 2.3) is now available. Thus, the Sandia Canyon sediment data have been reevaluated to determine if any additional study design COPECs was needed. The reevaluation identified six additional study design COPECs for soil: barium, methyl mercury, nickel, silver, Aroclor-1248, and 4,4'-DDD. PCB congeners were also measured in sediment and are included as study design COPECs because various Aroclor mixtures are also study design COPECs. A new maximum concentration of 10 PAHs was also reported in one of the supplemental samples collected in 2008, but PAHs were not added as study design COPECs because the concentrations were still bounded by those reported in the Pajarito Canyon watershed. In addition, the concentrations of PAHs in sample CASA-08-8764 were about 4 to 9 times larger than the next largest value in reach S-1N and the remaining concentrations of PAHs were consistent with those reported in other watersheds. No ecological risks were noted for field studies or bioassays in these previous watershed investigations. Thus, additional ecological risk assessment of PAHs is not warranted. Attachment 1 has the supporting information for the reevaluation.

Study design COPECs for sediment and water were chosen based on a comparison of maximum detected concentrations in the c1 and c1ct units (the active channel sediments) with the minimum ESLs for sediment and maximum detected concentrations in nonstorm-related surface water with the minimum ESLs for water. The 14 study design COPECs in sediment and water identified in the biota investigation work plan are cadmium, chromium, chromium hexavalent ion, copper, cyanide (total), lead, mercury, perchlorate, silver, thallium, zinc, Aroclor-1242, Aroclor-1254, and Aroclor-1260 (LANL 2007, 099152, Tables 5.1-3 and 5.1-4, pp. 32–33). The reevaluation of the active channel sediment and nonstorm-related surface water identified six additional study design COPECs for sediment and water: barium (water only), iron (sediment only), methyl mercury (sediment only), nickel (sediment only), selenium (sediment only), and Aroclor-1248 (sediment only). PCB congeners were also measured in active channel sediment samples and are included as study design COPECs because various Aroclor mixtures are also study design COPECs in active channel sediments. Attachment 1 has the supporting information for the re-evaluation.

The evaluation of stormwater versus ecologically relevant acute benchmarks (section 6.4) showed the maximum concentrations of seven inorganic chemicals were greater than benchmarks. Six of these seven inorganic chemicals are being evaluated as sediment or water study design COPECs (cadmium, chromium, copper, lead, silver, and zinc) and the potential for adverse effects on the aquatic community is being evaluated. The other inorganic chemical that is greater than an acute ecological benchmark, aluminum, will be evaluated as a confounding factor for the aquatic community measures.

Subsequent to the screening against minimum ESLs, the original study design COPECs, as documented in the biota work plan (LANL 2007, 099152) were screened against the ESLs for individual receptors to determine which COPECs should be addressed by each of the field measures. These comparisons were summarized in the biota investigation work plan (LANL 2007, 099152, Tables 2.3-10 and 2.3-12, pp. 26–28). A subset of COPECs was used to determine the appropriate analytical suites and locations for each measure. The lines of evidence for investigating potential effects of COPECs by media and uncertainties relating to the lines of evidence for the 14 original study design COPECs are presented in the biota

investigation work plan and are summarized in Table 8.1-1. The COPECs and analytical suites associated with each measure are described in the discussion of each individual field measure in section 8.1.2. The receptors potentially at risk from exposure to soil COPECs include plants, soil invertebrates (earthworms), small mammals, mammalian carnivores, omnivorous birds, and carnivorous birds representing a T&E species, the Mexican spotted owl (*Strix occidentalis lucida*). Receptors at potential risk from exposure to sediment and water include the swallow (also representing a T&E species, the southwestern willow flycatcher [*Empidonax traillii extimus*]), the bat, and the aquatic community (representing a number of aquatic species).

The generic DOE soil BCGs for cesium-137 and strontium-90 are more restrictive than soil ESLs for these radionuclides. Maximum soil concentrations of these radionuclides are less than 10% of the respective biota concentration guides or BCGs (cesium-137 maximum concentration is 1.1 pCi/g, BCG is 20.8 pCi/g; strontium-90 maximum concentration is 1.9 pCi/g, BCG is 22.5 pCi/g). Thus, doses in Sandia Canyon are clearly less than biota dose limits, and a detailed supplemental evaluation of radionuclide soil concentrations for Sandia Canyon is not required. No further evaluation of radionuclides based on either the ESLs or the BCGs is needed.

8.1.1.2 Literature Search of Known Ecological Effects

The following is a synopsis of the screening ecological receptors with the highest HQs (HQ >3) and the feeding guilds they represent. This section reviews both the study design COPECs from the biota investigation work plan and an assessment of sediment and nonstorm-related surface water data collected subsequent to that plan. The toxic effects are based on toxicity studies used as the basis for the ESLs as described in the ECORISK Database Version 2.3 (LANL 2008, 103352).

Mammals

Soil Pathway Receptors

The deer mouse represents mammalian omnivores and had HQs greater than 3 for cadmium, copper, lead, nickel, selenium, silver, zinc, and Aroclor-1248. The receptor representing the mammalian ground invertivores is the montane shrew. This receptor has HQs greater than 3 for cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, Aroclor-1248, Aroclor-1254, and dieldrin. The reaches with the highest HQs for the deer mouse or shrew were S-1N, S-1S, S-2, and S-3W. Chromium, copper, lead, mercury, silver, zinc, Aroclor-1254, and dieldrin are study design COPECs only in reach S-2. Cadmium, selenium, and Aroclor-1248 are study design COPECs in multiple reaches. The fox represents mammalian carnivores; this receptor had HQ above 3 for Aroclor-1248, Aroclor-1254, and Aroclor-1260. Aroclor-1254 was a study design COPEC in multiple reaches and the other two Aroclor mixtures were of more limited spatial extent in upper Sandia Canyon (reaches S-N, S-1S, and S-2). There were no study design COPECs for the desert cottontail (representing mammalian herbivores).

Sediment Pathway Receptors

The little brown myotis bat represents mammalian aerial insectivores, and HQs greater than 3 were calculated for cadmium, copper, nickel, selenium, silver, thallium, zinc, Aroclor-1248, and Aroclor-1254. There is an important distinction between the mammalian aerial insectivore (bat) and the two avian insectivores (robin and swallow). The home range of the bird species (0.68 ha, LANL 2004, 087630, p. 38) has a spatial scale similar to the reaches, while the home range of the bat is much larger (100 ha, LANL 2004, 087630, p. 39). Studies to directly address potential risk to the bat were not proposed in the

biota plan, but information on COPEC concentrations in prey (insects from bird nest boxes) will be evaluated to determine potential exposure of the bat from COPECs.

Water Pathway Receptors

There were no water study design COPECs for wildlife. Thus, there is no evaluation for exposure to multiple media for mammals.

Birds

Soil Pathway Receptors

The American robin is modeled as the representative for invertivorous birds, omnivorous birds, and herbivorous birds. The lowest ESLs for the COPECs in Sandia Canyon are associated with the invertivorous robin, which is modeled with a diet consisting solely of earthworms. HQs above 3 for the robin were calculated for cadmium, chromium, copper, total cyanide, lead, mercury, methyl mercury, nickel, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, 4,4'-DDD, and dieldrin. The majority of the reaches identified for these study design COPECs for the robin were in upper Sandia Canyon (reaches S-1N, S-1S, and S-2) and the exceptions were lead, zinc, and Aroclor-1254 with multiple reaches with HQs greater than 3 including reach S-3W and downstream reaches.

The kestrel modeled with a 100% flesh diet is used to represent all avian top carnivores, including the Mexican spotted owl. Because this receptor represents a T&E species, an HQ greater than 1 (instead of an HQ greater than 3) was used to determine study design COPECs. Total cyanide, mercury, Aroclor-1248, Aroclor-1254, and Aroclor-1260 had HQs greater than 1 for the kestrel modeled as a surrogate for the Mexican spotted owl. Total cyanide was a potential study design COPEC in more than one reach, but cyanide is extremely difficult to measure in samples of biological tissue. Therefore, this COPEC was not selected for bioaccumulation studies in this investigation. Mercury had an HQ greater than 1 only in reaches S-1S and S-2. Aroclor-1248 had an HQ greater than 1 only in reach S-1N and Aroclor-1260 had an HQ greater than 1 in reach S-1N. Aroclor-1254 had an HQ greater than 1 in multiple reaches.

Sediment Pathway Receptors

The violet-green swallow represents avian aerial insectivores and also serves as a surrogate for the southwestern willow flycatcher, a T&E species for which habitat exists within Sandia Canyon. HQs greater than 3 for active channel sediment and associated wetlands were used to determine study design COPECs for the violet-green swallow, and HQs greater than 1 were used to determine study design COPECs for the southwestern willow flycatcher. Study design COPECs for the flycatcher are cadmium, chromium, copper, total cyanide, lead, mercury, methyl mercury, nickel, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, and Aroclor-1260.

Water Pathway Receptors

There were no water study design COPECs for wildlife. Thus, there is no evaluation for exposure to multiple media for birds.

Terrestrial Plants

The plant is the representative for primary producers and had HQs greater than 3 in soil for barium, chromium, hexavalent chromium, copper, lead, selenium, and zinc. HQs greater than 3 for at least one of these COPECs were found in all the reaches sampled in Sandia Canyon. Mercury was identified as a study design COPEC for plants in the biota plan (LANL 2007, 099152) but does not meet the criterion for a study design COPEC (HQ is now less than 1) based on the ECORISK database Version 2.3 mercury soil ESL for plants.

Terrestrial Invertebrates

The earthworm is the representative of soil invertebrates (detritivores) and had HQs greater than 3 in soil for barium, chromium, hexavalent chromium, mercury, and zinc. Elevated HQs for chromium, hexavalent chromium, and mercury were seen in several reaches, but the HQ for barium and zinc was elevated only in one reach. Copper was identified as a study design COPEC for plants in the biota plan (LANL 2007, 099152) but does not meet the criterion for a study design COPEC (HQ is now less than 3) based on the ECORISK database Version 2.3 copper soil ESL for terrestrial invertebrates.

Aquatic Community Organisms

Sediment Pathway Receptors

ESLs for sediment are based on risk to the aquatic community instead of an individual receptor. HQs greater than 3 were calculated in sediment for barium, cadmium, chromium, copper, total cyanide, iron, mercury, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, and Aroclor-1260. Cr(VI) was identified as a study design COPEC for the aquatic community in the biota plan (LANL 2007, 099152) but does not meet the criterion for a study design COPEC (HQ is now less than 1) based on the ECORISK database Version 2.3 aquatic community sediment ESL.

Water Pathway Receptors

ESLs for water are based on risk to the aquatic community instead of an individual receptor. HQs greater than 3 were calculated in water for barium, lead, silver, zinc, and Aroclor-1254.

8.1.1.3 Conceptual Exposure Model

Section 2.2 of the biota investigation work plan (LANL 2007, 099152) discusses the types of habitats and receptors found within Sandia Canyon. Many of the reaches within Sandia Canyon have ponderosa pine as the dominant overstory vegetation, although some reaches also contain mixed conifer, piñon, or juniper trees depending on elevation and microclimate. As discussed in section 3.0 of the biota investigation work plan (LANL 2007, 099152), surface water is present in a variety of contexts in Sandia Canyon, including wetlands and perennial streams. Historical contaminant releases to the soils, sediments, and persistent surface water in Sandia Canyon have occurred from multiple SWMUs and AOCs, primarily through releases of effluent. For ecological receptors, the primary impacted media in the canyons are sediment deposits and surface water. Alluvial groundwater is not assessed separately because alluvial groundwater in Sandia Canyon mixes with surface water in the channel, and ecological receptors are directly affected only by COPECs in surface water. Therefore, the investigations of surface-water COPECs include COPECs that might be present in alluvial groundwater.

Only active channel sediments, wetland sediments, and surface water potentially have complete exposure pathways to truly aquatic species, whereas terrestrial animals and plants are exposed to COPECs in surface water, soil, or sediment. Contaminants have several potential exposure pathways to reach receptors.

Exposure of terrestrial receptors can occur through the following pathways:

- Air—through inhalation of dust and deposition of particulates
- Surface soil—through root uptake and rain splash on plants, food web transport to plants and animals, incidental ingestion of soil, dermal contact with contaminated soil, and external irradiation
- Persistent surface water and sediment—through root uptake and rain splash on plants, food web transport to animals, incidental ingestion of water and sediment, dermal contact with contaminated water or sediment, and external irradiation from sediment

The major soil-related exposure pathways are plant uptake, food web transport, incidental ingestion of contaminated soil, and external gamma radiation exposure. Water and sediment pathways can be less important to terrestrial receptors in the area of persistent surface water flow. Exposure to vapors does not represent a significant pathway because of the infrequent detection of VOCs in the watershed, the low VOC concentrations measured in soil, sediments, and water, and the rapid volatilization of VOCs in sediments near the ground surface. Exposure to airborne particulates is a minor pathway because of the limited amount of contamination at the ground surface and the dense plant cover in some reaches.

Also minor are the remaining pathways related to exposure to surface soil (dermal contact) and surface water and sediment (food web transport, incidental ingestion of contaminated sediment and water, dermal contact, and external gamma radiation exposure) because of the limited amount of contamination at the ground surface or in surface water. In addition, soil exposure pathway analysis performed by EPA to support the development of its ecological soil screening level has shown that inhalation and dermal pathways contribute a small fraction of the dose obtained orally (EPA 2003, 085643). All complete exposure pathways are at least qualitatively evaluated in the assessment because some of the measures proposed in this investigation are field measures of effect or exposure.

8.1.1.4 Assessment Endpoints

AEs consist of an entity (a receptor species) and an attribute (survival, growth, or reproduction) of the entity being assessed. Seven AEs for Sandia Canyon are identified based on the study design COPECs and the conceptual site exposure model. These endpoints were selected to represent T&E receptors (the Mexican spotted owl and the southwestern willow flycatcher) as well as receptors that are representative of the terrestrial and aquatic food web in Sandia Canyon. The conceptual site model indicates that ingestion exposure pathways, in particular, food web transport, are important pathways for COPECs. AEs were developed for the five terrestrial feeding guilds (including aerial insectivores) that represent the receptors with the highest HQs, as well as for the surrogates for the T&E species. A single AE for the aquatic community was selected. The seven assessment endpoints (AE1 through AE7) are as follows:

- survival and reproduction of the Mexican spotted owl (AE1)
- health and reproductive success of avian ground invertivore feeding guild species (e.g., American robin, bluebird) (AE2)
- survival of mammalian invertivore and omnivore feeding guild species (e.g., shrews and deer mice) (AE3)

- survival and growth of detritivore species (earthworms) (AE4)
- survival and growth of native plant species (AE5)
- survival and reproduction of the southwestern willow flycatcher (AE6)
- abundance and survival of the aquatic community in the reaches of Sandia Canyon that retain surface water long enough to support aquatic communities (AE7)

AEs are used as the basis for developing the measures of exposure and measures of effects. The measures evaluate impacts to the attributes of survival, growth, or reproduction in the receptor species and in the feeding guilds that those receptor species represent. The measures include field, laboratory, and model data. For the biota investigation in Sandia Canyon, the measures are based on the extension of the biota investigations done in the Los Alamos and Pueblo watershed (LANL 2004, 087390), in the Mortandad watershed (LANL 2005, 089308), and in the Pajarito watershed (LANL 2009, 106771).

8.1.2 Study Design, Field Verification, and Site Investigation

This section discusses the ecological risk assessment study design, field verification, and site investigation; this encompasses ERAGS Steps 4 and 5 and the first part of Step 6. Biological data were collected as measures of exposure and effect (lines of evidence) to evaluate the potential for adverse ecological effects from contaminants in soil, sediment, and persistent surface water. The initial design of each study is documented in the biota investigation work plan (LANL 2007, 099152). Figure 8.1-1 shows the reaches and sampling locations in Sandia Canyon. The rapid bioassessment characterization studies were collocated with the chironomid toxicity tests indicated in Figure 8.1-1. Table 8.1-2 shows the reaches included in each type of study, as well as the study design COPECs used as the basis for including that reach for that type of study. The locations selected for the Sandia Canyon biota studies were based primarily on the concentrations of chromium (both total and hexavalent) and PCBs (Aroclor-1242, Aroclor-1254, Aroclor-1260). Some analytes have been added as study design COPECs, and the concentration range for these additional study design COPECs has not been captured with of the sampling locations and reaches considered in this report. The highest concentrations of barium and PCBs were measured in either reaches S-1N or S-1S, and neither of these reaches was included in the biota studies discussed below. This omission represents an uncertainty but not a significant one with regard to evaluating population level ecological risks in Sandia Canyon.

8.1.2.1 Small Mammal Trapping and Analysis of Carcasses

Trapping small mammals was conducted in three reaches within Sandia Canyon. The results of the trapping determined measures of effect on the small mammal population including relative abundance, species composition, reproductive status, and body weight. The field measures of the small mammals are lines of evidence for the effects to the small mammals themselves, in support of AE3, as presented in Table 4.1-1 in the biota investigation work plan (LANL 2007, 099152).

Small mammals were also collected for laboratory analysis to determine the concentration of COPECs in the whole animal tissues. The concentrations in the tissues were lines of evidence for the exposure of the Mexican spotted owl (AE1) as well as for the mammalian carnivore (the red fox), which was not designated as an individual AE. Whole animal chemical analyses were conducted on composite samples of multiple whole animals from separate species (e.g., one composite sample for all deer mice from a reach); compositing was done to provide sufficient mass for analyses of key COPEC analytical suites. Appendix B (Table B-3.0-2) shows the sample IDs associated with these whole animal samples as well as the weights for the composite pelt and tissue samples from each species. Animals that tested positive for

Hantavirus after collection were not included in the composite samples. The total number of animals of each species trapped is discussed in section 8.1.3.4. The number of animals collected (excluding released or Hantavirus-infected animals) from each reach is shown in Table 8.1-3.

The analytical suites were prioritized based on study design COPECs for predators, as shown in Table 5.2-3 of the biota investigation work plan (LANL 2007, 099152). Analyses conducted on the whole animal samples included metals, mercury, PCBs, and pesticides.

8.1.2.2 Soil, Sediment, and Water Characterization

Samples of sediment were collected from the locations in Sandia Canyon used for laboratory toxicity tests and also from sediment within the small mammal trapping arrays for additional characterization of exposure to small mammals. Appendix B (Table B-3.0-1) shows the reach, location ID, and geomorphic unit associated with the composite sediment samples collected from the small mammal trapping arrays. Appendix B (Table B-3.0-3) shows the reach, location ID, and geomorphic unit associated with the laboratory toxicity tests. For the earthworm and plant toxicity tests, discrete samples were generally collected from 0 to 30 cm (0 to 1 ft) for the toxicity assays and for the analytical analysis of the same samples. One exception was that a sample with a location with a high concentration of chromium was mixed with sediment from a location with a low concentration of chromium to obtain an intermediate concentration of chromium. Samples for the earthworm and plant toxicity tests were collected from geomorphic units outside the active channel (generally c2, c3, or f1 units). Sediment samples for the *Chironomus tentans* toxicity tests were collected from 0 to 15 cm (0 to 0.5 ft) in the c1 or c1ct geomorphic units (the active channel and associated cattail wetland) to represent the sediment to which these aquatic organisms are exposed.

Samples of nonstorm-related surface water were collected from locations in Sandia Canyon to be used in the *Chironomus tentans* toxicity tests. Appendix B (Table B-3.0-4) shows the reach and location ID, associated with these water samples.

8.1.2.3 Nest Box Studies

An avian nest box monitoring network has existed at the Laboratory and its vicinity since 1997; the network includes both potentially contaminated and noncontaminated areas. As part of the baseline ecological risk assessment for Sandia Canyon, additional nest boxes were placed in the canyon bottom within Sandia Canyon. Figure 8.1-1 shows the boxes within Sandia Canyon sampled for the biota studies. Both the western bluebird (*Sialia mexicana*) and the ash-throated flycatcher (*Myiarchus cinerascens*) occupy these boxes. Measures collected using the nest box network included field measures of effect on reproductive success of these avian species (including clutch size, fledgling success, growth of fledglings, etc.) and measures of exposure through analysis of COPEC concentrations in unhatched western bluebird eggs and unconsumed prey (insects) collected within the boxes. Appendix B (Table B-3.0-6) shows the egg and insect samples collected for analyses within Sandia Canyon; the locations of the boxes within the reaches are shown in Figure 8.1-1. Boxes in the Cañada del Buey watershed (near TA-51) and boxes from one area outside the Laboratory (Guaje Canyon [LANL 2004, 087390, Figure 8.1-1]) were also included as reference locations. Eggs from individual boxes within a reach were submitted as samples. In some cases, individual boxes contained sufficient insects for analysis, but in other cases insects from more than one box in a reach were combined to obtain sufficient sample size for analysis. Table 8.1-4 shows a summary of the eggs and insects collected per reach.

Because of sample size limitations, egg and insect samples were analyzed only for metals. These measures were collected to evaluate AE2, the endpoint for avian ground invertivores. The COPEC

concentrations in nest box insects were used as a measure for AE6 for the avian insectivore (southwestern willow flycatcher) and the mammalian insectivore (the occult little brown myotis bat). Results of the field measures of effect through reproductive success are discussed in section 8.1.3.3. The measures of exposure through COPEC concentrations measured in insects are discussed in section 8.1.3.2, and exposure based on COPEC concentrations in eggs is discussed in section 8.1.3.3.

8.1.2.4 Earthworm Toxicity Tests

Sediment collected from the 0- to 30-cm- (0- to 1-ft-) depth interval was used for the earthworm toxicity tests (a measure for AE4). The earthworm tests used the standard American Society for Testing and Materials (ASTM) Method E1676-97. The toxicity tests compared the growth and mortality of the earthworms from the five reaches shown in Table 8.1-2 with the reference site in reach PA-0 (Pajarito Canyon). As shown in the table, the reaches were selected to represent a gradient of chromium and PCB concentrations to evaluate risks to both the soil invertebrate receptor and the mammalian and avian receptors that feed on the soil invertebrate. Earthworms were sent to an analytical laboratory for chemical analyses. Appendix B, Table B-3.0-5, provides a crosswalk of earthworms, the bioassay, and the soil samples. Section 8.1.3.5 discusses the results of the statistical analysis of the growth and mortality between reaches.

8.1.2.5 Seedling Germination Tests

Sediment collected from the 0- to 30-cm- (0- to 1-ft-) depth interval was used for the plant toxicity tests (a measure for AE5). The plant toxicity tests used the standard ASTM Method E1963-98. The plant toxicity tests compared survival rates and shoot and root mass in plants grown in soil from the same locations used for the earthworm toxicity tests with plants grown in the soil sample from the reference site (reach PA-0). The tests used perennial ryegrass (*Lolium perenne*), which is one of the standard test species for the seedling germination test. The species was selected based on the availability of seeds and the experience of the bioassay laboratory in successfully completing tests with ryegrass. The results from the ryegrass test are not directly comparable to tests conducted in the Los Alamos, Pueblo, and Mortandad watersheds with yarrow (*Achillea millefolium* L. var *occidentalis*) (LANL 2004, 087390; LANL 2006, 094161), but the ryegrass results are comparable to tests performed on Pajarito Canyon sediments (LANL 2009, 106771). Section 8.1.3.6 discusses the results of the statistical analysis of the growth and survival between reaches.

8.1.2.6 *Chironomus tentans* Toxicity Test

Sediment samples from the reaches shown in Table 8.1-2 were used in the EPA Method 100.2 (EPA 2000, 073776) 10-d growth and survival test with the larval insect *Chironomus tentans*. Each sediment sample was tested at 100% only; dilution series were not run on the sites. Some of the tests were run with field water from location D123.8 and some were run with laboratory water. Standard controls and reference toxicants were included. The endpoints for this test include both survival and growth (as ash-free dry weight). The results of the test are discussed in section 8.1.3.7.

The biota investigation work plan (LANL 2007, 099152) called for analyzing the chironomid bioassay test water midway through the 10-d test to quantify the concentration of hexavalent chromium during the test. Cr(VI) sampling results were not obtained because the samples CASA-08-8863 and CASA-08-8864 were not correctly preserved for chemical analysis. The impact of these missing data is discussed in the uncertainty analysis (section 8.1.4.2).

8.1.2.7 Rapid Bioassessment Characterization

Rapid bioassessment characterization was conducted at four locations in three Sandia Canyon reaches that had sufficient flow to potentially support aquatic macroinvertebrate communities (EPA 1999, 073728) using the EPA Rapid Bioassessment Protocol (1999, 073728). Aquatic macroinvertebrates were collected in association with the bioassessment. Collection and assessment were completed at all three reaches specified in Table 8.1-2 in November 2007, and a second location was characterized in reach S-2. The biota investigation work plan (LANL 2007, 099152) specified use of a Hess sampler to collect aquatic macroinvertebrates when sufficient water was present to use this sampler and all locations had sufficient flow to use the Hess sampler. The Hess sampler is needed to collect data for comparison to the NMED Stream Condition Index (SCI); therefore, aquatic macroinvertebrates from all four locations were compared with the SCI. The SCI compares sites with a reference condition, which is based on historical data from New Mexico streams.

8.1.2.8 Spatial Modeling Using ECORSK.9

The ECORSK.9 model was used to model HQs and hazard indexes (HIs) across Sandia Canyon for the Mexican spotted owl and southwestern willow flycatcher as presented in Gonzales et al. (2009, 106682). HIs are the sum of HQs and account for the potential additive effects of COPECs with similar modes of toxicity. ECORSK.9 includes both canyon and noncanyon sources as well as measured and interpolated concentrations of COPECs from these sources. The model estimates exposure based on an environmental exposure unit that consists of foraging throughout the home range centered on known or potential nest sites input into the model. For the Mexican spotted owl, the model restricted the nest sites within the buffer area for this T&E species. For the southwestern willow flycatcher, the model restricted the nest sites within the wetland areas designated as potential flycatcher habitat. The model produces mean total HIs that provide an estimate of risk to populations. For evaluating T&E species, risk to individuals and therefore the number of individual grid cells with elevated HIs are better indicators of locations and COPECs that may need additional investigation. The model calculates both unadjusted HQs and HIs and adjusted HQs and HIs; the adjusted values do not include the contribution of background concentrations of COPECs. For many organic chemicals, nondetects constituted more than 75% of the data set values, resulting in detection limits heavily influencing the HQ and HI values. The first scenario was run with nondetects for organic chemicals treated as zeros to focus the results on the actual detected COPECs in the model. For comparison purposes, a second scenario evaluated all nondetects at one-half of their detection limit.

8.1.3 Characterization of Exposure and Effects

This section discusses the baseline ecological risk assessment characterization of exposure and effects, which represents the second part of ERAGS Step 6 and provides the results from the studies and their interpretation, as well as supporting information in tables and figures. Revised calculations of dose to predators based on concentrations of COPECs in prey are also presented in this section.

8.1.3.1 Mexican Spotted Owl

ECORSK.9 Model

The results of ECORSK.9 model did not indicate that there are areas of potential risk to individual Mexican spotted owls (Gonzales et al. 2009, 106682). This was true for both the unadjusted and adjusted mean HI. The adjusted mean HQ and mean HI values calculated in the first scenario (all organic nondetects treated as zeros) are the most representative of potential risk from Laboratory sources to the

modeled receptors, although the adjustment for background made little difference for the HQ and HI values for the owl. The adjusted total mean HI with nondetects treated as zeros for the owl is 0.11; no COPECs had an HQ >0.1. The HI was <1 in about 98% of the focal points. The area with the highest potential for owl habitat was in Sandia Canyon is around reaches S-3W and S-3E, and there were no apparent groupings of potential nest sites with elevated His. In the eastern half of the owl habitat in Sandia Canyon, the HIs appear to be influenced by nearby AOCs or SWMUs. The single HI in the 10–100 range is at a nest site close to TA-60 SWMUs located on the mesa top.

Concentrations of COPECs in Prey

This section estimates the potential dose to avian and mammalian predators using COPEC concentrations in small mammals collected from three reaches in Sandia Canyon.

COPECs for the Mexican spotted owl were identified in section 8.1.1.2. Total cyanide, mercury, Aroclor-1248, Aroclor-1254, and Aroclor-1260 met the criterion for study design COPECs (HQ >1 for a T&E species). Perchlorate was also identified as a COPEC because there is no avian toxicity reference value (TRV) for this COPEC; this COPEC is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2).

Total cyanide was not included in the tissue analyses because the analytical method used to analyze for cyanide is inappropriate for this matrix. The analytical methods used for measuring cyanide concentrations follow EPA SW-846 Method 9010A or 9012A, "Total and Amenable Cyanide." These methods were specifically developed and validated for solid samples, such as sediment, soil, waste, and leachate. Biological samples have not been validated for these methods; it is not appropriate to apply analytical methods to matrices other than those recommended and previously validated. Potential problems that may arise if these methods are used for biological samples include interference from thiocyanate, found in blood plasma. High levels of aldehydes and ketones can also pose interference problems. In addition, fatty acids (lipids) found in high concentrations in biological tissues interfere with the distillation step. This interference can result in difficulty in finding the titration endpoint, used for quantitative measurement, and makes quantitation difficult. Cyanide is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). Analytical results for the other COPECs are provided in Appendix C.

The HQ is calculated by dividing the normalized food intake times the COPEC concentration by the TRV for a COPEC from the ECORISK Database, Version 2.3 (LANL 2008, 103352).

$$HQ = \frac{Exposure}{Effect}; \qquad HQ_{pathway,COPEC} = \frac{I_{receptor,pathway} \cdot C_{pathway,COPEC}}{NOAEL_{receptor,COPEC}}; \qquad \textbf{Equation 1}$$

where $C_{pathway,COPEC}$ is the concentration of the COPEC for the pathway (food and incidental soil) with units mg of COPEC/kg fresh weight);

$NOAEL_{receptor,COPEC}$ is the NOAEL for COPEC (mg-COPEC/kg-body weight/day); and

$I_{receptor,pathway}$ is the normalized daily intake rate for the receptor and pathway (kg-intake fresh weight/kg-body weight/day).

For the Mexican spotted owl, the normalized food intake of 0.102 kg food fresh weight/kg owl/day is based on the average intake of one wood rat per day (or 0.059 kg fresh weight per day) and the average body weight of 0.58 kg (Weathers et al. 2001, 73476). Table 8.1-5 shows the calculated HQs for the Mexican spotted owl based on ingestion of the concentration measured in small mammals. Because the Mexican spotted owl has a relatively large home range (over 400 ha, Gonzales et al. 2009, 106682) the

mammal tissue COPEC concentrations are averaged for each reach where they were sampled. Table 8.1-5 presents all results for the food pathway if the HQ for a COPEC in any reach was greater than 1; otherwise, the results for the reach with the largest HQ are presented. Reach S-2 has the largest HQ for the two owl study design COPECs detected in small mammals.

Small mammals are also assumed to be the prey of the receptor representing the carnivorous mammal, the red fox. Study design COPECs for the fox identified in section 8.1.1.2 are Aroclor-1248, Aroclor-1254, and Aroclor-1260. The HQ is calculated by dividing the normalized food intake times the COPEC concentration by the TRV for a COPEC from the ECORISK Database, Version 2.3 (LANL 2008, 103352) (Equation 1). The exposure parameters and TRVs used for the fox are summarized in Appendix E-1.0. Because the fox has a relatively large home range (1030 ha, LANL 2004, 087630, p. 39) the mammal tissue COPEC concentrations are averaged for each reach where they were sampled. Table 8.1-6 displays all results for the food pathway if the HQ for a COPEC in any reach was greater than 1; otherwise, the results for the reach with the largest HQ are presented. Reach S-2 has the largest HQ for the only fox study design COPEC detected in small mammal tissues (Aroclor-1260).

8.1.3.2 Aerial Insectivores

ECORSK.9 Model for the Southwestern Willow Flycatcher

In the ECORSK.9 model, a number of grid cells within Sandia Canyon with elevated HIs indicated there may be areas of potential risk to southwestern willow flycatchers (Gonzales et al. 2009, 102790). All COPECs were evaluated in the ECORSK.9 model and not just the study design COPECs that are the focus of the other site-specific studies conducted for Sandia Canyon. The adjusted mean HQ and mean HI values calculated in the first scenario (all organic nondetects treated as zeros) are the most representative of potential risk from Laboratory sources to the modeled receptors. The adjusted mean HI value for the flycatcher was 18 for the first scenario. The dominant COPECs were mercury (adjusted HQ = 11.4), bis(2-ethylhexyl)phthalate (BEHP) (adjusted HQ = 5.1), cyanide (adjusted HQ = 4.3), Aroclor-1254 (adjusted HQ = 2.7), silver (adjusted HQ = 1.2), zinc (adjusted HQ = 0.9), selenium (adjusted HQ = 0.7), cadmium (adjusted HQ = 0.7), copper (adjusted HQ = 0.6), and lead (adjusted HQ = 0.5). HIs were ≥1.0 in 87% of the grids; half of these HIs were greater than 10. The flycatcher was modeled only for areas that contain potential flycatcher habitat; therefore, the area with elevated HIs is limited to the upper part of Sandia Canyon (reach S-2).

Concentrations of COPECs in Prey for the Southwestern Willow Flycatcher

This section estimates the potential dose to the southwestern willow flycatcher using the concentrations in the insects collected from the nest boxes or concentrations in worms from the earthworm bioaccumulation bioassay.

Study design COPECs for the southwestern willow flycatcher were identified in section 8.1.1.2. Cadmium, chromium, copper, total cyanide, lead, mercury, methyl mercury, nickel, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, and Aroclor-1260 met the criterion for study design COPECs (HQ >1 for a T&E species). Perchlorate was also identified as a COPEC because there is no avian TRV for this COPEC; this COPEC is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). For the reasons discussed in section 8.1.3.2, cyanide was not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). Methyl mercury was also not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2).

The HQ is calculated by dividing the normalized food intake times the COPEC concentration by the TRV for a COPEC from the ECORISK Database, Version 2.3 (LANL 2008, 103352) (Equation 1). For the flycatcher, normalized food intake was calculated from the body weight (bw) of 12.7 g (OEHHA 2005, 088488) and estimating the food ingestion rate using the allometric equation for passerine birds from EPA's Wildlife Exposure Factors Handbook (1993, 059384, Equation 3-4). The calculated food ingestion rate is 0.0034 kg/d. This food ingestion rate is in grams of dry weight per day and was converted to fresh weight (fw) using the dry weight to fresh weight ratio for honeybees (Fresquez and Ferenbaugh 1999, 091269). The final insect ingestion rate used in the calculations for the southwestern willow flycatcher is 0.79 kg fw food/ kg bw/d. The TRVs used for the flycatcher are summarized in Appendix E-1.0.

Table 8.1-7 shows the calculated HQs for the flycatcher based on ingestion of the concentration measured in nest box insects or earthworms. Sampling results were averaged by reach and sampling location. At most locations, there is a single sampling result for insects or earthworms in each reach. Table 8.1-7 presents all results for the food pathway if the HQ for a COPEC in any reach was greater than 1; otherwise, the results for the reach with the largest HQ are presented. Reach S-2 has the largest HQs for all COPECs.

The HQs for the insect or earthworm ingestion pathway (Table 8.1-7) generally predict a much lower level of potential adverse ecological effect than the screening against ESLs did, even though HQs for seven COPECs exceed 1 (Aroclor-1242, Aroclor-1248, Aroclor-1254, copper, mercury, selenium, and zinc). Copper and zinc also had HQs greater than 1 in samples from reference areas collected outside Sandia Canyon in the Cañada del Buey, Pueblo, or Rendija watersheds (LANL 2006, 094161, p. 289). Thus, the potential for risk is calculated for copper and zinc in insects collected from most locations, regardless of the presence of Laboratory contaminant sources. Selenium also had HQs greater than 1 for all locations sampled for either insects or earthworms, including the reference location (reach PA-0). Therefore a difference in exposure for selenium associated with Laboratory sources is not indicated.

Sediment data discussed in section 7.1, as well as data from SWMUs, indicate that Aroclor-1254 and mercury have Laboratory sources and the exposure evaluation for the flycatcher identifies reaches where these COPECs have an HQ greater than 1. At three reaches (S-2, S-3W, and S-4W), the HQs for Aroclor-1254 or mercury were greater than 1. The southwestern willow flycatcher has not been observed in this part of the Laboratory, so the risk is hypothetical at this time. However, further evaluation may be warranted if the flycatcher is observed to utilize this area in the future.

Estimate of COPEC Dose to the Bat through Food

Eight COPECs in Sandia Canyon reaches had HQs >3 for the bat (cadmium, copper, nickel, selenium, silver, thallium, zinc, Aroclor-1248, and Aroclor-1254), but the bat is not identified as an AE because its large home range and high food-ingestion rate indicate that much of a bat's food is obtained from outside the watershed. However, because nest box insect and earthworm tissues were analyzed to evaluate avian receptors, these analytical results were used to calculate the potential COPEC dose to the occult little brown myotis bat through food, as shown in Table 8.1-8. Application of earthworm concentrations to the bat exposure evaluation is protective in that the realistic diet for the bat does not include prey with such an intimate association with soil. The HQ is calculated by dividing the normalized food intake times the COPEC concentration by the TRV for a COPEC from the ECORISK Database, Version 2.3 (LANL 2008, 103352) (Equation 1). Exposure parameters for the bat are from the SLERA methods document (LANL 2004, 087630, p. 39) and are listed in Appendix E-1.0. The TRVs used for the bat are summarized in Appendix E-1.0. Because the bat has a relatively large home range (100 ha, LANL 2004, 087630, p. 39) the insect or earthworm tissue COPEC concentrations are averaged for each reach where they were sampled. Aroclor-1248 was not detected in earthworms but the nondetected sampling results for

Aroclor-1248 in earthworms lead to calculating pathway HQs greater than 1 in three reaches (S-2, S-4W, and S-5E). The pathway HQs for Aroclor-1254 and copper were slightly greater than 1 (1.1 and 1.2, respectively) in one reach (S-2). The pathway HQs for selenium and thallium in earthworms were greater than 1 in three reaches (the HQs are 1.2 to 2.4 in reaches S-2, S-4W, and S-5E), indicating some potential for adverse effects on the bat through ingestion of earthworms (or insects with a similar association with soil) and under the assumption that all insects are eaten from these reaches in Sandia Canyon. The selenium earthworm pathway HQs were greater than 1 for the reference reach (PA-0) and for insects collected in reach S-2. However, considering the large home range of 100 ha or larger for the bat and the protective nature of the food data, the potential for adverse effects on the bat is greatly overestimated by this analysis.

8.1.3.3 Avian Invertivore Feeding Guild

This section provides results for trends of COPEC concentration in sediment versus field measures for the avian invertivore feeding guild in Sandia Canyon, such as nest success and eggshell thickness. Field measures are derived from Colestock and Fair (2005, 093691).

Nest Success

As part of the Laboratory's nest box monitoring program, a large number of field measures are collected from the nest boxes each year (Colestock and Fair 2005, 093691). Two measures related to juvenile survival were selected for comparison to concentrations of COPECs in sediment. The measures selected are percent fledged and percent female (the latter may relate specifically to PCBs as COPECs). Occupied bird boxes were found in reaches S-2 and S-5E in Sandia Canyon. Reference locations for nest box measures include boxes deployed in Cañada del Buey and Guaje Canyon. Data are provided for comparison purposes from nest boxes in potentially impacted areas in other canyons (e.g., Los Alamos, Mortandad, and Pajarito).

All species occupying the nest boxes (western bluebirds, violet-green swallows, ash-throated flycatchers, and mountain bluebirds) are included in the analysis of the measures to provide a larger data set because the overall number of occupied boxes in the reaches is fairly small. Appendix E-1.3 provides box plots comparing these two measures between species. Because western bluebirds are the main species occupying nests, data for the western bluebird are presented and discussed below.

Comparisons of the selected nest measures for western bluebirds between Sandia Canyon and reference locations are shown in Figure 8.1-2 for percent fledged and Figure 8.1-3 for percent female. Boxes in these figures indicate the interquartile range of the sampling results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values, and horizontal lines above and below the boxes represent the 5th and 95th percentiles of the data. Dunnett's *t*-test results are presented in the right-hand section of each figure. The comparison circles indicate statistical differences between the tests and the reference sites. The reference site sample for the Dunnett's *t*-test is displayed as a heavy red circle, and the text for the reference site is printed in bold red text on the x-axis. Thin red circles represent samples that are not statistically different ($p < 0.05$), and the watershed names are displayed in red on the axis. Heavy gray circles represent samples that are statistically different, and these names are printed in black on the x-axis. There were no significant differences in percent fledged or percent female. These measures were recorded from 1997 to 2009; bivariate plots of each measure versus year were made and are shown in Appendix E-1.3. Variation in these measures is not biologically significant, so data from all years are included in Figures 8.1-2 and 8.1-3.

Egg Measurements

Another set of parameters collected as part of the nest box network is related to the condition of the eggs. Numerous parameters have been collected; three of these parameters were chosen for inclusion in this study. Eggshell length (in millimeters) and total egg weight correlate well with each other and provide an estimate of egg size. Eggshell thickness was also chosen because previous studies have shown that some thinning of eggshells has occurred at the Laboratory in Sandia Canyon (Fair and Myers 2002, 082655). As with the other nest measures described above, all species have been included to provide a larger data set. Appendix E-1.3 shows the comparison between species for egg length, egg weight, and eggshell thickness; the comparison shows no significant differences among species for these parameters. Appendix E-1.3 also compares length, weight, and thickness across years (1997 to 2008) in bivariate plots. Variation in these measures is not biologically significant, so data from all years are included in the analysis.

The measures for the eggs are compared between watersheds and are also compared with reference locations. Figures 8.1-4 to 8.1-6 show the comparisons for the western bluebirds egg measures between Sandia Canyon locations and reference locations. None of these three measures shows any significant differences between watersheds based on the results of the Dunnett's *t*-test (discussed above).

COPEC Concentrations in Eggs

Concentrations measured in eggs collected from Sandia Canyon nest boxes provide information on exposures to COPECs. Five sets of COPEC measurements were reported for reach S-2 and one measurement from reach S-5E. Sampling results are available from eggs for eight study design COPECs (cadmium, chromium, copper, lead, nickel, selenium, silver, zinc). Mercury, perchlorate, PCBs, and pesticides were also identified as study design COPECs but were not analyzed in eggs because of sample mass limitations; these COPEC are evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). For the reasons discussed in section 8.1.3.2, cyanide was not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2).

Concentrations in eggs collected from Sandia Canyon were compared to concentrations in eggs from reference locations (Cañada del Buey and Guaje Canyon) that were distant from SWMUs and AOCs. The sampling results and statistical comparisons of Sandia Canyon to reference location eggs for eight study design COPECs are summarized in Table 8.1-9. Concentrations of copper and selenium from Sandia Canyon eggs are statistically greater than reference locations. Concentrations of the other COPECs are not different or the concentrations in Sandia Canyon are less than those measured at reference locations.

Eggs had been collected from 1997 to 2001 across the monitoring network and were analyzed for contaminants in 2002 (Fair et al. 2004, 085524). Two of the previously collected egg samples were obtained from nest boxes in reach S-2 and were analyzed for selected PCB congeners (26 congeners were reported but only 2 [PCB 77 and PCB 105] of the 12 toxic congeners were reported and neither was detected). Because a partial list of congeners was reported for these two egg samples, these PCB results are of limited utility in evaluating bioaccumulation or in fingerprinting contaminant sources. The total PCB concentration was approximately 1 mg/kg in one egg sample and was <0.02 mg/kg in the other egg sample from Sandia Canyon. The historical egg samples from Sandia Canyon also provide information on organochlorine pesticides and PAHs, 4,4'-DDE (dichlorophenyltrichloroethylene) was most frequently detected pesticide and PAHs were not detected in the Sandia Canyon eggs.

COPEC Concentrations in Insects and Worms

The remainder of this section estimates the potential dose to the robin using the concentrations in the insects collected from the nest boxes or concentrations in worms from the earthworm bioaccumulation bioassay. The equation for calculating HQs is presented in section 8.1.3.2, and exposure parameters for the robin are from the SLERA methods document (LANL 2004, 087630, p. 37) and are listed in Appendix E-1.0.

Study design COPECs for the robin were identified in section 8.1.1.2. Cadmium, chromium, copper, total cyanide, lead, mercury, nickel, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, 4,4'-DDD, and dieldrin met the criterion for study design COPECs (HQ >3). Perchlorate was also identified as a COPEC because there is no avian TRV for this COPEC; this COPEC is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). For the reasons discussed in section 8.1.3.2, cyanide was not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). Methyl mercury was also not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). Dieldrin and 4,4'-DDD were not measured in earthworms or insects from sample mass limitations and are evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). The TRVs used for the robin are summarized in Appendix E-1.0.

Table 8.1-10 shows the calculated HQs for the robin based on exposure to concentrations measured in nest box insects or earthworms. In all cases, there is a single sampling result for insects or earthworms in each reach. Table 8.1-10 displays all results for the food pathway if the HQ for a COPEC in any reach was greater than 1; otherwise the results for the reach with the largest HQ are presented and the results for reach S-2 are presented. Reach S-2 has the largest HQ for many COPECs.

The HQs for the insect or earthworm ingestion pathway are shown in Table 8.1-10 and predict a potential for adverse ecological effect based on HQs for nine COPECs exceeding 1 (Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, cadmium, copper, mercury, selenium, and zinc). Aroclors were not measured in nest box insects because of sample mass limitations. Aroclor-1242 and Aroclor-1248 were not detected in earthworms, but the nondetected sampling results for these Aroclors in earthworms lead to pathway HQ greater than 1 in three reaches (S-2, S-4W, and S-5E). Copper and zinc also had HQs greater than 1 from insect samples collected from reference areas outside Sandia Canyon in the Cañada del Buey, Pueblo Canyon, and Rendija Canyon watersheds (LANL 2006, 094161, p. 289). Thus, the potential for risk is calculated for copper and zinc in insects collected from most locations, regardless of the presence of Laboratory contaminant sources. Selenium also had HQ greater than 1 for all locations sampled for either insects or earthworms, including the reference location (reach PA-0). Therefore a difference in exposure for selenium associated with Laboratory contaminant sources is not indicated.

The magnitude of the earthworm pathway HQs for Aroclor-1260, cadmium, and copper was low (earthworm pathway HQs were in the 1 to 2 range for these COPECs) and limited to one or more locations in reach S-2. The HQ for the mercury earthworm pathway was 10 at one location in reach S-2 and was otherwise less than 2 in other locations and reaches. Thus, it is unlikely population-level effects from these COPECs exist based on the soil invertebrate exposure pathway.

The contaminant trends indicate that Aroclor-1254 has Laboratory contaminant sources and the exposure evaluation for the robin identifies reaches where Aroclor-1254 has an HQ greater than 3: reaches S-2, S-3W, and S-4W.

8.1.3.4 Mammalian Invertivore Feeding Guild

Field Surveys of Small Mammal Relative Abundance and Reproductive Status

A variety of field measures were collected during the trapping and collection of small mammals for this biota investigation (Bennett and Robinson 2008, 106938). The mean percent daily capture rate, which is an estimate of relative population density, was highest in reach S-4E at 32% and lowest in reach S-5E at 5% (Table 8.1-3). The Mortandad Canyon small mammal studies provide a comparison to these relative abundance values in Sandia Canyon, a reference location (the LA-BKG reach) was 7% and the Mortandad Canyon investigation reaches ranged between 9% and 22% (Bennett et al. 2006, 093701).

Species composition (the frequency of capture for each species at a site) varied markedly among the three Sandia Canyon reaches. Species diversity expressed as a Shannon-Weaver Index was lowest at reach S-4E because only two species total were captured and the majority of the animals were a single species (harvest mouse); species diversity was greatest at reach S-2 and included captures of shrews and other small mammals associated with wetlands. The total number of animals captured and the Shannon-Weaver Index for each reach are provided in Table 8.1-3. Shannon-Weaver Index values were calculated using the online diversity calculator at http://math.hws.edu/javamath/ryan/DiversityTest.html.

Data collected during the trapping study indicated one statistical difference in ratios of males to females, and no differences in body weights or reproductive status between reaches, using chi square analysis (Bennett and Robinson 2008, 106938); however, the number of animals in this study is small for detecting differences in these measures. There were significantly more female harvest mice (74) than male harvest mice (7) captured at reach S-4E. The reason for this difference is not known and is likely not related to contaminants as COPEC concentrations are only moderately greater than background in reach S-4E (section 7.1).

Concentrations of COPECs in Small Mammals

Concentrations measured in small mammal tissues collected from Sandia Canyon provide information on exposures to COPECs. COPEC concentrations were measured for reaches S-2, S-4E, and S-5E. Each sample was a composite of the species collected from these reaches. Sample results are available from mammal tissue for 11 study design COPECs (cadmium, chromium, copper, lead, perchlorate, mercury, nickel, selenium, silver, zinc, and Aroclor-1254). Although Aroclor-1260 was not identified as study design COPEC, it was frequently detected in mammals and is evaluated along with the other COPECs. For the reasons discussed in section 8.1.3.2, cyanide was not measured in tissues and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2).

Long tailed vole (MILO), montane vole (MIMO), brush mouse (PEBO), deer mouse (PEMA), piñon mouse (PETR), and vagrant shrew (SOVA) were collected in reach S-2. Three species of small mammals were collected from reach S-4E (deer mouse, piñon mouse, western harvest mouse [REME]), and four species were collected from reach S-5E (brush mouse, deer mouse, piñon mouse, and western harvest mouse). Each of the small mammal trapping arrays had a composite sediment sample collected for comparison to the whole animal tissue concentrations. Figure 8.1-7 shows how the whole-animal tissue concentrations for six mammal species caught in reach S-2 compare to the sediment concentrations from the trapping array. The vagrant shrew has notably higher concentrations of two COPECs (mercury and Aroclor-1260) and the concentration of Aroclor-1260 in the shrew was about 20 times greater than the sediment concentration. Previous studies in the Sandia Canyon wetland also showed that shrews had the highest concentrations of PCBs and similar concentrations have been reported in these studies (Bennett et al. 1999, 082652). Figure 8.1-8 shows how the concentrations in three mammal species caught in reach S-4E compare to the sediment concentrations from the trapping array. The piñon mouse has higher

concentrations of seven COPECs (cadmium, chromium, lead, nickel, selenium, zinc, and Aroclor-1260) and the tissue concentration of Aroclor-1260 in piñon mouse tissue was about 3 times greater than the sediment concentration. Figure 8.1-9 shows how the tissue concentrations for four mammal species caught in reach S-5E compare to the sediment concentrations from the trapping array. No species has consistently the highest concentration in tissue and concentrations of two COPECs have notable observations among the reach S-5E sampling results. The tissue concentration of Aroclor-1260 in harvest mouse tissue was about 1.5 times greater than the sediment concentration. The tissue lead concentration of the harvest mouse was greater than the sediment concentration and about 30 times larger than the average of the other 12 tissue samples.

The concentrations measured for lead, mercury, perchlorate, Aroclor-1254, and Aroclor-1260 in sediment and small mammals are summarized in Table 8.1-11. There is some evidence for exposure based on all of these COPECs, but mercury and Aroclor-1260 provide the strongest evidence for contamination associated with Laboratory sources and with sources in the wetland (reach S-2). Aroclor-1254 was not reported as detected in small mammals. Perchlorate was reported as detected in mammal tissues in all reaches and with varying levels in sediments. One species (piñon mouse) in the most downstream reach had higher concentrations of lead in tissues; thus, a clear association with Laboratory sources is not indicated based on the minimal increase in lead above background in sediments and a lack of significant detections of lead in the other small mammal species from reach S-5E.

Refinement of COPEC Dose to the Shrew from Earthworms and Insects

The representative receptors for the mammalian invertivore feeding guild are the deer mouse and shrew; all deer mouse COPECs were also shrew COPECs. Therefore, this section estimates the potential dose to shrews using the concentrations in the insects collected from the nest boxes or concentrations in worms from the earthworm bioaccumulation bioassay. The equation for calculating HQs is presented in section 8.1.3.2, and exposure parameters for the shrew are from the SLERA document (LANL 2004, 087630, p. 38) and are listed in Appendix E-1.0.

COPECs for the shrew were identified in section 8.1.1.2. Cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, Aroclor-1248, Aroclor-1254, and dieldrin met the criterion for study design COPECs (HQ >3). Perchlorate was also identified as a COPEC because there is no mammalian TRV for this COPEC; this COPEC is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). Note that dieldrin was not measured in shrew food and is evaluated in a qualitative manner in the uncertainty analysis (section 8.1.4.2). The TRVs used for the shrew are summarized in Appendix E-1.0.

Table 8.1-12 shows the calculated HQs for the shrew based on exposure to concentrations measured in nest box insects or earthworms. In all cases, there is a single sampling result for insects or earthworms in each reach. Table 8.1-12 displays all results for the food pathway if the HQ for a COPEC in any reach was greater than 1; otherwise, the results for the reach with the largest HQ are presented. Reach S-2 has the largest HQ for all COPECs.

The HQs for insect or earthworm ingestion pathway are shown in Table 8.1-12 and predict a potential for adverse ecological effect based on HQs for five COPECs exceeding 1 (Aroclor-1248, Aroclor-1254, cadmium, copper, and selenium). Aroclors were not measured in nest box insects because of sample mass limitations. Aroclor-1248 was not detected in earthworms but the nondetected sampling results lead to pathway HQ greater than 1 in four reaches (S-2, S-3W, S-4W, and S-5E). Copper also had similar concentrations in insect samples collected from reference areas outside Sandia Canyon in the Cañada del Buey, Pueblo, and Rendija watersheds (LANL 2006, 094161, p. 289). Thus, the potential for risk is

calculated for copper in insects collected from most locations, regardless of the presence of Laboratory sources. Selenium also had HQs greater than 1 for all locations sampled for either insects or earthworms, including the reference location (reach PA-0). Therefore, a difference in exposure for selenium associated with Laboratory sources is not indicated.

The magnitude of the earthworm pathway HQs for cadmium were low (the maximum earthworm pathway HQs was 1.4 for one location in reach S-2) and was otherwise less than 1 in other locations and reaches. The magnitude of the earthworm pathway HQs for Aroclor-1254 were moderate at one location in reach S-2 (HQ was 3) and was otherwise less than 1 in other locations and reaches. Thus, it is unlikely population-level effects from these COPECs exist based on the soil invertebrate exposure pathway.

Comparison of PCB Congener to Aroclor Sample Results

Six sediment samples were analyzed for both PCB congeners and Aroclors. No small mammal samples nor their food were analyzed for PCB congeners; thus, a comparison of the sediment PCB congener to sediment Aroclor results provides information on the weathering of the Aroclor mixtures and the concentrations of the more toxic congeners. This supplemental evaluation of PCB congener sampling results is not considered representative of risks in the reach because the samples submitted for PCB-congener analysis included the geomorphic units and locations with the highest concentrations of PCBs. Lower risk for PCB congeners would be calculated using area- and depth-integrated representative samples in reach S-2.

To evaluate the ecological risks associated with PCB congeners the concentrations are converted to dioxin equivalents, specifically the 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) equivalent concentration (TEC). Twelve of the 209 PCB congeners have TCDD equivalency factors (TEFs) that are the ratio of the toxicity of these 12 congeners to TCDD. The most toxic PCB congener (126) has a TEF equal to 0.1 for mammals. Appendix C provides the TEFs used to calculate mammal and bird TECs.

Table 8.1-13 provides the mammal TECs and the HQ for the shrew; the HQs based on the dioxin-like toxicity of PCB congeners in reach S-2 sediment samples ranges from 62 to 1900 or 200 times the HQs calculated based on the Aroclor concentrations in the samples. Thus, all of these PCB congener sampling results indicate the potential for ecological risk, but only three of the six Aroclor-1254 sampling results yield HQs greater than 1 (Table 8.1-13).

There are three reasons for this large discrepancy in the HQs based on congeners versus Aroclors. The Aroclor results estimate lower concentrations of PCBs compared to the congener method and the abundance of the most toxic congener is also underestimated relative to what has been measured in unweathered Aroclor lots. PCB 126 has a reported percent weight composition of 0.002% or 0.015% in two Aroclor-1254 lots (Frame et al. 1996, 106797). PCB 126 was not reported in Aroclor-1242 or Aroclor-1260 and was reported as 0.003% or 0.004% in Aroclor-1248. Concentration related factors appear to contribute roughly a factor of 10 to the discrepancy in the HQs for congeners versus Aroclors. The last factor, which apparently is the most significant, is the relative values of the TRVs for Aroclors versus TCDD.

8.1.3.5 Detritivores

COPECs for detritivores (earthworms) were identified in section 8.1.1.2. Barium, chromium, hexavalent chromium, mercury, and zinc met the criterion for study design COPECs (HQ >3). The potential for adverse ecological effects from these COPECs was evaluated by measuring growth and survival of earthworms at 10 locations in Sandia Canyon in comparison with one reference location (reach PA-0).

There was a single replicate of these samples in Sandia Canyon; the Sandia Canyon results were compared with the replicate earthworm bioassay results from the Los Alamos, Pueblo, Mortandad, and Pajarito Canyons watersheds (LANL 2004, 087390; LANL 2006, 094161; LANL 2009, 106771) for a more comprehensive assessment. Reference site earthworm toxicity tests from the Los Alamos, Pueblo, Mortandad, and Pajarito watershed studies were also included in the statistical analyses.

The results for the earthworm bioaccumulation test are summarized with box plots for survival and growth (as ending weight) in Figures 8.1-10 and 8.1-11. The boxes on these plots indicate the interquartile range of the sampling results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values, and lines above and below the boxes represent the 5th and 95th percentiles of the data. Dunnett's *t*-test results are presented in the right-hand section of each figure. The comparison circles indicate statistical differences between the tests and the reference sites. The reference site sample for the Dunnett's *t*-test is displayed as a heavy red circle, and the text for the reference site is printed in bold red text on the x-axis. Thin red circles represent samples that are not statistically different ($p < 0.05$), and the watershed names are displayed in red on the axis. Heavy gray circles represent samples that are statistically different, and these names are printed in black on the x axis. No significant differences in survival were seen between any of the Sandia Canyon reaches and the reference locations; survival was greater than 80% in most samples. In all treatments, earthworms showed weight loss, which is typical of earthworms in this assay (EP&T 2005, 091267). There were no significant differences in ending weight relative to reference sites.

The sediment samples were also analyzed for COPECs; the concentrations of earthworm study design COPECs did not correlate to differences in survival or weight loss. Organic matter in soil can serve as a food source for earthworms during this type of test. Organic matter was measured in each of these samples; the organic matter in the sample did not correlate with survival or weight change in the test groups. Analyses of earthworm survival and growth with COPECs and confounding factors are presented in Appendix E-1.0.

8.1.3.6 Plant (Primary Producers)

COPECs for plants were identified in section 8.1.1.2. Barium, chromium, hexavalent chromium, copper, lead, manganese, selenium, and zinc met the criterion for study design COPECs (HQ>3). The potential for adverse ecological effects from these COPECs was evaluated by measuring germination and growth of ryegrass at 10 locations in Sandia Canyon in comparison with one reference location (reach PA-0). There were five replicates for each location.

A number of measures of plant growth and survival are included in the laboratory toxicity test on samples collected from Sandia Canyon; these measures include mass of wet shoots, mass of wet roots, and percent germination (survival). The results are plotted on box plots with the results of the Dunnett's *t*-test comparison is printed on the right-hand side of the figure; this type of figure is explained in section 8.1.3.5. As shown in Figure 8.1-12, the mass of shoots showed no significant differences between the reaches and the reference location. In the analysis of root mass shown in Figure 8.1-13, the mass of roots showed no significant differences between the reaches and the reference location. Survival of plants did not differ from the reference location (Figure 8.1-14).

The sediment samples were also analyzed for COPECs; the concentrations of plant study design COPECs did not correlate to differences in survival or weight with three exceptions. Selenium and zinc concentrations were negatively correlated with plant survival, but there was no relationship of these COPECs and growth measures. As discussed in section 7.1, selenium has an unusual spatial distribution and its sources are unclear. Perchlorate concentrations were also correlated with growth and survival

measures, but perchlorate concentrations in sediment are not consistent with Laboratory sources. Organic matter, nutrients, or particle size can be confounding factors for seedling germination tests; confounding factors did correlate with the percent survival or weight change in the test groups. Analyses of plant survival and growth with COPECs and confounding factors are presented in Appendix E-1.0.

8.1.3.7 Aquatic Community

COPECs for aquatic community were identified in section 8.1.1.2. Barium, cadmium, chromium, copper, total cyanide, iron, mercury, selenium, silver, zinc, Aroclor-1242, Aroclor-1248, Aroclor-1254, and Aroclor-1260 met the criterion for study design COPECs in sediment or water (HQ >3). The potential for adverse ecological effects from these COPECs was evaluated with the *Chironomus tentans* toxicity test and the information obtained from the rapid bioassessment protocol.

***Chironomus tentans* Toxicity Bioassay**

The *Chironomus tentans* toxicity test measures survival and growth of larval insects in active channel sediment collected from the five Sandia Canyon reaches and one reference site specified in Table 8.1-2. There were eight replicates per test for each location. The Sandia Canyon chironomid tests were run in pairs–one set of tests used laboratory water and the other set used field water from Sandia Canyon. Figure 8.1-15 shows the comparison of mean survival for field water versus laboratory water and Figure 8.1-16 compares chironomid growth. A paired t-test indicated that survival was significantly lower for the field water tests and that growth was significantly higher. Thus, there was an effect of the type of water used in the bioassay. Figure 8.1-17 shows box plots of larval survival for each replicate at the conclusion of the test. This box plot shows no statistical difference in survival from the reference site (PA-0). Figure 8.1-18 shows that all sampled Sandia Canyon reaches (S-2, S-3W, S-3E, S-4E, and S-5E) had significantly less larval growth than the reference site. Thus, there are statistically significant differences in growth for chironomid bioassays in Sandia Canyon.

Additional comparisons were performed based on the average chironomid survival and growth for bioassays completed in the Los Alamos and Pueblo, Mortandad, Pajarito, and Sandia watersheds, and reference locations. The chironomid bioassay test procedure allows for second or third instar (or growth phase) larvae to be used in the test; these animals vary in size. To make different test batches comparable, the growth numbers were divided by the average laboratory control growth. Figure 8.1-19 presents the mean chironomid survival by watershed, and Figure 8.1-20 presents the mean normalized larval growth. Mean survival was 80% or greater for all but two sampling locations. Normalized larval growth was generally around 1 (or equal to the laboratory control).

The EPA chironomid test protocol (EPA 2000, 073776) recommended testing for a variety of physical measurements because survival and growth can be influenced by such confounding factors. Some of the sediment size measures did correlate with particle size measures. Figure 8.1-21 shows the most significant relationship, which was between larval survival and the amount of clay-sized material in the sample. The sediment samples were also analyzed for COPECs; the concentrations of aquatic community study design COPECs (PCBs, barium, chromium, copper, cyanide, iron, lead, mercury, perchlorate, selenium, and silver) did correlate to decreased survival or growth. Further analyses of chironomid survival and growth with COPECs and confounding factors are presented in Appendix E-1.0.

Rapid Bioassessment Characterization

Data on collected macroinvertebrates, habitat scores, and dissolved oxygen levels in reaches S-2 and S-3E indicate that these sites are suboptimal for sustaining a diverse community of aquatic life (Henne

2009, 106683). Table 8.1-14 provides the habitat assessment scores by parameter for each reach. Habitat at reach S-2 was scored as suboptimal from lack of stabile habitat for colonization, embeddedness of the streambed substrate, heavy sediment deposition, lack of complexity in the velocity/depth regime, low flow, and lack of vegetative protection of the stream banks. The habitat score at reach S-3E indicted suboptimal conditions for aquatic life because of the lack of stable substrate for colonization, embeddedness of the streambed substrate, lack of complexity in the velocity/depth regime, sediment deposition, flow status, bank stability, and impact in the riparian zone because of the proximity of the road.

Macroinvertebrates were collected from reaches S-2 and S-3E using the Hess sampler. Mayflies dominated the counts at these locations but chironomids were also identified from both reaches. Data on macroinvertebrate sample abundance and number of taxa are provided in Table 8.1-15. The observation of chironomids supports the use of the *Chironomus tentans* laboratory toxicity test as the appropriate assay to determine if sediment COPECs are adversely impacting the macroinvertebrate communities in this semiarid stream system.

NMED's unpublished SCI, a statistically validated multimetric index for estimating stream condition based on various characteristics of macroinvertebrate assemblages (e.g., diversity, number of taxa), was used to assess stream impairment (Henne 2009, 106683). The SCI compares test sites to a reference condition, which is based on a group of minimally impacted reference sites that are physically, chemically, and biologically similar to the test sites and that account for the natural variability in aquatic communities among sites. The reference condition for the SCI is based on historical data from New Mexico streams. Both reaches S-2 and S-3E were rated as severely impaired based on the macroinvertebrate samples (Table 8.1-15). Most of the previous sampling at these locations has also indicated impairment (Table 8.1-16). Habitat assessments at all of the sites rated higher than the SCI. This result indicates that water and/or sediment quality, as opposed to habitat limitations, are impairing aquatic life at the sample sites. Poor water quality is likely from the effluent discharged into the stream and stormwater runoff from nearby developed areas. Sediment can also be contaminated by these sources as well as by historical Laboratory releases.

8.1.4 Risk Characterization

ERAGS Step 7 is risk characterization, which includes risk estimation and the uncertainty analysis. Risk estimation includes a summary of the results for the measures used to evaluate potential for ecological effects. A qualitative weight of evidence (WOE) criterion was assigned to each measure based on Appendix D of the NMED-approved Pajarito Canyon biota investigation work plan (LANL 2006, 093553), which provides some of the technical details for the ecological investigations in Sandia Canyon. If measures indicate different outcomes, meaning one measure indicates a potential for adverse effects and one does not, then the overall conclusion is weighted toward the measure with the higher WOE.

8.1.4.1 Risk Estimation

Mexican Spotted Owl

The two main measures for the Mexican spotted owl are the ECORSK.9 modeling and the modeling of estimated dose through the food chain from the study design COPECs detected in small mammals. The WOE assigned to each measure is shown in Table 8.1-17. In the ECORSK.9 model, the total adjusted mean HI (using zero for nondetects) across the core and buffer areas for the owl was 0.11. This value is less than the HI target of 1.0, indicating no adverse effects on individual owls exist from COPECs considered in the model. No Mexican spotted owls currently nest in Sandia Canyon. The other measure

estimated the dose to the Mexican spotted owl based on concentrations in their food (section 8.1.3.1). HQs based on measured concentrations of COPEC in small mammals were less than 1 and thus did not indicate risk. Based on the measurements of COPECs in small mammal tissue and the ECORSK.9 model results, the WOE indicates no adverse effects of COPECs on survival and reproduction of the Mexican spotted owl (AE1).

Aerial Insectivore Feeding Guild

The aerial insectivores applicable measures for the southwestern willow flycatcher are the ECORSK.9 model, the results of estimated dose through prey using the COPEC concentrations detected in nest box insects and earthworms, and the field nest box measures. The WOE assigned to each measure is presented in Table 8.1-18. The ECORSK.9 model had a total mean-adjusted HI of 18, indicating potential for risk to the flycatcher through exposure to mercury, BEHP, cyanide, Aroclor-1254, silver, zinc, selenium, cadmium, copper, and lead, as presented in section 8.1.3.2. The exposure evaluation calculated HQ values >1 for PCBs and four metals based on the concentrations in earthworms or insects. These calculations indicate potential for risk to flycatchers from ingestion of invertebrates, and the locations where HQs are greater than 1 include potential southwestern willow flycatcher habitat (reach S-2). The WOE from these measures indicates some potential for adverse effects on survival and reproduction of the southwestern willow flycatcher (AE6) from COPECs in sediment. However, the field measures (nest box studies) of other avian insectivores do not show impacts to nest success, which indicate that the models used for assessing the flycatcher overestimate the potential for ecological risk to avian insectivores. In addition, the southwestern willow flycatcher has not been observed in this part of the Laboratory, so the risk to this species is hypothetical at this time.

The potential for risk to the occult little brown myotis bat is evaluated based on exposure to COPECs in their food. There was potential for adverse effects from Aroclor-1248, selenium, and thallium, if all insects come from specific Sandia Canyon reaches. Aroclors are detected frequently in sediment and earthworm samples; Aroclor-1248 and Aroclor-1254 were not measured in nest box insects. The HQs for selenium were greater than 1 in all reaches where insects or earthworms were sampled. The HQs for thallium were generally less than 1, which indicates no potential for adverse effects to the bat for most of Sandia Canyon. The potential for adverse effects of COPECs on bat survival and reproductions is unlikely given the low HQs and also accounting for the large home range for the bat.

Avian Ground Invertivore Feeding Guild

A number of measures were evaluated for the avian ground invertivore feeding guild. The WOE assigned to each measure is provided in Table 8.1-19. An exposure evaluation to COPECs in diet was also done; this analysis evaluated COPEC concentrations in the earthworms and nest box insects. The dose modeling indicates a potential for adverse effects on avian ground invertivores through ingestion of COPECs in food. The following COPECs had HQs>1: Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, cadmium, copper, mercury, selenium, and zinc. A number of field measures of impacts on avian invertivore species were also conducted. The measures of nest success through percent fledged, percent female nestlings, and egg size and thickness show no differences between Sandia Canyon and reference locations based on using all available observations from 1997 to 2009. Because the avian monitoring network was expanded in 2008, there are two field seasons of information on nest success for one reach and less information on exposures. As summarized in the biota plan (LANL 2007, 099152), some of the initial evaluations of avian monitoring network in Sandia Canyon have indicated decreased hatching success and eggshell thinning were prevalent in the Sandia wetland or that higher survivorship was observed at nest boxes further from contaminant sources. However, more robust evaluations based on a longer record of observations of on sex ratios of fledgling birds have shown no statistically significant

differences in sex ratios between canyons or watersheds (Fair et al. 2009, 106686). Thus, there is no indication of contaminant effects on sex ratios across the monitoring network or based on the field measures of nest success evaluated in this report. There are no analyses of Aroclors or PCB congeners on nest box insects. Overall, the WOE indicates that COPECs in Sandia Canyon reaches do not pose a potential risk to population abundance or persistence and species diversity of avian ground invertivore feeding guild species (AE2).

Mammalian Invertivore and Omnivore Feeding Guild

The mammalian invertivore and omnivore feeding guilds include both the deer mouse (an omnivore) and the shrew (an insectivore). Two lines of evidence were evaluated for these species, and the WOE for these lines is presented in Table 8.1-20. One measure for the small mammals was to estimate the potential dose to them through ingestion of earthworms or nest box insects. Both the shrew and deer mouse are modeled for the ESL development with invertebrates in their diet but, as explained in section 8.1.3.4, the exposure evaluation was conducted using only the shrew. Aroclor-1248, Aroclor-1254, cadmium, copper, and selenium had HQs>1 for the shrew, which indicates a potential for adverse effects on small mammals from these COPECs. Aroclor-1248 was identified based on nondetect sampling results in earthworms, and Aroclor-1254 was detected only in a single earthworm sample. Thus, the data do not indicate the potential for adverse effects on shrew populations from Aroclors. The HQ for cadmium was equal to 1.4, and thus exposure was roughly equal to the no-effect level. Cadmium had HQs >1 but less than 3 at two locations, which is not likely to be associated with the potential for adverse effects on shrew populations in Sandia Canyon. Selenium had an HQ >3 for shrews in a single location, and the spatial extent of selenium in sediments is not consistent with a Laboratory source (section 7.1, Table 7.1-1). Overall, the WOE for small animals indicates that COPECs in soil do not have adverse effects on population abundance or persistence and diversity of mammalian invertivore and omnivore feeding guild species (AE3).

Detritivores

A laboratory toxicity test measured both survival and weight change in earthworms from samples in reaches with and without soil COPECs (section 8.1.3.5). The WOE for this measure and measures of detritivores relevant to other receptors is presented in Table 8.1-21. There was no difference in survival or growth between any of the reaches. The WOE for detritivores indicates that COPECs in soil in Sandia Canyon reaches do not adversely impact survival and growth of detritivore species (AE4).

Plants (Primary Producers)

Lines of evidence and their WOE for plants are provided in Table 8.1-22. The main line of evidence is the seedling germination test. Survival and measures of growth in roots and shoots showed no difference between reaches and reference sites (section 8.1.3.6). The overall WOE indicates no adverse effects of COPECs in soil on native plant species presence and diversity (AE5).

Aquatic Community

Table 8.1-23 provides the measures used as lines of evidence for evaluating potential impacts to the aquatic community in Sandia Canyon, and the WOE assigned to each measure. The laboratory toxicity test using *C. tentans* showed differences in growth and no difference in survival compared to reference site results. Both survival and growth were negatively correlated with some sediment COPEC concentrations (PCBs, barium, chromium, copper, cyanide, iron, lead, mercury, perchlorate, selenium,

and silver) and with possible confounding factors for *C. tentans* growth and survival. The field bioassessment characterization indicated that chironomids are present in the aquatic community in one of the sampled reaches and that the toxicity test using chironomids is an appropriate measure of impacts to the aquatic community. The field bioassessment suggested that the reaches S-2 and S-3E were impaired, and possibly associated with physical conditions, water quality (runoff from developed areas), and contamination in sediments. The WOE for measures of the aquatic community indicates adverse effects from COPECs in sediment and water on abundance and survival of the aquatic community in the Sandia Canyon reaches (AE7).

8.1.4.2 Uncertainty Analysis

Exposure Uncertainty

Uncertainties in the ecological risk assessment are potentially associated with the characterization of sediment. Maximum detected concentrations were used for some comparisons, which overestimates the exposure concentration in a reach. For the ECORSK.9 model, arithmetic mean concentrations in soil in each grid cell were used; because sampling is biased toward locations where contaminant concentrations are highest, the straight means generally overestimate actual exposure concentrations. Media concentrations for evaluating the results of laboratory toxicity tests came from the discrete sediment samples used in those tests and provide a good estimate of the exposure concentration for the assay organisms. These concentrations overestimate exposure concentrations throughout the sampled reaches because sampling was biased to specific locations with higher concentrations of COPECs in these reaches.

For the laboratory analyses of biological tissues, the sample mass was insufficient for analysis of all study design COPECs. For example, Aroclors were not measured in nest box insects and mercury was not measured in eggs. In other cases the COPECs are not detected (e.g., PCBs in invertebrates), but the detection limits result in HQ values greater than 1. Based on the significant concentrations of PCB 126 (the most toxic congener) in sediments, the lack of PCB congener data for tissues represents a significant uncertainty relative to exposures through the food chain.

Cyanide was not measured in tissues, but this COPEC has very limited spatial extent in sediments (section 7.1, Table 7.1-1). This omission does not represent a significant uncertainty for this assessment because the main receptor of concern for adverse effects of cyanide is invertivorous birds and the nest box field studies show no adverse effects in Sandia Canyon relative to other locations.

Pesticides were not measured in earthworms or nest box insects, which limits information on exposures to soil or sediments. This underestimates exposure and therefore underestimates risk, but as noted above, the field measures (e.g., the nest box network) provide some quantitative and qualitative information on effects.

Measured COPEC concentrations in earthworms provide a comparison to the uptake of COPECs predicted by the transfer factors used to develop the ESLs. The measured COPEC concentrations were used in the exposure evaluation, and in some cases the measured exposure leads to calculating HQs greater than 1. Thus, the assumptions made to identify COPECs and receptors are generally protective, but there is potential for over- or underestimating risk in some cases.

Another uncertainty is the adequacy of the toxicity and bioaccumulation data used to develop the assessment endpoints and select the associated measures and develop the study design. Toxicity information is lacking for some classes of COPECs on some receptors that hamper evaluating those COPEC-receptor combinations except in the field studies. Perchlorate is one COPEC that lacks TRVs for

any terrestrial receptor, but the spatial distribution of perchlorate in sediments does not indicate a Laboratory source in Sandia Canyon (section 7.1, Table 7.1-1).

The study design included field, laboratory, and model components to provide complementary information and reduce uncertainties related to toxicity and bioaccumulation data. Uncertainties associated with each of these measures are discussed below.

Field Measures

Empirical ecological effects data are the most relevant data for determining if adverse effects on ecological receptors exist, especially at the population level. However, these data are inherently more variable and difficult to quantify than laboratory measures. Uncertainty associated with a limited number of locations and a limited number of sampling events is mitigated by collecting information across a variety of measures of exposure and effect. Factors unrelated to COPECs, such as drought and other climatic variations, fire, and annual variation in species, may have confounding effects on analysis of field measures.

The avian nest box monitoring network provides the field measures implemented for this ecological risk assessment. The network was expanded in 2008 to encompass areas in Sandia Canyon. Thus, there are limited field measures based on two field seasons.

Field measures can also provide some information on adverse effects that cannot be obtained with other methods, including an estimate of impacts from COPECs for which there are no toxicity values. Field measures also provide valuable information on the usefulness of models and transfer factors in predicting ecological effects.

Laboratory Measures

Laboratory toxicity tests provide more standardized results than field data because they are conducted under controlled conditions, but they are still subject to uncertainties associated with sample collection and representativeness. Confounding factors are also possible, as was demonstrated in this investigation by the effect of particle on the results of the chironomid toxicity test (section 8.1.3.7). Other confounding factors may include variability in the test species selected; for example, the size of chironomid larvae vary between the various batches of bioassays. Sandia Canyon soil and sediment are generally nutrient-poor, which can influence growth in plant, earthworm, and chironomid tests. Sampling sites were also selected to represent a gradient of COPEC concentrations to improve the representativeness of the toxicity tests.

Model Measures

ECORSK.9 represents a modified exposure model with many of the limitations of the simple exposure models used in screening-level ecological risk assessments. ECORSK.9 blends more realistic information on spatial use of the watershed with simple models of contaminant bioaccumulation and toxicity (Gonzales et al. 2009, 106682). In ECORSK.9, conservatism is still present for key parameters like TRVs and bioaccumulation factors. For example, the TRVs are based on NOAELs or the geometric mean of NOAEL values, and risks are assessed assuming the additivity of response or summing of exposure across COPECs. ECORSK.9 is also based on conservative estimates of COPEC concentrations; it assumes that the average of the sample data for a model grid cell is representative of the true concentration, although sampling is typically biased toward areas with higher concentrations of contaminants. For this study, nondetected organic chemical results were handled as either one-half their detection limits or as zero. The different results demonstrate that assumptions regarding nondetects may

obscure sources of problem contaminants and overestimate risks. The simple dose modeling from concentrations in food done for this investigation is subject to many of the same uncertainties arising from toxicity values, transfer factors, and assumptions about concentrations and nondetects as the ECORSK.9 modeling.

8.1.5 Summary

Many COPECs were identified as study design COPECs in the ecological screening of soil, sediment, and surface water in Sandia Canyon. The WOE demonstrated by the various lines of evidence for the seven AEs indicates potential adverse effects of COPECs on terrestrial and aquatic receptors exist in Sandia Canyon. For the terrestrial environment, the main COPECs of concern are PCBs and the potential for adverse effects through the food web. There are uncertainties with regard to PCB congener concentrations. For the aquatic environment, both the field macroinvertebrate surveys and the chironomid bioassay point toward differences that may be related to contaminants from Laboratory operations or other sources. The main uncertainty associated with this conclusion is that non-COPEC confounding factors are also correlated to bioassay measures. The ecological studies point toward significant exposures in the wetlands and the potential for adverse effects from these exposures. Other reaches in Sandia Canyon have much lower exposures and no potential for ecological risk based on the WOE.

8.2 Human Health Risk Assessment

The human health risk assessment evaluates the potential for adverse effect on human health in the Sandia Canyon from COPCs identified in section 6 of this report. The risk assessment approach used in this report follows guidance from NMED (2009, 106420), and is organized in seven major subsections. The approach uses media- and scenario-specific SLs to evaluate the potential for human health risks separately from sediment and surface water and cumulative risks from sediment and surface water in Sandia Canyon. Section 8.2.1 provides the basis for selecting exposure scenarios for the human health risk assessment. In section 8.2.2, the data collection and evaluation processes described in previous sections of the report are summarized, focusing on aspects of data analysis that are pertinent to the risk assessment. Section 8.2.2 also lays out the logic for selecting COPCs for the human health risk assessment. The exposure assessment (section 8.2.3) provides information used in quantifying human exposure to COPCs in sediments and water. The toxicity assessment (section 8.2.4) provides information on potential human health effects from chemicals and radionuclides evaluated in the risk assessment. Section 8.2.4 provides the sources for the media- and scenario-specific SLs. Risk characterization (section 8.2.5) is based on the sum of fractions (SOFs) method for evaluating the potential for additive effects with COPCs that are classified as noncarcinogens, carcinogens, or radionuclides. Uncertainty related to the various assumptions and inputs used in the risk assessment is evaluated in section 8.2.6 to support interpretation of the risk characterization. A summary of the risk assessment is provided in section 8.2.7.

8.2.1 Problem Formulation

The risk assessment uses information pertaining to current and reasonably foreseeable future land use in Sandia Canyon to assess potential impacts under reasonable maximum exposure (RME) conditions. The canyon bottoms in Sandia Canyon include a mixture of land ownership, as discussed in section 1.3, potentially supporting a variety of land-uses.

The assessment employs the recreational user exposure scenario, which combines both adult trail user and child-extended backyard exposures, to represent the current and reasonably foreseeable future exposure activities for contaminated sediment and surface water in the watersheds. The trail user is an

adult individual who contacts contaminated sediment and surface water while hiking or jogging in the canyons. The extended backyard scenario describes an older child (age 6–11 yr) living in a home sufficiently close to the canyon that he or she may use as an extension of the play areas immediately surrounding the home. All of the areas being evaluated in the human health risk assessment for Sandia Canyon are within the Laboratory boundary, and therefore other uses of Sandia Canyon to include traditional lifestyles or hunting are not appropriate under the current and reasonably foreseeable future exposures. Thus, these uses are inclusive of realistic present-day potential exposure activities in canyon bottoms in areas of the watersheds where COPCs are at levels requiring a human health risk assessment. One supplemental exposure scenario, residential, is evaluated in the human health risk assessment for comparison purposes only. A description of this supplemental exposure scenario is provided in section 8.2.3.2. Unlike the recreational scenario, residential use is not currently applicable across Sandia Canyon. A residential scenario does not represent current or reasonably foreseeable future land uses within the parts of the canyons subject to flooding. In contrast to the recreational scenario, residential exposure is limited to canyons sediment and does not include exposure to surface water or groundwater.

8.2.2 Data Collection and Evaluation

The approach to sampling design, data collection, and characterization is described in sections 3 and 4 and Appendix B. Sampling locations, sampling results, and data quality for data used in the human health risk assessment are presented in Appendix C. Section 6 describes how sediment data within reaches were combined for the comparison of contaminant data with BVs. Water data were evaluated at each surface-water sampling location and associated with sediment sampling reaches.

Identifying COPCs for the Human Health Risk Assessment

COPCs for the human health risk assessment are identified based on screening level risk calculations using a residential scenario based on the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 087390, p. E-33) and the "Mortandad Canyon Investigation Report" (LANL 2006, 094161, p. 126). This process includes calculating a ratio, which is the maximum concentration of an analyte in a specific media in a reach or at a water-sampling station divided by the SL. This is analogous to the HQ as used in section 8.1 for assessing potential ecological risk. An SOF is the sum of these ratios for each risk type, i.e., carcinogens (SOF_{ca}), noncarcinogens (SOF_{nc}), and radionuclides (SOF_{rad}). These are analogous to HIs calculated in section 8.1. Ratios based on maximum detected concentrations for all COPCs within a reach or water location are summed to calculate the SOF for the risk class of those analytes (carcinogen, noncarcinogen, or radionuclide). For all reaches or water locations with an SOF >1.0 for a risk class within a reach or surface-water sampling location, all COPCs within that risk class with ratios greater than 0.10 are retained as COPCs for the site-specific risk assessment. COPCs with a ratio ≤0.10 based on maximum sampling results are excluded because they are unlikely to significantly contribute to risk. If the risk ratio for an individual analyte was greater than 0.10 but the SOF for the reach the analyte was detected in was less than 1.0, the analyte was not carried through to the human health risk assessment.

Sediment COPCs: The human health SLs for nonradionuclides in sediment used in this screening assessment are the NMED residential SSLs from Revision 5 of NMED guidance (2006, 092513). For analytes for which NMED does not provide a value, the residential screening value from the current EPA screening tables (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm) was used as the SL (carcinogens are adjusted to a 10^{-5} risk level to be consistent with the NMED target risk level). NMED-approved surrogate compounds were used for some COPCs that lack NMED or EPA SLs (NMED 2003, 081172). Residential SALs were used for radionuclides and are based on the DOE target dose limit of 15 mrem/yr (DOE 2000, 067489). SALs are derived using RESRAD version 6.21 (LANL 2005, 088493).

Tables 8.2-1 to 8.2-3 present the residential SLs and SALs used to calculate ratios; these tables also provide the SOFs for each reach for each risk class for all sediment COPCs, based on the maximum detected concentrations for each analyte. COPCs and reaches shaded gray are those retained for the risk assessment. Table 8.2-1 provides the results for noncarcinogens, Table 8.2-2 provides the results for carcinogens, and Table 8.2-3 provides the results for radionuclides.

Screening levels for chromium were based on the total chromium SL from the EPA regional screening levels compilation (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm) and the NMED Cr(VI) SL (NMED 2009, 106420). NMED has SL values for Cr(III) and Cr(VI), but not total chromium. Nonspeciated analytical results for chromium are for total chromium. Hence the EPA regional total chromium SL is the best match to the total chromium analytical results.

Mercury screening levels were based on the SL for inorganic salts of mercury from the EPA regional screening levels compilation (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm). The NMED compilation (NMED 2009, 106420) provides only an SL for elemental mercury. The analysis of environmental samples conducted for the Laboratory was for total mercury. Because most of the total mercury is from the presence of inorganic salts, and not methyl mercury or elemental mercury, the SL from the EPA based on the inorganic salts of mercury is a better match to the analytical sampling results.

Surface Water COPCs: SLs for surface water for organic and inorganic COPCs are the tap water values from tap water screening values from NMED guidance (2006, 092513). The NMED values were supplemented in the following order by screening values from the EPA regional screening tables (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm), drinking water standards (MCLs) issued under the Safe Drinking Water Act (http://www.epa.gov/safewater/contaminants/index.html), or 20.6.4 NMAC "Standards for Interstate and Intrastate Surface Waters." Radionuclide SLs are based on a dose of 4 mrem/yr and are from the DOE DCGs (DOE Order 5400.5, "Radiation Protection of the Public and the Environment") or based on EPA preliminary remediation goals (PRGs) (adjusted to a target risk level of 10^{-5}) (http://epa-prgs.ornl.gov/radionuclides/).

In evaluating surface water associated with sediment reaches in Sandia Canyon, only data for nonstorm-related surface water samples were evaluated (e.g., perennial water or persistent snowmelt runoff). For many of the surface-water samples, chemical analysis was performed on both the unfiltered and filtered samples (all samples, unfiltered, were analyzed, a portion of which were filtered and then analyzed). However, since the analyses on the filtered samples were aliquots from the unfiltered samples, the filtered samples are essentially duplicate results. Consequently, only the unfiltered sampling results were used for the surface water COPC evaluation. In addition, since the primary exposure pathway for the recreational exposure scenario is ingestion of surface waters, the unfiltered sampling results will be more representative of the actual intake. Unfiltered samples will generally have higher COPC concentrations (from contaminants absorbed on the unfiltered particulate material suspended in the surface water), so the evaluation of the health effects based upon these unfiltered samples will be more protective than if the evaluation was based upon filtered samples.

Tables 8.2-4 to 8.2-6 present the human health water-SLs used to calculate ratios; these tables also provide the SOFs for each risk class for all surface water COPCs. COPCs and water locations shaded gray are those retained for the further assessment. Table 8.2-4 provides the results for noncarcinogens; Table 8.2-5 provides the results for carcinogens; Table 8.2-6 provides the results for radionuclides.

Screening levels for chromium were based on the total chromium SL MCL (http://www.epa.gov/safewater/contaminants/index.html) and the NMED Cr(VI) SL (NMED 2009, 106420). NMED has SL values for Cr(III) and Cr(VI), but not total chromium, and the NMED SL for Cr(VI) was used for the Cr(VI) sampling results. Nonspeciated analytical results for chromium reflect total chromium in the

sample. Hence the MCL for total chromium is the best match to the total chromium (or chromium) analytical results.

COPC Summary: Table 8.2-7 presents a summary of endpoints and reaches considered in the human health risk assessment for Sandia Canyon. For each reach and endpoint combination with both sediment and water COPCs retained, a multimedia assessment was also performed for this reach to assess potential cumulative risks. The only reaches evaluated for multimedia effects were S-1N, S-1S, and S-2.

Calculating Exposure Point Concentrations

According to EPA (1989, 008021) the measure of exposure appropriate for a risk assessment is the average concentration of a contaminant throughout an exposure unit or a geographic area to which humans are exposed. This premise is based on the assumption that over a period of time, a receptor would contact all parts of the exposure unit. A receptor is not likely to be exposed to only the maximum or any other particular detected concentration of a chemical for the full period of exposure. A conservative estimate of the average concentration of a chemical across an exposure unit (the exposure point concentration [EPC]) is the upper confidence limit (UCL) (typically a 95% UCL) on the mean. Different methods are available to estimate the UCL, depending upon the underlying distribution of the data set.

Sediment: The investigation approach for sediment resulted in representative samples associated with different geomorphic units and sediment facies within each reach. These data are combined to estimate means and 95% UCLs on the means for COPCs retained for the human health risk assessment in each reach. The EPA software, ProUCL version 4.00.04 (http://www.epa.gov/esd/tsc/software.htm), was used to calculate the sediment UCLs. If the recommended calculated UCL was less than the maximum detected value for a COPC within a reach, then the UCL suggested by ProUCL was used for the EPC. However, if the calculated UCL on the mean suggested by ProUCL was greater than the maximum detected value for a COPC within a reach, then an alternative UCL was selected per the ProUCL logic. If the number of samples was small (≤3) and an appropriate UCL not recommended by ProUCL, then the maximum detected value was used for the EPC. Further details on the calculation of the UCLs used in this risk assessment are provided in Appendix E-2 and in the ProUCL guidance (EPA 2007, 102895). Many of the data sets for COPCs include nondetect values. The approach to estimating averages and UCLs with data that include nondetects is also described in section E-2.0 (Appendix E). The sediment EPCs for the recreational user scenario are presented in section 8.2.5 and Table 8.2-8.

Surface Water: Surface-water COPC concentrations are evaluated for each sampling location, unlike sediments where multiple sampling locations are combined to generate an EPC for a reach (section 8.2-2). The only exception is for locations that are basically collocated within a few meters of each other. For reach S-1N, there were two associated surface-water locations: Sandia left fork at asphalt plant and South Fork of Sandia Canyon at E122. Because it cannot be assumed that a receptor is only limited to accessing and using one water source, contamination in both surface-water sources in reach S-1N is used in calculating EPCs and the human health risk assessment. Otherwise, EPCs for surface water were calculated similarly to the sediment EPCs using ProUCL version 4.00.04 when there was sufficient sample support (Appendix E-2.0). The surface-water EPCs for the recreational user scenario are presented in section 8.2.5 and Table 8.2-9.

8.2.3 Exposure Assessment

The recreational user scenario applies to all reaches identified in Table 8.2-7. Additionally, potential risk associated with the residential scenario is provided as a point of comparison (see Appendix E-2). Sediment SLs for the recreational scenario are provided in Laboratory guidance (LANL 2007, 094496).

Exposures from surface-water ingestion are evaluated based on the recreational scenario described in the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 087390, p. 8-37) and the "Mortandad Canyon Investigation Report" (LANL 2006, 094161, p. 128), which also provide risk-based concentrations for surface-water exposures (LANL 2004, 087390, p. E-317). Residential SSLs are from NMED guidance (NMED 2006, 092513), and residential SALs are from Laboratory guidance (LANL 2005, 088493).

8.2.3.1 Exposure Scenario Description

The human health risk assessment focuses on potential risks and doses resulting from direct exposure to contaminants in sediments through ingestion, inhalation, external irradiation (radionuclides only), and dermal contact (chemicals only). The water pathways for the recreational user consist of ingestion and dermal contact (chemicals only) using persistent surface-water data. If necessary, cumulative risks resulting from the exposures to sediments and persistent surface water are evaluated. Stormwater data in comparison to applicable standards are summarized in section 6, and no analytes have potential for acute human health effects based on exposure to stormwater. Stormwater is not included as part of the quantitative human health risk assessment because stormwater is transient and does not occur frequently enough to sustain chronic exposures. Exposure to groundwater is not evaluated because no groundwater in Sandia Canyon is available for human uses under current conditions or the reasonably foreseeable future for a recreational user. Exposures to the recreational user are evaluated at the scale of sediment investigation reaches or water location. This local-scale evaluation is protective compared with an assessment based on a more realistic scale encompassing numerous reaches and areas between reaches. A summary of potentially complete exposure pathways, by scenario, is provided in Table 8.2-10.

Exposure scenario parameters were selected to provide an RME estimate of potential exposures. As discussed in EPA guidance (1989, 008021), the RME estimate is generally the principal basis for evaluating potential health impacts. In general, an RME estimate of risk is at the high end of a risk distribution, i.e., 90th–99.9th percentiles (EPA 2001, 085534). An RME scenario assesses risk to individuals whose behavioral characteristics may result in much higher potential exposure than seen in the average individual.

The recreational scenario addresses limited site use for outdoor activities, such as hiking, playing, and jogging. The receptor for this scenario is anticipated to be an adult hiker or a child at a residence near the canyon, using the canyon over an extended period of time. Therefore, receptors for the recreational user scenario are defined as adults and older children (6–11-yr-old). A complete description of the parameter values and associated rationale is provided in Laboratory guidance (LANL 2004, 087390, p. 8-37). Exposure parameters for the recreational scenario are provided in Appendix E-2.0.

8.2.3.2 Supplemental Exposure Scenario

Risk estimates are provided for a resident as a supplemental exposure scenario. A more detailed discussion of the basis and parameterization of this scenario is provided in NMED guidance NMED (2009, 106420) and Laboratory guidance (2005, 088493). Exposure parameters and results for the resident are provided in Appendix E-2. No other uses of Sandia Canyon, to include traditional lifestyles or hunting, are appropriate for the portion of Sandia Canyon being evaluated in this report under the current and reasonably foreseeable future conditions.

8.2.3.3 Spatial Scales of Application for the Exposure Scenarios

Each exposure scenario is evaluated at the scale of a reach for sediments and at the scale of individual sampling locations for water. The investigations evaluated in this report have multiple investigation reaches and water-sampling locations. The risk assessment does not attempt to integrate exposure across multiple reaches for sediment or across water-sampling locations for surface water. By assessing each reach and associated water-sampling locations separately, the impacts of local variability in COPC concentrations upon the risk assessment results are preserved. The assessment is protective and thus likely overestimates risks and doses by assuming that all exposures occur within sediment investigation reaches (roughly 200 m long, with the exception of reach S-2 that is roughly 700 m in length) and from specific water-sampling locations. Risks for more realistic exposures from multiple reaches or water locations within Sandia Canyon are therefore expected to be lower.

8.2.4 Toxicity Assessment

This section of the human health risk assessment provides information related to the basis for distinguishing among the three classes of chemicals evaluated in this assessment: systemic toxicants (noncarcinogens), chemical carcinogens, and radionuclides. This information provides a context for interpreting the results of the risk assessment, which employs COPC-specific values of toxicity and radiation dose to evaluate potential health impacts.

Using SLs simplifies aspects of the risk assessment in that exposure and toxicity information has been compiled in available guidance documents and reports. The sources for toxicity data used for this risk assessment include NMED, Laboratory, and EPA guidance documents and databases (NMED 2006, 092513; LANL 2007, 094496; http://cfpub.epa.gov/ncea/iris/index.cfm). The Laboratory's "Technical Approach for Calculating Recreational Soil Screening Levels for Chemicals" (LANL 2007, 094496) is used as the basis for calculating surface-water screening values. Toxicity information used to develop surface-water screening values is also generally consistent with values used in NMED, Laboratory, and EPA guidance documents (as discussed below).

SLs are from several sources based on COPC type and exposure medium.

- Recreational scenario for carcinogens and noncarcinogens
    - ❖ Sediment: used the recreational SSLs developed in Laboratory guidance (LANL 2004, 087800).
    - ❖ Surface water: calculated based upon method in "Technical Approach for Calculating Recreational Soil Screening Levels for Chemicals" (LANL 2007, 094496).
- Recreational scenario for radionuclides
    - ❖ Sediment: used the recreational SALs developed in Laboratory guidance (LANL 2005, 088493).
    - ❖ Surface water: calculated based upon method in "Derivation and Use of Radionuclide Screening Action Levels, Revision 1" (LANL 2005, 088493).
- Residential scenario for carcinogens and noncarcinogens
    - ❖ SLs from NMED guidance (2006, 092513), except for certain values from EPA regional screening tables (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).
    - ❖ Surface Water (screening only): tap water screening values from NMED guidance (2006, 092513), except for certain values from EPA regional screening tables

(http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm), U.S. primary drinking water standards issued under the Safe Drinking Water Act (http://www.epa.gov/safewater/contaminants/index.html.), and 20.6.4 NMAC, "Standards for Interstate and Intrastate Surface Waters"

- Residential scenario for radionuclides
  - ❖ Sediment: used the residential SALs developed in Laboratory guidance (LANL 2005, 088493).
  - ❖ Surface Water (screening only): 4 mrem/yr DOE DCG (DOE Order 5400.5, "Radiation Protection of the Public and the Environment").

Table 8.2-11 summarizes recreational sediment and surface-water SLs and target adverse effect levels. Comparing the screening values with COPCs for a given risk endpoint provides some information of the relative toxicity of these analytes. Because these risk-based screening values are obtained from references prepared from 2004 to 2009, there is potential for differences in the toxicity values used in the screening-level calculations. The toxicity values in the EPA's Integrated Risk Information System (IRIS) database (http://cfpub.epa.gov/ncea/iris/index.cfm) and the analytes listed in Tables 8.2-1 8.2-2, 8.2-4, and 8.2-5 (for sediment and surface water, noncarcinogens and carcinogens) were reviewed. None of the IRIS toxicity values for any of the COPCs listed has been updated since 2006; hence, the SLs (see Appendix E-2.0) used to calculate risk ratios are based upon the most current toxicological data available.

8.2.5 Risk Characterization

In this section of the human health risk assessment, information provided in the exposure and toxicity assessments (sections 8.2.3 and 8.2.4, respectively) is integrated to characterize potential risk and dose. The risk characterization is conducted on the basis of the general principles described in section 8.0 of the risk assessment guidance for Superfund (EPA 1989, 008021). Potential adverse effects related to noncarcinogens, chemical carcinogens, and radionuclides are discussed in sections 8.2.5.1, 8.2.5.2, and 8.2.5.3, respectively. The presentation of potential adverse effects focuses on the quantitative expressions of potential impacts. In the uncertainty analysis (section 8.2.6), the confidence associated with the quantitative risk estimates is discussed through an evaluation of the uncertainties pertaining to each step of the risk assessment process.

This risk assessment employs SLs to evaluate COPCs for potential adverse health effects. COPC intake and toxicity are combined within the screening value calculations; therefore, separate calculations of intake and health effects (cancer risk, hazard, and dose) were not generated. Potential human health effects were assessed using the ratios of EPCs to SLs for each COPC retained in this assessment for each of the exposure scenarios. These ratios were summed (SOF) for an investigation reach and (when applicable) a water-sampling location within the COPC classes of chemical carcinogens, noncarcinogens, and radionuclides (SOFs). A sum of less than 1.0 indicates that exposure is unlikely to result in an unacceptable cancer risk, hazard, or radiation dose. SOF values are then multiplied by the target effect level (i.e., HI = 1, risk = 1×10^{-5}, or dose = 15 mrem/yr sediment, 4 mrem/yr water) to provide risk and dose estimates for each COPC class.

For the recreational scenario, there were three reaches where cumulative exposure to sediment and surface water needed to be evaluated through a multimedia sum. For COPCs with a common target effect level (e.g. all carcinogens are based on 1×10^{-5} incremental cancer risk [ICR]), the multimedia sum can be converted into an approximate effect level. Carcinogen and noncarcinogen SLs are based on a common adverse effect level across sediment and surface water, but the radionuclide adverse effect levels are not the same for sediment (15 mrem/yr) and surface water (4 mrem/yr).

For the recreational user scenario cumulative multimedia sums and the risk values for noncarcinogens, carcinogens, and radionuclides based on EPCs were calculated. Multimedia exposures, for noncarcinogens were calculated for reaches S-1N and S-2, and multimedia exposure for carcinogens were calculated for reaches S-1N, S-1S and S-2. No multimedia exposures were calculated for radionuclides because radionuclides were not COPCs in sediment and nonstorm-related surface water (Tables 8.2-7 and 8.2-12). The risk for sediment and the multimedia sum for reach S-1N were greater than 1.0×10^{-5}. For reach S-1S, the risk for sediment and water were below 1.0×10^{-5}, but the multimedia sum was greater than 1.0×10^{-5}. None of the other reaches had sediment, water, or multimedia risks or doses above target levels.

Table 8.2-13 presents the COPC and reach-specific recreational risk values for sediment, and Table 8.2 14 presents the COPC and reach-specific recreational risk values for surface water. The EPCs for sediment were presented in Table 8.2-8, and the EPCs for surface water were presented in Table 8.2 9. Results for the supplemental exposure scenario (residential) are provided in Tables E-2.4-2 and E-2.4-3.

8.2.5.1 Noncarcinogenic Effects

Chemical hazard for an individual chemical is commonly defined by the HQ, which is calculated as the ratio of the chemical intake to the reference dose for that chemical. An HQ greater than 1.0 is indicative of the potential for adverse effects; therefore, an HQ of 1.0 was used in the calculation of SLs for noncarcinogenic effects. When the potentially additive effects of two or more chemicals are considered, HQs are summed to generate an HI. However, summing of chemical HQs to create an HI assumes the target organs and mechanisms of toxicity are similar. The SOF_{nc} values in this human health risk assessment are functionally equivalent to generating an HI. The protective approach of summing these ratios does not warrant refinement because the HI values are in all cases well below 1.0.

Potential noncarcinogenic effects for contaminants in sediment were calculated (Table 8.2-7) for reaches S-1N and S-2 and for contaminants in surface water in reaches S-1N, S-1S, S-2, S-3E, and S-4W. Reaches S-1N and S-2 were evaluated for multimedia exposure for noncarcinogens. The calculated sediment and surface water HIs for all reaches were all less than 1.0 (Tables 8.2-13 and 8.2-14). The multimedia HI for reaches S-1N and S-2 were also less than 1.0 (Table 8.2-12).

Lead: Lead was evaluated for both sediment and surface water in reaches S-1N and S-2 (Tables 8.2-13 and 8.2-14). The risk ratio for lead in sediment for reach S-1N was 0.051 and in surface water the risk ration was 0.022. For reach S-2, the sediment risk ratio was 0.14 and the surface water risk ratio was 0.034. These values indicate that exposure to lead in these two reaches does not make a significant contribution to chemical hazard for Sandia Canyon.

Mercury: Where significant concentrations of total mercury are measured and the conditions are favorable it is useful to have samples analyzed for methyl mercury to evaluate the likelihood for the conversion of inorganic mercury to the more toxic and bioaccumulative methyl mercury species. As shown in Table 8.2-1, mercury was present in sediment in reach S-2, and additional samples were collected and analyzed for methyl mercury. Mercury was selected as a COPC, but methyl mercury was not (Table 8.2-1). Table 8.2-1 shows only the results of the maximum concentrations for mercury and methyl mercury from reach S-2. However, in order to evaluate any propensity for conversion of inorganic mercury to organic mercury, it is best to assess the analytical results for paired samples. These results are presented in Table 8.2-15. There were six paired mercury/methyl mercury samples from four locations. In all cases the methyl mercury was only a small percentage of the total mercury results (≤0.61%) and the maximum methyl mercury concentration (Table 8.2-1) was significantly less than the applicable sediment

SL (7.82 mg/kg). These results indicate that conversion of inorganic mercury to the more toxic organic mercury does not warrant further evaluation in Sandia Canyon.

8.2.5.2 Carcinogenic Effects

Cancer risk for an individual chemical is defined by the ICR, which is calculated as the product of exposure to a single chemical and the cancer slope factor (SF) for that chemical. ICRs for each exposure route and chemical are then summed to calculate the total ICR to an individual. A target risk level of 1×10^{-5} was used in this human health risk assessment to calculate risk-based concentrations for carcinogenic effects (NMED 2009, 106420). Lifetime cancer risk is considered to be additive over time; childhood and adulthood exposures are summed to calculate the ICR.

Potential risks from carcinogens in sediment were evaluated for reaches S-1N, S-1S, S-2, and S-3W and in surface water for reaches S-1N, S-1S, S-2, S-3E, and S-4W (Table 8.2-7). Reaches S-1N, S-1S, and S-2 were evaluated for multimedia exposure to carcinogens. Reach S-1N has sediment and multimedia risk of approximately 2×10^{-5} and reach S-1S has a multimedia risk of approximately 1×10^{-5}; all of the ICRs in reach S-1S were less than 1×10^{-5} (Tables 8.2-12, 8.2-13, and 8.2-14). The results for these reaches S-1N and S-1S indicates that risk from carcinogens in sediment and surface water in these two reaches may be a concern for the recreational scenario.

PCB Congener Analysis: Reach S-2 sediment samples were analyzed for individual dioxin like PCB congeners at four locations within the reach. These samples were selected from locations with the highest concentrations of Aroclors in the reach and therefore represent a biased sample. This evaluation of the PCB congeners is provided as a point of reference and comparison to the Aroclor risk results. These sampling results are presented in Table 8.2-16. Based upon the total toxic equivalent quotient results for each sample, the risk ratio was calculated using the 2,3,7,8-TCDD Recreational SSL of 2.77E-4 mg/kg (LANL 2007, 094496). These calculations show one sample from location SA-600113 and one sample from location SA-600115 had risk ratios greater than 1.0. The maximum incremental lifetime cancer risk for the sampling location with the highest total toxic equivalent quotient is 2×10^{-5}. This analysis was also conducted using residential 2,3,7,8-TCDD SLs and is presented as part of the supplemental exposure scenario results in Appendix E-2.0 (Table E-2.4-4). PCBs were also measured by the Aroclor method for these same samples. At location SA-600113, two Aroclor mixtures were detected (Aroclor-1254 was reported as 3 mg/kg and Aroclor-1260 was reported as 2.3 mg/kg). The risk ratio for this single sample would be 0.5 (Aroclor-1254 and Aroclor-1260 concentration divided by the recreational SL of 10.5 mg/kg and summed). The carcinogenic risk (5×10^{-6}) estimated by the Aroclor method sampling result at location SA-600113 is a factor of 4 less than the PCB congener results (2×10^{-5}). Similar differences are noted for the other paired congener and Aroclor sampling results. Thus, from the weathering of the PCBs it appears that the Aroclor method may underestimate the risks, and it is possible that the total carcinogenic risks in reach S-2 could approach the target risk value of 1×10^{-5}.

8.2.5.3 Radiation Dose

The radiation dose associated with the dose conversion factors (DCFs) used in the human health risk assessment is the annual committed effective dose equivalent (internal) or annual effective dose equivalent (external), expressed in units of mrem/yr. The target dose limit used for calculating SLs related to soil pathways is 15 mrem/yr, which is consistent with guidance from DOE (2000, 067489). For water-based exposure pathways, SLs were calculated using a target dose limit of 4 mrem/yr. Use of this more protective dose limit for water pathways is based on the radiation dose limit for a public drinking water supply in DOE Order 5400.5, “Radiation Protection of the Public and the Environment.” Consistent with

EPA guidance (1989, 008021), dose through dermal absorption is not quantified because it is probably negligible compared with the other exposure pathways.

Exposure to radionuclides was evaluated for sediment in reaches S-4E and S-5W (Table 8.2-7). Radionuclides in surface water were not evaluated because none of the detected radionuclides above background were selected as COPCs (Table 8.2-6). None of the reaches were evaluated for multimedia exposure to radionuclides. The radionuclide dose for reach S-4E was 6.3 mrem/yr and for reach S-5W is was 0.40 mrem/yr (Table 8.2-13). The primary source of the dose in both reaches S-4E is thorium-232. The background mean concentration of thorium-232 is 1.4 pCi/g (McDonald et al. 2003, 076084), which is associated with a dose of 4.2 mrem/yr. Thus, the dose above the background mean concentration is approximately 2.1 mrem/yr.

8.2.6 Uncertainty Analysis

The uncertainty analysis uses qualitative and semiquantitative information to evaluate uncertainties associated with the risk, hazard, and dose estimates described in section 8.2.5. This analysis pertains to the results of the recreational scenario and is organized according to the major aspects of the human health risk assessment: data collection and evaluation (section 8.2.6.1), exposure assessment (section 8.2.6.2), and toxicity assessment (section 8.2.6.3).

8.2.6.1 Data Collection and Evaluation

COPCs identified in section 6 were retained for evaluation in the human health risk assessment. COPCs that were retained for calculation of EPCs were those that had ratios greater than 0.10 for endpoints with SOF values greater than 1.0 for the residential screen. Thus, the COPCs retained represent an inclusive list of potential human health risk drivers.

As noted in section 8.2.5.2, the carcinogenic risks calculated based on the mixture of PCB congeners measured in a small set of samples in reach S-2 are about a factor of 10 greater than the risks calculated from the Aroclor mixtures. Because risks appear to be greater for PCB congener sampling results, the estimates of carcinogenic risk are based on Aroclor results and may be biased low, especially in reach S-2 where a notable inventory of PCBs exists.

Some of the COPCs retained for the human health risk assessment, (e.g., thallium) have their main inferred source from variations in natural background concentrations (section 7.1, Table 7.1-1). Other COPCs have a combination of sources, including SWMUs and variations in natural background. The assessment is protective by including all of these COPCs in the assessment of the potential for human health effects.

No background data are available for surface water. The inability to distinguish COPCs in surface water based on comparisons with background concentrations is a source of uncertainty in the results of the human health risk assessment for this media. For example, concentrations of arsenic (contributes to carcinogenic risk) and iron (contributes to noncarcinogenic HI) in surface water may be associated with local background and not with releases from Laboratory SWMUs or AOCs.

The possibility of underestimating EPCs for investigation reaches is another potential source of uncertainty. Four approaches were used to minimize that possibility. First, the emphasis of the geomorphic characterization and sediment sampling was to identify and sample post-1942 sediment deposits, which focuses sampling on potentially contaminated areas, excluding areas not impacted by dispersion of contaminants by post-1942 floods. The process of characterizing reaches and focusing on sampling is discussed further in sections 4.1 and B-1.0 of Appendix B. Second, 95% UCLs on the

average sediment concentrations were used as EPCs to minimize the chance of underestimating concentrations in a reach. Third, sampling was biased to fine facies sediment deposits where concentrations are generally highest, as discussed in section 7.1, with fewer samples collected from coarse facies sediment deposits where concentrations are generally lower. Fourth, for radionuclides, no correction was made for radioactive decay since the time of sampling, although present-day concentrations are lower than at the time of sampling for cesium-137 or strontium-90.

Uncertainty also exists for estimating EPCs for water-sampling locations. COPC concentrations often change with hydrologic conditions, particularly suspended sediment concentrations. The data evaluated in this assessment represent a snapshot of the current hydrological conditions and generally reflect a range of hydrologic conditions at each sampling location. As discussed in sections 7.2.1 and B-2.0, sampling was conducted during a range of water-level conditions and field parameters, so the EPCs calculated from these data represent the range of COPC concentrations at the sampling locations.

As discussed in section 8.2.2, only unfiltered samples were used to evaluate intake and exposure for this risk assessment. For the water ingestion pathway, the use of unfiltered water samples to calculate EPCs generally results in a conservative (protective) exposure estimate although suspended particulate matter in the surface water may be ingested. For the dermal exposure pathway, EPCs based on unfiltered samples also likely results in overestimation of exposure. Because the dermal pathway represents only a small proportion of the total intake of the COPCs evaluated as part of this risk assessment for the recreational exposure scenario, this overestimation is small and unlikely to affect the overall quantitative outcome and consequently the final risk assessment conclusions.

8.2.6.2 Exposure Assessment

Uncertainty pertaining to exposure parameters was addressed in the human health risk assessment by using RME estimates for several exposure parameters (Appendix E, section E-2.0). The use of RME assumptions, coupled with upper-bound estimates of the average concentration of COPCs in sediment, is intended to produce a protective bias in the risk calculations. The results of the risk assessment, discussed in section 8.2.5, include a description of the key COPCs and exposure pathways associated with potential health impacts. This evaluation of uncertainty in exposure is focused on these COPCs and pathways.

Key exposure pathways for contaminated sediments across hazard, ICR, and dose for the recreational scenario include dust inhalation, dermal absorption, incidental soil ingestion, and external irradiation. A common source of protective bias in the exposure assessment for these pathways is that the entire 1-h daily exposure time defined for the recreational scenario is spent on contaminated sediment deposits within a reach. To the extent that time may be spent in other canyon areas, such as uncontaminated stream terraces, colluvial slopes, or bedrock areas during recreational activities, exposure to contaminated sediment deposits, is overestimated. The assessment is protective and thus likely overestimates risks and doses by assuming that all exposures occur within sediment investigation reaches (roughly 200 m long, except for reach S-2 that is about 700 m long) and from specific water-sampling locations. Risks for more realistic exposures from multiple reaches or water locations within Sandia Canyon are therefore expected to be lower.

Because each reach is treated equally from an exposure perspective, no consideration is made regarding ease of access or land area available for recreation. In addition, it is implicitly assumed that all exposure for a single individual takes place in one investigation reach, rather than some random combination of some or all of the investigation reaches and intervening areas.

For both carcinogens and radionuclides, the exposure assessment should be evaluating incremental exposures that are greater than background. EPCs are calculated that include background concentrations. For the most part, background exposures are likely negligible, with the exception of some metals in sediment and surface water (e.g., arsenic and thorium-232) and do not lead to overestimating risk or dose.

Dermal contact with sediments and incidental soil ingestion have a second exposure characteristic in addition to time spent on-site that was biased in a protective manner. The soil adherence factors used to define soil loading on skin for children and adults are both protectively biased. The adult adherence factor is based on a high-exposure activity (gardening) that would result in greater exposure than would be the case during trail use. Adult soil ingestion was assumed to be 100 mg/d, which is twice the EPA-recommended value for adults (EPA 1997, 066596).

Because external gamma radiation is one contributor to radionuclide dose, the assessment should also be protective of child exposures because behaviors that increase child exposure through some pathways (incidental soil ingestion and dermal contact) play basically no role in external gamma dose. Exposure related to external irradiation from soil is primarily a function of time spent on-site. However, the external DCFs used in the calculation of external dose protectively assume an effectively infinite area and depth of contamination.

An important aspect of uncertainty in exposure to COPCs in surface water relates to exposure intensity. Dermal contact and surface-water ingestion were assumed to occur 20 times per year for 30 yr (recreational user). This assumption was developed to bound a high-end exposure condition. Potential contact by adults with surface water in Sandia Canyon are highly intermittent at some locations based on the limited availability of water.

8.2.6.3 Toxicity Assessment

The SLs compiled by NMED (dated 2009) and EPA (regional screening levels dated 2009, medium specific screening levels dated 2007 from EPA Region 6, and PRGs dated 2004 from EPA Region 9) were used. These data compilations are infrequently updated (greater than yearly) and therefore it is possible that SLs used in this risk assessment may not be reflective of the latest toxicity factors available from the EPA IRIS database for any given analyte. Review of the IRIS database (http://cfpub.epa.gov/ncea/iris/index.cfm) revealed that for the analytes evaluated in Tables 8.2-1 and 8.2-2, none of the toxicity values have been updated since 2006. Consequently, all the screening values used are based upon the most up-to-date toxicity data available.

8.2.7 Summary of the Human Health Risk Assessment

The potential health effects associated with COPCs in Sandia Canyon were assessed relative to a dose criterion of 15 mrem/yr for sediment, a cancer risk criterion of 1×10^{-5}, and a hazard criterion of 1.0. The risk-assessment results for carcinogenic risk in sediment in reach S-1N are above these thresholds for the recreational scenario (2×10^{-5}); all other reaches are below the carcinogenic threshold. Chemical hazards and radiologic dose in sediment are all below these thresholds. For the surface waters evaluated in Sandia Canyon, none of the risks, doses, or hazards exceeded these criteria for any of the reaches. The exceedance of the of the carcinogenic risk threshold in reach S-1N is driven by elevated concentrations of benzo(a)pyrene and other carcinogenic PAHs in sediment. A supplemental evaluation of PCB congener sampling results from four locations, including the highest measured concentrations of Aroclors in reach S-2, show that the risk from PCBs is greater than 1×10^{-5} using one of these samples. This evaluation approach was conducted as a point of reference but is not considered representative of

risks in the reach because the samples submitted for PCB congener analysis included the geomorphic units and locations with the highest concentrations of PCBs. Lower risk for PCB congeners would be calculated using area- and depth-integrated representative samples in reach S-2.

The Laboratory's Environmental as Low As Reasonably Achievable (ALARA) Program (PD410, p. 7) states, "quantitative ALARA evaluations are not necessary for Laboratory activities that have a potential for public exposure that is less than a 3-mrem TEDE [total effective dose equivalent] individual dose…." The radiation doses for the recreational scenario are less than 3 mrem/yr greater than background exposures to soils and sediment. Consequently, no further quantitative evaluation of radiation exposure and dose is required.

Parts of Sandia Canyon and some of the property evaluated in the assessment are open to the public, but none of the reaches included in the risk assessment are planned for release by DOE in the foreseeable future. Therefore, an ALARA evaluation for radiological exposure to the public is not currently required. Should DOE's plans for releasing these areas change, an ALARA evaluation will be conducted at that time. It should be noted that the Laboratory addresses considerations for radiation exposures to workers under the Laboratory's occupational radiological protection program in compliance with 10 CFR 835. The Laboratory's radiation protection program implements ALARA and consists of the following elements: management commitment, training, design review, radiological work review, performance assessments, and documentation.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Investigations of sediment, surface water, and groundwater in the Sandia watershed indicate inorganic, organic, and radionuclide COPCs are present in these media at concentrations above SLs and federal and/or state groundwater standards. These COPCs are derived from several sources, including Laboratory SWMUs and AOCs, runoff from developed areas, and natural sources such as noncontaminated soils, sediments, and bedrock. The nature and extent of these COPCs are defined in sediment, surface water, the vadose zone and regional groundwater. A remaining uncertainty exists with regards to the extent of chromium in the regional aquifer, as discussed below.

The spatial distribution of contaminants in the Sandia watershed, supported by data from previous investigations, indicates that SWMUs and AOCs within TA-03 are the most important sources of contamination with respect to potential human health risk, ecological risk, and groundwater impacts. Important source areas for Laboratory-derived COPCs in TA-03 include the former outfall for the power plant cooling towers in upper Sandia Canyon [SWMU 03-012(b)] and a former PCB transformer storage area [SWMU 03-056(c)] along the south fork of Sandia Canyon, and the former asphalt batch plant [Consolidated Unit 03-009(a)-00)] along the north fork of Sandia Canyon. Additional Laboratory sources (e.g., TA-53 and the Protective Force firing range at TA-72) are indicated by the characterization data, although the concentrations, extent, and inventory of COPCs from these sources are minor compared to the TA-03 sources.

Contaminants in sediment originally released from TA-03 extend for approximately 10 to 12 km (6 to 7 mi) downcanyon from the sources. Stormwater runoff and surface-water flow from daily effluent releases generally infiltrate alluvium in the middle portion of Sandia Canyon, resulting in deposition of contaminated sediment in that area. This finding is consistent with the lack of evidence of past transport of Laboratory-derived contaminants from Sandia Canyon into the Rio Grande. The most important sediment deposition area is in the upper canyon where a broad wetland exists (reach S-2). This area contains approximately 80% to 90% of the inventory of chromium and PCBs within Sandia Canyon sediment deposits. Chromium is detected at low concentrations above the BV at the eastern Laboratory

boundary (reach S-5E), and is below the BV farther downcanyon on Pueblo de San Ildefonso land. Similarly, PCBs have been detected at low concentrations in reach S-5E but not farther downcanyon. PAHs are another important COPC and are detected in sediments primarily in reaches S-1N and S-2.

Investigations of surface water and groundwater have identified the nature and extent of contaminants released into Sandia Canyon. The COPCs in surface water and alluvial groundwater relate closely to those identified for sediment but generally extend for a shorter distance downcanyon from the source than do the sediment COPCs. A group of COPCs, including PCBs and several adsorbing and precipitating trace metals, are limited to surface water and alluvial groundwater within Sandia Canyon, as predicted by their geochemical behavior. Other more mobile COPCs are found in the underlying vadose zone, perched-intermediate groundwater, and regional groundwater. A conceptual model informed by multiple lines of evidence, including a water balance study based on extensive gage data, geochemical data, and transport modeling, indicates these mobile COPCs are present along a migration pathway that includes a spatially limited infiltration window in the middle portion of Sandia Canyon near TA-53. COPCs along the pathway, particularly chromium and nitrate, are found in various phases. These phases include pore water collected from unsaturated core, perched horizons on top of and within the Cerros del Rio basalt, and, in the case of chromium, an adsorbed or reduced solid phase fixed on bedrock units extending from the base of alluvium to the base of the basalts. Dissolved-phase chromium [Cr(VI)] is present within the regional aquifer at concentrations exceeding the 50 μg/L New Mexico groundwater standard. Nitrate (as nitrogen) is also present in the regional aquifer at concentrations approximately one-half the New Mexico groundwater standard of 10 mg/L.

Many organic and inorganic COPECs have been identified in the ecological screening assessments conducted on surface media; subsequently, a baseline ecological risk assessment was implemented. Multiple lines of evidence used in the study indicate exposures in the wetland and the potential for adverse effects of COPECs on terrestrial and aquatic receptors in the upper part of Sandia Canyon. For the terrestrial environment, the main COPECs are PCBs for which there are the potential for adverse effects through the food web for shrews and other wildlife, particularly in reach S-2. For the aquatic environment, both the field macroinvertebrate surveys and the chironomid bioassay point toward potential ecological impacts that could be related to contaminants from Laboratory operations or other sources. However, other non-COPEC factors related to habitat quality also correlate to decreased growth or survival from the bioassay measures and may be the cause of the findings.

The site-specific human health risk assessment uses a recreational exposure scenario to represent the present-day and reasonably foreseeable future land use in Sandia Canyon. The assessment results indicate that for the recreational scenario, no areas in Sandia Canyon have contaminant concentrations greater than levels acceptable for noncarcinogens (HI of 1) or radionuclides (target dose limit of 15 mrem/yr in sediment and 4 mrem/yr in water). However, potential carcinogenic risk is twice the target risk level (ICR criterion of 1×10^{-5}) in reach S-1N, almost entirely from PAHs in sediment. These PAHs may originate from the former asphalt batch plant located near the reach and/or runoff from developed areas at the head of the watershed. A supplemental evaluation using available PCB congener data was conducted using sampling results from four locations within reach S-2 that include the highest measured concentrations of Aroclors in reach S-2. The maximum risk from these biased PCB congener samples is 2×10^{-5}. This evaluation approach was conducted as a point of reference but is not considered representative of risks in the reach because the samples submitted for PCB congener analysis included the geomorphic units and locations with the highest concentrations of PCBs. A lower risk for PCB congeners would be estimated using an area- and depth-integrated representative set of samples for the reach. Surface water is a negligible contributor to risk, hazard, or dose.

More mobile constituents occur below the depths that apply to the risk assessments. The spatial distribution of these more mobile COPCs from Sandia Canyon is significantly affected by complex vadose-zone stratigraphy, porous-media hydrologic properties, and perched-intermediate and regional groundwater flow directions. Contaminants that infiltrate beneath Sandia Canyon may be partly transported laterally via mixing with perched-intermediate groundwater that flows southward from beneath Los Alamos Canyon towards Mortandad Canyon. The footprint of the breakthrough locations from the vadose zone into the regional groundwater is estimated based on groundwater data and a calibrated groundwater model used to support the conceptual model.

Data from groundwater monitoring wells and the groundwater model provide information on the extent of chromium contamination at concentrations in the regional groundwater greater than the 50 μg/L New Mexico groundwater standard. However, transport modeling conducted for this report identified a possible uncertainty in extent to the south of R-28, which will be addressed by the installation of a new regional monitoring well, R-50. This modeling indicates that contaminant transport in the regional aquifer is expected to occur predominantly east-southeast from R-42 and R-28 (toward R-44 and R-45), which is consistent with the observed hydraulic gradients along the regional water table. However, there is potential for contaminant transport to be diverted to the south from the main infiltration zone near R-42 and R-28, caused perhaps by aquifer heterogeneity associated with west-southwestward dipping strata in the Puye Formation and Santa Fe Group. Anthropogenic chromium is not observed in nearby regional water-supply wells.

Data on the estimated area and thickness of the zone of chromium contamination in the regional aquifer, along with estimates for mass in the surface sediment and vadose zone, are used to reconcile against the total estimated chromium mass released from the TA-03 power plant cooling tower outfall from 1956 to 1972. The mass-balance estimate suggests that the majority of the mass released from the original source is contained as Cr(III) in the reach S-2 sediments and as adsorbed and reduced phases in the vadose zone. Data from geochemical studies presented in this report indicate that the adsorbed and reduced chromium in the sediments and in the vadose zone are predominantly geochemically stable, meaning that the Cr(III) inventory is not likely to act as secondary sources for Cr(VI) under current hydrogeochemical conditions. A continued source of Cr(VI) to the regional aquifer might be present as perched-intermediate groundwater and in pore water within the vadose zone. However, measured chromium concentrations in perched-intermediate groundwater and vadose-zone pore water are less than maximum observed chromium concentrations in the regional aquifer (well R-42). This finding indicates continuing recharge of the regional aquifer may result in decreasing chromium concentrations over time in the regional aquifer, although short-term variability, including slight increases, might be expected.

Fluctuations of the chromium concentrations may relate to local heterogeneities and small-scale transients in the local hydrogeochemical conditions, particularly close to the primary location of contaminant arrival at the regional water table near R-42. Model estimates indicate that approximately 10 to 20 kg/yr have historically entered the regional aquifer and may continue to enter at this approximate rate. Analyses of groundwater fluxes and contaminant concentrations in the vadose zone and the regional aquifer suggest the chromium concentrations may be sustained at levels above the applicable groundwater standards for some period in the future. Modeling analyses also indicate that further downgradient plume advancement will be limited from hydrodynamic dispersion. It is possible the current chromium-contaminant plume has generally reached a steady-state condition within the regional aquifer and is decreasing in overall mass in the vadose zone. Mass balance calculations suggest that a small mass of chromium causes the observed regional aquifer concentrations and spatial distribution of mass.

The uncertainty in the southern extent of chromium contamination in the regional aquifer will be further refined with the installation of regional aquifer well R-50, which is planned for installation beginning in the

fall of 2009. The conceptual model for fate and transport is based on steady-state conditions of effluent released from the present-day outfall. A project has been proposed to expand the use of the Laboratory's Sanitary Effluent Reclamation Facility (SERF) to meet the Laboratory's NPDES permit requirements and the federal government's water-recycling goals. When implemented, this project is expected to result in a significant reduction in the volume of water released to Sandia Canyon and will also potentially affect the chemical nature of outfall water. These changes might be expected to affect the reach S-2 wetland physically and geochemically in a manner that is not currently quantified. Design criteria for the SERF Expansion Project will take wetland stability into account. DOE's Los Alamos Site Office is currently evaluating the level of National Environmental Policy Act (NEPA) documentation and analysis required for the SERF Expansion Project. It is expected that the NEPA document will evaluate impacts to Sandia Canyon, and any mitigation actions required would be closely coordinated with any corrective measures identified under the Consent Order.

Groundwater will continue to be monitored for potential changes in concentrations or distribution of contaminants for each of the zones, particularly with respect to chromium and nitrate in perched-intermediate and regional groundwater. The monitoring plan will be included in the Laboratory's annual interim facility-wide groundwater monitoring plan. An assessment of remedial alternatives may be appropriate in the future and, if necessary, will address all pertinent issues in the watershed in an integrated manner.

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- Project Leaders: Danny Katzman and Kay Birdsell
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Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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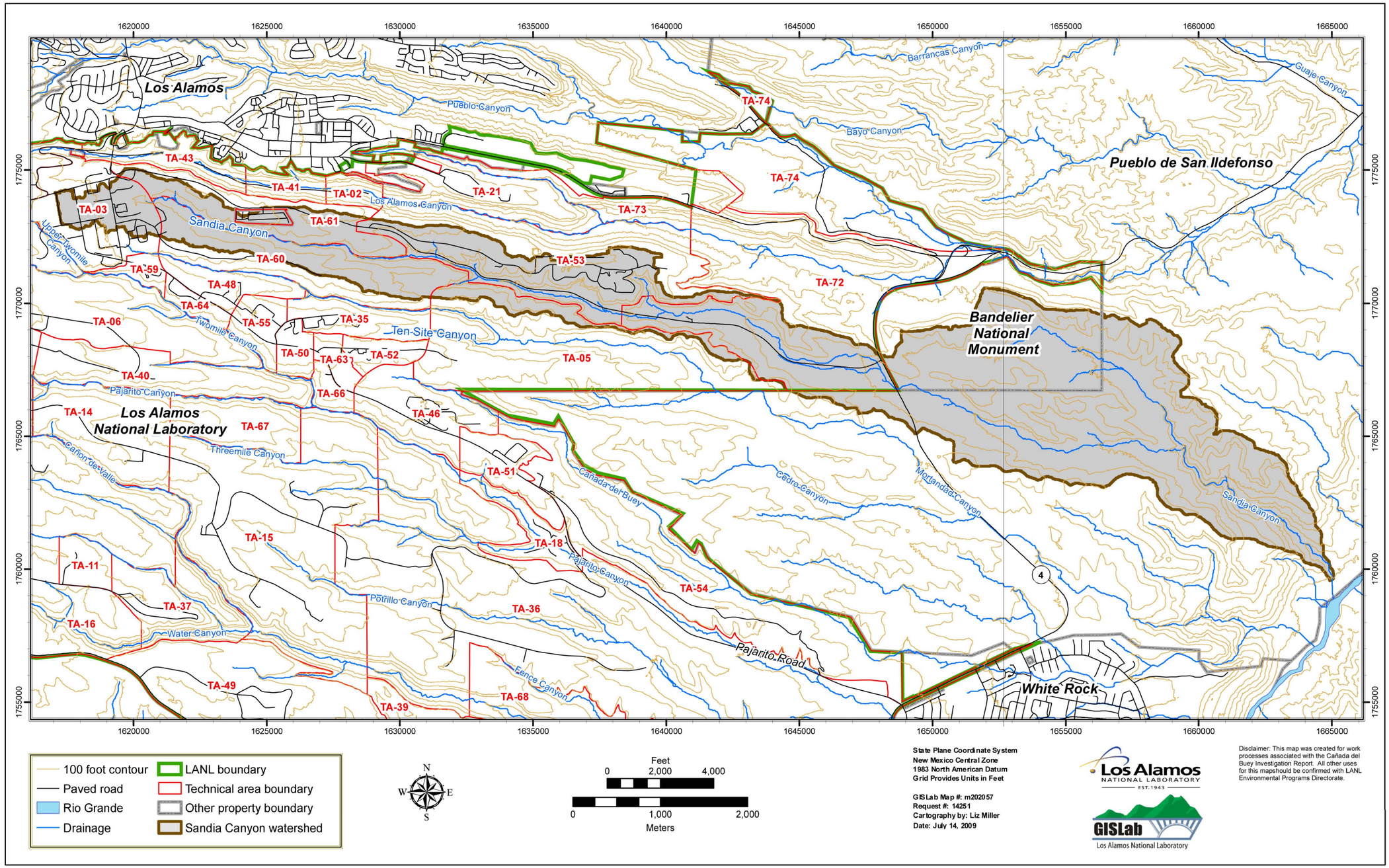


Figure 1.1-1 Sandia Canyon watershed showing technical area boundaries

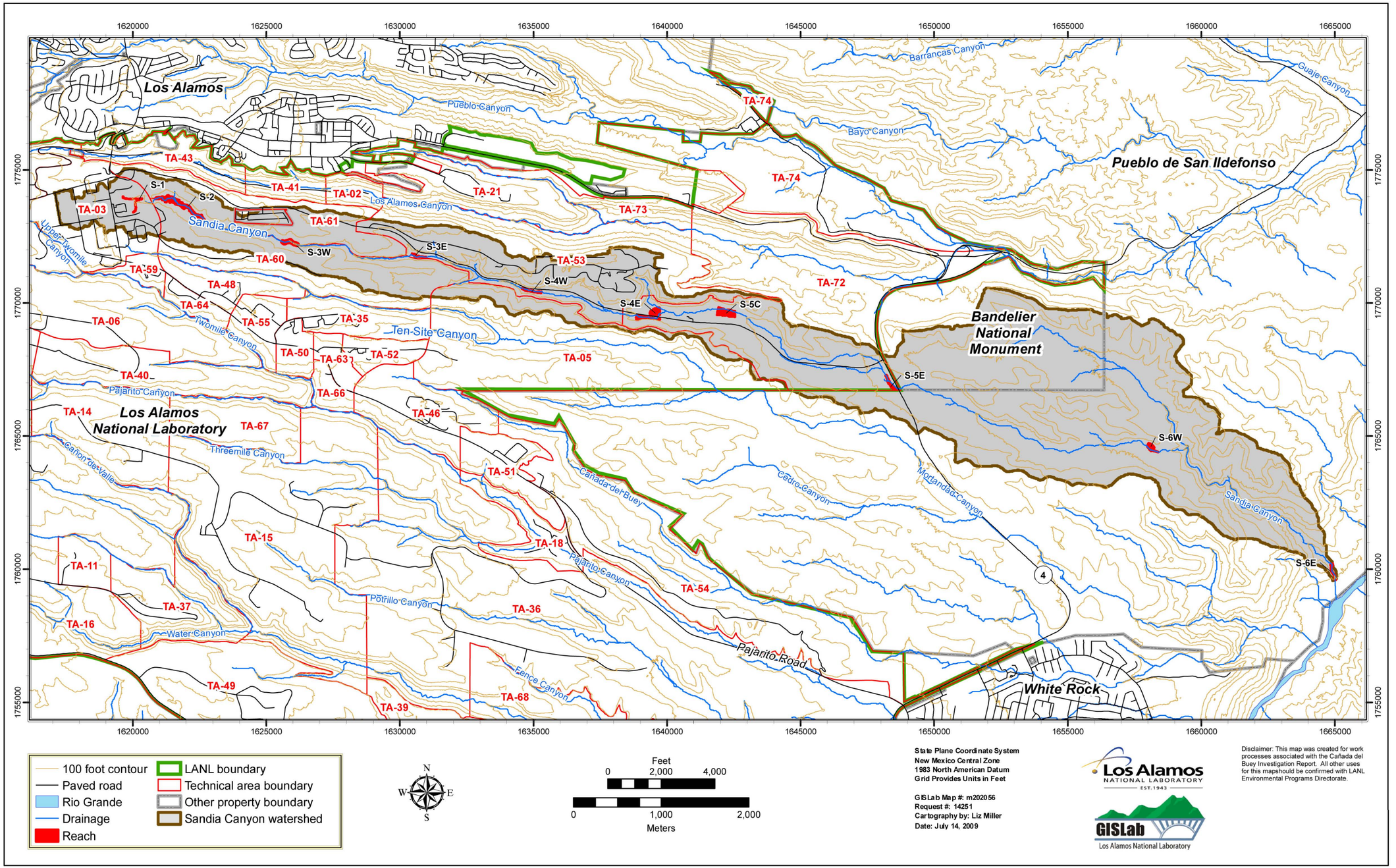


Figure 3.1-1 Sandia Canyon watershed showing reach boundaries

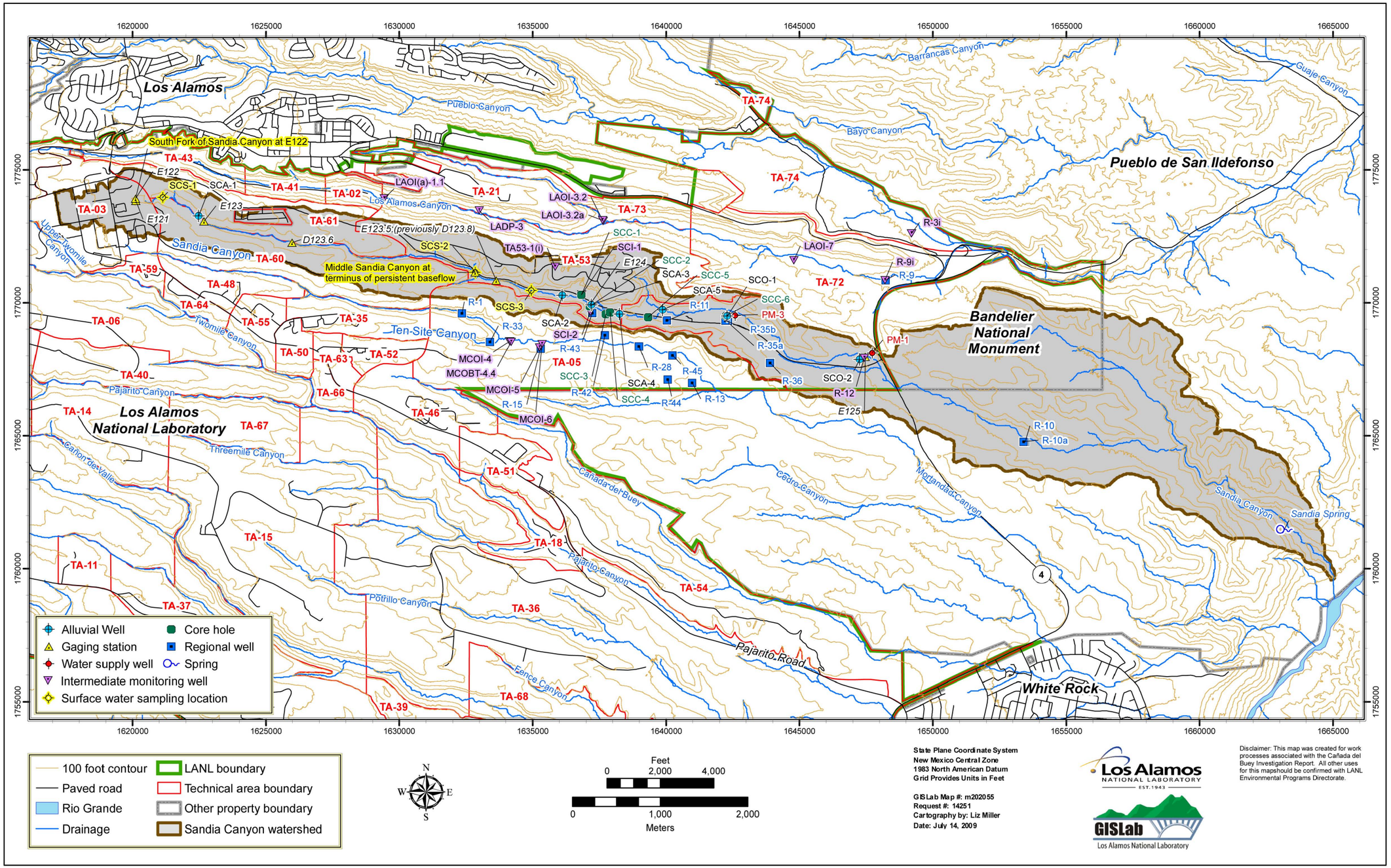
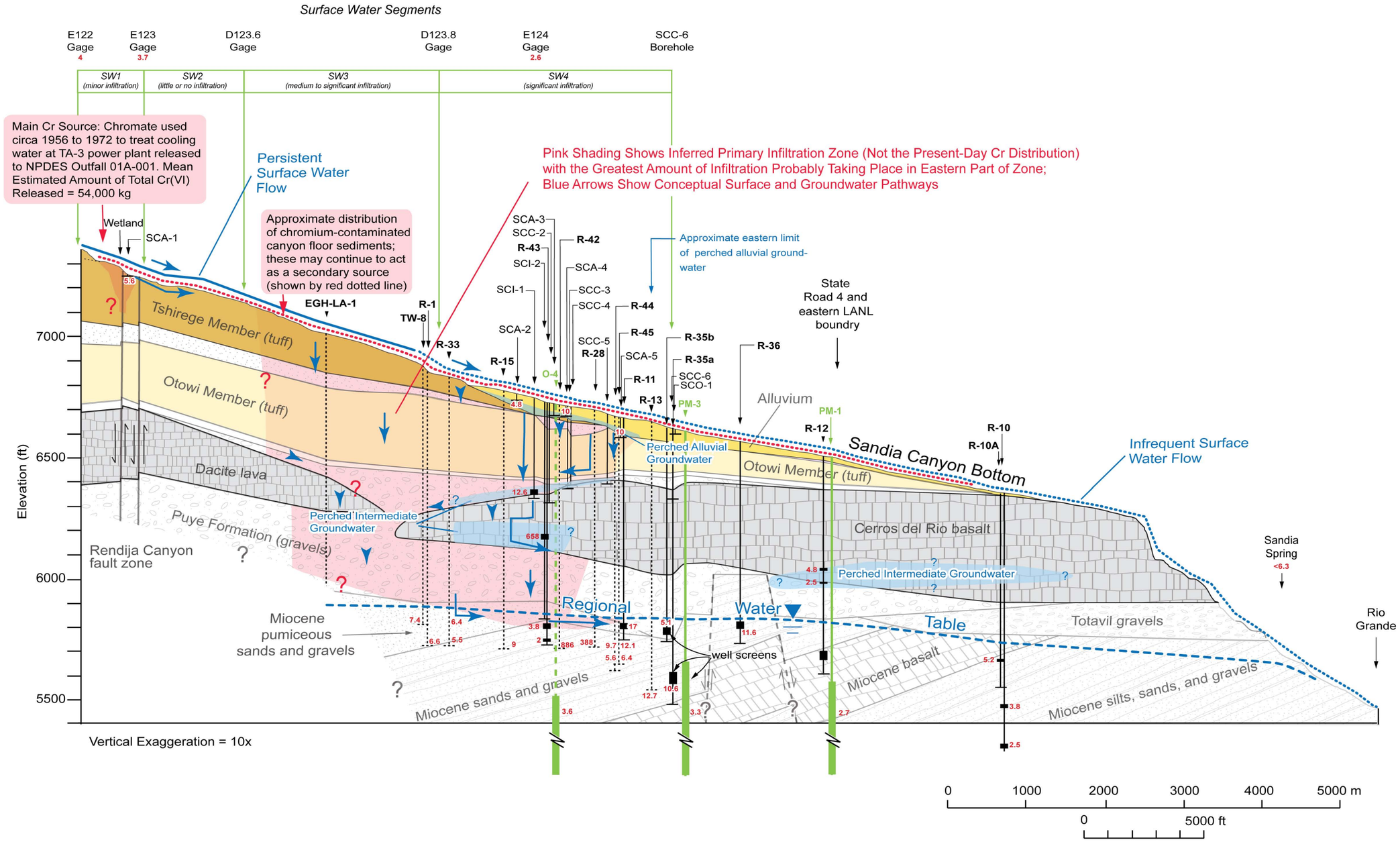


Figure 3.2-1 Sandia Canyon watershed showing water sampling locations



Notes: Red numbers indicate most recent (mostly 2009) values of chromium in units of μg/L. Wells indicated by solid lines are in Sandia Canyon; dashed wells are projected into Sandia Canyon from adjacent canyons.

Figure 7.0-1 Conceptual hydrogeologic cross-section for Sandia Canyon that includes potential chromium transport pathways and dissolved hexavalent chromium for surface water, monitoring wells, and water-supply wells

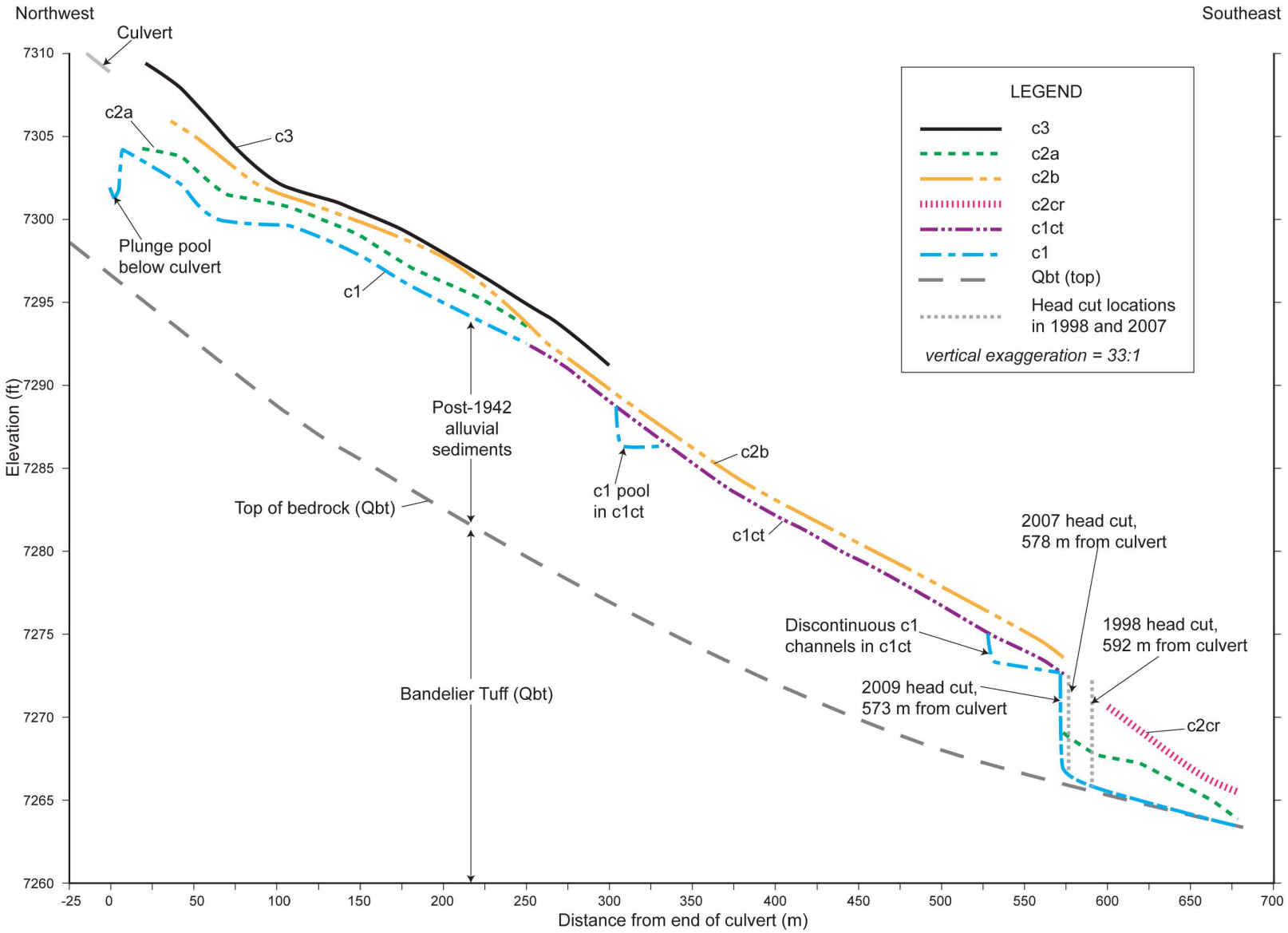


Figure 7.1-1 Longitudinal profile through reach S-2, showing elevations of different post-1942 geomorphic units and sediment thickness

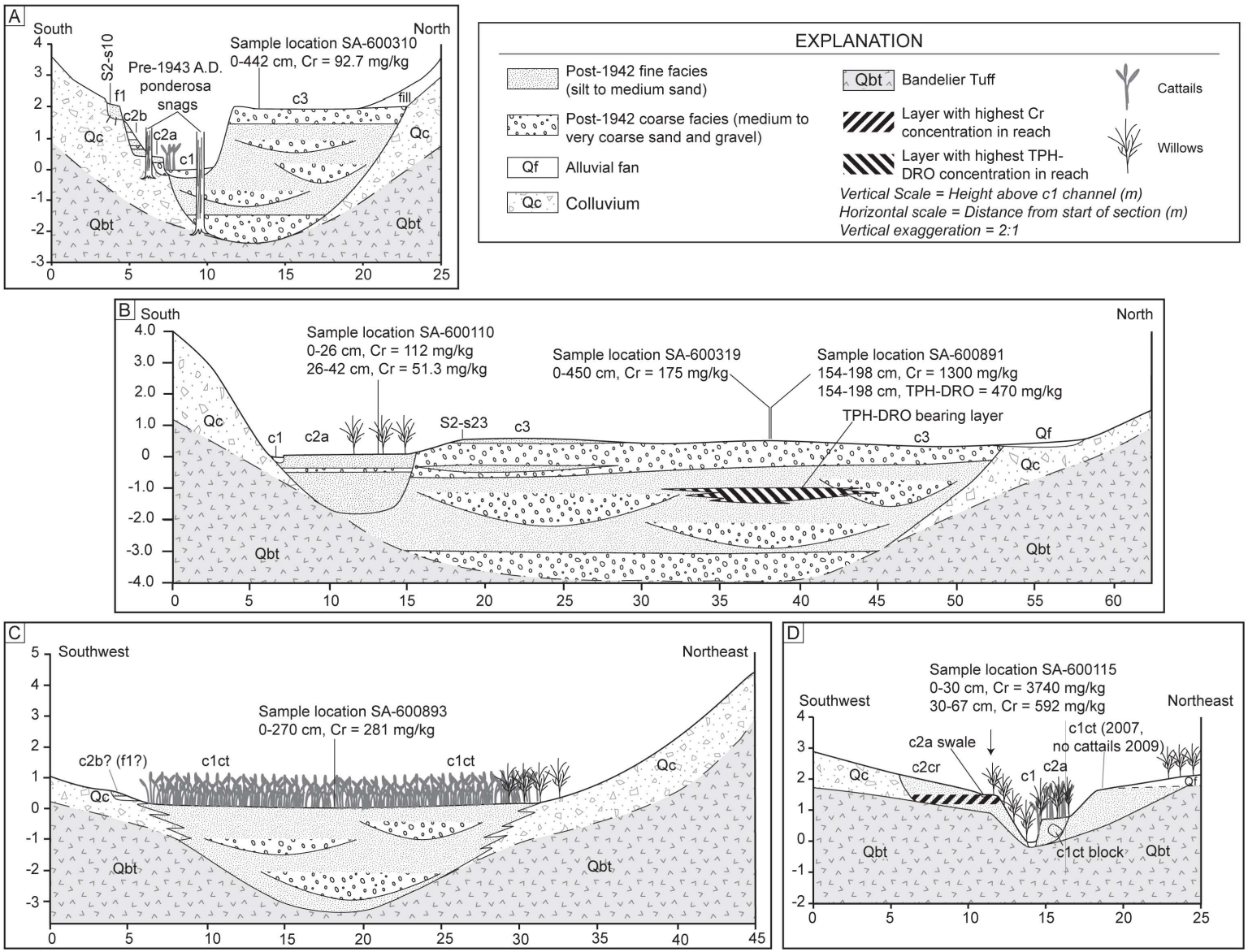


Figure 7.1-2 Schematic cross-sections showing post-1942 coarse facies and fine facies sediment deposits in reach S-2; (a) 22 m, (b) 151 m, (c) 498 m, and (d) 600 m from culvert

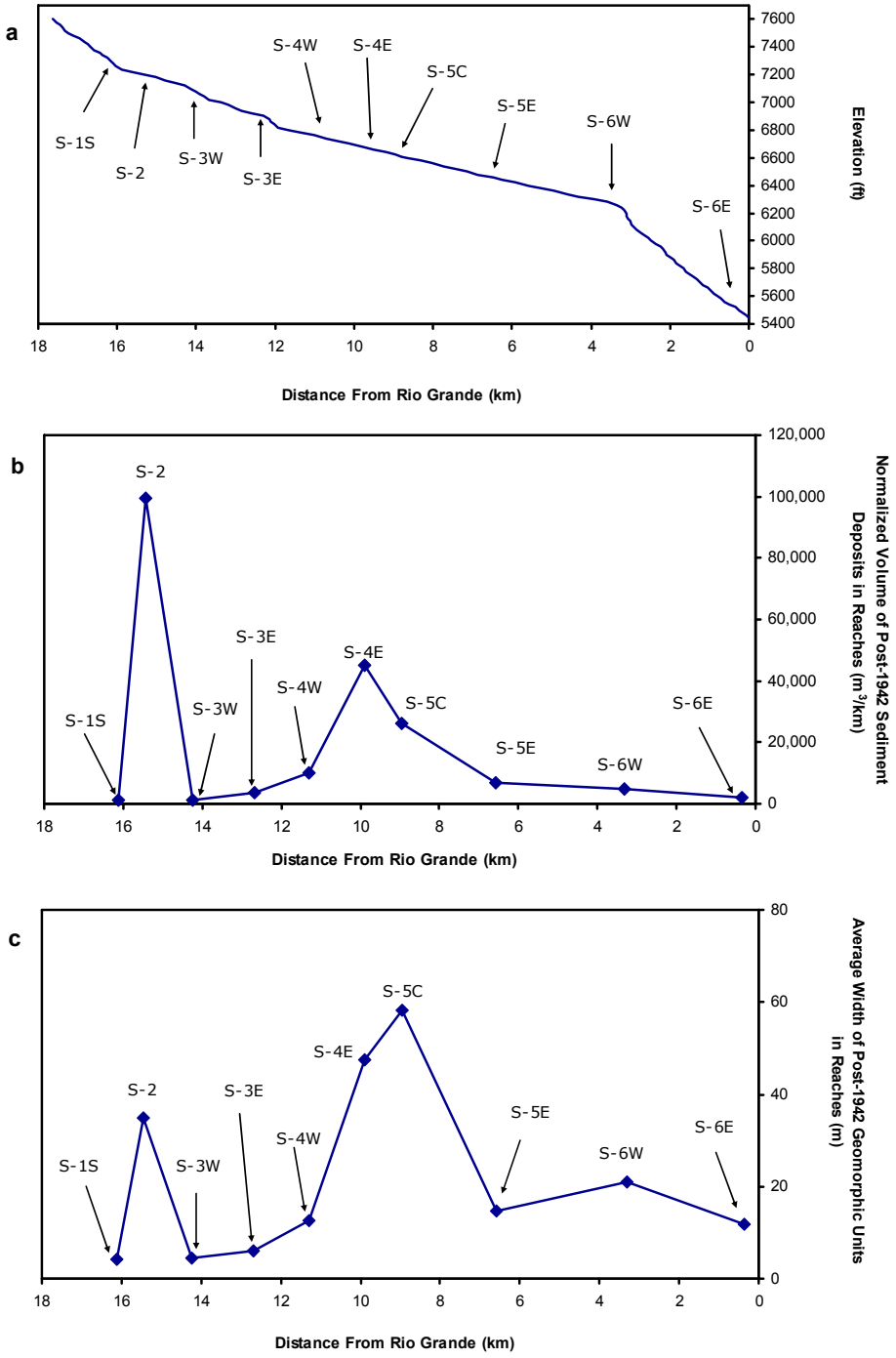


Figure 7.1-3 Longitudinal stream profile (a) and longitudinal variations in normalized volume ([b] in units of m^3/km) and average width (c) of post-1942 sediment and geomorphic units in Sandia Canyon

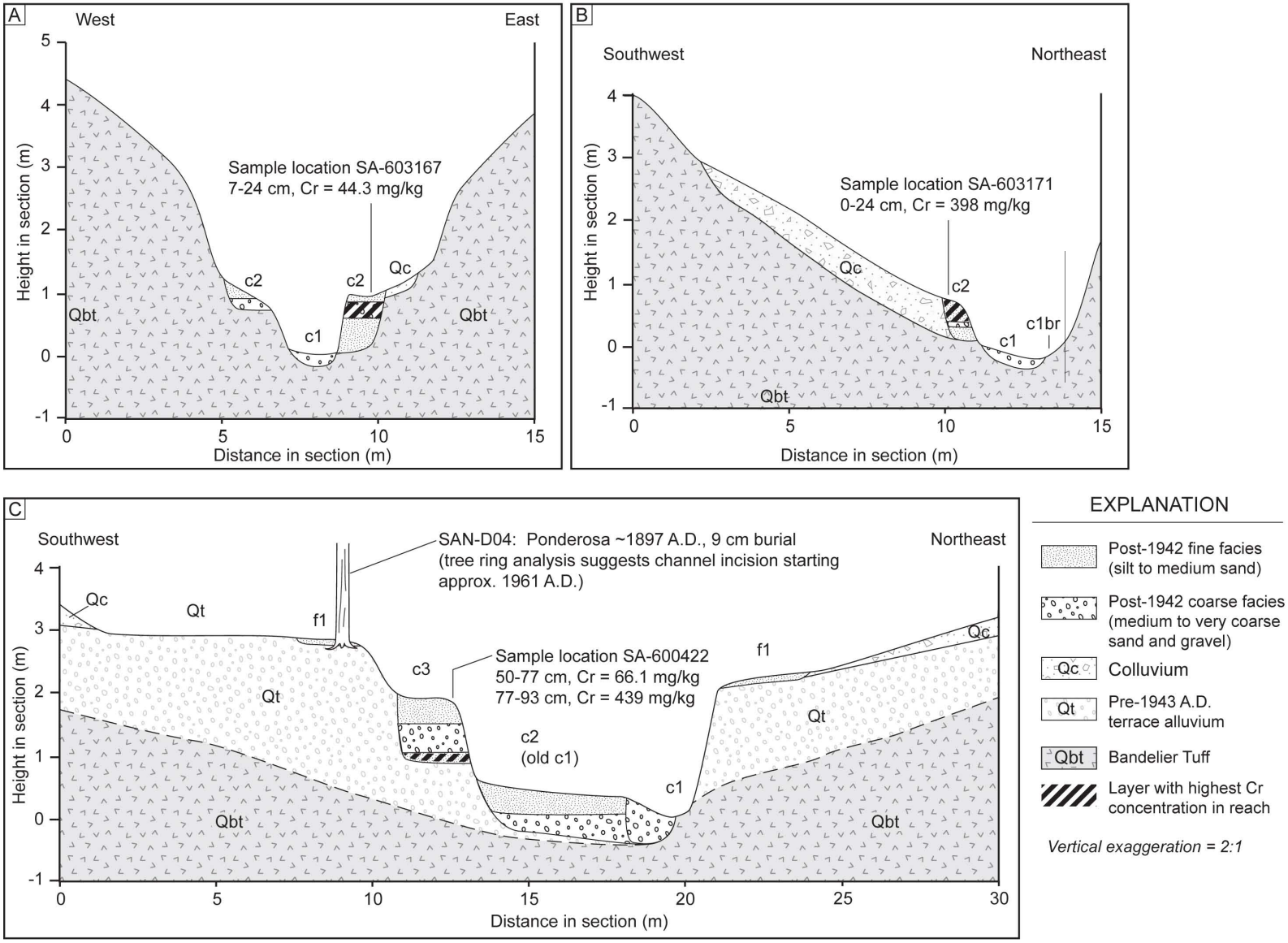


Figure 7.1-4 Schematic cross-sections showing post-1942 coarse facies and fine facies sediment deposits in reaches (a) S-1S, (b) S-3W, (c) S-3E

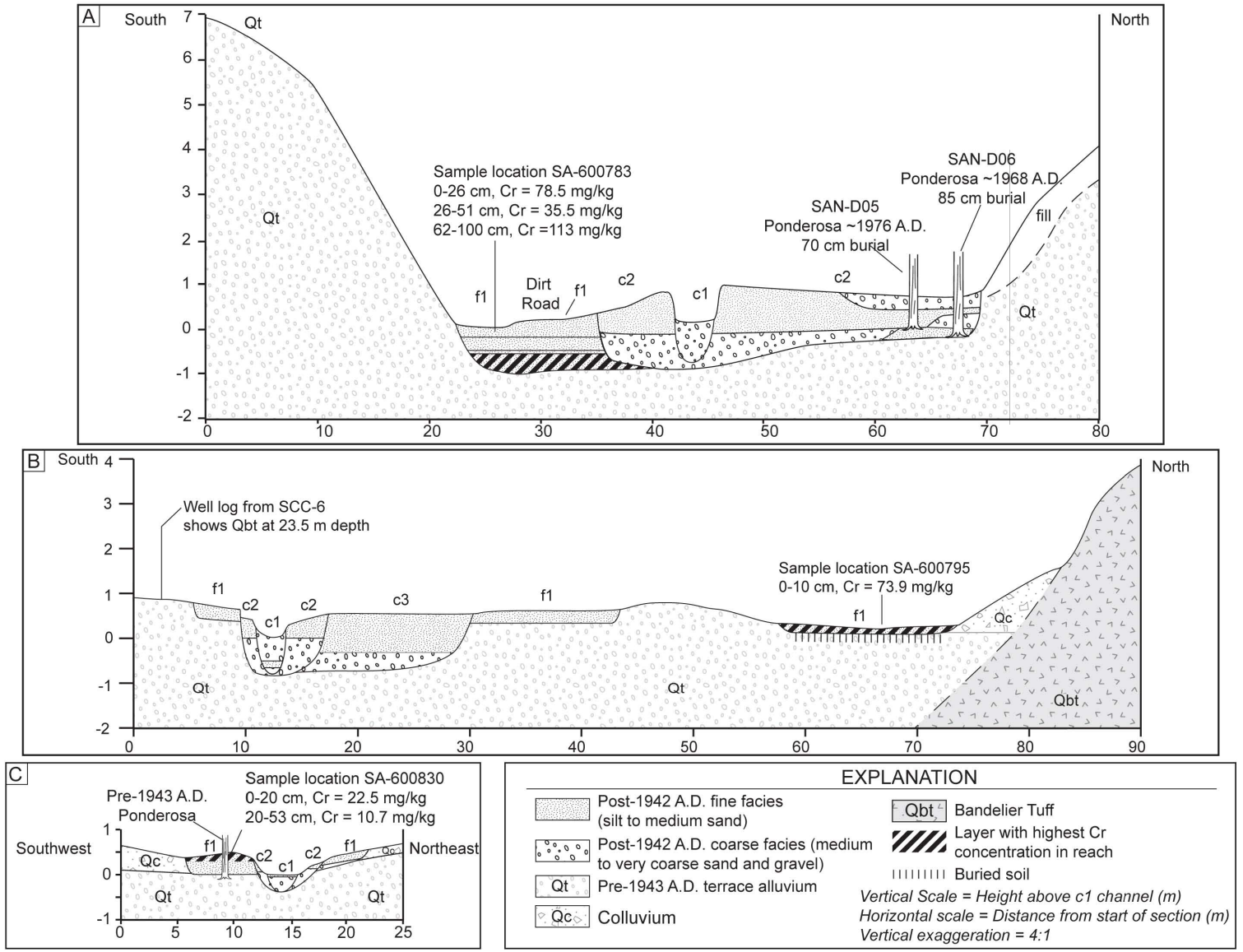


Figure 7.1-5 Schematic cross-sections showing post-1942 coarse facies and fine facies sediment deposits in reaches (a) S-4E, (b) S-5C, and (c) S-5E

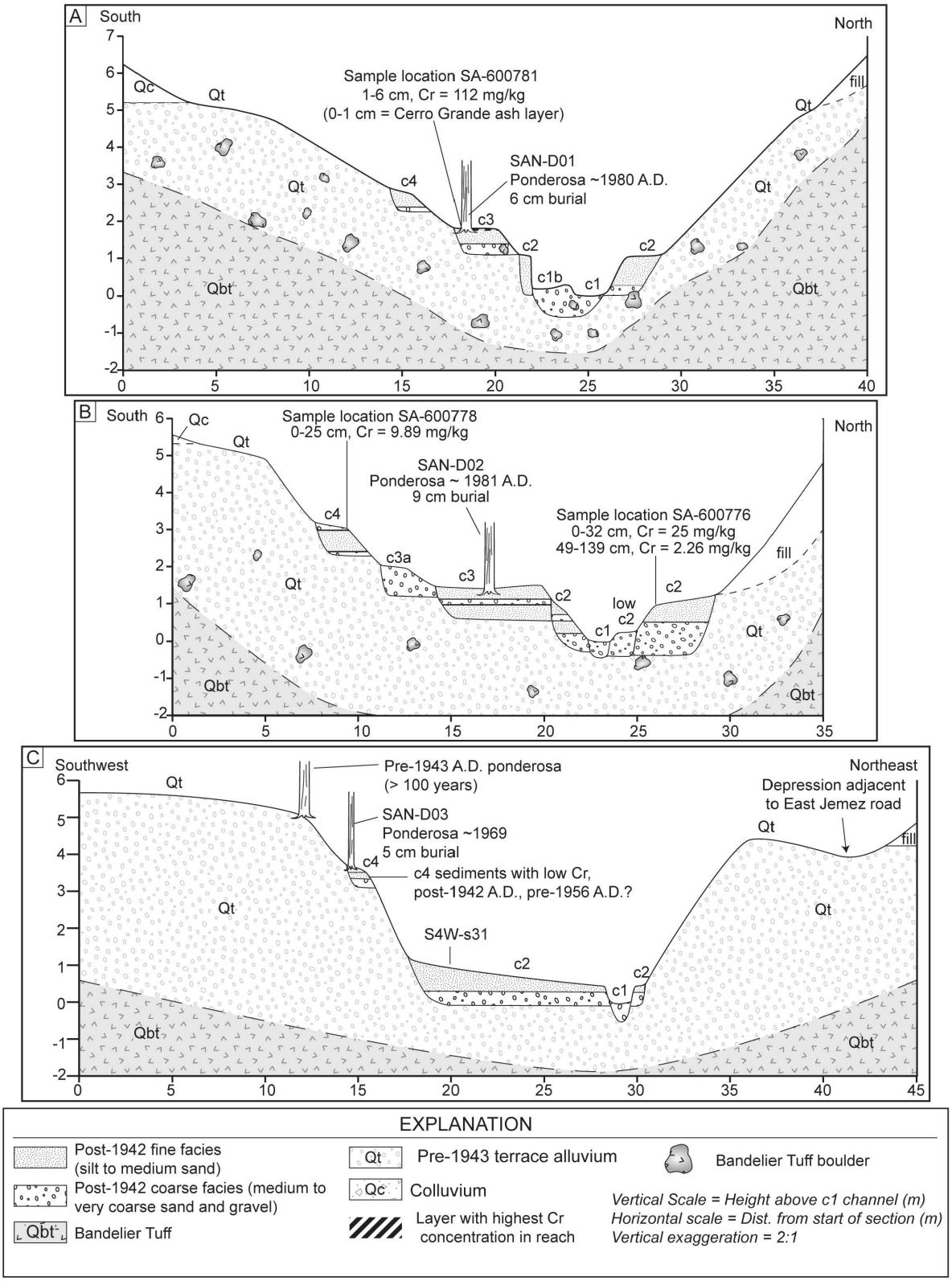
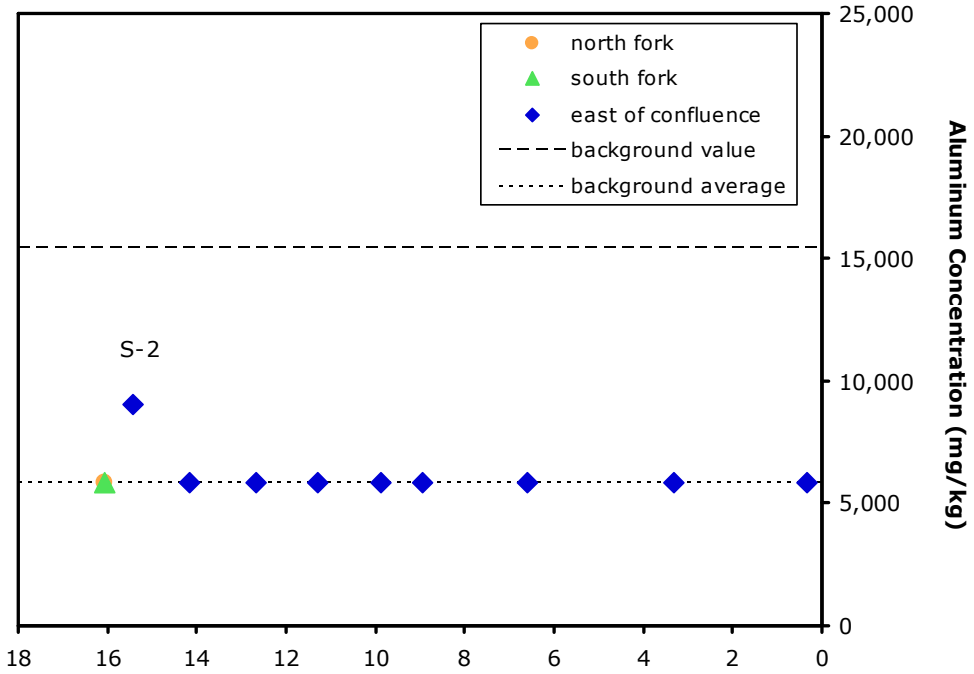
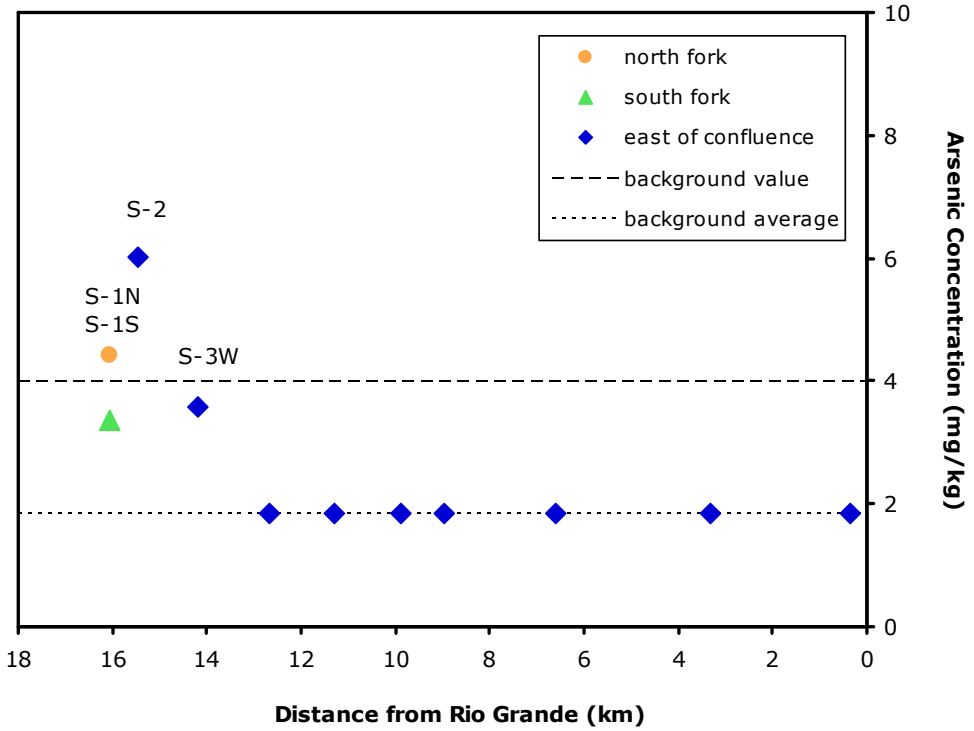


Figure 7.1-6 Schematic cross-sections showing post-1942 coarse facies and fine facies sediment deposits in reach S-4W; (a) 50 m, (b) 113 m, and (c) 191 m from west end of reach

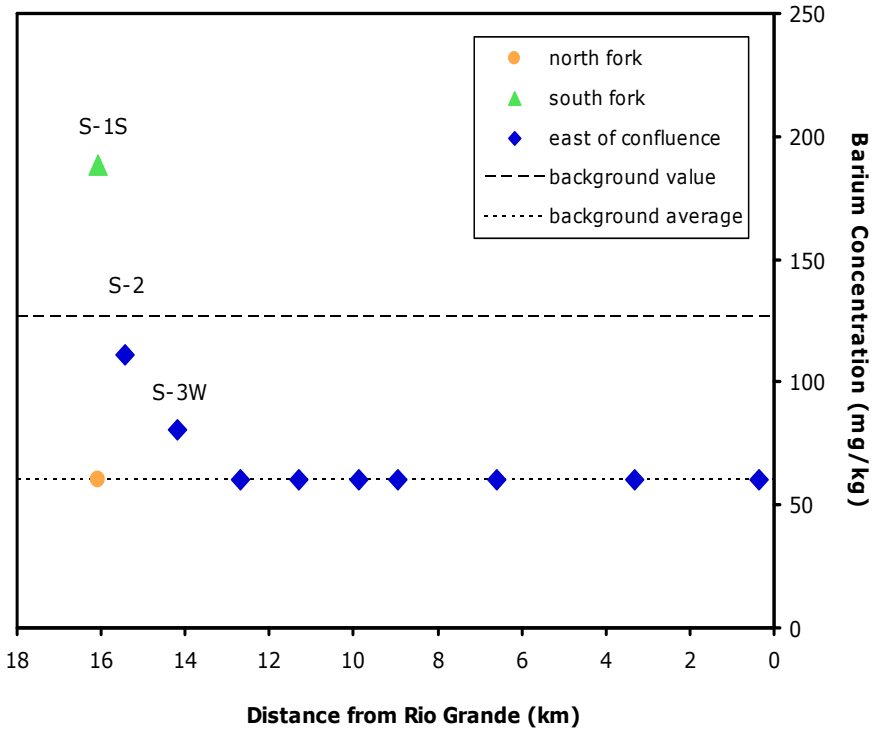


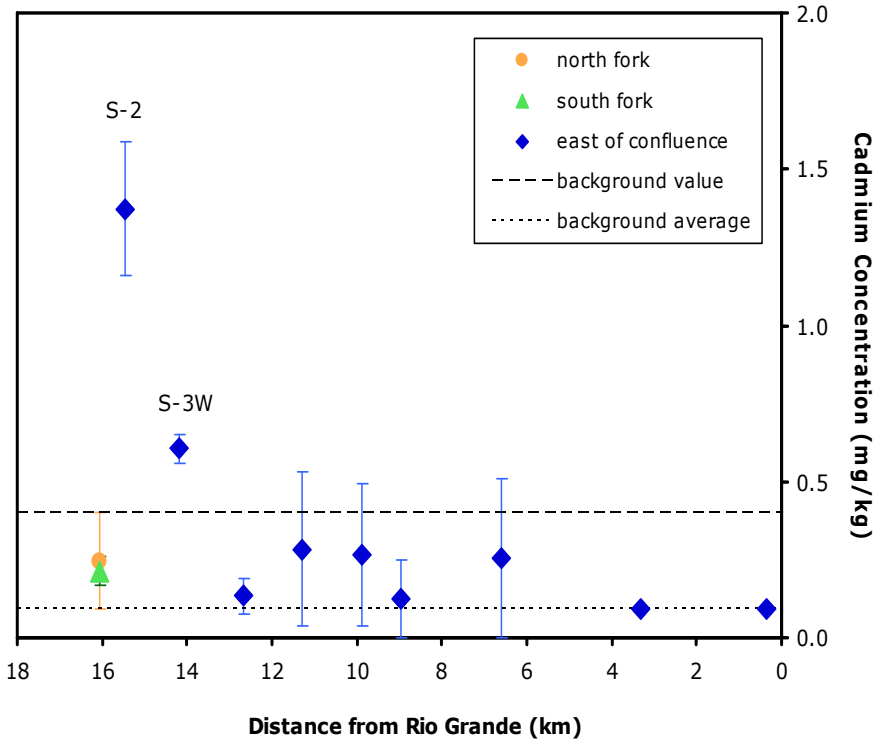


a.

Note: Error bars indicate upper and lower bounds on the averages based on replacing nondetect values with either the detection limit (upper bound) or zero (lower bound).

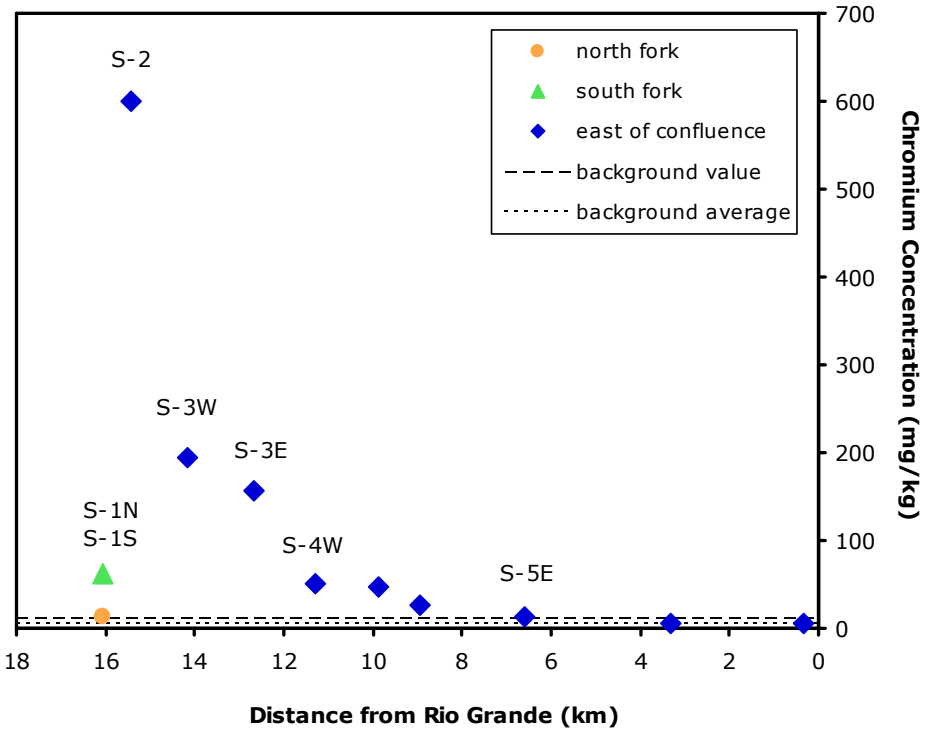
Figure 7.1-7 Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

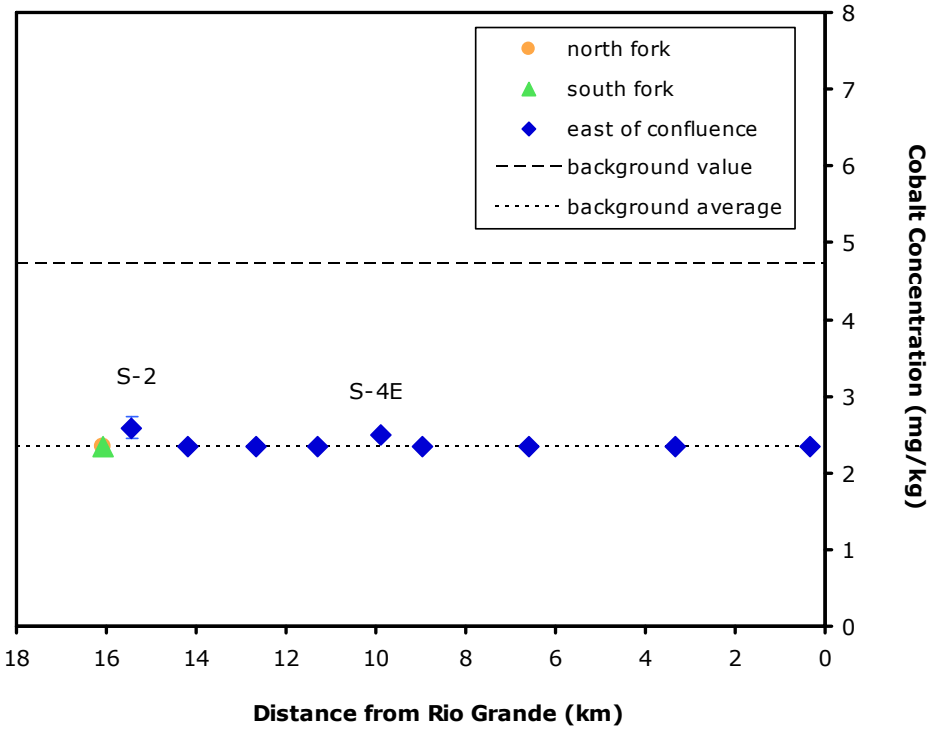




b.

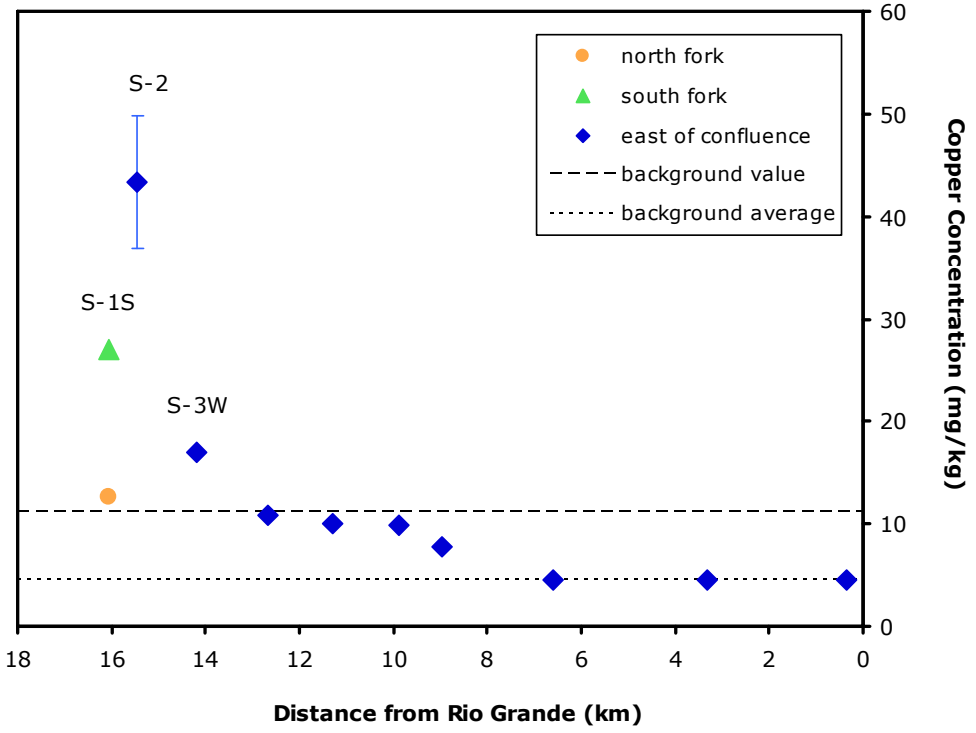
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

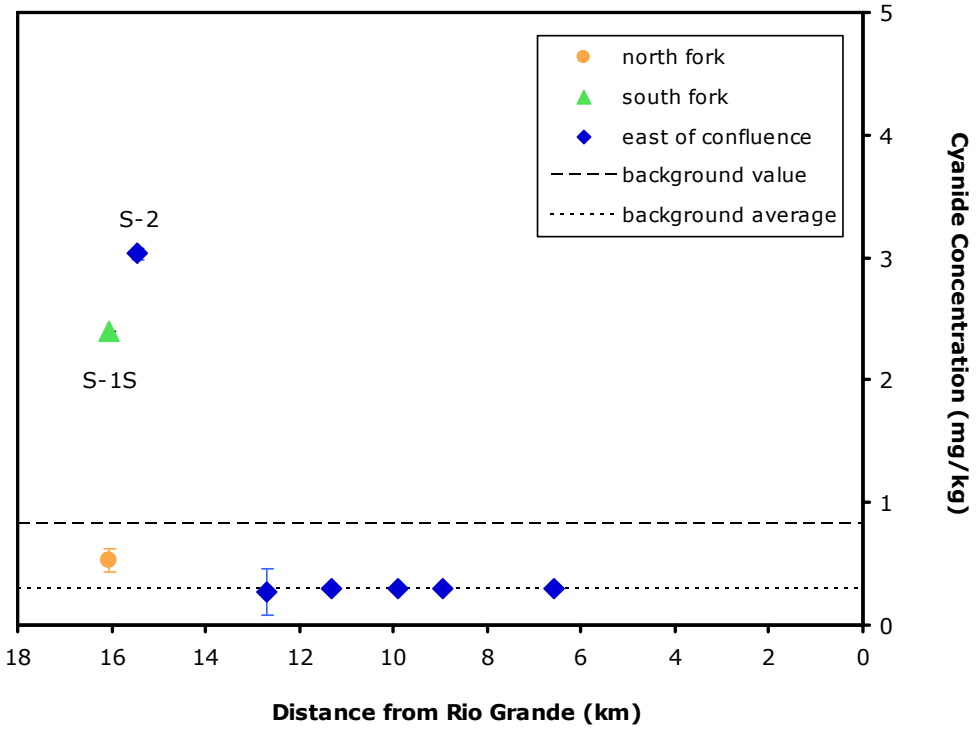




c.

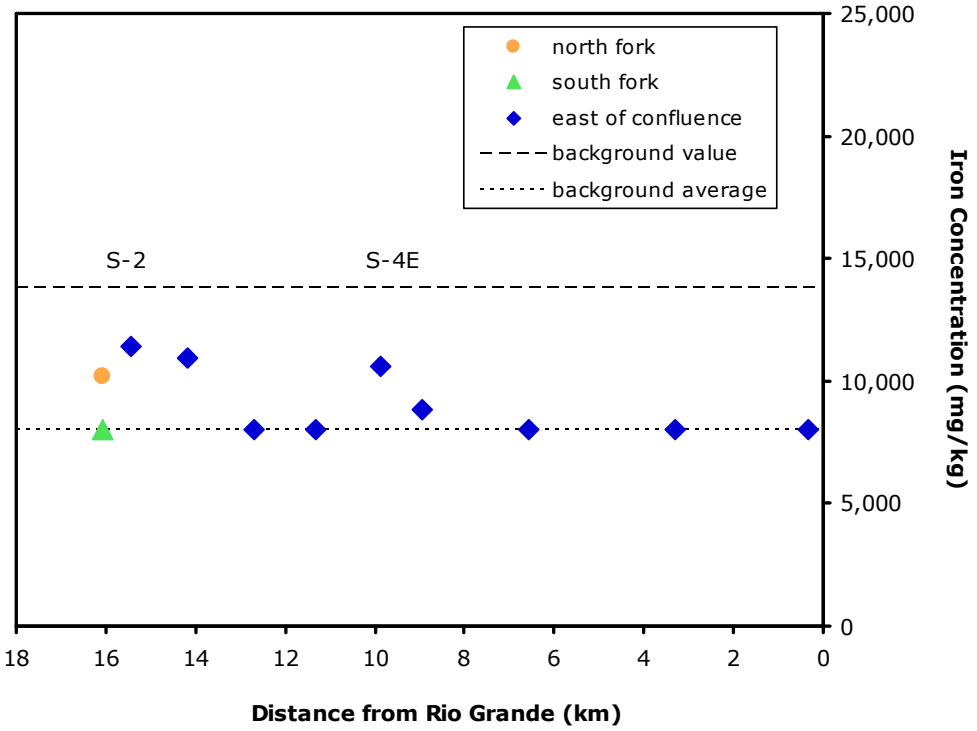
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

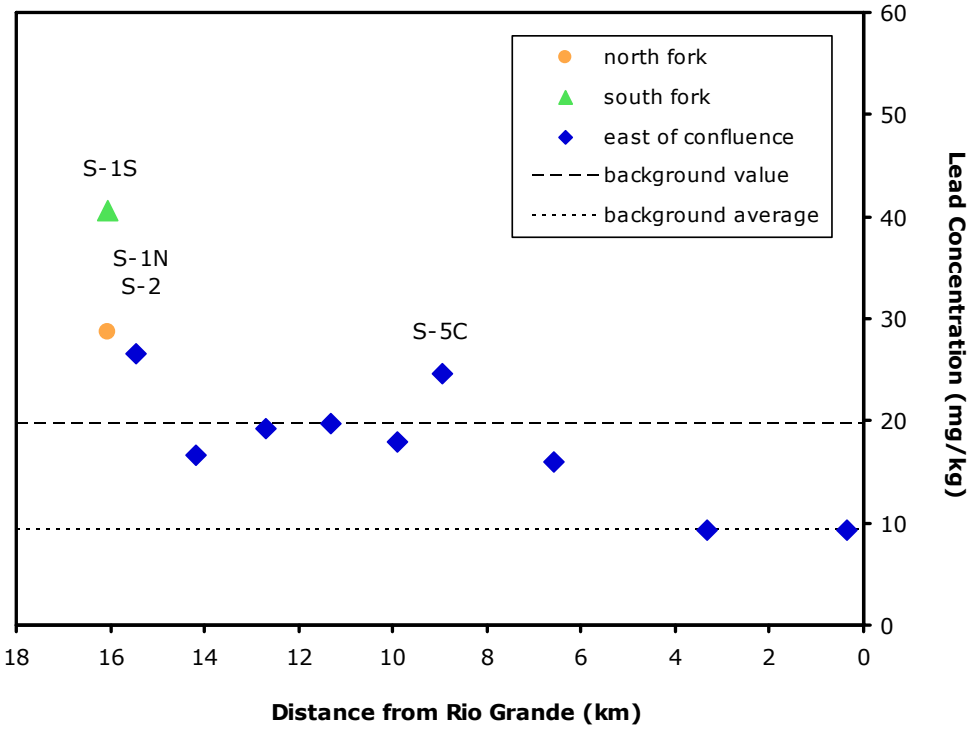




d.

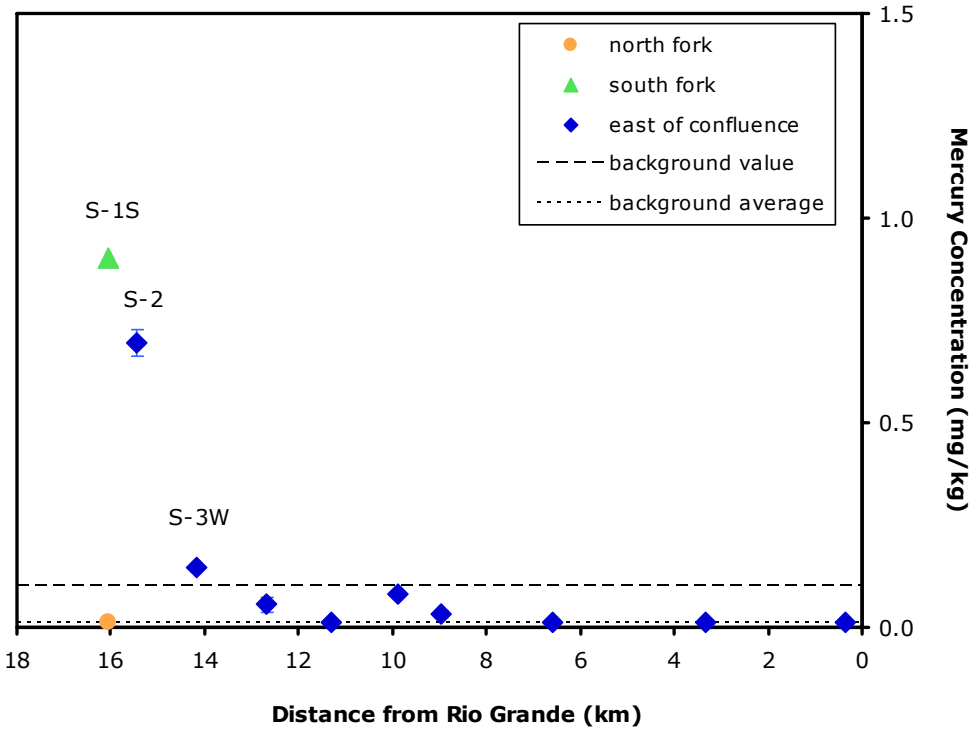
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

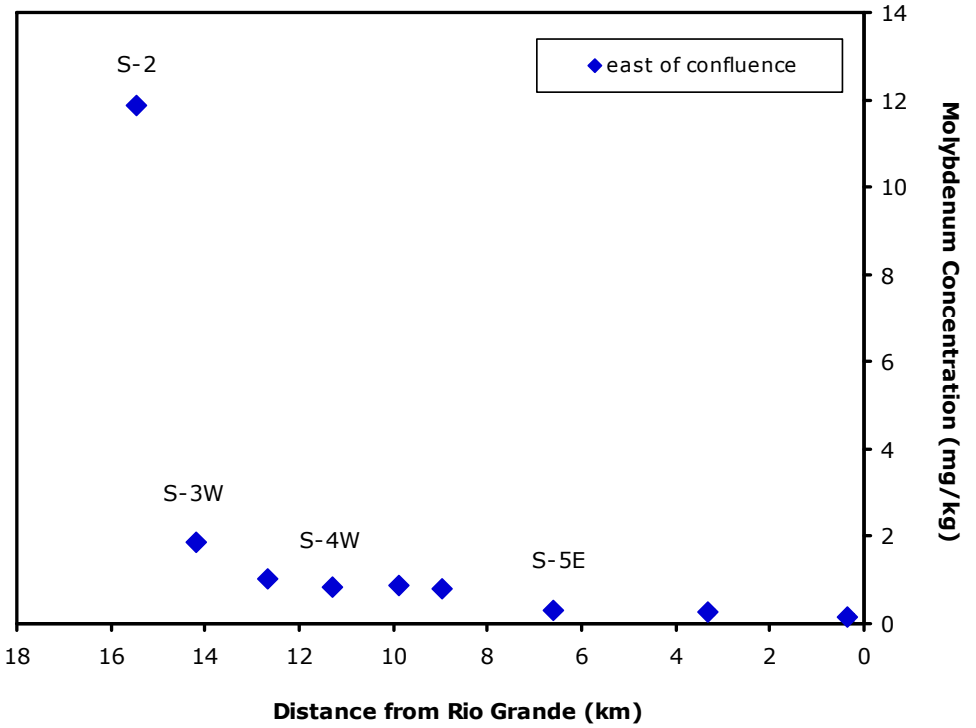




e.

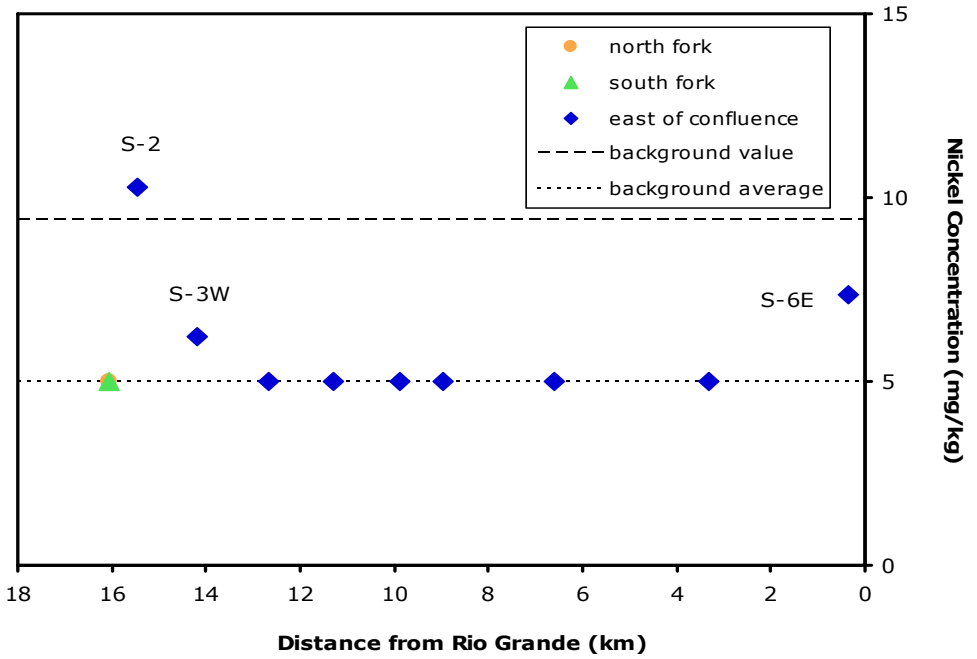
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

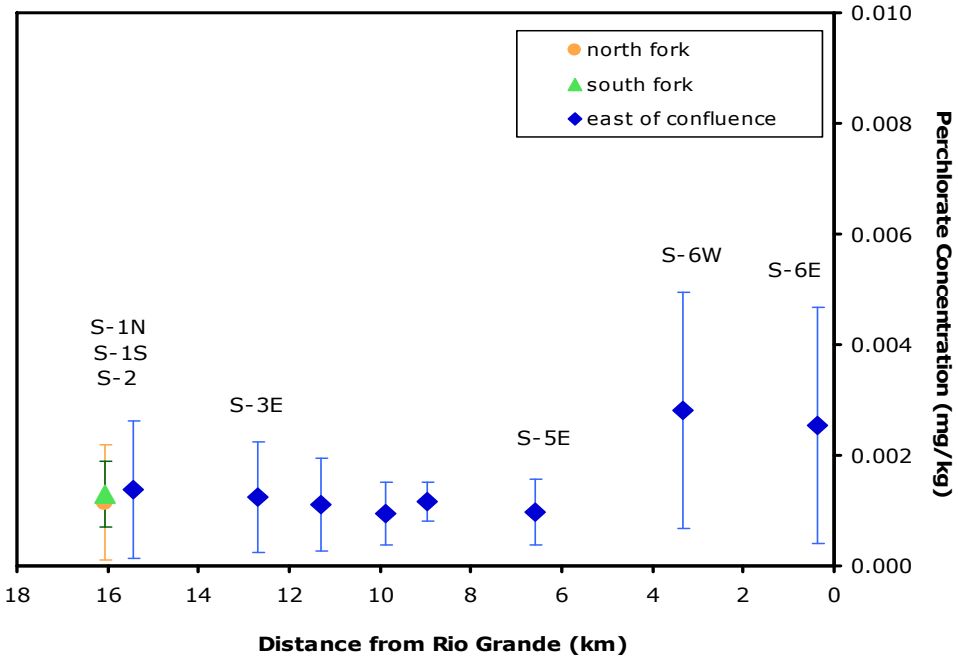




f.

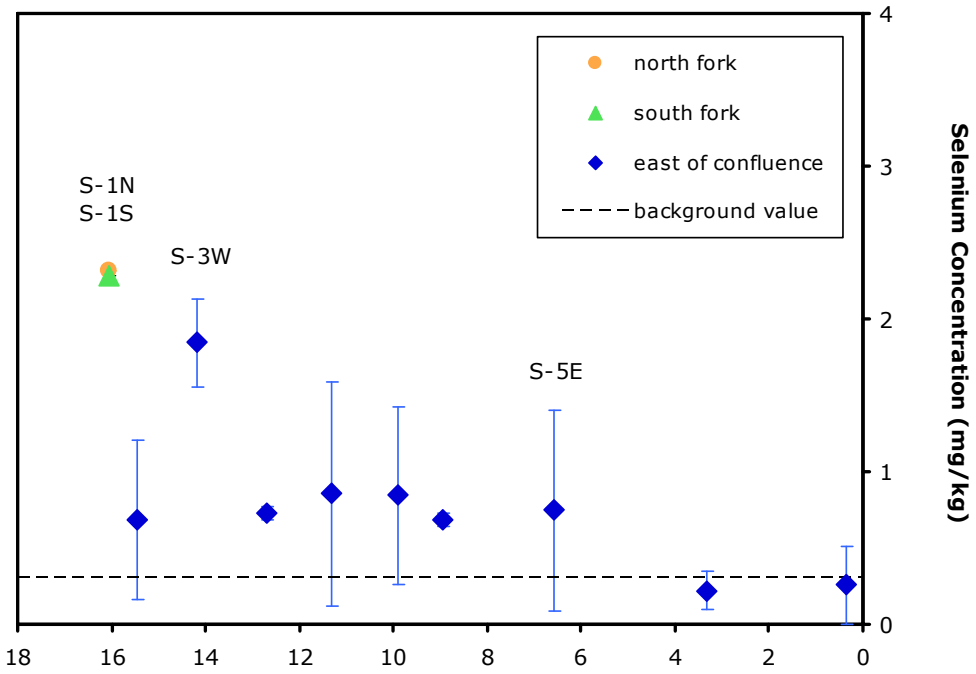
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

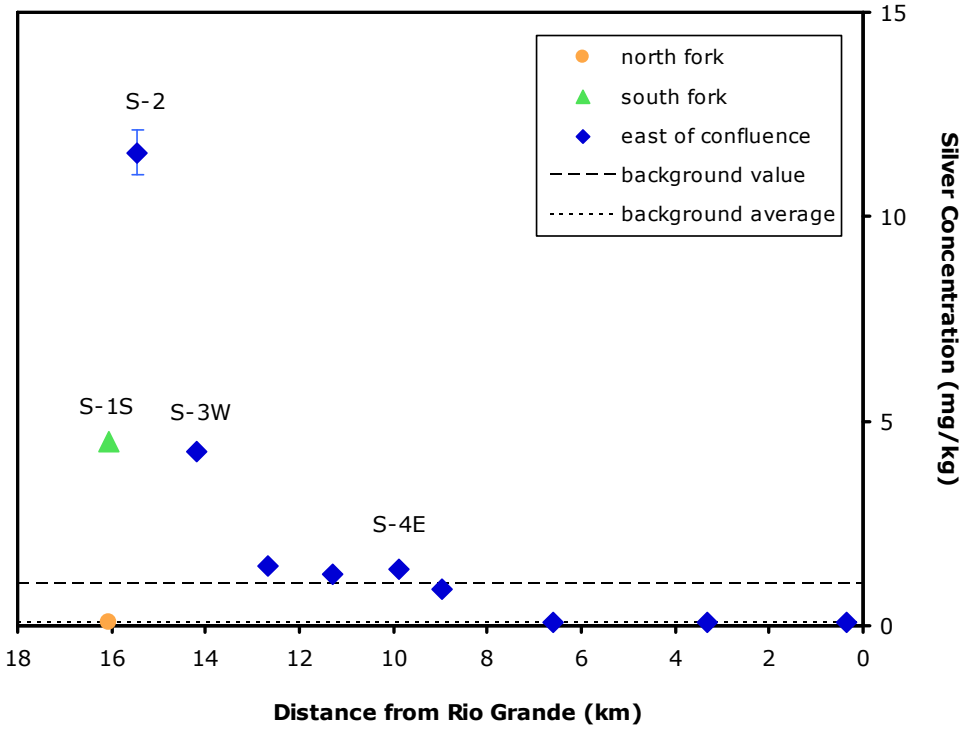




g.

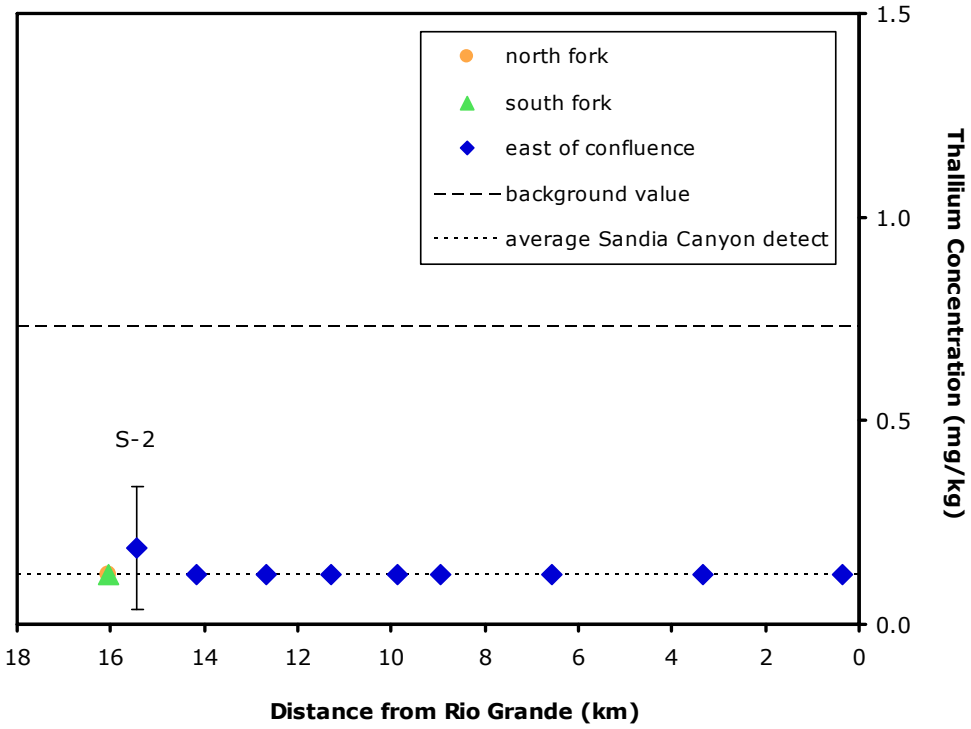
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

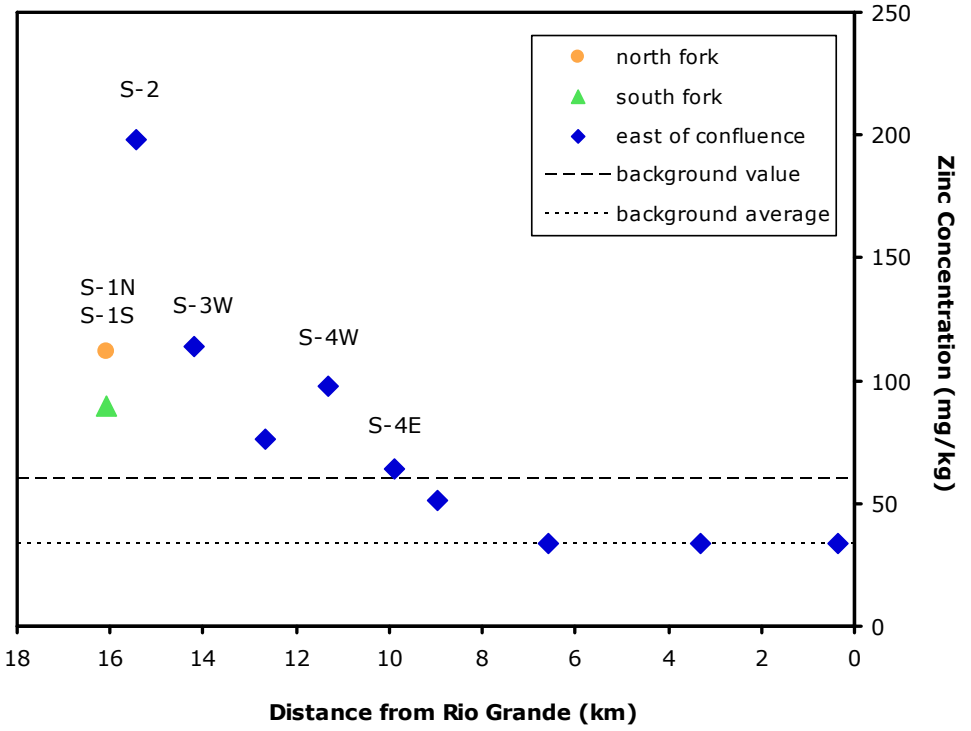




h.

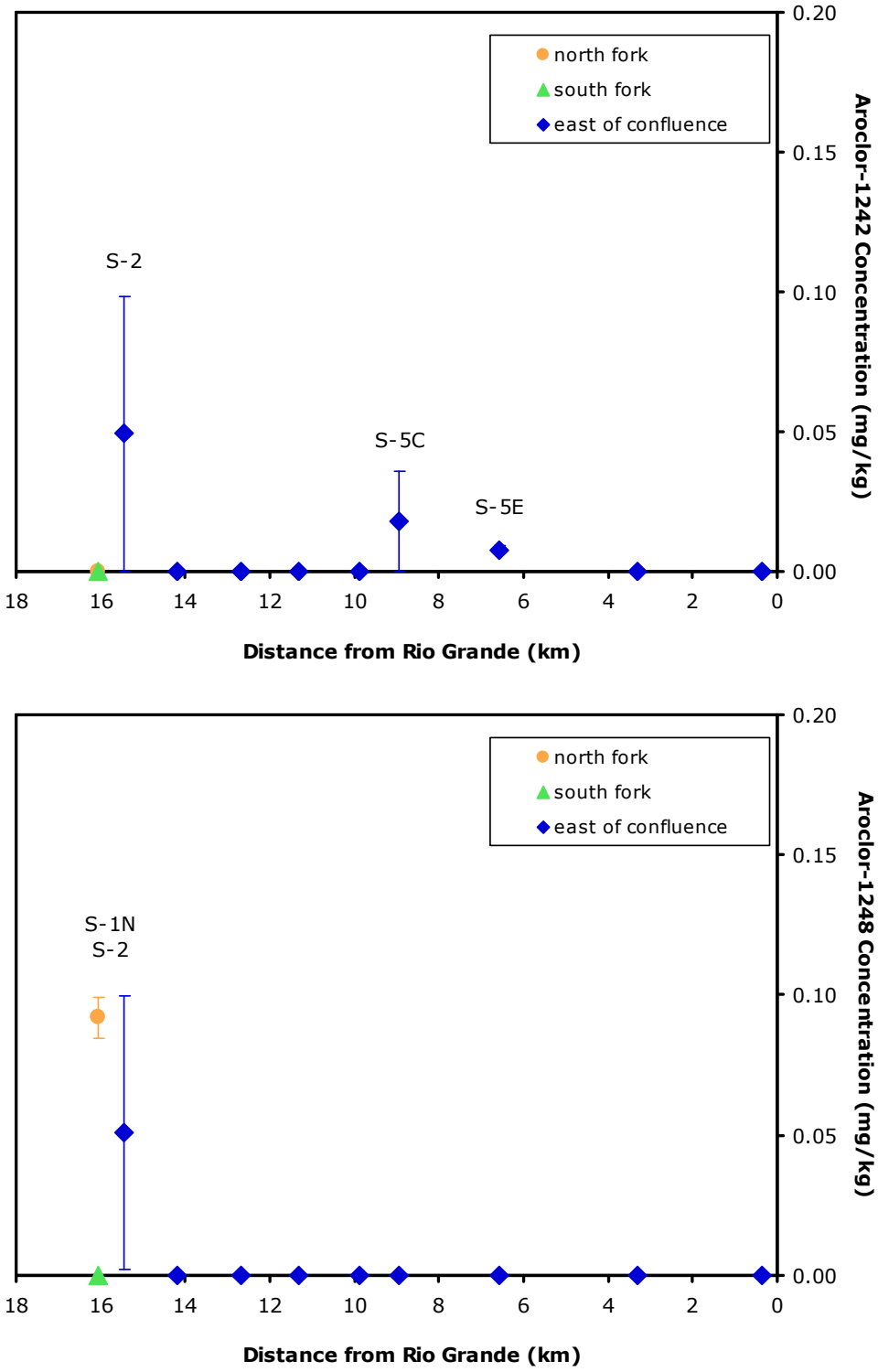
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon





i.

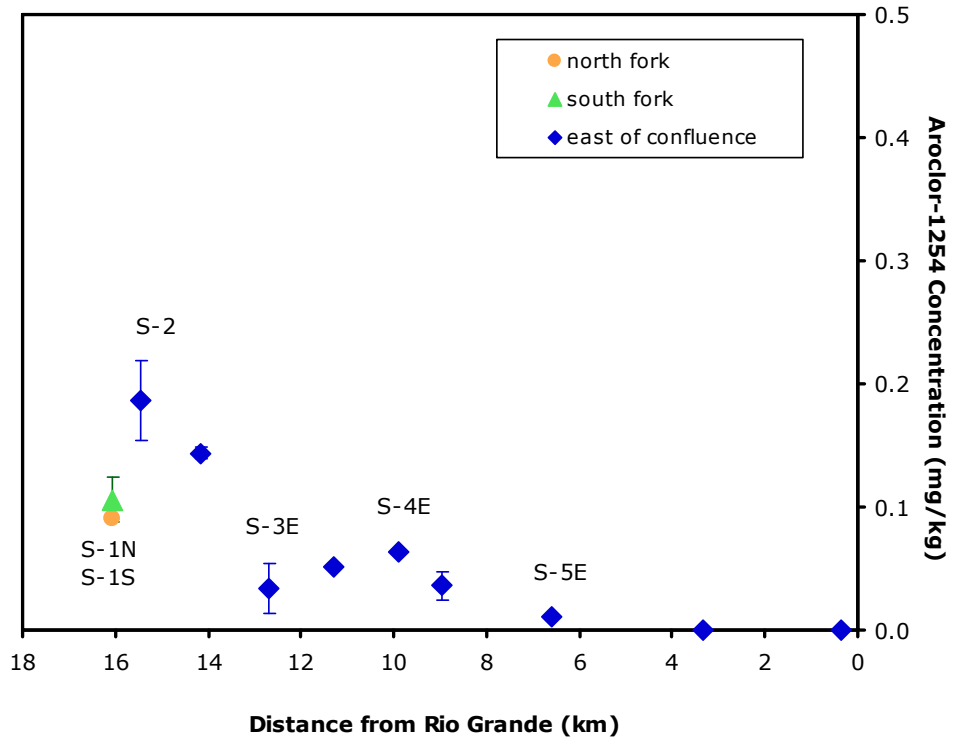
Figure 7.1-7 (continued) Estimated average concentrations of select inorganic chemicals in fine facies sediment in Sandia Canyon

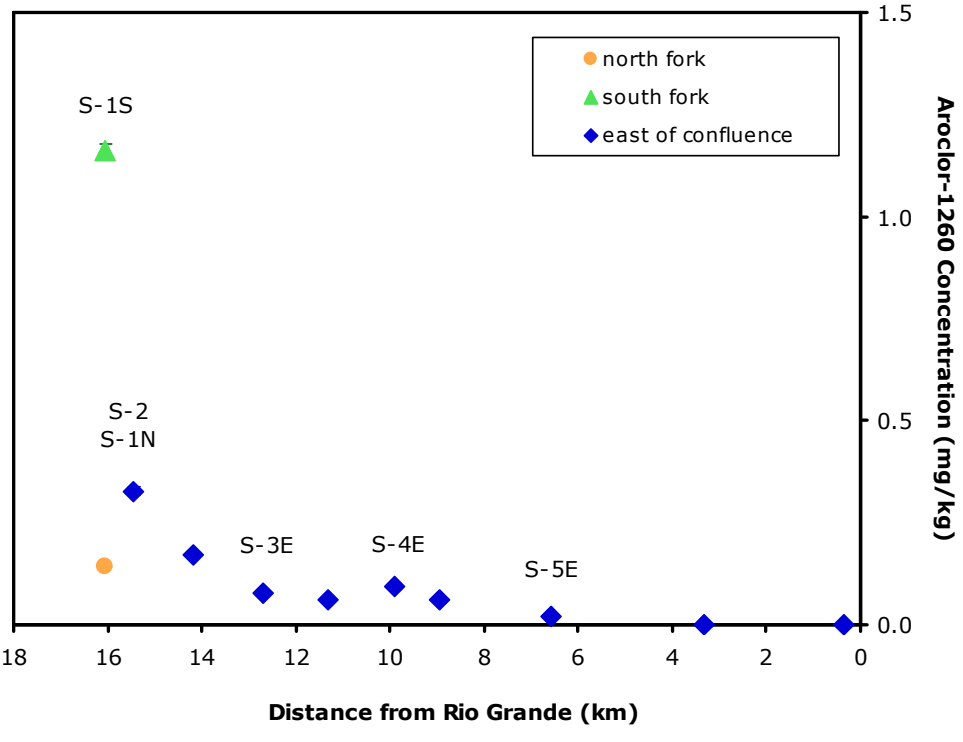


a.

Notes: Error bars indicate upper and lower bounds on the averages based on replacing nondetect values with either the detection limit (upper bound) or zero (lower bound). A value of zero is shown where there are no detected results.

Figure 7.1-8 Estimated average concentrations of select PCBs in fine facies sediment in Sandia Canyon





b.

Figure 7.1-8 (continued) Estimated average concentrations of select PCBs in fine facies sediment in Sandia Canyon

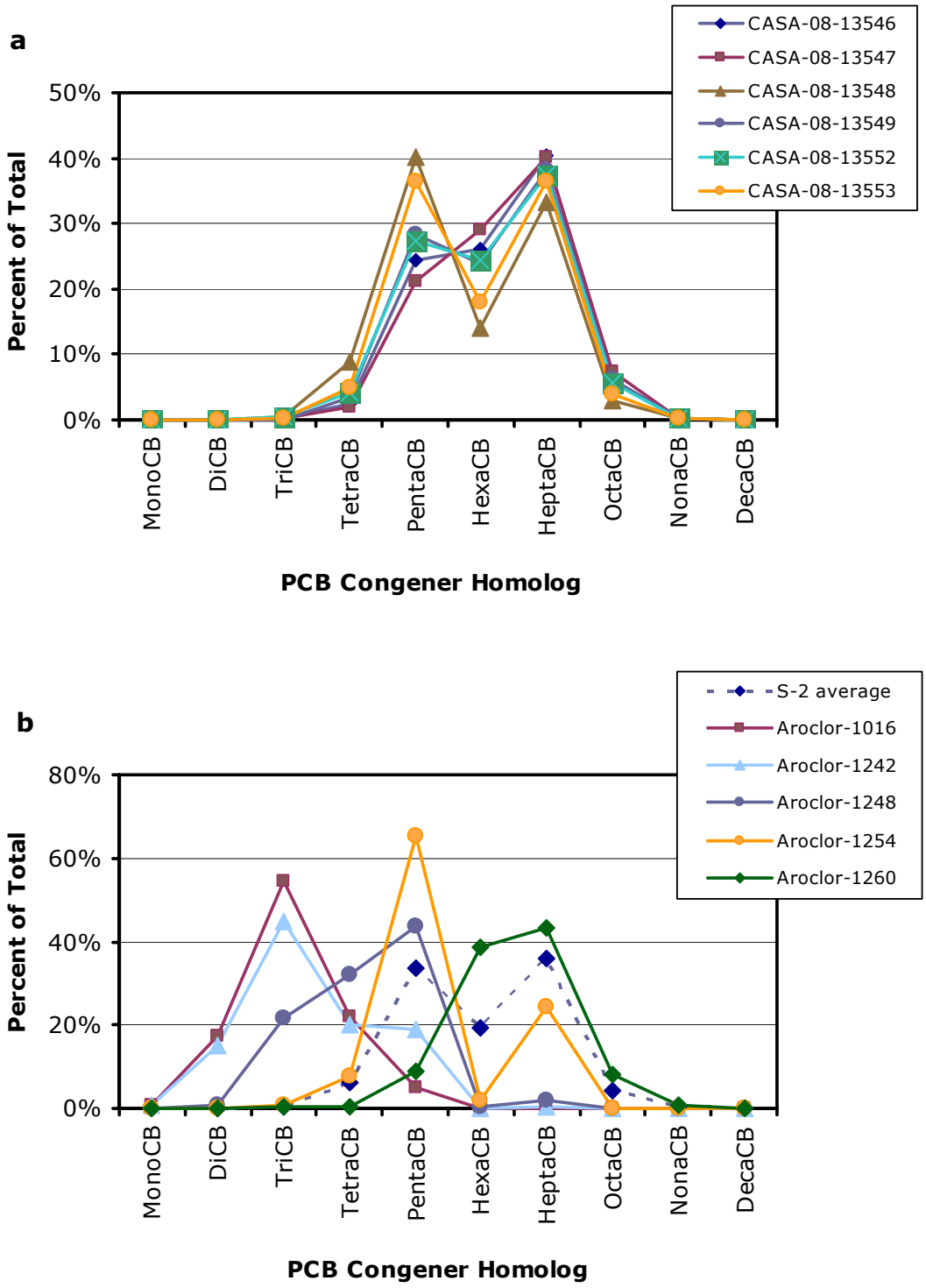
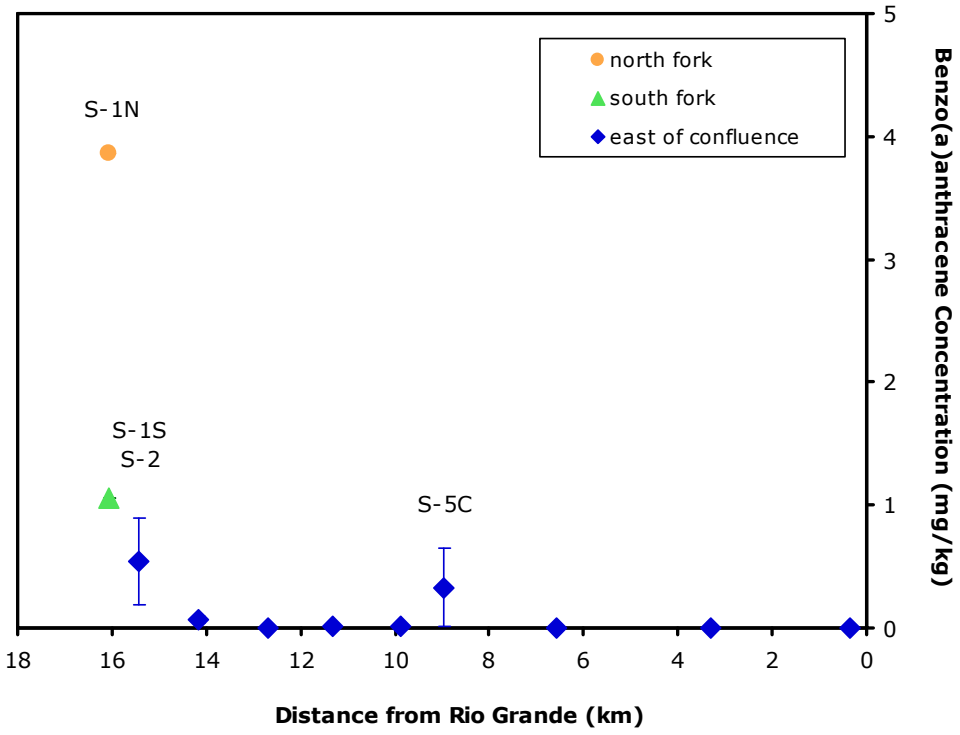
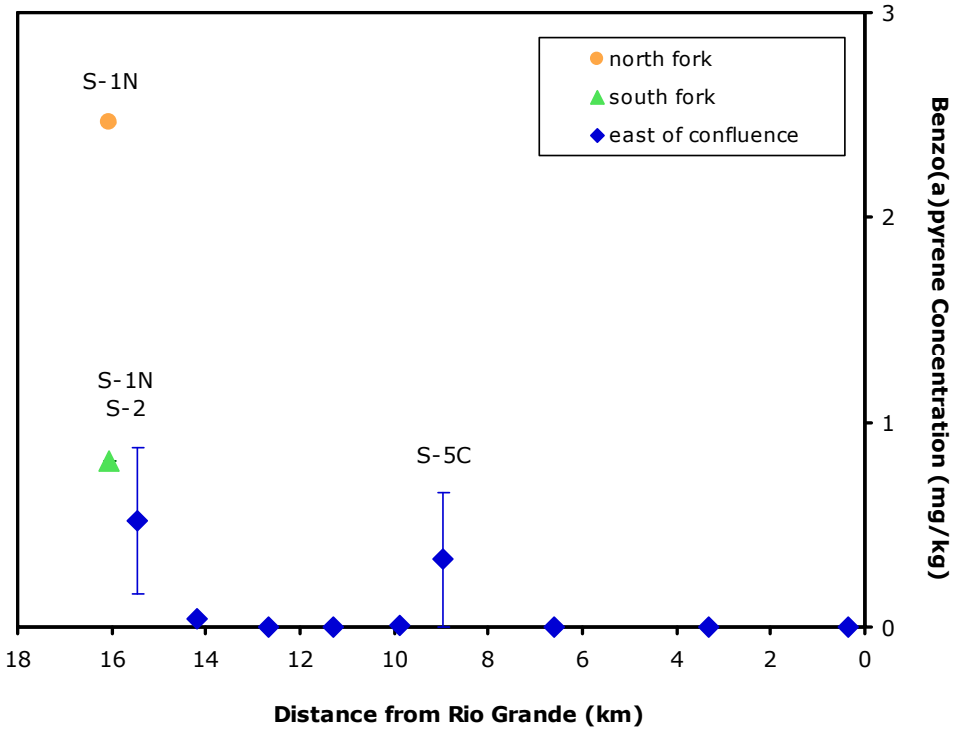


Figure 7.1-9 **PCB congener homolog data, presented as percent of total; (a) homolog data for six Sandia Canyon sediment samples; (b) average homolog percentages for Sandia Canyon sediment samples and Aroclor samples**

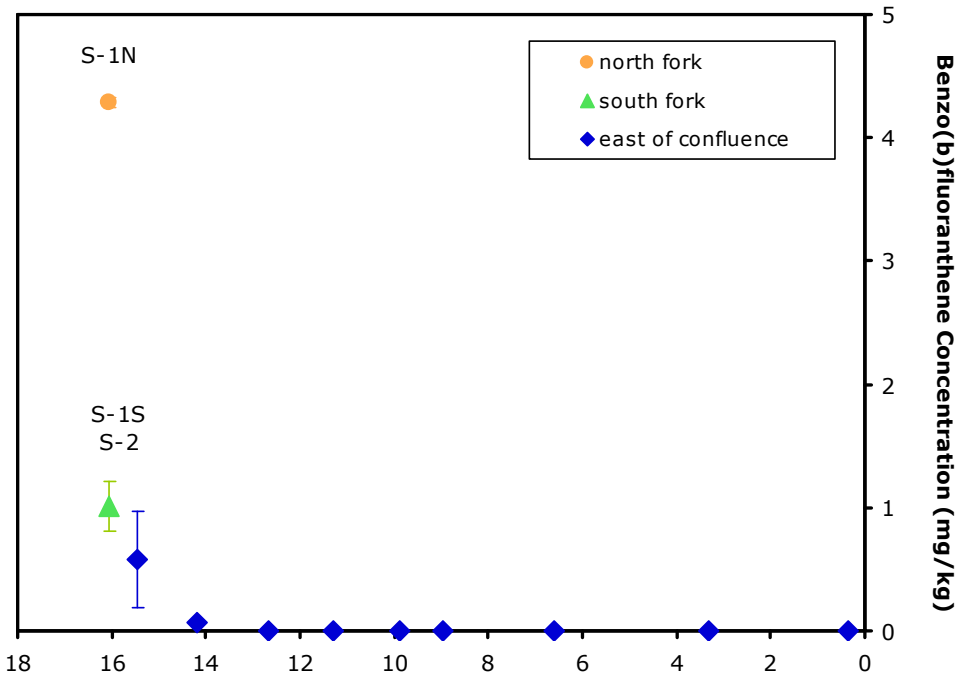


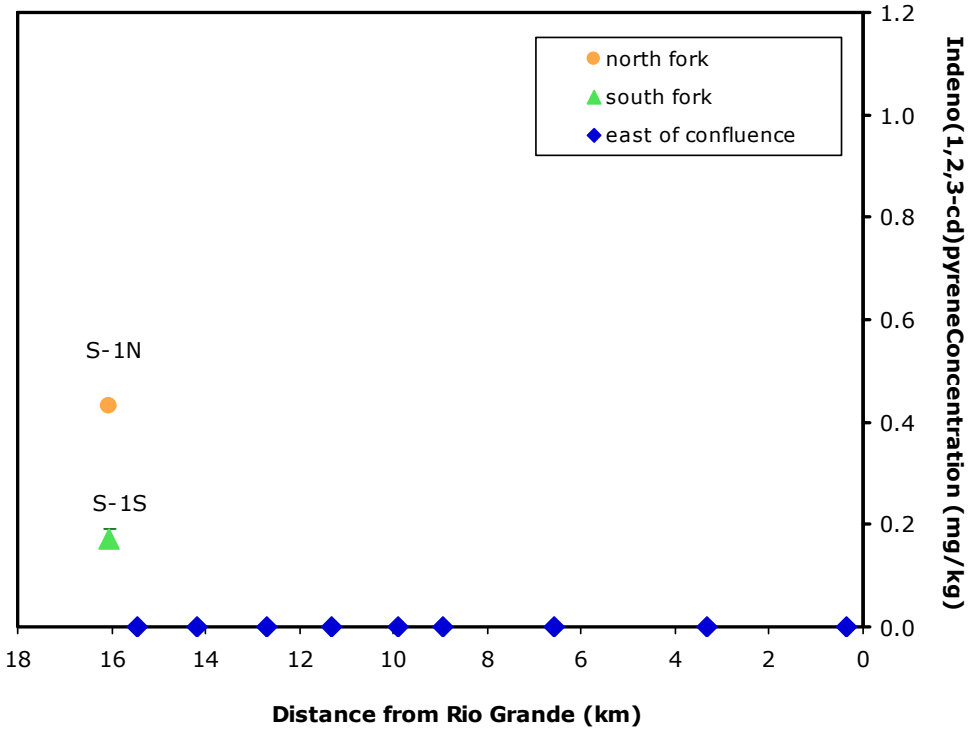


a.

Notes: Error bars indicate upper and lower bounds on the averages based on replacing nondetect values with either the detection limit (upper bound) or zero (lower bound). A value of zero is shown where there are no detected results.

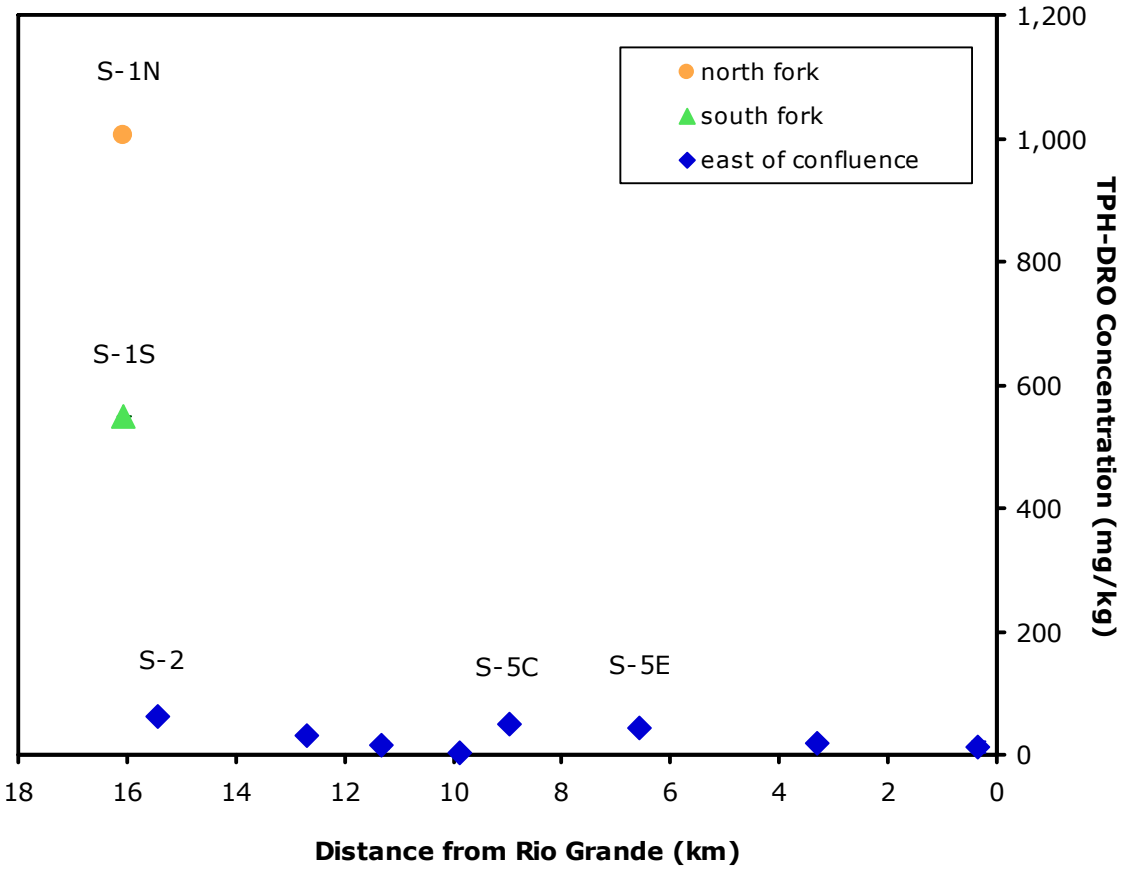
Figure 7.1-10 Estimated average concentrations of select PAHs in fine facies sediment in Sandia Canyon





b.

Figure 7.1-10 (continued) Estimated average concentrations of select PAHs in fine facies sediment in Sandia Canyon



Notes: Error bars indicate upper and lower bounds on the averages based on replacing nondetect values with either the detection limit (upper bound) or zero (lower bound).

Figure 7.1-11 Estimated average concentrations of TPH-DRO in fine facies sediment in Sandia Canyon

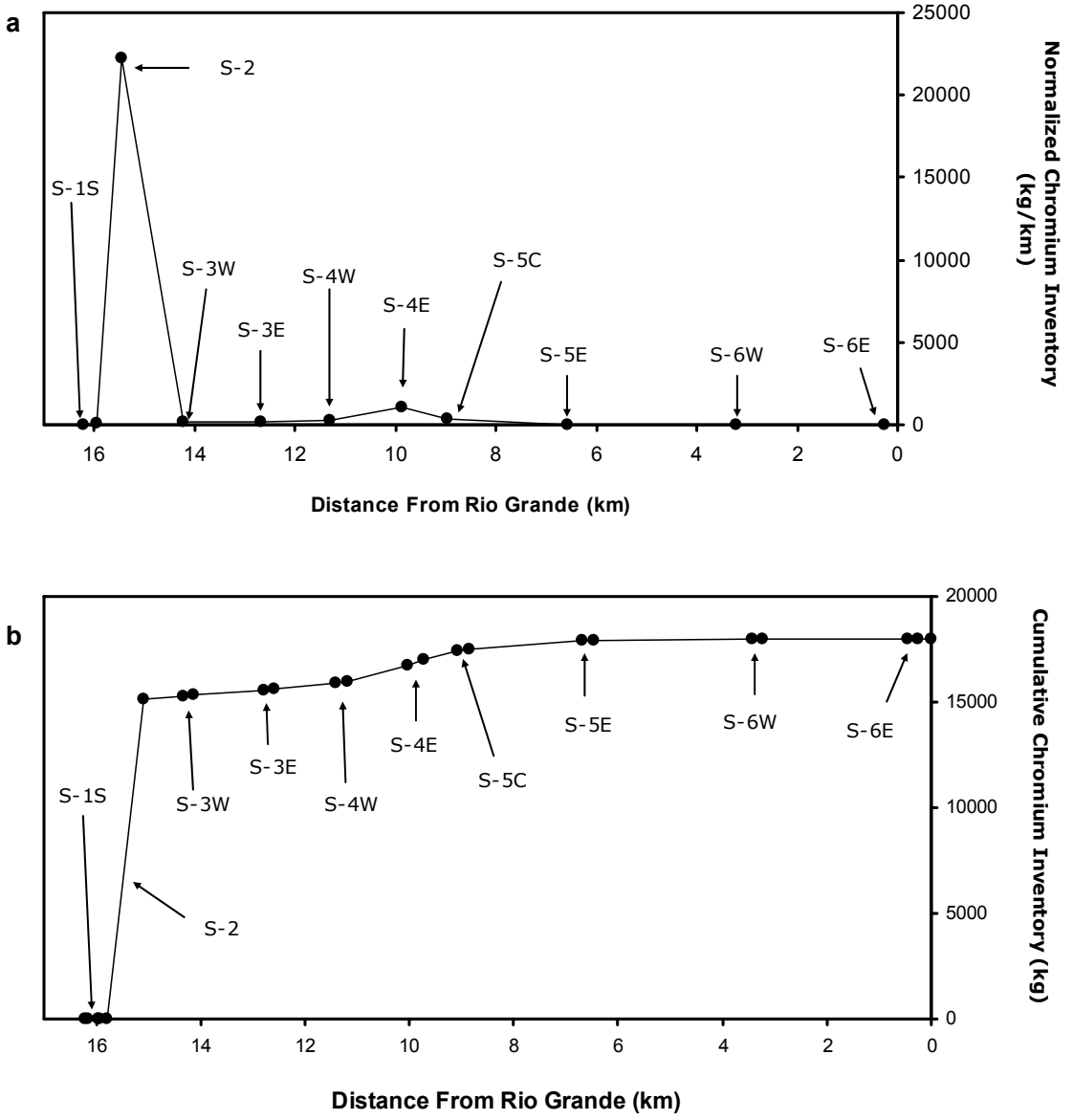


Figure 7.1-12 Estimated anthropogenic chromium inventory in Sandia Canyon; (a) normalized inventory (kg/km); (b) cumulative inventory (kg)

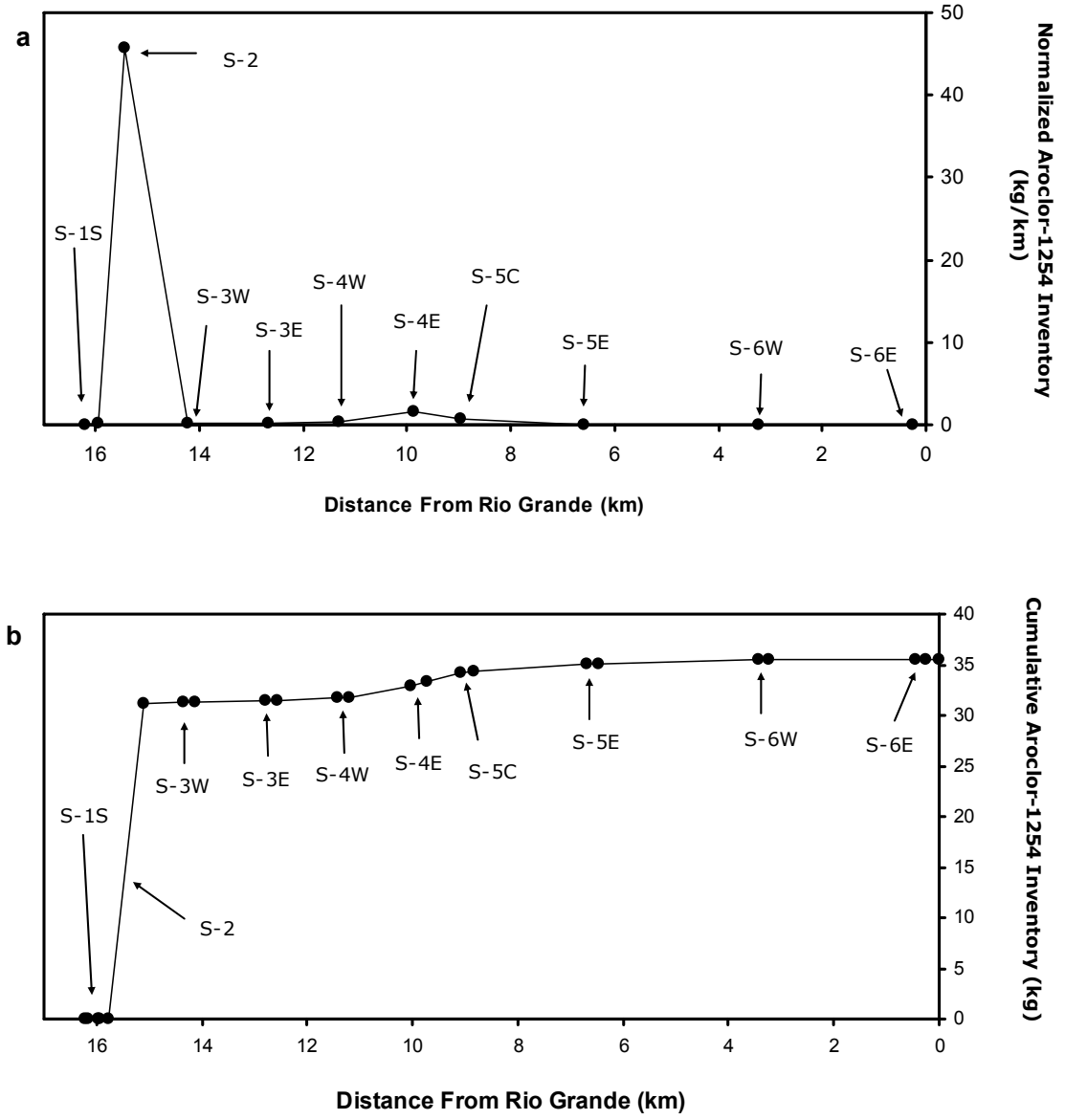


Figure 7.1-13 Estimated Aroclor-1254 inventory in Sandia Canyon; (a) normalized inventory (kg/km); (b) cumulative inventory (kg)

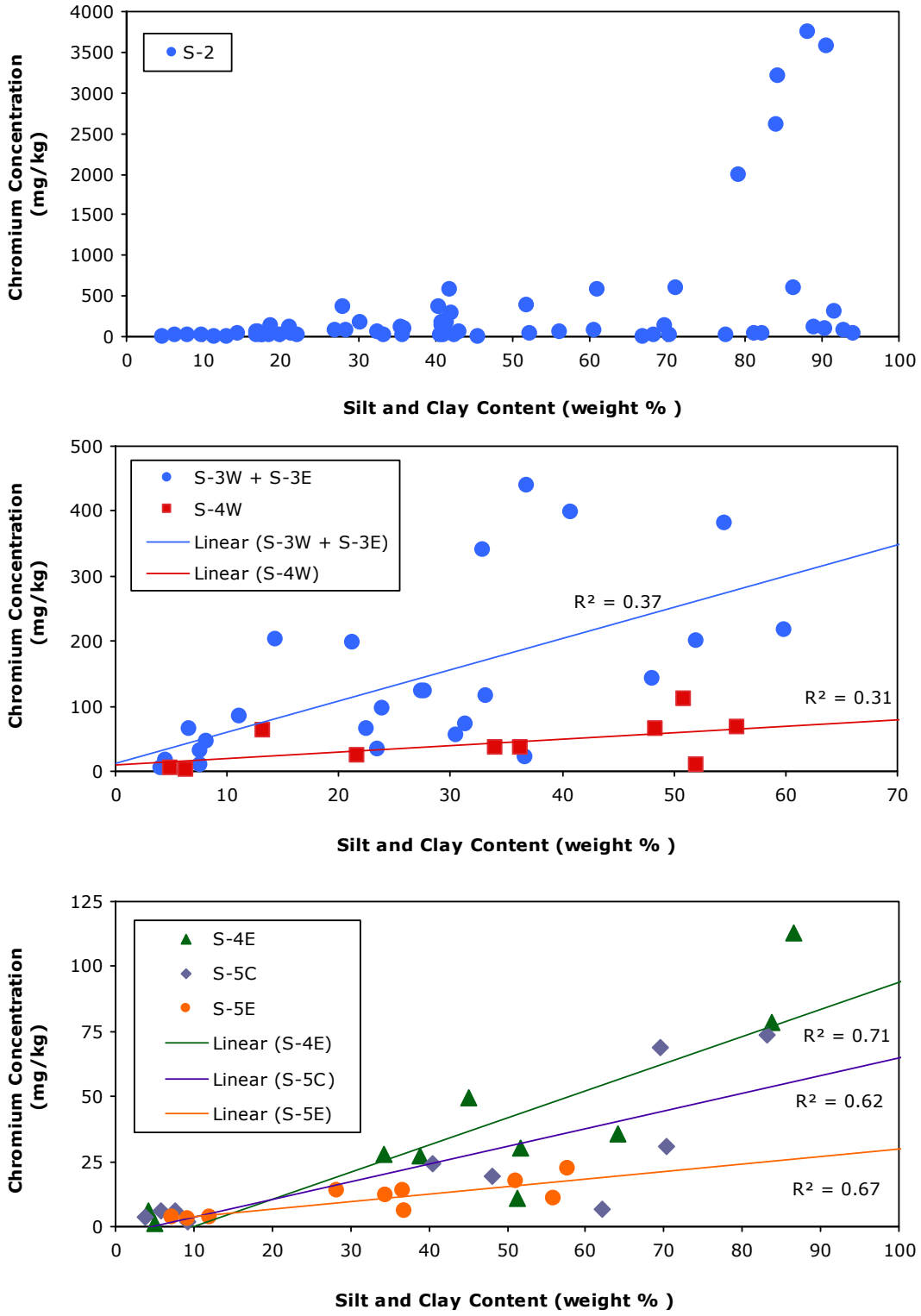


Figure 7.1-14 Relations between chromium concentration and silt and clay content in Sandia Canyon sediment samples

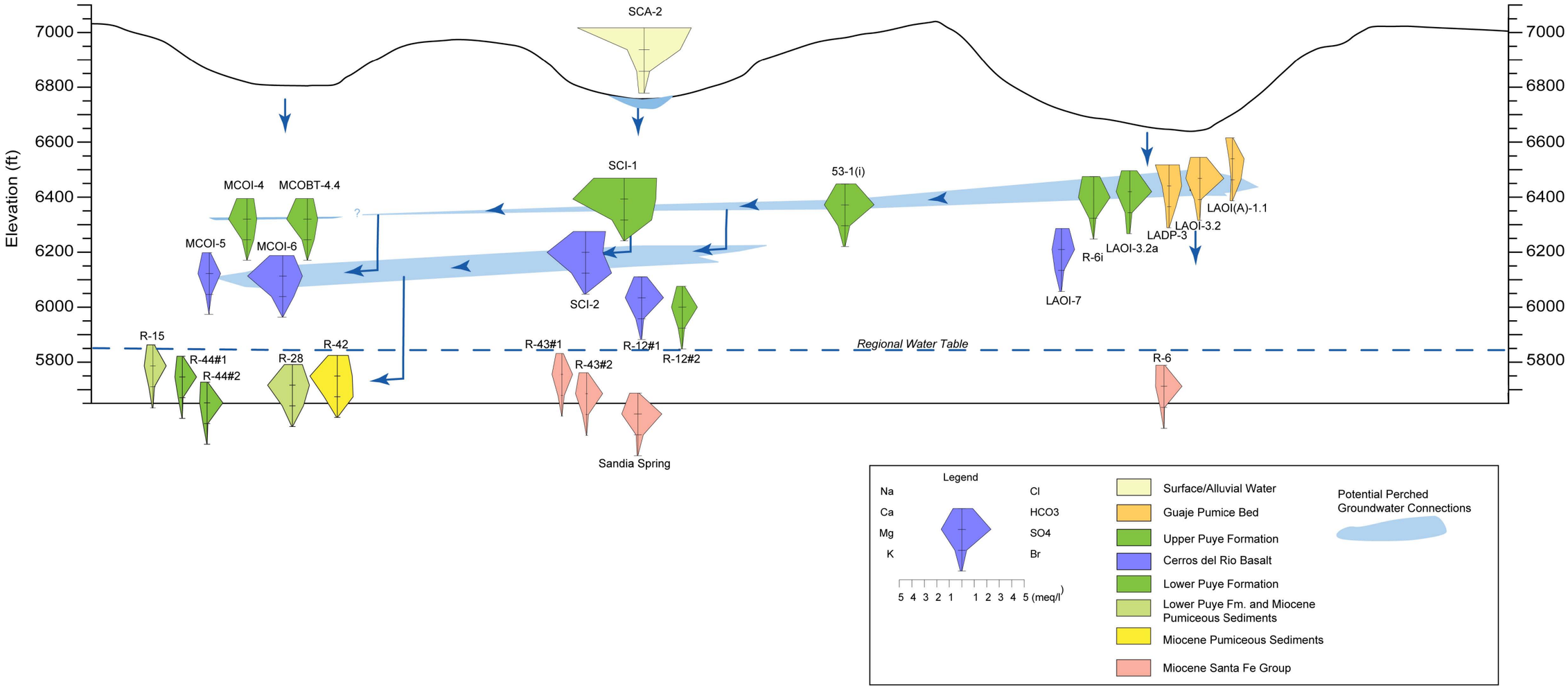


Figure 7.2-1 Conceptual model for mixing of groundwater types beneath various canyons, including major ion chemistry

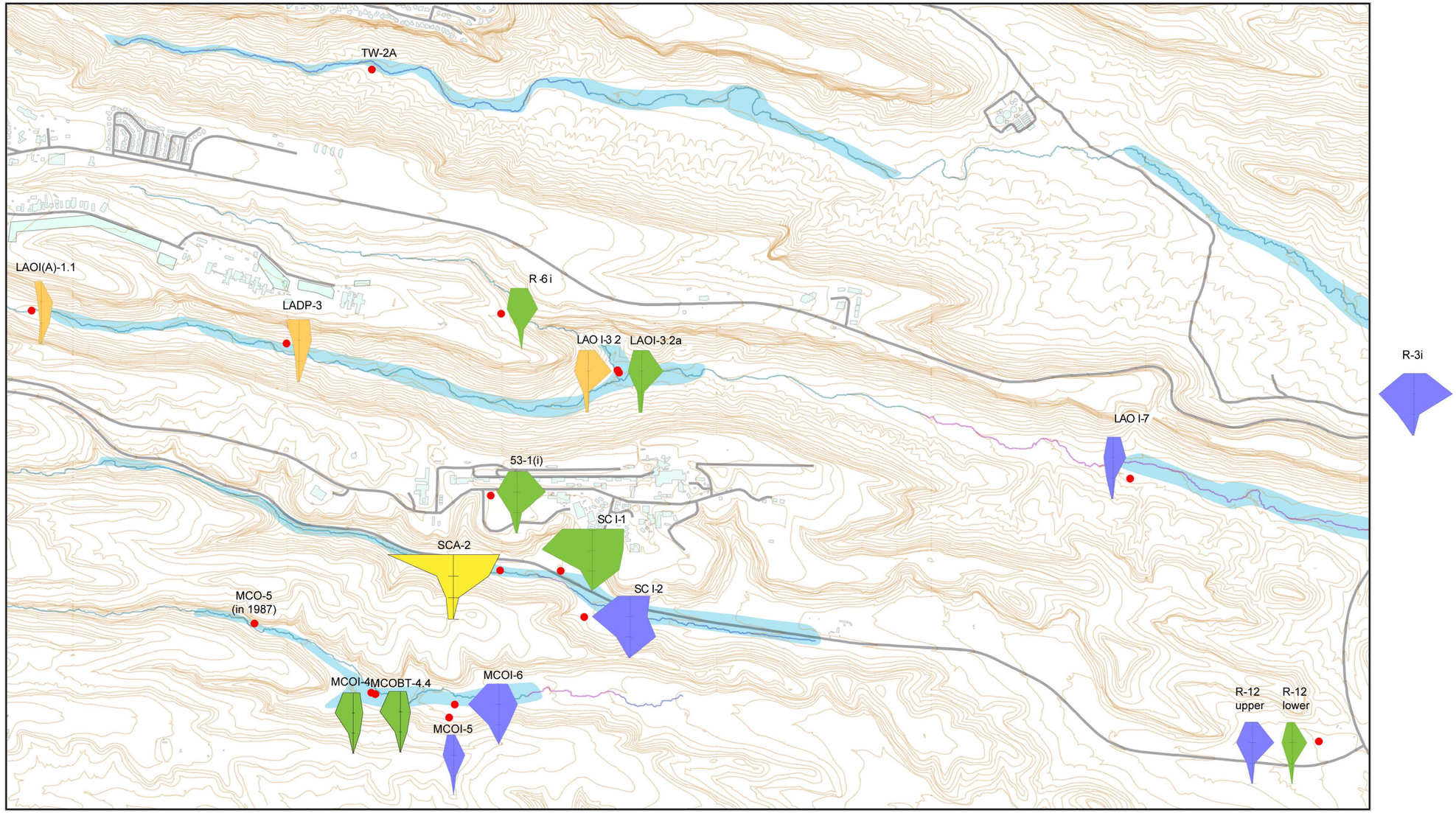


Figure 7.2-2 Major ion chemistry of perched intermediate groundwaters near Sandia Canyon

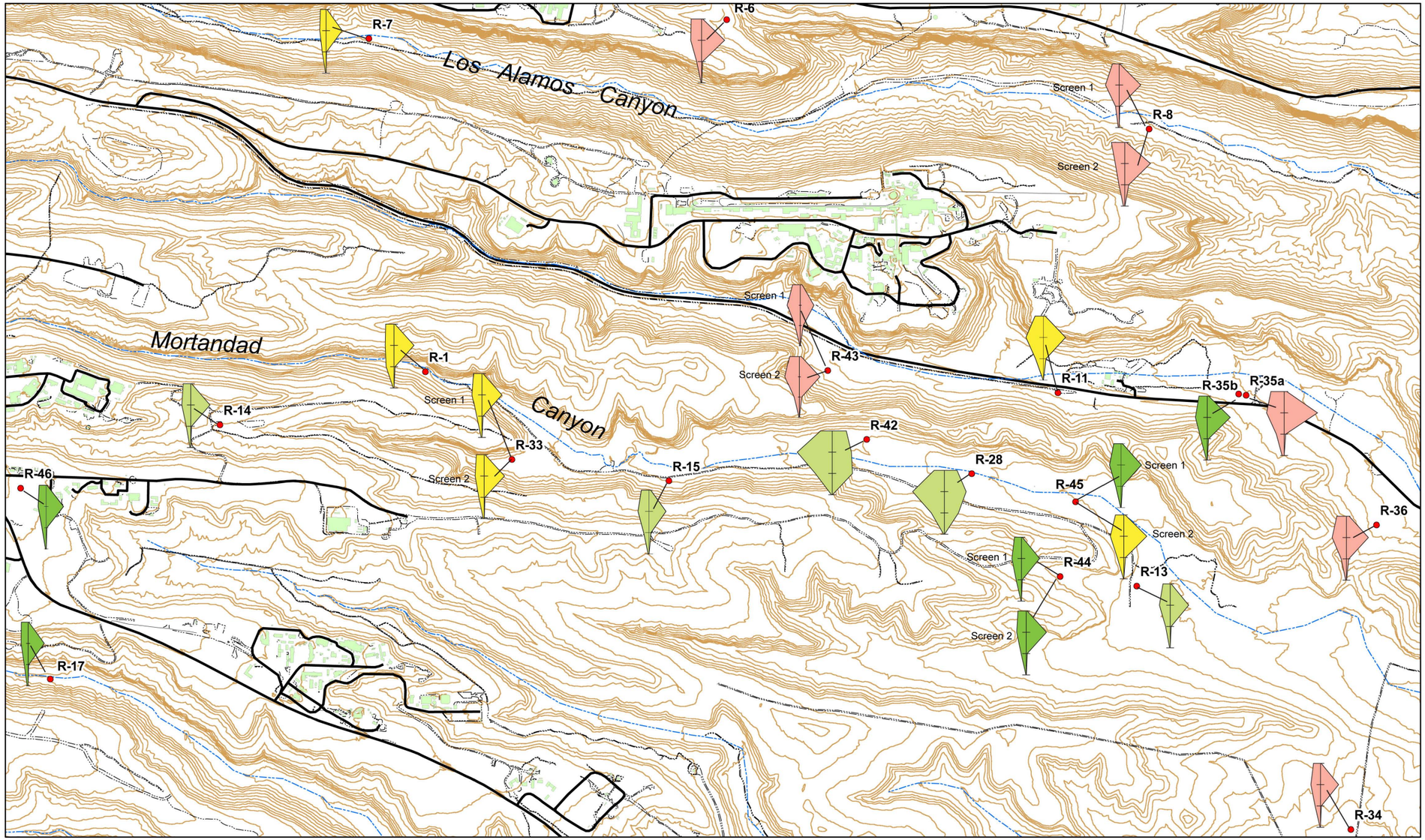
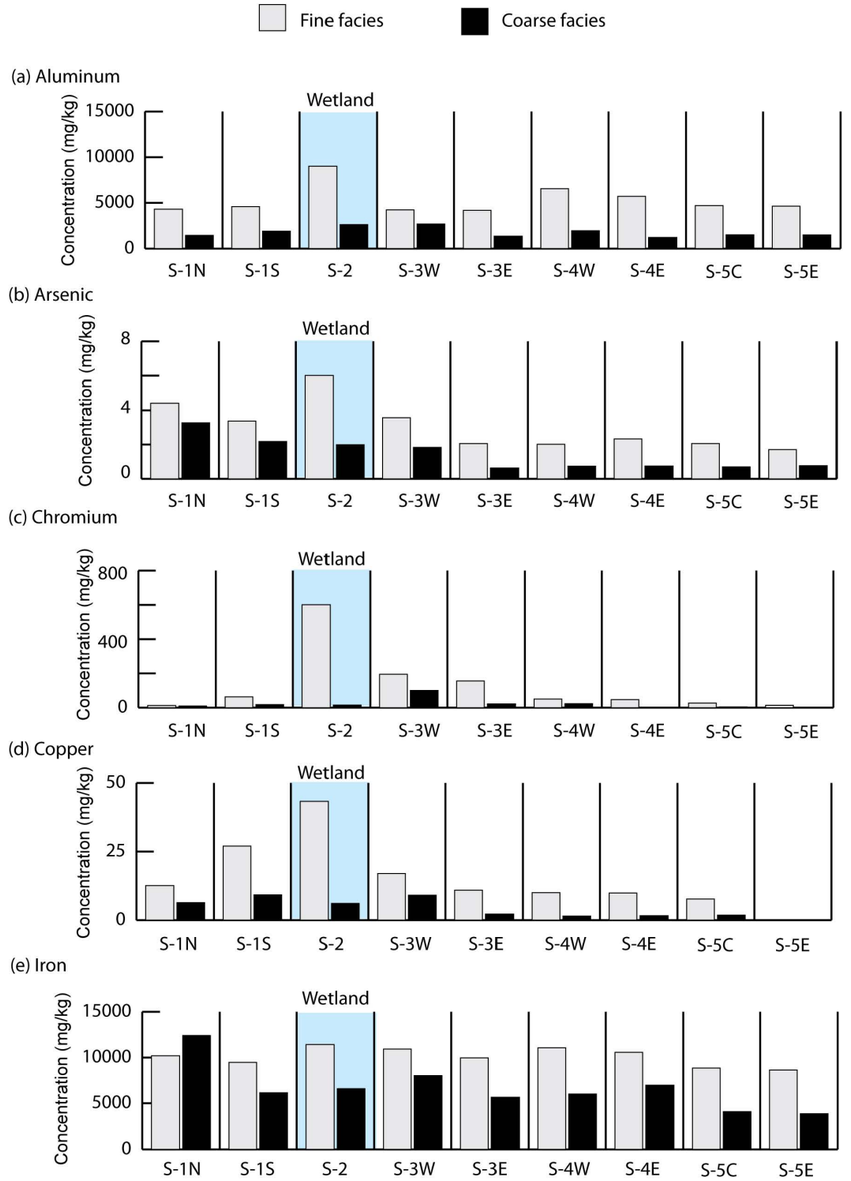


Figure 7.2-3 Major ion chemistry of regional groundwaters near Sandia Canyon



Notes: Mid-point averages shown in these plots are from Table D-1.2-1 or were calculated from the raw data in Appendix B. The average lead concentration shown here for the coarse facies in S-2 is less than that reported in Table D-1.2-1 because it was recalculated after removing a single high value that skewed the average.

Figure 7.2-4 Average concentrations of selected trace metals in fine and coarse facies of sediments in Sandia Canyon: (a) aluminum, (b) arsenic, (c) chromium, (d) copper, (e) iron, (f) lead, (g) manganese, (h) molybdenum, (i) selenium, and (j) zinc

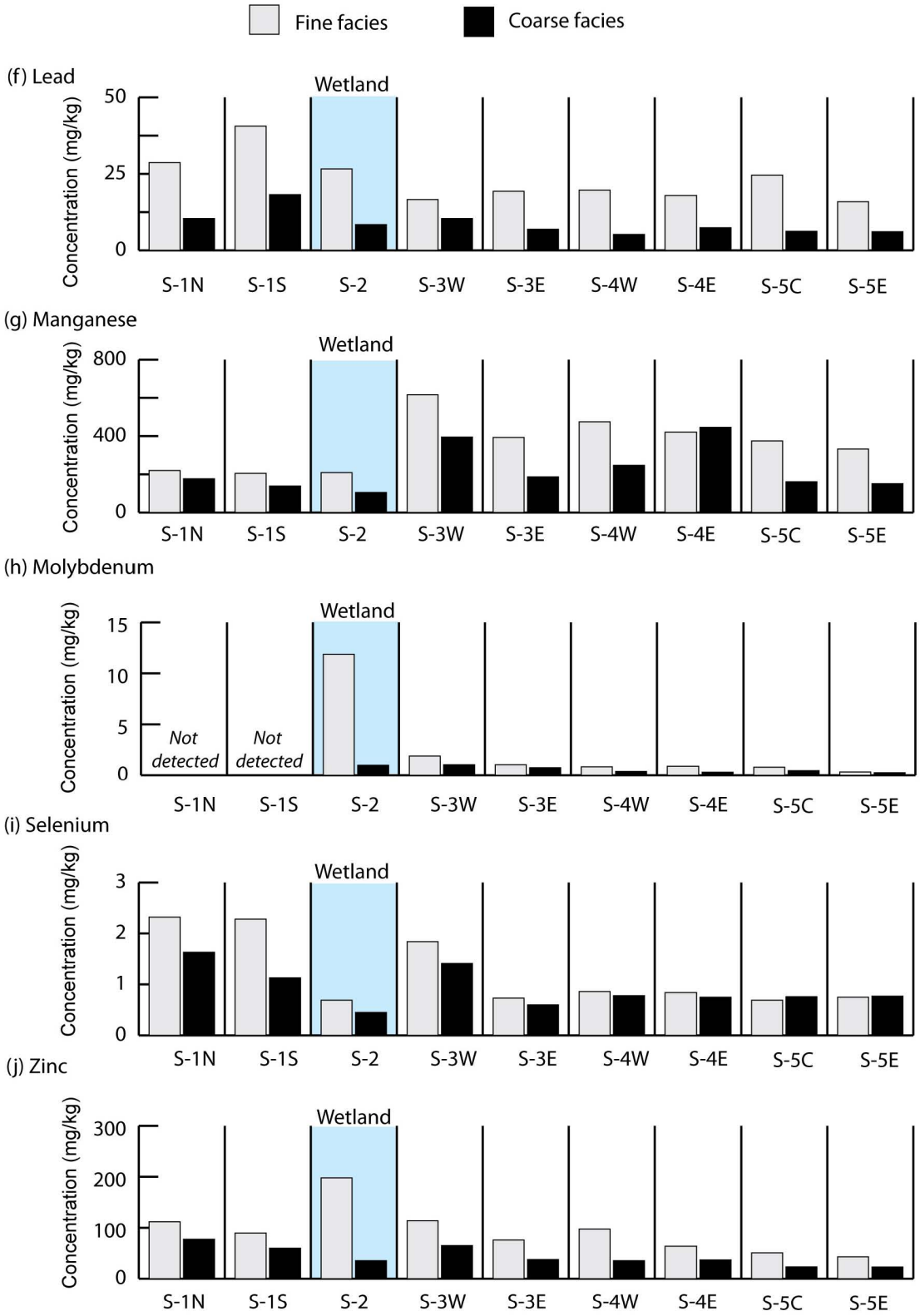


Figure 7.2-4 (continued) **Average concentrations of selected trace metals in fine and coarse facies of sediments in Sandia Canyon: (a) aluminum, (b) arsenic, (c) chromium, (d) copper, (e) iron, (f) lead, (g) manganese, (h) molybdenum, (i) selenium, and (j) zinc**

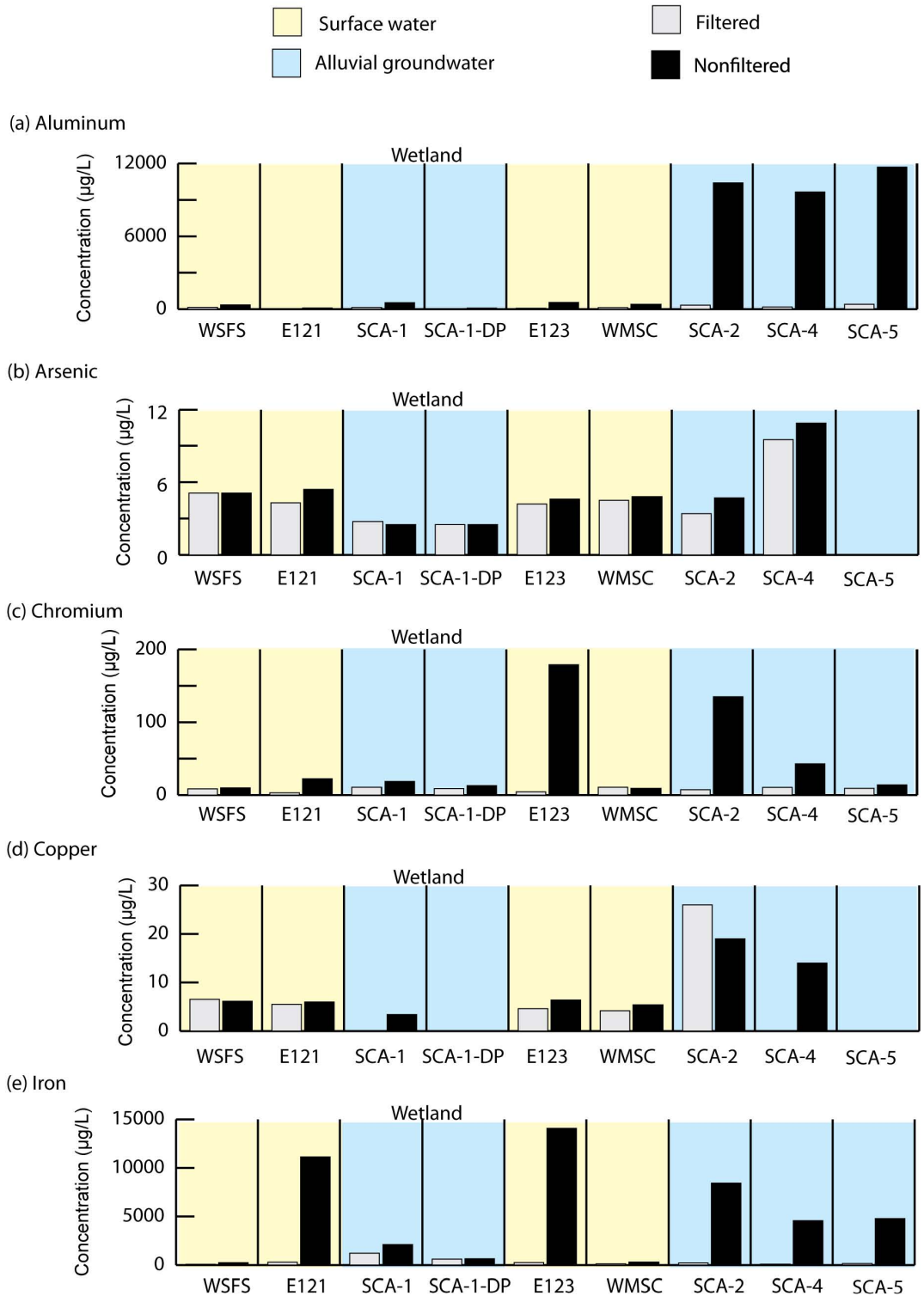


Figure 7.2-5 Average concentrations of selected trace metals in surface water and alluvial groundwater in Sandia Canyon, 2003–2009: (a) aluminum, (b) arsenic, (c) chromium, (d) copper, (e) iron, (f) lead, (g) manganese, (h) molybdenum, (i) selenium, and (j) zinc

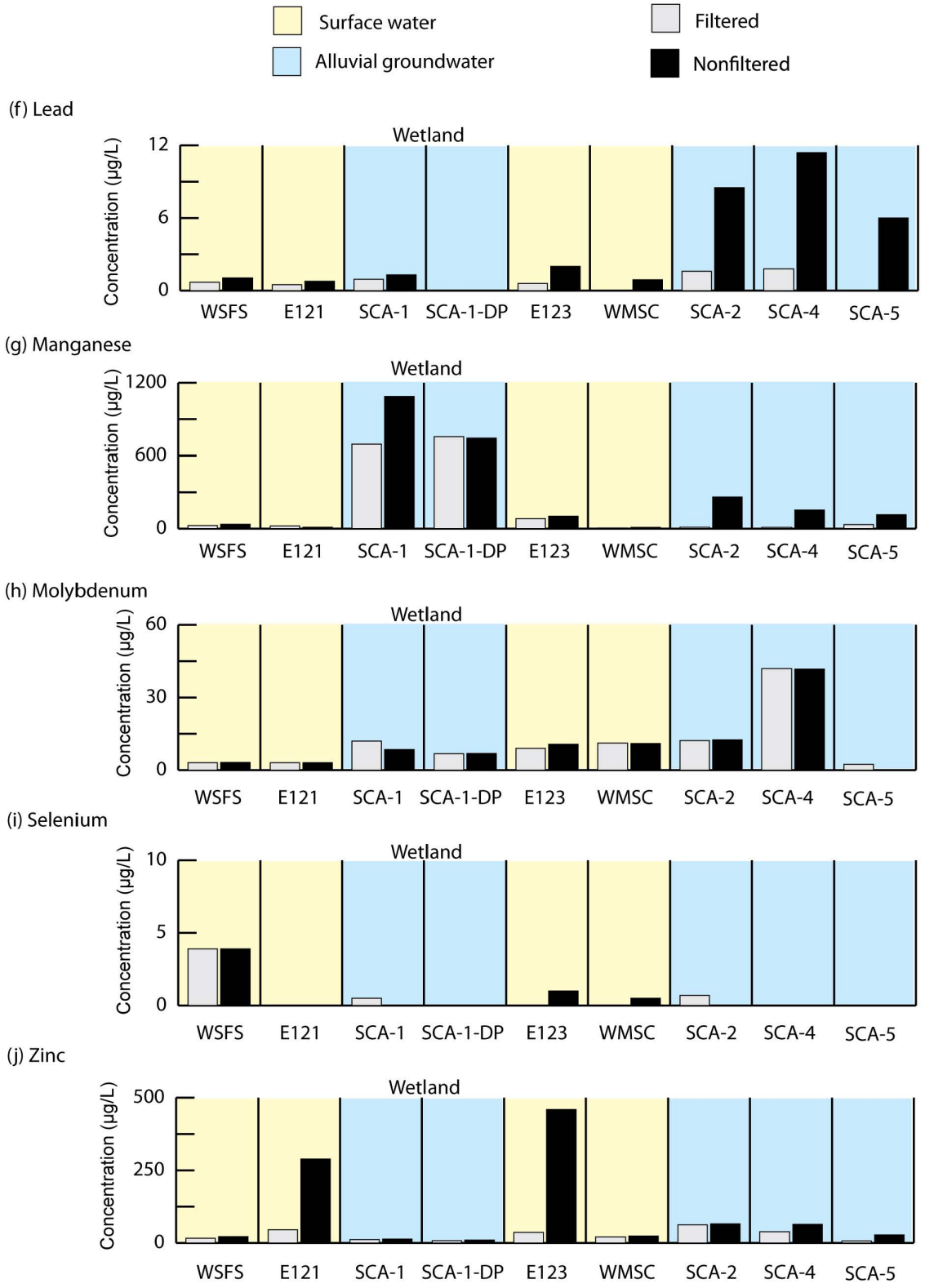


Figure 7.2-5 (continued) **Average concentrations of selected trace metals in surface water and alluvial groundwater in Sandia Canyon, 2003–2009: (a) aluminum, (b) arsenic, (c) chromium, (d) copper, (e) iron, (f) lead, (g) manganese, (h) molybdenum, (i) selenium, and (j) zinc**

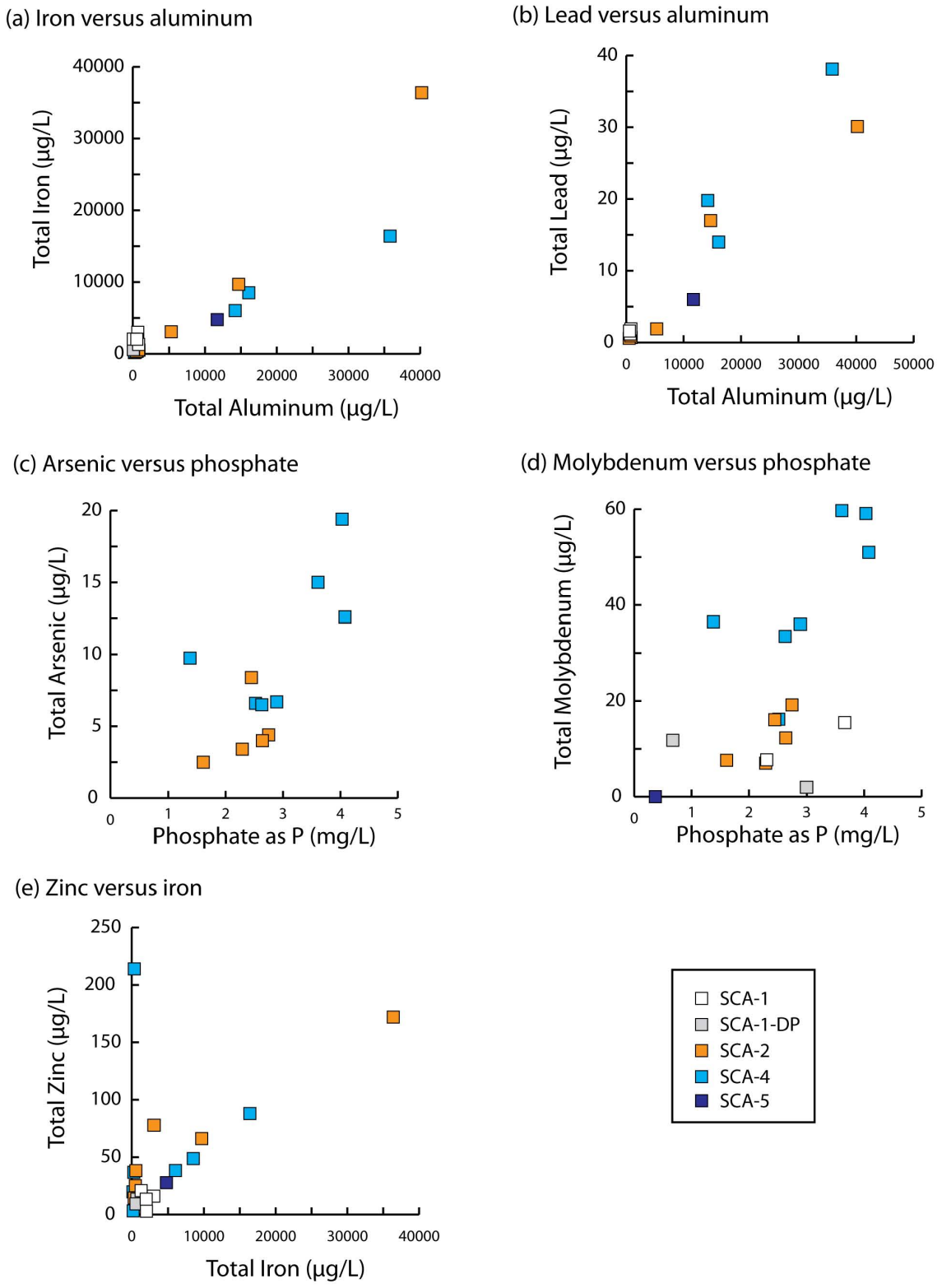


Figure 7.2-6 **Cross-plots of trace metal concentrations in alluvial groundwaters in Sandia Canyon, 2003–2009: (a) iron vs. aluminum, (b) lead vs. aluminum, (c) arsenic vs. phosphate, (d) molybdenum vs. phosphate, and (e) zinc vs. iron**

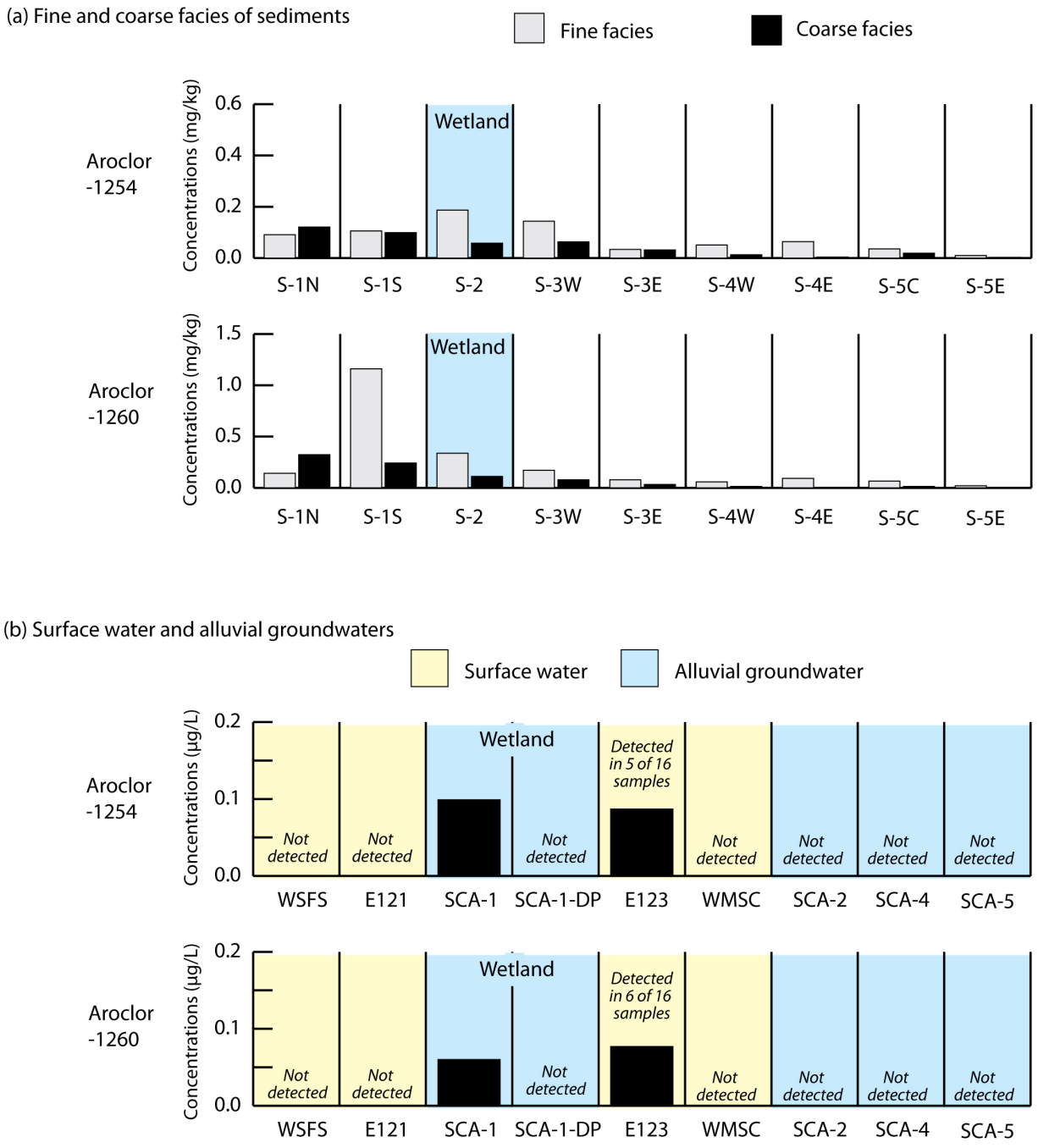


Figure 7.2-7 Average concentrations of selected PCBs in Sandia Canyon: (a) fine and coarse facies of sediments, and (b) surface water and alluvial groundwater, 2003–2009

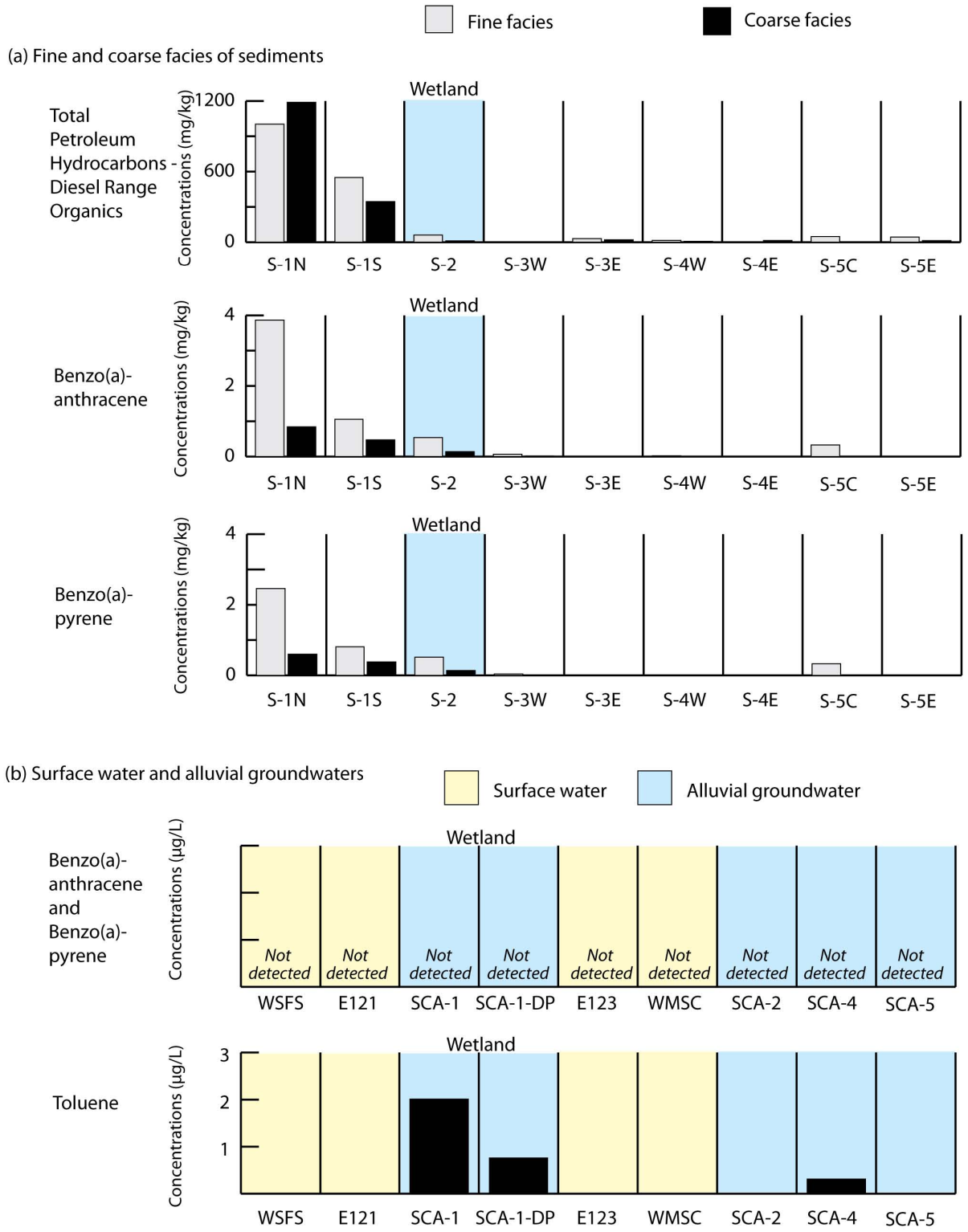


Figure 7.2-8 Average concentrations of other organic COPCs in Sandia Canyon: (a) fine and coarse facies of sediments, and (b) surface water and alluvial groundwater, 2003–2009

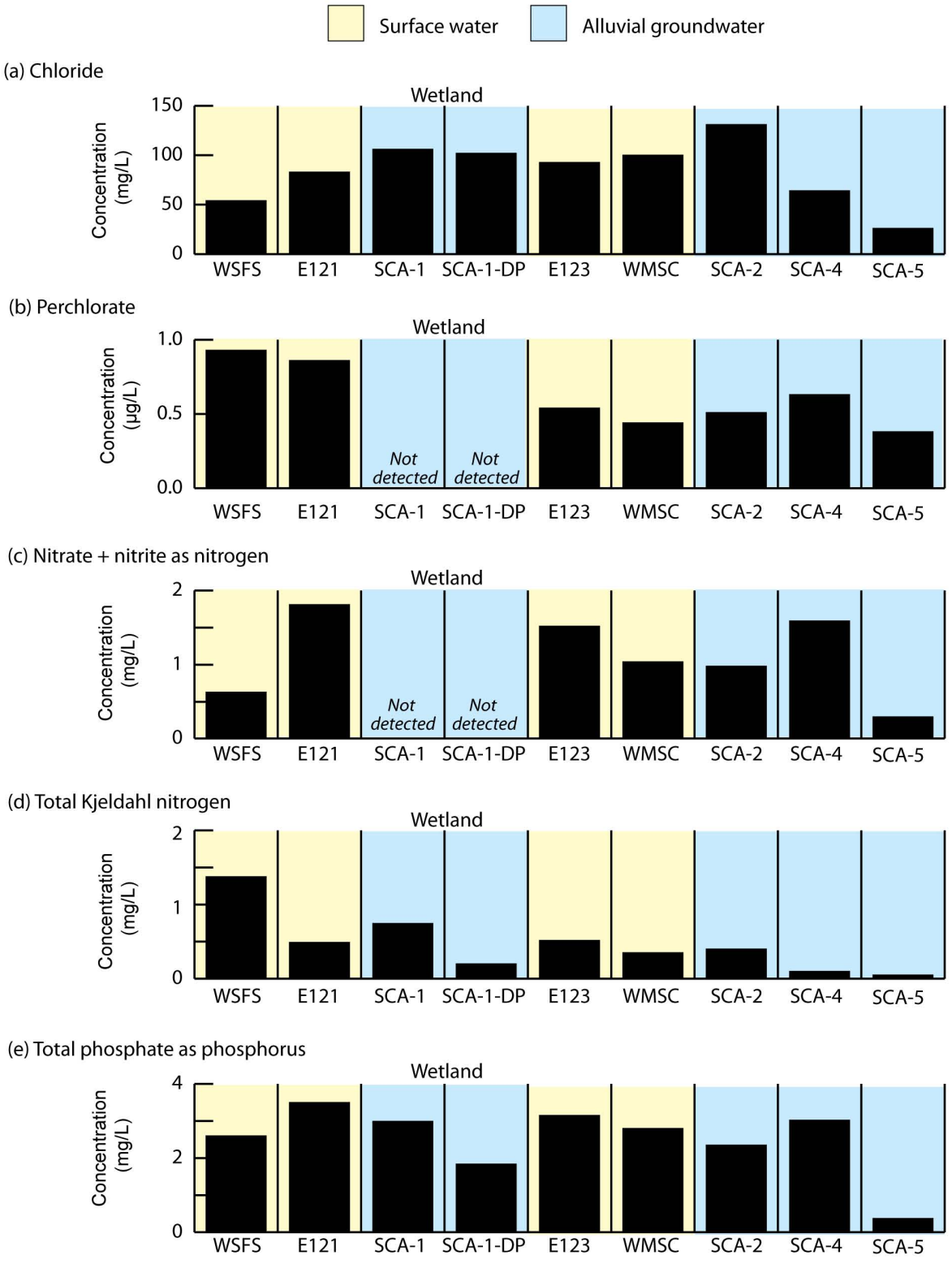


Figure 7.2-9 Average concentrations of other selected inorganic COPCs in surface water and alluvial groundwater in Sandia Canyon, 2003–2009: (a) chloride, (b) perchlorate, (c) nitrate-nitrite as nitrogen, (d) total Kjeldahl nitrogen, and (e) total phosphate as phosphorus

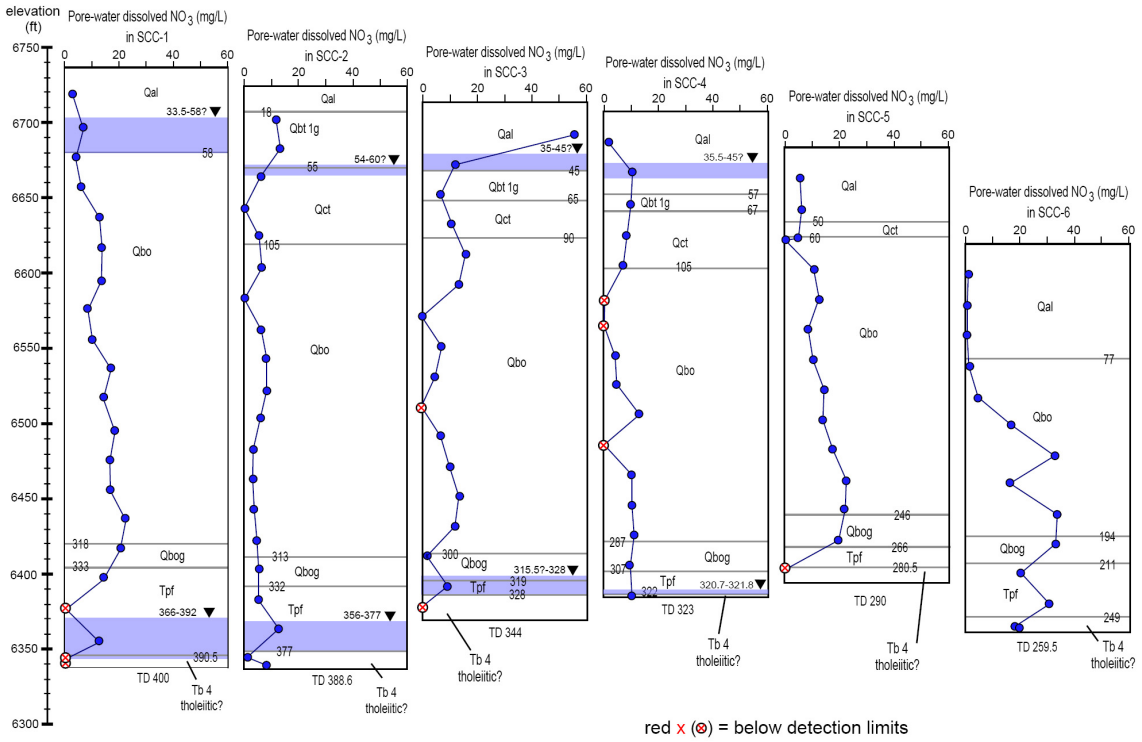


Figure 7.2-10 Porewater nitrate concentrations (mg/L) in vadose zone coreholes SCC-1 to SCC-6

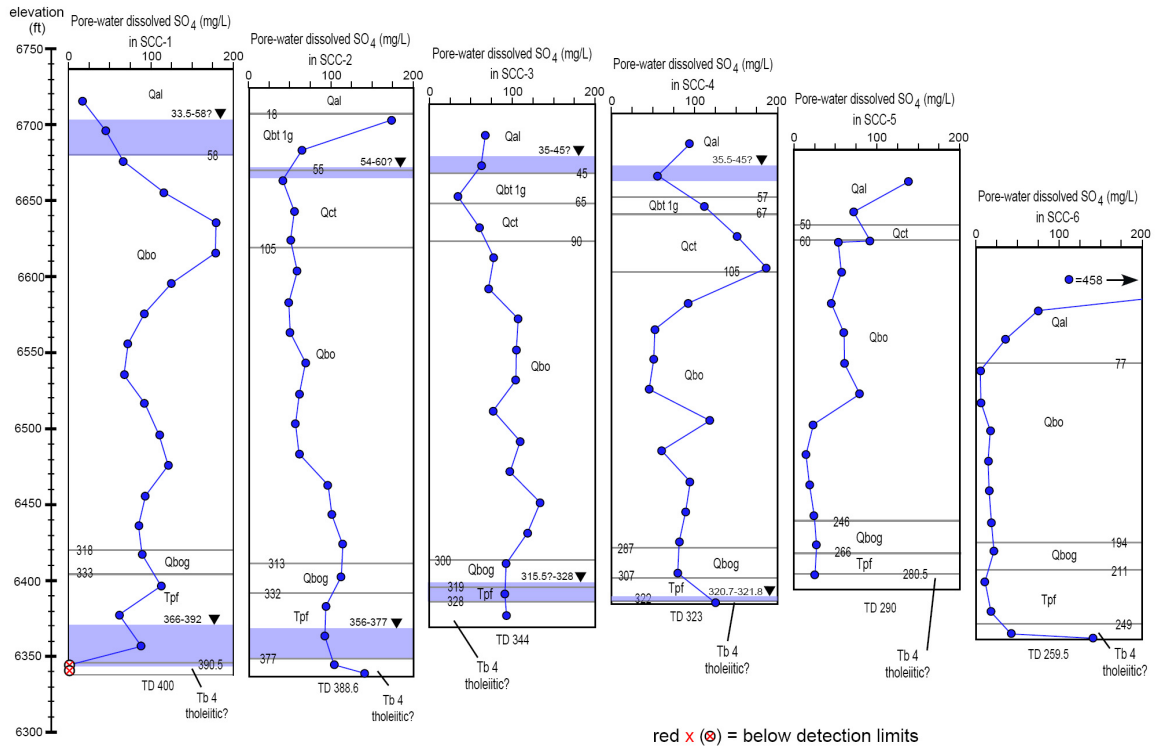


Figure 7.2-11 Porewater sulfate concentrations (mg/L) in vadose zone coreholes SCC-1 to SCC-6

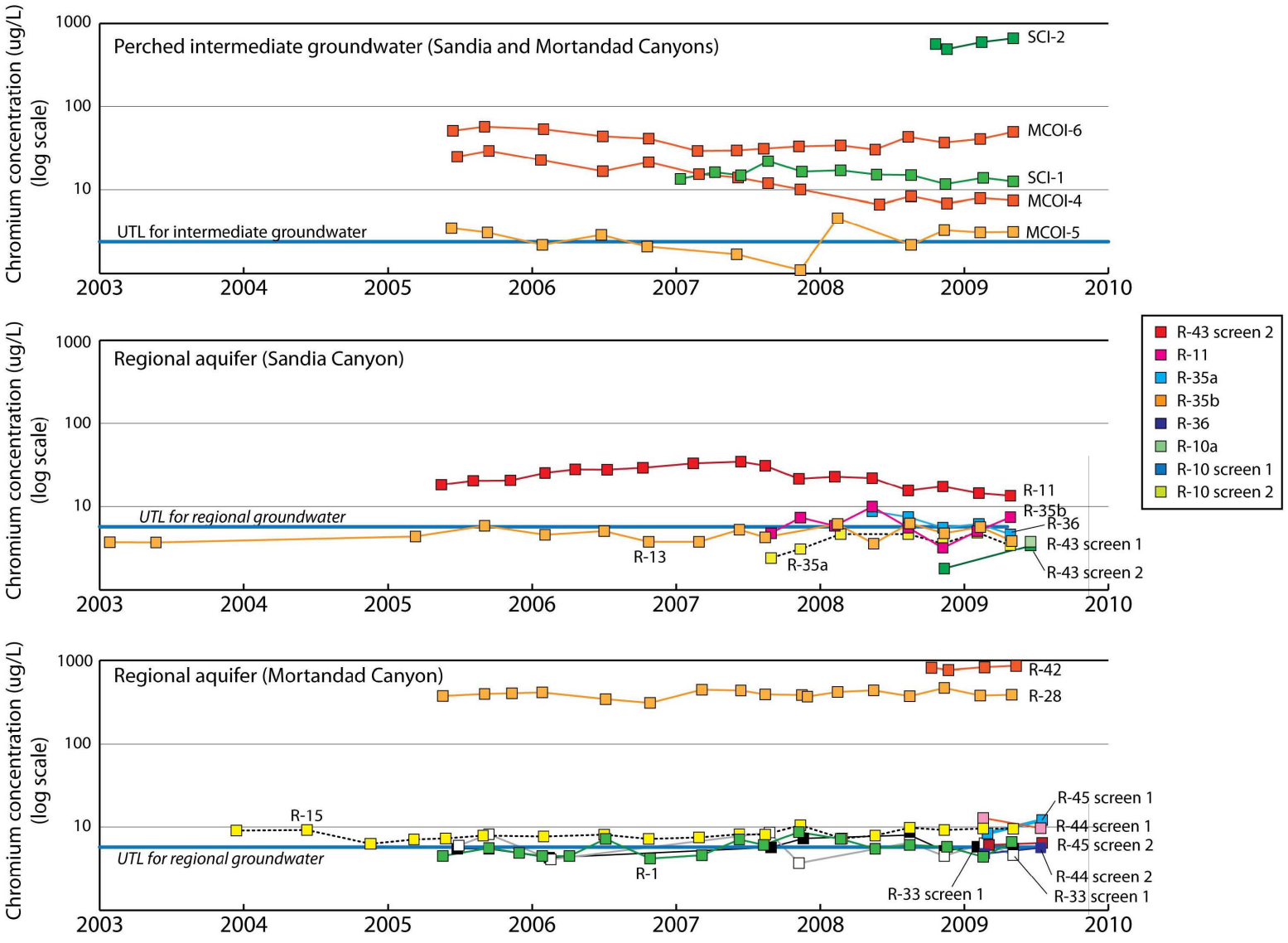


Figure 7.2-12 Chromium concentrations in filtered groundwater samples, Sandia and Mortandad Canyons, 2003 to 2009

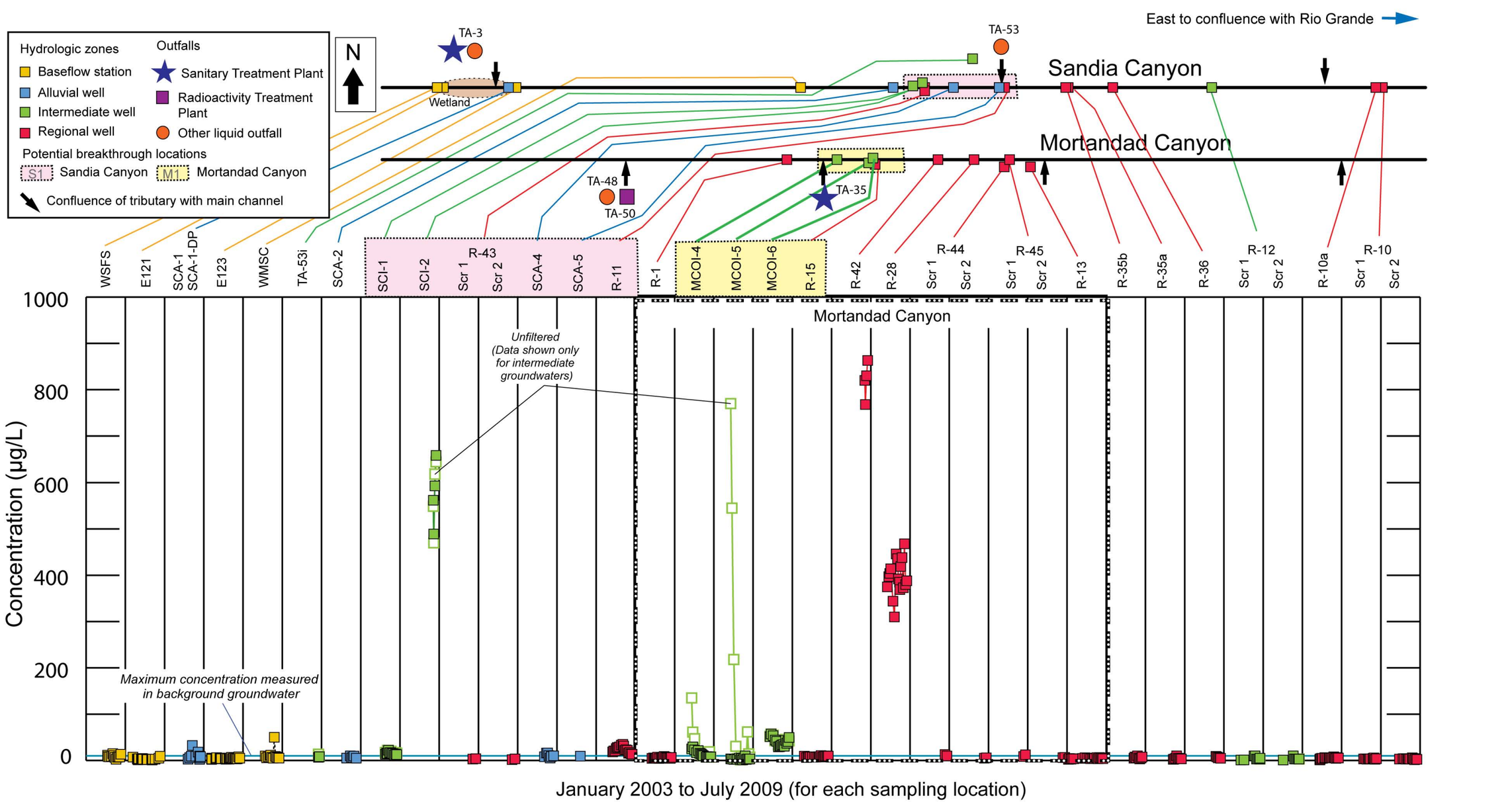


Figure 7.2-13 Chromium concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009

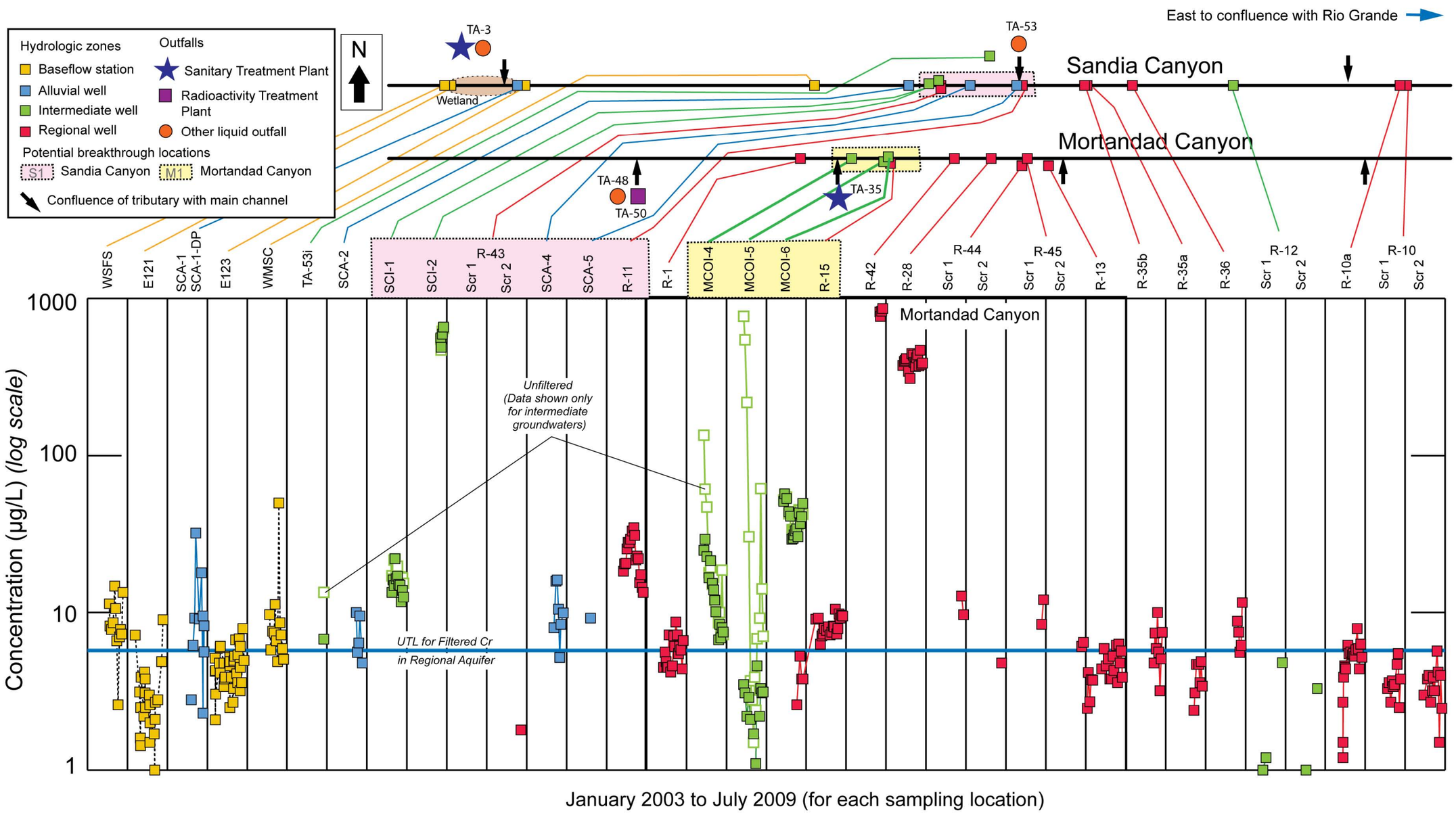


Figure 7.2-13 (continued) **Chromium concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009**

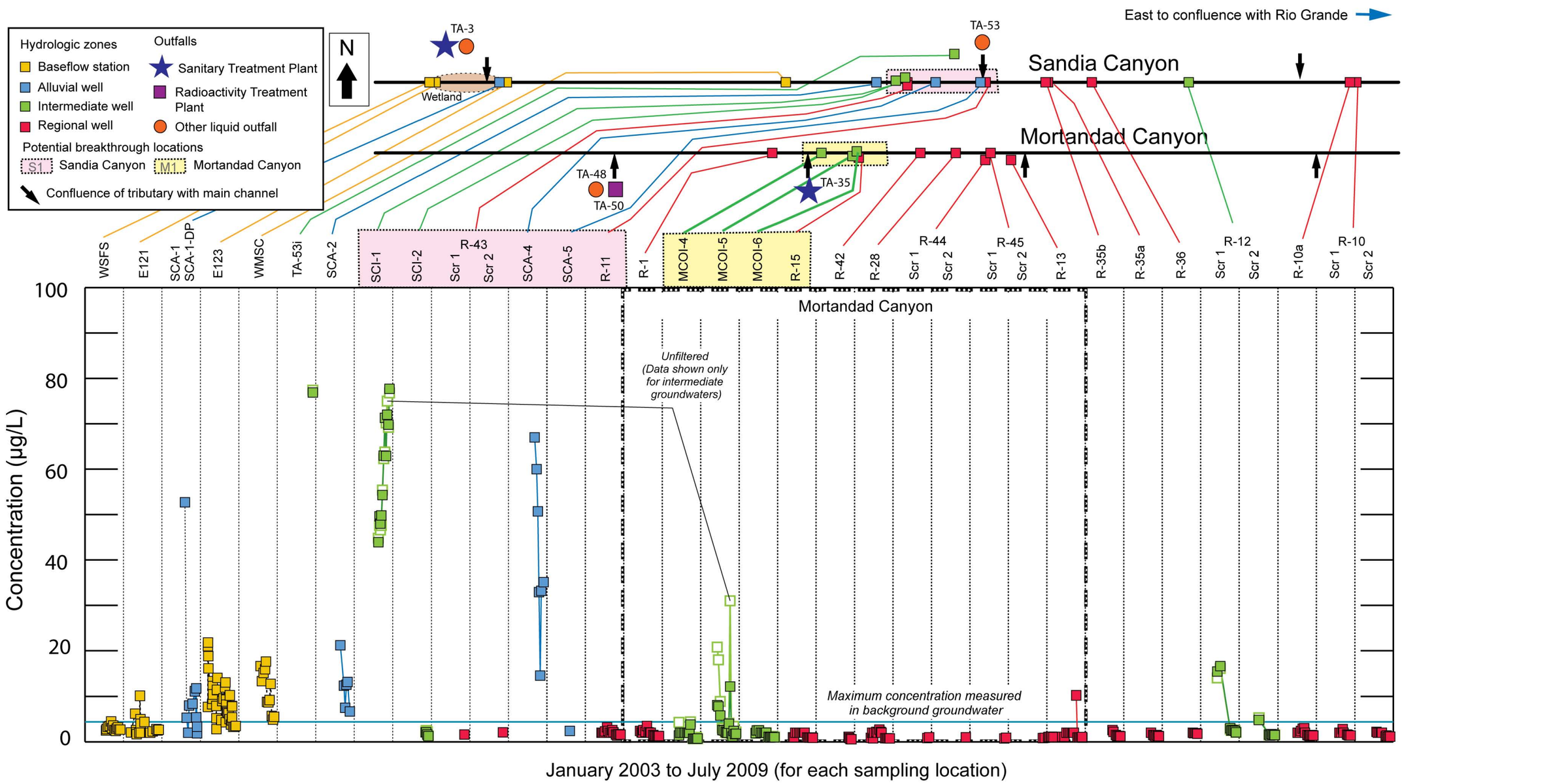


Figure 7.2-14 Molybdenum concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009

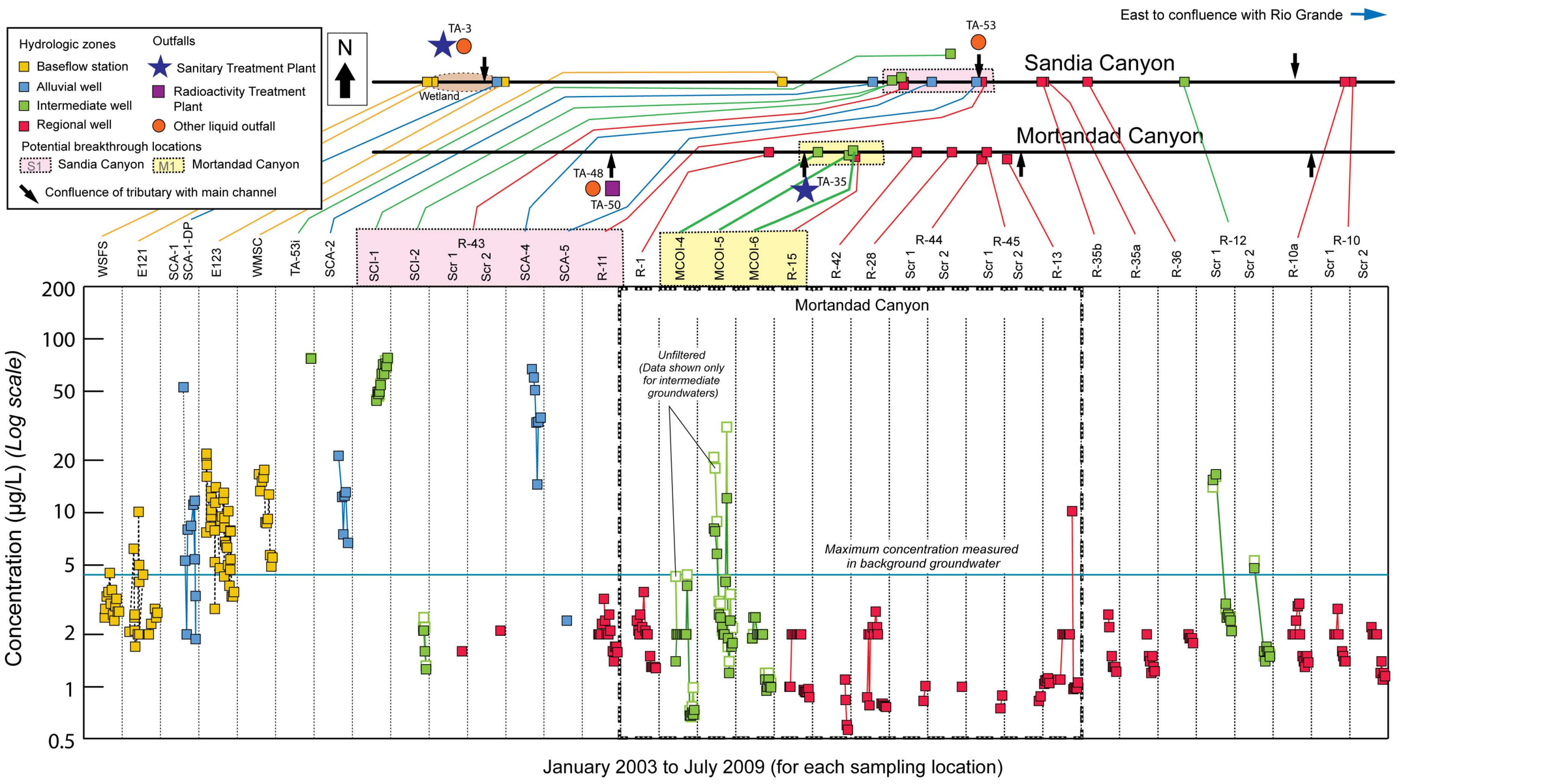


Figure 7.2-14 (continued) **Molybdenum concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009**

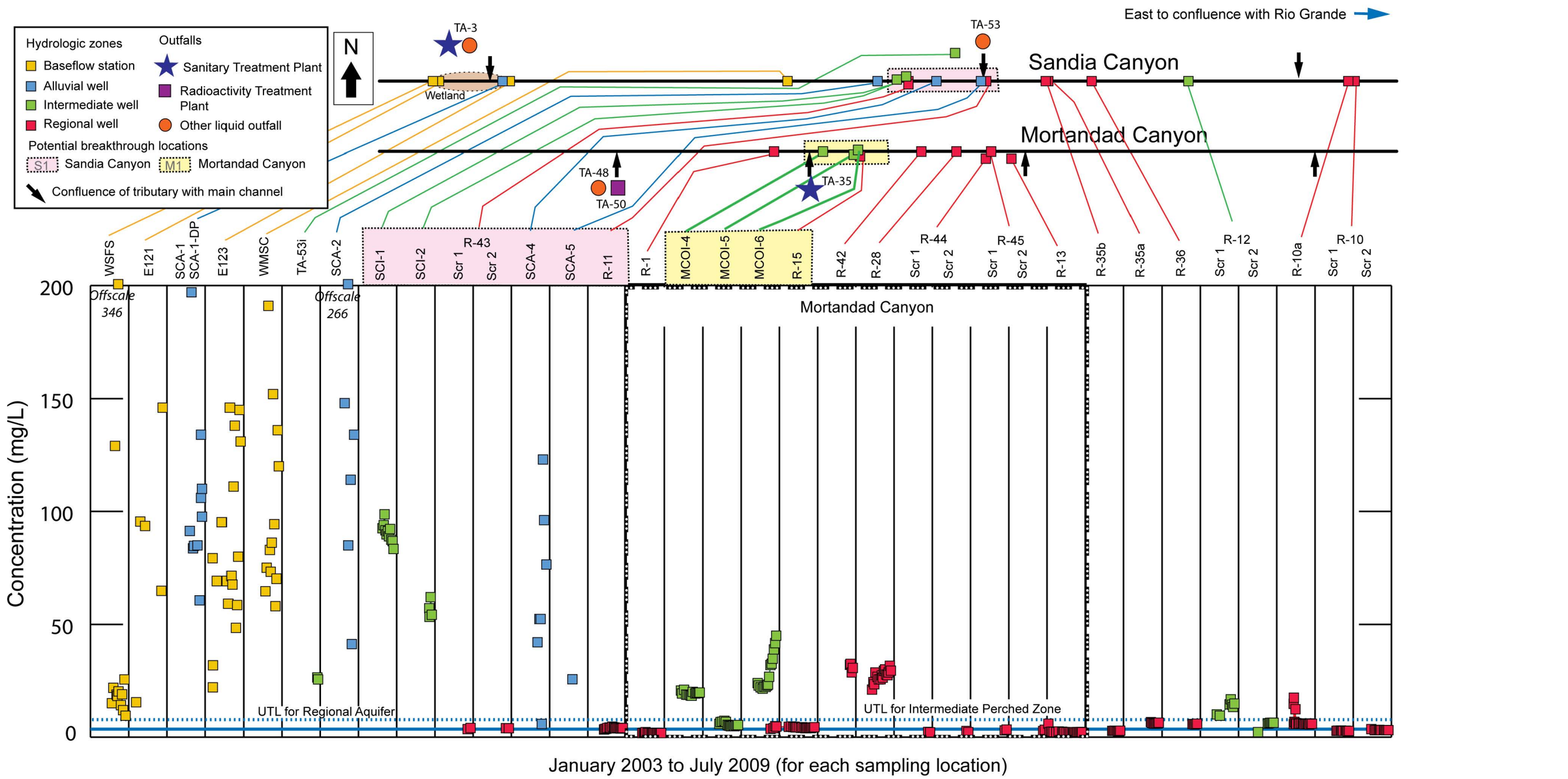


Figure 7.2-15 Chloride concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009

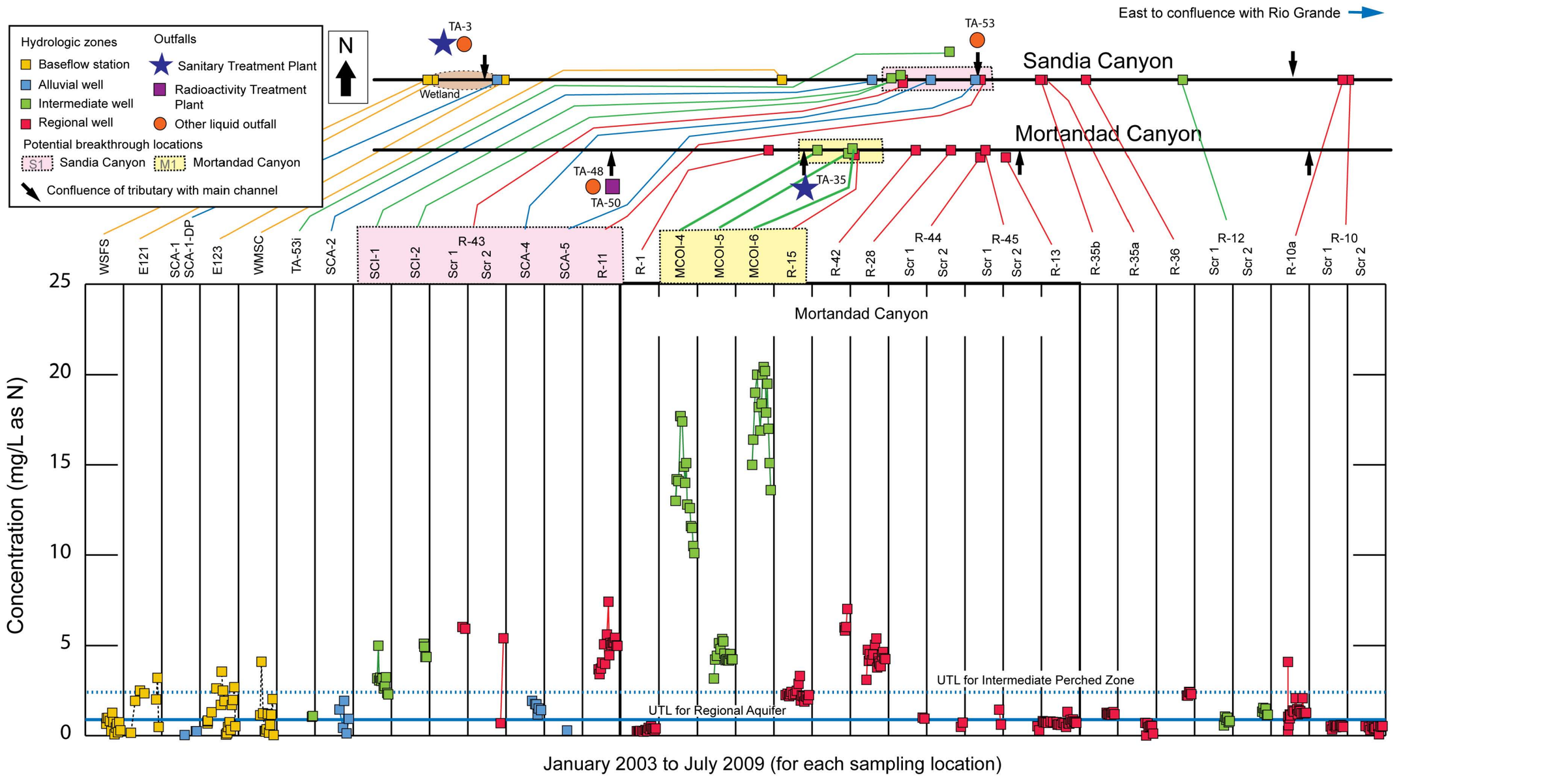


Figure 7.2-16 Nitrate + nitrite concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009

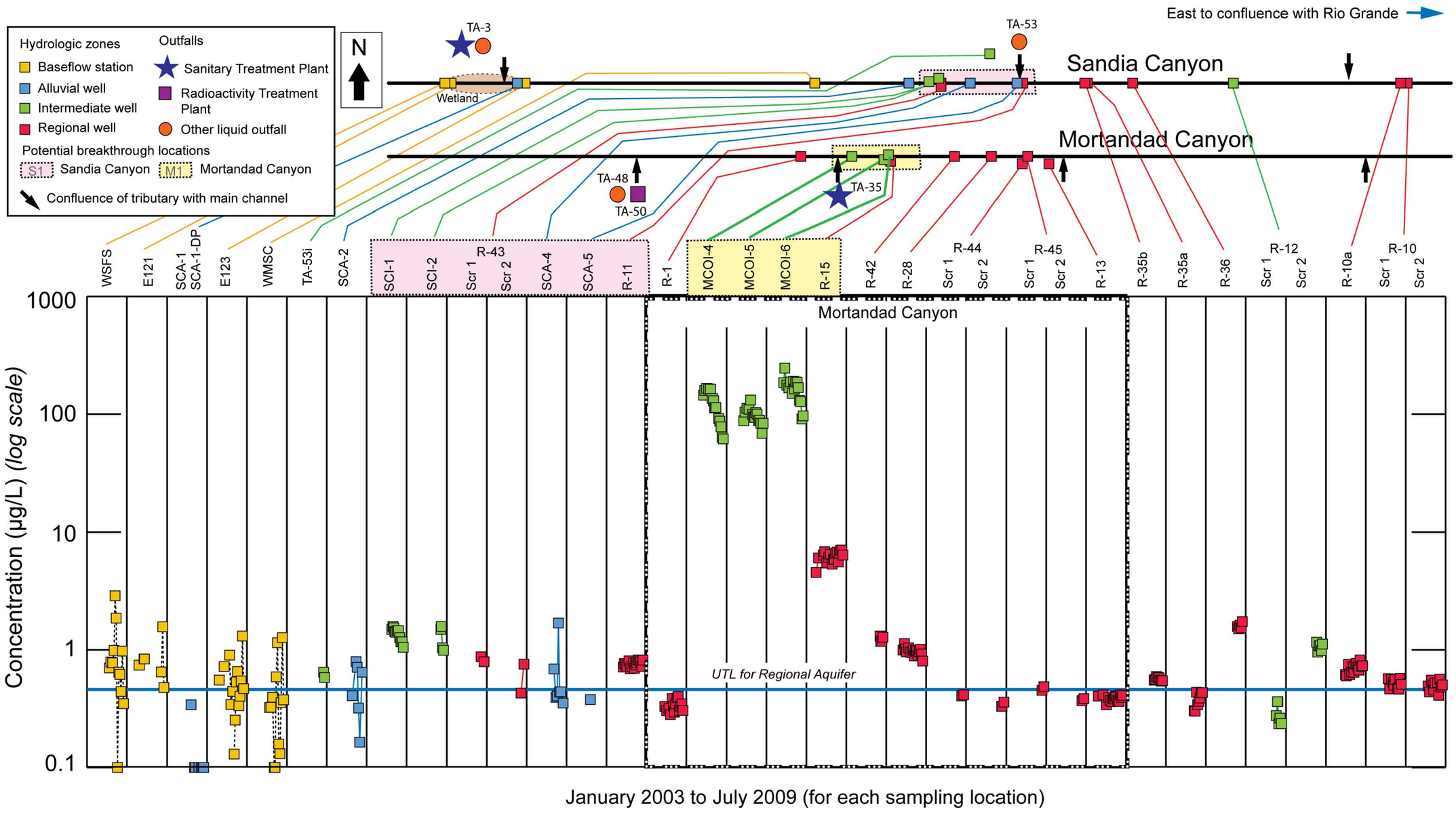


Figure 7.2-17 Perchlorate concentrations in water collected from Sandia and Mortandad Canyons, 2003 to 2009

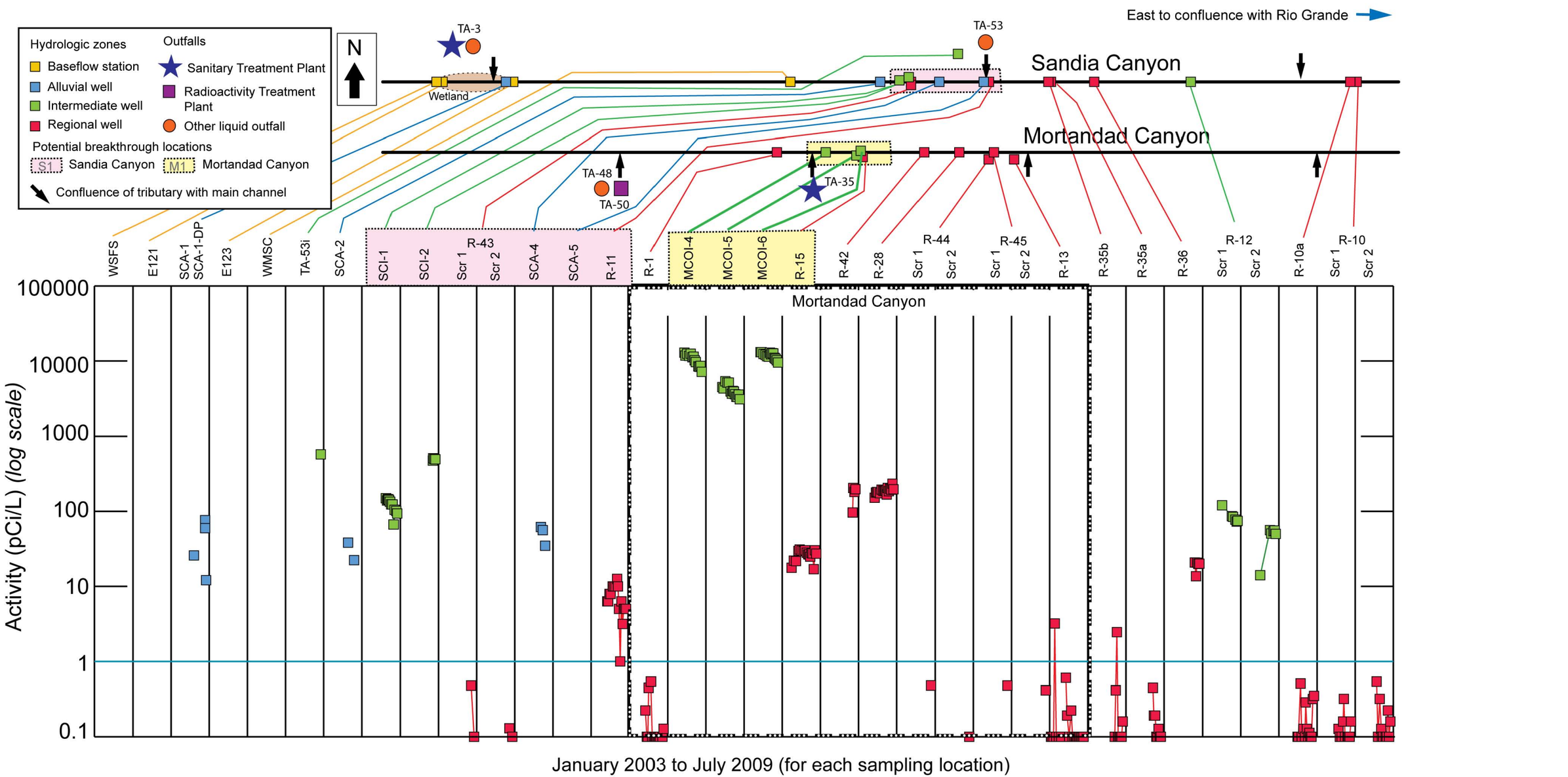


Figure 7.2-18 Tritium activities in water collected from Sandia and Mortandad Canyons, 2003 to 2009

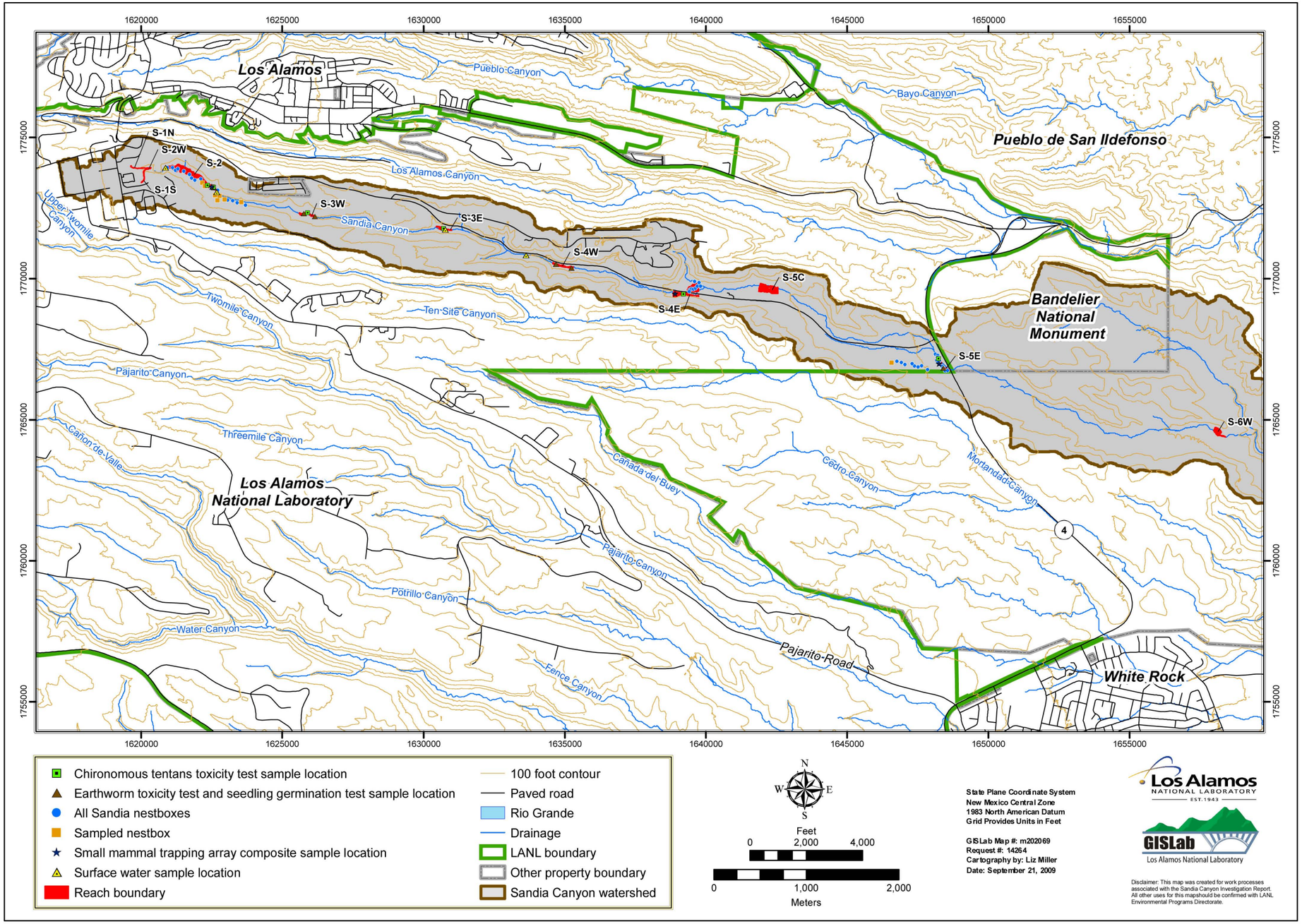


Figure 8.1-1 Biota investigation locations in Sandia Canyon

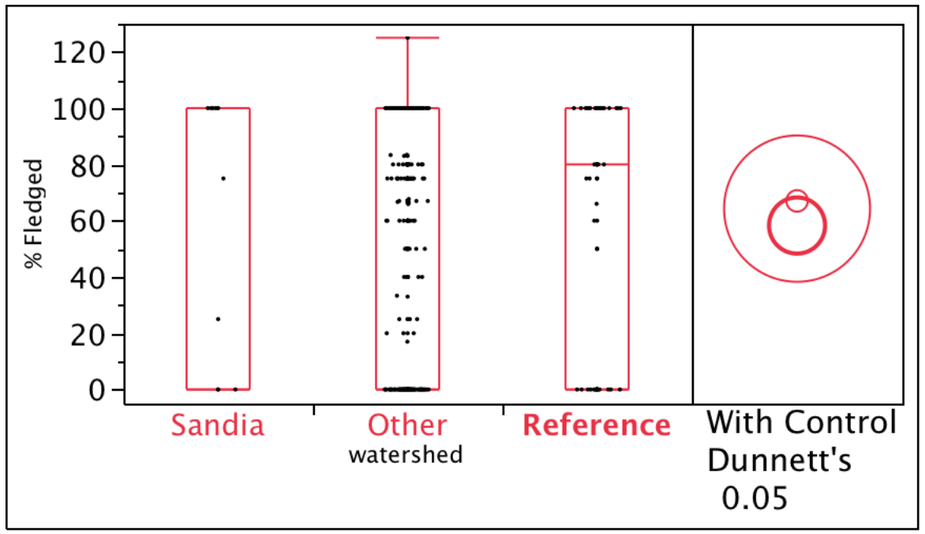


Figure 8.1-2 **Box plots showing percent fledged in Sandia Canyon compared with reference for western bluebirds**

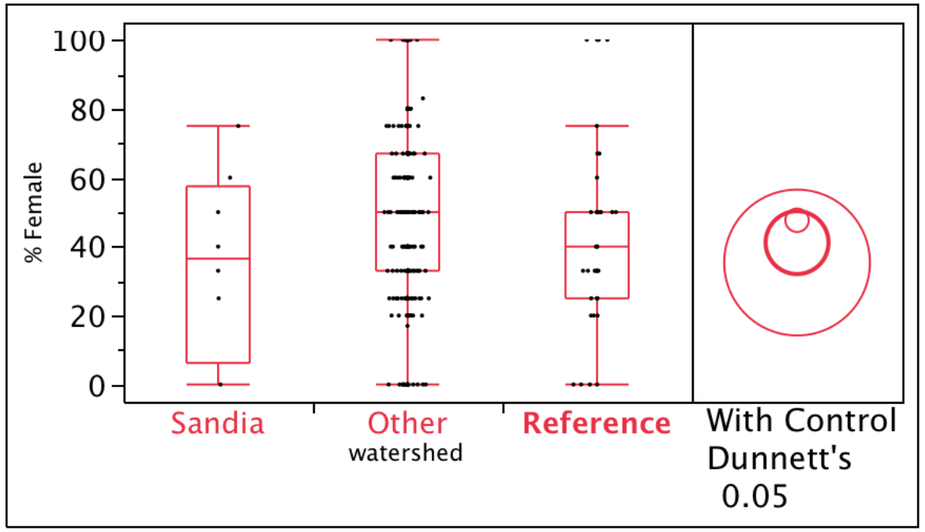


Figure 8.1-3 **Box plots showing percent female in Sandia Canyon compared with reference for western bluebirds**

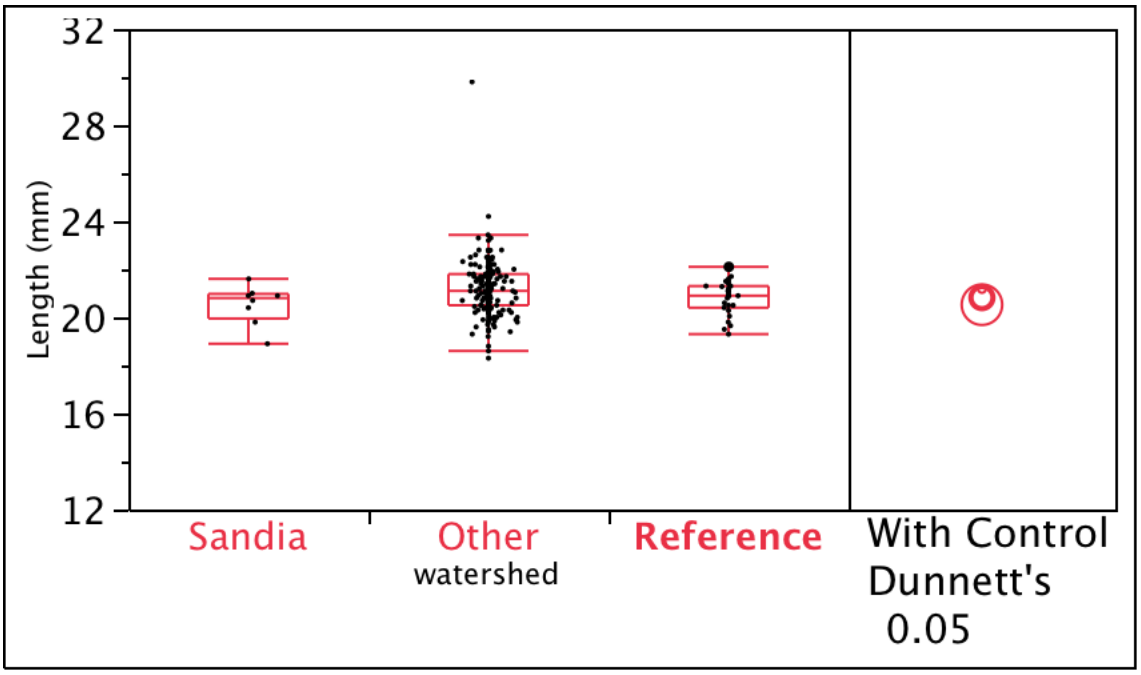


Figure 8.1-4 **Box plots showing egg length for Sandia Canyon compared with reference for western bluebirds**

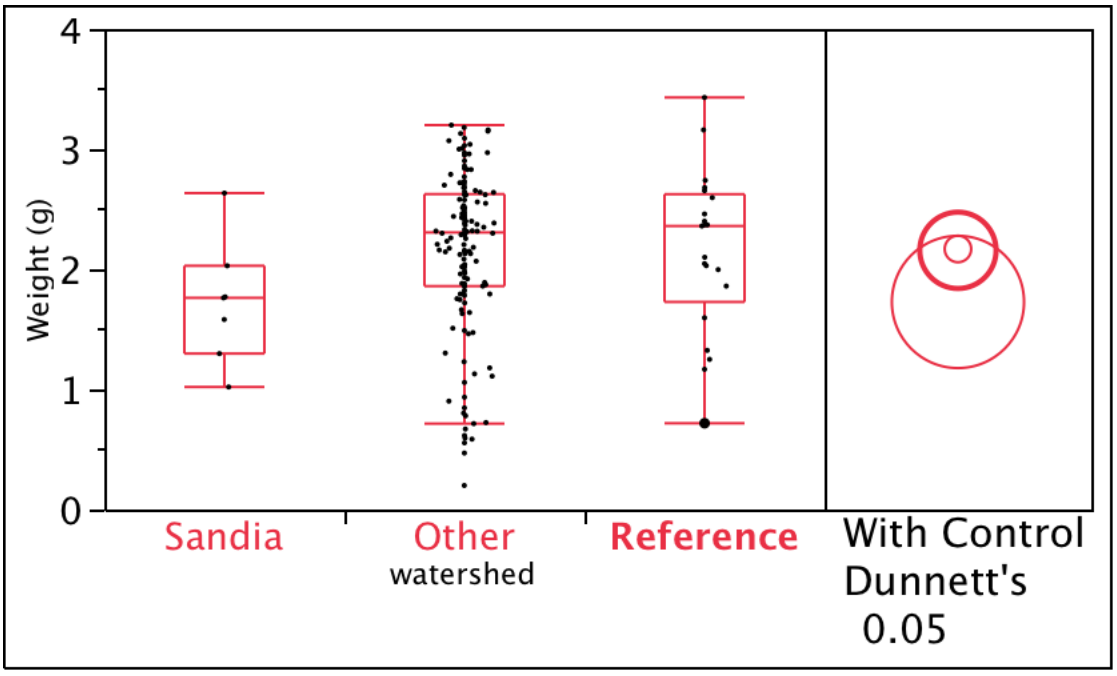


Figure 8.1-5 **Box plots showing egg weight for Sandia Canyon compared with reference for western bluebirds**

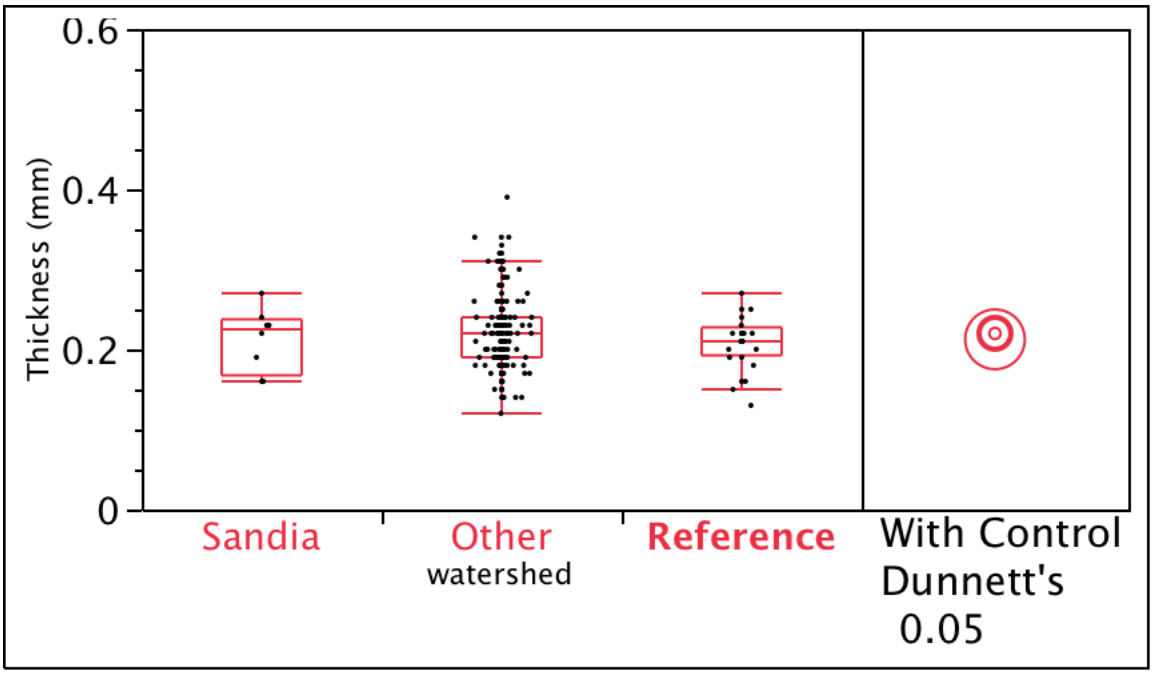


Figure 8.1-6 **Box plots showing eggshell thickness for Sandia Canyon compared with reference for western bluebirds**

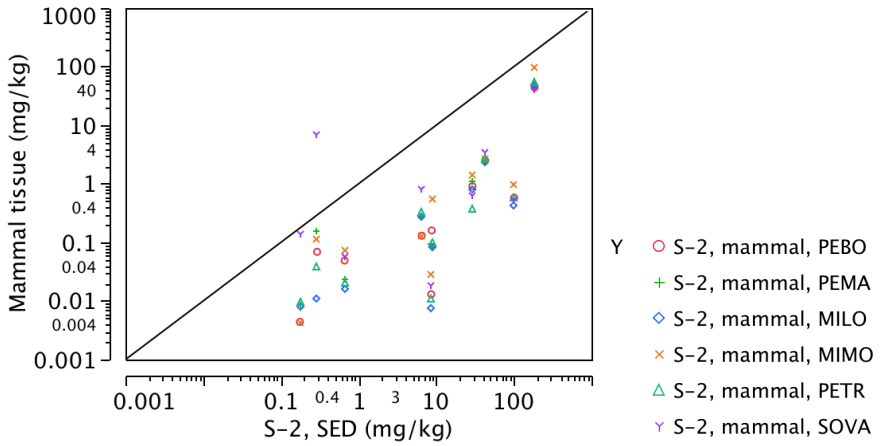


Figure 8.1-7 Overlay plot showing COPEC concentrations in small mammal versus sediment for Reach S-2

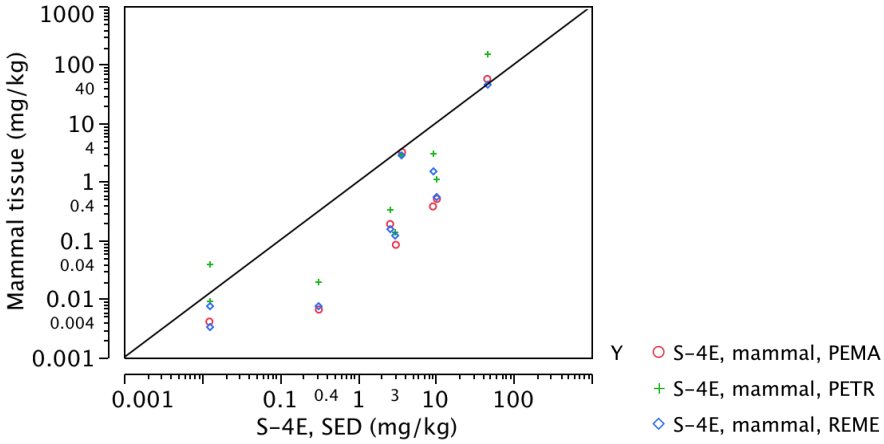


Figure 8.1-8 Overlay plot showing COPEC concentrations in small mammal versus sediment for Reach S-4E

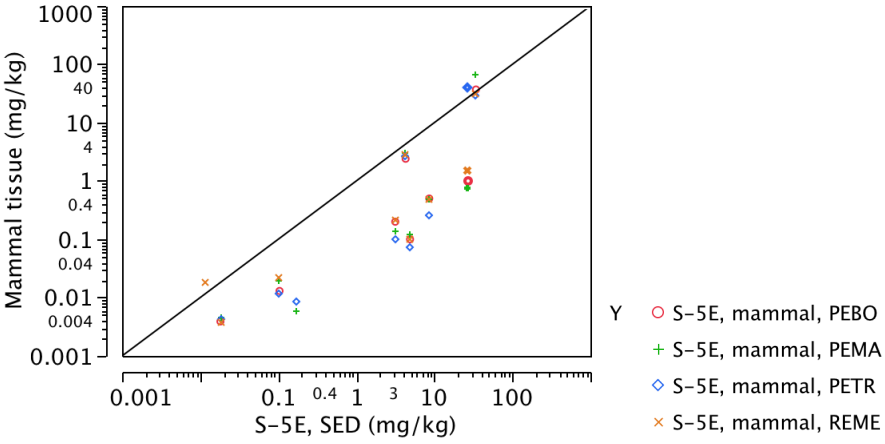


Figure 8.1-9 Overlay plot showing COPEC concentrations in small mammal versus sediment for Reach S-5E

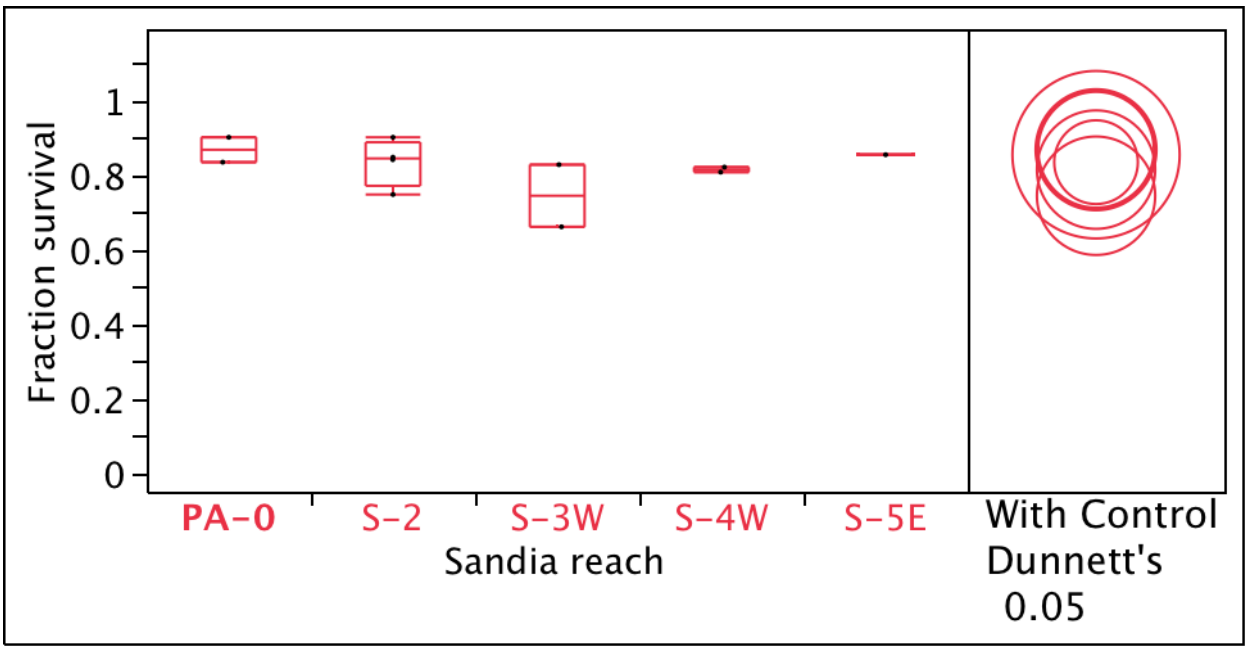


Figure 8.1-10 Survival of earthworms in toxicity test compared with reference

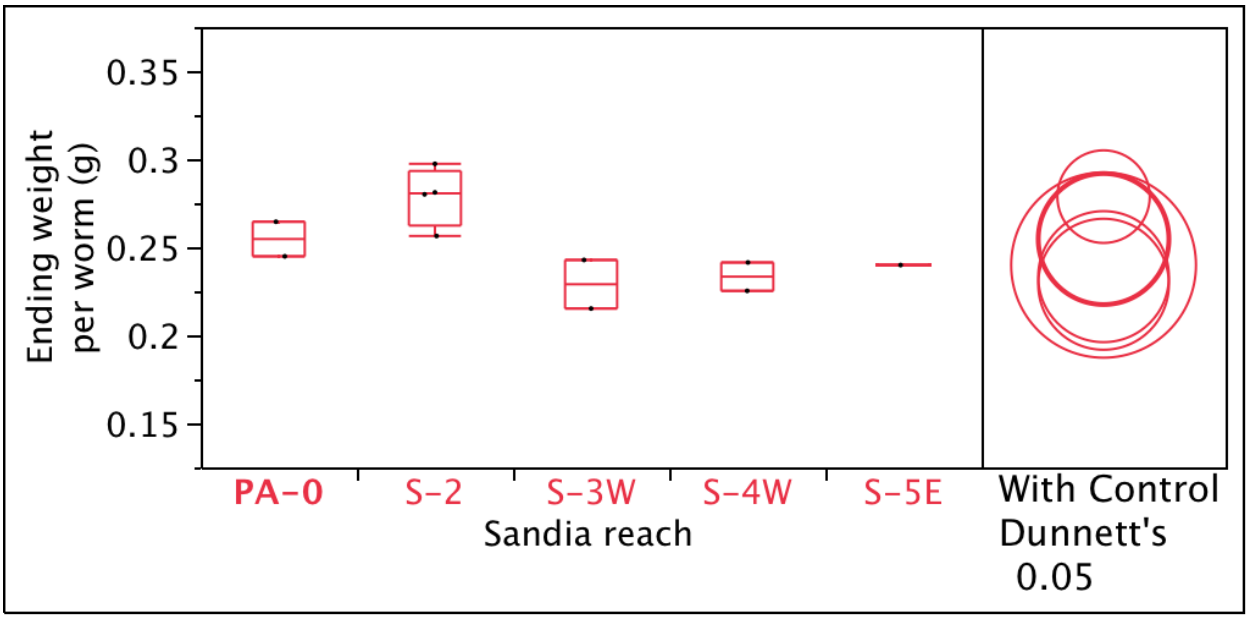


Figure 8.1-11 Ending weight in earthworms during toxicity test compared with reference

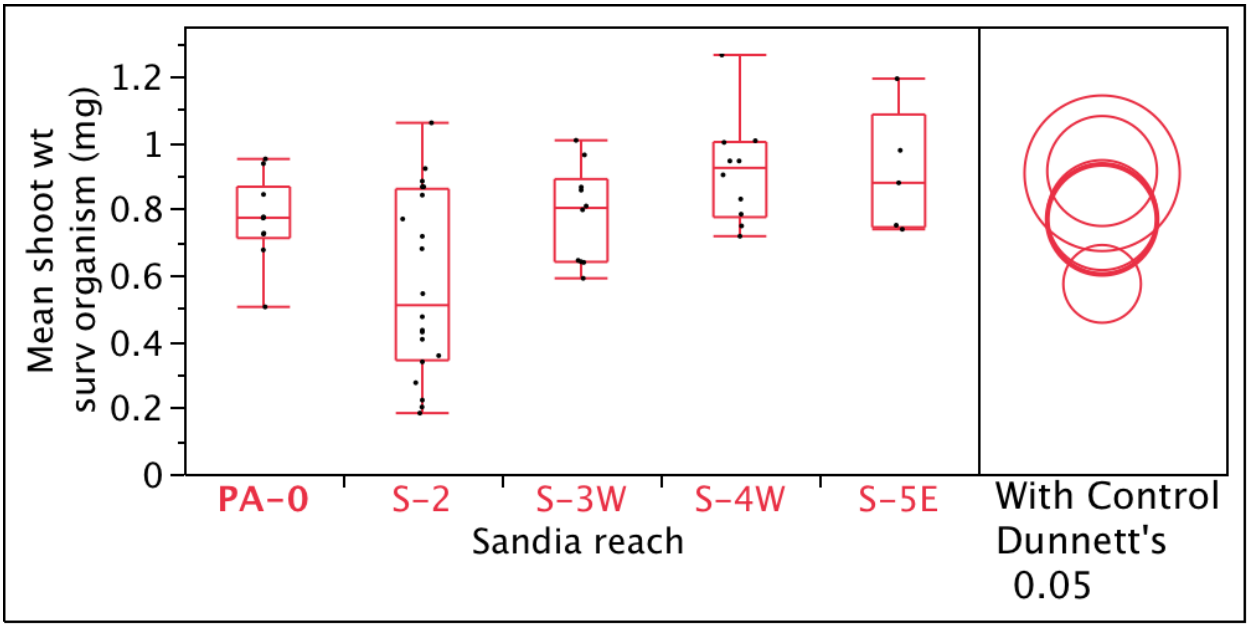


Figure 8.1-12 Shoot weight of surviving organisms in toxicity test by reach

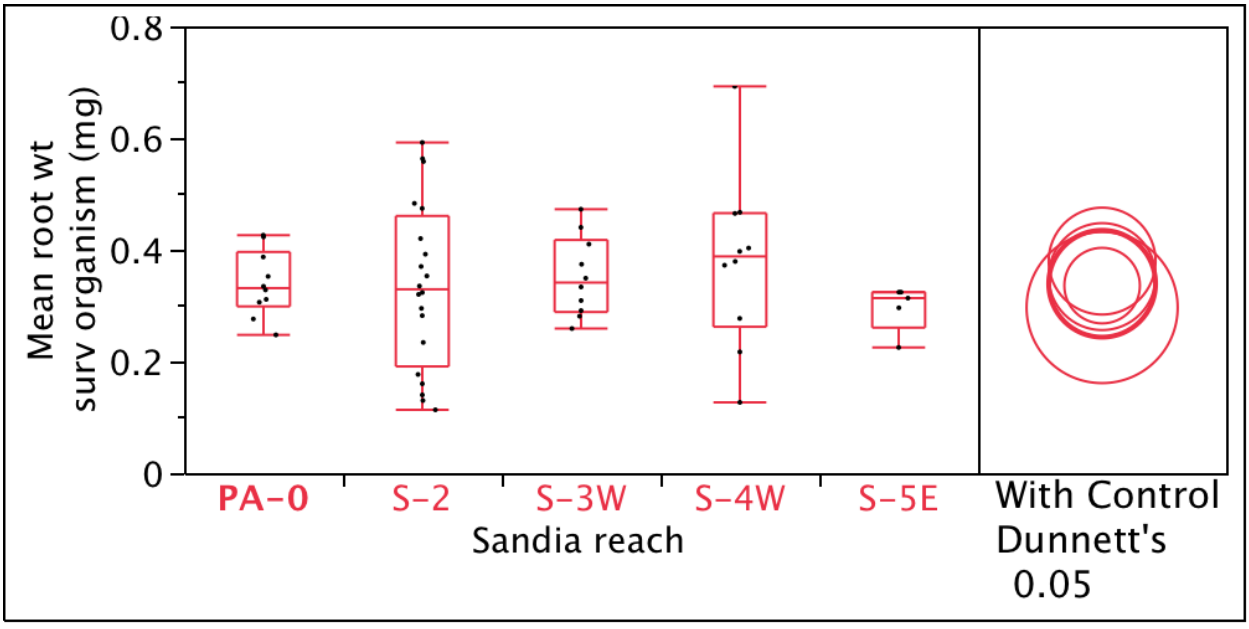


Figure 8.1-13 Root weight of surviving organisms in toxicity test by reach

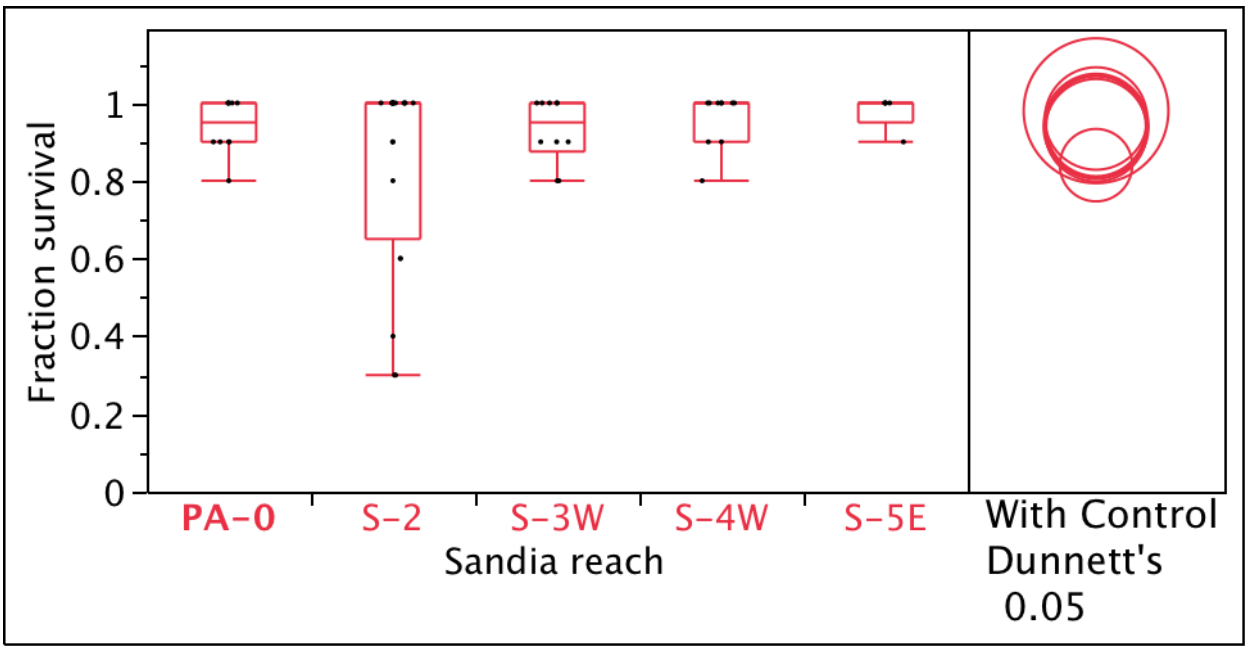


Figure 8.1-14 Fraction of plants surviving at end of toxicity test by reach

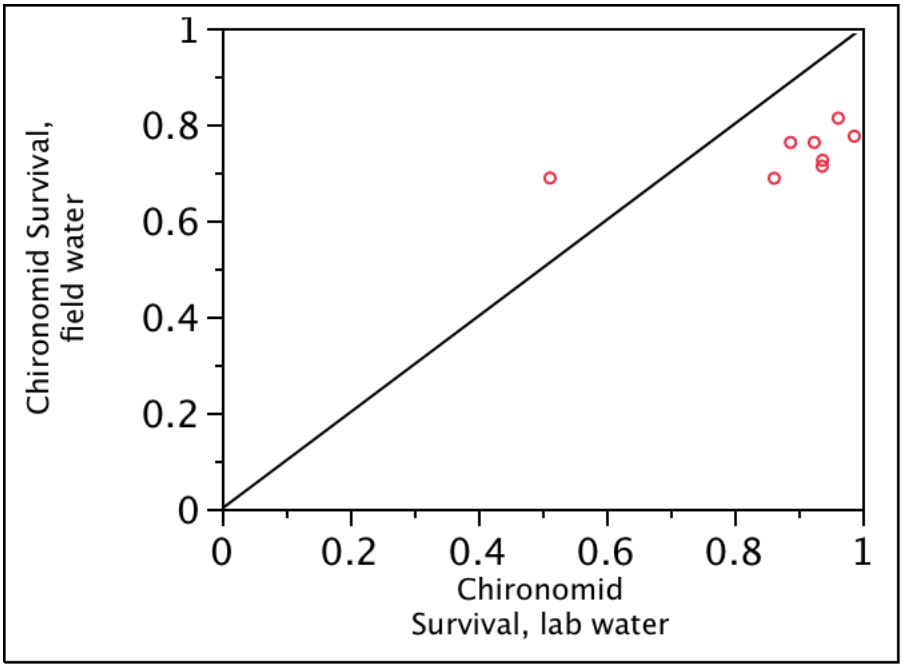


Figure 8.1-15 Comparison of mean fraction survival for field water versus laboratory water for chironomid toxicity tests

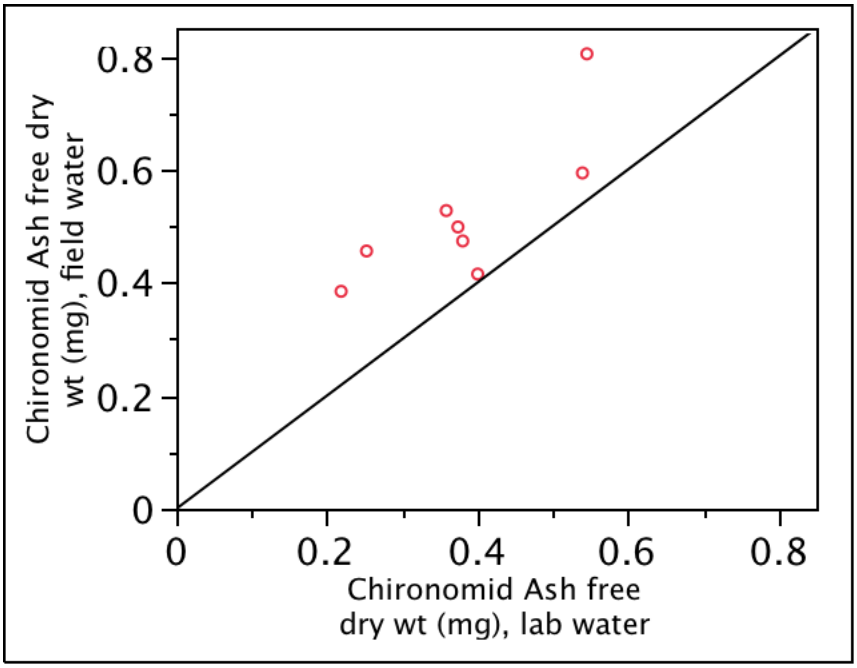


Figure 8.1-16 Comparison of mean dry larval weight (in mg) for field water versus laboratory water for chironomid toxicity tests

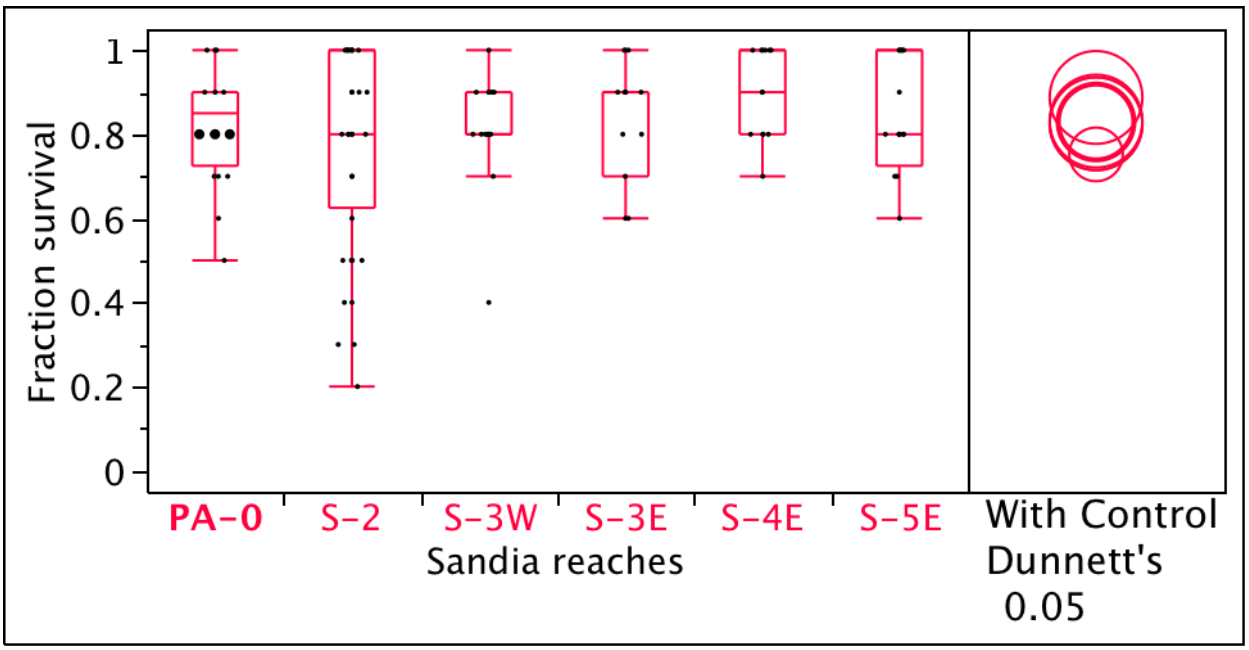


Figure 8.1-17 Box plot of Sandia Canyon reach fraction survival at conclusion of chironomid toxicity test

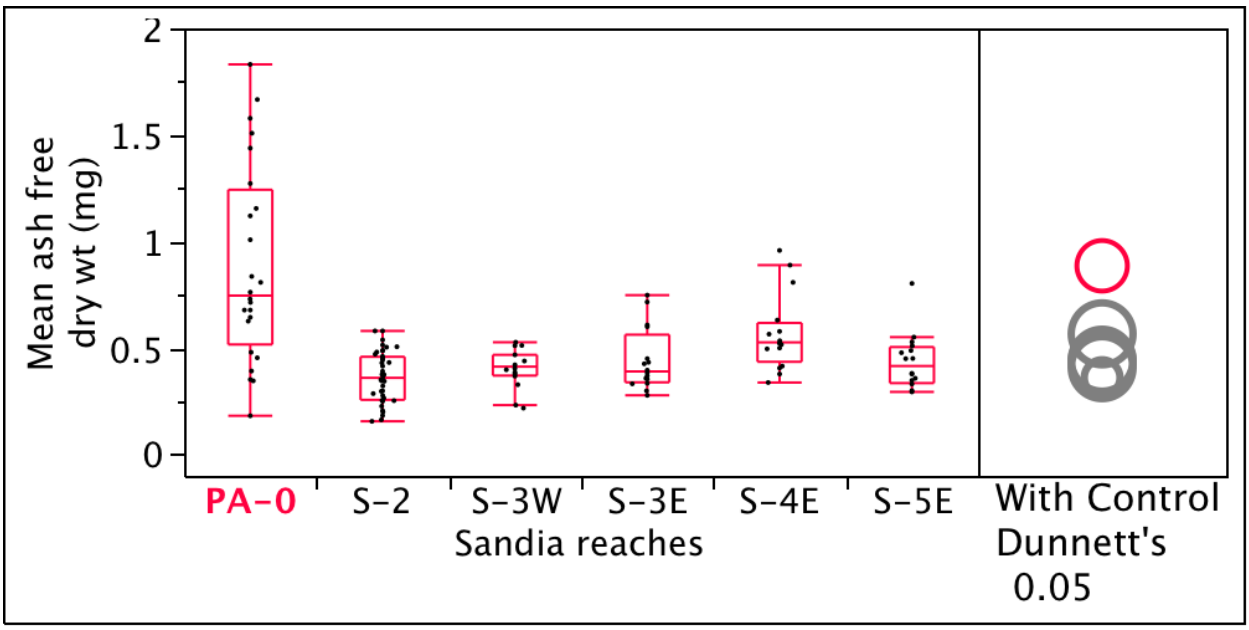


Figure 8.1-18 Box plot of Sandia Canyon reach mean dry larval weight (in mg) per replicate after chironomid toxicity test

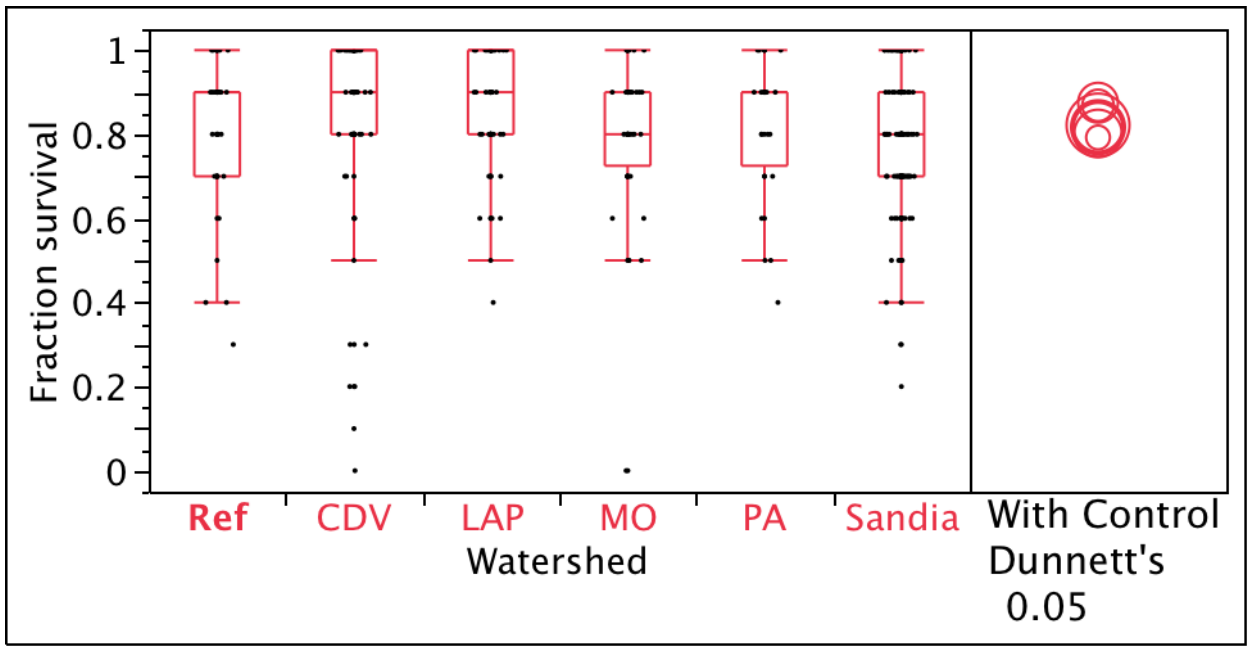


Figure 8.1-19 Box plot of mean chironomid survival by watershed compared with reference.

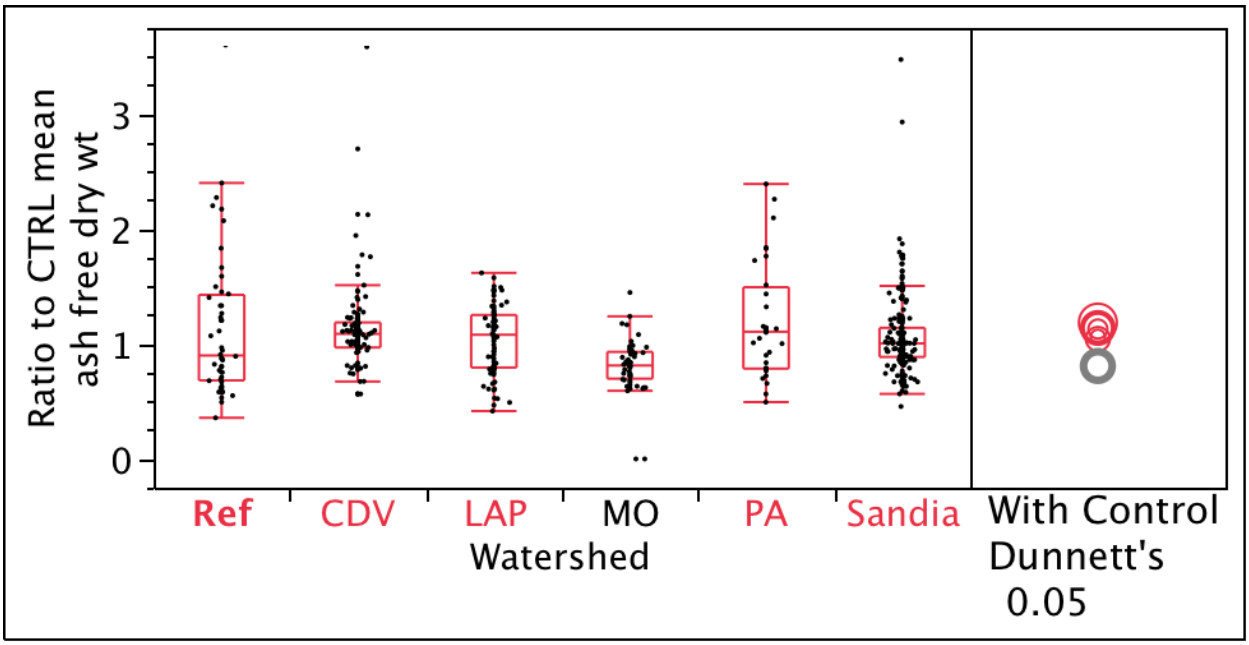
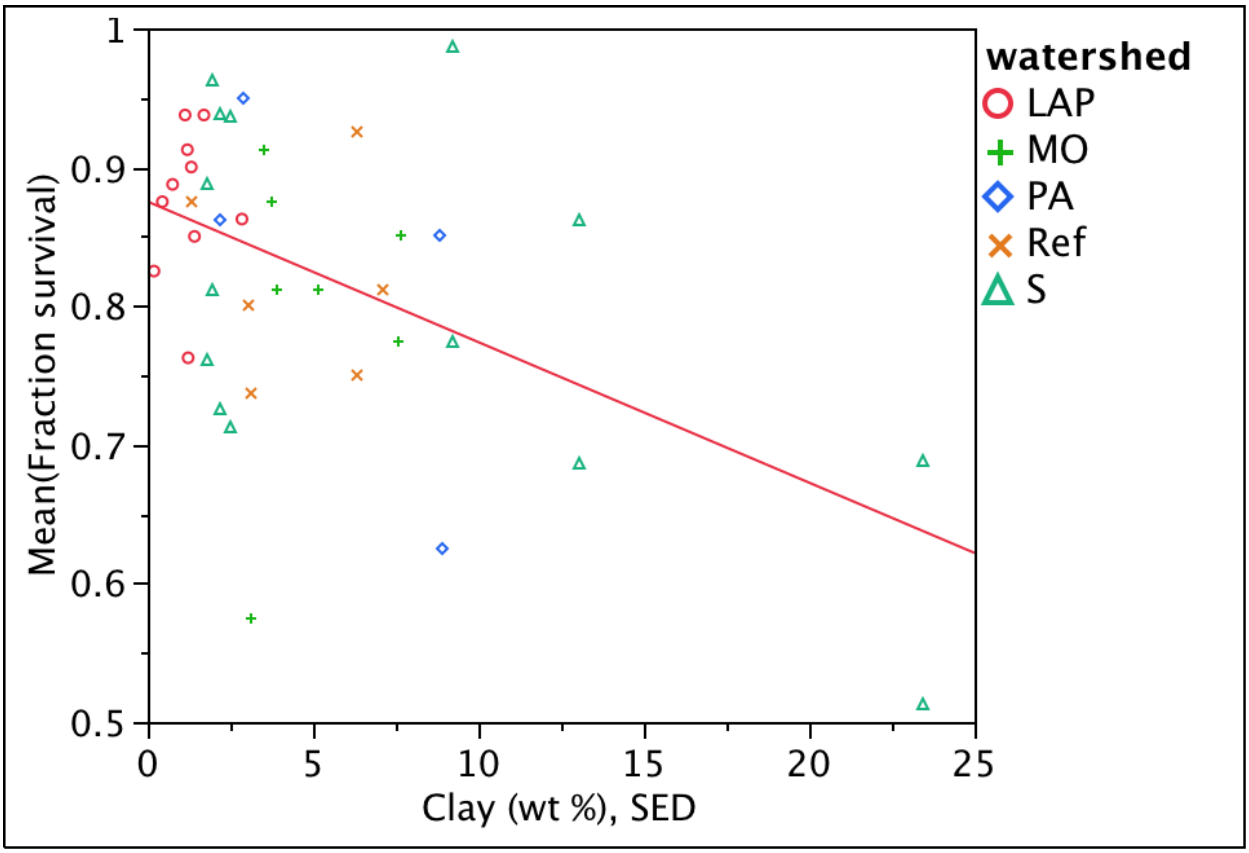


Figure 8.1-20 Box plot of mean chironomid growth relative to laboratory control compared with reference



Note: Linear regression: y = 0.88 + 0.0101*X; r^2=0.26; n=41.

Figure 8.1-21 Scatter plot of mean chironomid survival versus clay

Table 3.1-1
Sediment Investigation Reaches in Sandia Canyon

Investigation Reach	Reach Abbreviation	Approximate Distance From Rio Grande to Midpoint of Reach (km)	Reach Length (km)*	Year(s) of Sample Collection (Canyons Investigations)	Notes
S-1 North	S-1N	16.06	0.20	1998, 2008	North fork of Sandia Canyon; below former asphalt batch plant
S-1 South	S-1S	16.06	0.20	1998, 2008	South fork of Sandia Canyon; below power plant
S-2 West	S-2W	15.95	0.03	1998	Upcanyon from landfill bridge; below confluence of north and south forks
S-2	S-2	15.44	0.68	1998, 2007, 2008	Downcanyon from landfill bridge; Sandia wetland and vicinity
S-3 West	S-3W	14.18	0.21	2007, 2008	Bouldery reach in narrow canyon bottom; below La Mesa trailer park
S-3 East	S-3E	12.68	0.20	2000, 2007	Bouldery reach in narrow canyon bottom; below East Jemez Road
S-4 West	S-4W	11.31	0.23	2007	Downcanyon from western TA-53 SWMUs; incising reach
S-4 East	S-4E	9.89	0.31	2007	Upcanyon from eastern TA-53 drainage; aggrading reach
S-5 Central	S-5C	8.96	0.24	2000, 2007	Downcanyon from TA-53 and Protective Force firing range; near well R-35
S-5 East	S-5E	6.59	0.23	2007	Upcanyon from NM 4 and eastern Laboratory boundary
S-6 West	S-6W	3.32	0.20	2008	Pueblo de San Ildefonso land; above basalt knickpoint
S-6 East	S-6E	0.35	0.20	2008	Pueblo de San Ildefonso land; above Rio Grande

*Length refers to area mapped and characterized.

Table 3.2-1
Sandia Canyon Surface and Groundwater Sampling Locations and Rationale

Location Name	Location and Rationale
Base Flow (west to east)	
Surface Water Gaging Station E121	South Fork of Sandia Canyon, near power plant. Located west of wetland. Provides information about potential contaminant releases from TA-03 facilities to the west and baseline data about surface water entering the wetland.
Surface Water Gaging Station E122 (equivalent WSFS)	North Fork of Sandia Canyon, near power plant. Located west of wetland. Down gradient of main contaminant release sites in Sandia Canyon. Provides baseline data about surface water entering the wetland.
Surface Water Sampling Station SCS-1	Surface water sampling station at west end of wetland. Provides baseline data about surface water entering the wetland.
Surface Water Gaging Station E123	Sandia Canyon just east of wetland. Location selected to monitor persistent surface water exiting the wetland.
Surface Water Gaging Station E123.6	Surface water base flow collected at gage station E123.6. Location selected to monitor persistent surface water in narrow, bedrock-dominated portion of middle Sandia Canyon.
Surface Water Sampling Station SCS-2 (equivalent WMSC)	Middle Sandia Canyon. Location selected to monitor surface water near the eastern terminus of persistent base flow.
Surface Water Sampling Station SCS-3	Near eastern end of middle Sandia Canyon. Provides baseline data about surface water up gradient of TA-53 facilities. Area of ephemeral surface water flow.
Surface Water Gaging Station E124	Surface water base flow collected at gage station E124. Location selected to monitor surface water in area where Sandia Canyon widens and there is ephemeral surface water flow.
Surface Water Gaging Station E125	Surface water base flow collected at gage station E125. Location selected to monitor surface water near eastern Laboratory boundary. Area of ephemeral surface water flow.
Springs	
Sandia Spring	Lower Sandia Canyon about 1 km west of the Rio Grande. Provides water quality near the Rio Grande.
Alluvial Groundwater Wells (west to east)	
SCA-1	Upper Sandia Canyon in the wetland, straddling the TA-60 and TA-61 boundary. Provides alluvial groundwater monitoring location within the wetland.
SCA-2	Sandia Canyon at TA-53. Provide samples of alluvial groundwater where Sandia Canyon begins to widen and alluvium begins to thicken eastward. Part of main infiltration area for Sandia Canyon.
SCA-3	Sandia Canyon at TA-53. Provide samples of alluvial groundwater in area where persistent alluvial saturation occurs in thick canyon-floor alluvium. Part of main infiltration area for Sandia Canyon.
SCA-4	Sandia Canyon at TA-53. Provide samples of alluvial groundwater in area where persistent alluvial saturation occurs in thick canyon-floor alluvium. Part of main infiltration area for Sandia Canyon.
SCA-5	Sandia Canyon at TA-72. Provide samples of alluvial groundwater near the eastern limit of persistent alluvial saturation. Near eastern limit of main infiltration area for Sandia Canyon.
SCO-1	Sandia Canyon at TA-72 near municipal supply well PM-3. Alluvial well is always dry during sampling events.

Table 3.2-1 (continued)

Location Name	Location and Rationale
SCO-2	Sandia Canyon at TA-72 near eastern Laboratory boundary. Alluvial well is always dry during sampling events.
SCO-3	Sandia Canyon at TA-72 near eastern Laboratory boundary. Alluvial well is always dry during sampling events.
Perched Intermediate Groundwater (west to east by canyon)	
SCI-1	Sandia Canyon at TA-53. Provide samples of perched intermediate groundwater in main infiltration area for Sandia Canyon.
SCI-2	Sandia Canyon at TA-53. Provide samples of perched intermediate groundwater in main infiltration area for Sandia Canyon.
TA-53i	Mesita de los Alamos, north of Sandia Canyon at TA-53. Provide samples of perched intermediate groundwater originating in Los Alamos Canyon that may affect groundwater beneath Sandia Canyon.
R-12, screens 1 and 2	Sandia Canyon at TA-72 near eastern Laboratory boundary. Provide samples of perched intermediate groundwater east of main infiltration area in Sandia Canyon.
MCOBT-4.4	Mortandad Canyon at TA-05 near confluence with Ten Site Canyon. Existing monitoring well included in this investigation to provide information about the potential effects of perched intermediate groundwater on water quality of the regional monitoring wells that are affected by chromium contamination.
MCOI-4	Mortandad Canyon at TA-05 near confluence with Ten Site Canyon. Existing monitoring well included in this investigation to provide information about the potential effects of perched intermediate groundwater on water quality of the regional monitoring wells that are affected by chromium contamination.
MCOI-5	Mortandad Canyon at TA-05 near regional well R-15. Existing monitoring well included in this investigation to provide information about the potential effects of perched intermediate groundwater on water quality of the regional monitoring wells that are affected by chromium contamination.
MCOI-6	Mortandad Canyon at TA-05 near regional well R-15. Existing monitoring well included in this investigation to provide information about the potential effects of perched intermediate groundwater on water quality of the regional monitoring wells that are affected by chromium contamination.
Regional Groundwater (west to east by canyon)	
R-43	Sandia Canyon at TA-53. Provide samples of regional groundwater in main infiltration area for Sandia Canyon.
R-11	Sandia Canyon at TA-72. Provide samples of regional groundwater down gradient of main infiltration area for Sandia Canyon.
R-35a	Sandia Canyon at TA-72. Provide samples of regional groundwater up gradient of municipal supply well PM-3. The R-35a well screen is set at same depth as the top of PM-3 well screen.
R-35b	Sandia Canyon at TA-72. Provide samples of regional groundwater near the water table up gradient of municipal supply well PM-3.
PM-3	Sandia Canyon at TA-72. Municipal supply well sampled to determine if produced groundwater is affected by Laboratory contaminants.
R-36	Sandia Canyon at TA-72. Provide samples of regional groundwater for defining the nature and extent of chromium contamination in the regional aquifer. Provide samples of regional groundwater up gradient of municipal supply well PM-1.
PM-1	Sandia Canyon at TA-72. Municipal supply well sampled to determine if produced groundwater is affected by Laboratory contaminants.

Table 3.2-1 (continued)

Location Name	Location and Rationale
R-1	Mortandad Canyon at TA-05 west of confluence with Ten Site Canyon. Existing monitoring well included in this investigation to provide water quality information about the nature and extent of chromium contamination in the regional aquifer.
R-10	Sandia Canyon on San Ildefonso Pueblo land. Well screen deep within the aquifer provides samples of regional groundwater to monitor water quality along deep flow paths.
R-10a	Sandia Canyon on San Ildefonso Pueblo land. Well screen set in upper part of the aquifer provides samples of regional groundwater to monitor water quality along flow paths near the water table.
R-33	Ten Site Canyon at TA-05 near confluence with Mortandad Canyon. Existing monitoring well included in this investigation to provide water quality information about the nature and extent of chromium contamination in the regional aquifer.
R-15	Mortandad Canyon at TA-05 east of confluence with Ten Site Canyon. Existing monitoring well included in this investigation to provide water quality information about the nature and extent of chromium contamination in the regional aquifer.
R-42	Mortandad Canyon at TA-05. New monitoring well installed as part of this investigation to provide samples of regional groundwater for defining the nature and extent of chromium contamination. Located down gradient of main infiltration area for Sandia Canyon.
R-28	Mortandad Canyon at TA-05. New monitoring well installed as part of this investigation to provide samples of regional groundwater for defining the nature and extent of chromium contamination. Located down gradient of main infiltration area for Sandia Canyon.
R-45	Mortandad Canyon at TA-05. New monitoring well installed as part of this investigation to provide samples of regional groundwater for defining the nature and extent of chromium contamination. Located down gradient of main infiltration area for Sandia Canyon. Contains two well screens; upper screen monitors groundwater near water table and lower screen monitors deeper flow paths.
R-44	Mortandad Canyon at TA-05. New monitoring well installed as part of this investigation to provide samples of regional groundwater for defining the nature and extent of chromium contamination. Located down gradient of main infiltration area for Sandia Canyon. Contains two well screens; upper screen monitors groundwater near water table and lower screen monitors deeper flow paths.
R-13	Mortandad Canyon at TA-05. Existing monitoring well included in this investigation to provide water quality information about the nature and extent of chromium contamination in the regional aquifer. Located down gradient of main infiltration area for Sandia Canyon. Monitors water quality near the Laboratory's boundary with San Ildefonso Pueblo.

Table 6.1-1
Water Screening Location, Synonym and Reach

Location Name[a]	Location Synonym	Reach[b]
Surface Water		
North Fork of Sandia Canyon at E122	WSFS	S-1N
Sandia left fork at Asphalt Plant	E122	S-1N
Sandia right fork at Power Plant	E121	S-1S
SA-00007	—[c]	S-2
SA-603204	—	S-2
Sandia below Wetlands	E123	S-2
SA-10005	—	S-3E
Middle Sandia Canyon at terminus of persistent baseflow	WMSC	S-3E and S-4W
SCS-2	—	S-3E and S-4W
SA-603205	—	S-3E and S-4W
Sandia Spring[d]	—	S-6E
Sandia above Firing Range	E124	S-4W and S-4E
Sandia above SR-4	E125	S-5E
Alluvial Groundwater		
SCA-1	—	—
SCA-1-DP	—	—
SCA-2	—	—
SCA-4	—	—
SCA-5	—	—
Intermediate Perched Groundwater[e]		
SCI-1	—	—
SCI-2	—	—
R-12	—	—
Regional Aquifer (Sandia monitoring locations)		
R-43	—	—
R-11	—	—
R-35b	—	—
R-35a	—	—
R-36	—	—
R-10a	—	—
R-10	—	—
Sandia Spring[d]	—	—
Regional Aquifer (Mortandad monitoring locations)		
R-1	—	—
R-33	—	—
R-15	—	—

Table 6.1-1 (continued)

Location Name[a]	Location Synonym	Reach[b]
R-42	—	—
R-28	—	—
R-44	—	—
R-45	—	—
R-13	—	—
Regional Aquifer (Water supply wells)		
O-4	G4OW	—
PM-1	G1MP	—
PM-3	G3MP	—
PM-5	G5MP	—

[a] Locations are listed from west to east.

[b] The listed location is either within the reach, or else the nearest reach is listed; for locations midway between reaches, both reaches are listed.

[c] — = Not applicable.

[d] Sandia Spring is screened as part of the surface water dataset as well as part of the regional aquifer dataset.

[e] Additional monitoring wells from Mortandad watershed (MCOI-4, MCOI-5, MCOI-6) are included in the frequency of detection tables in Section D-2.0.

Table 6.2-1
Inorganic COPCs in Sandia Canyon Sediment Samples

Reach	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chloride	Chromium	Chromium Hexavalent Ion	Cobalt	Copper	Cyanide [Total]	Fluoride	Iron	Lead	Magnesium
BV (mg/kg)[a]	15400	3.98	127	1.3	0.4	4420	17.1	10.5	na[b]	4.73	11.2	0.82	na	13800	19.7	2370
Minimum Soil ESL[c]	pH dependent	6.8	110	2.5	0.27	na	na	2.3	0.34	13	15	0.1	31	pH dependent	14	na
Residential SSL[d]	78100	3.59	15600	156	77.9	na	na	2800[e]	219	23[e]	3130	1560	4690	54800	400	na
S-1N	—[f]	6.05	—	—	0.674 (U)	6110	—	18.7	0.271 (J-)	—	18.2	1.27 (J)	—	29500	46.3	—
S-1S	—	4.61	1060	—	0.638 (U)	5330	—	160 (J-)	1.07 (J-)	—	48 (J-)	8.35	—	—	77 (J-)	—
S-2	20000	15.6	297	4	8.69	6080	66 (J-)	3740	2.01 (J+)	8.2	223	11.6	3.31 (J-)	21000	690	2800
S-3W	—	5.85	128 (J-)	—	2.41	—	—	398 (J-)	0.548 (J+)	—	30.1	—	—	18300	24.4 (J)	—
S-3E	—	—	—	1.6	0.64 (U)	—	79.4	439	1.96	—	26	0.86 (U)	4.87 (J-)	—	34	—
S-4W	—	—	—	—	0.665 (U)	—	43.6 (J-)	112	—	—	16.2	—	1.88 (J-)	—	30.1	—
S-4E	—	—	—	—	0.559 (U)	—	—	113	2.53	5.2	18.4	—	4.56 (J-)	13900 (J+)	28.5	—
S-5C	—	—	—	—	0.55(U)	—	—	73.9	—	—	15.2	—	1.89 (J-)	14600	63.2	—
S-5E	—	—	—	—	0.535(U)	—	—	22.5	0.587 (J)	—	—	—	2.44 (J-)	—	25.1	—
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	6.7	—	—	—
S-6E	—	—	—	—	—	18300 (J)	—	—	—	—	—	—	3.4	—	—	—

Table 6.2-1 (continued)

Reach	Manganese	Mercury	Molybdenum	Nickel	Nitrate	Perchlorate	Potassium	Selenium	Silver	Sulfate	Sulfide, Extractable	Thallium	Uranium (Calculated Total)	Vanadium	Zinc
BV (mg/kg)[a]	543	0.1	na	9.38	na	na	2690	0.3	1	58.2	na	0.73	6.99	19.7	60.2
Minimum Soil ESL[c]	220	0.013	na	9.7	na	na	na	0.52	2.6	na	na	0.03	25	0.03	48
Residential SSL[d]	10700	23[e]	391	1560	125000	54.8	na	391	391	na	na	5.16	235	391	23500
S-1N	—	—	—	—	12.9 (J+)	0.000604 (J)	—	4.37 (J)	—	—	—	—	—	—	190
S-1S	—	1.92	—	—	2.37 (J+)	0.00252	—	4.03 (J)	14 (J-)	—	—	—	—	—	110 (J-)
S-2	582	5.57	44.4	69.3 (J+)	13 (J-)	0.000997 (J)	3500	1.36 (J)	87.3 (J+)	1340 (J-)	467	1.06	12.0	40	1140
S-3W	1060 (J-)	0.26	3.4	11	1.43	—	—	5.07	15.8	—	1.6 (J)	—	—	—	150 (J-)
S-3E	—	0.154	1.6	—	3.75	0.00141 (J)	—	1.44 (J)	4.2	59.5	—	—	—	—	100
S-4W	636	—	1.12	—	4.72 (J-)	0.00123 (J)	—	0.856 (J)	2.29	—	—	—	—	—	158
S-4E	629	0.239	1.6	—	5.87 (J-)	0.00101 (J)	—	1.3 (J)	3	—	—	—	—	—	102
S-5C	597	0.106	1.54	—	1.65 (J-)	0.00221 (J-)	—	1.76	2.4	—	—	—	—	—	89.9
S-5E	—	—	0.394	—	1.37 (J-)	0.00113 (J)	—	0.628 (J)	—	—	—	—	—	—	—
S-6W	—	—	0.37 (J)	—	15.3	0.0041	—	0.52 (U)	—	—	—	—	—	—	—
S-6E	—	—	0.34 (J)	10.7	3.2	0.0025	—	0.52(U)	—	—	—	—	—	—	—

Notes: Values are in mg/kg. Values are maximum values greater than the sediment BV for analytes with a BV, and the maximum detected value for analytes without a BV. Grey shading indicates the residential SSL was exceeded. All SSLs adjusted to a target risk of 10^{-5}.

[a] BVs are from LANL (1998, 059730).

[b] na = Not available.

[c] ESLs are from the ECORISK Database, Version 2.3 (LANL 2008, 103352).

[d] SSLs are from NMED (2009, 106420) unless otherwise noted.

[e] SSL from EPA regional screening tables (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[f] — = Not a COPC in that reach (not detected, not detected > BV, or not analyzed).

Table 6.2-2
Organic COPCs in Sandia Canyon Sediment Samples

Reach	Acenaphthene	Acenaphthylene	Acetone	Anthracene	Aroclor-1016	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260	Benzene	Benzo[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene	Benzoic Acid	BHC[delta-]	Bis[2-ethylhexyl]phthalate	Butanone[2-]	Butylbenzene[n-]	Butylbenzene[sec-]	Butylbenzylphthalate	Carbon Disulfide	Chlordane[gamma-]	Chloroaniline[4-]
Minimum Soil ESL[a]	0.25	120	1.2	6.8	1	0.041	0.007	0.041	0.14	24	3	53	18	24	62	1	na[b]	0.02	360	na	na	90	na	2.2	na
Residential SSL[c]	3440	1720[d]	67500	17200	3.93	1.7	1.7	1.12	1.7	15.5	4.81	0.481	4.81	1720[d]	48.1	240000[e]	2.18[f]	280	39600	145[g]	112[g]	2600[e]	1940	14.6[f]	24[e]
S-1N	9.45	—[h]	—	11.9	—	—	0.354	0.559	1.58	—	17	10.4	18.2	4.54	1.29	0.551 (J)	0.00741 (J)	0.415	—	—	—	0.116 (J)	—	—	—
S-1S	0.44	—	—	1.9 (J)	—	—	—	0.648	11	—	3.6	3.3	3	0.509	2.8	0.634 (J)	—	0.248 (J-)	—	—	—	0.0779 (J)	—	—	—
S-2	—	0.0608 (J)	0.207 (J+)	0.233	0.02	0.366	0.076	2.53	2.08	—	0.615	0.545	0.88	0.304	0.39 (J)	0.466 (J)	—	1.35	0.0339 (J+)	0.000847 (J)	0.000877 (J)	—	0.012 (J+)	0.05	0.342 (J)
S-3W	—	—	—	0.0172 (J)	—	—	—	0.266	0.308	—	0.102	0.07	0.14	0.059	0.081	—	—	—	—	—	—	—	—	—	—
S-3E	—	—	—	—	—	—	—	0.06	0.3 (J-)	—	—	—	—	—	—	—	—	0.111 (J)	—	—	—	—	—	—	—
S-4W	—	0.0631	—	—	—	—	—	0.112	0.12	—	0.057	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-4E	—	—	—	—	—	—	—	0.17	0.219	—	0.047	0.043	—	—	—	—	—	—	—	—	—	—	—	—	—
S-5C	—	—	—	—	—	0.043	—	0.098	0.157	—	0.052	0.044	—	—	—	—	—	—	—	—	—	—	—	—	—
S-5E	—	—	—	—	—	0.041	—	0.026	0.0527	—	—	—	—	—	—	—	—	0.0932 (J)	—	—	—	—	—	—	—
S-6W	—	—	—	—	—	—	—	—	—	0.00071 (J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.003 (J)	—	—	—	—	—	—

Table 6.2-2 (continued)

Reach	Chloroform	Chrysene	DDD[4,4'-]	Dibenzofuran	Dieldrin	Di-n-butylphthalate	Di-n-octylphthalate	Ethylbenzene	Fluoranthene	Fluorene	Indeno[1,2,3-cd]pyrene	Isopropyltoluene[4-]	Methoxychlor[4,4']	Methyl Mercury	Methylnaphthalene[2-]	Naphthalene	Phenanthrene	Pyrene	Styrene	Toluene	TPH DRO	Trimethylbenzene[1,2,4-]	Xylene [Total]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Minimum Soil ESL[a]	8	2.4	0.006	6.1	0.0045	0.011	1.1	na	10	3.7	62	na	5	0.00035	2.5	1	5.5	10	na	23	na	na	1.4	na	na
Residential SSL[c]	5.72	481	16.3	145 [g]	0.245	6110	280 [f]	69.6	2290	2290	4.81	3210 [i]	310 [e]	7.82	310[e]	45	1830	1720	8970	5570	520 [j]	67 [e]	1090	9550	1090 [k]
S-1N	—	13.4	—	0.426	—	0.0571 (J)	—	—	57.7	6.28	1.23	0.00418	—	—	0.1	0.32	44.7	59.2	—	0.000422 (J)	2700	—	—	0.000435 (J)	0.000278 (J)
S-1S	—	3.7	—	0.187 (J)	—	0.0663 (J)	0.0854 (J)	0.000725 (J)	9	0.344	1.2 (J)	—	—	—	0.1	0.27	6.8	6.3	—	0.00376	897	0.000514 (J)	—	0.00105	0.00234
S-2	0.000383 (J)	0.666	0.036	1.22	0.037	0.106 (J)	—	0.001 (J)	1.29	0.117	—	0.0798	—	0.0046 (J-)	0.46	—	0.952	1.18	—	0.00651	470 (J)	—	—	—	—
S-3W	—	0.102	—	—	—	—	—	—	0.208	—	—	—	—	—	—	—	0.0908	0.139	—	—	—	—	—	—	—
S-3E	0.0003 (J)	0.0243	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.056	—	—	81.9	—	—	—	—
S-4W	0.000344 (J)	—	—	—	—	—	—	—	0.164	—	—	—	—	—	—	—	0.0515	0.103	—	—	28.8 (J)	—	—	—	—
S-4E	—	0.067	—	—	—	—	—	—	0.105	0.00976 (J)	—	0.00543	—	—	—	—	0.0486	0.091	—	0.00613	52.5	—	—	—	—
S-5C	—	0.0394	—	—	—	—	—	—	0.085	—	—	—	—	—	—	—	0.0387	0.083	—	0.00223 (J+)	120 (J)	—	—	—	—
S-5E	0.00024 (J)	0.0086	—	—	0.0027	—	—	—	0.013	—	—	—	—	—	—	—	0.00791 (J)	0.013	—	0.000887 (J)	69.6	—	—	—	—
S-6W	0.00052 (J)	—	—	—	—	—	—	0.00068 (J)	—	—	—	—	0.0028 (J)	—	—	—	—	—	0.00046 (J)	0.0035 (J)	47	—	0.0029 (J)	—	—
S-6E	—	—	—	—	—	—	—	0.00095 (J)	—	—	—	0.00083 (J)	—	—	—	—	—	—	0.00057 (J)	0.0048 (J)	14 (J)	—	0.004 (J)	—	—

Notes: Values are in mg/kg. Values are maximum detected values. Grey shading indicates the residential SSL was exceeded. All SSLs adjusted to a target risk of 10^{-5}.

[a] ESLs are from the ECORISK Database, Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] SSLs are from NMED (2009, 106420) unless otherwise noted.

[d] Pyrene SSL used as a surrogate for acenaphthylene and benzo(g,h,i)perylene based on structural similarity.

[e] SSL from EPA regional screening tables (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[f] BHC[beta-] used as surrogate for BHC[delta-], chlordane used as a surrogate for chlordane[gamma-], bis[2-ethylhexyl]phthalate used as a surrogate for di-n-octylphthalate.

[g] SSL from USEPA Region VI HHMSSLs (EPA 2007, 099314).

[h] — = Not a COPC in that reach (not detected or not analyzed).

[i] Isopropylbenzene (cumene) SSL used as a surrogate for isopropyltoluene[4-] based on structural similarity.

[j] Screening guidelines for diesel #2/crankcase oil (NMED 2006, 094614).

[k] Xylene[total] used as a surrogate for Xylene[1,3-]+Xylene[1,4-].

Table 6.2-3
Radionuclide COPCs in Sandia Canyon Sediment Samples

Reach	Americium-241	Cesium-137	Plutonium-238	Plutonium-239/240	Strontium-90	Thorium-228	Thorium-232	Tritium	Uranium-234	Uranium-235/236	Uranium-238
BV (pCi/g)[a]	0.04	0.9	0.006	0.068	1.04	2.28	2.33	0.093	2.59	0.2	2.29
Minimum Soil ESL[b]	44	680	44	47	560	43	6.2	36000	51	55	55
Residential SAL[c]	30	5.6	37	33	5.7	2.3	5	750	170	17	86
S-1N	—[d]	—	0.0195	—	—	—	—	—	—	—	—
S-1S	—	—	—	0.113	—	—	—	—	—	—	—
S-2	0.05	1.1	0.125	0.391	1.9	—	—	4.46	4.29	0.228	4.04
S-4W	—	—	0.0251	—	—	2.47	2.37	—	—	—	—
S-4E	—	—	—	1.72	—	—	—	—	—	—	—
S-5C	—	0.96	—	—	—	—	—	—	—	—	—
S-5E	0.0431	—	—	—	—	2.35	—	—	—	—	—

Notes: Values are in pCi/g. Values are maximum detected values greater than the sediment BV. Grey shading indicates the residential SAL was exceeded.

[a] BVs are from LANL (1998, 059730).

[b] ESLs are from the ECORISK Database, Version 2.3 (LANL 2008, 103352).

[c] SALs are from LANL (2005, 088493) unless otherwise noted.

[d] — = Not a COPC in that reach (not detected, not detected > BV, or not analyzed).

Table 6.3-1
Inorganic COPCs in Filtered Alluvial Groundwater Samples

Location	Arsenic	Barium	Boron	Chromium	Cobalt	Copper	Manganese	Mercury	Molybdenum	Strontium	Uranium	Vanadium	Zinc
LANL Alluvial GW BV[a]	5	68.57	51.89	5	5	5	21	0.1	5	120	1.03	5	10
Standard Level	10	1000	750	50	50	1000	200	2	1000	22000	30	260	10000
Standard Type	MCL[b]	NMGSF[c]	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	MCL	NMGSF	Reg[d]	NMGSF	Reg	NMGSF
NMED Tap Water[e]	0.448	7300	7300	110[f]	na[g]	1460	876	0.562	183	21900	110	183	11000
SCA-1	8.7	88.8	85.4	32.2	14.8	—[h]	1380	0.13	52.7	169	1.4	16.7	29.2
SCA-1-DP	—	85.4	75.2	8.22	—	—	792	—	11.7	121	—	—	—
SCA-2	—	131	62	10	—	120	39.9	—	13.1	243	1.5	19.1	195
SCA-4	15.7	105	86.1	16.2	—	—	—	—	67	120	—	13.7	198
SCA-5	—	71.4	—	9.2	—	—	33.2	—	—	123	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV. Grey shading indicates a standard screening value was exceeded.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665).

[b] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[c] MCL = EPA Maximum Contaminant Level.

[d] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[e] NMED Tap Water (2009, 106420).

[f] The NMED tap water value for hexavalent chromium is used for filtered chromium.

[g] na = Not available.

[h] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-2
Inorganic COPCs in Nonfiltered Alluvial Groundwater Samples

Location	Aluminum	Arsenic	Barium	Beryllium	Boron	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Strontium	Uranium	Vanadium	Zinc
LANL Alluvial GW BV[a]	15670	5	68.57	2.5	51.89	5	5	5	8270	1.88	21	0.03	5	10	120	1.03	5	10
Standard Level	37000	10	2000	4	7300	100	11	1300	26000	15	880	2	180	730	22000	30	260	11000
Standard Type	Reg[b]	MCL[c]	MCL	MCL	Reg	MCL	Reg	MCL	Reg	MCL	Reg	NMGSU[d]	Reg	Reg	Reg	MCL	Reg	Reg
NMED Tap Water[e]	36500	0.448	7300	73	7300	na[f]	na	1460	25600	na	876	0.562	183	730	21900	110	183	11000
SCA-1	—[g]	—	95	—	82.7	40.3	—	—	—	1.9	1460	—	15.5	—	186	—	8	20.9
SCA-1-DP	—	—	79.7	—	75.2	15	—	—	—	—	804	—	11.8	—	—	—	—	10.5
SCA-2	40200	8.4	498	4.6	57.8	552	10.3	66	36400	30.1	1140	0.061	16.1	23.3	228	3.2	66.8	172
SCA-4	35800	19.4	375	3.3	94.9	95.2	—	43.8	16400	38.1	415	—	59.7	20.5	150	3.8	31.2	214
SCA-5	—	—	119	—	—	13.9	—	—	—	6	115	—	—	—	127	1.1	13	27.8

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[c] MCL = EPA Maximum Contaminant Level.

[d] NMGSU = NMAC 20.6.2, Groundwater Standards (Unfiltered).

[e] NMED Tap Water (2009, 106420).

[f] na = Not available.

[g] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-3
Radionuclide COPCs in Filtered Alluvial Groundwater Samples

Location	Gross Alpha	Gross Beta	Strontium-90	Uranium-234	Uranium-238
LANL Alluvial GW BV[a]	na[b]	na	0.06	0.16	0.12
Standard Level	15	50	500	300	300
Standard Type	MCL[c]	SMCL[d]	NMRPS[e]	NMRPS	NMRPS
SCA-1	2.61	9.95	0.152	0.841	0.385
SCA-1-DP	—[f]	19	—	—	—
SCA-2	—	8.59	—	0.439	0.382
SCA-4	—	5.6	—	0.223	0.127
SCA-5	—	3.22	—	—	—

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] SMCL = EPA Secondary Maximum Contaminant Level.

[e] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[f] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-4
Radionuclide COPCs in Nonfiltered Alluvial Groundwater Samples

Location	Gross Beta	Potassium-40	Radium-226	Radium-228	Tritium	Uranium-234	Uranium-235/236	Uranium-238
LANL Alluvial GW BV[a]	na[b]	na	na	na	57.28	na	na	na
Standard Level	50	4000	5	5	20000	300	300	300
Standard Type	SMCL[c]	NMRPS[d]	MCL[e]	MCL	LWU[f]	NMRPS	NMRPS	NMRPS
SCA-1	7.58	—[g]	—	—	76.3	1.12	0.0364	0.621
SCA-1-DP	16.3	—	—	1.65	59.71	0.3	—	0.174
SCA-2	9.81	72.9	0.454	0.658	—	2.5	0.121	2.24
SCA-4	—	—	1.42	3.22	61.9	3.8	0.204	3.89
SCA-5	3.21	—	—	—	—	0.292	—	0.283

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] SMCL = EPA Secondary Maximum Contaminant Level.

[d] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[e] MCL = EPA Maximum Contaminant Level.

[f] LWU = NMAC 20.6.4, Livestock Watering (Unfiltered).

[g] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-5
Organic COPCs in Nonfiltered Alluvial Groundwater Samples

Location	Acetone	Aroclor-1254	Aroclor-1260	Bis[2-ethylhexyl]phthalate	Butanone[2-]	Chloroform	Dichlorobenzene[1,3-]	Dioxane[1,4-]	Styrene	Toluene
Standard Level	22000	0.5	0.5	6	7100	100	14	61	100	750
Standard Type	Reg[a]	MCL[b]	MCL	MCL	Reg	NMGSU[c]	Reg6[d]	Reg	MCL	NMGSU
NMED Tap Water[e]	21800	0.336	0.336	48	7060	1.93	na[f]	61.1	1620	2280
SCA-1	3.8	0.099	0.063	—	2.1	—	—	—	—	3.97
SCA-1-DP	—[g]	—	—	—	—	—	—	—	—	1.19
SCA-2	—	—	—	—	—	0.409	—	2.97	—	—
SCA-4	—	—	—	51.2	6.26	0.366	3.49	—	3.86	0.288
SCA-5	—	—	—	—	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm). adjusted to a target risk of 10^{-5}.

[b] MCL = EPA Maximum Contaminant Level.

[c] NMGSU = NMAC 20.6.2, Groundwater Standards (Unfiltered).

[d] Reg6 = EPA Region6 (historical) Tap Water Screening Level, LANL (2007, 099314).

[e] NMED Tap Water (2009, 106420).

[f] na = Not available.

[g] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-6
General Inorganic COPCs in Filtered Alluvial Groundwater Samples

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Potassium	Silicon Dioxide	Sodium	Sulfate	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
LANL Alluvial GW BV[a]	250	100	26360	69760	270	7780	570	5210	64210	15540	24830	460	40
Standard Level	na[b]	na	na	250000	1600	na	10000	na	na	na	600000	na	na
Standard Type	na	na	na	NMGSF[c]	NMGSF	na	NMGSF	na	na	na	NMGSF	na	na
NMED Tap Water[d]	na	na	na	na	2190	na	na	na	na	na	na	na	na
SCA-1	414	1290	36500	197000	638	9850	5940	20700	116000	153000	36300	849	3660
SCA-1-DP	—[e]	611	—	106000	706	—	—	15800	112000	108000	36000	—	3000
SCA-2	—	555	54400	266000	549	13300	1930	17300	91700	157000	37300	—	2750
SCA-4	—	526	—	123000	1070	—	1930	—	67400	103000	25000	—	4080
SCA-5	—	179	—	—	555	—	—	—	74100	35800	—	—	370

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Regional Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[d] NMED Tap Water (2009, 106420).

[e] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-7
General Inorganic COPCs in Nonfiltered Alluvial Groundwater Samples

Location	Bromide	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Potassium	Silicon Dioxide	Sodium	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
LANL Alluvial GW BV[a]	100	26360	69760	na[b]	270	7780	5210	64210	15540	460	40
Standard Level	na	na	na	200	4000	na	na	na	na	na	na
Standard Type	na	na	na	MCL[c]	MCL	na	na	na	na	na	na
NMED Tap Water[d]	na	na	na	na	2190	na	na	na	na	na	na
SCA-1	409	40300	76600	7.51	408	11000	20800	106000	156000	601	4380
SCA-1-DP	—[e]	—	—	—	—	—	15400	—	109000	—	—
SCA-2	—	51900	—	6.87	—	12900	19800	—	152000	689	—
SCA-4	—	—	—	4.14	—	—	6890	—	105000	—	—
SCA-5	181	—	—	—	550	—	—	105000	35200	—	428

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] NMED Tap Water (2009, 106420).

[e] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-8
Inorganic COPCs in Filtered Perched Intermediate Groundwater Samples

Location	Antimony	Boron	Chromium	Lead	Manganese	Molybdenum	Strontium	Uranium	Zinc
LANL Intermediate GW BV[a]	0.5	15.12	2.4	0.3	3.63	4.3	154.76	0.72	19
Standard Level	6	750	50	15	200	1000	22000	30	10000
Standard Type	MCL[b]	NMGSF[c]	NMGSF	MCL	NMGSF	NMGSF	Reg[d]	NMGSF	NMGSF
NMED Tap Water[e]	14.6	7300	110[f]	na[g]	876	183	21900	110	11000
SCI-1	1.9	98	22.1	—[h]	4.3	77.7	383	3.05	—
SCI-2	—	18.7	658	—	12.8	—	297	1.75	—
R-12, screen 1	—[g]	74	4.82	2.1	288	16.6	—	1.1	204
R-12, screen 2	—	41.7	3.3	—	45.9	4.8	—	0.81	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV. Grey shading indicates a standard screening value was exceeded.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665).

[b] MCL = EPA Maximum Contaminant Level.

[c] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[d] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[e] NMED Tap Water (2009, 106420).

[f] The NMED tap water value for hexavalent chromium is used for filtered chromium.

[g] na = Not available.

[h] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-9
Inorganic COPCs in Nonfiltered Perched Intermediate Groundwater Samples

Location	Boron	Chromium	Chromium Hexavalent Ion	Copper	Iron	Lead	Manganese	Molybdenum	Strontium	Tin	Uranium	Zinc
LANL Intermediate GW BV[a]	15.12	2.4	na[b]	5.32	839.99	0.3	3.63	4.3	154.76	1.25	0.72	19
Standard Level	7300	100	110	1300	26000	15	880	180	22000	22000	30	11000
Standard Type	Reg[c]	MCL[d]	Reg	MCL	Reg	MCL	Reg	Reg	Reg	Reg	MCL	Reg
NMED Tap Water[e]	7300	na	110	1460	25600	na	876	183	21900	na	110	11000
SCI-1	101	22	—[f]	11.3	1660	—	10.9	76.8	394	4.7	3.05	—
SCI-2	19	644	—	—	870	—	13.8	—	306	—	1.68	—
R-12, screen 1	77	6.03	0.33	—	—	3.27	260	19.2	—	—	0.89	150
R-12, screen 2	44	3.2	0.5	—	—	—	50.9	5.3	—	—	—	48

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] na = Not available.

[c] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[d] MCL = EPA Maximum Contaminant Level.

[e] NMED Tap Water (2009, 106420).

[f] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-10
Radionuclide COPCs in Filtered Perched Intermediate Groundwater Samples

Location	Gross Alpha	Gross Alpha/Beta	Gross Beta	Gross Gamma	Potassium-40	Uranium-234	Uranium-235/236	Uranium-238
LANL Intermediate GW BV[a]	na[b]	na	na	na	na	0.26	na	0.2
Standard Level	15	na	50	na	4000	300	300	300
Standard Type	MCL[c]	na	SMCL[d]	na	NMRPS[e]	NMRPS	NMRPS	NMRPS
SCI-1	3.73	—[f]	3.8	—	—	2.17	0.101	1.01
SCI-2	—	—	4.2	89.9	—	0.758	0.0622	0.406
R-12, screen 1	1.17	—	3.49	—	58	0.526	—	0.351
R-12, screen 2	—	0.735	2.3	64.4	—	0.447	0.0364	—

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] SMCL = EPA Secondary Maximum Contaminant Level.

[e] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[f] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-11
Radionuclide COPCs in Nonfiltered Perched Intermediate Groundwater Samples

Location	Gross Alpha	Gross Beta	Gross Gamma	Radium-226	Radium-228	Tritium	Uranium-234	Uranium-235/236	Uranium-238
LANL Intermediate GW BV[a]	na[b]	na	na	na	na	7.54	na	na	na
Standard Level	15	50	na	5	5	20000	300	300	300
Standard Type	MCL[c]	SMCL[d]	na	MCL	MCL	LWU[e]	NMRPS[f]	NMRPS	NMRPS
SCI-1	5.58	4.5	—[g]	—	2.3	149.8	2.29	0.153	1.09
SCI-2	—	4.39	90.8	—	0.854	510.9	0.791	0.0298	0.415
R-12, screen 1	—	5.27	—	—	0.74	149.4	0.455	—	0.292
R-12, screen 2	—	3.64	75.7	0.705	1.31	67.12	0.399	0.0342	0.207

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] SMCL = EPA Secondary Maximum Contaminant Level.

[e] LWU = NMAC 20.6.4, Livestock Watering (Unfiltered).

[f] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[g] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-12
Organic COPCs in Nonfiltered Perched Intermediate Groundwater Samples

Location	Acetone	Aldrin	Benzoic Acid	Bis[2-ethylhexyl]phthalate	Chloroform	Chloromethane	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	Dieldrin	Endosulfan II	Endosulfan Sulfate	Endrin	Heptachlor	Heptachlor Epoxide	Naphthalene	Toluene	Total Petroleum Hydrocarbons Diesel Range Organics
Standard Level	22000	0.04	150000	6	100	190	2.8	2	2	0.042	220	220	2	0.4	0.2	30	750	na[a]
Standard Type	Reg[b]	Reg	Reg	MCL[c]	NMGSU[d]	Reg	Reg	Reg	Reg	Reg	Reg	Reg	MCL	MCL	MCL	NMGSU	NMGSU	na
NMED Tap Water[e]	21800	0.0392	na	48	1.93	17.8	2.8	1.98	1.98	0.042	na	na	11	0.149	na	1.43	2280	na
SCI-1	1.52	0.0122	—[f]	—	0.853	—	0.0495	0.0495	0.0659	0.0389	0.0185	0.0186	0.0285	0.0229	0.0257	1.52	—	47.1
SCI-2	3.12	0.0175	—	—	0.339	0.589	—	—	—	—	—	—	—	—	—	—	—	—
R-12, screen 1	5.32	—	19.7	—	—	—	—	—	—	—	—	—	—	—	—	—	0.489	—
R-12, screen 2	—	—	—	25.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] na = Not available.

[b] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm). adjusted to a target risk of 10^{-5}.

[c] MCL = EPA Maximum Contaminant Level.

[d] NMGSU = NMAC 20.6.2, Groundwater Standards (Unfiltered).

[e] NMED Tap Water (2009, 106420).

[f] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-13
General Inorganic COPCs in Filtered Perched Intermediate Groundwater Samples

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Silicon Dioxide	Sodium	Sulfate	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
LANL Intermediate GW BV[a]	70	30	17310	7780	na[b]	230	6120	2410	0.18	50720	12190	40030	200	80
Standard Level	na	na	na	250000	200	1600	na	10000	15	na	na	600000	na	na
Standard Type	na	na	na	NMGSF[c]	NMGSF	NMGSF	na	NMGSF	MCL[d]	na	na	NMGSF	na	na
NMED Tap Water[e]	na	na	na	na	na	2190	na	na	na	na	na	na	na	na
SCI-1	—[f]	1530	87600	98700	3.23	278	13000	4990	1.58	67800	62100	112000	—	914
SCI-2	—	498	64800	62100	7.98	269	14700	5100	1.04	65200	22800	101000	—	179
R-12, screen 1	1400	128	28700	16800	—	671	6280	—	0.363	—	20600	—	1540	367
R-12, screen 2	101	101	17800	—	—	673	—	—	1.16	—	13000	—	—	8860

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[d] MCL = EPA Maximum Contaminant Level.

[e] NMED Tap Water (2009, 106420).

[f] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-14
General Inorganic COPCs in Nonfiltered Perched Intermediate Groundwater Samples

Location	Ammonia as Nitrogen	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Sodium	Sulfide, Total	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
LANL Intermediate GW BV[a]	70	17310	7780	na[b]	230	6120	12190	na	200	80
Standard Level	na	na	na	200	4000	na	na	na	na	na
Standard Type	na	na	na	MCL[c]	MCL	na	na	na	na	na
NMED Tap Water[d]	na	na	na	na	2190	na	na	na	na	na
SCI-1	—[e]	90300	—	5.22	—	13300	64600	13	604	—
SCI-2	—	65000	—	7.97	—	14700	22100	—	—	—
R-12, screen 1	1660	27000	10300	2.67	660	—	20800	—	1490	335
R-12, screen 2	220	18100	—	—	373	—	13400	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Intermediate Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] na = Not available.

[c] NMED Tap Water (2009, 106420).

[d] MCL = EPA Maximum Contaminant Level.

[e] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-15
Inorganic COPCs in Filtered Regional Groundwater Samples

Location	Aluminum	Barium	Boron	Chromium	Chromium Hexavalent Ion	Copper	Iron	Molybdenum	Nickel	Selenium	Tin	Uranium	Vanadium	Zinc
LANL Regional GW BV[a]	73.5	56.83	38.77	5.75	na[b]	5	147	4.4	50	3.93	3.6	1.9	13.41	32
Standard Level	5000	1000	750	50	50	1000	1000	1000	200	50	22000	30	260	10000
Standard Type	NMGSF[c]	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	Reg[d]	NMGSF	Reg	NMGSF
NMED Tap Water[e]	36500	7300	7300	110[f]	110	1460	25600	183	730	183	na	110	183	11000
Sandia Canyon Wells														
R-10, screen 1	—[g]	—	—	—	—	—	—	—	—	—	36.5	—	—	—
R-10, screen 2	—	—	—	—	—	6.24	—	—	—	—	—	—	—	—
R-10a	—	104	—	6.3	4.2	5	—	—	—	—	—	4.6	—	111
R-11	75	—	43.8	34.8	27.3	5	—	—	—	9.2	—	—	—	37
R-35a	—	340	44.2	10.6	—	—	315	—	—	—	—	—	19	185
R-35b	—	—	—	5.9	—	—	—	—	—	—	—	—	15.5	62.3
R-36	—	—	—	11.6	—	—	—	—	—	—	—	—	15.2	75.3
R-43, screen 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-43, screen 2	—	—	—	—	—	—	255	—	—	—	—	—	—	—
Sandia Spring	—	81.5	—	—	—	—	—	—	—	—	—	—	—	—
Mortandad Canyon Wells														
R-1	—	—	—	8.7	4.9	—	—	—	—	—	—	—	—	—
R-13	—	—	—	12.7	4.4	—	—	10.2	—	—	—	—	—	—
R-15	—	—	—	10.5	7	—	—	—	—	—	—	—	—	—
R-28	—	67.5	—	468	417	—	—	—	—	6.8	—	—	—	—
R-33, screen 1	—	—	—	8.6	4.9	11.6	918	—	—	—	—	—	—	38.6

Table 6.3-15 (continued)

Location	Aluminum	Barium	Boron	Chromium	Chromium Hexavalent Ion	Copper	Iron	Molybdenum	Nickel	Selenium	Tin	Uranium	Vanadium	Zinc
LANL Regional GW BV[a]	73.5	56.83	38.77	5.75	na[b]	5	147	4.4	50	3.93	3.6	1.9	13.41	32
Standard Level	5000	1000	750	50	50	1000	1000	1000	200	50	22000	30	260	10000
Standard Type	NMGSF[c]	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	NMGSF	Reg[d]	NMGSF	Reg	NMGSF
NMED Tap Water[e]	36500	7300	7300	110[f]	110	1460	25600	183	730	183	na	110	183	11000
R-33, screen 2	—	—	—	8	4.8	—	430	10.9	168	—	—	—	—	—
R-42	—	81.5	—	886	—	—	—	—	—	—	—	—	—	—
R-44, screen 1	—	—	—	12.8	—	—	—	—	—	—	—	—	—	53.3
R-44, screen 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-45, screen 1	—	—	—	12.1	—	—	—	—	—	—	—	—	—	63.2
R-45, screen 2	—	—	—	6.45	—	—	390	—	—	—	—	—	—	—
Water-Supply Wells														
O-4	—	—	—	5.9	4	—	—	—	—	—	—	—	—	—
PM-1	—	78.2	54.3	5.8	4.1	—	—	—	—	—	—	—	—	—
PM-3	—	—	53.2	11.5	4.5	—	—	—	—	—	—	—	15.7	—
PM-5	—	—	—	15.6	5.7	—	—	—	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Regional Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[d] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[e] NMED Tap Water (2009, 106420).

[f] The NMED tap water value for hexavalent chromium is used for filtered chromium.

[g] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-16
Inorganic COPCs in Nonfiltered Regional Groundwater Samples

Location	Aluminum	Barium	Boron	Chromium	Chromium Hexavalent Ion	Copper	Iron	Lead	Molybdenum	Selenium	Tin	Uranium	Vanadium	Zinc
LANL Regional GW BV[a]	73.5	56.83	38.77	5.75	na[b]	5	147	2.9	4.4	4.99	3.6	1.9	13.41	32
Standard Level	37000	2000	7300	100	110	1300	26000	15	180	50	22000	30	260	11000
Standard Type	Reg[c]	MCL[d]	Reg	MCL	Reg	MCL	Reg	MCL	Reg	MCL	Reg	MCL	Reg	Reg
NMED Tap Water[e]	36500	7300	7300	na	110	1460	25600	na	183	183	na	110	183	11000
Sandia Canyon Wells														
R-10, screen 1	—[f]	—	—	5.8	2.5	—	152	—	—	—	—	—	—	73.4
R-10, screen 2	101	—	—	—	2.3	—	—	—	—	—	—	—	—	33.6
R-10a	—	104	95	12.7	4.3	15.3	362	3.5	—	—	—	4.4	—	309
R-11	477	—	47	35.1	28.2	6	—	—	—	—	159	—	—	—
R-35a	—	342	43.4	13.9	—	9	792	4.4	—	—	—	—	18.2	364
R-35b	80.5	—	—	6.6	—	5.3	350	—	—	—	—	—	15	105
R-36	—	—	—	12.2	—	—	238	—	—	—	—	—	15.2	127
R-43, screen 1	83.4	—	—	6.81	—	—	2330	—	—	—	—	—	—	—
R-43, screen 2	—	—	—	—	—	—	994	—	—	—	—	—	—	—
Sandia Spring	610	85.7	—	—	—	—	462	—	—	6.2	—	1.95	15.3	—
Mortandad Canyon Wells														
R-1	—	—	—	8.9	4.9	—	525	—	—	—	—	—	—	—
R-13	263	—	—	8.4	4.4	—	208	—	49.3	—	—	—	—	46.7
R-15	—	—	—	11.3	7.1	—	276	—	—	—	—	—	—	—
R-28	—	64.3	—	490	423	—	184	—	—	6.3	—	—	—	—
R-33, screen 1	85.1	—	—	12.3	4.8	5.2	402	—	—	6.2	—	—	—	63.2
R-33, screen 2	—	—	—	8.9	4.1	—	681	—	—	—	—	—	—	—

Table 6.3-16 (continued)

Location	Aluminum	Barium	Boron	Chromium	Chromium Hexavalent Ion	Copper	Iron	Lead	Molybdenum	Selenium	Tin	Uranium	Vanadium	Zinc
LANL Regional GW BV[a]	73.5	56.83	38.77	5.75	na[b]	5	147	2.9	4.4	4.99	3.6	1.9	13.41	32
Standard Level	37000	2000	7300	100	110	1300	26000	15	180	50	22000	30	260	11000
Standard Type	Reg[c]	MCL[d]	Reg	MCL	Reg	MCL	Reg	MCL	Reg	MCL	Reg	MCL	Reg	Reg
NMED Tap Water[e]	36500	7300	7300	na	110	1460	25600	na	183	183	na	110	183	11000
R-42	—	82.7	—	910	—	—	158	—	—	—	—	—	—	—
R-44, screen 1	—	—	—	13.5	—	—	376	—	—	—	—	—	—	81.1
R-44, screen 2	—	—	—	6.73	—	—	235	—	—	—	—	—	—	—
R-45, screen 1	—	—	—	12.4	—	—	227	—	—	—	—	—	—	95.6
R-45, screen 2	—	—	—	7.62	—	—	453	—	—	—	—	—	—	32.9
Water-Supply Wells														
O-4	—	60.7	58.3	5.9	4.1	—	—	—	—	—	—	—	17.8	—
PM-1	—	75.8	56.4	6.1	3.9	—	—	—	—	—	—	1.95	—	—
PM-3	—	—	53.6	11.6	4.6	—	—	—	—	—	—	—	16.1	—
PM-5	—	—	—	15.5	5.5	—	—	—	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] na = Not available.

[c] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm).

[d] MCL = EPA Maximum Contaminant Level.

[e] NMED Tap Water (2009, 106420).

[f] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-17
Radionuclide COPCs in Filtered Regional Groundwater Samples

Location	Gross Alpha	Gross Alpha/Beta	Gross Gamma	Radium-226	Uranium-234	Uranium-235/236	Uranium-238
LANL Regional GW BV[a]	2.54	na[b]	123	na	2.17	na	1.2
Standard Level	15	na	na	5	300	300	300
Standard Type	MCL[c]	na	na	MCL	NMRPS[d]	NMRPS	NMRPS
Sandia Canyon Wells							
R-10, screen 1	—[e]	—	—	—	—	0.0539	—
R-10, screen 2	—	—	—	—	—	0.0488	—
R-10a	3.1	3	—	—	2.2	0.105	1.24
R-11	—	—	—	—	—	—	—
R-35a	—	—	—	—	—	0.0519	—
R-35b	—	—	—	—	—	—	—
R-36	—	—	—	—	—	—	—
R-43, screen 1	—	—	—	—	—	—	—
R-43, screen 2	—	—	—	—	—	—	—
Sandia Spring	—	—	—	2.25	—	0.193	—
Mortandad Canyon Wells							
R-1	—	—	—	—	—	0.049	—
R-13	—	—	—	—	—	—	—
R-15	—	—	—	—	—	—	—
R-28	—	—	—	—	—	0.0748	—
R-33, screen 1	—	—	—	0.579	—	—	—
R-33, screen 2	—	—	191	—	—	0.0378	—
R-42	—	—	—	—	—	—	—

Table 6.3-17 (continued)

Location	Gross Alpha	Gross Alpha/Beta	Gross Gamma	Radium-226	Uranium-234	Uranium-235/236	Uranium-238
LANL Regional GW BV[a]	2.54	na[b]	123	na	2.17	na	1.2
Standard Level	15	na	na	5	300	300	300
Standard Type	MCL[c]	na	na	MCL	NMRPS[d]	NMRPS	NMRPS
R-44, screen 1	—	—	—	—	—	—	—
R-44, screen 2	—	—	—	—	—	—	—
R-45, screen 1	—	3.38	131	—	—	—	—
R-45, screen 2	—	2.54	—	—	—	—	—
Water-Supply Wells							
PM-1	—	—	—	—	—	—	—
PM-3	—	—	—	—	—	—	—
PM-5	—	—	—	—	—	—	—

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Regional Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[e] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-18
Radionuclide COPCs in Nonfiltered Regional Groundwater Samples

Location	Americium-241	Gross Alpha	Gross Alpha/Beta	Gross Beta	Gross Gamma	Plutonium-238	Potassium-40	Radium-226	Radium-228	Strontium-90	Thorium-230	Tritium	Uranium-234	Uranium-235/236	Uranium-238
LANL Regional GW BV[a]	na[b]	na	na	na	na	na	na	na	na	na	na	11.43	na	na	na
Standard Level	20	15	na	50	na	20	4000	5	5	500	na	20000	300	300	300
Standard Type	NMRPS[c]	MCL[d]	na	SMCL[e]	na	NMRPS	NMRPS	MCL	MCL	NMRPS	na	LWU[f]	NMRPS	NMRPS	NMRPS
Sandia Canyon Wells															
R-10, screen 1	—[g]	—	—	3.9	69.7	—	—	—	—	—	—	—	0.918	0.0513	0.47
R-10, screen 2	—	3.62	—	4.6	—	—	—	0.692	—	—	—	—	1.05	0.0494	0.571
R-10a	—	3.45	2.79	6.78	—	—	—	—	—	—	—	—	2.89	0.128	1.53
R-11	—	1.27	—	3.7	—	—	—	—	0.481	0.825	—	11.65	0.696	—	0.304
R-35a	—	—	—	5.2	—	—	—	0.428	—	—	—	—	0.601	—	0.281
R-35b	—	—	—	—	164	—	—	—	1.13	—	—	—	0.32	—	0.239
R-36	—	—	—	3.4	—	—	—	—	—	—	—	20.82	0.371	—	0.147
R-43, screen 1	—	—	—	2.48	67	—	—	0.883	0.521	—	—	—	0.144	—	0.0537
R-43, screen 2	—	—	—	—	—	—	—	0.73	1.45	—	—	—	1.03	—	0.402
Sandia Spring	—	2.47	—	3.24	—	—	—	—	—	—	—	293	0.784	0.0589	0.414
Mortandad Canyon Wells															
R-1	—	14.5	—	3.75	—	—	—	1.13	0.804	—	—	—	0.698	0.0672	0.288
R-13	—	0.647	—	2.58	—	—	—	0.443	0.811	—	—	—	0.31	0.0637	0.15
R-15	—	—	—	—	—	—	—	0.926	—	—	—	37.84	0.339	0.0403	0.18
R-28	—	1.75	—	12.4	—	0.0324	—	—	—	—	—	233.6	0.851	0.0844	0.399
R-33, screen 1	—	—	—	2.64	—	—	36.8	0.706	—	—	—	137.3	0.538	0.0334	0.297
R-33, screen 2	—	0.901	—	5.77	—	—	—	—	—	—	—	—	0.626	0.0505	0.343

Table 6.3-18 (continued)

Location	Americium-241	Gross Alpha	Gross Alpha/Beta	Gross Beta	Gross Gamma	Plutonium-238	Potassium-40	Radium-226	Radium-228	Strontium-90	Thorium-230	Tritium	Uranium-234	Uranium-235/236	Uranium-238
LANL Regional GW BV[a]	na[b]	na	na	na	na	na	na	na	na	na	na	11.43	na	na	na
Standard Level	20	15	na	50	na	20	4000	5	5	500	na	20000	300	300	300
Standard Type	NMRPS[c]	MCL[d]	na	SMCL[e]	na	NMRPS	NMRPS	MCL	MCL	NMRPS	na	LWU[f]	NMRPS	NMRPS	NMRPS
R-42	—	—	—	—	—	—	—	—	0.872	—	—	205.3	0.6	0.038	0.251
R-44, screen 1	—	—	—	2.99	—	—	—	0.781	—	—	—	—	0.327	—	0.175
R-44, screen 2	—	—	—	3.67	—	—	—	—	—	—	—	—	0.483	—	0.178
R-45, screen 1	—	—	—	7.96	—	—	—	1.68	1.54	—	—	—	0.559	—	0.236
R-45, screen 2	—	—	—	4.31	—	—	—	—	—	—	—	—	0.525	—	0.239
Water-Supply Wells															
O-4	—	—	—	4.33	—	—	—	0.656	—	—	—	—	0.622	0.0947	0.31
PM-1	0.0373	2.76	—	5.12	—	—	—	0.709	1.02	—	—	—	1.31	0.0841	0.642
PM-3	—	9.09	—	8.93	—	—	—	0.68	—	—	—	—	0.829	0.0836	0.364
PM-5	0.157	—	—	5.35	—	—	—	0.565	—	—	0.209	—	0.414	0.044	0.235

Notes: Values are in pCi/L. Values are maximum values greater than the LANL BV; if no BV, value is maximum detected value.

[a] Regional Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[d] MCL = EPA Maximum Contaminant Level.

[e] SMCL = EPA Secondary Maximum Contaminant Level.

[f] LWU = NMAC 20.6.4, Livestock Watering (Unfiltered).

[g] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-19
Organic COPCs in Nonfiltered Regional Groundwater Samples

Location	Acetone	Aroclor-1016	Aroclor-1254	Aroclor-1260	Benzene	Benzoic Acid	Bis[2-ethylhexyl]phthalate	Bromomethane	Butanone[2-]	Carbon Disulfide	Chloromethane	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	DNX	Dichlorobenzene[1,3-]	Dichlorophenol[2,4-]	Dieldrin	Diethylphthalate	Dinitrobenzene[1,3-]	Endrin	Heptachlor	Heptachlor Epoxide	Methyl-2-pentanone[4-]	Methylene Chloride	Nitrotoluene[3-]	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	Phenanthrene	Phenol	Toluene	Total Petroleum Hydrocarbons Diesel Range Organics	Trichlorophenol[2,4,5-]	Trichlorophenol[2,4,6-]	Xylene[1,3-]+Xylene[1,4-]
Standard Level	22000	0.5	0.5	0.5	5	150000	6	8.7	7100	1000	190	2.8	2	2	na[a]	14	110	0.042	29000	3.7	2	0.4	0.2	2000	5	730	na	na	5	750	na	3700	61	na
Standard Type	Reg[b]	MCL[c]	MCL	MCL	MCL	Reg	MCL	Reg	Reg	Reg	Reg	Reg	Reg	Reg	na	Reg6[d]	Reg	Reg	Reg	Reg	MCL	MCL	MCL	Reg	MCL	Reg	na	na	NMGSU[e]	NMGSU	na	Reg	Reg	na
NMED Tap Water[f]	21800	2.56	0.336	0.336	4.13	na	48	8.66	7060	1040	17.8	2.8	1.98	1.98	na	na	110	0.042	29200	na	11	0.149	na	na	48	na	na	1100	11000	2280	na	3650	36.5	na
Sandia Canyon Wells																																		
R-10, screen 1	3.06	0.0739	—[g]	0.075	—	—	—	—	—	—	0.318	—	—	—	—	—	—	—	—	—	—	—	—	—	2.93	—	—	—	—	—	—	—	—	—
R-10, screen 2	3.56	—	—	—	—	14.3	—	—	—	—	—	—	—	—	0.078	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-10a	3.49	—	—	—	—	9.69	2.83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.66	—	—	—	—	—	25.3	—	—	—	—
R-11	1.99	—	—	—	—	—	—	—	—	3.02	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.237	—	0.26	—	—	—	—
R-35a	3.35	—	—	—	—	—	—	—	4.76	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.31	—	—	—	—
R-35b	—	—	0.051	—	—	—	2.49	—	—	2.91	0.45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.19	—	—	—	—
R-36	9.02	—	—	—	—	—	59.1	23.6	—	—	1.86	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.2	—	—	—	—
R-43, screen 1	114	—	—	—	—	—	4.67	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.46E-06	—	—	—	—	—	—
R-43, screen 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sandia Spring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.318	0.58	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.2	2.1	—
Mortandad Canyon Wells																																		
R-1	2.44	—	—	—	—	—	—	—	—	—	—	0.00973	0.0118	0.0136	—	—	—	—	7.44	—	—	—	—	—	—	—	—	4.93E-06	—	—	0.278	—	—	—	0.341
R-13	1.37	—	—	—	—	—	—	—	—	2.15	—	—	0.0059	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-15	6.32	—	—	—	0.318	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.184	—	—	—	—	—	—	—	—
R-28	1.52	—	—	—	—	—	—	—	—	—	1.17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29.1	—	—	—	—
R-33, screen 1	2.83	—	—	—	—	—	4.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0335	—	—	—	—	—	—	4.87	—	—	—	—	—
R-33, screen 2	—	—	—	—	—	—	8.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-42	19.4	—	—	—	—	—	11.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12.2	—	—	—	—
R-44, screen 1	24.6	—	—	—	—	—	—	—	—	—	0.316	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.261	—	—	—	—
R-44, screen 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-45, screen 1	18.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.167	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-45, screen 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.42E-06	—	—	—	—	—	—

Table 6.3-19 (continued)

Location	Acetone	Aroclor-1016	Aroclor-1254	Aroclor-1260	Benzene	Benzoic Acid	Bis[2-ethylhexyl]phthalate	Bromomethane	Butanone[2-]	Carbon Disulfide	Chloromethane	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	DNX	Dichlorobenzene[1,3-]	Dichlorophenol[2,4-]	Dieldrin	Diethylphthalate	Dinitrobenzene[1,3-]	Endrin	Heptachlor	Heptachlor Epoxide	Methyl-2-pentanone[4-]	Methylene Chloride	Nitrotoluene[3-]	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	Phenanthrene	Phenol	Toluene	Total Petroleum Hydrocarbons Diesel Range Organics	Trichlorophenol[2,4,5-]	Trichlorophenol[2,4,6-]	Xylene[1,3-]+Xylene[1,4-]
Standard Level	22000	0.5	0.5	0.5	5	150000	6	8.7	7100	1000	190	2.8	2	2	na[a]	14	110	0.042	29000	3.7	2	0.4	0.2	2000	5	730	na	na	5	750	na	3700	61	na
Standard Type	Reg[b]	MCL[c]	MCL	MCL	MCL	Reg	MCL	Reg	Reg	Reg	Reg	Reg	Reg	Reg	na	Reg6[d]	Reg	Reg	Reg	Reg	MCL	MCL	MCL	Reg	MCL	Reg	na	na	NMGSU[e]	NMGSU	na	Reg	Reg	na
NMED Tap Water[f]	21800	2.56	0.336	0.336	4.13	na	48	8.66	7060	1040	17.8	2.8	1.98	1.98	na	na	110	0.042	29200	na	11	0.149	na	na	48	na	na	1100	11000	2280	na	3650	36.5	na
Water-Supply Wells																																		
O-4	1.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	130	—	—	—
PM-1	1.89	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35	—	—	—
PM-3	—	—	—	—	—	—	—	—	—	1.74	—	0.0222	—	—	—	—	—	0.00967	—	—	0.0105	—	0.00645	—	—	—	—	—	—	—	—	—	—	—
PM-5	—	—	—	—	—	—	—	—	—	—	—	0.00792	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.266

Notes: Values are in µg/L. Values are maximum detected value. Grey shading indicates a Standard screening value was exceeded.

[a] na = Not available.

[b] Reg = EPA Regional Tap Water Screening Level (http://www.epa.gov/region06/6pd/rcra_c/pd-n/screen.htm) adjusted to a target risk of 10^{-5}.

[c] MCL = EPA Maximum Contaminant Level.

[d] Reg6 = EPA Region6 (historical) Tap Water Screening Level, LANL (2007, 099314).

[e] NMGSU = NMAC 20.6.2, Groundwater Standards (Unfiltered)

[f] NMED Tap Water (2009, 106420).

[g] — = Analyte is not a COPC at that location (not detected or not analyzed).

Table 6.3-20
General Inorganic COPCs in Filtered Regional Groundwater Samples

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Potassium	Silicon Dioxide	Sulfate	Total Phosphate as Phosphorus
LANL Regional GW BV[a]	250	180	24880	3570	na[b]	570	4150	890	0.46	2630	88500	7200	340
Standard Level	na	na	na	250000	200	1600	na	10000	15	na	na	600000	na
Standard Type	na	na	na	NMGSF[c]	NMGSF	NMGSF	na	NMGSF	MCL[d]	na	na	NMGSF	na
NMED Tap Water[e]	na	na	na	na	na	2190	na	na	na	na	na	na	na
Sandia Canyon Wells													
R-10, screen 1	—[f]	—	—	—	—	—	4300	—	0.573	2690	—	—	—
R-10, screen 2	—	—	—	—	—	—	4790	—	0.563	2970	—	—	—
R-10a	—	—	35200	6290	—	—	4830	2080	0.821	3560	—	12900	—
R-11	—	—	—	4650	—	—	6410	7430	0.82	—	—	9310	—
R-35a	529	—	—	6670	—	—	6230	—	—	5220	—	—	—
R-35b	—	—	—	—	—	698	5060	1310	0.593	—	—	—	445
R-36	—	—	—	5950	—	711	4380	2430	1.74	—	—	7410	—
R-43, screen 1	—	—	—	4070	—	—	—	6030	0.873	—	—	9010	—
R-43, screen 2	—	—	—	4000	—	—	4870	5400	0.756	—	—	8920	—
Sandia Spring	—	—	38500	4020	—	633	4770	—	—	2940	—	7350	—
Mortandad Canyon Wells													
R-1	—	—	—	—	—	—	4220	—	—	—	—	—	—
R-13	—	—	—	—	—	—	—	1320	—	—	—	—	370
R-15	—	—	—	4430	—	—	—	3310	7.06	—	—	—	—
R-28	—	232	44300	31700	5.09	—	11300	5390	1.13	—	—	46300	—
R-33, screen 1	—	—	—	—	—	—	4150	905	—	—	—	—	—

Table 6.3-20 (continued)

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Potassium	Silicon Dioxide	Sulfate	Total Phosphate as Phosphorus
LANL Regional GW BV[a]	250	180	24880	3570	na[b]	570	4150	890	0.46	2630	88500	7200	340
Standard Level	na	na	na	250000	200	1600	na	10000	15	na	na	600000	na
Standard Type	na	na	na	NMGSF[c]	NMGSF	NMGSF	na	NMGSF	MCL[d]	na	na	NMGSF	na
NMED Tap Water[e]	na	na	na	na	na	2190	na	na	na	na	na	na	na
R-33, screen 2	—	—	—	—	—	—	4360	—	—	—	—	—	340
R-42	—	193	45700	32500	2.9	—	12900	7030	1.31	—	—	62100	—
R-44, screen 1	—	—	—	—	—	—	—	1000	—	—	—	—	—
R-44, screen 2	—	—	—	—	—	—	4220	—	—	—	—	—	—
R-45, screen 1	—	—	—	—	—	—	4770	1440	0.486	—	—	—	—
R-45, screen 2	—	—	—	—	—	—	4780	—	—	—	—	—	—
Water-Supply Wells													
O-4	—	—	—	—	—	—	—	—	—	—	—	—	—
PM-1	—	—	25200	—	—	—	6390	—	—	3880	—	—	—
PM-3	—	—	—	—	—	—	7930	—	—	3620	89500	—	—
PM-5	—	—	—	—	—	—	4400	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV.

[a] Regional Groundwater BVs are from LANL (2007, 096665).

[b] na = Not available.

[c] NMGSF = NMAC 20.6.2, Groundwater Standards (Filtered).

[d] MCL = EPA Maximum Contaminant Level.

[e] NMED Tap Water (2009, 106420).

[f] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-21
General Inorganic COPCs in Nonfiltered Regional Groundwater Samples

Location	Bromide	Calcium	Chloride	Cyanide [Total]	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Potassium	Silicon Dioxide	Sodium	Sulfate	Sulfide, Total	Total Phosphate as Phosphorus
LANL Regional GW BV[a]	180	24880	3570	na[b]	4150	890	0.44	2630	88500	24500	7200	na	340
Standard Level	na	na	na	200	na	10000	15	na	na	na	na	na	na
Standard Type	na	na	na	MCL[c]	na	MCL	MCL	na	na	na	na	na	na
NMED Tap Water[d]	na	na	na	na	na	na	na	na	na	na	na	na	na
Sandia Canyon Wells													
R-10, screen 1	—[e]	—	—	—	4190	—	0.569	2740	—	—	—	—	—
R-10, screen 2	—	—	—	—	4560	—	0.529	2820	—	—	—	—	—
R-10a	—	35000	5990	—	4850	1380	0.637	3720	—	940000	10900	28	—
R-11	—	—	4280	3.36	6290	4580	0.766	—	—	—	7950	1	—
R-35a	—	—	—	2.75	5770	—	—	5360	—	—	—	—	—
R-35b	—	—	—	—	5000	—	—	—	—	—	—	—	—
R-36	—	—	—	2.84	4550	—	—	—	—	—	—	—	—
R-43, screen 1	—	—	—	—	—	—	—	—	—	—	—	—	—
R-43, screen 2	—	—	—	—	4760	—	—	—	—	—	—	—	—
Sandia Spring	—	26900	—	—	—	—	0.451	2640	—	—	—	—	—
Mortandad Canyon Wells													
R-1	—	—	—	2.32	4220	—	—	—	—	—	—	3	—
R-13	—	—	—	2.36	—	—	—	3740	—	—	—	—	—
R-15	—	—	4770	6.56	—	2530	6.03	—	—	—	—	—	—
R-28	206	42900	29300	5.68	11000	4890	1.13	—	—	—	42700	5	—
R-33, screen 1	—	—	—	—	4210	—	0.479	—	—	—	—	50	—
R-33, screen 2	—	—	—	—	4240	—	—	—	—	—	—	32	—

Table 6.3-21 (continued)

Location	Bromide	Calcium	Chloride	Cyanide [Total]	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Potassium	Silicon Dioxide	Sodium	Sulfate	Sulfide, Total	Total Phosphate as Phosphorus
LANL Regional GW BV[a]	180	24880	3570	na[b]	4150	890	0.44	2630	88500	24500	7200	na	340
Standard Level	na	na	na	200	na	10000	15	na	na	na	na	na	na
Standard Type	na	na	na	MCL[c]	na	MCL	MCL	na	na	na	na	na	na
NMED Tap Water[d]	na	na	na	na	na	na	na	na	na	na	na	na	na
R-42	—	45100	—	2.74	13100	—	—	—	—	—	—	—	—
R-44, screen 1	—	—	—	—	—	—	—	—	—	—	—	—	—
R-44, screen 2	—	—	—	—	4330	—	—	—	—	—	—	—	—
R-45, screen 1	—	—	—	—	4790	—	—	—	—	—	—	—	—
R-45, screen 2	—	—	—	—	4870	—	—	—	—	—	—	—	—
Water-Supply Wells													
O-4	—	—	7820	—	8810	—	—	3830	95100	—	—	—	2400
PM-1	—	26500	6290	2.39	6420	—	0.5	3930	—	—	—	—	—
PM-3	—	—	6430	—	8070	—	—	3710	89400	—	—	—	—
PM-5	—	—	—	—	4790	—	0.444	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum values greater than the LANL BV.

[a] Alluvial Groundwater BVs are from LANL (2007, 096665). The BV for filtered samples was used in the absence of BV for nonfiltered samples.

[b] na = Not available.

[c] MCL = EPA Maximum Contaminant Level.

[d] NMED Tap Water (2009, 106420).

[e] — = Analyte is not a COPC at that location (not detected, not analyzed, or maximum detect < BV).

Table 6.3-22
Inorganic COPCs in Filtered Nonstorm-related Surface Water Samples

Location	Aluminum	Antimony	Arsenic	Barium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Selenium	Silver	Strontium	Thallium	Uranium	Vanadium	Zinc
ESL[a]	87	100	150	3.8	540	0.15	77	3	5	1000	1.2	80	na[b]	28	5	0.36	620	18	1.8	19	66
Standard Level (Perennial Stream Classification)	87	640	9	na	750	0.1	27.6	50	3.2	na	0.66	na	1000	18.8	50	0.4	na	6.3	na	100	42
Standard Type	AqChrF[c]	HHF[d]	HHF	na	IrF[e]	AqChrF	AqChrF	IrF	AqChrF	na	AqChrF	na	IrF	AqChrF	LWF[f]	AqChrF	na	HHF	na	IrF	AqChrF
NMED Tap Water[g]	36500	14.6	0.448	7300	7300	18.3	110[h]	na	1460	25600	na	876	183	730	183	183	21900	2.41	110	183	11000
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	250	—[i]	5.8	39.7	68.3	—	11.3	1.28	5.8	275	0.5	14.2	17.6	2.1	—	0.21	138	0.43	1.2	14	38.1
SCS-2 (W2CS)	139	0.277	1.68	39.3	114	0.104	10.5	8.58	6.99	462	0.97	16.2	19.3	2.3	—	0.24	122	—	0.44	12.7	46.8
Sandia Spring	—	—	1.8	81.5	24	—	3.5	1.4	4.4	36.1	—	56.5	2.3	1.1	—	—	332	0.6	1.62	11.5	3.36
Sandia below Wetlands (E123)	100	0.275	6.9	45.3	115	—	7.9	7.4	5.9	505	0.65	271	11.9	3.14	—	—	144	0.4	0.76	16.6	74.8
Sandia right fork at Power Plant (E121)	55	0.371	3.7	47.9	102	—	9	5.04	6.7	118	0.596	123	10.1	1.5	—	—	149	0.45	1	16.3	390
South Fork of Sandia Canyon at E122 (WSFS)	552	0.855	10.4	108	93.2	—	14.8	1.8	7.2	358	0.97	130	3.6	1.3	5.2	—	218	0.53	1.6	36.6	93.8

Notes: Values are in µg/L. Values are maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] AqChrF = NMAC 20.6.4, Aquatic Life Chronic (Filtered) Hardness=30 mg/L.

[d] HHF = NMAC 20.6.4, Human Health (Filtered).

[e] IrF = NMAC 20.6.4, Irrigation Standard (Filtered).

[f] LWF = NMAC 20.6.4, Livestock Watering (Filtered).

[g] NMED Tap Water (2009, 106420).

[h] The NMED tap water value for hexavalent chromium is used for filtered chromium.

[i] — = Not detected or not analyzed.

Table 6.3-23
Inorganic COPCs in Nonfiltered Nonstorm-Related Surface Water Samples

Location	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Chromium Hexavalent Ion	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Thallium	Uranium	Vanadium	Zinc
ESL[a]	87	150	3.8	5.3	540	0.15	77	11	5	1000	1.2	80	0.77	na[b]	28	5	0.36	620	18	1.8	19	66
Standard Level (Perennial Stream Classification)	na	na	na	na	na	na	na	na	na	na	na	na	10	na	na	20	na	na	na	na	na	na
Standard Type	na	na	na	na	na	na	na	na	na	na	na	na	WHU[c]	na	na	AqAcU[d]	na	na	na	na	na	na
NMED Tap Water[e]	36500	0.448	7300	73	7300	18.3	na	110	1460	25600	na	876	0.562	183	730	183	183	21900	2.41	110	183	11000
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	1010	5.3	42.6	—[f]	116	0.12	15	—	6.9	672	1.3	19.4	—	17.2	6.4	1	0.36	144	—	1.3	14	36.1
SA-00007	77.4	9.3	51.1	—	—	—	3.6	3.11	4.9	55	—	13.1	—	—	—	6.2	—	—	—	—	9.7	63.9
SA-10005	72	8.6	32.3	—	—	—	6.8	6.47	3.3	106	—	9.1	—	—	—	—	—	—	—	—	9	30.7
SA-603204	110	5.1	33	0.14	—	—	5.7	—	—	412	—	96	—	—	—	—	—	—	0.81	—	11.2	18.1
SA-603205	—	—	31.3	—	—	—	6.8	4.79	3	77.3	—	3.5	—	—	—	—	—	—	—	—	8	32.8
SCS-2 (W2CS)	354	—	30.6	—	—	—	12.5	—	5.3	426	1	10.5	—	17.7	2.4	—	0.34	99	—	0.48	12.3	47.3
Sandia Spring	610	—	85.7	—	27.3	—	3.6	—	—	462	0.664	17.5	—	1.01	1.4	6.2	—	329	0.53	1.95	15.3	6.23
Sandia below Wetlands (E123)	1290	8.9	56.3	—	76.8	0.12	40.4	—	10.9	1550	4.7	224	0.09	12.5	3.1	2.51	1.5	144	0.4	0.89	16.6	97.8
Sandia left fork at Asphalt Plant (E122)	1010	—	—	—	—	—	—	—	—	1270	—	—	—	—	—	—	—	—	—	—	—	382
Sandia right fork at Power Plant (E121)	171	4.8	46.2	—	52.5	—	10.1	—	8.3	206	0.92	17.8	—	9.9	1.8	1.06	—	146	—	1.2	18.1	76.3
South Fork of Sandia Canyon at E122 (WSFS)	2420	10.1	129	—	106	—	15.1	9.2	10.6	1610	4	236	—	4	6.4	5.1	—	245	0.54	1.5	43.1	144

Notes: Values are in ug/L. Values are maximum detected value.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] WHU = NMAC 20.6.4, Wildlife Habitat (Unfiltered).

[d] AqAcU = NMAC 20.6.4, Aquatic Life Acute (Unfiltered).

[e] NMED Tap Water (2009, 106420).

[f] — = Not detected or not analyzed.

Table 6.3-24
Radionuclide COPCs in Filtered Nonstorm-related Surface Water Samples

Location	Americium-241	Gross Beta	Plutonium-238	Plutonium-239/240	Potassium-40	Radium-226	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
ESL[a]	5.8	na[b]	19	20	na	0.1	570	22	24	24
Standard Level (Perennial Stream Classification)	20	na	20	20	4000	60	500	200	300	200
Standard Type	NMRPS[c]	na	NMRPS	NMRPS	NMRPS	NMRPS	NMRPS	BCG[d]	NMRPS	BCG
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	2.79	22.8	2.8	3.99	—[e]	—	—	0.538	—	0.555
Sandia Spring	—	4.33	—	—	—	2.25	0.14	0.99	0.193	0.634
Sandia below Wetlands (E123)	0.0232	16.5	—	0.0348	—	—	—	0.511	—	0.264
Sandia right fork at Power Plant (E121)	—	8.27	—	—	—	—	—	0.168	—	0.0628
South Fork of Sandia Canyon at E122 (WSFS)	—	25.9	—	—	117	—	—	0.919	0.0568	0.448

Notes: Values are in pCi/L. Values are maximum detected value.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[d] BCG = DOE Biota Concentration Guidelines (BCG) for radionuclides (DOE 2002, 085637).

[e] — = Not detected or not analyzed.

Table 6.3-25
Radionuclide COPCs in Nonfiltered Nonstorm-related Surface Water Samples

Location	Gross Alpha	Gross Beta	Potassium-40	Radium-226	Strontium-90	Tritium	Uranium-234	Uranium-235/236	Uranium-238
ESL[a]	na[b]	na	na	0.1	570	1.6E+08	22	24	24
Standard Level (Perennial Stream Classification)	na	na	4000	60	500	20000	200	300	200
Standard Type	na	na	NMRPS[c]	NMRPS	NMRPS	LWU[d]	BCG[e]	NMRPS	BCG
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	4.13	20.3	—[f]	—	—	121	0.55	—	0.528
SCS-2 (W2CS)	—	19	—	—	—	—	0.193	—	0.153
Sandia Spring	2.47	3.24	—	—	—	293	0.784	0.0589	0.414
Sandia below Wetlands (E123)	1.86	42.9	68.8	0.347	0.223	29.7	0.528	0.0448	0.317
Sandia right fork at Power Plant (E121)	—	24.2	63.9	0.321	—	—	0.253	—	0.138
South Fork of Sandia Canyon at E122 (WSFS)	—	20.4	—	—	—	46.6	0.888	—	0.435

Notes: Values are in pCi/L. Values are maximum detected value.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] NMRPS = NMEIB Radiation Protection Standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.003.0004.htm).

[d] LWU = NMAC 20.6.4, Livestock Watering (Unfiltered).

[e] BCG = DOE Biota Concentration Guidelines (BCG) for radionuclides (DOE 2002, 085637).

[f] — = Not detected or not analyzed.

Table 6.3-26
Organic COPCs in Nonfiltered Nonstorm-related Surface Water Samples

Location	2,4-Diamino-6-nitrotoluene	2,6-Diamino-4-nitrotoluene	Acetone	Aroclor-1254	Aroclor-1260	BHC[delta-]	Benzoic Acid	Bromodichloromethane	Bromoform	Chlorodibromomethane	Chloroform	Dichlorobenzene[1,3-]	Dichlorophenol[2,4-]	Dioxane[1,4-]	Trichlorophenol[2,4,5-]	Trichlorophenol[2,4,6-]
ESL[a]	60	60	11000	0.02	10	na[b]	41	na	na	na	180	na	na	na	na	na
Standard Level (Perennial Stream Classification)	na	na	na	0.00064	0.00064	0.17	na	170	1400	130	4700	960	290	na	na	24
Standard Type	na	na	na	HHPU[c]	HHPU	HHPU	na	HHPU	HHPU	HHPU	HHPU	HHPU	HHPU	na	na	HHPU
NMED Tap Water[d]	na	na	21800	0.336	0.336	na	na	1.17	85.1	na	1.93	na	110	61.1	3650	36.5
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	—[e]	—	1.86	—	—	—	9.81	—	—	—	0.326	—	—	7.53	—	—
SA-00007	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SA-10005	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SA-603204	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SA-603205	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SCS-2 (W2CS)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sandia Spring	—	—	—	—	—	—	—	—	—	—	—	0.318	0.58	—	1.2	2.1
Sandia below Wetlands (E123)	—	—	2.58	0.112	0.1	—	—	0.458	1	0.68	0.278	—	—	30.4	—	—
Sandia right fork at Power Plant (E121)	—	—	—	—	—	—	—	7.8	2.8	18.5	1.9	—	—	—	—	—
South Fork of Sandia Canyon at E122 (WSFS)	0.571	0.499	6.62	—	—	0.292	—	—	1.87	—	—	—	—	—	—	—

Notes: Values are in µg/L. Values are maximum detected value. Grey shading indicates a standard screening value was exceeded.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] HHPU = NMAC 20.6.4, Human Health Perennial (Unfiltered).

[d] NMED Tap Water (2009, 106420).

[e] — = Not detected or not analyzed.

Table 6.3-27
General Inorganic COPCs in Filtered Nonstorm-related Surface Water Samples

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Phosphorus, Orthophosphate [Expressed as PO4]	Potassium	Silicon Dioxide	Sodium	Sulfate	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
ESL[a]	na[b]	na	na	230000	5.2	1600	na	na	35000	na	na	na	na	na	na	na
NMED Tap Water[c]	na	na	na	na	na	2190	na	na	na	na	na	na	na	na	na	na
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	120	882	30600	191000	—[d]	591	8650	4100	1.27	—	22800	100000	148000	23100	404	3400
SCS-2 (W2CS)	—	662	25700	88700	—	674	7380	990	0.385	—	21000	108000	135000	100000	475	4340
Sandia Spring	26	—	38500	4020	—	633	4770	478	0.442	—	2940	53700	16000	7350	724	57
Sandia below Wetlands (E123)	144	1280	31800	146000	3.22	910	9200	3550	1.31	3890	27900	118000	141000	161000	720	4750
Sandia right fork at Power Plant (E121)	293	660	32100	146000	2.75	601	9560	3210	1.57	4440	23800	127000	139000	130000	730	5460
South Fork of Sandia Canyon at E122 (WSFS)	309	5190	43200	346000	13.3	946	13700	1270	6.36	2410	75100	225000	245000	71000	3020	4880

Notes: Values are in µg/L. Values are maximum detected value.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] NMED Tap Water (2009, 106420).

[d] — = Not detected or not analyzed.

Table 6.3-28
General Inorganic COPCs in Nonfiltered Nonstorm-related Surface Water Samples

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Cyanide, Amenable to Chlorination	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Phosphorus, Orthophosphate [Expressed as PO4]	Potassium	Silicon Dioxide	Sodium	Sulfate	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
ESL[a]	na[b]	na	na	230000	5.2	na	1600	na	na	35000	na	na	na	na	na	na	na
Standard Level (Perennial Stream Classification)	8190	na	na	na	na	22	na	na	132000	na	na	na	na	na	na	na	na
Standard Type	AqChrU[c]	na	na	na	na	AqAcU[d]	na	na	LWU[e]	na	na	na	na	na	na	na	na
NMED Tap Water[f]	na	na	na	na	na	na	2190	na	na	na	na	na	na	na	na	na	na
Middle Sandia Canyon at terminus of persistent baseflow (WMSC)	42	282	30400	75000	1.85	—[g]	470	9090	4390	—	—	22800	92300	1160000	18200	829	3110
SA-00007	—	—	28900	—	—	—	—	8940	—	0.613	—	13100	—	108000	—	—	—
SA-10005	—	—	28500	—	—	—	—	8080	—	0.683	—	13200	—	101000	—	—	—
SA-603204	—	—	23400	—	—	—	—	6720	—	0.675	—	10500	—	76300	—	—	—
SA-603205	—	—	27700	—	—	—	—	7790	—	0.647	—	12600	—	97800	—	—	—
SCS-2 (W2CS)	—	—	21100	—	—	—	—	5720	—	0.306	—	14600	—	107000	—	—	—
Sandia Spring	—	—	26900	3140	—	—	513	1940	209	0.451	—	2640	47100	15200	6780	83	—
Sandia below Wetlands (E123)	52	322	31700	70300	9.07	4.98	520	9060	3650	0.553	3670	21800	109000	139000	19400	989	3850
Sandia left fork at Asphalt Plant (E122)	—	—	—	—	—	—	—	—	236	—	—	—	—	—	—	—	—
Sandia right fork at Power Plant (E121)	—	—	31300	—	5.41	—	—	9410	2270	18.5	4200	15700	—	142000	—	830	4280

Table 6.3-28 (continued)

Location	Ammonia as Nitrogen	Bromide	Calcium	Chloride	Cyanide [Total]	Cyanide, Amenable to Chlorination	Fluoride	Magnesium	Nitrate-Nitrite as Nitrogen	Perchlorate	Phosphorus, Orthophosphate [Expressed as PO4]	Potassium	Silicon Dioxide	Sodium	Sulfate	Total Kjeldahl Nitrogen	Total Phosphate as Phosphorus
ESL[a]	na[b]	na	na	230000	5.2	na	1600	na	na	35000	na	na	na	na	na	na	na
Standard Level (Perennial Stream Classification)	8190	na	na	na	na	22	na	na	132000	na	na	na	na	na	na	na	na
Standard Type	AqChrU[c]	na	na	na	na	AqAcU[d]	na	na	LWU[e]	na	na	na	na	na	na	na	na
NMED Tap Water[f]	na	na	na	na	na	na	2190	na	na	na	na	na	na	na	na	na	na
South Fork of Sandia Canyon at E122 (WSFS)	281	5120	47700	24700	11.1	—	857	14900	985	—	2630	118000	180000	341000	17000	3660	3610

Notes: Values are in µg/L. Values are maximum detected value.

[a] Water ESLs from LANL ECORISK Database Version 2.3 (LANL 2008, 103352).

[b] na = Not available.

[c] AqChrU = NMAC 20.6.4, Aquatic Life Chronic (Unfiltered).

[d] AqAcU = NMAC 20.6.4, Aquatic Life Acute (Unfiltered).

[e] LWU = NMAC 20.6.4, Livestock Watering (Unfiltered).

[f] NMED Tap Water (2009, 106420).

[g] — = Not detected or not analyzed.

Table 6.4-1
Sandia Canyon Stormwater Screen

Location Name	Field Preparation	Type of Analyte	Analyte	Total Number of Analyses	Count of Detected Analytes	Count of Nondetected Analytes	Average Detected Concentration	Minimum Detected Concentration	Maximum Detected Concentration	Count of Detected Analytes with Concentrations Greater than the Lowest Comparison Value*	Lowest Comparison Value*	Units
Sandia above Firing Range	Filtered	INORGANIC	Aluminum	18	18	0	360.2778	105	1020	3	750	µg/L
Sandia above Firing Range	Filtered	INORGANIC	Arsenic	18	5	13	5.74	1.7	12.6	1	9	µg/L
Sandia above Firing Range	Filtered	INORGANIC	Copper	18	15	3	5.312667	2.9	9	12	4.3	µg/L
Sandia above Firing Range	Nonfiltered	ORGANIC	Aroclor-1242	14	1	13	0.11	0.11	0.11	1	0.00064	µg/L
Sandia above Firing Range	Nonfiltered	ORGANIC	Aroclor-1254	15	7	8	0.418143	0.076	1.7	7	0.00064	µg/L
Sandia above Firing Range	Nonfiltered	ORGANIC	Aroclor-1260	15	10	5	0.514	0.046	3.2	10	0.00064	µg/L
Sandia above Firing Range	Nonfiltered	RAD	Gross alpha	18	18	0	170.5389	2.12	877	15	15	pCi/L
Sandia above Firing Range	Nonfiltered	INORGANIC	Mercury	16	9	7	0.795556	0.1	3	3	0.77	µg/L
Sandia above SR-4	Filtered	INORGANIC	Aluminum	3	3	0	30386.33	989	88800	3	750	µg/L
Sandia above SR-4	Filtered	INORGANIC	Arsenic	3	1	2	20.3	20.3	20.3	1	9	µg/L
Sandia above SR-4	Filtered	INORGANIC	Cadmium	3	1	2	2.7	2.7	2.7	1	0.6	µg/L
Sandia above SR-4	Filtered	INORGANIC	Chromium	3	3	0	92.46667	2.5	272	1	213	µg/L
Sandia above SR-4	Filtered	INORGANIC	Copper	3	3	0	30.76667	4.1	82.4	2	4.3	µg/L
Sandia above SR-4	Filtered	INORGANIC	Lead	3	3	0	58.43333	1.5	168	1	17	µg/L
Sandia above SR-4	Filtered	INORGANIC	Silver	3	1	2	10.1	10.1	10.1	1	0.4	µg/L
Sandia above SR-4	Filtered	INORGANIC	Zinc	3	3	0	201.9	15.3	572	1	42	µg/L
Sandia above SR-4	Nonfiltered	ORGANIC	Aroclor-1254	3	1	2	0.12	0.12	0.12	1	0.00064	µg/L
Sandia above SR-4	Nonfiltered	ORGANIC	Aroclor-1260	3	2	1	0.175	0.13	0.22	2	0.00064	µg/L
Sandia above SR-4	Nonfiltered	RAD	Gross alpha	2	2	0	112.15	47.3	177	2	15	pCi/L
Sandia below Wetlands	Filtered	INORGANIC	Aluminum	24	19	5	337.2684	28.4	1070	2	750	µg/L
Sandia below Wetlands	Filtered	INORGANIC	Copper	24	22	2	6.549545	3.7	11.5	19	4.3	µg/L
Sandia below Wetlands	Filtered	INORGANIC	Zinc	24	23	1	38.82609	11.5	108	7	42	µg/L
Sandia below Wetlands	Nonfiltered	ORGANIC	Aroclor-1254	24	15	9	0.309133	0.059	1.1	15	0.00064	µg/L

Table 6.4-1 (continued)

Location Name	Field Preparation	Type of Analyte	Analyte	Total Number of Analyses	Count of Detected Analytes	Count of Nondetected Analytes	Average Detected Concentration	Minimum Detected Concentration	Maximum Detected Concentration	Count of Detected Analytes with Concentrations Greater than the Lowest Comparison Value*	Lowest Comparison Value*	Units
Sandia below Wetlands	Nonfiltered	ORGANIC	Aroclor-1260	24	18	6	0.278778	0.059	0.9	18	0.00064	µg/L
Sandia below Wetlands	Nonfiltered	ORGANIC	Benzo[a]pyrene	5	1	4	1.2	1.2	1.2	1	0.18	µg/L
Sandia below Wetlands	Nonfiltered	INORGANIC	Cyanide, Amenable to Chlorination	16	6	10	9.416667	1.81	34.1	2	5.2	µg/L
Sandia below Wetlands	Nonfiltered	RAD	Gross alpha	12	12	0	30.81667	11	66.9	10	15	pCi/L
Sandia below Wetlands	Nonfiltered	INORGANIC	Hexachlorobenzene	5	1	4	0.71	0.71	0.71	1	0.0029	µg/L
Sandia below Wetlands	Nonfiltered	INORGANIC	Mercury	25	18	7	0.7805	0.097	2.7	9	0.77	µg/L
Sandia left fork at Asphalt Plant	Filtered	INORGANIC	Aluminum	13	12	1	652.5333	70.4	4080	2	750	µg/L
Sandia left fork at Asphalt Plant	Filtered	INORGANIC	Cadmium	13	2	11	0.99	0.08	1.9	1	0.6	µg/L
Sandia left fork at Asphalt Plant	Filtered	INORGANIC	Copper	13	12	1	16.14583	3.55	86.7	10	4.3	µg/L
Sandia left fork at Asphalt Plant	Filtered	INORGANIC	Lead	13	9	4	16.84967	0.4	145	1	17	µg/L
Sandia left fork at Asphalt Plant	Filtered	INORGANIC	Zinc	13	12	1	157.1083	6.9	1100	7	42	µg/L
Sandia left fork at Asphalt Plant	Nonfiltered	ORGANIC	Aroclor-1254	14	2	12	0.1965	0.063	0.33	2	0.00064	µg/L
Sandia left fork at Asphalt Plant	Nonfiltered	ORGANIC	Aroclor-1260	14	2	12	0.08	0.05	0.11	2	0.00064	µg/L
Sandia left fork at Asphalt Plant	Nonfiltered	RAD	Gross alpha	7	6	1	15.34	3.81	32.2	3	15	pCi/L
Sandia right fork at Power Plant	Filtered	INORGANIC	Aluminum	16	16	0	684.8125	116	5590	1	750	µg/L
Sandia right fork at Power Plant	Filtered	INORGANIC	Copper	16	16	0	6.2625	3.1	10.8	12	4.3	µg/L
Sandia right fork at Power Plant	Filtered	INORGANIC	Zinc	16	15	1	20.79333	5.1	51.4	1	42	µg/L
Sandia right fork at Power Plant	Nonfiltered	ORGANIC	Aroclor-1254	14	7	7	0.442286	0.056	0.71	7	0.00064	µg/L
Sandia right fork at Power Plant	Nonfiltered	ORGANIC	Aroclor-1260	15	10	5	0.5442	0.027	1.2	10	0.00064	µg/L
Sandia right fork at Power Plant	Nonfiltered	INORGANIC	Cyanide, Amenable to Chlorination	10	1	9	8.4	8.4	8.4	1	5.2	µg/L
Sandia right fork at Power Plant	Nonfiltered	RAD	Gross alpha	14	14	0	20.13071	5.32	45.1	9	15	pCi/L
Sandia right fork at Power Plant	Nonfiltered	INORGANIC	Mercury	16	13	3	0.328923	0.073	0.883	1	0.77	µg/L

*See Table 6.4-2 for comparison value.

Table 6.4-2
Stormwater Comparison Values

Pollutant	Field Preparation	Analyte Reporting Name	Chemical Abstract Service Number	NMWQCC[a] Livestock Watering (µg/L)	NMWQCC Wildlife Habitat (µg/L)	NMWQCC Human Health Persistent (µg/L)	NMWQCC Acute Aquatic Life (µg/L)
Aluminum	Filtered	Aluminum, dissolved	7429-90-5	5,000	—[b]	—	750
Antimony	Filtered	Antimony, dissolved	7440-36-0	—	—	640	—
Arsenic	Filtered	Arsenic, dissolved	7440-38-2	200	—	9.0	340
Boron	Filtered	Boron, dissolved	7440-42-8	5,000	—	—	—
Cadmium	Filtered	Cadmium, dissolved	7440-43-9	50	—	—	0.6
Chromium	Filtered	Chromium, dissolved	18540-29-9	1,000	—	—	213
Cobalt	Filtered	Cobalt, dissolved	7440-48-4	1,000	—	—	—
Copper[c]	Filtered	Copper, dissolved	7440-50-8	500	—	—	4.3
Lead[c]	Filtered	Lead, dissolved	7439-92-1	100	—	—	17.0
Mercury	Nonfiltered	Mercury	7439-97-6	10	0.77	—	1.4
Nickel[c]	Filtered	Nickel, dissolved	7440-02-0	—	—	4,600	169
Selenium	Nonfiltered	Selenium	7782-49-2	50	5.0	4,200	20.0
Silver[c]	Filtered	Silver, dissolved	7440-22-4	—	—	—	0.4
Thallium	Filtered	Thallium, dissolved	7440-28-0	—	—	6.3	—
Vanadium	Filtered	Vanadium, dissolved	7440-62-2	100	—	—	—
Zinc[c]	Filtered	Zinc, dissolved	7440-66-6	25,000	—	26,000	42
Cyanide, weak acid dissociable	Nonfiltered	Cyanide, weak acid dissociable	57-12-5	—	5.2	—	22.0
Ra-226 + Ra-228 (pCi/L)	Nonfiltered	Ra-226 + Ra-228	—	30 pCi/L	—	—	—
Gross Alpha (pCi/L)	Nonfiltered	Gross alpha	—	15 pCi/L	—	—	—
Aldrin	Nonfiltered	Aldrin	309-00-2	—	—	0.00050	3.0
Benzo(a)pyrene	Nonfiltered	Benzo(a)pyrene	50-32-8	—	—	0.18	—
Gamma-BHC (Lindane)	Nonfiltered	Gamma-BHC (Lindane)	58-89-9	—	—	—	0.95
Chlordane	Nonfiltered	Chlordane	57-74-9	—	—	0.0081	2.4
4,4'-DDT	Nonfiltered	4,4'-DDT	50-29-3	—	0.001	0.0022	1.1

Table 6.4-2 (continued)

Pollutant	Field Preparation	Analyte Reporting Name	Chemical Abstract Service Number	NMWQCC[a] Livestock Watering (µg/L)	NMWQCC Wildlife Habitat (µg/L)	NMWQCC Human Health Persistent (µg/L)	NMWQCC Acute Aquatic Life (µg/L)
4,4'-DDD	Nonfiltered	4,4'-DDD	72-54-8	—	0.001	0.0022	1.1
4,4'-DDE	Nonfiltered	4,4'-DDE	72-55-9	—	0.001	0.0022	1.1
Dieldrin	Nonfiltered	Dieldrin	60-57-1	—	—	0.00054	0.24
2,3,7,8-TCDD Dioxin	Nonfiltered	2,3,7,8-TCDD Dioxin	1746-01-6	—	—	5.10E-08	—
alpha-Endosulfan	Nonfiltered	alpha-Endosulfan	959-98-8	—	—	—	0.22
beta-Endosulfan	Nonfiltered	beta-Endosulfan	33213-65-9	—	—	—	0.22
Endrin	Nonfiltered	Endrin	72-20-8	—	—	—	0.086
Heptachlor	Nonfiltered	Heptachlor	76-44-8	—	—	—	0.52
Heptachlor epoxide	Nonfiltered	Heptachlor epoxide	1024-57-3	—	—	—	0.52
Hexachlorobenzene	Nonfiltered	Hexachlorobenzene	118-74-1	—	—	0.0029	—
PCBs	Nonfiltered	PCBs	1336-36-3	—	0.014	0.00064	—
Pentachlorophenol	Nonfiltered	Pentachlorophenol	87-86-5	—	—	—	19
Toxaphene	Nonfiltered	Toxaphene	8001-35-2	—	—	—	0.73

[a] NMWQCC = New Mexico Water Quality Control Commission. NMWQCC comparison values from the State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC).

[b] — = None available.

[c] Hardness dependent screening values are based on a hardness value of 30 µg/L.

Table 6.4-3
Summary of Stormwater Analytes with Concentrations Greater Than Comparison Values

Analyte	Field Preparation	Number Of Detected Results > Lowest Comparison Value	Maximum Detected Concentration	Comparison Value	Units	Lowest Comparison Value Basis[a]	Locations with Results > Lowest Comparison Value
Aluminum	Filtered	11	88800	750	µg/L	NM WQCC Acute Aquatic Life	Sandia above SR-4, Sandia above Firing Range, Sandia below Wetlands, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant
Aroclor-1242	Nonfiltered	1	0.11	0.00064	µg/L	NM WQCC Human Health Persistent	Sandia above Firing Range
Aroclor-1254	Nonfiltered	32	1.7	0.00064	µg/L	NM WQCC Human Health Persistent	Sandia above SR-4, Sandia above Firing Range, Sandia below Wetlands, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant
Aroclor-1260	Nonfiltered	42	3.2	0.00064	µg/L	NM WQCC Human Health Persistent	Sandia above SR-4, Sandia above Firing Range, Sandia below Wetlands, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant
Arsenic	Filtered	2	20.3	9	µg/L	NM WQCC Human Health Persistent	Sandia above SR-4, Sandia above Firing Range
Benzo[a]pyrene	Nonfiltered	1	1.2	0.18	µg/L	NM WQCC Human Health Persistent	Sandia below Wetlands
Cadmium	Filtered	2	2.7	0.6	µg/L	NM WQCC Acute Aquatic Life	Sandia left fork at Asphalt Plant, Sandia above SR-4
Chromium	Filtered	1	272	213	µg/L	NM WQCC Acute Aquatic Life	Sandia above SR-4
Copper	Filtered	55	86.7	4.3	µg/L	NM WQCC Acute Aquatic Life	Sandia above SR-4, Sandia above Firing Range, Sandia below Wetlands, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant
Cyanide, Amenable to Chlorination	Nonfiltered	3	34.1	5.2	µg/L	NM WQCC Wildlife Habitat	Sandia right fork at Power Plant, Sandia below Wetlands

Table 6.4-3 (continued)

Analyte	Field Preparation	Number Of Detected Results > Lowest Comparison Value	Maximum Detected Concentration	Comparison Value	Units	Lowest Comparison Value Basis[a]	Locations with Results > Lowest Comparison Value
Gross alpha	Nonfiltered	39	877	15	pCi/L	NM WQCC Wildlife Habitat[b]	Sandia above SR-4, Sandia above Firing Range, Sandia below Wetlands, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant
Hexachlorobenzene	Nonfiltered	1	0.71	0.0029	µg/L	NM WQCC Human Health Persistent	Sandia below Wetlands
Lead	Filtered	2	168	17	µg/L	NM WQCC Acute Aquatic Life	Sandia left fork at Asphalt Plant, Sandia above SR-4
Mercury	Nonfiltered	13	3	0.77	µg/L	NM WQCC Wildlife Habitat[b]	Sandia below Wetlands, Sandia above Firing Range, Sandia right fork at Power Plant
Silver	Filtered	1	10.1	0.4	µg/L	NM WQCC Acute Aquatic Life	Sandia above SR-4
Zinc	Filtered	16	1100	42	µg/L	NM WQCC Acute Aquatic Life	Sandia below Wetlands, Sandia above SR-4, Sandia left fork at Asphalt Plant, Sandia right fork at Power Plant

[a] Basis from State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC).

[b] Basis is inconsistent with existing, designated, or reasonably anticipated attainable uses of stormwater in Sandia Canyon.

Table 6.4-4
Ecologically Relevant Stormwater Comparisons

Analyte	Field Preparation	Maximum Detected Value (µg/L)	Benchmark (µg/L)*	Maximum > Benchmark?	Location with Maximum Detected Result
Aluminum	Filtered	88800	750	Yes	Sandia above SR-4
Cadmium	Filtered	2.7	0.6	Yes	Sandia above SR-4
Chromium	Filtered	272	213	Yes	Sandia above SR-4
Copper	Filtered	86.7	4.3	Yes	Sandia left fork at Asphalt Plant
Lead	Filtered	168	17	Yes	Sandia above SR-4
Silver	Filtered	10.1	0.4	Yes	Sandia above SR-4
Zinc	Filtered	1100	42	Yes	Sandia left fork at Asphalt Plant

*Basis from State of New Mexico Standards for acute aquatic life (20.6.4.900[H], 20.4.6.900[I], and 20.4.6.900[J] NMAC).

Table 6.4-5
Human Health-Relevant Stormwater Comparisons

Analyte	Field Preparation	Maximum Detected Value (µg/L)	Benchmark (µg/L)*	Maximum > Benchmark?	Location with Maximum Detected Result
Aroclor-1242	Nonfiltered	0.11	4.65	No	Sandia above Firing Range
Aroclor-1254	Nonfiltered	1.7	4.65	No	Sandia above Firing Range
Aroclor-1260	Nonfiltered	3.2	4.65	No	Sandia above Firing Range
Arsenic	Filtered	20.3	775	No	Sandia above SR-4
Benzo[a]pyrene	Nonfiltered	1.2	7130	No	Sandia below Wetlands
Hexachlorobenzene	Nonfiltered	0.71	1240	No	Sandia below Wetlands

*See Section 6.4.2.3.

Table 6.5-1
Sandia Canyon Watershed COPC and Stormwater Summary

Analyte	Sediment	Stormwater[a]	Nonstorm-Related Surface Water[b]	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater[b]
Metals						
Aluminum	X[c]	X	X	X	—[d]	X
Antimony	—	X	X	—	X	—
Arsenic	X	X	X	X	—	—
Barium	X	X	X	X	—	X
Beryllium	X	X	X	X	—	—
Boron	—	X	X	X	X	X
Cadmium	X	X	X	—	—	—
Calcium	X	X	X	X	X	X
Chromium	X	X	X	X	X	X
Chromium Hexavalent Ion	X	—	X	—	X	X
Cobalt	X	X	X	X	—	—
Copper	X	X	X	X	X	X
Iron	X	X	X	X	X	X
Lead	X	X	X	X	X	X
Magnesium	X	X	X	X	X	X
Manganese	X	X	X	X	X	—
Mercury	X	X	X	X	—	—
Molybdenum	X	X	X	X	X	X
Nickel	X	X	X	X	—	X
Potassium	X	X	X	X	—	X
Selenium	X	X	X	—	—	X
Silver	X	X	X	—	—	—
Sodium	—	X	X	X	X	X
Strontium	—	X	X	X	X	—
Thallium	X	X	X	—	—	—
Tin	—	X	—	—	X	X
Uranium	X	X	X	X	X	X
Vanadium	X	X	X	X	—	X
Zinc	X	X	X	X	X	X
Other Inorganic Chemicals						
Ammonia as Nitrogen	—	X	X	X	X	X
Bromide	—	—	X	X	X	X
Chloride	X	X	X	X	X	X

Table 6.5-1 (continued)

Analyte	Sediment	Stormwater[a]	Nonstorm-Related Surface Water[b]	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater[b]
Cyanide [Total]	X	X	X	X	X	X
Cyanide, Amenable to Chlorination	—	X	X	—	—	—
Fluoride	X	X	X	X	X	X
Nitrate	X	—	—	—	—	—
Nitrate-Nitrite as Nitrogen	—	X	X	X	X	X
Perchlorate	X	—	X	—	X	X
Phosphorus, Orthophosphate [Expressed as PO4]	—	—	X	—	—	—
Silicon Dioxide	—	X	X	X	X	X
Sulfate	X	X	X	X	X	X
Sulfide, Extractable	X	—	—	—	—	—
Sulfide, Total	—	—	—	—	X	X
Total Kjeldahl Nitrogen	—	X	X	X	X	—
Total Phosphate as Phosphorus	—	X	X	X	X	X
Dioxins and Furans						
Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	—	—	—	—	—	X
High Explosives						
2,4-Diamino-6-nitrotoluene	—	—	X	—	—	—
2,6-Diamino-4-nitrotoluene	—	—	X	—	—	—
Amino-2,6-dinitrotoluene[4-]	—	X	—	—	—	—
Amino-4,6-dinitrotoluene[2-]	—	X	—	—	—	—
Dinitrobenzene[1,3-]	—	—	—	—	—	X
Dinitrotoluene[2,6-]	—	X	—	—	—	—
DNX	—	—	—	—	—	X
HMX	—	X	—	—	—	—
Nitrotoluene[3-]	—	—	—	—	—	X
Nitrotoluene[4-]	—	X	—	—	—	—
RDX	—	X	—	—	—	—
Tetryl	—	X	—	—	—	—
Pesticides and PCBs						
Aldrin	—	—	—	—	X	—
Aroclor-1016	X	—	—	—	—	X
Aroclor-1242	X	X	—	—	—	—
Aroclor-1248	X	—	—	—	—	—
Aroclor-1254	X	X	X	X	—	X

Table 6.5-1 (continued)

Analyte	Sediment	Stormwater[a]	Nonstorm-Related Surface Water[b]	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater[b]
Aroclor-1260	X	X	X	X	—	X
BHC[delta-]	X	—	X	—	—	—
Chlordane[gamma-]	X	—	—	—	—	—
DDD[4,4'-]	X	—	—	—	X	X
DDE[4,4'-]	—	—	—	—	X	X
DDT[4,4'-]	—	—	—	—	X	X
Dieldrin	X	—	—	—	X	X
Endosulfan II	—	—	—	—	X	—
Endosulfan Sulfate	—	—	—	—	X	—
Endrin	—	—	—	—	X	X
Heptachlor	—	—	—	—	X	X
Heptachlor Epoxide	—	—	—	—	X	X
Methoxychlor[4,4']	X	—	—	—	—	—
SVOCs						
Acenaphthene	X	X	—	—	—	—
Acenaphthylene	X	X	—	—	—	—
Anthracene	X	X	—	—	—	—
Benzo[a]anthracene	X	X	—	—	—	—
Benzo[a]pyrene	X	X	—	—	—	—
Benzo[b]fluoranthene	X	X	—	—	—	—
Benzo[g,h,i]perylene	X	—	—	—	—	—
Benzo[k]fluoranthene	X	—	—	—	—	—
Benzoic Acid	X	—	X	—	X	X
Bis[2-chloroethoxy]methane	—	X	—	—	—	—
Bis[2-ethylhexyl]phthalate	X	X	—	X	X	X
Butylbenzylphthalate	X	X	—	—	—	—
Chloroaniline[4-]	X	—	—	—	—	—
Chloronaphthalene[2-]	—	X	—	—	—	—
Chrysene	X	X	—	—	—	—
Dibenzofuran	X	X	—	—	—	—
Dichlorophenol[2,4-]	—	—	X	—	—	X
Diethylphthalate	—	X	—	—	—	X
Di-n-butylphthalate	X	X	—	—	—	—
Di-n-octylphthalate	X	—	—	—	—	—

Table 6.5-1 (continued)

Analyte	Sediment	Stormwater[a]	Nonstorm-Related Surface Water[b]	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater[b]
Fluoranthene	X	X	—	—	—	—
Fluorene	X	X	—	—	—	—
Indeno[1,2,3-cd]pyrene	X	—	—	—	—	—
Isophorone	—	X	—	—	—	—
Methylnaphthalene[2-]	X	X	—	—	—	—
Nitroso-di-n-propylamine[N-]	—	X	—	—	—	—
Phenol	—	—	—	—	—	X
Pyrene	X	X	—	—	—	—
Trichlorophenol[2,4,5-]	—	—	X	—	—	X
Trichlorophenol[2,4,6-]	—	X	X	—	—	X
Total Petroleum Hydrocarbons						
Diesel Range Organics	X	X	—	—	X	X
VOCs						
Acetone	X	—	X	X	X	X
Benzene	X	—	—	—	—	X
Bromodichloromethane	—	—	X	—	—	—
Bromoform	—	—	X	—	—	—
Bromomethane	—	—	—	—	—	X
Butanone[2-]	X	—	—	X	—	X
Butylbenzene[n-]	X	—	—	—	—	—
Butylbenzene[sec-]	X	—	—	—	—	—
Carbon Disulfide	X	—	—	—	—	X
Chlorodibromomethane	—	—	X	—	—	—
Chloroform	X	—	X	X	X	—
Chloromethane	—	—	—	—	X	X
Dichlorobenzene[1,3-]	—	—	X	X	—	X
Dioxane[1,4-]	—	—	X	X	—	—
Ethylbenzene	X	—	—	—	—	—
Hexachlorobenzene	—	X	—	—	—	—
Isopropyltoluene[4-]	X	—	—	—	—	—
Methyl-2-pentanone[4-]	—	—	—	—	—	X
Methylene Chloride	—	—	—	—	—	X
Naphthalene	X	X	—	—	X	—
Phenanthrene	X	X	—	—	—	X

Table 6.5-1 (continued)

Analyte	Sediment	Stormwater[a]	Nonstorm-Related Surface Water[b]	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater[b]
Styrene	X	—	—	X	—	—
Toluene	X	—	—	X	X	X
Trimethylbenzene[1,2,4-]	X	—	—	—	—	—
Xylene [Total]	X	—	—	—	—	—
Xylene[1,2-]	X	—	—	—	—	—
Xylene[1,3-]+Xylene[1,4-]	X	—	—	—	—	X
Other						
Methyl Mercury	X	—	—	—	—	—
Radionuclides						
Americium-241	X	X	X	—	—	X
Cesium-137	X	X	—	—	—	—
Gross alpha	—	X	X	X	X	X
Gross alpha/beta	—	—	—	—	X	X
Gross beta	—	X	X	X	X	X
Gross gamma	—	—	—	—	X	X
Lead-210	—	X	—	—	—	—
Plutonium-238	X	X	X	—	—	X
Plutonium-239/240	X	X	X	—	—	—
Polonium-210	—	X	—	—	—	—
Potassium-40	—	X	X	X	X	X
Radium-226	—	X	X	X	X	X
Radium-228	—	X	—	X	X	X
Strontium-90	X	X	X	X	—	X
Thorium-228	X	X	—	—	—	—
Thorium-230	—	X	—	—	—	X
Thorium-232	X	X	—	—	—	—
Tritium	X	X	X	X	X	X
Uranium-234	X	X	X	X	X	X
Uranium-235/236	X	X	X	X	X	X
Uranium-238	X	X	X	X	X	X

Note: Grey shading indicates analyte exceeded SAL or SSL for sediment or a standard for water.

[a] For stormwater, an analyte is marked with "x" if it was detected and is shaded gray if it exceeded an acute benchmark.

[b] Sandia spring is screened both as surface water and regional groundwater.

[c] x = Analyte is a COPC for given medium.

[d] — = Analyte is not a COPC for a given medium or not detected in stormwater.

Table 7.1-1
Inferred Primary Sources and Downcanyon Extent of Select COPCs in Sediment in Sandia Canyon

Type of COPC	COPC	Inferred Primary Source(s) in the Sandia Canyon Watershed[a]	Inferred Downcanyon Extent from Laboratory Sources[b]
Inorganic chemical	Aluminum	Natural background	n/a[c]
	Arsenic	TA-03	Sandia Canyon between reaches S-3W and S-3E
	Barium	TA-03	Sandia Canyon between reaches S-3W and S-3E
	Cadmium	TA-03	Sandia Canyon between reaches S-3W and S-3E
	Chromium	TA-03	Sandia Canyon between reaches S-5E and S-6W
	Cobalt	Natural background	n/a
	Copper	TA-03	Sandia Canyon between reaches S-5C and S-5E
	Cyanide (total)	TA-03	Sandia Canyon between reaches S-3E and S-4W
	Iron	Natural background and possibly minor releases from TA-03	n/a
	Lead	TA-03 and possibly TA-53 and/or TA-72	Sandia Canyon between reaches S-5E and S-6W
	Mercury	TA-03	Sandia Canyon between reaches S-5C and S-5E
	Molybdenum	TA-03	Sandia Canyon between reaches S-5E and S-6W
	Nickel	TA-03 and natural background	Sandia Canyon between reaches S-3W and S-3E
	Perchlorate	Natural background	n/a
	Selenium	uncertain; possibly natural background or dispersed Laboratory sites	Uncertain
	Silver	TA-03	TA-03
	Thallium	Natural background	n/a
	Zinc	TA-03	Sandia Canyon between reaches S-5C and S-5E

Table 7.1-1 (continued)

Type of COPC	COPC	Inferred Primary Source(s) in the Sandia Canyon Watershed[a]	Inferred Downcanyon Extent from Laboratory Sources[b]
Organic chemical	4,4'-DDD	TA-03	Sandia Canyon between reaches S-2 and S-3W
	Aroclor-1242	TA-03 and TA-53 and/or TA-72	Sandia Canyon between reaches S-5E and S-6W
	Aroclor-1248	TA-03	Sandia Canyon between reaches S-2 and S-3W
	Aroclor-1254	TA-03	Sandia Canyon between reaches S-5E and S-6W
	Aroclor-1260	TA-03	Sandia Canyon between reaches S-5E and S-6W
	Benzo(a)anthracene	TA-03 and possibly TA-53 and/or TA-72	Sandia Canyon between reaches S-5C and S-5E
	Benzo(a)pyrene	TA-03 and possibly TA-53 and/or TA-72	Sandia Canyon between reaches S-5C and S-5E
	Benzo(b)fluoranthene	TA-03	Sandia Canyon between reaches S-3W and S-3E
	Dieldrin	Uncertain; possibly dispersed Laboratory sites	uncertain
	Indeno(1,2,3-cd)pyrene	TA-03	Sandia Canyon reaches S-1N and S-1S
	TPH-DRO	TA-03 and possibly TA-53 and/or TA-72	uncertain; possibly Sandia Canyon between reaches S-5E and S-6W or the Rio Grande
Radionuclide	Thorium-228	Natural background	n/a
	Thorium-232	Natural background	n/a

[a] Primary source(s) indicated by maximum concentrations and/or spatial distribution.

[b] Downcanyon extent indicates area where COPC remains detected and/or above background and can probably or possibly be traced to an upcanyon Laboratory source.

[c] n/a = Not applicable (inferred source is natural background).

Table 7.2-1
Inferred Primary Sources and Downgradient Extent of Select COPCs in Surface Water and Groundwater

Analyte	Extent of COPC Distribution related to Sandia Source(s)[a,b]						Inferred Primary Source(s) in the Sandia Canyon Watershed[c]	Inferred Downgradient Extent from Laboratory Sources[d]
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater (Sandia)	Intermediate Groundwater (Mortandad)	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)		
Trace Metal COPCs								
Aluminum	Above standard	Above BV	-	n/a	n/a	n/a	Natural sources (section 7.1.2)	Presence of Sandia COPC limited to surface water and alluvial water.
Arsenic	Above standard	Above standard	-	-	-	-	TA-03	Presence of Sandia COPC limited to surface water and alluvial water.
Chromium	Detected	Above standard	Above standard	Above standard	Above BV	Above standard	TA-03	Presence of Sandia COPC in alluvial, intermediate, and regional groundwater underlying Middle Sandia Canyon and in intermediate and regional groundwater underlying middle Mortandad canyon.
Copper	Above standard	Above BV	Above BV	Above BV	n/a	n/a	TA-03; TA-50	Presence of Sandia COPC in surface water and alluvial water, possibly extending to intermediate groundwater underlying middle Sandia canyon and middle Mortandad canyon.
Iron	Above wESL	Above standard	Above BV	n/a	n/a	n/a	Natural background; possibly minor releases from TA-03.	Possible presence of Sandia COPC in surface water and alluvial water, possibly extending to intermediate groundwater underlying middle Sandia canyon.

Table 7.2-1 (continued)

Analyte	Extent of COPC Distribution related to Sandia Source(s)[a,b]						Inferred Primary Source(s) in the Sandia Canyon Watershed[c]	Inferred Downgradient Extent from Laboratory Sources[d]
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater (Sandia)	Intermediate Groundwater (Mortandad)	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)		
Lead	Above standard	Above standard	n/a	n/a	n/a	-	TA-03 and possibly TA-53 and/or TA-72.	Presence of Sandia COPC limited to surface water and alluvial water.
Manganese	Above wESL	Above standard	n/a	n/a	-	-	Natural background; possibly minor releases form TA-03.	Presence of Sandia COPC limited to surface water and alluvial water.
Molybdenum	Detected	Above BV	Above BV	n/a	-	n/a	TA-03	Presence of Sandia COPC limited to surface water and alluvial water, and possibly extends to intermediate groundwater beneath Sandia canyon
Zinc	Above Standard	Above BV	n/a	n/a	n/a	n/a	TA-03	Presence of Sandia COPC limited to surface water and alluvial water.
Other Inorganic COPCs								
Chloride	Detected	Above BV	Above BV		Above BV	Above BV		
Perchlorate	Detected	Detected	Detected	n/a	n/a	n/a	Natural background	
Nitrate-Nitrite as Nitrogen	Detected	Above BV	Above BV		Above BV	Above BV		
Organic COPCs								
Aroclor-1254	Above standard	-	-	-	-	-		Presence of Sandia COPC limited to surface water
Aroclor-1260	Above standard	Detected	-	-	-	-		Presence of Sandia COPC limited to surface water and alluvial water

Table 7.2-1 (continued)

Analyte	Extent of COPC Distribution related to Sandia Source(s)[a,b]						Inferred Primary Source(s) in the Sandia Canyon Watershed[c]	Inferred Downgradient Extent from Laboratory Sources[d]
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater (Sandia)	Intermediate Groundwater (Mortandad)	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)		
Benzo[a]anthracene	-	-	-	-	-	-		Sandia COPC is not present in water
Benzo[a]pyrene	-	-	-	-	-	-		Sandia COPC is not present in water
Benzo[b]fluoranthene	-	-	-	-	-	-		Sandia COPC is not present in water
bis[2-ethylhexyl]phthalate	-	-	-	-	Above standard	Above standard	Uncertain	
Bromomethane	-	-	-	-	Above standard	-	Uncertain	
Toluene	-	Detected	n/a	-	Detected	Detected	Uncertain	
Radionuclide COPCs								
Radium-226	Above wESL	Detected	n/a	n/a	n/a	n/a	Natural	
Tritium	Detected	Above BV	Above BV	Above BV	Above BV	Above BV	Uncertain	
Uranium-234	Detected	n/a	n/a	n/a	n/a	n/a	Natural	
Uranium-238	Detected	n/a	n/a	n/a	n/a	n/a	Natural	

[a] Compiled from Table D-2.1-1, Table D-2.0-1, Table D-2.0-5, Table D-2.0-9, and Table D-2.0-13, modified as discussed in Section 7.2.2.

[b] Explanation of column entries for "Extent of COPC Distribution related to Sandia Source(s)"

Above Standard	This analyte is detected more than once in this media, at a concentration exceeding a water-quality standard used for screening. [Table cell is highlighted in pink.]
Above wESL	This analyte is detected more than once in a surface-water sample, at a concentration exceeding the water ESL. [Table cell is highlighted in yellow.]
Above BV	This analyte is detected more than once in groundwater from this media, at a concentration exceeding the background value (BV). [Table cell is highlighted in yellow.]
Detected	This analyte is detected more than once in this media, and detected concentrations are below any water-quality standard, wESL, or BV used for screening. This entry is used for analytes for which wESLs or BVs are not available.
n/a	This analyte is detected more than once in this media, and maximum detected concentrations are above a water-quality standard, wESL, or BV used for screening. However, exceedances are not representative of groundwater concentrations for reasons discussed in text. However, concentrations exceed a screening value either as a residual effect of well drilling , construction, rehabilitation, or conversion, or from a source located in a watershed other than Sandia.
-	This analyte is either not detected in this media, not detected above the BV, not detected more than once, or detected in <5% of the samples from this media.

[c] Information from Table 7.1-1, modified as discussed in Section 7.2.2 text.

[d] Based on discussion in Section 7.2.2.

Table 8.1-1
Study Design COPECs by Media and Lines of Evidence
Supporting Investigation of Each COPEC based on the Sandia Biota Plan

Media	Study Design COPEC[a]	Lines of Evidence	Uncertainty in Line of Evidence
Soil	Barium[b] Chromium Chromium hexavalent ion Copper Lead Selenium Zinc	Plant toxicity study	Collected soil samples generally represent worst-case concentrations of COPECs and thus likely overestimate exposure concentrations.
			Variability in the test organism response may limit the ability of the test to detect statistical differences.
			Confounding factors (e.g., nutrient enrichment) may affect results.
	Barium[b] Chromium Chromium hexavalent ion Mercury[b] Zinc	Earthworm toxicity and bioaccumulation study (including tissue concentrations for risk to robin, deer mouse, or shrew)	Collected soil samples generally represent worst-case concentrations of COPECs and thus likely overestimate exposure concentrations for populations.
			Variability in the test organism response may limit the ability of the test to detect statistical differences.
			Confounding factors (e.g., particle size or organic matter) may affect results.
	Cadmium Chromium Copper Lead Mercury Nickel[b] Selenium[b] Silver[b] Zinc Aroclor-1248 Aroclor-1254 Aroclor-1260 (for owl) Dieldrin	Small mammal study (including tissue concentrations for risk to spotted owl or red fox)	Mean concentrations in investigation reaches generally represent worst-case concentrations of COPECs and thus likely overestimate exposures to populations.
			Factors other than COPECs (e.g., precipitation) may affect field measures of populations.
			Selected locations or measurements may not capture all potential effects.
	Cadmium Chromium Copper Cyanide (total) Lead Mercury Methyl mercury[b] Nickel[b] Selenium[b] Silver[b] Zinc Aroclor-1242 Aroclor-1248 Aroclor-1254 Aroclor-1260[b] 4,4'-DDD[b] Dieldrin[b]	Nest box studies (including insect concentrations for risk to robin, deer mouse, or shrew)	Mean concentrations in investigation reaches generally represent worst-case concentrations of COPECs and thus likely overestimate exposures that resulted in egg or insect concentrations or exposures to adult populations.
			Factors other than COPECs (e.g., precipitation) may affect field measures of populations.
			Exposures occur throughout the bird home range and reflect contaminant sources beyond affected media in the canyons.

Table 8.1-1 (continued)

Media	Study Design COPEC[a]	Lines of Evidence	Uncertainty in Line of Evidence
Sediment	Barium[b] Cadmium Chromium Copper Cyanide (total) Iron[b] Mercury Selenium[b] Silver Zinc Aroclor-1242 Aroclor-1248[b] Aroclor-1254 Aroclor-1260	Chironomid toxicity studies	Selected locations or measurements may not capture all potential effects.
			Collected sediment samples generally represent worst-case concentrations of COPECs and thus likely overestimate exposure concentrations for populations.
	Barium[b] Cadmium Chromium Copper Cyanide (total) Iron[b] Mercury Selenium[b] Silver Zinc Aroclor-1242 Aroclor-1248[b] Aroclor-1254 Aroclor-1260	Aquatic community diversity and abundance	Differences in habitat may overwhelm any potential for contaminant effects.
			Community measures may rebound and thus reflect only current conditions
	Cadmium Chromium[b] Copper Cyanide (total) Lead[b] Mercury Methyl mercury[b] Nickel[b] Selenium[b] Silver Zinc Aroclor-1242 Aroclor-1248[b] Aroclor-1254 Aroclor-1260[b]	Nest box studies (including insect concentrations to estimate risk to the southwestern willow flycatcher)	Variability in the test organism response may limit the ability of the test to detect statistical differences.
			Confounding factors (e.g., water-quality parameters) may affect results.
			Mean concentrations in investigation reaches generally represent worst-case concentrations of COPECs and thus likely overestimate exposures that resulted in egg or insect concentrations or exposures to populations.
	Cadmium Copper Nickel[b] Selenium[b] Silver[b] Thallium Zinc Aroclor-1248[b] Aroclor-1254	Nest box studies (including insect concentrations to estimate risk to bats)	Variability in the test organism response may limit the ability of the test to detect statistical differences.
			Confounding factors (e.g., water-quality parameters) may affect results.
			Mean concentrations in investigation reaches generally represent worst-case concentrations of COPECs and thus likely overestimate exposures to aerial insectivore populations.

Table 8.1-1 (continued)

Media	Study Design COPEC[a]	Lines of Evidence	Uncertainty in Line of Evidence
Water	Barium[b] Lead Silver Zinc Aroclor-1254	Chironomid toxicity studies	Collected water samples generally represent worst-case concentrations of COPECs and thus likely overestimate exposure concentrations for populations of aquatic organisms
			Variability in the test organism response may limit the ability of the test to detect statistical differences.
	Barium[b] Lead Silver Zinc Aroclor-1254	Aquatic community diversity and abundance	Differences in habitat may overwhelm any potential for contaminant effects.
			Community measures may rebound and thus reflect only current conditions

[a] Based Sandia Biota Plan assessment of HQ >3 using minimum ESL or HQ>1 for T&E species surrogates (kestrel, swallow).

[b] Based on the re-evaluation of study design COPECs using additional sediment and water sample results and the ECORISK database Version 2.3 ESLs.

Table 8.1-2
Field Studies Implemented Sandia Canyon

Assay Type	Reach	Rationale for Reach Selection Based on HQ
Soil COPECs		
Plant Toxicity	PA-0	Background reach
	S-2	Plant: chromium, hexavalent chromium
	S-3W	Plant: chromium
	S-4W	Plant: chromium
	S-5E	Plant: chromium
Earthworm Toxicity and Bioaccumulation	PA-0	Background reach
	S-2	Worm: chromium, hexavalent chromium Robin: chromium, Aroclor-1242, Aroclor-1248, Aroclor-1254 Shrew: chromium, Aroclor-1242, Aroclor-1248, Aroclor-1254
	S-3W	Worm: chromium Robin: chromium Shrew: chromium
	S-4W	Worm: chromium Robin: chromium Shrew: chromium
	S-5E	Worm: chromium Robin: chromium Shrew: chromium
Small Mammal Trapping	S-2	Shrew: chromium, Aroclor-1242, Aroclor-1248, Aroclor-1254
	S-4E	Shrew: chromium
	S-5E	Shrew: chromium
Existing or Additional Nest Boxes (measures of reproductive success; insect and egg collection)	S-2	Robin: chromium, Aroclor-1242, Aroclor-1248, Aroclor-1254
	S-4W	Robin: chromium
	S-5E	Robin: chromium
Sediment COPECs		
Existing or Additional Nest Boxes (insect collection)	S-2	Bat: Aroclor-1254 Swallow: Aroclor-1242, Aroclor-1254 Southwestern willow flycatcher: Aroclor-1242, Aroclor-1254
	S-4W	Bat: no study COPECs Swallow: no study COPECs Southwestern willow flycatcher: no study COPECs
	S-5E	Bat: no study COPECs Swallow: no study COPECs Southwestern willow flycatcher: no study COPECs

Table 8.1-2 (continued)

Assay Type	Reach	Rationale for Reach Selection Based on HQ
Aquatic Toxicity	PA-0	Background location
	S-2	Aquatic community: chromium, hexavalent chromium, Aroclor-1242, Aroclor-1254, Aroclor-1260
	S-3W	Aquatic community: chromium
	S-3E	Aquatic community: chromium
	S-4E	Aquatic community: chromium
	S-5E	Aquatic community: chromium
Rapid Bioassessment Protocol for Aquatic Invertebrates	S-2	Aquatic community: chromium, hexavalent chromium, Aroclor-1242, Aroclor-1254, Aroclor-1260
	Between S-3W and S-3E	Aquatic community: chromium, hexavalent chromium
	S-3E	Aquatic community: chromium
Water COPECs		
Aquatic Toxicity	Between S-3W and S-3E	Aquatic community: chromium, hexavalent chromium
Rapid Bioassessment Protocol for Aquatic Invertebrates	S-2	Aquatic community: chromium, hexavalent chromium, Aroclor-1254
	Between S-3W and S-3E	Aquatic community: chromium, hexavalent chromium
	S-3E	Aquatic community: chromium

Table 8.1-3
Number of Each Species Collected for Analysis in Each Reach in the Sandia Canyon

Reach	S-2	S-4E	S-5E
PEMA Deer Mouse (*Peromyscus maniculatus*)	23	43	8
PEBO Brush Mouse (*Peromyscus boylii*)	7	2	3
MILO Long-tailed Vole (*Microtus longicaudus*)	9		
MIMO Montane vole (*Microtus montanus*)	10		
PETR Piñon Mouse (*Peromyscus truei*)	2	1	3
REME Western Harvest Mouse (*Reithrodontomys megalotis*)		83	5
SOVA Vagrant Shrew (*Sorex vagrans*)*	4		
Mean % daily capture rates (relative abundance)	14%	32%	5%
Species diversity	2.2	1.0	1.9

* Numbers for vagrant shrew include animals caught in both pit fall and Sherman traps, whereas population analysis only includes those caught in Sherman traps.

Table 8.1-4
Samples Collected from Nest Boxes

Reach/Location	Number of Egg Samples	Number of Insect Samples
S-2	5	2
S-5E	1	0

Table 8.1-5
Exposure Evaluation for the Mexican Spotted Owl

COPEC	Reach	Pathway	Reach Average Concentration (mg/kg)	Reach Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1248	S-2	Mammal	0.158	0	0.16
Aroclor-1254	S-2	Mammal	0.158	0	0.16
Aroclor-1260	S-2	Mammal	1.18	1.18	0.06
Mercury	S-2	Mammal	0.0292	0.0292	0.16

Table 8.1-6
Exposure Evaluation for the Red Fox

COPEC	Reach	Pathway	Reach Average Concentration (mg/kg)	Reach Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1248	S-2	Mammal	0.1575	0	**2.2**
Aroclor-1248	S-5E	Mammal	0.01675	0	0.24
Aroclor-1248	S-4E	Mammal	0.015	0	0.21
Aroclor-1254	S-2	Mammal	0.1575	0	0.71
Aroclor-1260	S-2	Mammal	1.18	1.18	**5.3**
Aroclor-1260	S-4E	Mammal	0.0205	0.0155	0.09
Aroclor-1260	S-5E	Mammal	0.016	0.0045	0.07

Note: Cells are shaded if the HQ >1.

Table 8.1-7
Exposure Evaluation for the Southwestern Willow Flycatcher

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1242	PA-0	PA-26500	Worm	0.015	0	0.12
Aroclor-1242	S-2	SA-600115	Worm	0.36	0	**2.8**
Aroclor-1242	S-2	SA-603199	Worm	0.07	0	0.55
Aroclor-1242	S-2	SA-600113	Worm	0.015	0	0.12
Aroclor-1242	S-3W	SA-600376	Worm	0.073	0	0.58
Aroclor-1242	S-3W	SA-600368	Worm	0.071	0	0.56
Aroclor-1242	S-4W	SA-600773	Worm	0.029	0	0.23
Aroclor-1242	S-4W	SA-600782	Worm	0.014	0	0.11
Aroclor-1242	S-5E	SA-600830	Worm	0.071	0	0.56
Aroclor-1248	PA-0	PA-26500	Worm	0.015	0	0.12
Aroclor-1248	S-2	SA-600115	Worm	0.36	0	**2.8**
Aroclor-1248	S-2	SA-603199	Worm	0.07	0	0.55
Aroclor-1248	S-2	SA-600113	Worm	0.015	0	0.12
Aroclor-1248	S-3W	SA-600376	Worm	0.073	0	0.58
Aroclor-1248	S-3W	SA-600368	Worm	0.071	0	0.56
Aroclor-1248	S-4W	SA-600773	Worm	0.029	0	0.23
Aroclor-1248	S-4W	SA-600782	Worm	0.014	0	0.11
Aroclor-1248	S-5E	SA-600830	Worm	0.071	0	0.56
Aroclor-1254	PA-0	PA-26500	Worm	0.015	0	0.12
Aroclor-1254	S-2	SA-600115	Worm	2.95	2.95	**23**
Aroclor-1254	S-2	SA-603199	Worm	0.56	0.56	**4.4**
Aroclor-1254	S-2	SA-600113	Worm	0.17	0.17	**1.3**

Table 8.1-7 (continued)

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1254	S-3W	SA-600368	Worm	0.8	0.8	**6.3**
Aroclor-1254	S-3W	SA-600376	Worm	0.66	0.66	**5.2**
Aroclor-1254	S-4W	SA-600773	Worm	0.21	0.21	**1.7**
Aroclor-1254	S-4W	SA-600782	Worm	0.14	0.14	**1.1**
Aroclor-1254	S-5E	SA-600830	Worm	0.071	0	0.56
Aroclor-1260	S-2	SA-600115	Worm	1.55	1.55	0.57
Cadmium	S-2	SA-603380	Insects	0.3	0.3	0.16
Cadmium	S-2	SA-600115	Worm	1.7	1.7	0.91
Copper	PA-0	PA-26500	Worm	1.7	1.7	0.33
Copper	S-2	SA-603380	Insects	19	19	**3.7**
Copper	S-2	SA-603381	Insects	14	14	**2.7**
Copper	S-2	SA-603199	Worm	4.1	4.1	0.80
Copper	S-2	SA-600115	Worm	4	4	0.78
Copper	S-2	SA-600113	Worm	3.5	3.5	0.68
Copper	S-3W	SA-600376	Worm	2.4	2.4	0.47
Copper	S-3W	SA-600368	Worm	2.3	2.3	0.45
Copper	S-4W	SA-600773	Worm	1.9	1.9	0.37
Copper	S-4W	SA-600782	Worm	1.9	1.9	0.37
Copper	S-5E	SA-600830	Worm	1.9	1.9	0.37
Lead	S-2	SA-603380	Insects	0.99	0.99	0.48
Lead	S-2	SA-600115	Worm	0.595	0.595	0.29
Mercury	PA-0	PA-26500	Worm	0.0054	0.0054	0.22
Mercury	S-2	SA-600115	Worm	0.126	0.126	**5.2**
Mercury	S-2	SA-603199	Worm	0.0061	0.0061	0.25
Mercury	S-2	SA-600113	Worm	0.0036	0.0036	0.15
Mercury	S-3W	SA-600368	Worm	0.018	0.018	0.75
Mercury	S-3W	SA-600376	Worm	0.014	0.014	0.58
Mercury	S-4W	SA-600773	Worm	0.009	0.009	0.37
Mercury	S-4W	SA-600782	Worm	0.0078	0.0078	0.32
Mercury	S-5E	SA-600830	Worm	0.013	0.013	0.54
Nickel	S-2	SA-603380	Insects	0.23	0.23	0.03
Nickel	S-2	SA-600113	Worm	0.41	0.41	0.05
Selenium	PA-0	PA-26500	Worm	0.55	0.55	**1.5**
Selenium	S-2	SA-603380	Insects	1.3	1.3	**3.5**
Selenium	S-2	SA-603381	Insects	0.58	0.58	**1.6**
Selenium	S-2	SA-603199	Worm	0.45	0.45	**1.2**
Selenium	S-2	SA-600115	Worm	0.435	0.435	**1.2**

Table 8.1-7 (continued)

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Selenium	S-2	SA-600113	Worm	0.41	0.41	**1.1**
Selenium	S-3W	SA-600376	Worm	0.59	0.59	**1.6**
Selenium	S-3W	SA-600368	Worm	0.49	0.49	**1.3**
Selenium	S-4W	SA-600782	Worm	0.55	0.55	**1.5**
Selenium	S-4W	SA-600773	Worm	0.5	0.5	**1.4**
Selenium	S-5E	SA-600830	Worm	0.58	0.58	**1.6**
Silver	S-2	SA-603380	Insects	0.16	0.16	0.06
Silver	S-2	SA-603199	Worm	0.76	0.76	0.30
Zinc	PA-0	PA-26500	Worm	18	18	0.22
Zinc	S-2	SA-603380	Insects	100	100	**1.2**
Zinc	S-2	SA-603381	Insects	96	96	**1.2**
Zinc	S-2	SA-600115	Worm	17	17	0.20
Zinc	S-2	SA-603199	Worm	17	17	0.20
Zinc	S-2	SA-600113	Worm	16	16	0.19
Zinc	S-3W	SA-600376	Worm	19	19	0.23
Zinc	S-3W	SA-600368	Worm	16	16	0.19
Zinc	S-4W	SA-600773	Worm	18	18	0.22
Zinc	S-4W	SA-600782	Worm	17	17	0.20
Zinc	S-5E	SA-600830	Worm	17	17	0.20

Note: Cells are shaded if the HQ >1.

Table 8.1-8
Exposure Evaluation for the Bat

COPEC	Reach	Pathway	Reach Average Concentration (mg/kg)	Reach Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1248	PA-0	Worm	0.015	0	0.62
Aroclor-1248	S-2	Worm	0.202	0	**8.3**
Aroclor-1248	S-3W	Worm	0.072	0	**3.0**
Aroclor-1248	S-4W	Worm	0.0215	0	0.89
Aroclor-1248	S-5E	Worm	0.071	0	**2.9**
Aroclor-1254	PA-0	Worm	0.015	0	0.01
Aroclor-1254	S-2	Worm	1.66	1.66	**1.1**
Aroclor-1254	S-3W	Worm	0.73	0.73	0.49
Aroclor-1254	S-4W	Worm	0.175	0.175	0.12
Aroclor-1254	S-5E	Worm	0.071	0	0.05
Cadmium	S-2	Insects	0.23	0.23	0.12
Cadmium	S-2	Worm	1.10	1.10	0.58
Copper	S-2	Insects	16.5	16.5	**1.2**
Copper	S-2	Worm	3.9	3.9	0.28
Copper	S-3W	Worm	2.35	2.35	0.17
Copper	S-4W	Worm	1.9	1.9	0.14
Copper	S-5E	Worm	1.9	1.9	0.14
Copper	PA-0	Worm	1.7	1.7	0.12
Nickel	S-2	Insects	0.158	0.115	0.04
Nickel	S-2	Worm	0.393	0.393	0.09
Selenium	PA-0	Worm	0.55	0.55	**1.6**
Selenium	S-2	Insects	0.94	0.94	**2.7**
Selenium	S-2	Worm	0.433	0.433	**1.2**
Selenium	S-3W	Worm	0.54	0.54	**1.5**
Selenium	S-4W	Worm	0.525	0.525	**1.5**
Selenium	S-5E	Worm	0.58	0.58	**1.7**
Silver	S-2	Insects	0.14	0.14	0.01
Silver	S-2	Worm	0.625	0.625	0.04
Thallium	PA-0	Worm	0.016	0.016	0.92
Thallium	S-2	Insects	0.0047	0	0.27
Thallium	S-2	Worm	0.0408	0.0408	**2.4**
Thallium	S-3W	Worm	0.0121	0.0121	0.69
Thallium	S-4W	Worm	0.045	0.045	**2.6**
Thallium	S-5E	Worm	0.025	0.025	**1.4**
Zinc	S-2	Insects	98	98	0.53
Zinc	S-3W	Worm	17.5	17.5	0.09
Zinc	S-4W	Worm	17.5	17.5	0.09

Note: Cells are shaded if the HQ > 0.1.

Table 8.1-9
Comparison of Sandia Canyon to Reference Location Egg Concentrations

COPEC	Reference			Sandia Canyon			WRS Result	p-Value
	Count	Detect Frequency	Concentration Range (mg/kg)	Count	Detect Frequency	Concentration Range (mg/kg)		
Cadmium	3	0%	[0.01 to 0.01]	6	50%	[0.00023] to 0.047	Not different	0.15
Chromium	3	33%	[0.25] to 0.68	6	100%	0.068 to 0.29	Not different	0.09
Copper	3	100%	0.37 to 0.58	6	100%	0.67 to 2.2	Sandia>Ref	0.03
Lead	3	0%	[0.02 to 0.02]	6	17%	[0.0099] to 0.1	Not different	0.51
Nickel	3	33%	[0.25] to 1.7	6	17%	0.026 to [0.16]	Ref>Sandia	0.03
Selenium	3	100%	0.4 to 0.41	6	100%	0.61 to 1.9	Sandia>Ref	0.03
Silver	3	0%	[0.005 to 0.005]	6	17%	[0.0017] to 0.06	Not different	1.00
Zinc	3	100%	12 to 15	6	100%	10 to 26	Not different	0.24

Note: Values in [ ] are nondetects. Shaded cells indicate Sandia Canyon egg COPEC concentrations are statistically greater than reference.

Table 8.1-10
Exposure Evaluation for the Robin

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1242	PA-0	PA-26500	Worm	0.015	0	0.23
Aroclor-1242	S-2	SA-600115	Worm	0.36	0	**5.5**
Aroclor-1242	S-2	SA-603199	Worm	0.07	0	**1.1**
Aroclor-1242	S-2	SA-600113	Worm	0.015	0	0.23
Aroclor-1242	S-3W	SA-600376	Worm	0.073	0	**1.1**
Aroclor-1242	S-3W	SA-600368	Worm	0.071	0	**1.1**
Aroclor-1242	S-4W	SA-600773	Worm	0.029	0	0.44
Aroclor-1242	S-4W	SA-600782	Worm	0.014	0	0.21
Aroclor-1242	S-5E	SA-600830	Worm	0.071	0	**1.1**
Aroclor-1248	PA-0	PA-26500	Worm	0.015	0	0.23
Aroclor-1248	S-2	SA-600115	Worm	0.36	0	**5.5**
Aroclor-1248	S-2	SA-603199	Worm	0.07	0	**1.1**
Aroclor-1248	S-2	SA-600113	Worm	0.015	0	0.23
Aroclor-1248	S-3W	SA-600376	Worm	0.073	0	**1.1**
Aroclor-1248	S-3W	SA-600368	Worm	0.071	0	**1.1**
Aroclor-1248	S-4W	SA-600773	Worm	0.029	0	0.44
Aroclor-1248	S-4W	SA-600782	Worm	0.014	0	0.21
Aroclor-1248	S-5E	SA-600830	Worm	0.071	0	**1.1**
Aroclor-1254	PA-0	PA-26500	Worm	0.015	0	0.23
Aroclor-1254	S-2	SA-600115	Worm	2.95	2.95	**45**
Aroclor-1254	S-2	SA-603199	Worm	0.56	0.56	**8.5**
Aroclor-1254	S-2	SA-600113	Worm	0.17	0.17	**2.6**
Aroclor-1254	S-3W	SA-600368	Worm	0.8	0.8	**12**
Aroclor-1254	S-3W	SA-600376	Worm	0.66	0.66	**10**
Aroclor-1254	S-4W	SA-600773	Worm	0.21	0.21	**3.3**
Aroclor-1254	S-4W	SA-600782	Worm	0.14	0.14	**2.1**
Aroclor-1254	S-5E	SA-600830	Worm	0.071	0	**1.1**
Aroclor-1260	PA-0	PA-26500	Worm	0.015	0	0.01
Aroclor-1260	S-2	SA-600115	Worm	1.55	1.55	**1.1**
Aroclor-1260	S-2	SA-603199	Worm	0.41	0.41	0.29
Aroclor-1260	S-2	SA-600113	Worm	0.086	0.086	0.06
Aroclor-1260	S-3W	SA-600368	Worm	0.67	0.67	0.47
Aroclor-1260	S-3W	SA-600376	Worm	0.4	0.4	0.28
Aroclor-1260	S-4W	SA-600773	Worm	0.18	0.18	0.13
Aroclor-1260	S-4W	SA-600782	Worm	0.13	0.13	0.09
Aroclor-1260	S-5E	SA-600830	Worm	0.47	0.47	0.33

Table 8.1-10 (continued)

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Cadmium	PA-0	PA-26500	Worm	0.31	0.31	0.32
Cadmium	S-2	SA-603380	Insects	0.3	0.3	0.31
Cadmium	S-2	SA-603381	Insects	0.16	0.16	0.17
Cadmium	S-2	SA-600115	Worm	1.7	1.7	**1.8**
Cadmium	S-2	SA-603199	Worm	0.53	0.53	0.55
Cadmium	S-2	SA-600113	Worm	0.45	0.45	0.47
Cadmium	S-3W	SA-600368	Worm	0.67	0.67	0.69
Cadmium	S-3W	SA-600376	Worm	0.57	0.57	0.59
Cadmium	S-4W	SA-600773	Worm	0.44	0.44	0.45
Cadmium	S-4W	SA-600782	Worm	0.39	0.39	0.40
Cadmium	S-5E	SA-600830	Worm	0.45	0.45	0.47
Chromium	S-2	SA-603381	Insects	2	2	0.04
Chromium	S-2	SA-600115	Worm	17.3	17.3	0.34
Copper	PA-0	PA-26500	Worm	1.7	1.7	0.64
Copper	S-2	SA-603380	Insects	19	19	**7.1**
Copper	S-2	SA-603381	Insects	14	14	**5.3**
Copper	S-2	SA-603199	Worm	4.1	4.1	**1.5**
Copper	S-2	SA-600115	Worm	4	4	**1.5**
Copper	S-2	SA-600113	Worm	3.5	3.5	**1.3**
Copper	S-3W	SA-600376	Worm	2.4	2.4	0.90
Copper	S-3W	SA-600368	Worm	2.3	2.3	0.86
Copper	S-4W	SA-600773	Worm	1.9	1.9	0.71
Copper	S-4W	SA-600782	Worm	1.9	1.9	0.71
Copper	S-5E	SA-600830	Worm	1.9	1.9	0.71
Lead	S-2	SA-603380	Insects	0.99	0.99	0.92
Lead	S-2	SA-600115	Worm	0.595	0.595	0.55
Mercury	PA-0	PA-26500	Worm	0.0054	0.0054	0.43
Mercury	S-2	SA-600115	Worm	0.126	0.126	10
Mercury	S-2	SA-603199	Worm	0.0061	0.0061	0.49
Mercury	S-2	SA-600113	Worm	0.0036	0.0036	0.29
Mercury	S-3W	SA-600368	Worm	0.018	0.018	1.4
Mercury	S-3W	SA-600376	Worm	0.014	0.014	1.1
Mercury	S-4W	SA-600773	Worm	0.009	0.009	0.72
Mercury	S-4W	SA-600782	Worm	0.0078	0.0078	0.62
Mercury	S-5E	SA-600830	Worm	0.013	0.013	1.0
Nickel	S-2	SA-603380	Insects	0.23	0.23	0.05
Nickel	S-2	SA-603199	Worm	0.45	0.45	0.10

Table 8.1-10 (continued)

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Selenium	PA-0	PA-26500	Worm	0.55	0.55	**2.9**
Selenium	S-2	SA-603380	Insects	1.3	1.3	**6.8**
Selenium	S-2	SA-603381	Insects	0.58	0.58	**3.0**
Selenium	S-2	SA-603199	Worm	0.45	0.45	**2.4**
Selenium	S-2	SA-600115	Worm	0.435	0.435	**2.3**
Selenium	S-2	SA-600113	Worm	0.41	0.41	**2.2**
Selenium	S-3W	SA-600376	Worm	0.59	0.59	**3.1**
Selenium	S-3W	SA-600368	Worm	0.49	0.49	**2.6**
Selenium	S-4W	SA-600782	Worm	0.55	0.55	**2.9**
Selenium	S-4W	SA-600773	Worm	0.5	0.5	**2.6**
Selenium	S-5E	SA-600830	Worm	0.58	0.58	**3.0**
Silver	S-2	SA-603380	Insects	0.16	0.16	0.12
Silver	S-2	SA-603199	Worm	0.76	0.76	0.57
Zinc	PA-0	PA-26500	Worm	18	18	0.41
Zinc	S-2	SA-603380	Insects	100	100	**2.3**
Zinc	S-2	SA-603381	Insects	96	96	**2.2**
Zinc	S-2	SA-600115	Worm	17	17	0.39
Zinc	S-2	SA-603199	Worm	17	17	0.39
Zinc	S-2	SA-600113	Worm	16	16	0.37
Zinc	S-3W	SA-600376	Worm	19	19	0.44
Zinc	S-3W	SA-600368	Worm	16	16	0.37
Zinc	S-4W	SA-600773	Worm	18	18	0.41
Zinc	S-4W	SA-600782	Worm	17	17	0.39
Zinc	S-5E	SA-600830	Worm	17	17	0.39

Note: Cells are shaded if the HQ >1.

Table 8.1-11
COPEC Concentrations in Small Mammals and Sediment

Species Code[a]	Lead	Mercury	Perchlorate	Aroclor-1254	Aroclor-1260
Reach S-2					
Sediment					
n/a[b]	29.3	0.176	Not detected	0.223	0.293
Mammal Whole Body					
MILO	0.8	0.0081	0.024	Not detected	0.011
MIMO	1.4	0.0043	0.00092	Not detected	0.11
PEBO	0.91	0.0044	0.0012	Not detected	0.069
PEMA	1.1	0.0087	0.046	Not detected	0.16
PETR	0.38	0.0097	Not measured	Not detected	0.039
SOVA	0.64	**0.14**	0.0033	Not detected	**6.7**
Reach S-4E					
Sediment					
n/a	9.26	0.0125	0.000593	0.01	0.0125
Mammal Whole Body					
PEMA	0.38	0.0041	0.036	Not detected	Not detected
PETR	3.1	0.009	Not measured	Not detected	**0.039**
REME	1.5	0.0033	0.024	Not detected	0.0074
Reach S-5E					
Sediment					
n/a	27.1	0.0182	Not detected	0.0097	0.0115
Mammal Whole Body					
PEBO	1	0.0039	Not measured	Not detected	Not detected
PEMA	0.76	0.0045	0.07	Not detected	Not detected
PETR	**41**	0.0044	Not measured	Not detected	Not detected
REME	1.5	0.0038	Not measured	Not detected	0.018

Notes: Units are in mg/kg. Shaded values are significant detections of COPECs in tissues compared to sediment and other tissue samples.

[a] MILO = Long tailed vole, MIMO = montane vole, PEBO = brush mouse, PEMA = deer mouse, PETR = piñon mouse, REME = western harvest mouse, SOVA = vagrant shrew.

[b] n/a = Not applicable.

Table 8.1-12
Exposure Evaluation for the Shrew

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Aroclor-1248	PA-0	PA-26500	Worm	0.015	0	0.94
Aroclor-1248	S-2	SA-600115	Worm	0.36	0	**23**
Aroclor-1248	S-2	SA-603199	Worm	0.07	0	**4.4**
Aroclor-1248	S-2	SA-600113	Worm	0.015	0	0.94
Aroclor-1248	S-3W	SA-600376	Worm	0.073	0	**4.6**
Aroclor-1248	S-3W	SA-600368	Worm	0.071	0	**4.5**
Aroclor-1248	S-4W	SA-600773	Worm	0.029	0	**1.8**
Aroclor-1248	S-4W	SA-600782	Worm	0.014	0	0.88
Aroclor-1248	S-5E	SA-600830	Worm	0.071	0	**4.5**
Aroclor-1254	PA-0	PA-26500	Worm	0.015	0	0.02
Aroclor-1254	S-2	SA-600115	Worm	2.95	2.95	**3.0**
Aroclor-1254	S-2	SA-603199	Worm	0.56	0.56	0.57
Aroclor-1254	S-2	SA-600113	Worm	0.17	0.17	0.17
Aroclor-1254	S-3W	SA-600368	Worm	0.8	0.8	0.81
Aroclor-1254	S-3W	SA-600376	Worm	0.66	0.66	0.67
Aroclor-1254	S-4W	SA-600773	Worm	0.21	0.21	0.21
Aroclor-1254	S-4W	SA-600782	Worm	0.14	0.14	0.14
Aroclor-1254	S-5E	SA-600830	Worm	0.071	0	0.07
Cadmium	S-2	SA-603380	Insects	0.3	0.3	0.24
Cadmium	S-2	SA-603381	Insects	0.16	0.16	0.13
Cadmium	PA-0	PA-26500	Worm	0.31	0.31	0.25
Cadmium	S-2	SA-600115	Worm	1.7	1.7	**1.4**
Cadmium	S-2	SA-603199	Worm	0.53	0.53	0.43
Cadmium	S-2	SA-600113	Worm	0.45	0.45	0.36
Cadmium	S-3W	SA-600368	Worm	0.67	0.67	0.54
Cadmium	S-3W	SA-600376	Worm	0.57	0.57	0.46
Cadmium	S-4W	SA-600773	Worm	0.44	0.44	0.35
Cadmium	S-4W	SA-600782	Worm	0.39	0.39	0.31
Cadmium	S-5E	SA-600830	Worm	0.45	0.45	0.36
Chromium	S-2	SA-603381	Insects	2	2	0.03
Chromium	S-2	SA-600115	Worm	17.3	17.3	0.27
Copper	S-2	SA-603380	Insects	19	19	**2.1**
Copper	S-2	SA-603381	Insects	14	14	**1.6**
Copper	PA-0	PA-26500	Worm	1.7	1.7	0.19
Copper	S-2	SA-603199	Worm	4.1	4.1	0.45
Copper	S-2	SA-600115	Worm	4	4	0.44

Table 8.1-12 (continued)

COPEC	Reach	Location ID	Pathway	Location Average Concentration (mg/kg)	Location Average Nondetects Set to Zero (mg/kg)	Pathway HQ
Copper	S-2	SA-600113	Worm	3.5	3.5	0.39
Copper	S-3W	SA-600376	Worm	2.4	2.4	0.27
Copper	S-3W	SA-600368	Worm	2.3	2.3	0.25
Copper	S-4W	SA-600773	Worm	1.9	1.9	0.21
Copper	S-4W	SA-600782	Worm	1.9	1.9	0.21
Copper	S-5E	SA-600830	Worm	1.9	1.9	0.21
Lead	S-2	SA-603380	Insects	0.99	0.99	0.13
Lead	S-2	SA-600115	Worm	0.595	0.595	0.08
Mercury	S-2	SA-600115	Worm	0.126	0.126	0.06
Nickel	S-2	SA-603380	Insects	0.23	0.23	0.08
Nickel	S-2	SA-603199	Worm	0.45	0.45	0.16
Selenium	S-2	SA-603380	Insects	1.3	1.3	**5.6**
Selenium	S-2	SA-603381	Insects	0.58	0.58	**2.5**
Selenium	PA-0	PA-26500	Worm	0.55	0.55	**2.4**
Selenium	S-2	SA-603199	Worm	0.45	0.45	**2.0**
Selenium	S-2	SA-600115	Worm	0.435	0.435	**1.9**
Selenium	S-2	SA-600113	Worm	0.41	0.41	**1.8**
Selenium	S-3W	SA-600376	Worm	0.59	0.59	**2.6**
Selenium	S-3W	SA-600368	Worm	0.49	0.49	**2.1**
Selenium	S-4W	SA-600782	Worm	0.55	0.55	**2.4**
Selenium	S-4W	SA-600773	Worm	0.5	0.5	**2.2**
Selenium	S-5E	SA-600830	Worm	0.58	0.58	**2.5**
Silver	S-2	SA-603380	Insects	0.16	0.16	0.02
Silver	S-2	SA-603199	Worm	0.76	0.76	0.08
Zinc	S-2	SA-603380	Insects	100	100	0.82
Zinc	S-2	SA-600115	Worm	17	17	0.14
Zinc	S-3W	SA-600376	Worm	19	19	0.16

Note: Cells are shaded if the HQ >1.

Table 8.1-13
Comparison of Concentrations and Potential for Risk to Small Mammals
Based on Aroclor and PCB Congener Sediment Sample Results for Reach S-2

Sample ID	Depth (cm)	Geomorphic Unit	TEC Mammal (mg/kg)	Shrew TCDD HQ[a]	Total PCB (mg/kg)	PCB 126 Measured (mg/kg)	Fraction of Mammal TEC from PCB 126	PCB 126 wt %	Aroclor-1254 (mg/kg)	Shrew Aroclor-1254 HQ[b]	Aroclor-1260 (mg/kg)	Sum of Aroclors (mg/kg)	Predicted PCB 126 (mg/kg)[c]	Predicted HQ to TCDD	Predicted PCB 126 (mg/kg)[d]	Predicted HQ to TCDD
CASA-08-13546	108–133	c3	1.79E-04	620	4.02	1.71E-03	96%	0.043%	0.91	2.1	1.3	2.21	1.82E-05	6.3	1.37E-04	47
CASA-08-13547	0–26	c2a	3.13E-05	110	0.968	2.94E-04	94%	0.030%	0.35	0.80	0.68	1.03	7.00E-06	2.4	5.25E-05	18
CASA-08-13548	9–71	c1ct	5.46E-04	1900	13.9	5.09E-03	93%	0.037%	3	6.8	2.3	5.3	6.00E-05	21	4.50E-04	160
CASA-08-13552	71–101	c1ct	1.79E-05	62	0.535	1.67E-04	93%	0.031%	0.13	0.30	0.14	0.27	2.60E-06	0.9	1.95E-05	6.7
CASA-08-13549	0–30	c2cr	2.94E-04	1000	7.61	2.75E-03	94%	0.036%	2.8	6.4	3.9	6.7	5.60E-05	19	4.20E-04	140
CASA-08-13553	30–67	c2cr	2.94E-05	100	0.941	2.72E-04	93%	0.029%	0.37	0.84	0.33	0.7	7.40E-06	2.6	5.55E-05	19

[a] Shrew TCDD soil ESL is 2.9E-7 mg/kg.

[b] Shrew Aroclor-1254 soil ESL is 0.44 mg/kg.

[c] Lower value (PCB 126 is 0.002% by weight of Aroclor-1254) reported by Frame and others (Frame et al. 1996, 106797).

[d] Higher value (PCB 126 is 0.015% weight of Aroclor-1254) reported by Frame and others (Frame et al. 1996, 106797).

Table 8.1-14
Habitat Assessment Scores

Parameter	Reach ID			
	S-2 (west)	S-2 (east)	S-3E	S-3E (east)
Epifaunal Substrate & Cover	11	6	8	15
Embeddedness	14	8	8	14
Velocity/Depth Regime	8	11	10	15
Sediment Deposition	6	4	4	8
Channel Flow Status	10	10	10	10
Channel Alteration	18	18	20	18
Frequency of Riffles	13	16	16	18
Bank Stability - Left Bank	7	7	5	4
Bank Stability - Right Bank	7	6	5	4
Vegetative Bank Protection - Left Bank	8	5	8	5
Vegetative Bank Protection - Right Bank	8	5	8	5
Riparian Vegetative Zone - Left Bank	10	8	5	6
Riparian Vegetative Zone - Right Bank	10	8	10	10
Habitat Assessment Score	**130 - suboptimal**	**112 - suboptimal**	**117 - suboptimal**	**132 - suboptimal**

Note: Values from Henne (2009, 106683), indicating the score for each parameter in each reach and the total score possible for that parameter.

Table 8.1-15
Macroinvertebrate Sample Abundance and Number of Taxa

Taxonomic Measure	Reach ID			
	S-2 (west)	S-2 (east)	S-3E	S-3E (east)
Percent of sample processed	100	100	100	100
Number of individuals identified	1827	298	402	213
Number of tolerant individuals (tolerance value = 7–10)	528	43	195	24
Number of taxa	17	19	15	10
Number of tolerant taxa (tolerance value = 7–10)	5	8	3	3
Stream Condition Index	**Severely impaired**	**Severely impaired**	**Severely impaired**	**Severely impaired**

Table 8.1-16
SCI and Habitat Ratings for Prior Sampling Locations in Sandia Canyon

Sample Date	SCI Rating	
	Upstream of S-2W	Between S-2E and S-3E
March 1996*	—	Severely impaired
July 2001	Severely impaired	Moderately impaired
October 2001	Severely impaired	Severely impaired
May 2002	Severely impaired	Moderately impaired
October 2002	Severely impaired	Severely impaired
May 2003	Severely impaired	Moderately impaired
November 2003	Moderately impaired	Severely impaired
November 2004	Severely impaired	Severely impaired
May 2005	Severely impaired	Severely impaired
October 2005	Severely impaired	Severely impaired
Habitat Score	Optimal/suboptimal	Optimal/suboptimal

*NMED sample.

Table 8.1-17
Lines of Evidence and Rationale for the Mexican Spotted Owl (AE1)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Measured concentrations in prey species (small mammals) from Sandia Canyon	High	Dose of COPEC ingested had HQ <1.0 for all COPECs when compared with TRV, indicating that the risk through food ingestion was much lower than that predicted by the ESL.
(2) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage)	Medium	Total mean adjusted HI across watershed for owl equals 0.11, indicating no potential for adverse effects.
(3) Comparison of concentrations in sediment samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.1-18
Lines of Evidence and Rationale for Avian and Mammalian Aerial Insectivores (AE6)

Line of Evidence	Weight of Evidence Criteria	Result	Aerial Insectivore Receptors
(1) Nest box study—Determine nest success rate by bluebirds along a gradient of COPEC concentrations in Sandia Canyon	High (existing boxes) Medium (new boxes)	Percent fledged and percent female nestlings were not different between Sandia Canyon reaches or between Sandia Canyon and reference sites, indicating no effect on population (measured as nest success).	Southwestern willow flycatcher/violet-green swallow
(2) Nest box study—Determine eggshell thickness for bluebirds along a gradient of COPEC concentrations in Sandia Canyon	Medium	Egg size (length and weight) and eggshell thickness were not different between Sandia Canyon reaches or between Sandia Canyon and reference locations, indicating no effect on nest success.	Southwestern willow flycatcher/violet-green swallow
(3) Nest box study—Compare COPEC concentrations in eggs in Sandia Canyon and also compare concentrations with “reference” locations	Medium-low	No difference COPEC concentrations in eggs, but uncertain for PCBs (limited set of PCB congeners were measured in two egg samples).	Southwestern willow flycatcher/violet-green swallow
(4) Compare the measured concentrations of COPECs in insects with the TRV	Medium	Potential dose through food to southwestern willow flycatcher and little myotis bat modeled was based on measured COPEC concentrations in nest box insects and earthworms. PCB mixtures and metals had HQ >1 in selected reaches.	Southwestern willow flycatcher/violet-green swallow Occult little myotis bat
(5) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage)—could be based on a frequency of HQ values greater than 1 for the watershed	Medium	The mean adjusted total HI for the southwestern willow flycatcher was 18, based on Aroclor-1254 and inorganic chemicals. These values indicate a potential for risk to the flycatcher.	Southwestern willow flycatcher
(6) Comparison of concentrations in sediment and water samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.	Southwestern willow flycatcher/violet-green swallow Occult little myotis bat

Table 8.1-19
Lines of Evidence and Rationale for Avian Ground Invertevores (AE2)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Nest box study-Compare the measured concentrations of COPECs in insects with the TRV for the robin with the invertevore diet	Medium	Exposure through food to robin was evaluated based on measured COPEC concentrations in nest box insects. Metals had HQ >1 in selected reaches.
(2) Nest box study—Determine nest success rate by bluebirds along a gradient of COPEC concentrations in Sandia Canyon	Medium (new boxes)	Percent fledged and percent female nestlings were not different between Sandia Canyon reaches or between Sandia Canyon and reference sites, indicating no effect on population (measured as nest success).
(3) Nest box study—Determine eggshell thickness for bluebirds along a gradient of COPEC concentrations in Sandia Canyon	Medium	Egg size (length and weight) and eggshell thickness were not different between Sandia Canyon or between Sandia Canyon and reference locations, indicating no effect on nest success.
(4) Nest box study—Compare COPEC concentrations in eggs in Sandia Canyon and also compare concentrations with “reference” locations	Medium-low	No difference COPEC concentrations in eggs, but uncertain for PCBs (limited set of PCB congeners were measured in two egg samples).
(5) Modeled and measured concentrations in food (earthworm bioaccumulation test)—Determine if exposure concentrations differ within the watershed in relation to sediment concentrations; design used a gradient in COPEC concentrations in Sandia Canyon and also compared concentrations with “reference” locations	Medium	HQs based on concentrations in earthworms indicated that some COPECs may have potential for ecological risk to avian ground invertevores.
(6) Comparison of concentrations in sediment samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.1-20
Lines of Evidence and Rationale for Mammalian Invertevores and Omnivores (AE3)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Modeled and measured concentrations in food (earthworms)—Could determine if exposure concentrations differ within the watershed in relation to sediment concentrations; design could use a gradient in COPEC concentrations in Sandia Canyon and also compare concentrations with “reference” location	Medium	The exposure evaluation for the shrew or mouse using concentrations in earthworms or insects showed Aroclor-1242, Aroclor-1248, Aroclor-1254, cadmium, copper, and selenium with HQ large enough to indicate potential for adverse effects. Because high HQ >3 based on detected concentrations in food were observed in one reach (S-2) the potential for population effects is low.
(2) Comparison of concentrations in sediment samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.1-21
Lines of Evidence and Rationale for Detritivores (AE4)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Toxicity test (earthworm mortality) along gradient of COPEC concentrations in Sandia Canyon and Los Alamos. Pueblo Mortandad, and Pajarito watersheds —Compare mortality rates with "reference" locations	High	No differences in earthworm mortality or weight were seen between reaches, indicating no effect along COPEC gradient.
(2) The concentration of COPECs in earthworms	Contributor to other AEs	Bioaccumulation was measured for PCB mixtures and inorganic chemicals, which suggests the potential for exposure.
(3) Comparison of concentrations in sediment samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.1-22
Lines of Evidence and Rationale for Plants (AE5)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Toxicity test (seedling germination) along gradient of COPEC concentrations in Sandia Canyon and also compare germination rates with "reference" locations	High	No differences in mortality or shoot/root mass.
(2) Comparison of concentrations in sediment samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.1-23
Lines of Evidence and Rationale for the Aquatic Community (AE7)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Estimates of growth and mortality of aquatic invertebrates based on toxicity tests using *Chironomus tentans* compared with the reference location	High	There were significant differences in larval survival and growth. Differences were correlated to COPECs and confounding factors. Thus, there is potential for adverse effects of COPECs on larval survival and growth.
(2) A rapid bioassessment characterization to evaluate habitat ratings at selected locations based on watershed features, riparian vegetation, in-stream features, aquatic vegetation, and benthic substrate; assessment will also include measures of abundance and diversity of aquatic invertebrates through Hess sampling and dip net capture	Medium	Physical aspects of habitat similar between reaches; all rated as marginal using index scores. Chironomids were noted in both reaches, supporting their use as toxicity indicator organism. The community measures suggested impairment and could be potentially related to the physical system, water quality, or sediment contaminants.
(3) Comparison of concentrations in sediment and water samples to ESLs	Low	Screening of sediment data against ESLs identified study design COPECs and the potential for adverse effects on this receptor.

Table 8.2-1
Residential Risk Ratios Used to Identify Sediment COPCs, Noncarcinogens

Reach	Acenaphthene	Acenaphthylene	Acetone	Aluminum	Anthracene	Aroclor-1016	Aroclor-1254	Barium	Benzo[g,h,i]perylene	Benzoic Acid[a]	Beryllium	Butanone[2-]	Butylbenzene[n-][b]	Butylbenzene[sec-][b]	Cadmium	Carbon Disulfide	Chromium Hexavalent Ion	Cobalt[a]	Copper	Cyanide [Total]	Dibenzofuran[b]	Di-n-butylphthalate	Fluoranthene	Fluorene	Fluoride	Iron
Residential SL (mg/kg)	3440	1720	67500	78100	17200	3.93	1.12	15600	1720	240000	156	39600	145	112	77.9	1940	219	23	3130	1560	145	6110	2290	2290	4690	54800
S-1N	<0.010	—[c]	—	—	<0.010	—	0.50	—	<0.010	<0.010	—	—	—	—	—	—	<0.010	—	<0.010	<0.010	<0.010	<0.010	0.025	<0.010	—	0.54
S-1S	<0.010	—	—	—	<0.010	—	0.58	0.068	<0.010	<0.010	—	—	—	—	—	—	<0.010	—	0.015	<0.010	<0.010	<0.010	<0.010	<0.010	—	—
S-2	—	<0.010	<0.010	0.26	<0.010	<0.010	2.3	0.019	<0.010	<0.010	0.025	<0.010	<0.010	<0.010	0.11	<0.010	<0.010	0.36	0.071	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.38
S-3W	—	—	—	—	<0.010	—	0.24	<0.010	<0.010	—	—	—	—	—	0.031	—	<0.010	—	<0.010	—	—	—	<0.010	—	—	0.33
S-3E	—	—	—	—	—	—	0.054	—	—	—	0.010	—	—	—	—	—	<0.010	—	<0.010	—	—	—	—	—	<0.010	—
S-4W	—	<0.010	—	—	—	—	0.10	—	—	—	—	—	—	—	—	—	—	—	<0.010	—	—	—	<0.010	—	<0.010	—
S-4E	—	—	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—	0.012	0.23	<0.010	—	—	—	<0.010	<0.010	<0.010	0.25
S-5C	—	—	—	—	—	—	0.087	—	—	—	—	—	—	—	—	—	—	—	<0.010	—	—	—	<0.010	—	<0.010	0.27
S-5E	—	—	—	—	—	—	0.023	—	—	—	—	—	—	—	—	—	<0.010	—	—	—	—	—	<0.010	—	<0.010	—
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<0.010	—
S-6E	—	—	—	—	—	—	—	—	—	—	—	<0.010	—	—	—	—	—	—	—	—	—	—	—	—	<0.010	—

Table 8.2-1 (continued)

Reach	Isopropyltoluene[4-][d]	Lead	Manganese	Mercury {1}	Methoxychlor[4,4'-]	Methyl Mercury	Methylnaphthalene[2-][a]	Molybdenum	Nickel	Nitrate	Perchlorate	Phenanthrene	Pyrene	Selenium	Silver	Styrene	Thallium	Toluene	Trimethylbenzene[1,2,4-][a]	Uranium (Calculated Total)	Vanadium	Xylene [Total]	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]	Zinc	SOF
Residential SL (mg/kg)	3210	400	10700	23	310	7.82	310	391	1560	125000	54.8	1830	1720	391	391	8970	5.16	5570	67	235	391	1090	9550	1090	23500	
S-1N	<0.010	0.12	—	—	—	—	<0.010	—	—	<0.010	<0.010	0.02	0.03	0.01	—	—	—	<0.010	—	—	—	—	<0.010	<0.010	<0.010	1.3
S-1S	—	0.19	—	0.083	—	—	<0.010	—	—	<0.010	<0.010	<0.010	<0.010	0.01	0.036	—	—	<0.010	<0.010	—	—	—	<0.010	<0.010	<0.010	1.0
S-2	<0.010	1.7	0.054	0.24	—	<0.010	<0.010	0.11	0.044	<0.010	<0.010	<0.010	<0.010	<0.010	0.22	—	0.21	<0.010	—	0.051	0.10	—	—	—	0.049	6.3
S-3W	—	0.061	0.10	0.011	—	—	—	<0.010	<0.010	<0.010	—	<0.010	<0.010	0.01	0.040	—	—	—	—	—	—	—	—	—	<0.010	0.87
S-3E	—	0.085	—	<0.010	—	—	—	<0.010	—	<0.010	<0.010	—	<0.010	<0.010	0.011	—	—	—	—	—	—	—	—	—	<0.010	0.20
S-4W	—	0.075	0.059	—	—	—	—	<0.010	—	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	—	—	—	—	—	—	—	—	—	<0.010	0.26
S-4E	<0.010	0.071	0.059	0.010	—	—	—	<0.010	—	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	—	—	<0.010	—	—	—	—	—	—	<0.010	0.81
S-5C	—	0.16	0.056	<0.010	—	—	—	<0.010	—	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	—	—	<0.010	—	—	—	—	—	—	<0.010	0.60
S-5E	—	0.063	—	—	—	—	—	<0.010	—	<0.010	<0.010	<0.010	<0.010	<0.010	—	—	—	<0.010	—	—	—	—	—	—	—	<0.10
S-6W	—	—	—	—	<0.010	—	—	<0.010	—	<0.010	<0.010	—	—	—	—	<0.010	—	<0.010	—	—	—	<0.010	—	—	—	<0.10
S-6E	<0.010	—	—	—	—	—	—	<0.010	<0.010	<0.010	<0.010	—	—	—	—	<0.010	—	<0.010	—	—	—	<0.010	—	—	—	<0.10

Notes: Values are in mg/kg. Residential SLs are from NMED (2009, 106420), unless otherwise noted. Shaded cells indicate which reaches have SOFs >1.0 and which analytes have risk ratios >0.10. All values from EPA regional SSLs adjusted to 10^{-5} target risk level.

[a] EPA Regional SSLs (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[b] Region 6 MSSL.

[c] — = Not A COPC.

[d] Cumene (aka isoproylbenzene) surrogate (CASS 92-82-8) - NMED SL.

Table 8.2-2
Residential Risk Ratios Used to Identify Sediment COPCs, Carcinogens

Reach	Aroclor-1242	Aroclor-1248	Aroclor-1260	Arsenic	Benzene	Benzo[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[k]fluoranthene	BHC[delta-][a]	Bis[2-ethylhexyl]phthalate[b]	Butylbenzylphthalate[c]	Chlordane[gamma-][d]	Chloroaniline[4-][c]	Chloroform	Chromium[c]	Chrysene	DDD[4,4*-]	Dieldrin	Di-n-octylphthalate	Ethylbenzene	Indeno[1,2,3-cd]pyrene	Naphthalene	SOF
Residential SL (mg/kg)	1.7	1.7	1.7	3.59	15.5	4.81	0.481	4.81	48.1	2.18	280	2600	14.6	24	5.72	2800	481	16.3	0.245	280	69.6	4.81	45	
S-1N	—[e]	0.21	0.93	1.7	—	3.5	22	3.8	0.027	<0.010	<0.010	<0.010	—	—	—	<0.010	0.028	—	—	—	—	0.26	<0.010	32
S-1S	—	—	6.5	1.3	—	0.75	6.9	0.62	0.058	—	<0.010	<0.010	—	—	—	0.057	<0.010	—	—	<0.010	<0.010	0.25	<0.010	16
S-2	0.22	0.045	1.2	4.3	—	0.13	1.1	0.18	<0.010	—	<0.010	—	<0.010	0.014	<0.010	1.3	<0.010	<0.010	0.15	—	<0.010	—	—	8.8
S-3W	—	—	0.18	1.6	—	0.021	0.14	0.029	<0.010	—	—	—	—	—	—	0.14	<0.010	—	—	—	—	—	—	2.1
S-3E	—	—	0.18	—	—	—	—	—	—	—	<0.010	—	—	—	<0.010	0.16	<0.010	—	—	—	—	—	—	0.33
S-4W	—	—	0.071	—	—	0.012	—	—	—	—	—	—	—	—	<0.010	0.040	—	—	—	—	—	—	—	0.12
S-4E	—	—	0.13	—	—	<0.010	0.089	—	—	—	—	—	—	—	—	0.040	<0.010	—	—	—	—	—	—	0.27
S-5C	0.025	—	0.092	—	—	0.011	0.091	—	—	—	—	—	—	—	—	0.026	<0.010	—	—	—	—	—	—	0.25
S-5E	0.024	—	0.031	—	—	—	—	—	—	—	<0.010	—	—	—	<0.010	<0.010	<0.010	—	0.011	—	—	—	—	<0.10
S-6W	—	—	—	—	<0.010	—	—	—	—	—	—	—	—	—	<0.010	—	—	—	—	—	<0.010	—	—	<0.10
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<0.010	—	—	<0.10

Notes: Values are in mg/kg. Residential SLs are from NMED (2009, 106420), unless otherwise noted. Shaded cells indicate which reaches have SOFs >1 and which analytes have risk ratios >0.1. All values from EPA regional SSLs adjusted to 10^{-5} target risk level

[a] beta BHC surrogate (CAS 319-85-7) - NMED SL.

[b] di(n-octylphthalate) (117-84-0) as surrogate.

[c] EPA Regional SSLs (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[d] Chlordane surrogate (CAS 12789-03-6) - NMED SL.

[e] — =Not A COPC.

Table 8.2-3
Residential Risk Ratios Used to Identify Sediment COPCs, Radionuclides

Reach	Americium-241	Cesium-137	Plutonium-238	Plutonium-239/240	Strontium-90	Thorium-228	Thorium-232	Tritium	Uranium-234	Uranium-235/236	Uranium-238	SOF
Residential SL(pCi/g)	30	5.6	37	33	5.7	2.3	5	750	170	17	86	
S-1N	—*	—	<0.010	—	—	—	—	—	—	—	—	<0.10
S-1S	—	—	—	<0.010	—	—	—	—	—	—	—	<0.10
S-2	<0.010	0.20	<0.010	0.012	0.33	—	—	<0.010	0.025	0.013	0.047	0.64
S-4W	—	—	<0.010	—	—	1.1	0.47	—	—	—	—	1.5
S-4E	—	—	—	0.050	—	—	—	—	—	—	—	<0.10
S-5C	—	0.17	—	—	—	—	—	—	—	—	—	0.17
S-5E	<0.010	—	—	—	—	1.0	—	—	—	—	—	1.0

Note: Values are in pCi/g. All values are from LANL (2005, 088493).
*— = Not A COPC

Table 8.2-4
Residential Risk Ratios Used to Identify Surface Water COPCs, Noncarcinogens

Reach	2,4-Diamino-6-nitrotoluene[a]	2,6-Diamino-4-nitrotoluene[a]	Acetone	Aluminum	Barium	Benzoic Acid[a]	Beryllium	Boron	Cadmium	Chloride[b]	Chromium[b]	Chromium Hexavalent Ion	Copper	Cyanide [Total]	Dichlorobenzene[1,3-][c]	Dichlorophenol[2,4-]	Fluoride	Iron	Lead[b]	Manganese	Mercury[a]	Molybdenum	Nickel	Perchlorate[a]	Selenium	Silver	Strontium	Sulfate[b]	Thallium	Trichlorophenol[2,4,5-]	Trichlorophenol[2,4,6-]	Uranium	Vanadium	Zinc	SOF
Residential SL (µg/L)	37	37	21800	36500	7300	150000	73	7300	18.3	250000	100	110	1460	730	14.47934	110	2190	25600	15	876	11	183	730	26	183	183	21900	250000	2.41	3650	36.5	110	183	11000	
S-1N	0.015	0.013	<0.010	0.066	0.018	—[d]	—	0.015	—	0.099	0.15	0.084	<0.010	0.015	—	—	0.39	0.063	0.27	0.27	—	0.022	<0.010	—	0.028	—	0.011	0.068	0.22	—	—	0.014	0.24	0.035	2.1
S-1S	—	—	—	<0.010	<0.010	—	—	<0.010	—	—	0.10	—	<0.010	<0.010	—	—	—	<0.010	0.061	0.020	—	0.054	<0.010	0.71	<0.010	—	<0.010	—	—	—	—	0.011	0.099	<0.010	1.1
S-2	—	—	<0.010	0.035	<0.010	—	<0.010	0.011	<0.010	0.28	0.40	0.028	<0.010	0.012	—	—	0.24	0.061	0.31	0.26	<0.010	0.068	<0.010	0.026	0.034	<0.010	<0.010	0.078	0.34	—	—	<0.010	0.091	<0.010	2.3
S-3E	—	—	<0.010	0.028	<0.010	<0.010	—	0.016	<0.010	0.30	0.15	0.059	<0.010	<0.010	—	—	0.21	0.026	0.087	0.022	—	0.097	<0.010	0.026	<0.010	<0.010	<0.010	0.073	—	—	—	0.012	0.077	<0.010	1.2
S-4W	—	—	<0.010	0.028	<0.010	<0.010	—	0.016	<0.010	0.30	0.15	0.044	<0.010	<0.010	—	—	0.21	0.026	0.087	0.022	—	0.097	<0.010	0.025	<0.010	<0.010	<0.010	0.073	—	—	—	0.012	0.077	<0.010	1.2
S-6E	—	—	—	0.017	0.012	—	—	<0.010	—	0.013	0.036	—	—	—	0.022	<0.010	0.23	0.018	0.044	0.020	—	<0.010	<0.010	0.017	0.034	—	0.015	0.027	0.220	<0.010	0.058	0.018	0.084	<0.010	0.91

Notes: Values are in µg/L. Residential SLs are from NMED (2009, 106420), unless otherwise noted. Shaded cells indicate which reaches have SOFs >1.0 and which analytes have risk ratios >0.10. All values from EPA regional SSLs adjusted to 10^{-5} target risk level

[a] EPA Regional SSLs (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm).

[b] EPA MCL (http://www.epa.gov/safewater/contaminants/index.html).

[c] Region 6 MSSL.

[d] — = Not A COPC.

Table 8.2-5
Residential Risk Ratios Used to Identify Surface Water COPCs, Carcinogens

Reach	Aroclor-1254	Aroclor-1260	Arsenic	Benzo[a]anthracene	Benzo[a]pyrene	BHC[delta-][a]	Bis[2-ethylhexyl]phthalate	Bromodichloromethane	Bromoform	Chlorodibromomethane	Chloroform	Dioxane[1,4-]	SOF
Residential SL(µg/L)	0.336	0.336	0.448	0.921	0.0921	0.373	48	1.17	85.1	1.47	1.93	61.1	
S-1N	—[b]	—	23	—	—	0.78	—	—	0.022	—	—	—	23
S-1S	—	—	11	—	—	—	—	6.7	0.033	13	1.0	—	31
S-2	0.33	0.30	21	—	—	—	—	0.39	0.012	0.46	0.14	0.50	23
S-3E	—	—	19	—	—	—	<0.010	—	—	—	0.17	0.12	19
S-4W	—	—	12	—	—	—	<0.010	—	—	—	0.17	0.12	12
S-6E	—	—	—	0.12	1.6	—	—	—	—	—	—	—	1.7

Notes: Values are in µg/L. Residential SLs are from NMED (2009, 106420), unless otherwise noted. Shaded cells indicate which reaches have SOFs >1.0 and which analytes have risk ratios >0.10.

[a] beta-BHC (CAS 319-85-7) surrogate, NMED SL.

[b] — = Not A COPC

Table 8.2-6
Residential Risk Ratios Used to Identify Surface Water COPCs, Radionuclides

Reach	Radium-226	Strontium-90	Tritium	Uranium-234	Uranium-235/236	Uranium-238	SOF
Residential SL (pCi/L)	5	40	80000	20	24	24	
S-1N	—*	—	<0.010	0.044	—	0.018	<0.10
S-1S	0.064	—	—	0.013	—	<0.010	<0.10
S-2	0.069	<0.010	<0.010	0.026	<0.010	0.013	0.12
S-3E	—	<0.010	<0.010	0.028	<0.010	0.022	<0.10
S-4W	—	<0.010	<0.010	0.028	<0.010	0.022	<0.10
S-6E	—	—	<0.010	0.039	<0.010	0.017	<0.10

Note: All SL values from DOE DCGs.
*— = Not A COPC.

Table 8.2-7
Reaches Evaluated for Water, Sediment, and Multimedia Exposure

Reach	Sediment	Surface Water	Multimedia
S-1N	O_{nc},M_{nc},O_c,M_c	M_{nc},O_c,M_c	M_{nc},O_c,M_c
S-1S	O_c,M_c	M_{nc},O_c,M_c	O_c,M_c
S-2	O_{nc},M_{nc},O_c,M_c	M_{nc},O_c,M_c	M_{nc},O_c,M_c
S-3W	O_c,M_c	—*	—
S-3E	—	M_{nc},O_c,M_c	—
S-4W	RAD	M_{nc},O_c,M_c	—
S-4E	—	—	—
S-5C	—	—	—
S-5E	RAD	—	—
S-6W	—	—	—
S-6E	—	O_c	—

Note: Analyte class evaluated as: R = radionuclide; M_c = metal, carcinogen; M_{nc} = metal, noncarcinogen; O_c = organic, carcinogen; O_{nc} = organic, noncarcinogen.
*— = Not evaluated (see Tables 8.2-1 through 8.2-6).

Table 8.2-8
Exposure Point Concentrations for Sediment COPCs

Reach	End Point[a]	Analyte	UCL	Units	UCL Method
S-1N	ca	Aroclor-1248	0.146	mg/kg	95% KM[b] (t) UCL
S-1N	nc	Aroclor-1254	0.337	mg/kg	95% KM (Chebyshev) UCL
S-1N	ca	Aroclor-1260	1.147	mg/kg	97.5% KM (Chebyshev) UCL
S-1N	ca	Arsenic	4.684	mg/kg	95% Student's-t UCL
S-1N	ca	Benzo[a]anthracene	9.914	mg/kg	95% KM (Chebyshev) UCL
S-1N	ca	Benzo(a)pyrene	3.681	mg/kg	95% KM (BCA) UCL
S-1N	ca	Benzo[b]fluoranthene	7.072	mg/kg	95% KM (BCA) UCL
S-1N	ca	Indeno[1,2,3-cd]pyrene	1.23	mg/kg	Maximum Detected
S-1N	nc	Iron	16138	mg/kg	95% H-UCL
S-1N	nc	Lead	28.35	mg/kg	95% Student's-t UCL
S-1S	ca	Aroclor-1260	3.719	mg/kg	97.5% KM (Chebyshev) UCL
S-1S	ca	Arsenic	3.201	mg/kg	95% Student's-t UCL
S-1S	ca	Benzo[a]anthracene	2.09	mg/kg	95% KM (Chebyshev) UCL
S-1S	ca	Benzo(a)pyrene	1.106	mg/kg	95% KM (BCA) UCL
S-1S	ca	Benzo[b]fluoranthene	1.281	mg/kg	95% KM (t) UCL
S-1S	ca	Indeno[1,2,3-cd]pyrene	1.2	mg/kg	Maximum Detected
S-2	nc	Aluminum	7349	mg/kg	95% H-UCL
S-2	ca	Aroclor-1242	0.366	mg/kg	Maximum Detected
S-2	nc	Aroclor-1254	0.326	mg/kg	95% KM (BCA) UCL
S-2	ca	Aroclor-1260	0.522	mg/kg	95% KM (Chebyshev) UCL
S-2	ca	Arsenic	6.153	mg/kg	95% KM (Chebyshev) UCL
S-2	ca	Benzo[a]anthracene	0.245	mg/kg	95% KM (t) UCL
S-2	ca	Benzo(a)pyrene	0.215	mg/kg	95% KM (t) UCL
S-2	ca	Benzo[b]fluoranthene	0.287	mg/kg	95% KM (t) UCL
S-2	nc	Cadmium	1.278	mg/kg	95% KM (BCA) UCL
S-2	ca	Chromium	567.5	mg/kg	95% H-UCL
S-2	nc	Cobalt	2.653	mg/kg	95% KM (BCA) UCL
S-2	ca	Dieldrin	0.037	mg/kg	Maximum Detected
S-2	nc	Iron	10557	mg/kg	95% Student's-t UCL
S-2	nc	Lead	77.59	mg/kg	95% Chebyshev (Mean, Sd) UCL
S-2	nc	Mercury	1.129	mg/kg	95% KM (Chebyshev) UCL
S-2	nc	Molybdenum	27.97	mg/kg	95% Approximate Gamma UCL
S-2	nc	Silver	17.58	mg/kg	95% KM (Chebyshev) UCL
S-2	nc	Thallium	0.228	mg/kg	95% KM (% Bootstrap) UCL
S-2	nc	Vanadium	19.39	mg/kg	95% H-UCL
S-3W	ca	Aroclor-1260	0.172	mg/kg	95% KM (t) UCL
S-3W	ca	Arsenic	3.345	mg/kg	95% Student's-t UCL

Table 8.2-8 (continued)

Reach	End Point[a]	Analyte	UCL	Units	UCL Method
S-3W	ca	Benzo(a)pyrene	0.0546	mg/kg	95% KM (t) UCL
S-3W	ca	Chromium	204.8	mg/kg	95% Student's-t UCL
S-4W	RAD	Thorium-228	2.152	pCi/g	95% Student's-t UCL
S-4W	RAD	Thorium-232	1.976	pCi/g	95% Student's-t UCL
S-5E	RAD	Thorium-228	2.031	pCi/g	95% Student's-t UCL

[a] ca = Carcinogen, nc =noncarcinogen, RAD = radionuclide.

[b] KM = Kaplan-Meier.

Table 8.2-9
Exposure Point Concentrations for Surface Water COPCs, Recreational Scenario

Reach	Analyte	End Point[a]	UCL (µg/L)	UCL Method
S-1N	Arsenic	ca	5	95% KM[b] (t) UCL
S-1N	BHC[delta-]	ca	0.292	Maximum
S-1N	Chromium	nc	11.13	95% KM (BCA) UCL
S-1N	Fluoride	nc	857	Maximum
S-1N	Lead	nc	1.455	95% KM (BCA) UCL
S-1N	Manganese	nc	109.2	Use 95% Chebyshev (Mean, Sd) UCL
S-1N	Thallium	nc	0.54	Maximum
S-1N	Vanadium	nc	29.18	Use 95% Student's-t UCL
S-1S	Arsenic	ca	4.8	Maximum
S-1S	Bromdochloromethane	ca	7.8	Maximum
S-1S	Chlorodibromomethane	ca	18.5	Maximum
S-1S	Chloroform	nc	1.9	Maximum
S-1S	Chromium	nc	8.275	95% KM (t) UCL
S-1S	Perchlorate	ca	18.5	Maximum
S-2	Aroclor-1254	ca	0.089	95% KM (t) UCL
S-2	Aroclor-1260	ca	0.0872	95% KM (t) UCL
S-2	Arsenic	ca	4.127	95% KM (% Bootstrap) UCL
S-2	Bromdochloromethane	ca	0.458	Maximum
S-2	Chloride	nc	70300	Maximum
S-2	Chlorodibromomethane	ca	0.68	Maximum Detected
S-2	Chloroform	ca	0.278	Maximum
S-2	Chromium	nc	26.14	95% KM (Chebyshev) UCL
S-2	1,4-Dioxane	ca	24.8	95% KM (jackknife) UCL
S-2	Fluoride	nc	520	Maximum
S-2	Lead	nc	2.234	95% KM (t) UCL
S-2	Manganese	nc	147.4	95% Chebyshev (Mean, Sd) UCL

Table 8.2-9 (continued)

Reach	Analyte	End Point[a]	UCL (µg/L)	UCL Method
S-2	Thallium	nc	0.505	95% KM (t) UCL
S-3E	Arsenic	ca	4.492	95% KM (t) UCL
S-3E	Chloride	nc	75000	Maximum
S-3E	Chloroform	ca	0.326	Maximum Detected
S-3E	Chromium	nc	10.51	95% KM (Chebyshev) UCL
S-3E	1,4-Dioxane	ca	7.53	Maximum
S-3E	Fluoride	nc	470	Maximum
S-4W	Arsenic	ca	4.449	95% KM (t) UCL
S-4W	Chloride	nc	75000	Maximum
S-4W	Chloroform	ca	0.326	Maximum Detected
S-4W	Chromium	nc	10.51	95% KM (Chebyshev) UCL
S-4W	1,4-Dioxane	ca	7.53	Maximum
S-4W	Fluoride	nc	470	Maximum
S-6E	Benzo[a]anthracene	ca	0.11	Maximum
S-6E	Benzo[a]pyrene	ca	0.15	Maximum

[a] ca = Carcinogen, nc =noncarcinogen.

[b] KM = Kaplan-Meier.

Table 8.2-10
Site-Specific Exposure Scenarios and Complete Exposure Pathways

Exposure Pathways	Exposure Scenarios	
	Recreational	Residential
Incidental ingestion of soil	X[a]	X
Inhalation of dust	X	X
Dermal contact with soil	X	X
Ingestion of surface water	X	—[b]
Dermal contact with surface water	X	—
External irradiation	X	X

[a] X = Complete pathway.

[b] — = Incomplete pathway.

Table 8.2-11
Risk-Based Screening Levels for the Recreational Scenario

Medium	COPC	End Point[a]	Target Adverse-Effect Level	Recreational SL	Units	Reference
Sediment	Aluminum	nc	HQ=1	100000	mg/kg	LANL (2007, 094496)
Sediment	Aroclor-1242	ca	risk=10^{-5}	10.5	mg/kg	LANL (2007, 094496)
Sediment	Aroclor-1248	ca	risk=10^{-5}	10.5	mg/kg	LANL (2007, 094496)
Sediment	Aroclor-1254	nc	HQ=1	6.65	mg/kg	LANL (2007, 094496)
Sediment	Aroclor-1254	ca	risk=10^{-5}	10.5	mg/kg	LANL (2007, 094496)
Sediment	Aroclor-1260	ca	risk=10^{-5}	10.5	mg/kg	LANL (2007, 094496)
Sediment	Arsenic	ca	risk=10^{-5}	27.7	mg/kg	LANL (2007, 094496)
Sediment	Benzo[a]anthracene	ca	risk=10^{-5}	30.1	mg/kg	LANL (2007, 094496)
Sediment	Benzo[a]pyrene	ca	risk=10^{-5}	3.01	mg/kg	LANL (2007, 094496)
Sediment	Benzo[b]fluoranthene	ca	risk=10^{-5}	30.1	mg/kg	LANL (2007, 094496)
Sediment	Cadmium	nc	HQ=1	392	mg/kg	LANL (2007, 094496)
Sediment	Chromium	ca	risk=10^{-5}	14300	mg/kg	LANL (2007, 094496)
Sediment	Cobalt	nc	HQ=1	15700	mg/kg	LANL (2007, 094496)
Sediment	Dieldrin	ca	risk=10^{-5}	1.6	mg/kg	LANL (2007, 094496)
Sediment	Indeno[1,2,3-cd]pyrene	ca	risk=10^{-5}	30.1	mg/kg	LANL (2007, 094496)
Sediment	Iron	nc	HQ=1	100000	mg/kg	LANL (2007, 094496)
Sediment	Lead	nc	HQ=1	560	mg/kg	LANL (2007, 094496)
Sediment	Mercury	nc	HQ=1	238	mg/kg	LANL (2007, 094496)
Sediment	Molybdenum	nc	HQ=1	3960	mg/kg	LANL (2007, 094496)
Sediment	Silver	nc	HQ=1	3960	mg/kg	LANL (2007, 094496)
Sediment	Thallium	nc	HQ=1	52.3	mg/kg	LANL (2007, 094496)
Sediment	Thorium-228	RAD	15 mrem/yr	77	pCi/g	LANL (2005, 088493)
Sediment	Thorium-232	RAD	15 mrem/yr	5	pCi/g	LANL (2005, 088493)
Surface water	Aroclor-1260	ca	risk=10^{-5}	9.36	µg/L	LANL (2007, 094496), calculated
Surface water	1,4-Dioxane	ca	risk=10^{-5}	10781	µg/L	LANL (2007, 094496), calculated
Surface water	Aroclor-1254[b]	ca	risk=10^{-5}	9.36	µg/L	LANL (2007, 094496), calculated

Table 8.2-11 (continued)

Medium	COPC	End Point[a]	Target Adverse-Effect Level	Recreational SL	Units	Reference
Surface water	Aroclor-1260[b]	ca	risk=10^{-5}	9.36	µg/L	LANL (2007, 094496), calculated
Surface water	Arsenic	ca	risk=10^{-5}	78.4	µg/L	LANL (2007, 094496), calculated
Surface water	BHC[delta-]	ca	risk=10^{-5}	57.8	µg/L	LANL (2007, 094496), calculated
Surface water	Benzo[a]anthracene[b]	ca	risk=10^{-5}	23.8	µg/L	LANL (2007, 094496), calculated
Surface water	Benzo(a)pyrene[b]	ca	risk=10^{-5}	1.68	µg/L	LANL (2007, 094496), calculated
Surface water	Bromodichloromethane	ca	risk=10^{-5}	1816	µg/L	LANL (2007, 094496), calculated
Surface water	Chloride[c]	nc	HQ=1	1083333	µg/L	http://www.epa.gov/safewater/contaminants/index.html
Surface water	Chlorodibromomethane	ca	risk=10^{-5}	1363	µg/L	LANL (2007, 094496), calculated
Surface water	Chloroform	ca	risk=10^{-5}	3541	µg/L	LANL (2007, 094496), calculated
Surface water	Chromium	nc	HQ=1	4146	µg/L	LANL (2007, 094496), calculated
Surface water	Fluoride	nc	HQ=1	167102	µg/L	LANL (2007, 094496), calculated
Surface water	Lead[c]	nc	HQ=1	65.4	µg/L	http://www.epa.gov/safewater/contaminants/index.html
Surface water	Manganese	nc	HQ=1	284399	µg/L	LANL (2007, 094496), calculated
Surface water	Perchlorate	nc	HQ=1	1950	µg/L	LANL (2007, 094496), calculated
Surface water	Thallium	nc	HQ=1	184	µg/L	LANL (2007, 094496), calculated
Surface water	Vanadium	nc	HQ=1	8819	µg/L	LANL (2007, 094496), calculated

[a] ca = Carcinogen, nc =noncarcinogen, RAD = radionuclide.

[b] Toxicity based SL exceeds aqueous solubility limit.

[c] Based on MCL adjusted to recreational exposure parameters.

Table 8.2-12
Summary of Recreational Risk Assessment Results

Reach	Total Sediment Risk	Total Surface Water Risk	Total Multimedia Risk	Total Sediment HI	Total Surface Water HI	Total Multimedia HI	Total Sediment Dose	Total Surface Water Dose	Total Multimedia Dose
S-1N	2.2E-05	6.9E-07	2.2E-05	0.26	0.037	0.30	—*	—	—
S-1S	9.9E-06	8.0E-07	1.1E-05	—	0.011	—	—	—	—
S-2	4.9E-06	7.5E-07	5.3E-06	0.41	0.11	0.53	—	—	—
S-3E	—	5.8E-07	—	—	0.075	—	—	—	—
S-3W	1.7E-06	—	—	—	—	—	—	—	—
S-4E	—	—	—	—	—	—	—	—	—
S-4W	—	5.8E-07	—	—	0.075	—	6.3	—	—
S-5C	—	—	—	—	—	—	—	—	—
S-5E	—	—	—	—	—	—	—	—	—
S-6E	—	9.4E-07	—	—	—	—	—	—	—
S-6W	—	—	—	—	—	—	—	—	—

Note: Shaded cells: risk exceeds 1.0E-5.

*— = Not evaluated.

Table 8.2-13
Risk Ratios Based on Exposure Point Concentrations for Sediment, Recreational Scenario

Noncarcinogens													
Reach	**Aluminum**	**Aroclor-1254**	**Cadmium**	**Cobalt**	**Iron**	**Lead**	**Mercury**	**Molybdenum**	**Silver**	**Thallium**	**Vanadium**	**Total Risk Ratio**	**Hazard Index**
Recreational SL (mg/kg)	100000	6.65	662	15700	100000	560	238	3960	3960	52.3	792		
S-1N	—*	0.051	—	—	0.16	0.051	—	—	—	—	—	0.26	0.26
S-2	0.073	0.049	0.0019	0.00017	0.11	0.14	0.0047	0.0071	0.0044	0.0044	0.024	0.41	0.41
Carcinogens													
Reach	**Aroclor-1242**	**Aroclor-1248**	**Aroclor-1254**	**Aroclor-1260**	**Arsenic**	**Benzo[a]anthracene**	**Benzo(a)pyrene**	**Benzo[b] fluoranthene**	**Chromium**	**Dieldrin**	**Indeno[1,2,3-cd]pyrene**	**Total Risk Ratio**	**Total Risk**
Recreational SL (mg/kg)	10.5	10.5	10.5	10.5	27.7	30.1	3.01	30.1	14300	1.6	30.1		
S-1N	—	0.014	.032	0.11	0.17	0.33	1.2	0.23	—	—	0.041	2.2	2.2E-05
S-1S	—	—	—	0.35	0.12	0.070	0.37	0.043	—	—	0.040	0.99	9.9E-06
S-2	0.035	—	.031	0.050	0.22	0.0081	0.071	0.010	0.040	0.023	—	0.49	4.9E-06
S-3W	—	—	—	0.016	0.12	—	0.018	—	0.014	—	—	0.17	1.7E-06
Radionuclides													
Reach	**Thorium-228**	**Thorium-232**	**Total Dose Ratio**	**Total Dose**									
Recreational SL (pCi/g)	77	5											
S-4W	0.028	0.40	0.42	6.3									
S-5E	0.026	—	0.026	0.40									

Note: Shaded cells: risk exceeds 1.0E-5.
*— = Not evaluated.

Table 8.2-14
Risk Ratios Based on Exposure Point Concentrations for Surface Water, Recreational Scenario

Noncarcinogens

Reach	Chloride	Chromium	Fluoride	Lead	Manganese	Perchlorate	Thallium	Vanadium	Total Risk Ratio	Hazard Index
Recreational SL (µg/L)	1083333	4146	167102	65.4	284399	1950	184	8819		
S-1N	—[a]	0.0027	0.0051	0.022	0.0004	—	0.0029	0.0033	0.037	0.037
S-1S	—	0.0020	—	—	—	0.0095	—	—	0.011	0.011
S-2	0.065	0.006	0.0031	0.034	0.0005	—	0.0027	—	0.11	0.11
S-3E	0.069	0.0025	0.0028	—	—	—	—	—	0.075	0.075
S-4W	0.069	0.0025	0.0028	—	—	—	—	—	0.075	0.075

Carcinogens

Reach	1,4-Dioxane	Aroclor-1254[b]	Aroclor-1260[b]	Arsenic	Benzo[a]anthracene[b]	Benzo[a]pyrene[b]	BHC[delta-]	Bromodichloromethane	Chlorodibromomethane	Chloroform	Total Risk Ratio	Total Risk
Recreational SL (µg/L)	10781	9.36	9.36	78.4	23.8	1.68	58	1816	1363	3541		
S-1N	—	—	—	0.064	—	—	0.0051	—	—	—	0.069	6.9E-07
S-1S	—	—	—	0.061	—	—	—	0.0043	0.014	0.00054	0.080	8.0E-07
S-2	0.0023	0.010	0.0093	0.053	—	—	—	0.00025	0.00050	0.000079	0.075	7.5E-07
S-3E	0.00070	—	—	0.057	—	—	—	—	—	0.000092	0.058	5.8E-07
S-4W	0.00070	—	—	0.057	—	—	—	—	—	0.000092	0.058	5.8E-07
S-6E	—	—	—	—	0.0046	0.089	—	—	—	—	0.094	9.4E-07

[a] — = Not evaluated.

[b] Toxicity based SL is higher than water solubility.

Table 8.2-15
Reach S-2 Mercury Analytical Results

Location ID	Depth Interval (ft)	Mercury (mg/kg)	Methyl Mercury (mg/kg)	Methyl Mercury Percent
SA-600108	3.5–4.4	0.535	0.000484	0.090%
SA-600110	0–0.85	0.253	0.0000920	0.036%
SA-600113	0.2–2.3	5.57	0.00223	0.040%
	2.3–3.3	0.759	0.00460	0.61%
SA-600115	0–0.98	3.17	0.000222	0.0070%
	0.98–2.2	0.687	0.00221	0.32%

Table 8.2-16
Reach S-2 PCB Congener Analysis, Recreational Scenario

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Recreational Risk Ratio[d]
SA-600108	CASA-08-13546	3.54–4.36	PCB-105	0.0299	0.00003	8.97E-07	1.79E-04	0.64
			PCB-106/118	0.0954	0.00003	2.86E-06		
			PCB-114	0.000958	0.00003	2.87E-08		
			PCB-123	0.00135	0.00003	4.05E-08		
			PCB-126	0.00171	0.1	1.71E-04		
			PCB-156	0.0204	0.00003	6.12E-07		
			PCB-157	0.00488	0.00003	1.46E-07		
			PCB-167	0.011	0.00003	3.30E-07		
			PCB-169	0.0000752	0.03	2.26E-06		
			PCB-189	0.00385	0.00003	1.16E-07		
			PCB-77	0.0026	0.0001	2.60E-07		
			PCB-81	0.0000439	0.0003	1.32E-08		
SA-600110	CASA-08-13547	0–0.85	PCB-105	0.00593	0.00003	1.78E-07	3.13E-05	0.11
			PCB-106/118	0.0212	0.00003	6.36E-07		
			PCB-114	0.000169	0.00003	5.07E-09		
			PCB-123	0.000241	0.00003	7.23E-09		
			PCB-126	0.000294	0.1	2.94E-05		
			PCB-156	0.00456	0.00003	1.37E-07		
			PCB-157	0.000929	0.00003	2.79E-08		
			PCB-167	0.00227	0.00003	6.81E-08		
			PCB-169	0.0000255	0.03	7.65E-07		
			PCB-189	0.00098	0.00003	2.94E-08		
			PCB-77	0.000489	0.0001	4.89E-08		
			PCB-81	0.00011	0.0003	3.30E-08		

Table 8.2-16 (continued)

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Recreational Risk Ratio[d]
SA-600113	CASA-08-13548	0.3–2.33	PCB-105	0.222	0.00003	6.66E-06	5.50E-04	2.0
			PCB-106/118	0.796	0.00003	2.39E-05		
			PCB-114	0.0095	0.00003	2.85E-07		
			PCB-123	0.00926	0.00003	2.78E-07		
			PCB-126	0.00509	0.1	5.09E-04		
			PCB-156	0.0959	0.00003	2.88E-06		
			PCB-157	0.0208	0.00003	6.24E-07		
			PCB-167	0.0386	0.00003	1.16E-06		
			PCB-169	0.000119	0.03	3.57E-06		
			PCB-189	0.00805	0.00003	2.42E-07		
			PCB-77	0.0127	0.0001	1.27E-06		
			PCB-81	0.000404	0.0003	1.21E-07		
	CASA-08-13552	2.33–3.31	PCB-105	0.00515	0.00003	1.55E-07	1.79E-05	0.06
			PCB-106/118	0.0172	0.00003	5.16E-07		
			PCB-114	0.000192	0.00003	5.76E-09		
			PCB-123	0.000182	0.00003	5.46E-09		
			PCB-126	0.000167	0.1	1.67E-05		
			PCB-156	0.00265	0.00003	7.95E-08		
			PCB-157	0.000591	0.00003	1.77E-08		
			PCB-167	0.00125	0.00003	3.75E-08		
			PCB-169	0.000011	0.03	3.30E-07		
			PCB-189	0.000458	0.00003	1.37E-08		
			PCB-77	0.000281	0.0001	2.81E-08		
			PCB-81	0.0000863	0.0003	2.59E-08		

Table 8.2-16 (continued)

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Recreational Risk Ratio[d]
SA-600115	CASA-08-13549	0–0.98	PCB-105	0.0771	0.00003	2.31E-06	2.94E-04	1.1
			PCB-106/118	0.285	0.00003	8.55E-06		
			PCB-114	0.00287	0.00003	8.61E-08		
			PCB-123	0.00382	0.00003	1.15E-07		
			PCB-126	0.00275	0.1	2.75E-04		
			PCB-156	0.0493	0.00003	1.48E-06		
			PCB-157	0.01	0.00003	3.00E-07		
			PCB-167	0.0212	0.00003	6.36E-07		
			PCB-169	0.0000978	0.03	2.93E-06		
			PCB-189	0.00661	0.00003	1.98E-07		
			PCB-77	0.00418	0.0001	4.18E-07		
			PCB-81	0.0054	0.0003	1.62E-06		
	CASA-08-13553	0.98–2.2	PCB-105	0.011	0.00003	3.30E-07	2.94E-05	0.11
			PCB-106/118	0.0362	0.00003	1.09E-06		
			PCB-114	0.000344	0.00003	1.03E-08		
			PCB-123	0.000476	0.00003	1.43E-08		
			PCB-126	0.000272	0.1	2.72E-05		
			PCB-156	0.00513	0.00003	1.54E-07		
			PCB-157	0.00125	0.00003	3.75E-08		
			PCB-167	0.00234	0.00003	7.02E-08		
			PCB-169	0.0000121	0.03	3.63E-07		
			PCB-189	0.000649	0.00003	1.95E-08		
			PCB-77	0.000591	0.0001	5.91E-08		
			PCB-81	0.0000763	0.0003	2.29E-08		
						95th UCL	3.56E-04	1.3

[a] TEFs from WHO (http://www.who.int/entity/ipcs/assessment/tef_values.pdf).

[b] TEQ = [conc] x TEF.

[c] 2,3,7,8-TCDD SL = 2.77E-04 mg/kg from LANL (2007, 094496).

[d] Risk Ratio = [Total TEQ] x [TCCD SL].

Appendix A

Acronyms and Abbreviations,
Metric Conversion Table, and Data Qualifier Definitions

A-1.0 ACRONYMS AND ABBREVIATIONS

%D	percent difference
%R	percent recovery
%RSD	percent standard deviation
‰	per mil
acre-ft	acre-foot
AE	assessment endpoint
AHF	Advanced Hydrotest Facility
ALLH	all horizons
ANOVA	analysis of variance
AO	Administrative Order
AOC	area of concern
asl	above sea level
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BCG	Biota Concentration Guide (DOE)
BEHP	bis(2-ethylhexyl)phthalate
bgs	below ground surface
BV	background value
BW	body weight
CAH	chlorinated aliphatic hydrocarbon
CAS	Chemical Abstract Service
CCV	continuous calibration verification
CDF	cumulative distribution functions
CFR	Code of Federal Regulations
csf	cubic foot per second
CMR	Combined Magnetic Resonance
Consent Order	Compliance Order on Consent
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CR	concentration ratio
CRDL	contract-required detection limit
CRI	CRDL check standard

CWA	Clean Water Act
D&D	decontamination and decommissioning
DC	direct current
DCA	dichloroethane
DCE	dichlorethylene
DCF	dose conversion factor
DCG	Derived Concentration Guidelines (DOE)
DDD	dichlorodiphenyldichloroethane
DDE	dichlorophenyltrichloroethylene
DER	duplicate error ratio
DI	deionized
DO	dissolved oxygen
DOC	dissolved organic carbon
DOE	Department of Energy (U.S.)
DRI	Desert Research Institute
DRO	diesel range organics
DU	depleted uranium
ECDF	empirical cumulative distribution function
ED	exposure duration
EDL	estimated detection limit
EDS	energy dispersive spectroscopy
EES	Earth and Environmental Sciences
EPA	Environmental Protection Agency (U.S.)
EPC	exposure point concentration
EQL	estimated quantitation limit
ER	Environmental Restoration
ERAGS	Ecological Risk Assessment Guidance for Superfund
ERDB	Environmental Restoration Database
ESL	ecological screening level
ESP	Environmental Surveillance Program
ET	evapotranspiration
FFCA	Federal Facility Compliance Agreement
FR	Federal Register
FRS	flood retention structure

fw	fresh weight
GEL	General Engineering Laboratory
GFM	geologic framework model
gpm	gallon per minute
GPS	global-positioning system
HA	hand auger
HDPE	high-density polyethylene
HE	high explosives
HFO	hydrous ferric oxide
HHMSSL	Human Health Medium-Specific Screening Level (EPA Region 6)
HI	hazard index
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	hazard quotient
HSA	hollow-stem auger
IAP	ion activity product
IC	ion chromatography
ICPAES	inductively coupled plasma–atomic emission spectroscopy
ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectrometry
ICPOES	Inductively coupled (argon) plasma optical emission spectroscopy
ICR	incremental cancer risk
ICS	interference check sample
ICV	initial calibration verification
I.D.	inside diameter
ID	identification
IDL	instrument detection limit
IFGMP	Interim Facility-Wide Groundwater Monitoring Plan
ILCR	incremental lifetime cancer risk
IP	Individual Permit
IRIS	Integrated Risk Information System
IS	internal standard
IW	interstitial water
K_d	distribution coefficient
K_{ow}	octanol-water partition coefficient

LAL	lower acceptance limit
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LCS	laboratory control sample
LDCC	LANL Data Communications Center
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant levels (EPA)
MDA	material disposal area
MDC	minimum detectable concentration
MDL	method detection limit
MNA	monitored natural attenuation
mrem/yr	millirem per year
MRL	minimal risk level
MS	matrix spike
MSD	matrix spike duplicate
MSGP	Multi-Sector General Permit
mV	millivolt
NEPA	National Environmental Policy Act
NIST	National Institute of Standards and Technology
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMEIB	New Mexico Environmental Improvement Board
NMHWA	New Mexico Hazardous Waste Act
NMSA	New Mexico Statutes Annotated
NMWQCC	New Mexico Water Quality Control Commission
NOAEL	no observed adverse effect level
NOD	notice of disapproval
NPDES	National Pollutant Discharge Elimination System
NTS	Nevada Test Site
OB	Oversight Bureau (New Mexico)
O.D.	outside diameter
ORP	oxidation-reduction potential
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl

PCE	perchloroethylene
PID	photoionization detector
PQL	practical quantitation limit
PRG	preliminary remediation goal
PS	particle size
PVC	polyvinylchloride
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RER	relative ratio error
RF	radio frequency
RFI	RCRA facility investigation
RL	reporting limit
RLW	radioactive liquid waste
RME	reasonable maximum exposure
RPD	relative percent difference
rpm	revolutions per minute
RRF	relative response factor
RSD	relative standard deviation
RSL	regional screening level (EPA)
SAL	screening action level
SSC	Strategic Computing Complex
SCI	Stream Condition Index
SEM	scanning electron microscope
SERF	Sanitary Effluent Reclamation Facility
SF	slope factor
SI	saturation index
SL	screening level
SLERA	screening-level ecological risk assessment
SMCL	secondary maximum contaminant level (EPA)
SMDB	Sample Management Database
SOF	sum of fraction
SOM	solid organic matter

SOP	standard operating procedure
SOW	statement of work
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWSC	Sanitary Wastewater Systems Consolidation (plant)
T&E	threatened and endangered
TA	technical area
TATB	triaminotrinitrobenzene
TCA	1,1,1-trichloroethane
TCDD	tetrachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
TCE	trichloroethene
TD	total depth
TDS	total dissolved solids
TEC	TCDD-equivalent concentration
TEF	toxic equivalency factor
TF	transfer factor
TKN	total Kjeldahl nitrogen
TNT	2,4,6-trinitritoluene
TOC	total organic compound
TPH	total petroleum hydrocarbon
TPU	total propagated uncertainty
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
UAL	upper acceptance limit
UC	University of California
UCL	upper confidence limit
UDR	universal drill rig
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VCA	voluntary corrective action
VOC	volatile organic compound
wt %	weight percent

WHO	World Health Organization
WOE	weight of evidence
WQC	water-quality criteria
WQDB	Water Quality Database
wSAL	water screening action level
XANES	x-ray absorption near-edge spectroscopy
XRD	x-ray diffraction
XRF	x-ray fluorescence

A-2.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	by	To Obtain U.S. Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

A-3.0 DATA QUALIFIER DEFINITIONS

Data Qualifier	Definition
U	The analyte was analyzed for but not detected.
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the result is likely to be biased high.
J-	The analyte was positively identified, and the result is likely to be biased low.
UJ	The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
R	The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

Appendix B

Field Investigation Methods and Results

B-1.0 SEDIMENT INVESTIGATIONS

This appendix summarizes results from field investigations of potentially contaminated sediment deposits in reaches within Sandia Canyon that were conducted from 2007 through 2009 as part of implementation of the work plan for Sandia Canyon and Cañada del Buey (LANL 1999, 064617), as modified by subsequent documents (LANL 2003, 081597; LANL 2005, 091542; LANL 2007, 095060; LANL 2007, 098127). Also included are some results from previous investigations that occurred in 1998 (LANL 1998, 062340; Katzman 2000, 064349). Analytical data from sediment samples collected in two reaches in 2000 (S-3E and S-5C) as part of characterization of pre-Cerro Grande fire conditions are also used in this investigation. Investigations of sediment associated with evaluating potential adverse ecological impacts are presented separately in section B-3.0 of this appendix.

Geomorphic mapping at a scale of 1:200 occurred in each reach and focused on delineating geomorphic units with differences in physical characteristics and/or contaminant levels. These maps are presented on Plates 2 to 5. Unit designations followed those used in previous reports on canyons in and near the Los Alamos National Laboratory (LANL or the Laboratory) (e.g., LANL 2004, 087390; LANL 2006, 094161; LANL 2009, 106506; LANL 2009, 106771; LANL 2009, 106790), with “c” designating post-1942 channel units and “f” designating post-1942 floodplain units. Summaries of the physical characteristics of post-1942 geomorphic units in the Sandia Canyon investigation reaches are presented in Table B-1.0-1.

Sediment thickness measurements distinguished between fine facies sediment, with typical median particle size of silt to fine sand (0.015 to 0.25 mm) in the less than 2-mm fraction, and coarse facies sediment, with typical median particle size of coarse to very coarse sand (0.5 to 2 mm) in the less than 2-mm fraction. Samples with median particle size of medium sand (0.25 to 0.5 mm) were classified either as fine or coarse facies, depending on the stratigraphic context and the particle size of adjacent layers. Coarse facies sediment is characteristic of material transported along the streambeds as bed load, and fine facies sediment is characteristic of material transported in suspension (Malmon 2002, 076038, pp. 94–97; Malmon et al. 2004, 093018). Several methods were used to identify the bottom of post-1942 sediment deposits, including determining the depth of buried trees and associated buried soils and noting the presence or absence of materials imported to the watershed after 1942 (e.g., quartzite gravel, plastic). Sediment thickness measurements from the Sandia Canyon investigation reaches are shown in Table B-1.0-2 (see Attachment 1 on CD included with this document).

In most reaches, average facies thickness in each unit was combined with unit area, as determined from digitized geomorphic maps, to obtain an estimated volume. These volume estimates were combined with estimates of contaminant levels, where available, to allocate samples using a stratified sample allocation process (Gilbert 1987, 056179, pp. 45–57) designed to reduce uncertainties in the contaminant inventory in each reach. In this process, samples were preferentially allocated to units and sediment facies with a large portion of the total inventory (e.g., Ryti et al. 2005, 093019). One result of this sample allocation process is a high bias in sampling results because of a disproportionately large number of samples collected from the more contaminated geomorphic units and sediment facies. Weighted averages are used in this investigation in calculations of contaminant inventory to remove the bias introduced during sample collection. In contrast, in the human health risk assessment weighted averages are not used for simplicity in calculation, which results in systematic overestimates of average chemical of potential concern (COPC) concentrations.

In reach S-2, the investigation methods differed from that in other reaches because of thick sediment deposits and saturated conditions. In S-2, stratigraphic descriptions in stream banks and shallow hand-dug holes above the alluvial water table were supplemented with measurements of sediment thickness in 21 auger holes that penetrated the full thickness of alluvium. Quartzite clasts were found in the deepest

levels in some holes, indicating that virtually the entire thickness of alluvium in S-2 postdates initial Laboratory activities in the watershed (post-1942 sediment). Particle-size data were used to estimate the percentage of coarse and fine facies sediment in each hole and in each unit, and these estimates are presented in Table B-1.0-2 (see Attachment 1 on CD included with this document).

Field x-ray fluorescence (XRF) screening data were obtained in all reaches investigated in 2007 to evaluate variations in chromium concentration and to help bias sampling. At each stratigraphic description location, sediment was collected through the complete thickness of discrete layers and homogenized in a petri dish. Measurements were obtained for up to 2 min on each sample, depending on the chromium concentration (shorter count times were used where chromium concentration was higher because the plus-or-minus was relatively low for these). The measurements were made with a portable XRF spectrometer produced by Innox-X Systems, Inc. (model α-4000 SL), which was initialized and compared against National Institute for Standards and Testing standards daily. Multiple measurements were made on some layers to evaluate variability in the field XRF measurements and to confirm relatively high results in each reach. In addition, for each sample collected for off-site analyses, a split was obtained for comparing the analytical results with those obtained using the field XRF instrument. Each split was measured using the same instrument in an on-site laboratory at field moisture conditions, and wet samples were then oven-dried and remeasured to evaluate the effect of moisture content on the XRF data. XRF measurements vary with soil moisture content because the attenuation of x-rays varies with soil density. Wet soils are denser than dry soils; therefore, a wet soil will provide a lower signal than a dry soil with the same concentration of chromium. Thus, field measurements made at different locations with different moisture content or at the same location during different time periods may not be exactly comparable, although the relative levels of chromium between different locations can still be determined. Table B-1.0-3 presents XRF measurements of chromium on Sandia Canyon sediment samples, indicates whether the measurement occurred in the field or in the lab, and notes if the sample was oven-dried (see Attachment 1 on CD included with this document). Measurement locations are shown on Plates 3, 4, and 5.

For samples submitted to an off-site analytical laboratory, Table B-1.0-4 presents the average chromium concentration as measured with the field XRF instrument (the average of multiple measurements) under field moisture conditions and also oven-dried, where applicable (see Attachment 1 on CD included with this document). Table B-1.0-4 also presents the chromium concentration as measured at an off-site laboratory. These data are plotted in Figure B-1.0-1 to illustrate the relation of field XRF measurements to off-site analyses and also the effect of moisture content. Figure B-1.0-1a shows all the data, and Figure B-1.0-1b shows only the data where chromium is less than 300 mg/kg to illustrate relations in this lower part of the data set, which contains most of the samples. The oven-drying experiment indicated that XRF measurements averaged about 65% higher after wet samples were dried, confirming that variable water content under field conditions partially limits the precision of field XRF measurements. Scatter in Figure B-1.0-1 in the relation between chromium concentration measured using the field XRF instrument and the off-site laboratory is probably also because of heterogeneity within each sample. Note that a one-to-one correlation between XRF results and off-site analytical results is not expected, particularly at low concentrations, because the field instrument measures total chromium in a sample and the off-site analytical results follow a partial digestion sample preparation method. For samples with chromium concentrations below the sediment background value of 10.5 mg/kg (average of 4.6 mg/kg in these Sandia Canyon sediment samples), the average chromium concentration measured with the field XRF instrument was 28 ppm (range of 21 ppm to 49 ppm; 1 ppm = 1 mg/kg).

Particle-size analyses of sediment samples were obtained at an off-site laboratory at the Desert Research Institute (DRI) following the procedures described in Janitzky (1986, 057674) to examine the effect of particle-size distribution on contaminant concentrations. Organic-matter content was determined for some

of the samples at DRI using the loss-on-ignition method to provide additional information about the physical characteristics of potentially contaminated sediment deposits, and pH data were obtained from some samples because ecological screening levels (ESLs) are pH-dependant for some analytes. Particle size, organic matter, and pH from the Sandia Canyon investigation reaches are shown in Table B-1.0-5 (see Attachment 1 on CD included with this document).

Dendrochronological analyses (tree-ring dating) were obtained in some reaches to provide supplemental information on the age of sampled sediment deposits in Sandia Canyon. Sediments burying trees of known age are constrained to be younger than the trees, and sediments beneath the base of trees are constrained to be older. In some cases, nearby trees of different age can provide more precise determination of the ages of sediment deposits. For example, two adjacent trees of different age can be buried by different thicknesses of sediment recording a variable number of floods since the germination of each tree and approximate ages for such floods, or different age trees can be buried by the same thickness of sediment recording the absence of deposition during specific time periods. Cores were collected from six individual trees in Sandia Canyon using a 5-mm-diameter increment borer (Table B-1.0-6). Each tree was assigned a unique four-letter two-number identifier following the general convention used by the Laboratory of Tree-Ring Research at the University of Arizona, with the designation “SAN” chosen to indicate trees cored in Sandia Canyon. These trees are located at or near sediment sample sites, and data on the tree diameter and the thickness of sediment burying each tree were recorded. These analyses followed the methodology described in Stokes and Smiley (1996, 057644) and Phipps (1985, 058477), and the process is discussed further in Reneau et al. (Reneau et al. 1998, 065407, Appendix B, Section B-1.0).

B-2.0 WATER INVESTIGATIONS

The methods used during groundwater investigations in Sandia Canyon and adjacent canyons are described in the well completion reports listed in section 3.2 of this investigation report. The well completion reports provide information about drilling methodologies, use of drilling fluids and additives, sample collection methods, well construction, borehole geophysical logs, well development, and waste management.

To summarize, drilling investigations in Sandia Canyon and adjacent canyons were conducted using a variety of drilling methods. Two alluvial wells were emplaced using hand-auger methods in the wetland of upper Sandia Canyon (SCA-1) and in a narrow reach downcanyon (SCA-2). A CME 55 hollow-stem auger (HSA) track-mounted rig was used to install three other alluvial wells and two associated piezometer sets farther downcanyon (SCA-3 with associated piezometers SCP-2a,b; SCA-4 with associated piezometer nest SCP-1a,b,c; and SCA-5 without associated piezometers). A Speedstar 50K truck-mounted rig was used to collect both cuttings and core at six deeper holes (SCC-1 through SCC-6) that penetrated down to the top of the Cerros del Rio lavas. The SCI-2 core hole was drilled using sonic coring/drilling and conventional air-coring methods (when the former method became untenable). The regional aquifer boreholes were drilled using fluid-assisted rotary air-drilling methods.

B-3.0 BIOTA INVESTIGATIONS

This appendix contains supplemental information on biota investigations conducted to support the evaluation of potential adverse ecological impacts presented in Section 8.1. Sampling locations are presented in Figure 8.1-1 and on Plates 3, 4, and 5.

Sediment characterization in support of the small mammal study involved collecting one composite sample from each trapping array to obtain representative concentrations of chemicals of potential ecological concern (COPECs) within the foraging area, following the procedure used in prior biota investigations (LANL 2006, 094161, p. B-3). Each composite sample consisted of equal portions of sediment from a subset of trapping locations within that area. All the sediment samples were collected from depths of 0–15 cm (0–6 in.). The specific trapping locations were selected randomly using a random-number generator and included 10 trapping locations per array, or 10% of the locations in each array. At each location, field notes were taken on the geomorphic unit and sediment facies. Table B-3.0-1 presents information on the trap number, geomorphic unit, and sediment thickness for each portion of each composite sample, and average sediment thickness values in each composite sample.

Tables B-3.0-2 to B-3.0-6 present additional details of samples submitted for analysis associated with the biota investigation. Table B-3.0-2 presents specific information on the small mammals submitted for laboratory analyses, including reach, sample ID, species, number of individuals composited in sample, and weight. Table B-3.0-3 lists each sediment sample submitted for laboratory analyses, including reach, location ID, geomorphic unit, depth, date collected, and type of biota test. Table B-3.0-4 lists surface water samples collected for aquatic toxicity tests. Table B-3.0-5 lists earthworm samples submitted for analysis, including collocated sediment sample ID. Table B-3.0-6 lists egg and insect samples from nest boxes that were submitted for laboratory analysis, including the reach or general sample location, the nest box number (or numbers for insect samples that were composited from multiple boxes), the collection date, and other information on the samples.

B-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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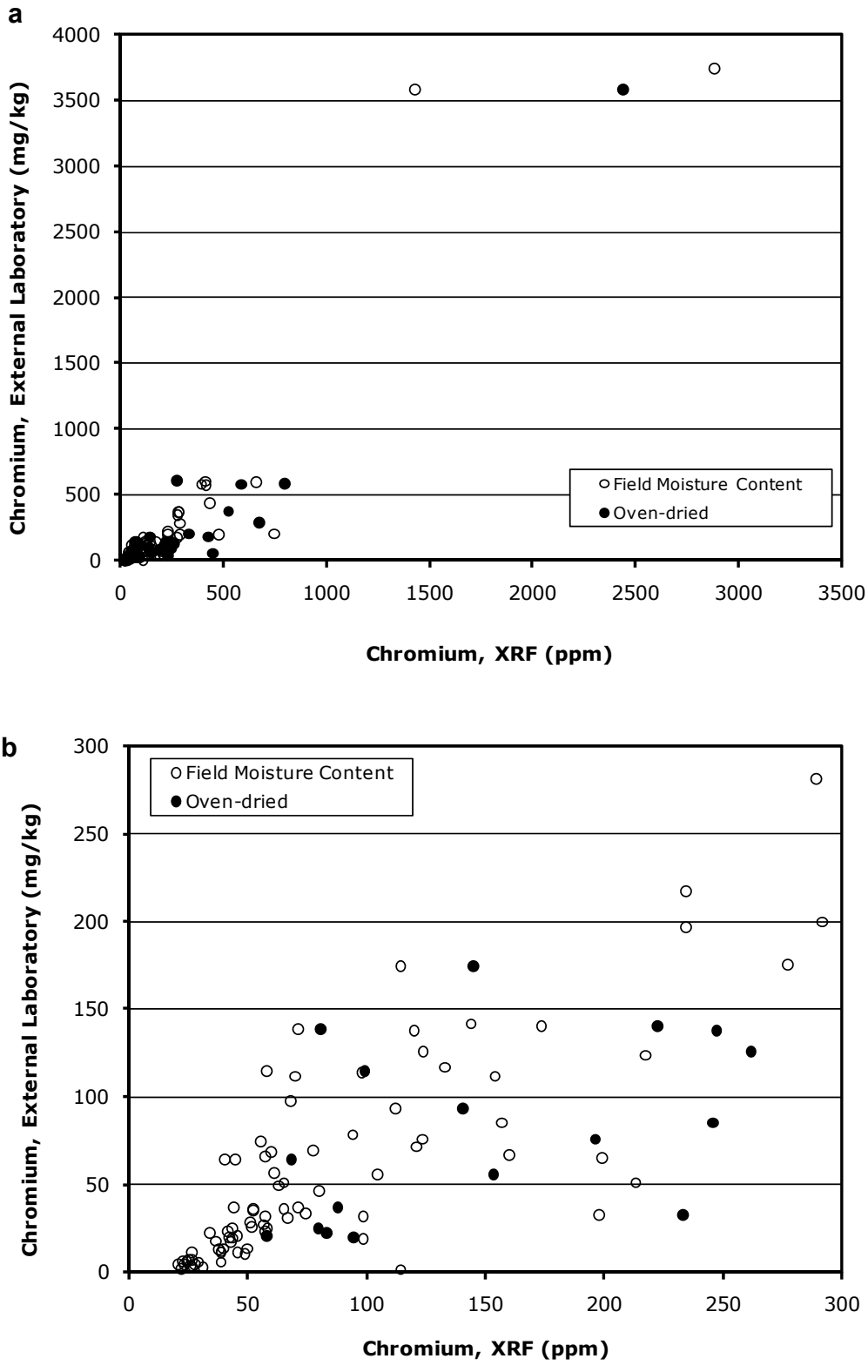

Figure B-1.0-1 Relation between chromium concentrations measured at an external laboratory and measured with a field XRF unit; (a) all samples; (b) all samples with chromium below 300 mg/kg

Table B-1.0-1
Physical Characteristics of Post-1942
Geomorphic Units in the Sandia Canyon Investigation Reaches

Reach	Geomorphic Unit	Average Unit Width (m)[a]	Sediment Facies	Estimated Average Sediment Thickness (m)	Typical Median Particle Size Class (<2-mm fraction)	Notes
S-1N	c1	0.9	Fine	0.15	Coarse silt	Active channel
			Coarse	0.15	Coarse sand	
	c1br	0.9	n/a	0	n/a[b]	Active channel on bedrock
	c2	0.8	Fine	0.19	Fine sand	Abandoned post-1942 channel
			Coarse	0.13	Coarse sand	
	f1	0.3	Fine	0.02	Very fine sand[c]	Post-1942 floodplain
	Total	**2.9**				
S-1S	c1	1.8	Coarse	0.2	Coarse sand	Active channel
	c1br	0.1	n/a	0	n/a	Active channel on bedrock
	c2	1.9	Fine	0.28	Fine sand	Abandoned post-1942 channel
			Coarse	0.2	Medium sand	
	f1	0.3	Fine	0.25	Coarse silt	Post-1942 floodplain
			Coarse	0.01	Medium sand[c]	
	Total	**4.1**				
S-2W	c1	1.5	Coarse	0.4	Coarse sand[c]	Active channel
	c2	5.8	Fine	0.27	Fine sand	Abandoned post-1942 channel
			Coarse	0.49	Medium sand	
	Total	**7.4**				
S-2[d]	c1	1.3	Fine	1.4	Very fine sand[c]	Active channel
			Coarse	1.1	Coarse sand	
	c1br	0.02	n/a	0	n/a	Active channel on bedrock
	c1ct	13.3	Fine	1.3	Coarse silt	Active cattail wetland in area of active channel
			Coarse	1.2	Medium sand[c]	
	c2a	3.4	Fine	1.4	Very fine sand	Low abandoned inset post-1998 channel
			Coarse	1.1	Medium sand[c]	
	c2b	2.4	Fine	1.4	Very fine sand[c]	High abandoned inset pre-1998 channel
			Coarse	1.1	Medium sand[c]	
	c2cr	0.7	Fine	0.90	Coarse silt	Abandoned incised cattail wetland below headcut with high chromium concentrations
			Coarse	0.05	Medium sand[c]	
	c2ct	1.2	Fine	1.3	Coarse silt	Active cattail wetland in area of abandoned post-1942 channels
			Coarse	1.2	Medium sand[c]	
	c2w	0.4	Fine	1.3	Coarse silt[c]	Abandoned channels with willows
			Coarse	1.2	Medium sand[c]	

Table B-1.0-1 (continued)

Reach	Geomorphic Unit	Average Unit Width (m)[a]	Sediment Facies	Estimated Average Sediment Thickness (m)	Typical Median Particle Size Class (<2-mm fraction)	Notes
	c3	11.7	Fine	2.0	Very fine sand	High abandoned post-1942 channel
			Coarse	1.7	Merdium sand	
	f1	0.2	Fine	0.52	Coarse silt[c]	Post-1942 floodplain
			Coarse	0.04	Medium sand[c]	
	Total	**34.8**				
S-3W	c1	2.1	Coarse	0.2	Very coarse sand	Active channel
	c1br	0.2	n/a	0	n/a	Active channel on bedrock
	c2	1.5	Fine	0.37	Very fine sand	Abandoned post-1942 channel
			Coarse	0.2	Coarse sand	
	f1	0.4	Fine	0.26	Fine sand	Post-1942 floodplain
	f2	0.1	Fine	0.28	Fine sand	Possible post-1942 floodplain
	Total	**4.4**				
S-3E	c1	2.5	Coarse	0.5	Very coarse sand	Active channel
	c1br	0.3	n/a	0	n/a	Active channel on bedrock
	c2	1.2	Fine	0.43	Fine sand	Low abandoned post-1942 channel
			Coarse	0.4	Merdium sand	
	c3	0.5	Fine	0.49	Fine sand	High abandoned post-1942 channel
			Coarse	0.3	Coarse sand	
	f1	0.8	Fine	0.50	Very fine sand[c]	Post-1942 floodplain
			Coarse	0.07	Medium sand[c]	
	f2	0.8	Fine	0.56	Very fine sand[c]	Possible post-1942 floodplain
			Coarse	0.17	Medium sand[c]	
	Total	**6.1**				
S-4W	c1	2.7	Coarse	0.5	Coarse sand	Active channel
	c2	6.8	Fine	0.52	Very fine sand	Lowest abandoned post-1942 channel
			Coarse	0.5	Coarse sand	
	c3	1.7	Fine	0.34	Coarse silt	Intermediate abandoned post-1942 channel
			Coarse	0.2	Coarse sand[c]	
	c3a	0.1	Coarse	0.8	Coarse sand[c]	Intermediate abandoned post-1942 channel
	c4	1.3	Fine	0.50	Coarse silt	Highest abandoned post-1942 channel
			Coarse	0.1	Coarse sand[c]	
	Total	**12.7**				

Table B-1.0-1 (continued)

Reach	Geomorphic Unit	Average Unit Width (m)[a]	Sediment Facies	Estimated Average Sediment Thickness (m)	Typical Median Particle Size Class (<2-mm fraction)	Notes
S-4E	c1	4.6	Coarse	1.2	Coarse sand	Active channel
	c2	19.9	Fine	0.74	Very fine sand	Abandoned post-1942 channel
			Coarse	0.6	Coarse sand	
	f1	22.3	Fine	0.55	Coarse silt	Post-1942 floodplain
			Coarse	0.02	Medium sand[c]	
	f2	0.7	Fine	0.12	Coarse silt[c]	Possible post-1942 floodplain
	Total	**47.5**				
S-5C	c1	2.0	Fine	0.18		Active channel
			Coarse	0.9	Coarse sand	
	c2	9.0	Fine	0.48	Very fine sand	Low abandoned post-1942 channel
			Coarse	0.7	Coarse sand	
	c3	4.5	Fine	0.48	Coarse silt[c]	High abandoned post-1942 channel
			Coarse	0.5	Coarse sand	
	f1	34.5	Fine	0.22	Coarse silt	Post-1942 floodplain
			Coarse	0.03	Medium sand[c]	
	f1g	0.5	Fine	0.16	Coarse silt[c]	Gully in post-1942 floodplain
			Coarse	0.06	Medium sand[c]	
	f2	8.1	Fine	0.05	Coarse silt[c]	Possible post-1942 floodplain
	Total	**58.3**				
S-5E	c1	1.3	Fine	0.12	Fine sand[c]	Active channel
			Coarse	0.6	Coarse sand	
	c2	3.2	Fine	0.21	Very fine sand	Abandoned post-1942 channel
			Coarse	0.5	Coarse sand	
	f1	9.1	Fine	0.31	Very fine sand	Post-1942 floodplain
			Coarse	0.1	Coarse sand	
	f2	0.9	Fine	0.10	Very fine sand[c]	Possible post-1942 floodplain
			Coarse	0.03	Medium sand[c]	
	Total	**14.6**				
S-6W	c1	4.5	Coarse	0.12	Coarse sand	Active channel
	c1br	0.1	n/a	0	n/a	Active channel on bedrock
	c2	3.4	Fine	0.10	Very fine sand	Abandoned post-1942 channel
			Coarse	0.21	Coarse sand	
	f1	13.1	Fine	0.21	Fine sand	Post-1942 floodplain
			Coarse	0.03	Coarse sand	
	Total	**21.0**				

Table B-1.0-1 (continued)

Reach	Geomorphic Unit	Average Unit Width (m)[a]	Sediment Facies	Estimated Average Sediment Thickness (m)	Typical Median Particle Size Class (<2-mm fraction)	Notes
S-6E	c1	4.0	Coarse	0.2	Coarse sand	Active channel
	c2	2.1	Fine	0.08	Medium sand	Abandoned post-1942 channel
			Coarse	0.12	Coarse sand	
	f1	4.7	Fine	0.09	Fine sand	Post-1942 floodplain
			Coarse	0.05	Medium sand	
	f2	1.2	Fine	0.05	Fine sand	Possible post-1942 floodplain
	Total	**11.9**				

[a] Average unit width is total area of unit in reach divided by reach length.

[b] n/a = Not applicable.

[c] No particle size data from unit; median particle size inferred based on data from other units and field descriptions.

[d] Estimated relative thickness of coarse and fine facies in most geomorphic units in reach S-2 utilize particle size data from depth-integrated samples from auger holes; typical median particle size class is based on near-surface samples of discrete facies, and may not be representative of deeper sediment.

Table B-1.0-6
Dendrochronological Analyses from Sandia Canyon Investigation Reaches

Core ID	Reach	Channel Distance (m)	Geomorphic Unit	Depth of Burial (cm)	Stratigraphic Description Location	Location ID	Species	Date of Pith Ring
SAN-D01A	S-4W	50	c3? (f1?)	6	S4W-s8	SA-600781	Ponderosa pine	1980[a]
SAN-D01B								1980[a]
SAN-D01C								1980[a]
SAN-D02A	S-4W	110	c3	9	—[b]	—	Ponderosa pine	1981
SAN-D03E	S-4W	191	c4	5	S4W-s32	—	Ponderosa pine	1970[a]
SAN-D03F								1970[a]
SAN-D03I								1969
SAN-D03J								1969
SAN-D04A	S-3E	71	f1	9	S3E-s12	—	Ponderosa pine	1895[a]
SAN-D04B								[c]
SAN-D05C	S-4E	46	c2	70	S4E-s7	—	Ponderosa pine	1976[a]
SAN-D06B	S-4E	14	c2	85	S4E-s1	—	Ponderosa pine	1968

[a] Age estimated; pith not encountered and/or poor match with chronology.

[b] — = Not applicable.

[c] Core shows anomalous change to small rings after 1961, possibly recording the time of channel incision and surface abandonment at this location.

Table B-3.0-1
Characteristics of Sediment in Composite Samples from Small Mammal Trapping Arrays in Sandia Canyon

Trap Number	Geomorphic Unit	Thickness Fine Facies Sediment, Post-1942 (cm)	Thickness Coarse Facies Sediment, Post-1942 (cm)	Thickness Pre-1942 Sediment or Colluvium (cm)	Thickness Fill (cm)
Sample CASA-08-8827, Location ID SA-603200, Reach S-2					
32	c2a	0	15	0	0
44	c1ct	15	0	0	0
59	c2cr	15	0	0	0
68	c1ct	15	0	0	0
82	c2w	15	0	0	0
84	c1ct	15	0	0	0
88	c1ct	15	0	0	0
93	Qc	0	0	15	0
95	Qc	0	0	15	0
100	Qc	0	0	15	0
Average		**9.0**	**1.5**	**4.5**	**0**
Percent of Total		**60%**	**10%**	**30%**	**0%**
Sample CASA-08-8828, Location ID SA-603201, Reach S-4E					
13	c2	0	15	0	0
14	fill	0	0	0	15
51	c2	0	15	0	0
61	c2	1	2	12	0
63	c1	8	7	0	0
69	c2	8	7	0	0
70	c2	10	5	0	0
76	c2	0	15	0	0
86	Qc+Qt	0	0	15	0
99	fill	0	0	0	15
Average		**2.7**	**6.6**	**2.7**	**3.0**
Percent of Total		**18%**	**44%**	**18%**	**20%**
Sample CASA-08-8829, Location ID SA-603202, Reach S-5E					
17	Qt	0	0	15	0
27	c2	15	0	0	0
38	c2	10	5	0	0
44	f1	14	0	1	0
49	Qc	0	0	15	0
55	f1	15	0	0	0
61	Qc	0	0	15	0
63	Qc	0	0	15	0
76	Qc	0	0	15	0
80	Qc	0	0	15	0
Average		**5.4**	**0.5**	**9.1**	**0**
Percent of Total		**36%**	**3%**	**61%**	**0%**

Table B-3.0-2
Small Mammals from Sandia Canyon Submitted for Laboratory Analysis

Sample ID	Reach	Species	Number of Individuals in Sample	Weight (g)
CASA-08-11146	S-2	Brush mouse (PEBO)	6	119.5
CASA-08-11147	S-2	Deer mouse (PEMA)	18	248.5
CASA-08-11148	S-2	Long tailed vole (MILO)	6	168
CASA-08-11149	S-2	Montane vole (MIMO)	9	230.5
CASA-08-11150	S-2	Piñon mouse (PETR)	2	46.1
CASA-08-11151	S-2	Vagrant shrew (SOVA)	4	15
CASA-08-11152	S-4E	Deer mouse (PEMA)	37	537
CASA-08-11153	S-4E	Piñon mouse (PETR)	1	19.5
CASA-08-11154	S-4E	Western harvest mouse (REME)	74	611
CASA-08-11155	S-5E	Brush mouse (PEBO)	2	40.5
CASA-08-11156	S-5E	Deer mouse (PEMA)	6	80
CASA-08-11157	S-5E	Piñon mouse (PETR)	3	67
CASA-08-11158	S-5E	Western harvest mouse (REME)	2	11.5

Table B-3.0-3
Sediment Samples Collected for Sandia Canyon Biota Investigation

Sample ID	Reach	Location ID	Geomorphic Unit	Depth (cm)	Date Collected	Notes
CAPA-08-8853	PA-0	PA-603102	c1	0–15	11/28/2007	*Chironomous tentans* test from background area, for use with field water
CAPA-08-8854	PA-0	PA-603102	c1	0–15	11/28/2007	*Chironomous tentans* test from background area, for use with lab water
CAPA-08-8855	PA-0	PA-26500	f1	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8826	S-2	SA-603199	c1ct + c1	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8827	S-2	SA-603200	mixed	0–15	11/20/2007	Composite sample from small mammal trapping array
CASA-08-8828	S-4E	SA-603201	mixed	0–15	11/20/2007	Composite sample from small mammal trapping array
CASA-08-8829	S-5E	SA-603202	mixed	0–15	11/20/2007	Composite sample from small mammal trapping array
CASA-08-8830	S-2	SA-603199	c1ct + c1	0–25	11/27/2007	*Chironomous tentans* test; mixture of soil from two locations, for use with field water
CASA-08-8833	S-2	SA-600113	c1ct	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8834	S-2	SA-600115	c2cr	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8835	S-2	SA-600115	c2cr	30–60	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8836	S-3W	SA-600368	c2	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8837	S-3W	SA-600376	c2	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8838	S-4W	SA-600782	c2	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8839	S-4W	SA-600773	c2	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8840	S-5E	SA-600830	f1	0–30	11/20/2007	Earthworm toxicity test and seedling germination test
CASA-08-8841	S-2	SA-600113	c1ct	10–25	11/27/2007	*Chironomous tentans* test, for use with field water
CASA-08-8842	S-3W	SA-600374	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with field water
CASA-08-8843	S-3E	SA-600426	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with field water
CASA-08-8844	S-4E	SA-600785	c1	0–15	11/28/2007	*Chironomous tentans* test, for use with field water

Table B-3.0-3 (continued)

Sample ID	Reach	Location ID	Geomorphic Unit	Depth (cm)	Date Collected	Notes
CASA-08-8845	S-5E	SA-600821	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with field water
CASA-08-8846	S-2	SA-600907	c1ct	0–15	11/27/2007	*Chironomous tentans* test, for use with field water
CASA-08-8849	S-5E	SA-600830	f1	0–30	11/20/2007	QA duplicate from earthworm and seedling test location
CASA-08-8850	S-5E	SA-600821	c1	0–15	11/27/2007	QA duplicate from *Chironomous tentans* test location
CASA-08-8856	S-4E	SA-600785	c1	0–15	11/28/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8857	S-3W	SA-600374	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8858	S-5E	SA-600821	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8859	S-2	SA-600113	c1ct	10–25	11/27/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8860	S-2	SA-600907	c1ct	0–15	11/27/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8861	S-3E	SA-600426	c1	0–15	11/27/2007	*Chironomous tentans* test, for use with lab water
CASA-08-8862	S-2	SA-603199	c1ct + c1	0–15	11/27/2007	*Chironomous tentans* test; mixture of soil from two locations, for use with lab water

Table B-3.0-4
Surface Water Samples from Sandia Canyon Submitted for Laboratory Analysis

Sample ID	Reach	Location ID	Collection Date	Notes
CASA-08-8831	S-2	SA-603204	11/28/2007	Stream gage E123, east of wetland
CASA-08-8832	None	SA-603205	11/28/2007	Stream gage D123.8, between reaches S-3E and S-4W
CASA-08-8847	S-2	SA-0007	11/28/2007	West of wetland, near landfill bridge
CASA-08-8848	S-3E	SA-10005	11/28/2007	

Table B-3.0-5
Earthworm Samples from Sandia Canyon Biota Investigation

Sample ID	Reach	Collocated Sediment Sample ID	Location ID	Geomorphic Unit
CAPA-08-12047	PA-0	CAPA-08-8855	PA-26500	f1
CASA-08-12048	S-2	CASA-08-8833	SA-600113	c1ct
CASA-08-12049	S-2	CASA-08-8834	SA-600115	c2cr
CASA-08-12050	S-2	CASA-08-8835	SA-600115	c2cr
CASA-08-12051	n/a*	n/a	SA-603199	n/a
CASA-08-12052	S-2	CASA-08-8826	SA-603199	c1ct + c1
CASA-08-12053	S-3W	CASA-08-8836	SA-600368	c2
CASA-08-12054	S-3W	CASA-08-8837	SA-600376	c2
CASA-08-12055	S-4W	CASA-08-8838	SA-600782	c2
CASA-08-12056	S-4W	CASA-08-8839	SA-600773	c2
CASA-08-12057	S-5E	CASA-08-8840	SA-600830	f1

*n/a = Not applicable; laboratory control sample.

Table B-3.0-6
Egg and Insect Samples from Sandia Canyon Submitted for Laboratory Analysis

Sample ID	Location ID	Reach	Nest Box Number(s)	Date Collected	Notes
CASA-08-11630	SA-603365	S-2	328	1998	2 western bluebird (WEBL) eggs
CASA-08-11631	SA-603366	S-2	331	1998	2 western bluebird (WEBL) eggs
CASA-08-11632	SA-603367	S-2	330	2000	2 western bluebird (WEBL) eggs
CASA-08-11633	SA-603368	S-5E	566	7/11/2002	4 ash-throated flycatcher (ATFL) eggs
CASA-08-11634	SA-603369	S-2	732	7/14/2006	1 violet green swallow (VGSW) egg
CASA-08-11889	SA-603379	S-2	729	6/20/2006	1 western bluebird (WEBL) egg
CASA-08-11890	SA-603380	S-2	47, 48, 328	?	insects from nest boxes
CASA-08-11891	SA-603381	S-2	331, 335	?	insects from nest boxes

Appendix C

Analytical Data

C-1.0 ANALYTICAL RESULTS

All available data packages are included as Attachment C-1 on DVDs. Data related to Sandia Canyon are presented on DVD as Attachment C-2. Data obtained from the Sample Management Database (SMDB) and Water Quality Database (WQDB) are grouped by sediment and water. Data are further subdivided in Attachment C-2 into analytical data (those data used in analyses presented in this report), field quality control (QC) data, and rejected data. Data obtained from sources other than the SMDB and WQDB are included as Attachment C-3 on DVD.

C-1.1 SMDB and WQDB Data

The following files containing SMDB and WQDB data are included as Attachment C-2 on DVD:

- Sandia Canyon Sediment Analytical Data
- Sandia Canyon Sediment Field QC Data
- Sandia Canyon Sediment Rejected Data
- Sandia Canyon Water Analytical Data
- Sandia Canyon Water Field QC Data
- Sandia Canyon Water Rejected Data
- Sandia Canyon Biota Analytical Data
- Sandia Canyon Biota Field QC Data
- Sandia Canyon Chromium-53/52 Analytical Data

C-1.2 Data Obtained from Other Sources

Data obtained from sources other than the SMDB and WQDB and discussed in this report are included as Attachment C-3 on DVD.

- Water level, gage, precipitation, and temperature data: The water-level and gage data were taken from "Groundwater Level Status Report for 2008, Los Alamos National Laboratory" (Koch and Schmeer 2009, 105181). These data can also be found at http://newnet.lanl.gov/water/level.asp and http://newnet.lanl.gov/water/gage.asp. Precipitation data were obtained from the Los Alamos National Laboratory (LANL) Weather Machine, http://weather.lanl.gov from tower Technical Area 54.
- Hydrology, geochemistry, and geology regional well core leachate and moisture data: These data were provided by the Earth and Environmental Sciences (EES) Division at LANL.
- Bioassay data: Bioassay results include replicate test results for ryegrass and chironomids. The data were obtained from data packages for request numbers 08-259 and 08-264, which are included in Attachment C-1 on DVDs.
- Total uranium: The total inorganic uranium results were calculated from the reported isotopic uranium results (see section C-5.0).
- 2,3,7,8-Tetrachlorodibenzodioxin (2,3,7,8-TCDD) equivalent concentration (TEC) data: The mammalian TEC data were calculated using the toxic equivalency factors (TEFs) referenced in "The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency

Factors for Dioxins and Dioxin-Like Compounds" (Van den Berg et al. 2006, 106990) and the bird TEC data were calculated using the TEFs referenced in Van den Berg (1998, 106987). The mammalian and birds TEFs are presented in Table C-1.2-1.

C-2.0 SUMMARY OF SAMPLES COLLECTED

- Samples collected in Sandia Canyon and analyses performed by analytical laboratories are summarized in Tables C-2.0-1 (sediment), C-2.0-2 (water), and C-2.0-3 (biota) that are included in Attachment 1 on CD. Tables C-2.0-1, C-2.0-2, and C-2.0-3 include all of the sediment, water, and biota samples (respectively) collected. However, only the water data from samples collected in 2003 and later are used in the chemical of potential concern (COPC) screens because these data are most representative of current site conditions. Media code definitions are provided in Table C-2.0-4.

C-3.0 SAMPLE COLLECTION METHODS

Historical groundwater samples have been collected using a variety of sampling methods: automated pump sampler, bailer, bladder pump, direct container grab sampling, discharge pipe/faucet, gear-driven submersible pump, peristaltic pump, transfer device for grab samples, weighted bottle, or West Bay sampler. Historical stormwater samples have been collected using an automated pump sampler, direct container grab sampling, or single-stage samplers.

Current LANL standard operating procedures (SOPs) for water sampling methods are

- SOP-5213, Revision 0, Collecting Storm Water Runoff Samples and Inspecting Samplers;
- SOP-5224, Revision 0, Spring and Surface Water Sampling;
- SOP-5226, Revision 0, Groundwater Sampling Using Pressure Probes Using Westbay System; and
- SOP-5232, Revision 0, Groundwater Sampling.

Historical sediment samples have been collected using a spade and scoop. The current Laboratory SOP for this sediment sampling method is

- SOP-06.09, Revision 2, Spade and Scoop Method for Collection of Soil Samples.

C-4.0 ANALYTICAL PROGRAM

Data validation for data from the WQDB is performed by an outside contractor that validates the analytical data according to U.S. Environmental Protection Agency (EPA) protocols. All of the data from the analytical laboratories that provide Level IV data packages are validated. Level IV data packages are defined as those containing chain-of-custody forms, quality assurance (QA) and QC documentation, the analytical laboratory form 1 (a summary of the analytical results), and the raw analytical data. Data validation packages are included in Attachment C-1 on DVDs.

Data validation for data from the SMDB is also performed by the same outside contractor. Data validation procedures were implemented in accordance with the requirements of the Laboratory "Quality Assurance Project Plan Requirements for Sampling and Analysis" (LANL 1996, 054609) and the Laboratory's analytical services statements of work (SOWs) for contract laboratories (LANL 1995, 049738; LANL 2000,

071233). All data obtained from the SMDB included in this report have accompanying Level IV data packages and have undergone routine validation according to SOPs specific to the analyte type (inorganic chemicals, organic chemicals, or radionuclides). The current SOPs include the following (http://www.lanl.gov/environment/air/qa.shtml?1):

- SOP-5161, Revision 0, Routine Validation of Volatile Organic Data
- SOP-5162, Revision 0, Routine Validation of Semivolatile Organic Compound (SVOC) Analytical Data
- SOP-5163, Revision 0, Routine Validation of Organochlorine Pesticide and PCB Analytical Data
- SOP-5164, Revision 0, Routine Validation of High Explosive Analytical Data
- SOP-5165, Revision 0, Routine Validation of Metals Analytical Data
- SOP-5166, Revision 0, Routine Validation of Gamma Spectroscopy, Chemical Separation Alpha Spectrometry, Gas Proportional Counting, and Liquid Scintillation Analytical Data
- SOP-5167, Revision 0, Routine Validation of General Chemistry Analytical Data
- SOP-5169, Revision 0, Routine Validation of Dioxin Furan Analytical Data (EPA Method 1618 and SW-846 EPA Method 8290)
- SOP-5171, Revision 0, Routine Validation of Total Petroleum Hydrocarbons Gasoline Range Organics/Diesel Range Organics Analytical Data (Method 80151B)
- SOP-5191, Revision 0, Routine Validation of LC/MS/MS Perchlorate Analytical Data (SW-846 EPA Method 6850)

Some analytical results were rejected for various reasons and are not usable. In some instances, the analysis was rerun and a valid result was obtained and is presented in the report. However, some rejected data represent data issues; there is no valid result for the analyte for the given sample. Rejected results that represent data issues are provided in Attachment C-2 on DVD and are discussed in section C-9.0. Field duplicates are used for QC purposes and are not included in the summary tables in section 6. When duplicate analytical results for an analyte in the same sample resulting from two methods are available, the result obtained from the more sensitive method (i.e., lower detection limit) is presented in the summary tables in section 6 of the report. Reporting qualifiers are presented in parentheses next to the results in the summary tables. Data qualifier definitions are listed in Appendix A.

C-5.0 INORGANIC CHEMICAL ANALYSIS METHODS

The analytical methods used for inorganic chemicals are listed in Tables C-5.0-1 (sediment), C-5.0-2 (water), and C-5.0-3 (biota).

Laboratory control samples (LCSs), method blanks, matrix spike (MS) samples, and laboratory duplicate samples were analyzed to assess accuracy and precision of inorganic chemical analyses. Each of these QA/QC sample types is defined in the analytical services SOWs (LANL 1995, 049738; LANL 2000, 071233) and is described briefly below.

The LCS serves as a monitor of the overall performance of each step during the analysis, including sample digestion. The analytical results for the samples were qualified according to National Functional Guidelines (EPA 1994, 048639) if the individual LCS recovery indicated an unacceptable bias in the measurement of individual analytes. The LCS recoveries should fall into the control limits of 75%–125% (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

Method blanks are used as a measurement of bias and potential cross-contamination. All target analytes should be below the contract-required detection limit (CRDL) in the blank (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

The accuracy of inorganic chemical analyses is also assessed using MS samples. An MS sample is designed to provide information about the effect of each sample matrix on the sample preparation procedures and analytical technique. The spike sample recoveries should be within the acceptance range of 75%–125% (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

Analyzing laboratory duplicate samples assesses the precision of analyses. All relative percent differences (RPDs) between the sample and laboratory duplicate should be ±35% for sediment samples and ±20% for water samples (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258). Field duplicates were not assessed.

The validation of inorganic chemical data using QA/QC samples and other methods may result in the rejection of the data or the assignment of various qualifiers to individual sample results. Reporting qualifier definitions are presented in Appendix A.

Inorganic Chemical Background Values

It is important to note that the previously used analytical services SOW (LANL 1995, 049738) was issued before the widespread use of axial view inductively coupled plasma emission spectroscopy (ICPES) (also known as trace ICPES). With the advent of axial view ICPES, detection limits for inorganic chemicals have greatly improved. For example, antimony soil detection limits for the older radial view ICPES are typically on the order of 12 mg/kg, whereas axial view ICPES detection limits are as low as 0.5 mg/kg.

"Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (LANL 1998, 059730) was developed after axial view ICPES was widely used. However, since some of the samples were collected and analyzed before widespread axial view ICPES use, not all detection limits are below the background values (BVs). If inorganic chemical sample results with detection limits above the BVs were reported, they are presented in section 6, Table 6.2-1.

Calculated Total Uranium

Total inorganic uranium was calculated from isotopic uranium to compare with the uranium sediment BV and soil screening levels. The specific activity used to convert isotopic data to total uranium is presented in "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (LANL 1998, 059730).

C-6.0 ORGANIC CHEMICAL ANALYSIS METHODS

The analytical methods used for organic chemicals are listed in Tables C-6.0-1 (sediment), C-6.0-2 (water), and C-6.0-3 (biota).

QC samples are designed to produce a quantitative measure of the reliability of a specific part of an analytical procedure. The results of the QC samples provide confidence about whether the analyte is present and whether the concentration reported is correct. The validation of organic chemical data using QA/QC samples and other methods may result in rejecting the data or in assigning various qualifiers to individual sample results. Reporting qualifier definitions are listed in Appendix A.

Calibration verifications, instrument-performance checks, LCSs, method blanks, MS samples, surrogates, and internal standards (ISs) were analyzed to assess the accuracy and precision of the organic chemical analyses. Each of these QA/QC sample types is defined in the analytical services SOWs (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258) and is described briefly below.

Calibration verification, which consists of initial and continuing verification, is the establishment of a quantitative relationship between the response of the analytical procedure and the concentration of the target analyte. The initial calibration verifies the accuracy of the calibration curve and the individual calibration standards used to perform the calibration. The continuing calibration ensures that the initial calibration is still holding and is correct as the instrument is used to process samples. The continuing calibration also serves to determine whether analyte identification criteria, such as retention times and spectral matching, are being met.

The LCS is a sample of a known matrix that has been spiked with compounds representative of the target analytes, and it serves as a monitor of the overall performance of a "controlled" sample. Daily, the LCS is the primary demonstration of the ability to analyze samples with good qualitative and quantitative accuracy. The analytical results for the samples were qualified according to National Functional Guidelines (EPA 1999, 066649) if the individual LCS recoveries were not within method-specific acceptance criteria. The LCS recoveries should fall within the control limits of 75%–125% (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

A method blank is an analyte-free matrix to which all reagents are added in the same volumes or proportions as those used in the environmental sample processing and which is extracted and analyzed in the same manner as the corresponding environmental samples. Method blanks are used to assess the potential for sample contamination during extraction and analysis. All target analytes should be below the CRDL in the method blank (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

The accuracy of organic chemical analyses is also assessed by using MS samples that are aliquots of the submitted samples spiked with a known concentration of the target analyte(s). MS samples are used to measure the ability to recover prescribed analytes from a native sample matrix. Spiking typically occurs before sample preparation and analysis. The spike sample recoveries should be within the acceptance range of 75%–125% (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

A surrogate compound (surrogate) is an organic chemical compound used in the analyses of organic target analytes that is similar in composition and behavior to the target analytes but that is not normally found in environmental samples. Surrogates are added to every blank, sample, and spike to evaluate the efficiency with which analytes are recovered during extraction and analysis. The recovery percentage of the surrogates must be within specified ranges or the sample may be rejected or assigned a qualifier (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

The ISs are chemical compounds added to every blank, sample, and standard extract at a known concentration. They are used to compensate for (1) analyte concentration changes that might occur during storage of the extract and (2) quantitation variations that can occur during analysis. ISs are used as the basis for quantitation of target analytes. The percent recovery (%R) for ISs should range between 50% and 200% (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258).

C-7.0 RADIOCHEMICAL ANALYSIS METHODS

Radionuclides were analyzed by the methods listed in Tables C-7.0-1 (sediment) and C-7.0-2 (water).

Radionuclides with reported values less than the minimum detectable activity were qualified as not detected (U). Each radionuclide result was also compared with the corresponding total propagated uncertainty (TPU). If the result was less than 3 times the TPU, the radionuclide was qualified as not detected (U).

The precision and bias of radiochemical analyses performed at off-site fixed laboratories were assessed using MS samples, LCSs, method blanks, and laboratory tracers. The analytical services SOWs (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258) specify that spike sample recoveries should be within ±25% of the certified value. LCSs were analyzed to assess the accuracy of radionuclide analyses. The LCSs serve as a monitor of the overall performance of each step during the analysis, including the radiochemical separation preparation. The analytical services SOWs (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258) specify that LCS recoveries should be within ±25% of the certified value. Method blanks are also used to assess bias. The analytical services SOWs (LANL 1995, 049738; LANL 2000, 071233; LANL 2007, 095258) specify that the method blank concentration should not exceed the required minimum detectable activity.

C-8.0 OTHER ANALYSIS METHODS

Other analyses conducted on Sandia Canyon sediment include pH; *Chironomus tentans* growth rate and survival rate; *Eisenia fetida* percent survival rate, starting weight, and ending weight; and total organic carbon. These analyses were conducted by the methods listed in Table C-8.0-1. Other analyses in Sandia Canyon water samples include carbon-14 % modern carbon, de-normalized; carbon-14 % modern carbon, normalized; carbon-14 years unadjusted, based on denormalized fraction; delta C-13 relative to Pee Dee Belemnite; deuterium ratio; dissolved organic carbon; nitrogen-15/nitrogen-14 ratio; oxygen-18/oxygen-16 ratio; pH; purge volume; specific conductance; specific gravity; total dissolved solids; total organic carbon; total suspended solids; and visual inspection. These analyses were conducted by the methods listed in Table C-8.0-2.

C-9.0 DATA QUALITY

Data-quality issues, including rejected analytical results, are summarized by media. Because of the large number of records that were qualified, the following sections provide a summary of the reasons for qualification, and the qualification is not addressed by individual records.

C-9.1 Sediment Data

A total of 31,335 results from sediment samples in Sandia Canyon reaches were reported. Of these results, 282 results were rejected during data validation. These rejected results represent less than 1% of all the sediment results and do not affect the ability to assess the contaminants within Sandia Canyon.

A total of 183 inorganic chemical results were rejected (R) because either the sample spike recovery was less than 30%, the associated matrix spike recovery was less than 10%, or the analytical holding time was exceeded. A total of 62 radionuclide results for samples analyzed by gamma spectroscopy were rejected (R) for cesium-134, cesium-137, cobalt-60, and ruthenium-106 because spectral interference prevented positive identification of the analytes. A total of 37 organic chemical results were rejected (R) for Aroclors, benzidine, carbazole, di-n-octylphalate, 3-nitroaniline, and polychlorinated biphenyls (PCBs) because the mass spectrometer performance was not evaluated at the required frequency or method criteria were not met; the surrogate is less 10%R, which indicates the potential for a severely low bias in the results; the associated IS area counts show less than 10%R when compared to the area counts in the

applicable continuing calibration standard; or the associated analyte did not have a valid 5-point calibration and/or a standard at the RL.

Hexavalent chromium results were rejected for 43 out of 162 samples. All 10 samples had rejected hexavalent chromium results in reach S-5C. Three other reaches (S-3W, S-4W, and S-6E) had rejected hexavalent chromium results in at least half of the samples collected in each reach. There is no BV for this analyte; however, it was detected in other samples and was presented in the screening in section 6 for further evaluation. Antimony results were rejected for 64 out of 222 samples. Valid results were reported in all reaches except reach S-2W, where all three samples had rejected antimony results. Antimony has a BV of 0.83 mg/kg and all reported detected results for antimony were below this BV. Cesium-134 results were rejected in some samples from multiple reaches. All 10 sample results for cesium-134 were rejected in reach S-4W. There were no detected cesium-134 results reported and cesium-134 does not have a BV, so cesium-134 was not evaluated further. Cesium-137 results were rejected in 17 out of 108 samples. Some cesium-137 results were detected above BV, so cesium-137 was further evaluated in Section 6. Results that were rejected for organic chemicals were in reaches where there was sufficient valid data with the exception of benzidine. Benzidine was analyzed in 15 samples from reaches S-3E and S-5C. All but one result were rejected and the valid result was a nondetect. These rejected sediment data do not affect the conclusions of the report.

A total of 1772 inorganic chemical results were qualified as estimated (J, J-, or J+), or estimated, not detected (UJ).

All inorganic chemical results detected between the method detection limit (MDL) and the estimated detection limit (EDL) are qualified as estimated (J).

All inorganic chemical results that were qualified as J, J-, J+, or UJ were because of one of the following.

- The sample and the duplicate sample results were greater than or equal to 5 times the reporting limit (RL) and the duplicate RPD >35% for soil samples.
- Both the sample and duplicate sample results were greater than or equal to 5 times the RL and the duplicate RPD was greater than 35% for soil samples.
- Either the sample or duplicate sample results or both were greater than or equal to 5 times the RL, and the difference between the samples is r greater than 2 times the RL for soil samples.
- The associated initial calibration verification (ICV) or continuous calibration verification (CCV) was recovered below the lower warning limit but is greater than the lower acceptable limit (LAL).
- The associated ICV or CCV was recovered below the lower warning limit but is greater than the LAL.
- The serial dilution sample RPD was greater than 10% and the sample result was greater than 50 times the MDL (greater than 100 times the MDL for ICPMS).
- The validator identified quality deficiencies in the reported data that require qualification.
- The sample volume was insufficient for an MS to be analyzed on a LANL sample.
- The MS was analyzed on a non-LANL sample.
- The analyte was recovered above 150% in the associated spike sample.
- The analyte was recovered above the upper acceptance level (UAL) but less than 150% of the associated spike sample.

- The analyte was recovered below the LAL but greater than 30% in the associated spike sample.
- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.
- The associated matrix spike recovery was less than the LAL but greater than 10%.
- The associated LCS was recovered above the upper warning limit.
- The associated matrix spike recovery was less than the LAL but greater than 10%.
- The associated matrix spike recovery was greater than the UAL.
- The ICV and/or CCV were recovered outside the method specific limits.
- The ICV and/or CCV were not analyzed at the appropriate method frequency.
- The result was reported as estimated by the laboratory.
- A total of 2029 organic chemical results were qualified as estimated—either detected (J, J+, or J-) or not detected (UJ).

Volatile Organic Compounds (VOCs): VOC results were qualified as J, J+, or UJ because of one of the following.

- The result was reported as estimated by the laboratory.
- The LCS %R was less than the LAL but greater than 10%.
- The associated LCS recovery was less than the LAL but greater than 10%.
- The associated IS area counts are less than 50% but greater than 10% of the previous continuing calibration standard.
- The IS area count for the quantitating IS is less than 50% but greater than 10% for organics window relation to the previous continuing calibration.
- The sample surrogate recovery was greater than the UAL.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The associated %RSD/%D exceeded criteria in the initial or continuing calibration standards.
- The ICV and/or CCV were recovered outside the method-specific limits.

Semivolatile Organic Compounds (SVOCs): SVOC results were qualified as J, J-, or UJ because of one of the following.

- The result was reported as estimated by the laboratory.
- The associated LCS recovery was less than the LAL but greater than 10%R.
- The associated IS area counts are less than 50% but greater than 10%R when compared to the area counts in the applicable continuing calibration standard.
- The IS area count for the quantitating IS is less than 50% but greater than 10% for organics window relation to the previous continuing calibration.
- The surrogate is less than the LAL but greater than 10%R, which indicates the potential for a low bias in the results.

- The associated sample concentration was greater than 5 or 10 times the amount in the method blank.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The associated %RSD/%D exceeded the criteria in the initial or continuing calibration standards.
- The ICV and/or CCV were recovered outside the method-specific limits.

Pesticides and PCBs: Pesticide and PCB results were qualified as J, J-, or UJ because of at least one of the following issues.

- The result was reported as estimated by the laboratory.
- The surrogate is less than 10%R, which indicates the potential for a severely low bias in the results.
- The associated surrogate was recovered below the LAL but greater than or equal to 10%R.
- The surrogate is less than the LAL but greater than 10%R, which indicates the potential for a low bias in the results.
- The associated surrogate was recovered at less than 10%R.
- The associated surrogate was recovered below the LAL but greater than or equal to 10%R.
- The associated sample concentration was greater than 5 times the amount in the method blank.
- The affected results were not analyzed with a valid 5-point calibration curve and/or a standard at the RL.
- The associated %RSD or %D exceeded criteria in the initial or continuing calibration standards.
- The ICV and/or CCV were recovered outside the method-specific limits.

Polycyclic Aromatic Hydrocarbons (PAHs): PAH results were qualified as J, J-, or UJ because either the associated LCS recovery was less than the LAL but greater than 10%R, the affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is <0.995, the extraction holding time was exceeded by less than 2 times the published method for holding time, or the result was reported as estimated by the laboratory.

Explosive Compounds: Explosive compound results were qualified as UJ because the associated %RSD/%D exceeded the criteria in the initial or continuing calibration standards.

Methyl Mercury: Methyl mercury results were qualified as J- because the associated matrix spike recovery was less than the LAL but greater than 10%.

Total Petroleum Hydrocarbons (TPH): TPH results were qualified as J, J-, or UJ because of one of the following.

- The MS/ matrix spike duplicate (MSD) %R was greater than or equal to 10% but less than 70%.
- The surrogate is less than the LAL but greater than or equal to 10%R, which indicates the potential for a low bias in the results.
- The result was reported as estimated by the laboratory.

- The associated sample concentration was greater than 5 times or 10 times the amount in the method blank.
- Forty radionuclide results were qualified as J-, J+, or UJ because the associated tracer recovery was less than 30% but greater than 10%, the tracer is less than the LAL but greater than 10%R, or the tracer %R value is greater than the UAL.

C-9.2 Water Data

A total of 121,503 results from water samples collected in Sandia Canyon were reported. The results from these samples are provided on the DVD in Attachment C-2. Of the 121,503 results reported, 1997 results were rejected during data validation. These rejected results represent less than 1% of the water sample results discussed here and do not affect the ability to assess the contaminants within Sandia Canyon.

The rejected water results were from a variety of analytes and locations. For every combination of rejected analyte and location, there were valid results for the same analyte at the same location. Therefore, the rejected water data do not affect the conclusions of the report.

Four sample results for nitrate-nitrite as nitrogen were excluded from the COPC identification and any subsequent analyses because of incorrect preservation of the samples which resulted in anomalous results.

A total of 197 inorganic chemical results were rejected (R) because of the following conditions.

- The RPD is greater than 10% in the serial dilution sample.
- The LANL project chemist identified quality deficiencies in the reported data that require further qualification.
- The associated matrix spike recovery was less than 10%.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The analytical holding time was exceeded.
- Negative blank samples results were greater than the MDL.
- A nonspecified QC failure occurred.

A total of 1712 organic chemical results were rejected (R).

VOCs: VOC results were rejected (R) because of the following conditions.

- The affected analytes were analyzed with a RRF of less than 0.05 in the initial calibration and/or CCV.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The spike %R value is less than 10%, which increases the potential for false negatives being reported. This could be caused by analytical interferences.
- A nonspecified QC failure occurred.
- The sample was improperly preserved.

- Calibration verification percent difference (%D) was greater than the acceptance criteria but less than 60%.

SVOCs: SVOC results were rejected (R) because of at least one of the following reasons.

- The LCS %R was less than 10%.
- The LCS %R was less than the LAL but greater than 10%.
- The surrogate is less than 10%R.
- The affected results were not analyzed with a valid 5 point calibration curve and/or a standard at the RL.
- The affected analytes were analyzed with a RRF of less than 0.05 in the ICV and/CCV.
- The relative percent difference of the MS/MSD is greater than the acceptance criteria.
- The calibration verification %D exceeded 60%.
- The LCS recovery was greater than the acceptance criteria.
- The spike percent recovery value is less than 10%, which increases the potential for false negatives being reported. This could be caused by analytical interferences.
- A nonspecified QC failure occurred.

PCBs: PCB results were rejected (R) because of at least one of the following reasons.

- The LANL project chemist identified quality deficiencies in the reported data that requires further qualification.
- The surrogate is <10%R.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The calibration verification %D exceeded acceptance criteria but was less than 60%.
- A nonspecified QC failure occurred.

Explosive Compounds: Explosive compound results were rejected (R) because of one of the following.

- The LCS percent recovery was less than the LAL but greater than 10%.
- The affected analytes were analyzed with a RRF of less than 0.05 in the initial calibration and/or CCV.
- A nonspecified QC failure occurred.
- The initial calibration y-intercept criteria were not met.
- The LCS %R failed low.
- *Dioxin/furans:* Dioxin/furan results were rejected (R) because a nonspecified QC failure occurred.
- Eighty-seven radionuclide results were rejected (R) because of at least one of the following issues.
- There was spectral interference in the gamma spectrum.
- The minimum detectable concentration (MDC) and/or TPU documentation is missing.

- Spectral interferences prevent positive identification of the analytes.
- The relative error ratio (RER) was greater than 4.
- A nonspecified QC failure occurred.

A total of 4711 inorganic chemical results were qualified as J, J-, J+ or UJ because of at least one of the following reasons.

- The sample result was reported as detected between the instrument detection limit (IDL) and the EDL.
- The duplicate sample RPD is greater than the advisory limit, and the sample result is a detect.
- The sample and the duplicate sample results were less than or equal to 5 times the RL and the duplicate RPD was less than 20% for water samples.
- The duplicate-sample analysis was not performed on a sample associated with this request number.
- The MS analysis was not performed on a sample associated with this request number.
- A CCV was not reported for this sample.
- The RPD is greater than 10% in the serial dilution sample.
- The affected analytes should be regarded as estimated because the ICV/CCV recovered low.
- Serial dilution sample RPD was greater than 10%, and the sample result was greater than 50 times the MDL (greater than 100 times the MDL for ICPMS).
- The spike %R value is greater than or equal to the UAL (125%) but less than or equal to 150% and the result is a detect, which indicates a potential high bias in the sample results.
- The spike %R value is greater than 30% and less than the LAL (75%), and the sample result is a detect, which indicates a potential low bias in the results.
- The spike %R value is less than 30%, and the result is a nondetect, which increases the potential for false negatives being reported. This could be caused by analytical interferences.
- The spike %R value is greater than 30% and less than the lower acceptance limit (75%), and the sample result is a nondetect, which indicates a potential for false negatives being reported.
- The spike %R value is less than 30% and the sample result is a detect, which indicates a potential low bias.
- The sample result is detected and the spike %R value is greater than 150%, which indicates a potential high bias in the sample result.
- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.
- The associated MS recovery was less than 10%.
- The associated MS recovery was below the LAL but greater than 10%.
- The associated MS recovery was above the UAL.
- The ICS %R value is greater than or equal to 50% and less than 80% and the result is a detect, which indicates a potential for a low bias.
- The ICV and/or CCV were recovered outside the method specific limits.

- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The sample temperature was elevated.
- Negative blank samples results were greater than the MDL.
- Sample should have been preserved by acidification, but was not.
- Sample should not have been acidified but was.
- A nonspecified QC failure occurred.
- Reporting limit verification recovery was greater than the acceptance criteria.
- The analytical laboratory qualified the detected result as estimated (J) because the result was less than the practical quantitation limit (PQL) but greater than the MDL.
- The CCV %D failed low.
- The holding time is exceeded for sample analysis.
- The holding time is exceeded for sample extraction.
- The initial calibration slope or radio frequency (RF) criteria were not met.
- Chorine isotope ratio criteria not met.
- An applicable MS/MSD analysis was not performed.
- The MS/MSD %R failed high.
- The MS/MSD %R failed low.
- There is no measure of precision for the sample (i.e., no replicate, MSD or LCS duplicate was performed).
- A nonspecified QC failure occurred.
- The MS/MSD %R was greater than 10% but less than 75%.
- The MS/MSD %R was less than 125%.
- The interference check sample (ICS) was not within ±20% of the known value.

A total of 8758 organic chemical results were qualified as J, J-, or J+ or UJ.

VOCs: VOC results were qualified as J or UJ because of at least one of the following.

- The result was less the PQL but greater than the MDL.
- The MS and/or the MSD analysis was not performed on a sample associated with a LANL request number.
- The sample result is less than or equal to 5 times (10 times for acetone, methylene chloride, and 2-butanone) the concentration of the related analyte in the method blank, which indicates the reported detection is considered indistinguishable from contamination in the blank.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The affected analytes were analyzed with a relative response factor (RRF) of less than 0.05 in the initial calibration and/or CCV.

- The ICV and or CCV recovered outside the method specific criteria.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The result was less than the EQL but greater than the MDL.
- Relative percent difference of the MS/MSD is greater than the acceptance criteria.
- The LCS recovery was greater than the acceptance criteria.
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.
- A nonspecified QC failure occurred.
- Calibration % RSD was greater than the acceptance criteria but less than 60%.
- Calibration verification %D was greater than the acceptance criteria but less than 60%.
- The LCS %R was less than the LAL but greater than 10%.

SVOCs: SVOC results were qualified as J, J-, J+ or UJ because of at least one of the following.

- The result was less the PQL but greater than the MDL.
- The result was less than the EQL but greater than the MDL.
- The IS area count for the quantitating IS is outside the -50% to +100% window in relation to the previous continuing calibration, which could affect the quantitation accuracy of the associated analytes and the correct quantitation of surrogate %R values.
- The LCS percent recovery was less than the LAL but greater than 10%.
- The LCS percent recovery was less than the LAL but greater than 10%, and the result is detected.
- Required calibration information is missing or samples were analyzed on an expired calibration.
- The surrogate is less than the LAL but greater than or equal to10%R.
- Two or more surrogates are greater than or equal to 10%R but less than the LAL, which indicates increased potential for false negative results.
- The sample result is greater than the EQL and less than or equal to 5 times (10 times for common phthalates) the concentration of the related analyte in the blank, which indicates the reported detection is considered indistinguishable from contamination in the blank.
- The affected analytes are considered estimated and biased high because this analyte was identified in the method blank but was greater than 5 times (10 times for common laboratory contaminates).
- The affected results were not analyzed with a valid 5-point calibration curve and/or a standard at the RL.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The affected analytes were analyzed with a RRF of less than 0.05 in the ICV or CCV.
- The ICV/CCV was recovered outside the method specific limits.
- The ICV/CCV was not analyzed at the appropriate method frequency.

- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The RPD of the MS/MSD is greater than the acceptance criteria.
- The LCS recovery was greater than the acceptance criteria
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.
- A nonspecified QC failure occurred.
- Calibration % RSD was greater than the acceptance criteria but less than 60%.
- Calibration verification %D was greater than the acceptance criteria but less than 60%.

Pesticides and PCBs: Pesticide and PCB results were qualified as J, J-, J+, and UJ because of at least one of the following.

- The result was less the PQL but greater than the MDL.
- The LCS percent recovery was less than 10%.
- The LCS percent recovery was less than the LAL but greater than 10%.
- The LCS percent recovery was greater than the UAL.
- Insufficient sample volume was received for an MS/MSD analysis.
- The MS/MSD analysis were not performed on a sample associated with a LANL request number.
- The surrogate is less than the LAL but greater than or equal to 10%R.
- The result is less than the EQL and the surrogate %R value is greater than10 % but less than the LAL, which indicates a potential for false negative results being reported.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The ICV and/or CCV were recovered outside the method specific limits.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- No MS/MSD data were included in the data package.
- Calibration verification %D exceeded acceptance criteria but was less than 60%.
- Relative percent difference of the MS/MSD is greater than the acceptance criteria.
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.
- A nonspecified QC failure occurred.
- The result is a nondetect and the LCS analyte is greater than 10%R but less than the LAL, which indicates the potential for false negative results.
- The LCS analyte %R value is greater than the UAL, which indicates the potential for high bias in the results and for false positive results.

- The sample result is a detect but less than 5 times the concentration of the related analyte in the blank, which indicates that the reported detection is considered indistinguishable from blank contamination.
- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.
- The spike %R value is greater than or equal to the UAL, and the result is a detect, which indicates a potential high bias in the sample results.

Explosive Compounds: Explosive compound results were qualified as J, J-, J+ or UJ because of at least one of the following.

- Insufficient sample volume was received for a MS/MSD analysis.
- The MS/MSD analyses were not performed on a sample associated with a LANL request number.
- The MS/MSD were analyzed on a sample associated with a different LANL request number but no summary was included.
- The surrogate %R is less than the LAL but greater than or equal to 10%R.
- The sample result is greater than the EQL and less than 5 times the concentration of the related analyte in the blank, which indicates that the reported detection is considered indistinguishable from blank contamination.
- The of the LCS analyte percent recovery is less than the LAL and greater than or equal to 10%R, which indicates (1) the RL is approximate and probably biased low for nondetected results, and (2) that detected results likely are biased low.
- The ICV and/or CCV were recovered outside the method limits.
- The holding time is exceeded.
- The MS/MSD percent recovery was greater than 10% but less than 70%.
- The MS/MSD relative percent difference was greater than 30%.
- The Contract Required Detection Limit Check Standard (CRI) sample did not pass method acceptance criteria.
- The IS area count for the quantitating IS is greater than 130% of the average of that obtained from the calibration standards.
- The affected analytes were analyzed with a RRF of less 0.05 in the initial calibration and/or CCV.
- The ICV and/or CCV were recovered outside the method limits.
- The result was less than the EQL but greater than the MDL.
- The RPD of the MS/MSD is greater than the acceptance criteria.
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.
- A nonspecified QC failure occurred.
- Calibration verification %D exceeded acceptance criteria but was less than 60%.
- The result was less the PQL but greater than the MDL.
- The CCV %D failed low.

- The CRI recovery failed high.
- The CRI recovery failed low.
- The holding time is exceeded for sample analysis.
- Required calibration information is missing or samples were analyzed on an expired calibration. Data may not be acceptable for use.
- The initial calibration slope or RF criteria were not met.
- The IS area count failed high.
- The ICV %D failed low.
- The LCS %R failed low.
- The LCS %Rs failed both high and low, or the LCS/LSCD RPD failed to meet criteria.
- An applicable MS/MSD analysis was not performed.
- The MS/MSD %R failed low.
- The RPD of the MS/MSD is greater than the acceptance criteria or the recoveries fail both high and low.
- The surrogate failed high.
- The surrogate failed low.
- The surrogate %R in the blank did not meet acceptance criteria.
- A nonspecified QC failure occurred.

Dioxins and Furans: Dioxin and furan results were qualified as UJ because of at least one of the following.

- A nonspecified QC failure occurred.
- The result was less the PQL but greater than the MDL.
- The sample result is greater than the EQL and less than or equal to 5 times (10 times for common phthalates) the concentration of the related analyte in the blank, which indicates the reported detection is considered indistinguishable from contamination in the blank.

Herbicides: Herbicide results were qualified as UJ because of at least one of the following.

- The LCS percent recovery was greater than the UAL.
- The MS/MSD analysis were not performed on a sample associated with a LANL request number.
- The affected analytes were analyzed with an initial calibration curve that exceeded the %RSD criteria and/or the associated multipoint calibration correlation coefficient is less than 0.995.
- The ICV and/or CCV were recovered outside the method specific limits.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.

TPH: TPH results were qualified as UJ because of at least one of the following.

- The MS/MSD %R was greater than or equal to 10% but less than 70%.
- The ICV and/or CCV were recovered outside the method specific limits.
- The result was less the PQL but greater than the MDL.
- The RPD of the MS/MSD is greater than the acceptance criteria.
- The spike %R value is greater than 10% and less than the LAL, which indicates a potential low bias in the results.
- A nonspecified QC failure occurred.
- The spike %R value is greater than or equal to the upper acceptance limit and the result is a detect, which indicates a potential high bias in the sample results.
- The sample result is greater than the EQL and less than or equal to 5 times (10 times for common phthalates) the concentration of the related analyte in the blank, which indicates the reported detection is considered indistinguishable from contamination in the blank.

A total of 700 radionuclide results were qualified as J, J-, J+, or UJ because of at least one of the following.

- Associated duplicate sample has DER or RER greater than the analytical laboratory's acceptance limits.
- The duplicate sample was not prepared and/or analyzed with the samples for unspecified reasons. The duplicate information is missing.
- The MS analysis was not performed on a sample associated with this request number.
- The tracer %R value is 10% to 30% inclusive and the sample result is greater than the minimum detectable activity.
- The tracer %R value is 10% to 30% inclusive and the sample result is less than the minimum detectable activity.
- The matrix spike %R value is greater than the upper limit, and the sample result is greater than the minimum detectable activity.
- The tracer is greater than the LAL but less than or equal to the 10%R.
- The tracer %R value is greater than the UAL.
- The matrix spike %R value is less than the lower limit and the sample result is less than the MDA.
- The sample result is less than or equal to 5 times the concentration of the related analyte in the method blank.
- Analyte is not detected because the amount reported is less than the MDC.
- Recovery of the analyte in the LCS is greater than the upper limit, and the analyte result is greater than the MDA.
- Recovery of analyte in the LCS is less than the lower limit, and the analyte is greater than the MDA in the sample.
- The associated MS recovery was less than the LAL but greater than 10%.

- The results for the affected analytes are qualified as estimated and biased low because the associated LCS was less than the LAL but greater than 10%, and the results are detected.
- The duplicate information is missing. Data may not be acceptable for use.
- The duplicate and sample results have a DER that is greater than 2.0.
- Planchets were flamed.
- Result values are less than 3 times the MDC.
- The tracer %R value is greater than 105% but less than 125%.
- A nonspecified QC failure occurred.

A total of 670 other results were qualified as J, J+, or J- because of at least one of the following.

- The duplicate sample RPD is greater than the advisory limit.
- The sample and the duplicate sample results were less than 5 times the RL and the duplicate RPD was greater than 20% for water samples.
- The duplicate-sample analysis was not performed on a sample associated with this request number.
- The MS analysis was not performed on a sample associated with this request number.
- The spike %R value is greater than or equal to the upper acceptance limit (125%) but less than or equal to 150% and the result is a detect, which indicates a potential high bias in the sample results.
- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.
- The holding time was greater than 1 and less than or equal to 2 times the applicable holding time requirement.
- The affected analytes should be regarded as estimated because the extraction holding time was exceeded by 2 times the acceptable holding time.
- A nonspecified QC failure occurred.
- The result was less the PQL but greater than the MDL.

C-9.2 Biota Data

Biota samples were collected in Sandia Canyon. A total of 1380 results from biota samples in this canyon were reported. Biota samples include eggs, insects, worms, whole body mammal, cattail leaves, and cattail roots. There were no results rejected during data validation.

C-9.2-1 Eggs

A total of 103 inorganic chemical results were qualified either J or UJ because of one of the following reasons.

- The duplicate sample was not prepared and/or analyzed with the samples for unspecified reasons. The duplicate information is missing.
- Serial dilution sample was not analyzed with the samples.

- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.

C-9.2-2 Insects

Thirty-seven inorganic chemical results were qualified either J or UJ because the serial dilution sample was not analyzed with the samples.

C-9.2-3 Worms

Twenty-eight inorganic chemical results were qualified J due to one of the following reasons.

- The sample result was reported as detected between the IDL and the EDL.
- The analyte was considered estimated because the results are greater than 5 times the amount in the method blank.

C-9.2-4 Whole Body Mammal

No inorganic chemical results were qualified as estimated; however, 13 organic chemical results were qualified J by the analytical laboratory.

C-9.2-5 Cattail Leaves

Eighty-seven inorganic chemical results were qualified J because the project chemist identified quality deficiencies in the reported data that require further qualification.

C-9.2-6 Cattail Roots

Ninety inorganic chemical results were qualified J because the project chemist identified quality deficiencies in the reported data that require further qualification.

C-10.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Table C-1.2-1
TEFs

PCB Congener	Mammal TEF[a]	Bird TEF[b]
PCB-77	0.0001	0.05
PCB-81	0.0003	0.1
PCB-105	0.00003	0.0001
PCB-106/118[c]	0.00003	0.00001
PCB-114	0.00003	0.0001
PCB-123	0.00003	0.00001
PCB-126	0.1	0.1
PCB-156	0.00003	0.0001
PCB-157	0.00003	0.0001
PCB-167	0.00003	0.00001
PCB-169	0.03	0.001
PCB-189	0.00003	0.00001

[a] TEF values are from Van den Berg et al. (2006, 106990).

[b] TEF values are from Van den Berg et al. (1998, 106987).

[c] Coeluting congeners; PCB 118 is the toxic congener; PCB 106 has no TEF.

Table C-2.0-4
Media Code Definitions

Media Code	Media Description
SED	Sediment
W	Water
WGA	Alluvial groundwater
WGI	Intermediate groundwater
WGR	Regional groundwater
WGS	Springs
WM	Snowmelt
WP	Water, precipitation
WS	Surface water
WT	Stormwater

Table C-5.0-1
Analytical Methods Used for Inorganic Chemicals in Sediment

Analyte Suite	Analytical Method
ANION	EPA:300.0
HEXAVALENT_CHROMIUM	SW-846:7196A
METALS	SW-846:6010
	SW-846:6010B
	SW-846:6020
	SW-846:7471 (Hg)
	SW-846:7471A (Hg)
	SW-846:7740 (Se)
	SW-846:7841 (Tl)
PERCHLORATE	SW-846:6850
WET_CHEMISTRY	EPA:365.4 (Phosphate)
	SW-846:9010 (Cyanide)
	SW-846:9012A (Cyanide)
	SW-846:9031 (Sulfide)

Table C-5.0-2
Analytical Methods
Used for Inorganic Chemicals in Water

Analyte Suite	Analytical Method
GENINORG	Acolr
	Color
	EPA:160.2
	EPA:160.4
	EPA:200.7
	EPA:200.8
	EPA:300.0
	EPA:310.1
	EPA:310.2
	EPA:314.0
	EPA:320.1
	EPA:325.1
	EPA:330.5
	EPA:335.1
	EPA:335.2
	EPA:335.3
	EPA:335.4
	EPA:340.1
	EPA:340.2
	EPA:350.1
	EPA:350.3
	EPA:351.2
	EPA:353.1
	EPA:353.2
	EPA:353.3
	EPA:365.1
	EPA:365.2
	EPA:365.4
	EPA:375.4
	EPA:410.4
	FIA
	Field
	Hardness
	IC
	ICPES
	SM:A2320B
	SM:A2340B

Table C-5.0-2 (continued)

Analyte Suite	Analytical Method
	SW846 6850
	SW-846:6010
	SW-846:6010B
	SW-846:6850
	SW-846:7470A
	SW-846:8321
	SW-846:9010
	SW-846:9012A
	SW-846:9056
	Titr
	USGS-WRI-79-4
HEXAVALENT_CHROMIUM	SW-846:7196A
METALS	ASTM
	CVAA
	EPA:200.7
	EPA:200.8
	EPA:200.9
	EPA:245.1
	EPA:245.2
	ETVAA
	FIA
	Field
	ICPES
	ICPMS
	SW-846:6010
	SW-846:6010B
	SW-846:6020
	SW-846:7196A
	SW-846:7199
	SW-846:7470
	SW-846:7470A
PERCHLORATE	SW-846:6850

Table C-5.0-3
Analytical Methods for
Inorganic Chemicals in Biota samples

Analytical Suite	Analytical Method
HEXAVALENT_CHROMIUM	SW-846:7196A
METALS	SW-846:6010B
	SW-846:6020
	SW-846:7471A
PERCHLORATE	SW-846:6850

Table C-6.0-1
Analytical Methods for Organic Chemicals in Sediment

Analytical Suite	Analytical Method
High Explosive Compounds	SW-846:8321A_MOD
Methyl mercury	EPA:1630
PAHs	SW-846:8310
PCBs	SW-846:8082
	EPA:1668A
Pesticides	SW-846:8081A
	SW-846:8081
SVOCs	SW-846:8270
	SW-846:8270C
Total Petroleum Hydrocarbons, Diesel Range Organics, Gasoline Range Organics	SW-846:8015M extractable
VOCs	SW-846:8260B

Table C-6.0-2
Analytical Methods
for Organic Chemicals in Water

Analyte Suite	Analytical Method
DIOXIN_FURAN	SW-846:8290
DRO	SW-846:8015
HERB	SW-846:8151A
HEXP	Hexp
	SW-846:8321
	SW-846:8330
PCB	EPA:1668A
	EPA:608
	SW-846:8080
	SW-846:8082
PEST/PCB	SW-846:8080
	SW-846:8081
	SW-846:8081A
	SW-846:8082
SVOA	EPA:625
	SW-846:8270
	SW-846:8270C
VOA	EPA:524.2
	EPA:624
	SW-846:8260
	SW-846:8260B

Table C-6.0-3
Analytical Methods
for Organic Chemicals in Biota Samples

Analytical Suite	Analytical Method
PCB	SW-846:8082
PEST/PCB	SW-846:8081A

Table C-7.0-1
Analytical Methods for Radionuclide Analysis in Sediment

Analytical Suite	Analytical Method
Americium-241 (AM_241)	HASL-300:AM-241
Gamma Spectroscopy (GAMMA_SPEC)	EPA:901.1
	Generic: Gamma Spec.
Tritium (H3)	EPA:906.0
Isotopic Plutonium (ISO_PU)	HASL-300:ISOPU
Isotopic Thorium (ISO_TH)	HASL-300:ISOTH
Isotopic Uranium (ISO_U)	HASL-300:ISOU
Strontium-90 (SR_90)	EPA:905.0

Table C-7.0-2
Analytical Methods for Radionuclide Analysis in Water

Analyte Suite	Analytical Method
ISOTOPE	SW-846:6020 (Chromium-53/52)
METALS	SW-846:6020 (Chromium-53/52)
RAD	Alpha
	Alpha Beta
	Alpha Spec
	Beta Counting
	EPA:900
	EPA:901.1
	EPA:903.1
	EPA:904
	EPA:905.0
	EPA:906.0
	Gamma
	Gamma Spec
	GFPC
	GPC
	Gross Alpha
	Gross Beta
	Gross Gamma
	HASL-300
	LLEE
	LSC
	SW-846:6020
	TIMS

Table C-8.0-1
Analytical Methods for Other Analyses in Sediment

Analyte	Analytical Method
pH	SW-846:9045C
Total Organic Carbon	EPA:415.1
Eisenia fetida starting weight, end weight, and percent survival rate	ASTM:E1676-97
Chironomus Tentans Growth and survival rate	EPA:100.2

Table C-8.0-2
Analytical Methods
for Other Analyses in Water

Analyte Suite	Analytical Method
GENINORG	ASTM
	Conductivity
	EPA:120.1
	EPA:150.1
	EPA:160.1
	EPA:160.2
	EPA:415.1
	Field
	Grav
	pH
	SM:A2710F
	Specific Gravity
	SW-846:9040B
	SW-846:9050A
	SW-846:9060
	USGS-WRI-79-4
ISOTOPE	AMS
	C-13 Ratio
	Deut Ratio
	Nitrogen Ratio
	Oxy Ratio

Attachments C-1 to C-3

Data Packages, Data from the Sample Management and Water Quality Databases, and Data from Other Sources (on DVDs included with this document)

Appendix D

Contaminant Trends and Inventory

D-1.0 SEDIMENT

This section presents information on contaminants in sediments in Sandia Canyon that supports the physical system conceptual model in section 7 of the investigation report and the risk assessments in section 8. It includes information on spatial and temporal variations in the concentrations of chemicals of potential concern (COPCs) that helps identify contaminant sources and provide an understanding of the effects of sediment redistribution by floods on contaminant concentrations and potential exposure to receptors. Calculations of the inventory (amount) of key sediment COPCs are included that support a conceptual understanding of the current distribution of contaminants.

D-1.1 Spatial Variations in Sample Results for Sediment COPCs

Figures D-1.1-1, D-1.1-2, and D-1.1-3 consist of plots showing sample results for all sediment COPCs identified in Sandia Canyon versus distance from the Rio Grande. These plots help to identify sources for the COPCs and show how concentrations change with distance from sources. Different colors on these plots are used for the north fork of Sandia Canyon (reach S-1N), the south fork of Sandia Canyon (reach S-1S), and Sandia Canyon east of the confluence of these two forks. Each sample is plotted at a location represented by the distance from the Rio Grande to the approximate midpoint of the reach. For inorganic and organic chemicals, nondetected sampling results are shown by an open circle, and the detected sampling results are represented by a filled circle (Figures D-1.1-1 and D-1.1-2). For radionuclides, detect status is not indicated because radionuclide sampling results are not censored (Figure D-1.1-3). Only sediment data from the Sample Management Database (SMDB) that have complete data packages and are validated are included in these plots.

The sample results in Figure D-1.1-1 are biased high as a result of biases accompanying sample collection, as discussed in section B-1 of Appendix B. Specifically, samples were typically biased toward geomorphic units and sediment facies with higher concentrations of contaminants, and units and facies with low concentrations (e.g., coarse facies sediment in the active channels) are underrepresented.

Some COPCs in these plots have clearly defined source areas, with concentrations decreasing downstream from these sources. For example, chromium, mercury, silver, and the polychlorinated biphenyls (PCBs) Aroclor-1254 and Aroclor-1260 had primarily releases into the south fork of Sandia Canyon and decrease downstream in Sandia Canyon. Some COPCs have no clearly defined source areas or spatial trends, which suggests that the sample results primarily represent variations in background concentrations and/or variability in detection limits. Examples include cobalt and perchlorate.

D-1.2 Spatial Variations in Average Concentrations of Select Sediment COPCs

This section presents information on the average concentrations of sediment COPCs in Sandia Canyon that are important for assessing potential human health risk in section 8.2 or potential ecological risk in section 8.1. This information supports the identification of sources for the COPCs and the examination of how concentrations change with distance from sources and how they vary with sediment facies. Averages were calculated separately for fine facies sediment samples and coarse facies samples to highlight differences between concentrations in these facies. All samples in each reach that were assigned to discrete sediment facies were weighted equally in these calculations, excluding resamples of specific sediment layers and samples that included a mixture of layers from different facies (e.g., from auger holes in reach S-2). For inorganic and organic COPCs that include nondetected results in a reach, upper and lower bounds on average concentrations in this section are calculated by replacing the sample result for nondetects with either the detection limit (upper bound) or zero (lower bound). The midpoint or median of

this range is also calculated by substituting one-half of the detection limit for nondetects. For some COPCs and some reaches, considerable uncertainty exists in average concentrations because of elevated detection limits, although for most COPCs and most reaches uncertainties related to nondetects do not obscure the general spatial trends in COPC concentration. If improved estimates of average concentrations were warranted, these estimates could be refined using the more robust nondetect replacement methods employed in Appendix E. Tables D-1.2-1 through D-1.2-5 present average concentrations for COPCs discussed in sections 7.1.1 through 7.1.3.

D-1.3 Contaminant Inventory

This section presents inventory estimates for key sediment COPCs in Sandia Canyon. The estimates for one COPC, chromium, have been updated from estimates presented in a previous report (LANL 2007, 098127). The term “inventory” refers to the total amount of a COPC in a geomorphic unit, in a reach, or in a canyon. Inventory estimates provide basic information for understanding how contaminants have been redistributed in the environment and hence for understanding the processes of contaminant transport. Inventory estimates are also useful when considering corrective action alternatives and as input into fate and transport models that predict future contaminant redistribution (e.g., Malmon 2002, 076038; Malmon et al. 2002, 082604; Malmon et al. 2003, 082603; Malmon et al. 2005, 093540).

Inventory estimates in this report are focused on chromium and PCBs because they have both well-documented sources and are potentially important in considering potential remedial options. In general, other COPCs released into the upper part of the Sandia Canyon watershed and associated with sediment particles are expected to share the same trends in inventory as chromium and PCBs.

Inventory estimates presented here use the same process that was used in previous reports (Reneau et al. 1998, 059159; Reneau et al. 1998, 065407; Reneau et al. 1998, 059667; LANL 1999, 063915; LANL 2004, 087390; LANL 2006, 094161) modified as discussed below. In these calculations, estimates of the average COPC concentration in each sediment facies and each geomorphic unit in most reaches are combined with estimates of sediment volume, sediment density, and gravel content. Sediment volume is calculated as unit area, as determined from digitized geomorphic maps, multiplied by average sediment thickness as determined from field measurements (as discussed in section B-1.0 of Appendix B of this report). Sediment density utilizes measurements made previously in Los Alamos and Pueblo Canyons (Reneau et al. 1998, 059159, Appendix B-4.0). Gravel content, as determined from particle-size analyses (section B-1.0), is used to adjust the effective volume of each unit because of the predominant association of contaminants with fine-grained particles (clay, silt, and sand). Samples from the same sediment facies but different geomorphic units are grouped together for calculating averages where there is no apparent difference between units.

In reach S-2, the inventory estimates mostly utilize average COPC concentrations measured in depth-integrated samples from auger holes that penetrate the full thickness of alluvium, and COPC concentrations are not divided into coarse and fine facies. The exception is the c2cr unit, which is present only east of the headcut and where analytical data were obtained from the full thickness of the unit in stream bank exposures. For PCBs, data were only obtained from auger holes in the eastern half of the reach, and use of these data probably provides an overestimate of the PCB inventory because the average particle size is somewhat finer and COPC concentrations are somewhat higher in the eastern auger holes. For example, in the 12 western auger holes, there is an average of 34% silt and clay and 135 mg/kg chromium, and in the 9 eastern holes there is an average of 39% silt and clay and 171 mg/kg chromium (15% and 27% higher, respectively).

For chromium, the average concentration from the background sediment data set (5.6 mg/kg) (McDonald et al. 2003, 076084, Table 10, p. 47) is subtracted from the average concentration in each unit. Background levels of chromium are subtracted because some of the unit averages are close to the background average, and background therefore dominates the inventory in some downcanyon reaches. The inventory is considered to be zero for units and facies where the average concentration is less than the background average.

For PCBs, a value of one-half the detection limit is used for nondetected sample results. The resulting uncertainty in average PCB concentrations in units and facies with nondetects is relatively small where the frequency of nondetects is relatively small and PCB concentrations are relatively high (e.g., reach S-2), and the uncertainty increases in downcanyon reaches where the detection frequency and concentrations are relatively low. However, these uncertainties do not affect identification of the general spatial distributions in PCB inventory (i.e., highest in S-2 and lower in upcanyon and downcanyon reaches).

Table D-1.3-1 presents detailed estimates of the inventory of chromium and PCBs in reaches where they are COPCs, along with the underlying data used in these calculations. Table D-1.3-2 uses the estimates in Table D-1.3-1 to provide estimated inventories of these COPCs along the length of Sandia Canyon. The inventory in nonsampled reaches uses the average of normalized inventories in bounding reaches (in units of kg/km), except for the area between S-2 and S-3W, where the inventory in S-3W is extrapolated through the nonsampled area. In Table D-1.3-2, the relative coarse versus fine facies inventory in S-2 assumes the same percentages of the total reach inventory as estimated downcanyon in S-3W (35% in coarse facies sediment and 65% in fine facies sediment for chromium). These estimates are applicable to the period when geomorphic mapping, characterization, and sediment sampling was conducted in each reach (2007 to 2008), and the distribution of the inventory will change over time because of subsequent flooding.

The accuracy of the canyon-scale inventory estimates are limited by uncertainties in reach S-2 where measured chromium and PCB concentrations vary by over 2 orders of magnitude and where relatively few exposures (e.g., bank cuts) exist. The uncertainty in the S-2 chromium inventory was evaluated using Monte Carlo simulations, following a process previously applied in Los Alamos and Pueblo Canyons investigations and presented in Ryti et al. (2005, 093019). The Monte Carlo simulations indicate a median estimate of ~11,000 kg and a mean estimate of approximately 15,000 kg of chromium in S-2, with a range of 5700 to 27,000 kg provided by the 10^{th} and 90^{th} percentiles, respectively (Figure D-1.3-1). Combined with data from the other reaches (Table D-1.3-2), these simulations indicate that approximately 65% to 90% of the total chromium inventory in Sandia Canyon sediment deposits is in S-2. The simulations also indicate that increasing the number of samples in S-2 would not have a significant effect on reducing this uncertainty.

D-2.0 WATER

This section presents information related to trends in contaminant distribution in surface water, springs, alluvial groundwater, perched intermediate groundwater, and regional groundwater in the Sandia watershed. It supports the physical system conceptual model in Section 7 and the risk assessments in Section 8. It includes information on spatial and temporal variations in the concentrations of chemicals of potential concern (COPCs) that helps identify contaminant sources and provide an understanding of the role of the wetland and redistribution by flowing surface waters and groundwater on contaminant concentrations and potential exposure to receptors, as well as outliers in the distributions. Calculations of the inventory (amount) of a key COPC are included that support a conceptual understanding of the current distribution of contaminants in the subsurface.

Tables D-2.0-1 through D-2.0-16 summarize the frequency of detection for each COPC in filtered and unfiltered samples from alluvial groundwater, perched intermediate groundwater, regional groundwater, and non-storm-related surface water (Tables D-2.0-1 through D-2.0-16 are in Attachment 1 on CD included with this document). The statistics presented in these tables are calculated using the same dataset as was used to prepare the screening tables in Section 6.3. The statistics include summary information for each analyte by location and from the combined sample results from all locations. The summary for combined samples lists the total number of samples, the detection rate, the range and median (50th percentile) of detected concentrations and separate tallies for detections exceeding standards and detections exceeding BVs. Summary information by location identifies the locations having detected concentrations exceeding standards and detected concentrations exceeding BVs.

D-2.1 Spatial Distribution of COPCs in Surface Water and Groundwater

This section provides information concerning the distribution of COPCs and other constituents in surface-water and groundwater sampling locations in the Sandia watershed, ordered in relation to distance along the assumed gradient. Analytes were selected for plotting in this appendix based upon the frequency with which they were detected above a standard or background value in an aqueous media, and the extent to which a data plot could be expected to show useful trends in contaminant concentrations. Application of this criterion, as documented in Tables D-2.1-1 through D-2.1-4, focuses attention on the more significant COPCs, and limits the number of plots dominated by nondetects that add little value to the assessment of a conceptual model. In addition to frequency of detection, other considerations underlying the decision whether or not to include a plot for a given analyte include the weight of evidence for its presence in surface or near-surface locations in the watershed.

Plots are grouped alphabetically by analyte within each of three categories:

- trace metals (Figure D-2.1-1),
- radionuclides (Figure D-2.1-2),
- organic analytes (Figure D-2.1-3), and
- general inorganic analytes (Figure D-2.1-4).

For each analyte plotted, data are shown for all hydrologic zones: non-storm related surface water, alluvial groundwater, perched intermediate groundwater, and regional groundwater. The data used in these plots were collected from 2003 to 2009 under the investigations described in Section 3 and were obtained from the SMDB and WQDB as described in Section 6.1 for the COPC screening. These data are included in Attachment C-2 in Appendix C. Only data from Water Quality Database (WQDB) that have complete data packages and are validated are included in these plots. The data for a location are presented as a time series to show any contaminant trends present over the time period. At location R-12 a rehabilitation of the well was performed in October 2007. A vertical line at that date separates the results collected before and after the well conversion.

Data from filtered and unfiltered samples, and screens at different depths for wells with multiple screens, are plotted using different colors to distinguish them from one another. Detected values are represented in the plots with filled symbols, and the nondetect values are open symbols. The detection limits reported for some analytes differ by year and may appear as step changes in the figures. For radionuclides, some nondetect values are reported as small negative values because radionuclide sample results are not censored. The entry "No data" in a plot field indicates that no data are available in the dataset for that particular analyte at that location. Background values, water ESLs (for surface water), and water-quality

standards used for the screening in Section 6.3 are shown on the plots when they are within the plotted range.

Plots for perched intermediate groundwater include data from four perched intermediate wells in Mortandad watershed because of their relevance to conceptual model evaluation, although these wells were not included in the screening in Section 6.3, nor in the frequency of detection statistics in Tables D-2.0-1 through D-2.0-16 (see Attachment 1 on CD included with this document). Data from regional water supply wells are excluded from the plots although they were included in the screening and in the frequency of detection statistics.

D-2.2 Mass Balance Estimates for Chromium in All Media Associated with Sandia Canyon Releases

The predominant source of anthropogenic chromium in the Sandia watershed is from the TA-03 power plant cooling towers, which discharged cooling water containing potassium dichromate into the south fork of Sandia Canyon. An estimated 31,000 to 72,000 kg of chromium(VI) was released to upper Sandia Canyon from 1956 to 1972 from SWMU 03-012(b) (LANL 2007, 098938). Chromium has been dispersed down canyon by a combination of surface water and sediment transport. A portion of the soluble chromium (as Cr(VI)) percolated into the vadose zone as pore water with some of this infiltrating water reaching the regional aquifer, causing the elevated chromium concentrations found at wells R-11, R-28, R-42, R-44, and R-45. A mass balance of chromium in the environment is presented here to reconcile the released chromium mass against the estimated mass of chromium distributed among three principal reservoirs: 1) sediment stored on the canyon floor, 2) pore water, perched intermediate groundwater, and bedrock of the vadose zone, and 3) groundwater and aquifer bedrock of the regional groundwater system. Many simplifying assumptions are incorporated into the mass balance presented here, as explained below, but the approach uses field data to provide a preliminary estimate of the chromium mass distribution including uncertainty ranges.

As presented in section 7.1.5, the total inventory of anthropogenic chromium in post-1942 sediment deposits in Sandia Canyon is estimated at approximately 18,000 kg (25 to 58% of the released chromium). An estimated 84% of the total is contained within reach S-2, where concentrations are highest and where a large volume of post-1942 sediment exists. Over 99.9% of the chromium in reach S-2 is stabilized as insoluble Cr(III). Approximately 5% of the chromium in sediment is contained along the next 4 km of channel, between reach S-2 and the east end of reach S-4W, where stormwater runoff is confined to a relatively narrow band along the channel. Approximately 11% occurs in the next 5 km, on Laboratory land east of NM 4, and less than 0.5% farther downcanyon.

The portion of the chromium stored in the vadose zone is less constrained than for sediments. Analyses of cores from the upper vadose zone indicate that the majority of the anthropogenic chromium is stored in the Bandelier Tuff, Puye Formation sediments above the Cerros del Rio basalts, and within the Cerros del Rio basalts and is associated with the solid phase rather than in porewater. Site-specific laboratory experiments performed for this investigation indicate that the basalts and dacitic gravels in the vadose zone are capable of attenuating large amounts of chromium through chemical reduction, precipitation and adsorption, accounting for their inventory of chromium (Appendix I). The Bandelier Tuff is poor in ferrous mineral components that may reduce Cr(VI) to less mobile Cr(III). However, the thickness and relatively homogenous porous structure of the Bandelier section promote porous flow through the tuff, which allows for infiltrating water to contact with a large surface area. The adsorption capacity of the Bandelier Tuff for chromium is expected to be variable, reflecting differences in abundance of volcanic glass, silicate and oxide minerals, and properties such as grain size and surface area. Adsorption of Cr(VI) species onto hydrous ferric oxide is considered to be one process that potentially can limit chromium migration through

the Bandelier Tuff under oxidizing conditions. Clay- and silt-sized particles with larger surface areas compared to sand-sized particles adsorb larger amounts of chromium contributing to the attenuation capacity of the Bandelier Tuff. The Bandelier Tuff has retained a significant amount of anthropogenic chromium probably because of this combination of properties (see Appendix I for discussion of the role of surface area in Cr retention)

To estimate the mass of anthropogenic chromium that may be stored in the vadose zone beneath Sandia Canyon, the stratigraphy at SCI-2 is used as a basis along with the chromium data obtained by the Environmental Protection Agency (EPA) 3050 digestion method using SCI-2 core and (where available) SCC-1 through SCC-6 core. The EPA 3050 digestion method is a strong acid leach (pH 1 to 2) that dissolves chromium (and other constituents) from the solid phase, including adsorbed and precipitated chromium. This method therefore provides data that accounts for Cr(VI) as well as less mobile Cr(III). The 3050 digestion data for chromium are presented in Appendix I (Figure I-3.2-2) for SCI-2 and in Figure 5.5-1 of the chromium interim measures investigation report (LANL 2006, 094431).

For the mass balance calculation, the vadose zone is subdivided into five major units based on lithology. The major units considered are (1) the Bandelier Tuff plus Cerro Toledo sediments, (2) Puye Formation above the Cerros del Rio basalts, (3) the Cerros del Rio basalt, (4) Puye Formation beneath the Cerros del Rio, and (5) the section of Miocene pumiceous sediments above the regional aquifer (see Figure N-1.0-1). To estimate the amount of 3050 digested chromium from each rock type that may represent background rather than anthropogenic chromium, an upper threshold for 3050 digestible background chromium was estimated for each unit. The current chromium upper threshold, based on the EPA 3050 digestion, for the Bandelier Tuff of 2.6 mg/kg was used in the analysis (LANL 1998, 059730). A chromium upper threshold for the Cerros del Rio basalt is not available, but an upper background limit was estimated using the data presented in Appendix I, Table I-3.2-3, where 3050 digestion chromium content in Cerros del Rio basalts unexposed to anthropogenic chromium averaged 6 mg/kg with a standard deviation of 3.5 mg/kg. The upper background limit estimated from these data is 13 mg/kg (average plus two standard deviations). The chromium upper background limits assumed for the Puye Formation (8 mg/kg) and the Miocene pumiceous sediments (5 mg/kg) are based on their intermediate bulk chromium contents that fall between those of the Bandelier Tuff and the Cerros del Rio basalts. Only the 3050 digestion chromium values above upper thresholds were used to average the estimated anthropogenic chromium abundances for the five major units, using a total infiltration area of 129,577 m^2 and the vadose zone unit thicknesses based on stratigraphy at SCI-2. The infiltration area is assumed to be a rectangle with the dimensions of 107 m by 1211 m that coincides with the zone of greatest infiltration beneath the canyon floor between well SCA-2 and well R-11 (Figure D-2.2-1). Figure D-2.2-2 presents a vertical vadose zone column centered on SCI-2 and showing the vadose zone units, along with estimated mean concentrations for each unit from Table D-2.2-1 (discussed below). An exception to propagation of anthropogenic chromium concentration throughout a vadose zone unit was made for the Cerros del Rio basalts, where core sampling was focused on only those fracture or rubble-zone samples where moisture contents would be measurable and chromium transport was assumed to occur. Such samples were restricted to moisture-bearing fractures or interflow rubble. Based on evaluation of the SCI-2 borehole video such samples only account for 1 to 10% of the Cerros del Rio mass. The remaining 90–99% is massive lava of low permeability that was unlikely to interact with dissolved Cr(VI). Accordingly, the inventory of chromium in the Cerros del Rio was scaled to only 1 to 10% of the total mass of basalt.

Table D-2.2-1 summarizes the results of this chromium inventory evaluation for the vadose zone. Among the many uncertainties in generating this table, those with the greatest influence over the calculations are (1) the assumed area of the infiltration zone, (2) the limited amount of chromium core concentration data from the top of the Cerros del Rio basalt to the regional aquifer, (3) the poorly constrained upper threshold values used for all units except the Bandelier Tuff, and (4) an immature conceptual model of

how chromium in solution may interact with the Cerros del Rio basalt. Despite these uncertainties, the analysis suggests that a significant amount of the anthropogenic chromium inventory resides in vadose zone rocks, a mean estimated value of 32,000 kg or 63% of the mean estimated chromium source.

A perched intermediate zone in SCI-2 has an elevated chromium concentration of approximately 600 μg/L (Figure D-2.1-1f). The mass of chromium in this perched zone was also calculated by assuming the same lateral extent for the perched zone as for the infiltration window used to define the affected rock mass, a thickness of 30 m, and a porosity of 10%, (Table D-2.2-1). This mass accounts for only 170 kg of chromium or less than 1% of the original mean source value. Porewater chromium in the vadose zone is assumed to represent a negligible mass.

Model estimates are that approximately 10 kg/yr have entered the regional aquifer starting potentially as early as 1960 and resulted in an average predicted 555 kg of chromium (Table D-2.2-1) (approximately 1% of the average released chromium) residing in the regional aquifer, assuming no reduction of chromium in the regional aquifer. The modeled estimate of a total introduced mass of 555 kg of chromium in the regional aquifer is capable of producing the distribution and concentrations of chromium observed in the regional aquifer today.

Overall, the mean estimates presented here can account for the distribution of the original chromium source in the environment. This mass is predominantly present in the vadose zone where it is thought that a substantial fraction of chromium is immobilized on the solid phase (rock) through precipitation and adsorption rather than dissolved in porewater. Appendix I provides a summary of experimental work on chromium retention on site-specific lithologies. A large mass of chromium is also located within sediments; experiments on chromium retention in the wetland of upper Sandia Canyon are described in Appendix J. Chromium retained in both the vadose zone lithologies and the wetland is currently stable.

D-2.3 Estimated Transport and Mixing of COPCs in Perched-Intermediate and Regional Aquifer Groundwater

This section focuses on providing bounding estimates of groundwater flow and transport pathways and rates for COPCs originating in Sandia Canyon. In conjunction with other lines of evidence such as geologic mapping, borehole profiles of COPC concentrations, and numerical modeling, distributions of mobile constituents in groundwaters are examined to test for the presence of hydrologic connections among different zones of saturation as postulated in the hydrologic conceptual model (section 7.2.1). Geochemical and isotopic tracers are used in this section to test or corroborate the following key features of the hydrologic conceptual model:

- Past releases into upper Sandia Canyon are the dominant source of elevated chromium concentrations observed in perched-intermediate and regional aquifer groundwaters beneath Sandia and Mortandad Canyons.
- The main infiltration window by which surface water from upper Sandia Canyon enters the deep vadose zone beneath middle Sandia Canyon is located approximately between alluvial wells SCA-2 and SCA-4.
- Stratigraphic controls could divert perched-intermediate groundwater from middle Sandia Canyon towards middle Mortandad Canyon.
- The breakthrough of vadose-zone porewater and perched-intermediate groundwater to the regional aquifer occurs predominantly at a “drip point” in the vicinity of well R-42 in middle Mortandad Canyon.

- Some fraction of perched-intermediate groundwater originating from upper Sandia Canyon may continue to move laterally to show up at wells MCOI-4 and MCOI-6.
- The area and maximum impact of the chromium plume in the regional aquifer is spatially restricted to wells R-42 and R-28.
- Contaminant plumes originating from sources in Mortandad and Sandia Canyons comingle in some deep saturated zones.

Some of the geochemical and isotopic data relevant to testing these aspects of the conceptual model are summarized in Table D-2.3-1 and Table D-2.3-2 and are also presented using a variety of graphical methods (Tables D-2.3-1 through D-2.3-3 are in Attachment 1 on CD included with this document).

- Plots showing temporal trends of COPCs in monitoring wells (Figure D-2.3-1) help identify characteristic groupings of mobile co-contaminants.
- Trilinear (Piper) plots help visualize geochemical groupings of waters and their evolution along flow paths through different hydrologic zones (Figures D-2.3-2 through D-2.3-6).
- Surface-water monitoring data collected between 1970 and 2005 are used to reconstruct the chemistry of past discharges into upper Sandia Canyon (Table D-2.3-2 and Figure D-2.3-7). Abrupt changes in discharge chemistries that manifest at depth provide a basis for travel-time estimates.
- Bivariate plots of COPC concentrations are used to test hypotheses about mixing of waters along potential flow paths and to provide bounding estimates of the relative proportions of potential mixing end-members.
- Stable nitrogen isotope ratios in nitrate show systematic variations among different sources and provide corroborating evidence for potential mixing end members and their relative proportions (Figure D-2.3-8). The distribution of chlorate in waters collected from various locations in Los Alamos, Sandia, and Mortandad Canyons is used in similar fashion (Figure D-2.3-9).

D-2.3.1 Correlations between Concentrations of Chromium and other COPCs

Temporal trends in compositions of chromium and other COPCs at key wells are used to identify characteristic groupings of COPCs that may have a common origin in time or place, as distinguished from COPCs which coexist at a location due to commingling of plumes emanating from different sources. Figure D-2.3-1 plots temporal trends for COPCs at four intermediate-perched wells (SCI-1, SCI-2, MCOI-4, and MCOI-6) and six regional groundwater wells (R-28, R-42, R-11, R-15, R-44, and R-45) in which chromium is consistently detected above water–quality screening levels or BVs. COPCs selected for these plots are mobile constituents for which data and other documentation exist showing their presence in water released into upper Sandia Canyon: bromide, chloride, chromium, nitrate, perchlorate, sulfate, and tritium.

Visual examination of the sets of plots in Figure D-2.3-1 yields two significant observations:

- Elevated concentrations of chromium are generally accompanied by elevated concentrations of calcium, chloride, perchlorate, sulfate, and tritium. At some but not all locations with elevated chromium concentrations, bromide and nitrate are also detected above local background values.
- Concentrations of these co-contaminants occasionally parallel the trends shown by chromium at a particular location but more frequently do not show a close correlation.

Documentation exists for the presence of each of these COPCs in water released into upper Sandia Canyon over the past fifty years (section 2.1). However, correlations of chromium with these and other COPCs in Sandia discharges are probably limited due to the frequency with which changes have occurred in chemical usage, wastewater-treatment processes, and the relative rates and volumes of various outfalls discharging into upper Sandia Canyon. For example, median concentrations of selected COPCs in surface-water samples (excluding stormwater runoff) from Sandia Canyon are shown for consecutive 5-yr intervals from 1975 to 2005 in Table D-2.3-2; some of these COPC concentrations are plotted in Figure D-2.3-7. Changes in discharge chemistries on short, as well as long, time-scales are also evident from the range of major-ion compositions observed on trilinear plots of alluvial groundwater and surface water from Sandia Canyon (Figures D-2.3-2 and Figure D-2.3-3).

Elevated calcium groundwater concentrations may be one of the most persistent characteristics of the chromium contaminant plume. High calcium concentrations appear to evolve through water-rock interactions along the flow path through the deep vadose zone (section D-2.3.2).

D-2.3.2 Major-ion Characteristics of Waters in Different Hydrologic Zones

Trilinear (Piper) plots provide a useful graphical representation of water chemistries. These plots are commonly used to identify waters with similar chemistries that plot in a distinct position on the Piper plot, or that appear to be evolving along similar paths. Relative percentages of major cations and major anions (expressed in milliequivalents (meq) per liter) are plotted on separate ternary plots. Major cations are calcium, magnesium, and sodium + potassium; major anions are generally chloride, sulfate, and bicarbonate + carbonate. However, when nitrate comprises a significant proportion of the total anion concentration meq/L, its contribution is then included with that from chloride–i.e., the bottom axis is labeled "Cl +NO_3" on the anion ternary plot–analogous to the inclusion of the contribution from potassium with that from sodium (Na+K) on the cation ternary plot. Points plotted on the two ternary plots are then projected upwards where they intersect on the central diamond. Figures D-2.3-2 through D-2.3-4 are trilinear plots for alluvial groundwater, surface water, perched-intermediate groundwater, and regional groundwater, respectively.

Another common application of this graphical tool is to identify potential mixing between end-members. Samples that plot along straight lines formed between two end members in all three fields of the trilinear diagram potentially represent mixing between these end members. An underlying assumption is that the products remain in the solution when two waters mix in some proportion. In addition, absolute concentrations in the mixture must be between the concentrations of the two end members. The trilinear plot in Figure D-2.3-6 is presented for this purpose and is populated with possible mixing end-members selected from among the surface waters and alluvial, perched-intermediate, and regional groundwaters shown on Figures D-2.3-2 through D-2.3-5.

Trilinear plots on Figure D-2.3-2 show compositions of individual samples collected at five alluvial groundwater wells in Sandia Canyon between 2006 and 2009. Alluvial groundwater at well SCA-1 in the wetland is distinctly different from groundwater at the other three locations insofar as it is characterized by higher carbonate alkalinities and more variable sulfate concentrations (Figure D-2.3-2a). However, alluvial groundwaters at wells SCA-2 and SCA-4 (Figure D-2.3-2b and c) are indistinguishable from one another on these trilinear plots. The geochemical significance of these waters is that they represent the initial compositions of water entering the vadose zone in the infiltration window along this stretch of Sandia Canyon and percolating to deeper zones of saturation. In this regard, the wide range in anion proportions (lower right triangle) is notable; the range is caused predominantly by shifts in chloride concentrations relative to carbonate alkalinities. The proportion of sulfate in these samples remains

relatively constant at about 10%. In contrast, cation proportions (lower left triangle) plot within a comparatively narrow range.

Present-day compositions of alluvial groundwater are unlikely to be representative of the infiltrating water now arriving at wells SCI-1 and SCI-2 or at the regional water table. However, up to three decades of geochemical data are available for three surface-water monitoring stations in Sandia Canyon. Station SCS-1 is in upper Sandia Canyon, station SCS-2 is in middle Sandia Canyon at the terminus of persistent baseflow, and station SCS-3 is east of SCS-2 and about 400 m west of alluvial well SCA-2. As is the case for alluvial groundwater wells SCA-2 and SCA-4, general similarities shown on Figure D-2.3-3 for average major-ion chemistries of waters collected at stations SCS-2 and SCS-3 during the same time periods (Figure D-2.3-3) suggest that minimal interaction occurs between the water and sediments during flow events that transit this segment of the channel. Significantly, and in contrast with the case for more recent samples from wells SCA-2 and SCA-4, the proportion of sulfate in these older surface-water samples ranges widely throughout the 30-year period, up to 40% in the 1980s. This observation is significant because of its implications for the interpretation of geochemical data to trace the progress of Sandia COPCs along postulated flow paths, as becomes obvious in later discussions about the appropriate compositions to use in mixing calculations.

Shifts in relative major-ion compositions of perched-intermediate and regional groundwaters occur more slowly than those in surface water and alluvial groundwater. Consequently, compositions of these groundwaters can often be approximated by a single sample, as has been done in Figure D-2.3-4 for intermediate perched groundwater at selected wells in Los Alamos, Sandia, and Mortandad Canyons. One of the most significant observations from this figure is the cluster of four star symbols that form a distinctive hydrochemical facies towards the top of the central diamond on the trilinear plot. The four groundwaters that map onto this region of the trilinear plot—wells SCI-1, SCI-2, MCOI-4, and MCOI-6—share similarities in their major-ion chemistries. Groundwater at these locations is distinctly different from perched-intermediate groundwater at nearby locations in Los Alamos Canyon (wells LAOI-3.2, LAOI-3.2a, R-6i, and TA-53i) and in lower Sandia Canyon (well R-12). Compared with groundwater at these other locations, these four Sandia and Mortandad groundwaters contain much higher proportions of sulfate and calcium. Sulfate comprises 20 to 36% of the total anion equivalents versus 6 to 14% for other groundwaters on this plot, including well MCOI-5, despite the proximity of wells MCOI-5 and MCOI-6 to one another. Groundwater in this distinctive hydrochemical facies is also characterized by higher proportions of calcium, which range from 54 to 60% of total cation equivalents, as compared to 40 to 52% for most other groundwaters plotted on this figure.

The trilinear plot in Figure D-2.3-5 shows major-ion distributions for regional groundwater in Los Alamos, Sandia, and Mortandad Canyons. As was the case for wells SCI-1 and SCI-2 in the previous figure, groundwaters at wells R-28 and R-42 are distinctly different from regional groundwater at other locations shown on this plot. The trilinear plot in Figure D-2.3-6 is populated with all six groundwaters that plot within the hydrochemical facies at the top of the diamond, along with many other groundwaters selected from the Figures D-2.3-2 through D-2.3-5, in order to identify potential relationships among the groundwaters from the different hydrologic zones.

Examination of the composite trilinear plot in Figure D-2.3-6 suggests that the present-day composition of groundwater at wells SCI-1 and MCOI-4 evolved from surface water infiltrating into Sandia Canyon sediments with an initial major-ion composition similar to the median surface-water concentrations at station SCS-2 during the 1980-1990 time frame (orange and yellow plotting symbols for SCS-2 on Figure D-3.2-6). However, no obvious candidate is found for the second mixing end-member. Water-rock interactions apparently dominate subsequent evolution of the cation composition of the infiltrating water,

such that simple mixing ratios cannot reproduce the observed composition without take such reactions into account.

D-2.3.3 Estimated Travel Times from the Surface to Deeper Zones of Saturation

As mentioned previously, the present-day compositions of alluvial groundwater is unlikely to be representative of the infiltrating water now arriving at wells SCI-1 and SCI-2. Figure D-2.3-7 compares present-day concentrations of selected analytes in wells SCA-2, SCI-1, and SCI-2 against 5-yr median concentrations of these analytes in surface-water samples from stations SCS-2 and SCS-3. Similarities in the chemistries of SCS-2 and SCS-3 suggest that minimal interaction occurs between the surface water and sediments along this segment of the channel flow. Presumably, the surface water is already approaching equilibrium with channel sediments by the time it reaches SCS-2, or is supersaturated with respect to the minerals present in those sediments. Geochemical concentrations of nonreactive, or only slightly reactive, constituents in alluvial groundwater at well SCA-2 are correlated with those in surface water at the same location (Figure D-2.3-7). This similarity suggests that the surface water composition may serve as a limited surrogate for the composition of alluvial groundwater. This allows reconstruction of the composition of the water infiltrating to the perched-intermediate zone for the period 1980 to 2006, for which no alluvial groundwater data are available. A few exceptions to the above generalization (comparing SCS-2 and SCS-3 chemistries to well SCA-2 chemistry) include pH, total carbonate alkalinity, and phosphorus (which has been discharged in different chemical forms over the years).

Among the tracers for which trends are plotted for SCS-2 and SCS-3, molybdenum and tritium show step functions in their releases and thus serve as time markers for COPC transport rates. The surface water data indicate that molybdenum was released into Sandia Canyon from 1991 to 1996, and tritium was discharged from 1978 to 1986. The present-day composition of well SCI-1 appears to be dominated by water infiltrating after 1990. Evidence for this timing is the increasing molybdenum concentrations, declining tritium activities, steady low chromium concentrations, and the presence of chlorate (section D-2.3-4). These trends support the expectation that the chromium peak has already moved through this part of the flow system.

D-2.3.4 Diversion of Perched-Intermediate Groundwater towards Mortandad Canyon and Potential Comingling of Contaminant Sources in Middle Mortandad Canyon

At wells MCOI-4 and MCOI-6, commingling of COPCs derived from sources in Sandia Canyon as well as in Mortandad Canyon is indicated by several lines of geochemical and isotopic evidence, some of which are presented below. These data support the conceptual model for mixing of groundwaters through the use of conceptual flow paths and geochemical stiff diagrams illustrated in Figure 7.2-1.

1,4-Dioxane

1,4-Dioxane is consistently detected at wells MCOI-4 (11 to 38 μg/L), MCOI-5 (5 to 10 μg/L), and MCOI-6 (11 to 30 μg/L) (Figure D-2.1-3). 1,4-Dioxane is not detected in any of the Sandia Canyon intermediate and deep groundwaters included in the COPC screening conducted in section 6 and appears most likely to derive from a source in Mortandad Canyon. This organic SVOC is a stabilizer for chlorinated solvents including trichloroethene (TCE), which is used in the processing of plutonium at TA-55. The presence of 1,4-dioxane at the three MCOI wells suggests that this miscible organic compound was released to Mortandad Canyon at TA-50.

Stable Nitrogen Isotopic Ratios

Mortandad Canyon watershed has received industrial effluents containing nitrate derived from treated-sewage effluent and neutralized nitric acid since the early 1950s. Releases from the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50 since 1963 have consisted of neutralized nitric acid. Sewage effluent previously discharged from TA-35 since the early 1950s was discharged into Ten Site Canyon, a tributary to Mortandad Canyon. Two isotopically distinct forms of neutralized nitric acid have been discharged from the RLWTF. The typical form discharged from the facility from 1963 until the present day has contained the stable nitrogen isotopes ^{15}N and ^{14}N in normal proportions. The other form was isotopically depleted with respect to ^{15}N and was discharged from the RLWTF from 1986 to 1989.

Well SCI-1 in Sandia Canyon is dominated by nitrate derived from treated sewage effluent (90 to 100 percent) most likely released from TA-03 since the early 1950s (Figure D-2.3-8).

Well MCOI-4 contains three types of nitrate with one being treated sewage effluent (approximately 30 to 50 percent) and two types of neutralized nitric acid, including typical neutralized nitric acid (approximately 40 to 60 percent) and ^{15}N-depleted neutralized nitric acid (approximately 10 to 20 percent) (Figure D-2.3-8).

Well MCOI-5 in Mortandad Canyon contains nitrate derived from treated sewage effluent (approximately 20 to 40 percent) as well as from typical neutralized nitric acid (approximately 60 to 80 percent), with a higher component of nonfractionated nitric acid. Decreasing amounts of nitrate derived from the sewage component occurs in the more recent groundwater samples analyzed from well MCOI-5 (Figure D-2.3-8).

Well MCOI-6 also contains three types of nitrate with one being treated sewage effluent (approximately 10 to 40 percent) and two types of neutralized nitric acid, including typical neutralized nitric acid (approximately 30 to 65 percent) and ^{15}N-depleted neutralized nitric acid (approximately 10 to 30 percent). Well MCOI-6 contains the greatest amount of ^{15}N-depleted, neutralized nitric acid compared to wells MCOI-4 and MCOI-5. Increasing amounts of nitrate derived from both the ^{15}N-depleted nitric acid and sewage components occur in the more recent groundwater samples analyzed from well MCOI-6 (Figure D-2.3-8).

Chlorate

The distribution of chlorate in local groundwaters may provide a characteristic marker of the TA-46 Sanitary Wastewater System Consolidation (SWSC) Facility effluent released at TA-03 National Pollutant Discharge Elimination System Outfall 001. Chlorate is detected in effluent from the SWSC facility at concentrations as high as 498 μg/L (Table D-2.3-3; Figure D-2.3-9). Table D-2.3-3 lists chlorate data obtained from EES-6 ion chromatographic data records or taken from ion-chromatography scans in analytical data packages submitted to LANL by an outside analytical laboratory. The highest chlorate concentrations in surface water as well as the highest frequencies of detection occur at three monitoring stations in Sandia Canyon (Plate 1): gage E121.9 east of the Power Plant (maximum = 221 μg/L), gage E121 at the right fork at the Power Plant (maximum = 264 μg/L), gage E123 below the wetlands (maximum = 269 μg/L), and twice at WMSC at the terminus of persistent baseflow (maximum = 178 μg/L). This chlorate most likely is present as a byproduct of the MIOX (Mixed Oxidants) process introduced at the SWSC in 2000. The mixed-oxidant solution is a mixture of chlorine and other chlor-oxygen compounds that are generated electrolytically using sodium chloride, water, and power.

In deep groundwater, the highest chlorate concentrations are observed in perched-intermediate wells SCI-1 (167 μg/L) and MCOI-6 (maximum = 137 μg/L). Its presence at these locations is consistent with

the close grouping of these two wells on a trilinear plot (Figure D-2.3-5) as a result of their similar major-ion chemistries.

Two caveats apply to this data set. First, these data should be considered rough estimates at best because the detection limits, precision, and accuracy of these chlorate data are not known, and the data did not undergo data review or secondary validation. Its use here is simply to support conceptual model development. Second, chlorate is not unique to sources in Sandia Canyon. Chlorate is consistently detected at well LAOI-3.2a (28 to 140 μg/L), and has also been detected in local tap water and in municipal water used for drilling (Table D-2.3-3). Common MIOX applications include on-site disinfection of potable water supplies and pipelines in water-distribution systems and control of biofilms in cooling towers. It therefore seems likely that the MIOX process is being used at other local facilities in addition to the SWSC Facility.

D-3.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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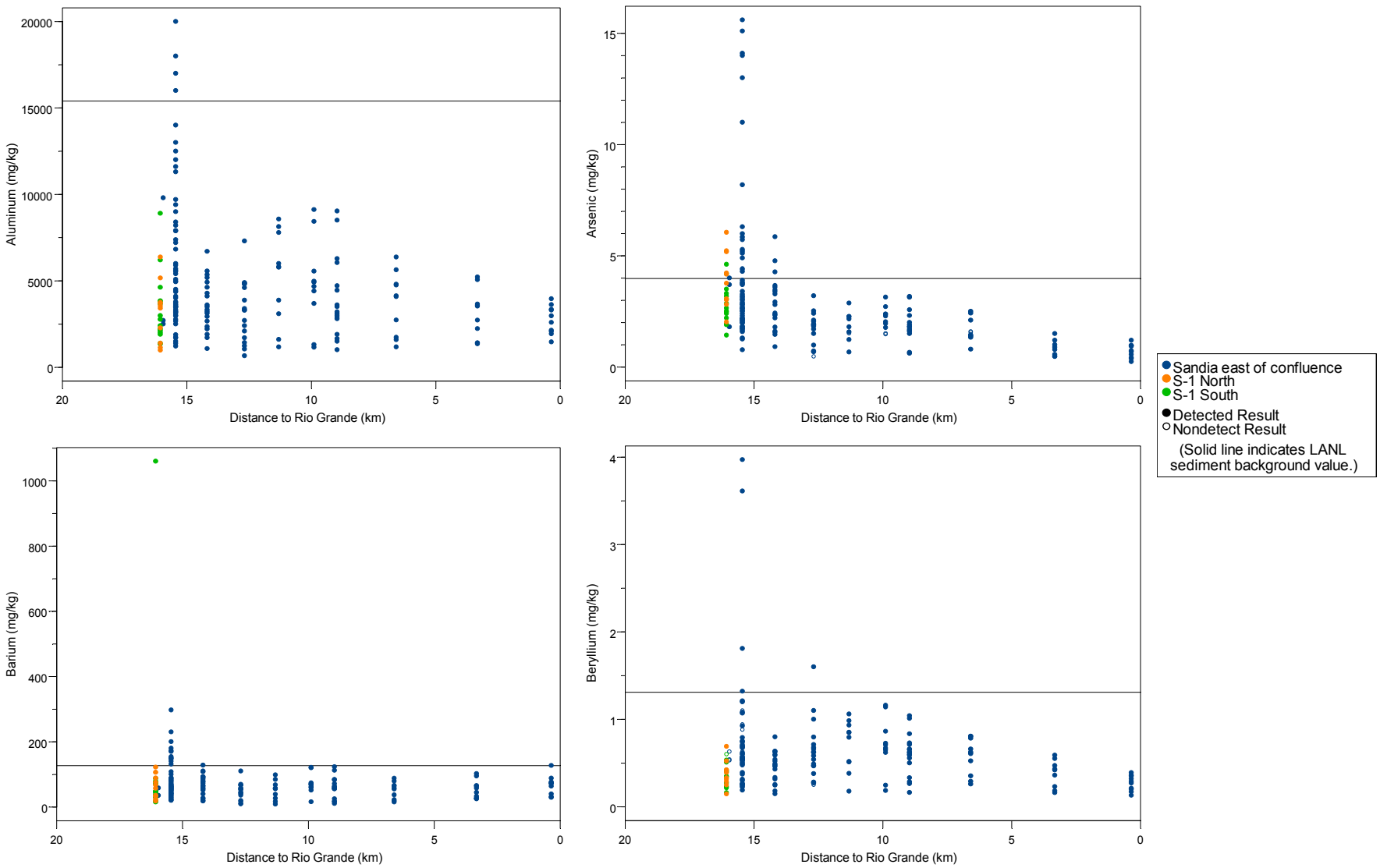


Figure D-1.1-1 Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

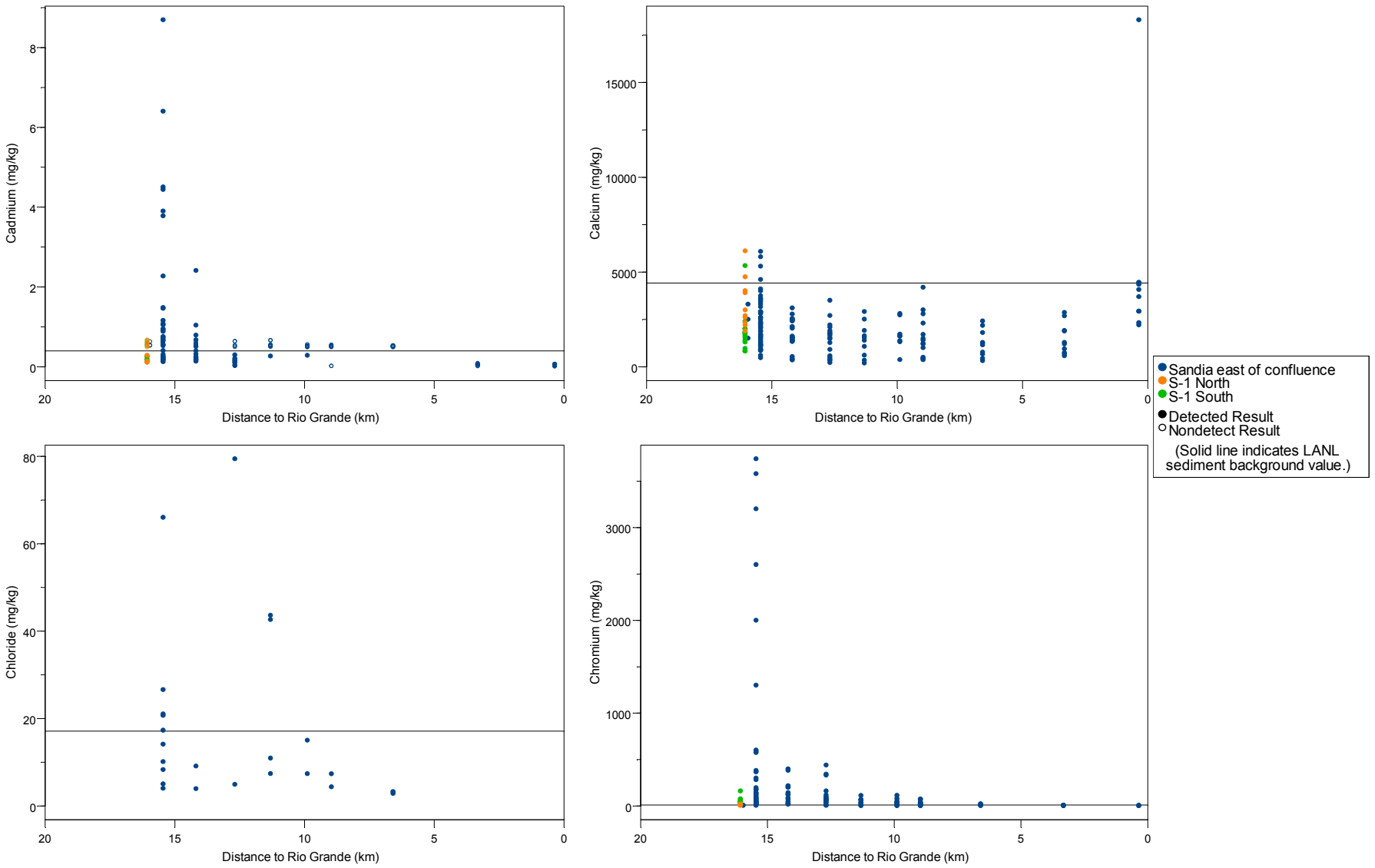


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

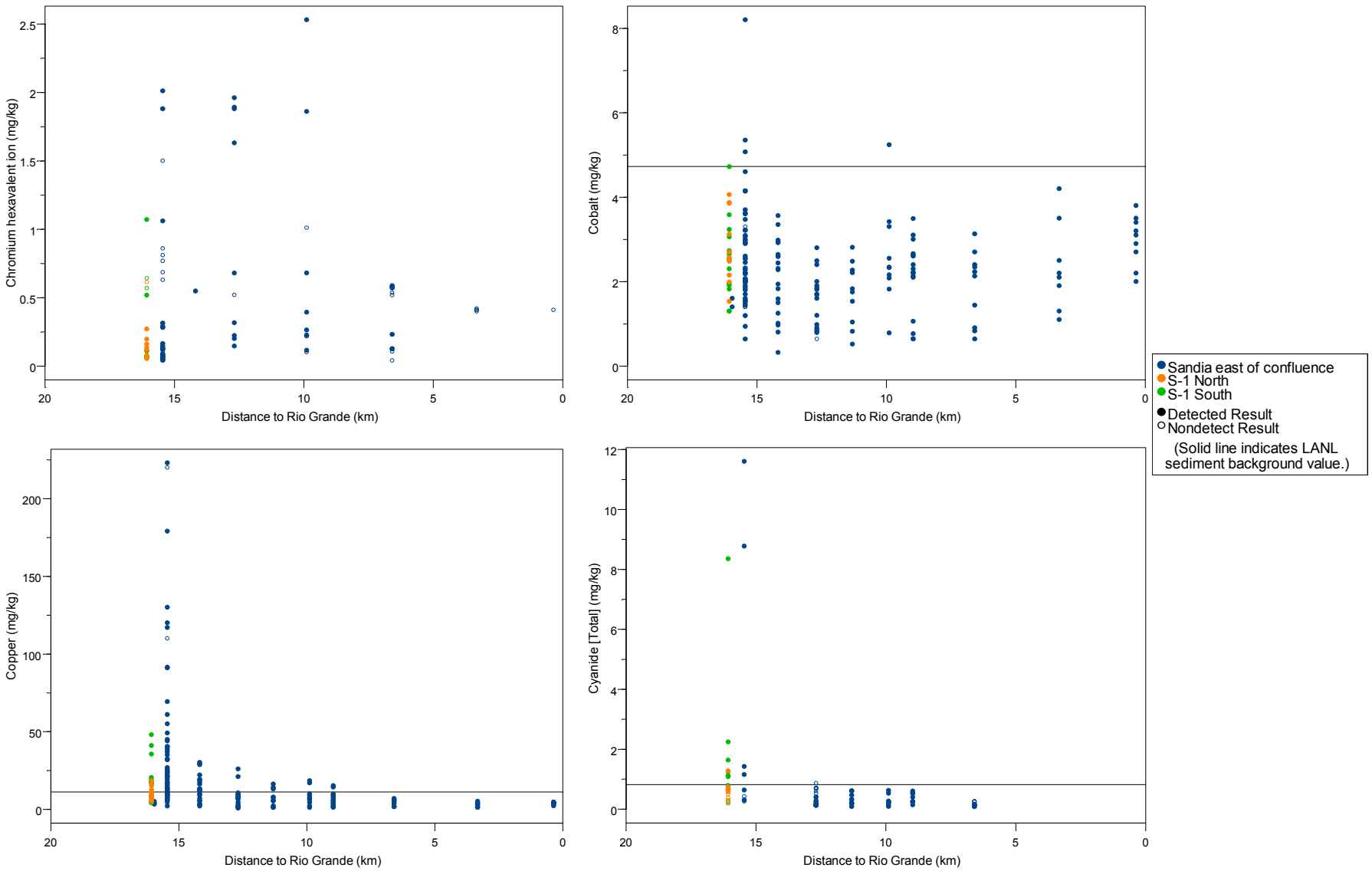


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

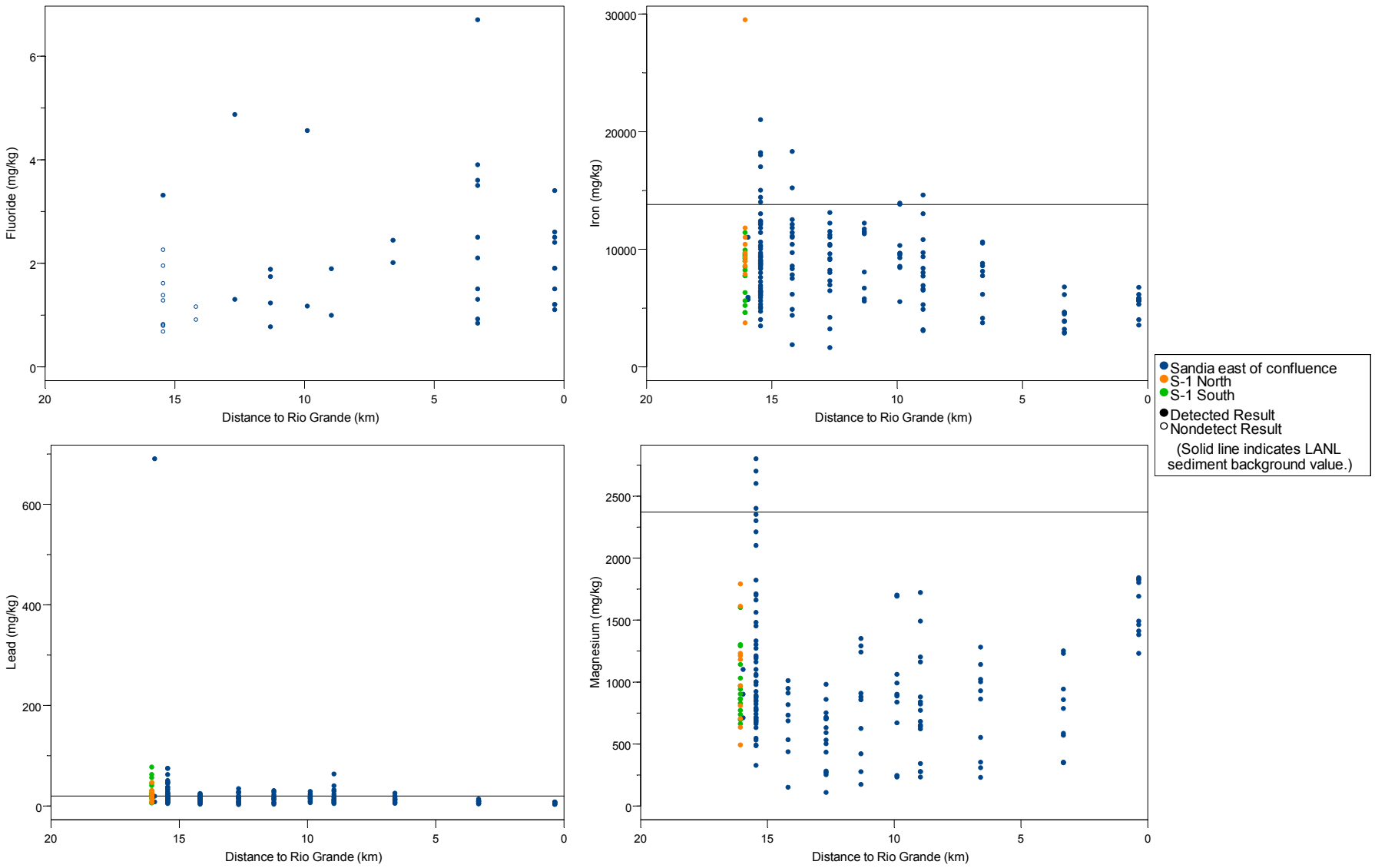


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

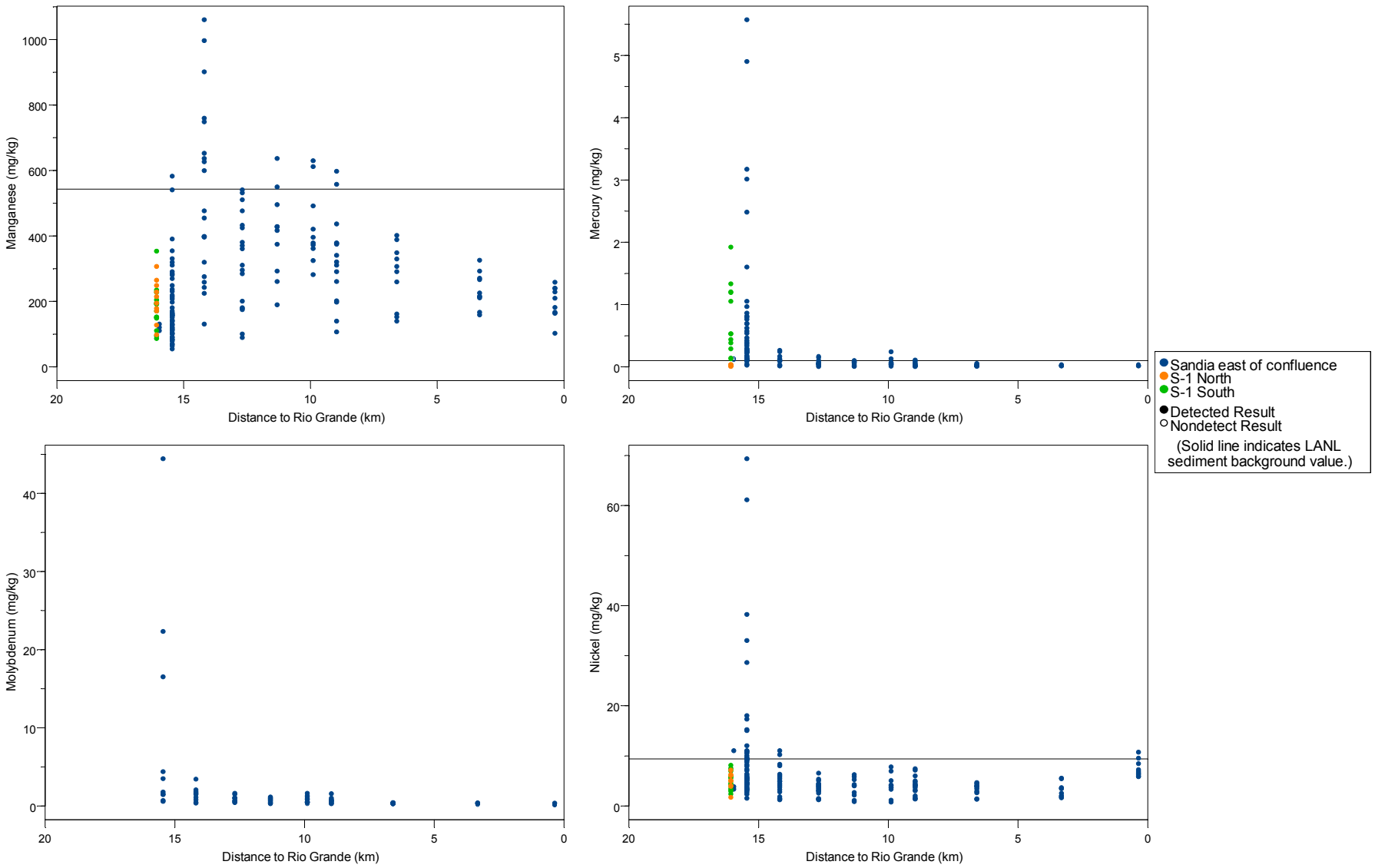


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

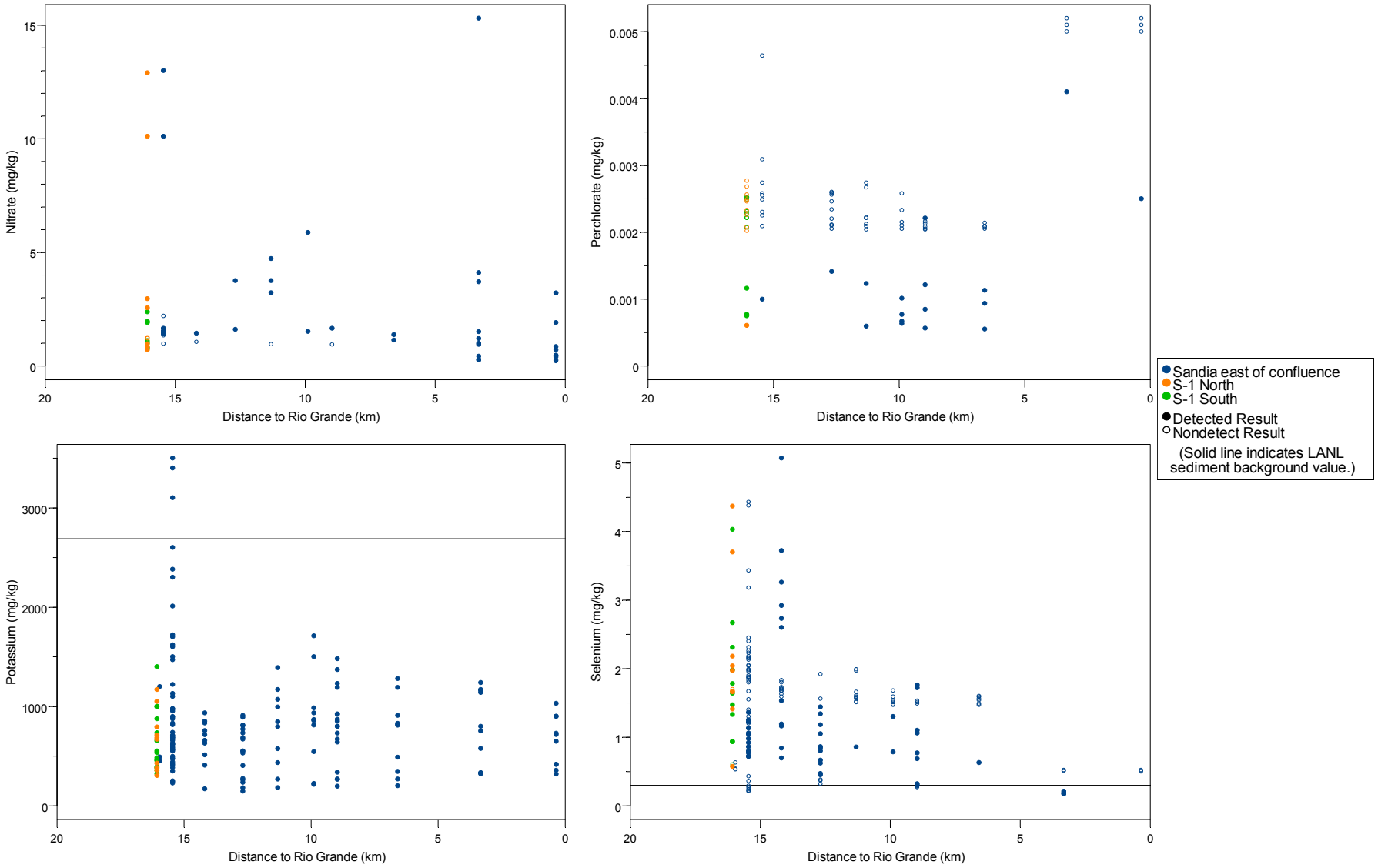


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

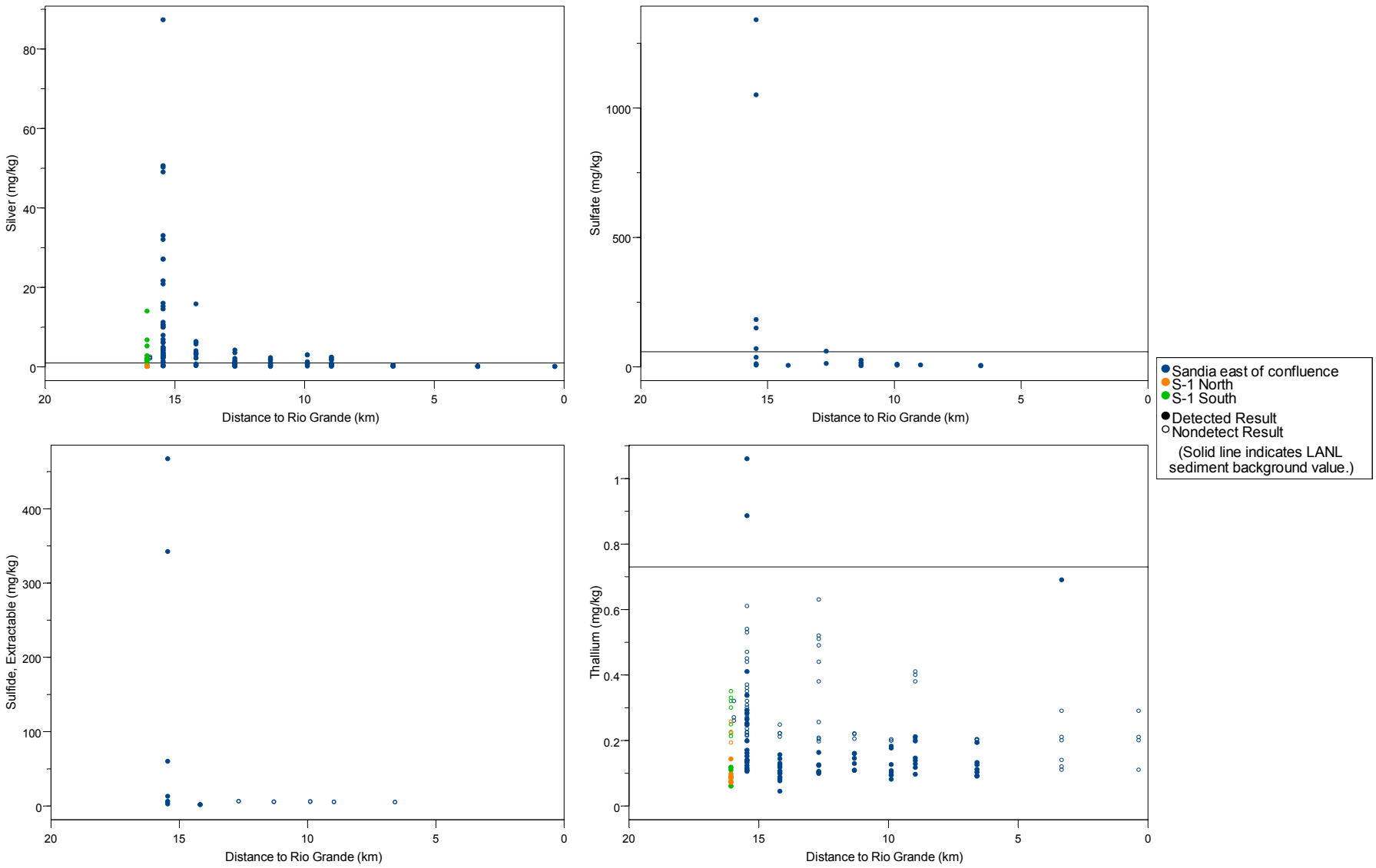


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

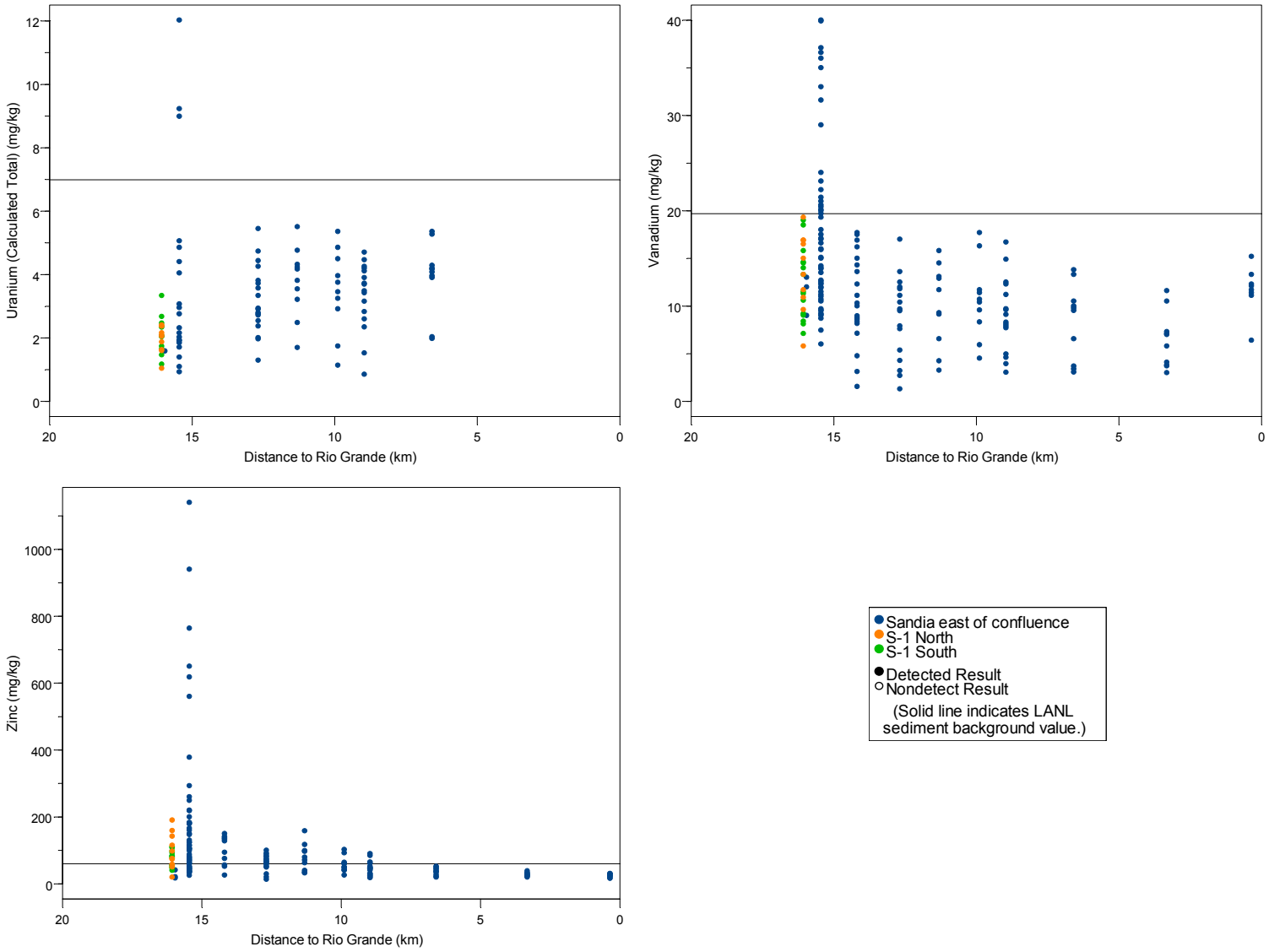


Figure D-1.1-1 (continued) Plots of sample results versus distance from the Rio Grande for all inorganic COPCs identified in sediment in the Sandia watershed

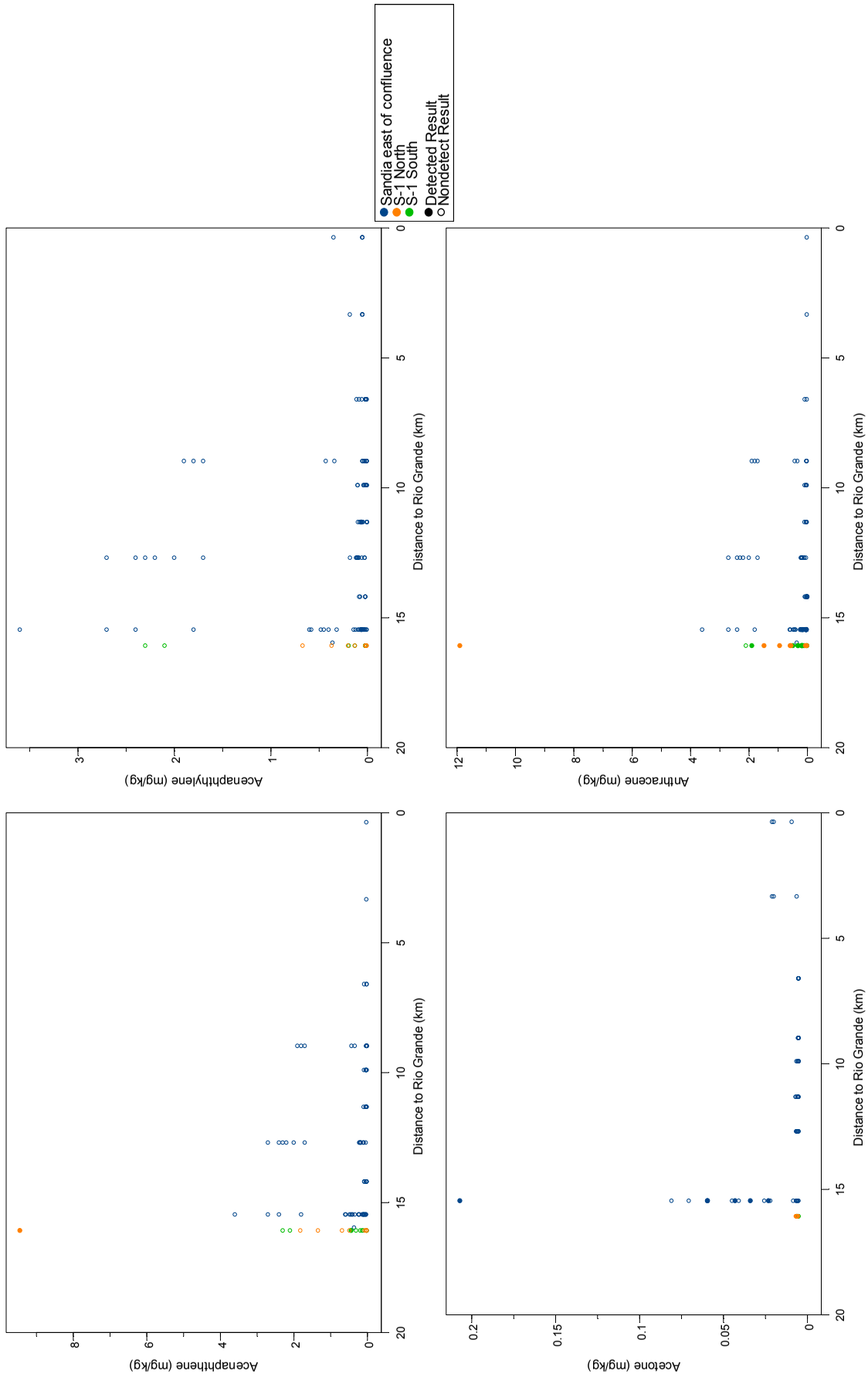


Figure D-1.1-2 Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

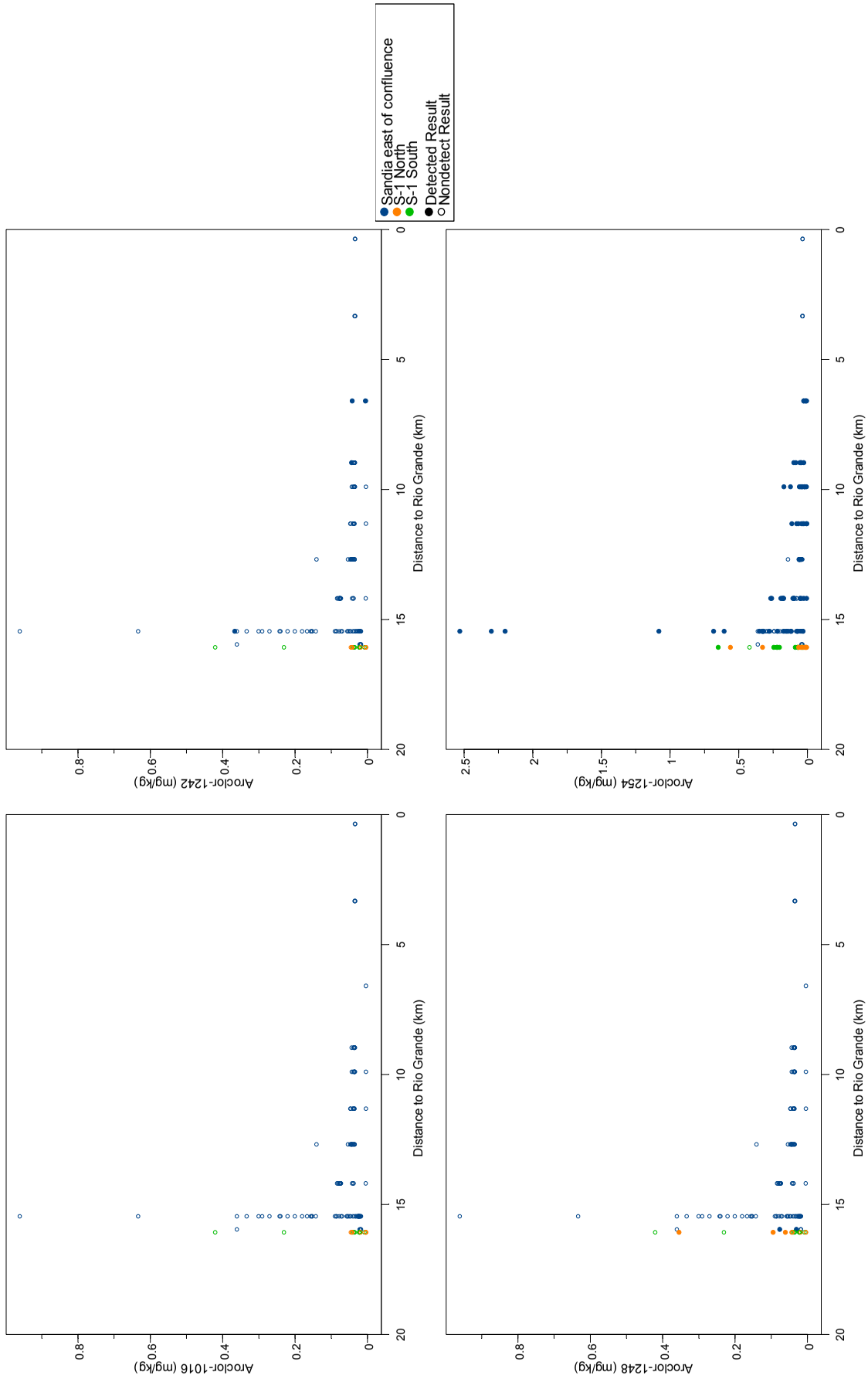


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

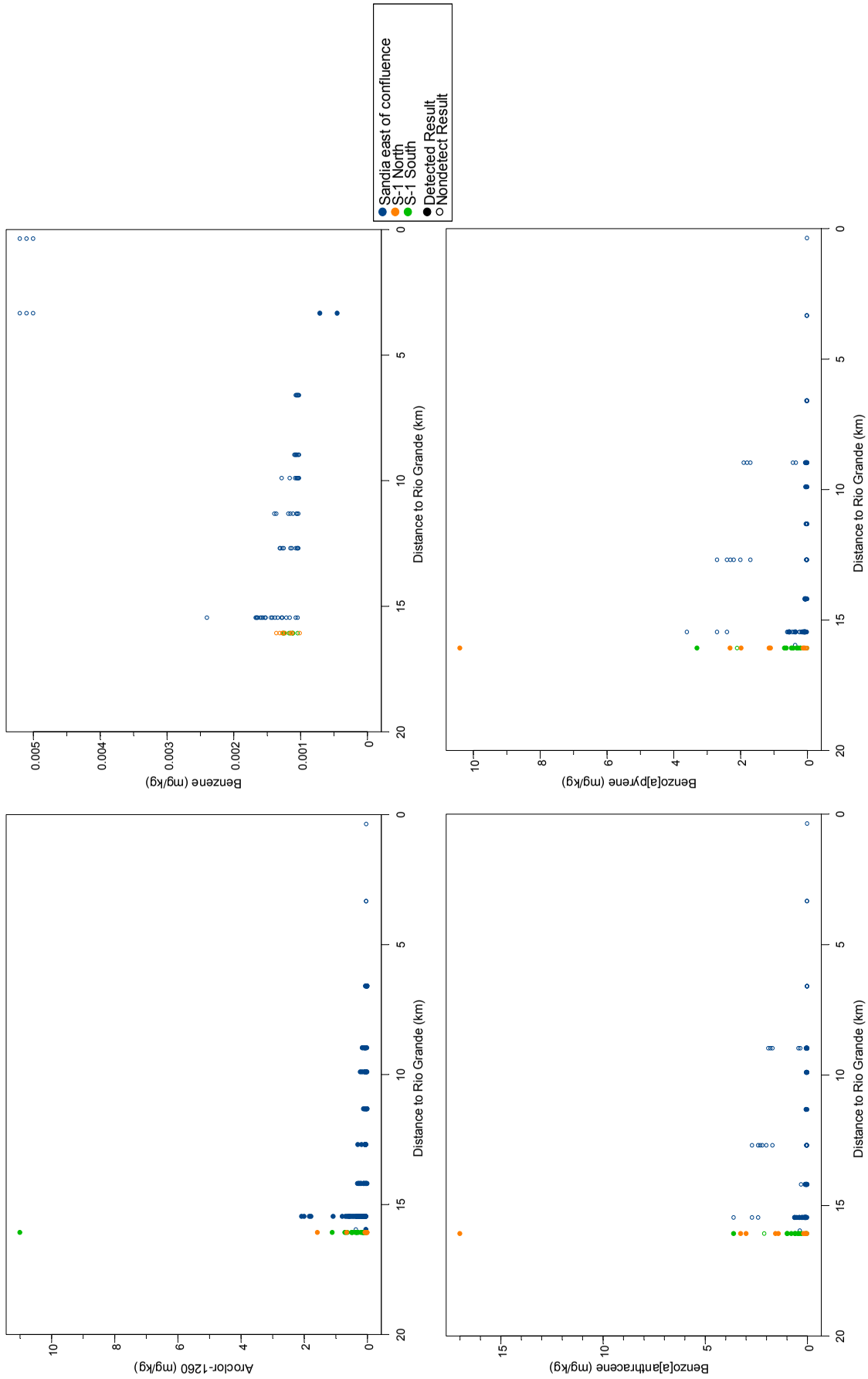


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

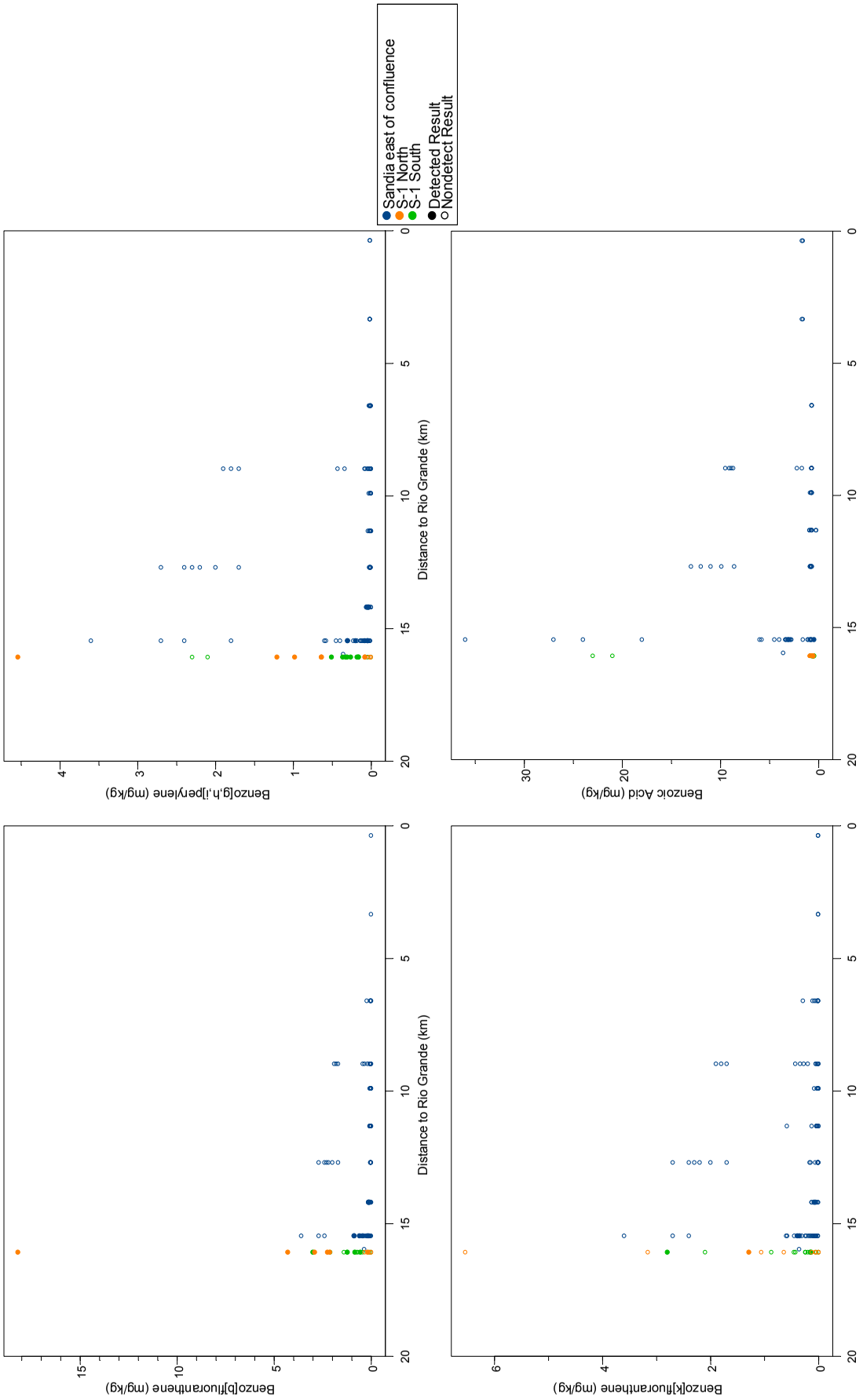


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

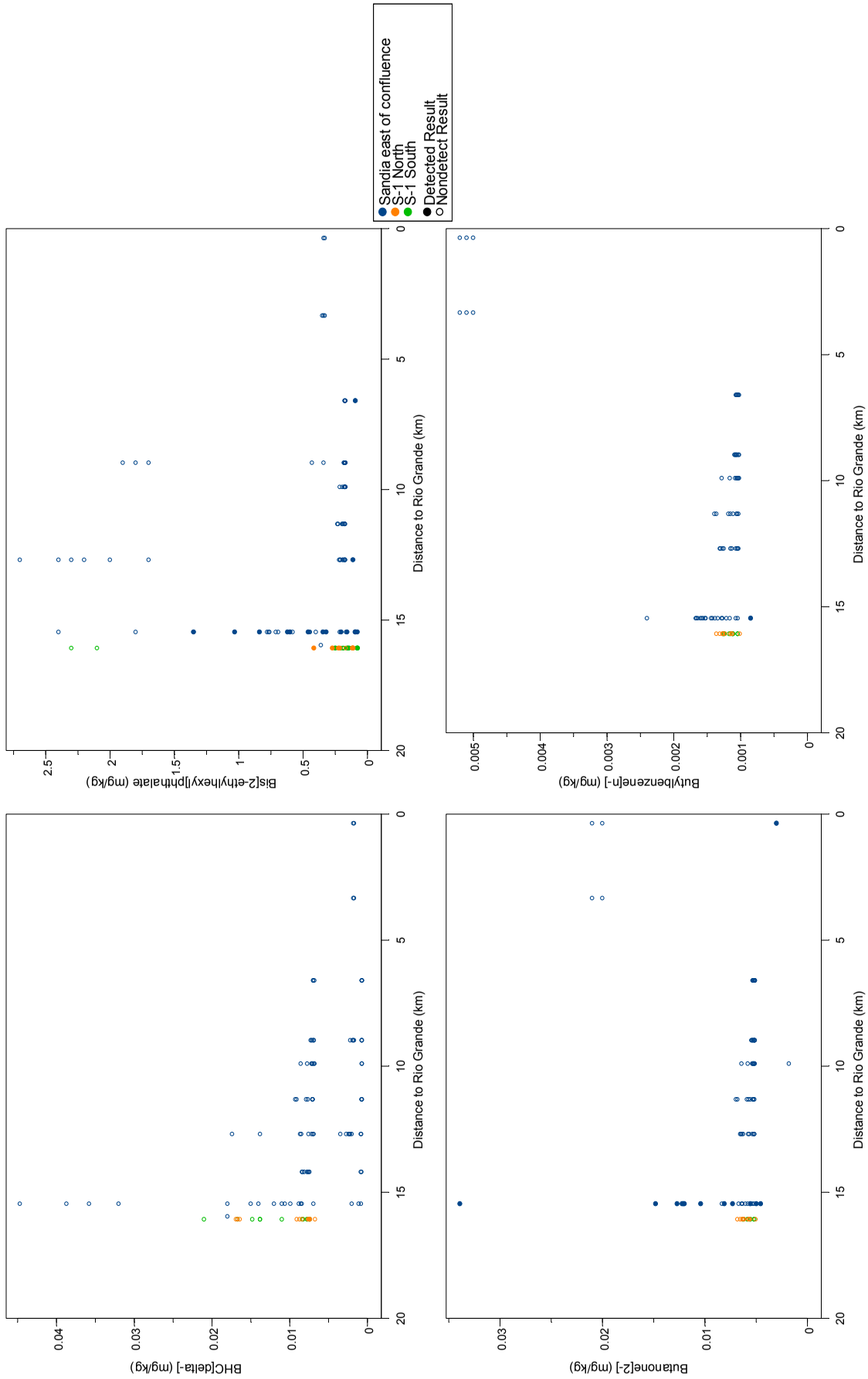


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

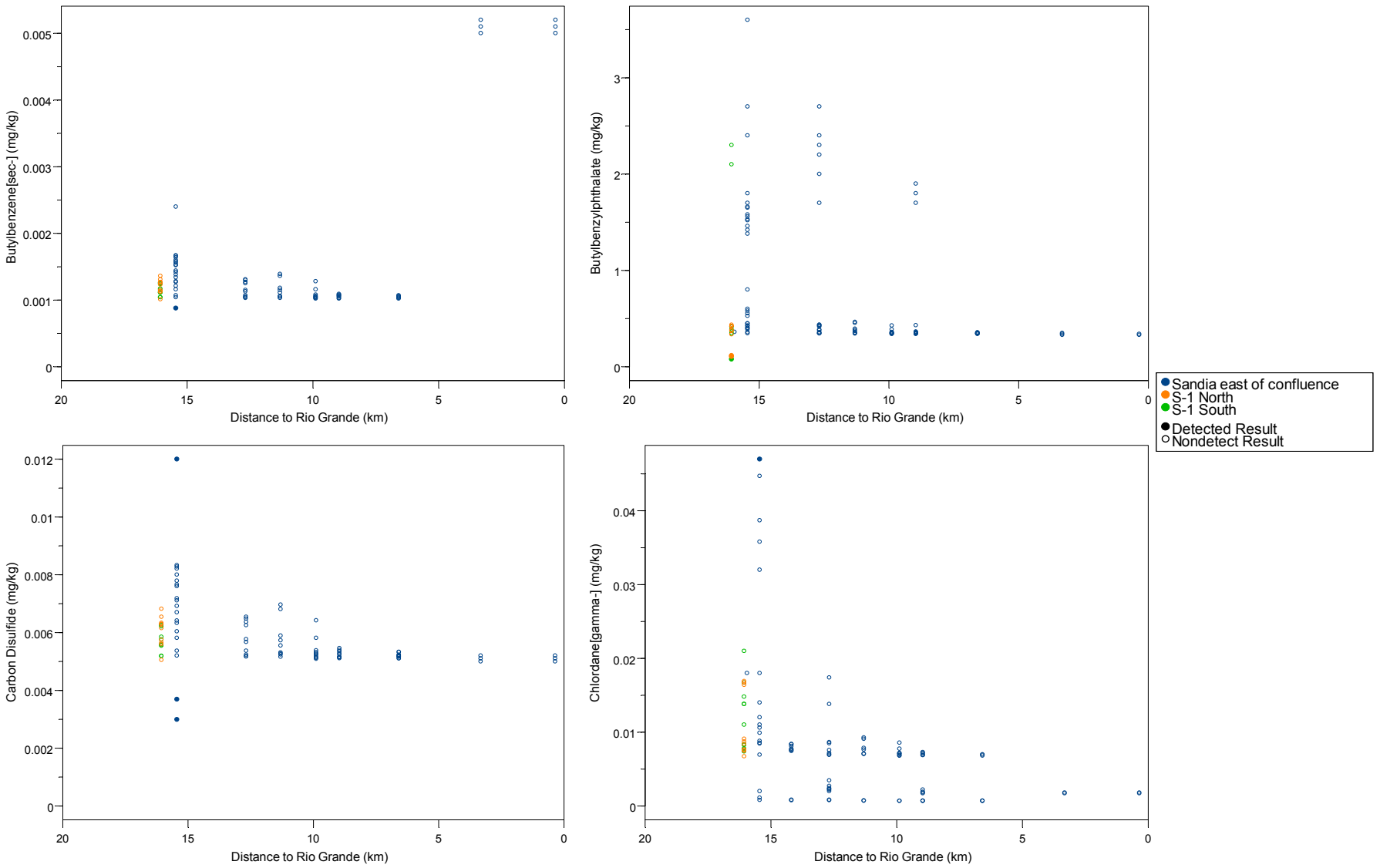


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

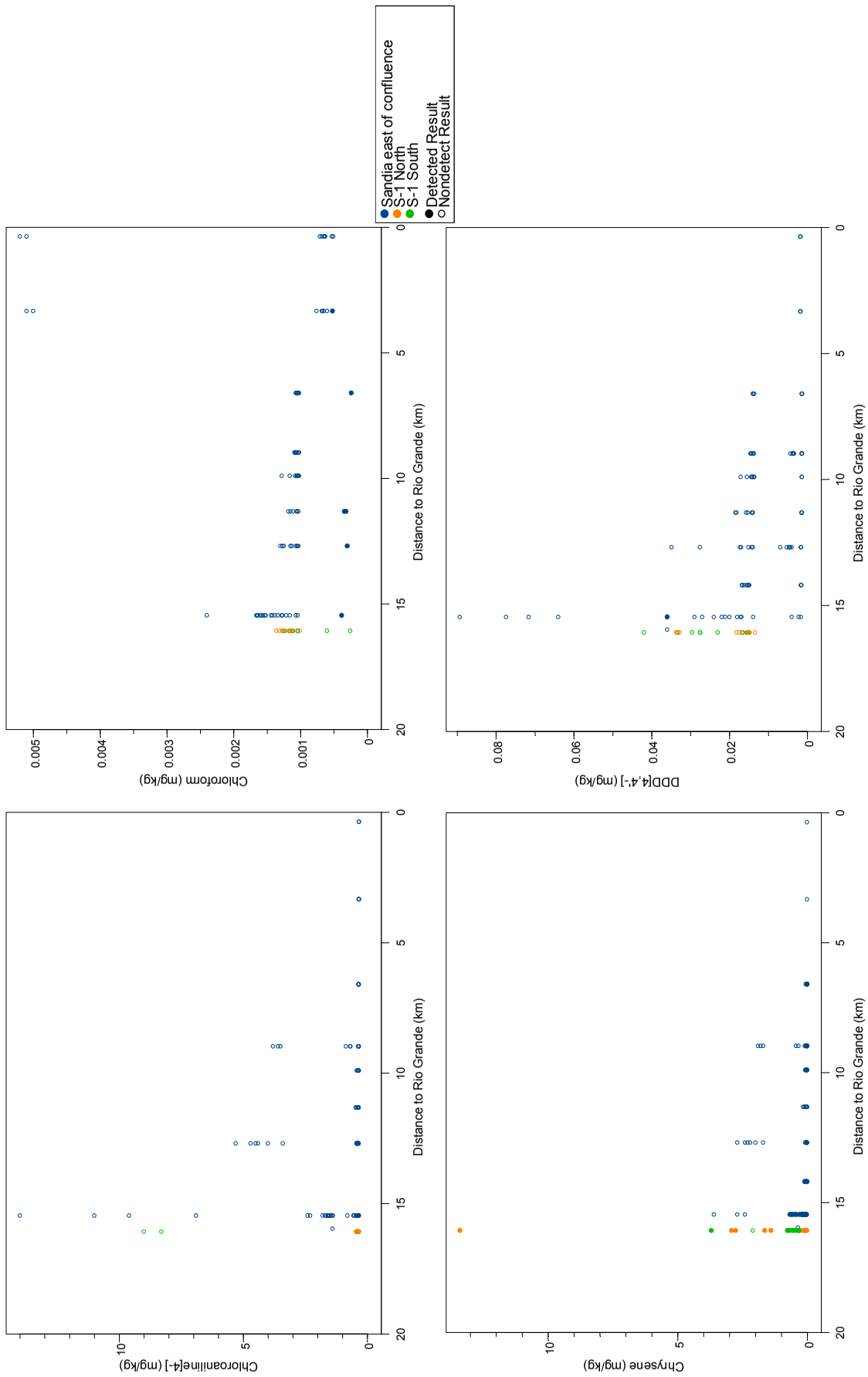


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

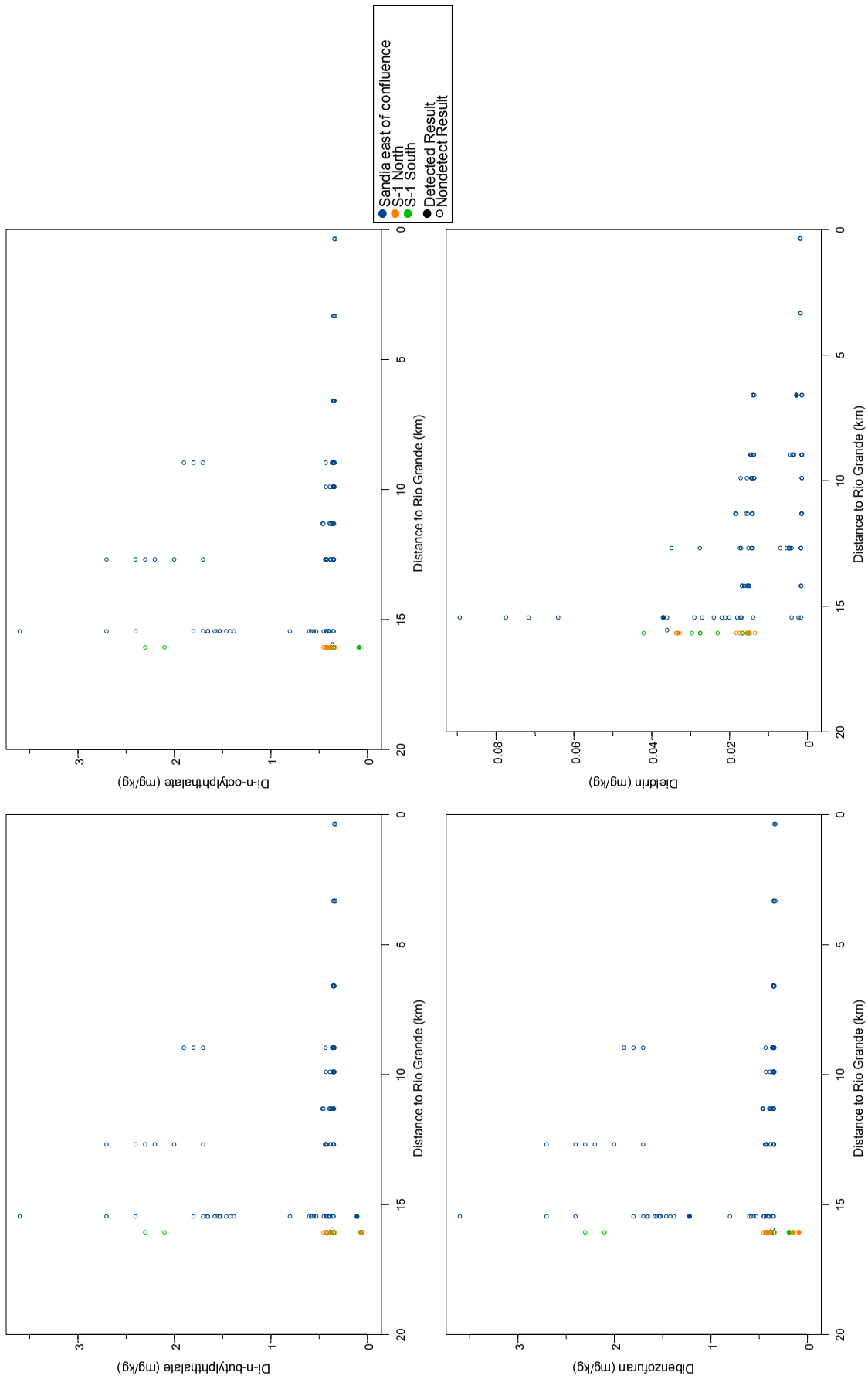


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

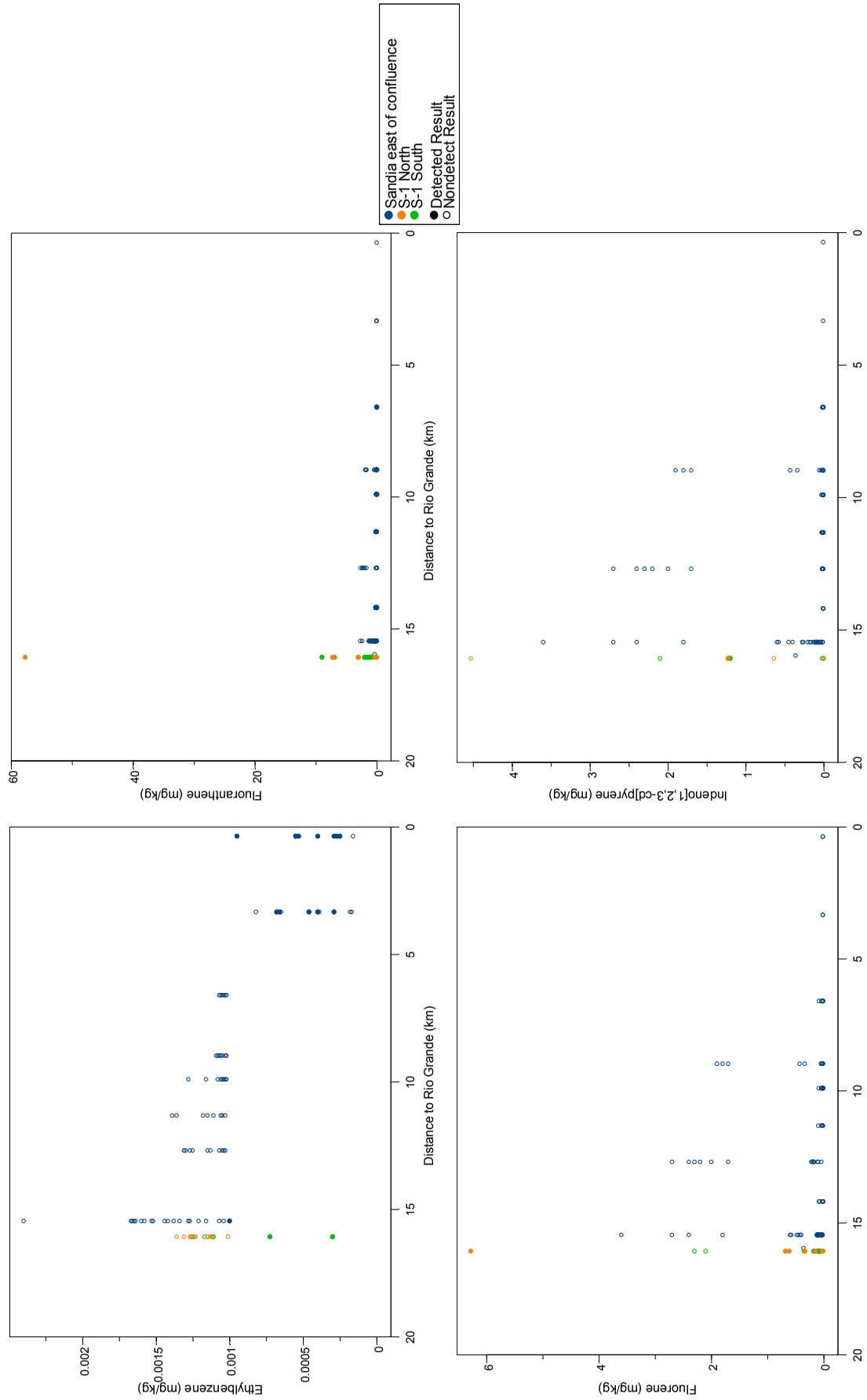


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

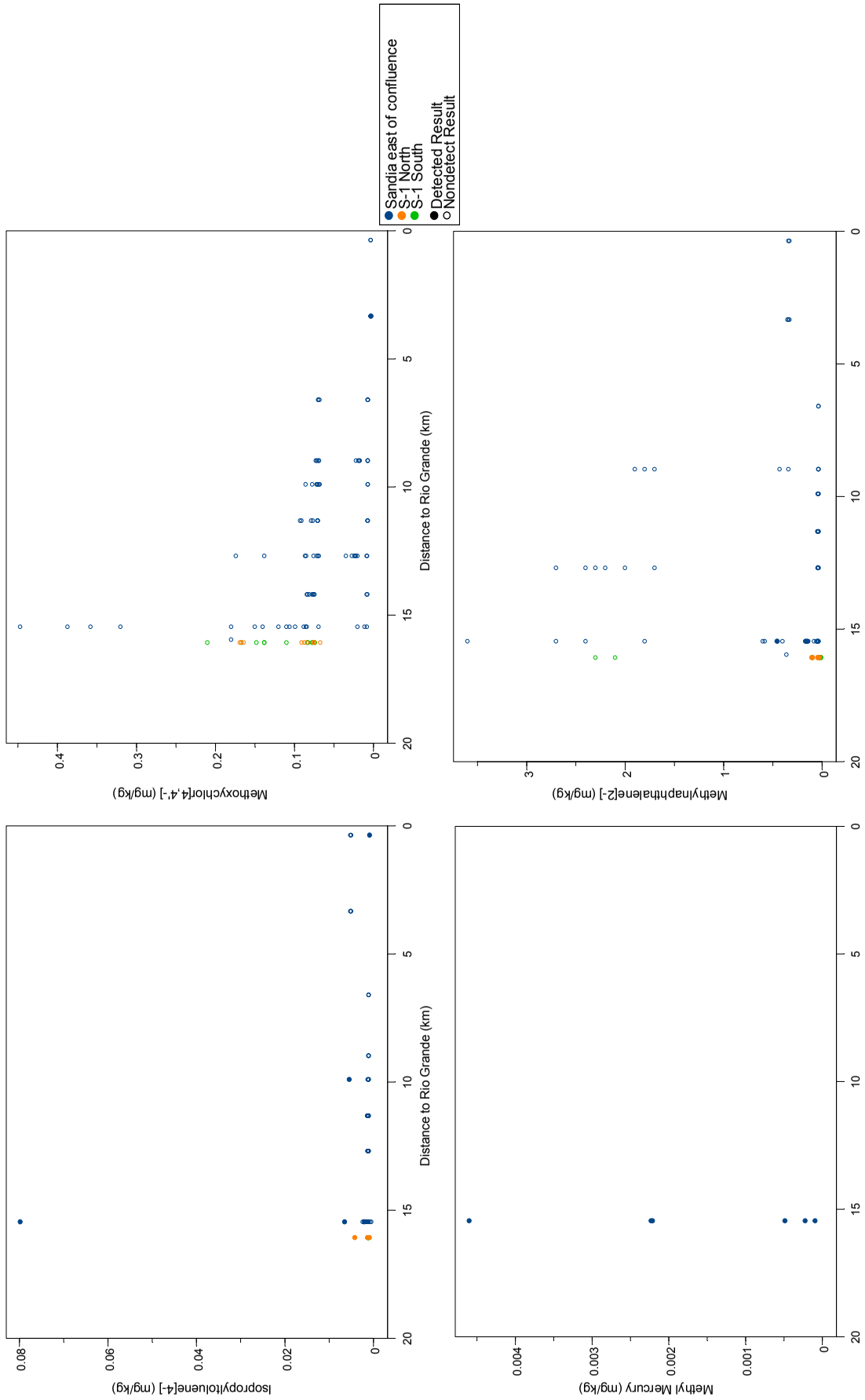


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

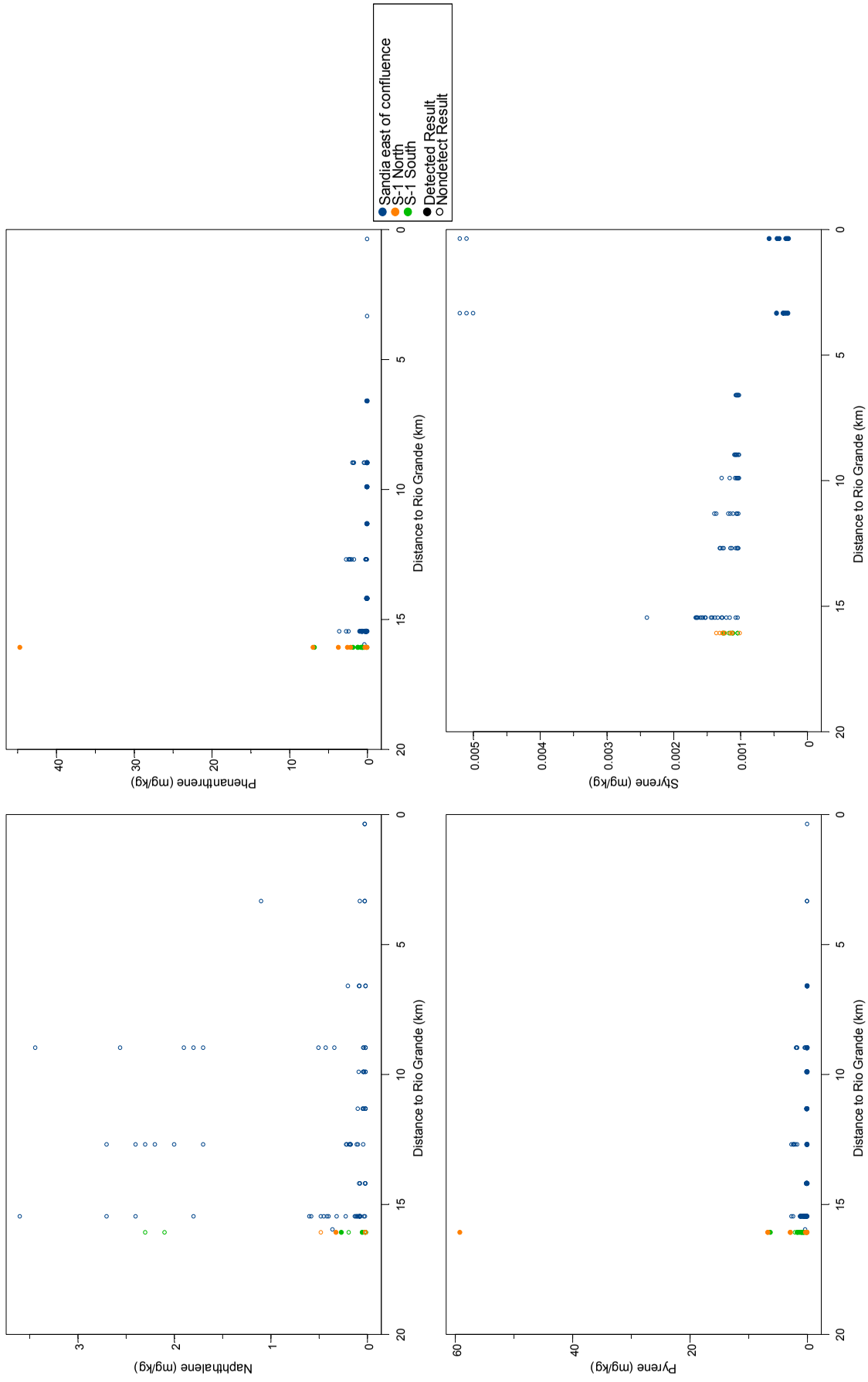


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

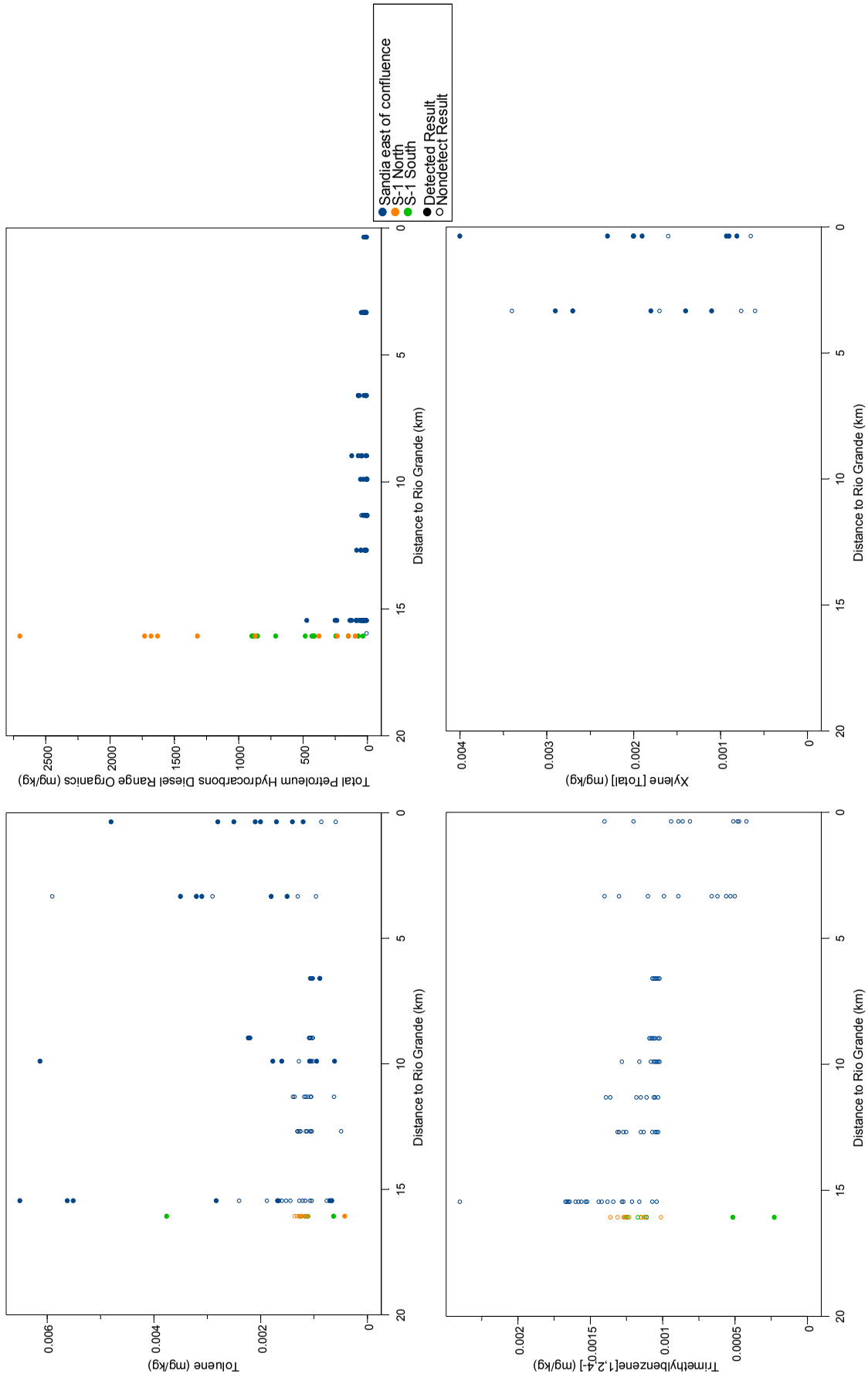


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

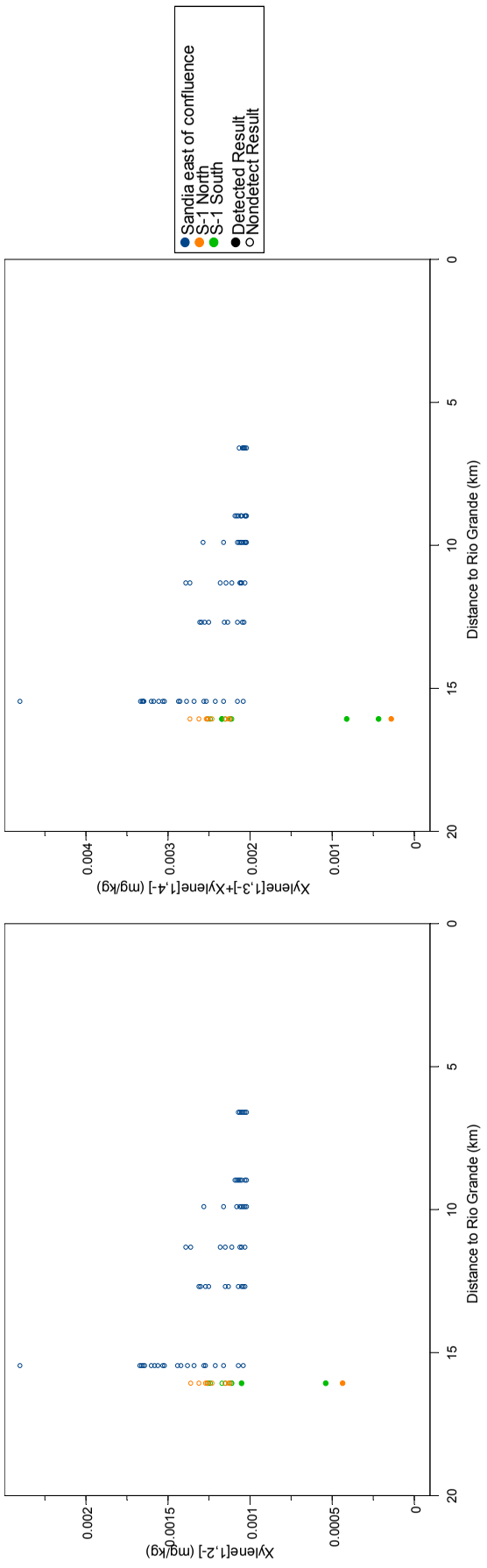


Figure D-1.1-2 (continued) Plots of sample results versus distance from the Rio Grande for all organic COPCs identified in sediment in the Sandia watershed

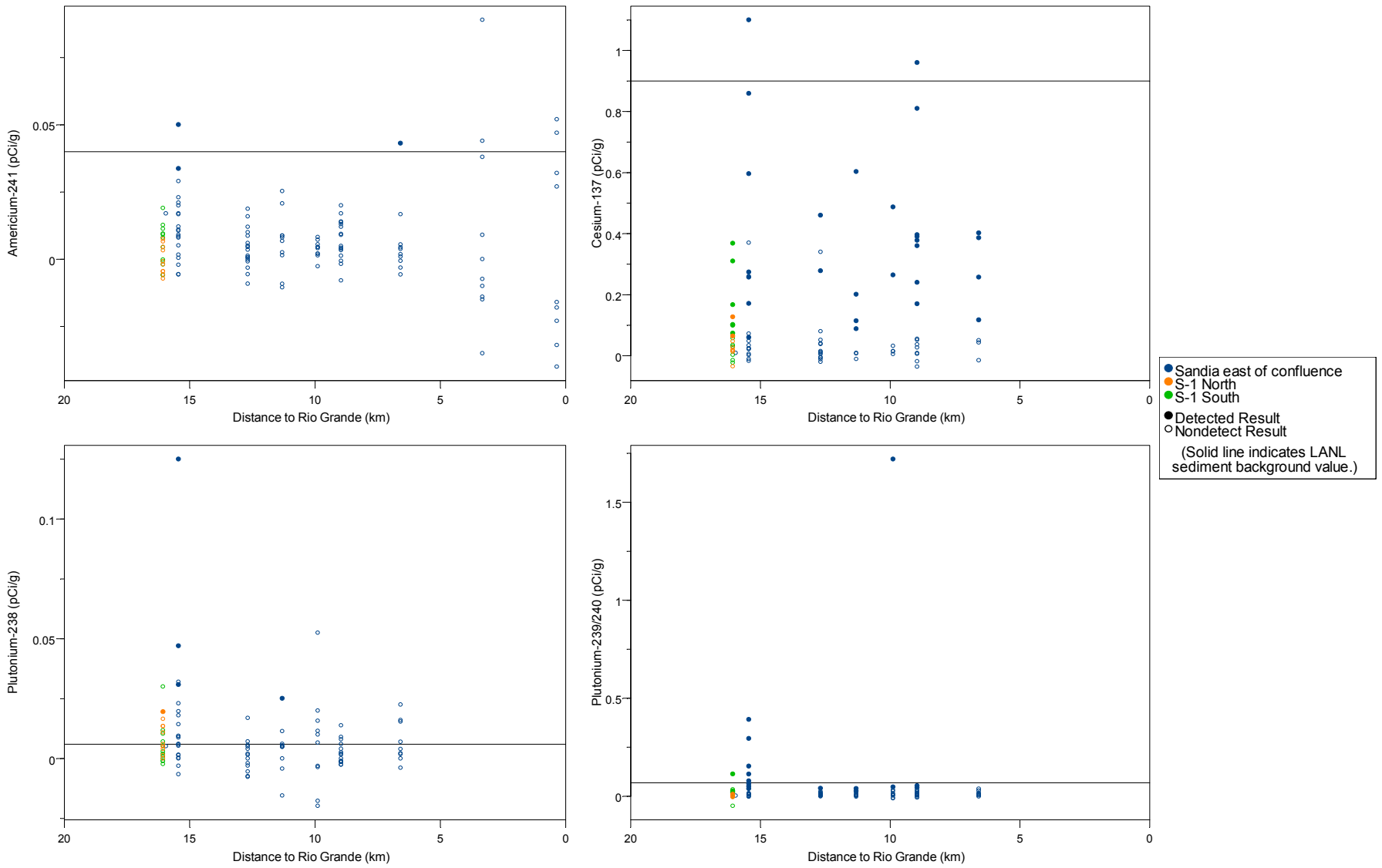


Figure D-1.1-3 Plots of sample results versus distance from the Rio Grande for all radionuclide COPCs identified in sediment in the Sandia watershed

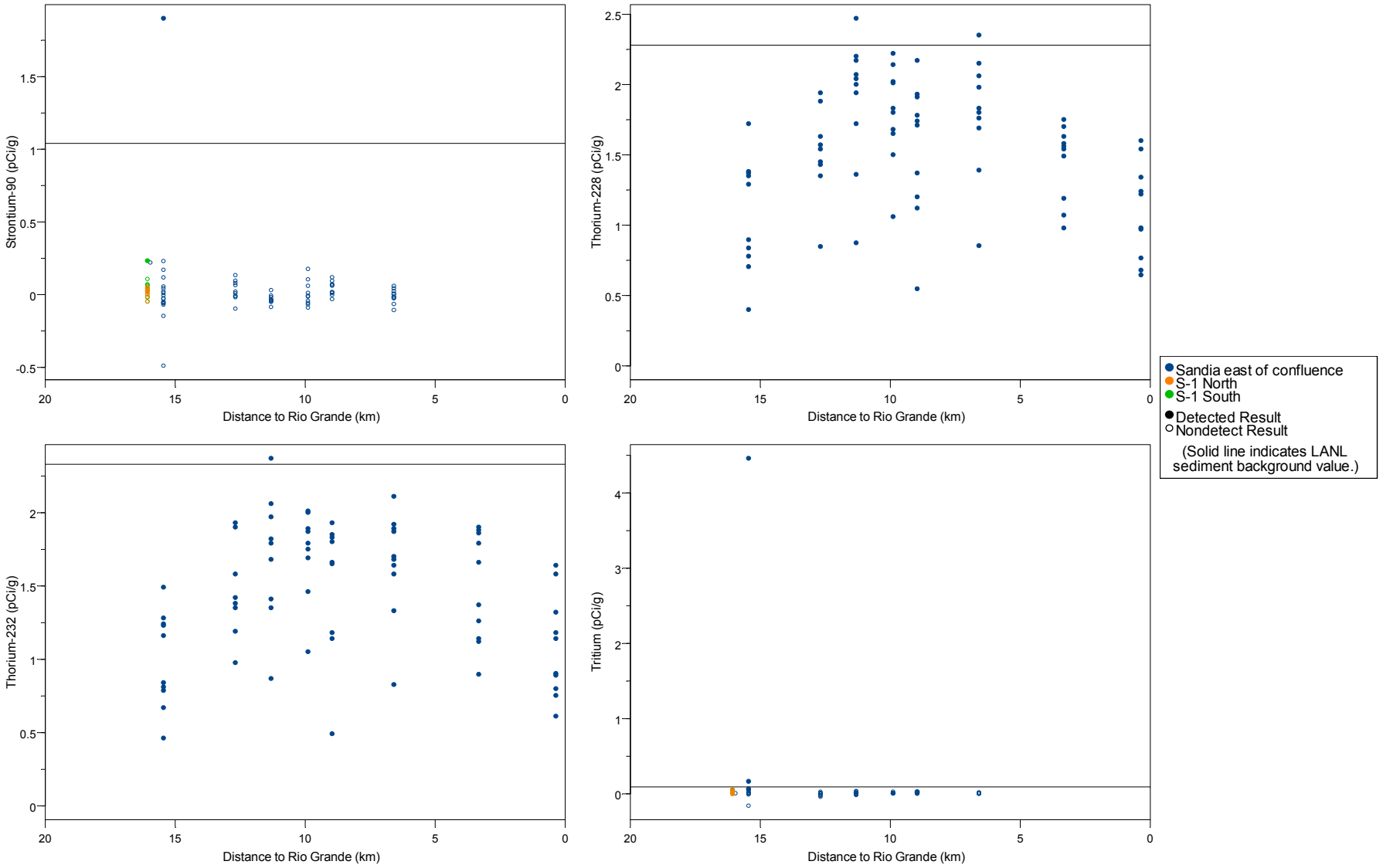


Figure D-1.1-3 (continued) Plots of sample results versus distance from the Rio Grande for all radionuclide COPCs identified in sediment in the Sandia watershed

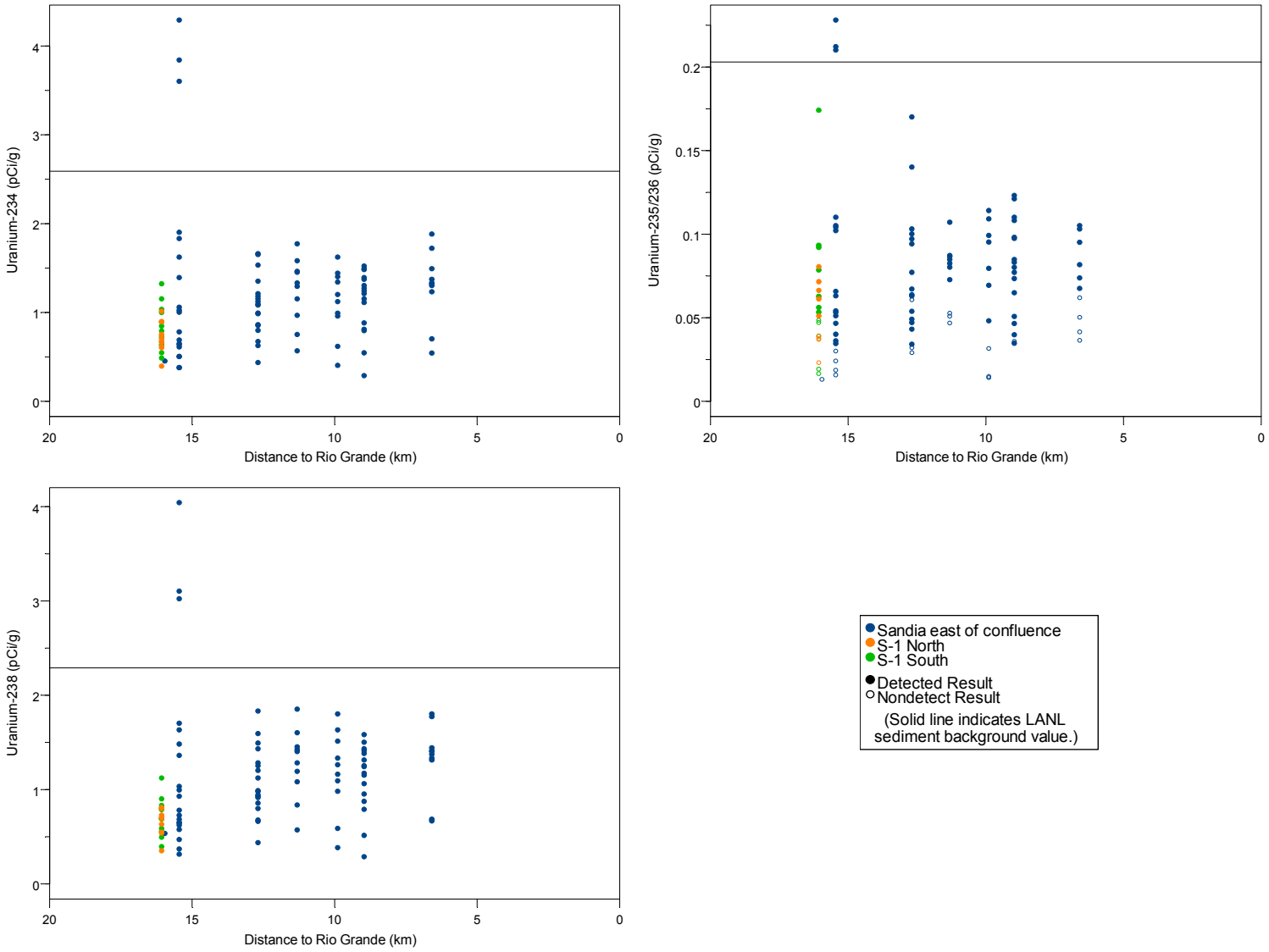


Figure D-1.1-3 (continued) Plots of sample results versus distance from the Rio Grande for all radionuclide COPCs identified in sediment in the Sandia watershed

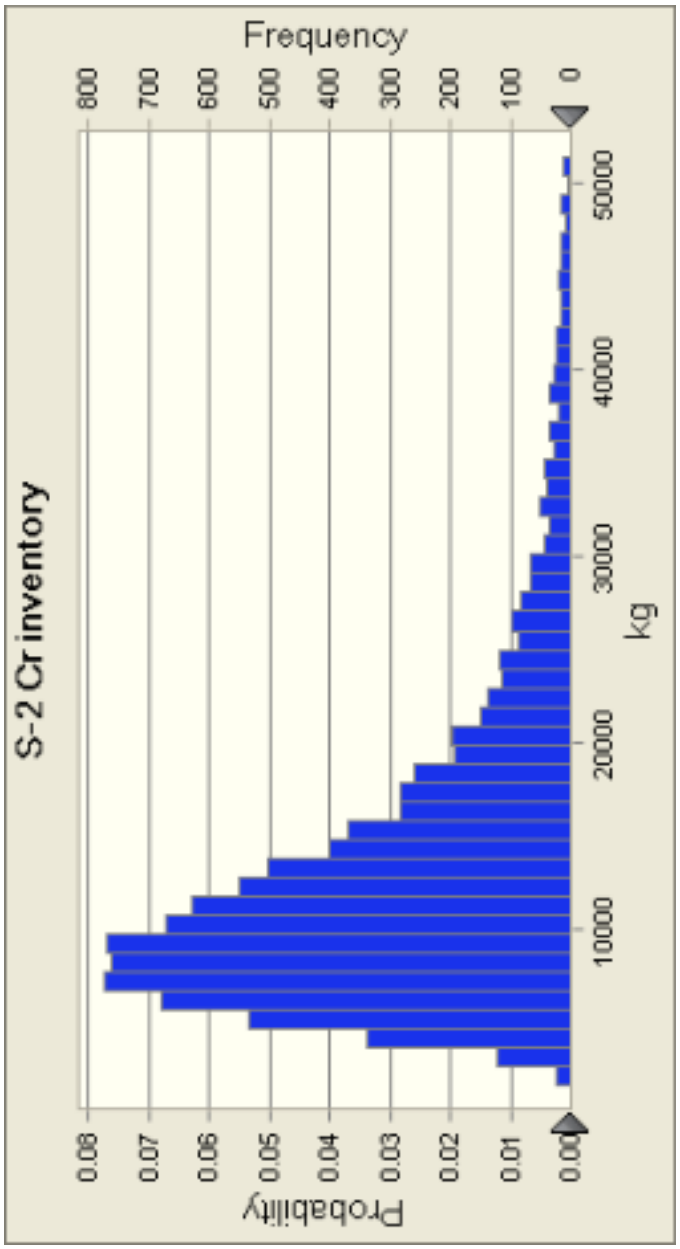
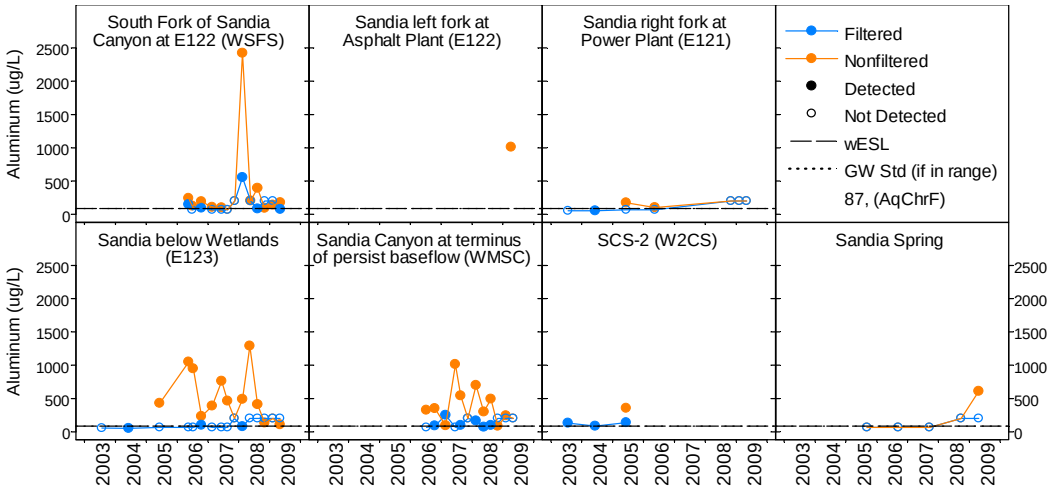
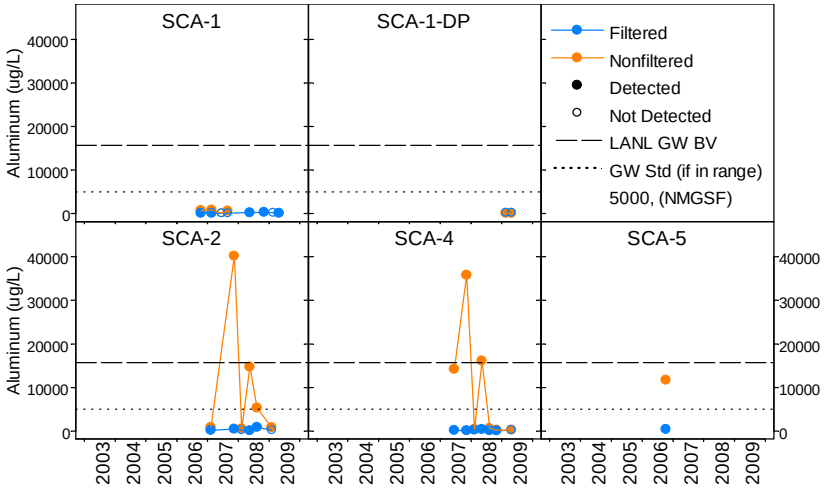


Figure D-1.3-1 Uncertainties in chromium inventory in reach S-2 using Monte Carlo simulations (n = 10,000; Crystal Ball software)

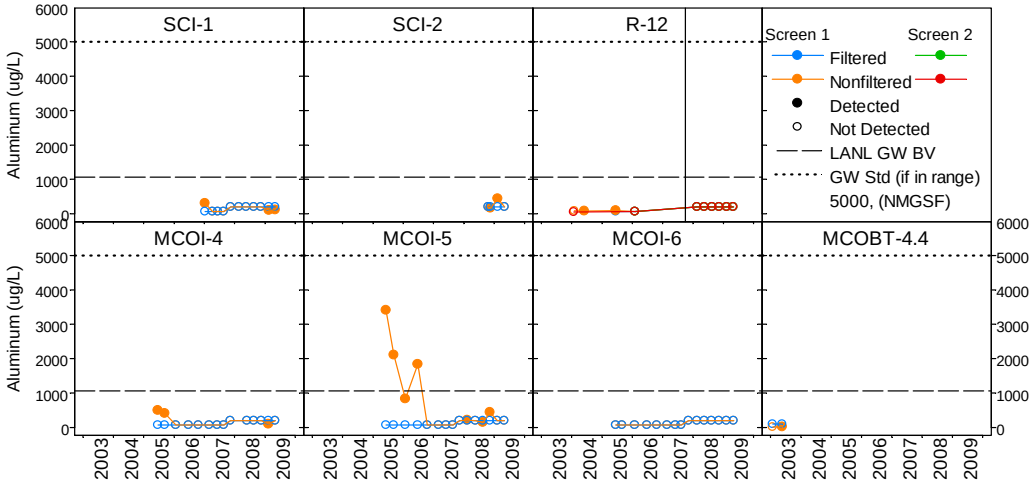


a. Aluminum in nonstorm-related surface water in Sandia Canyon.

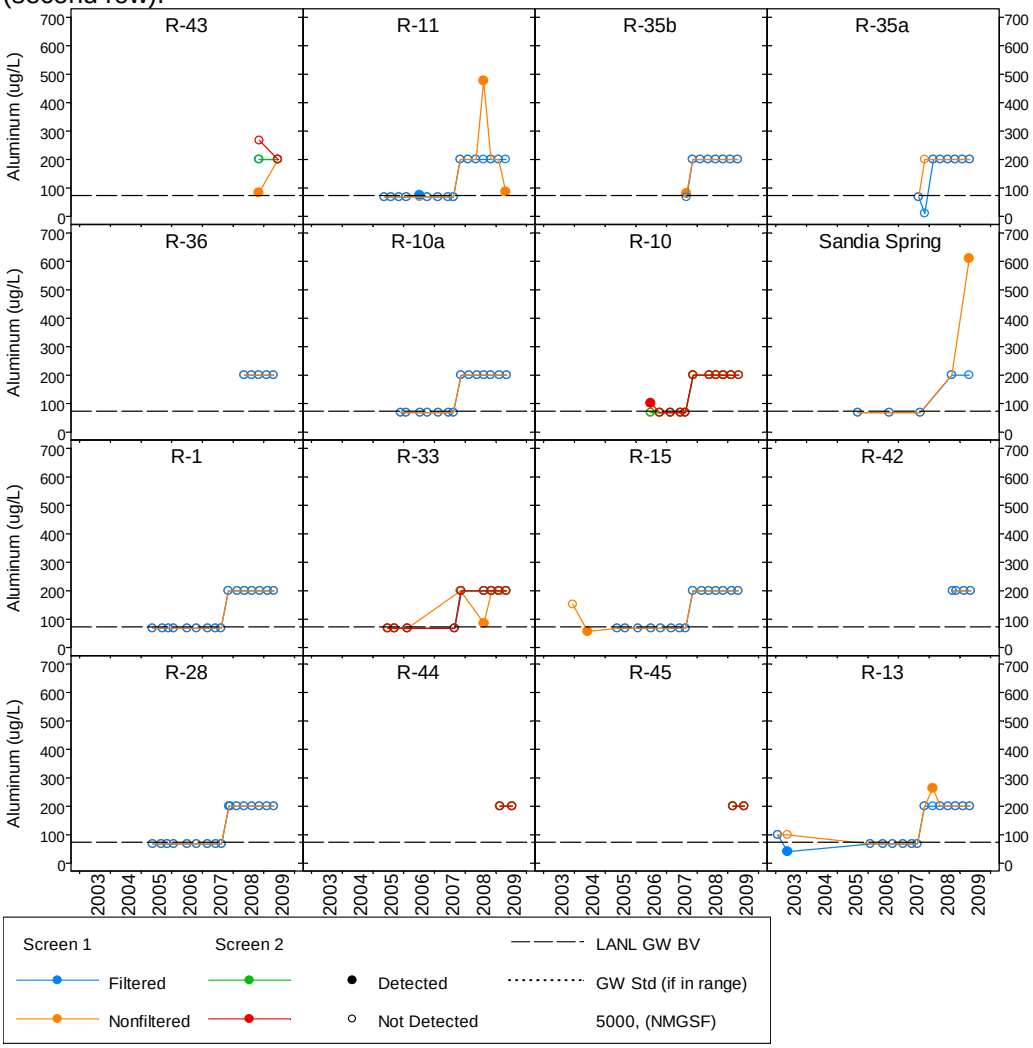


a. Aluminum in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

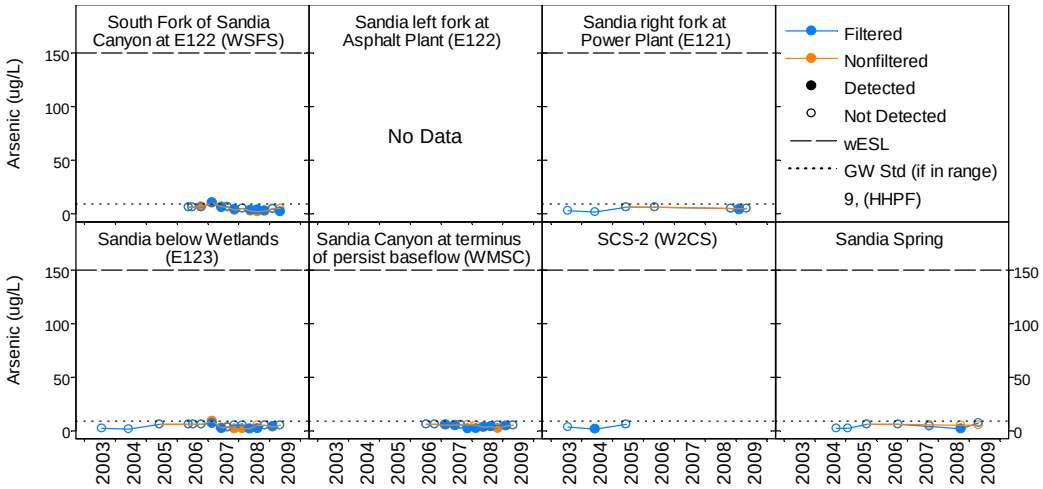


a. Aluminum in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

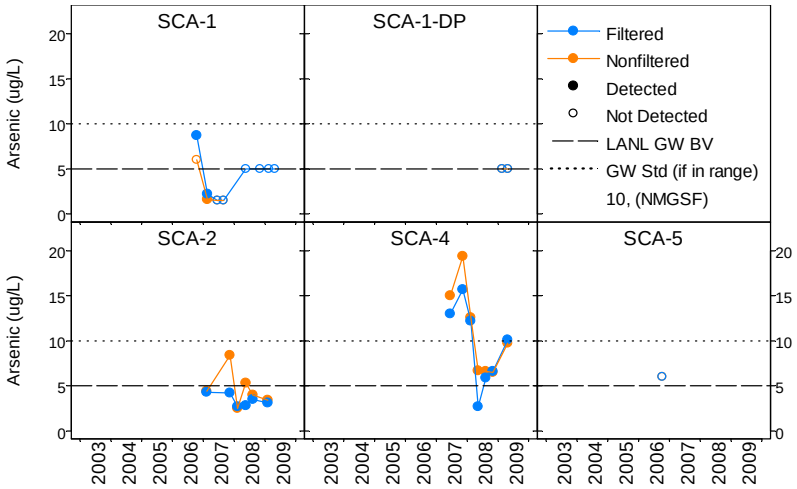


a. Aluminum in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

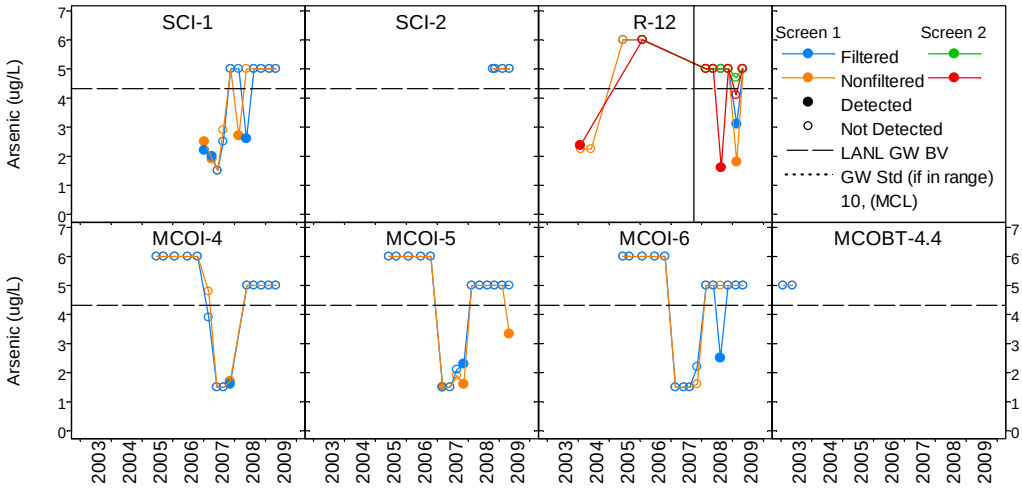


b. Arsenic in nonstorm-related surface water in Sandia Canyon.

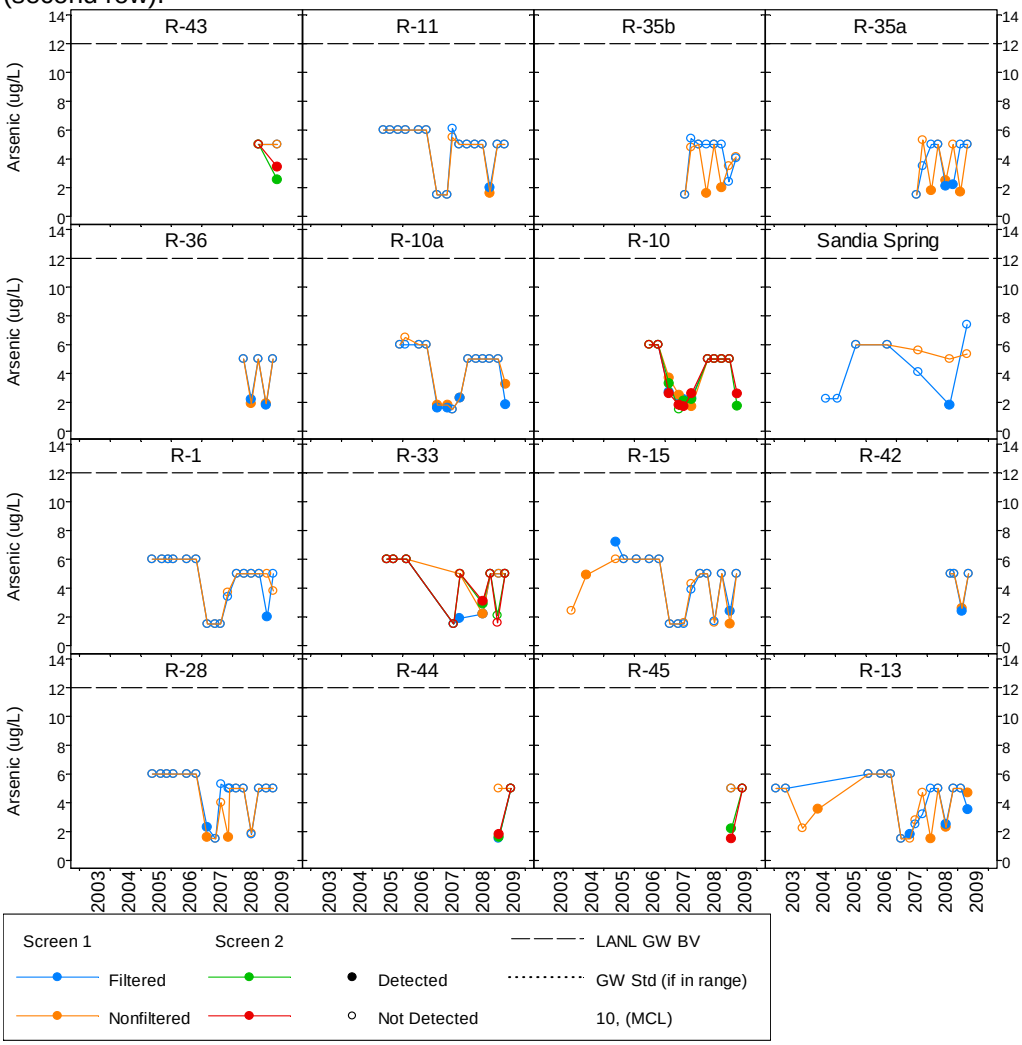


b. Arsenic in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

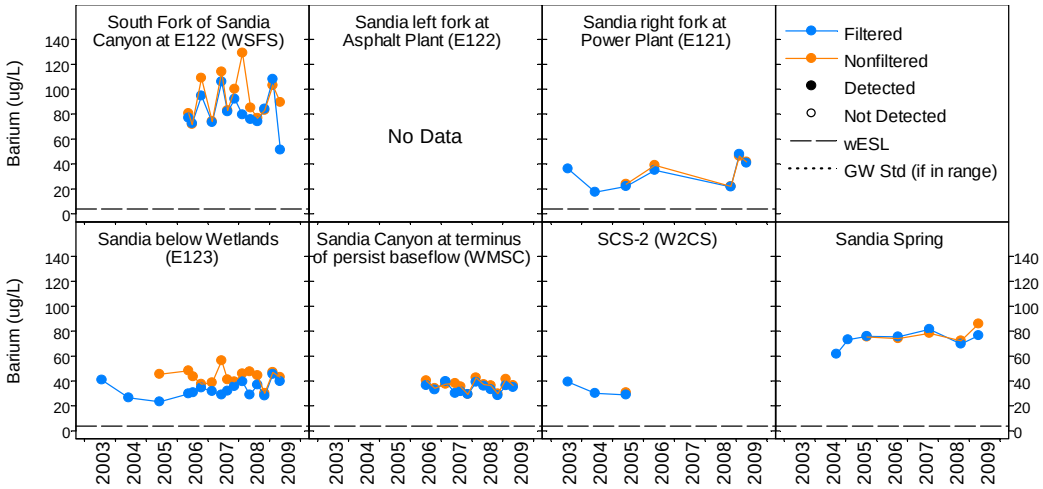


b. Arsenic in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

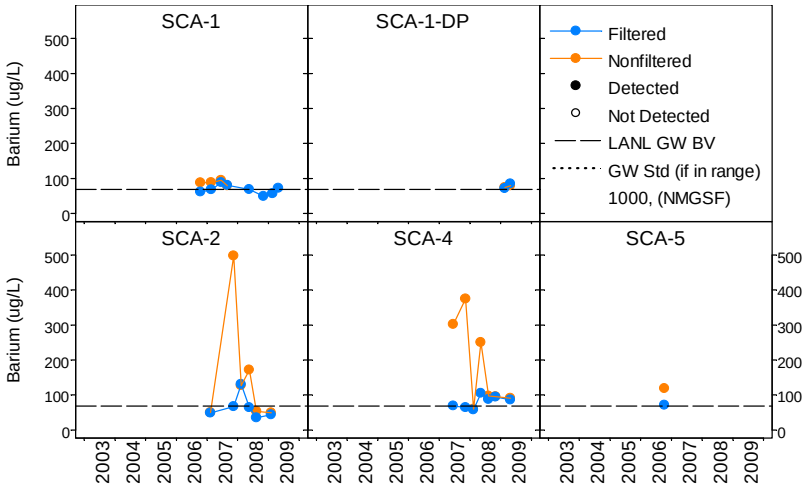


b. "Arsenic in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

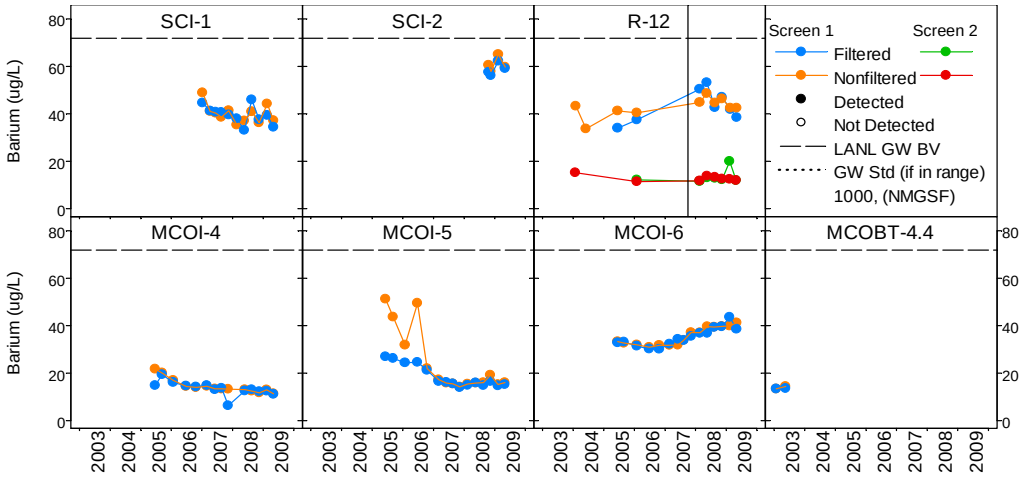


c. Barium in nonstorm-related surface water in Sandia Canyon.

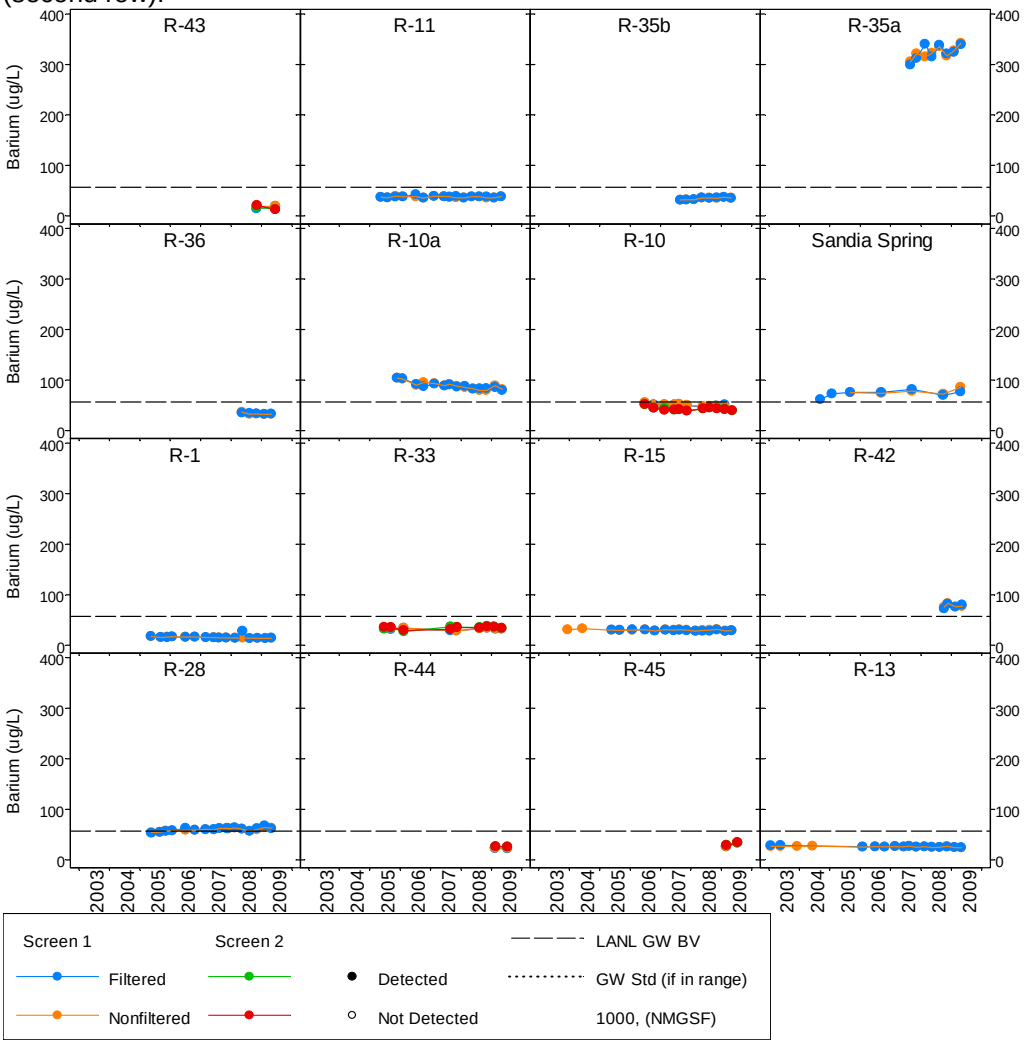


c. Barium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

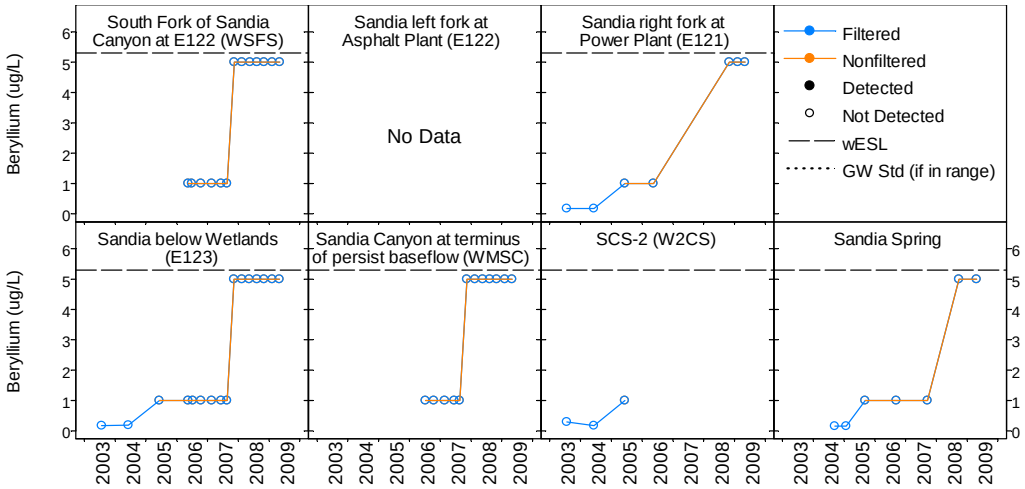


c. Barium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

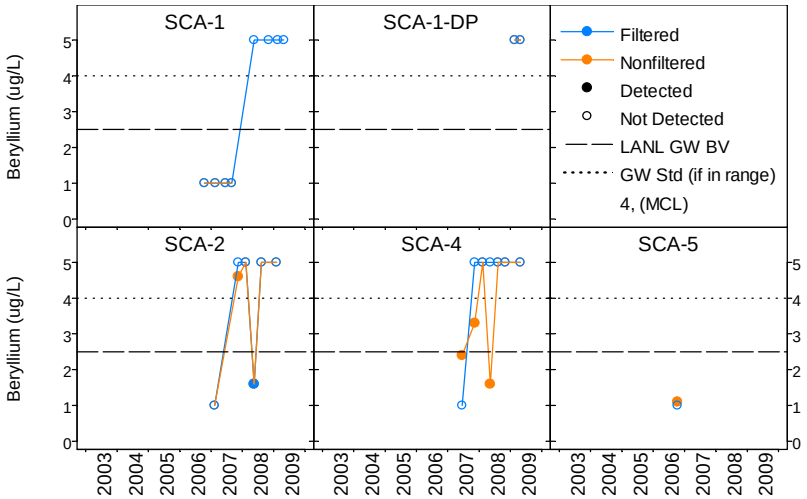


c. Barium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

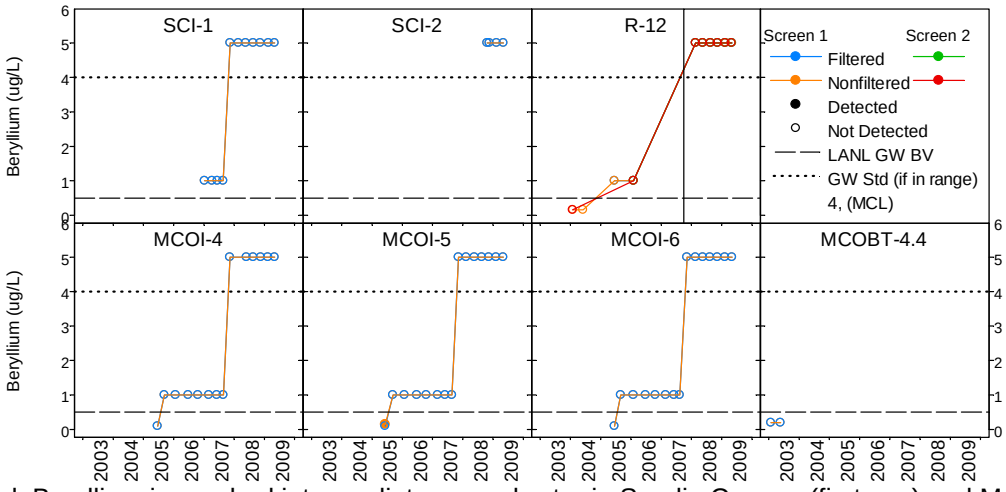


d. Beryllium in nonstorm-related surface water in Sandia Canyon.

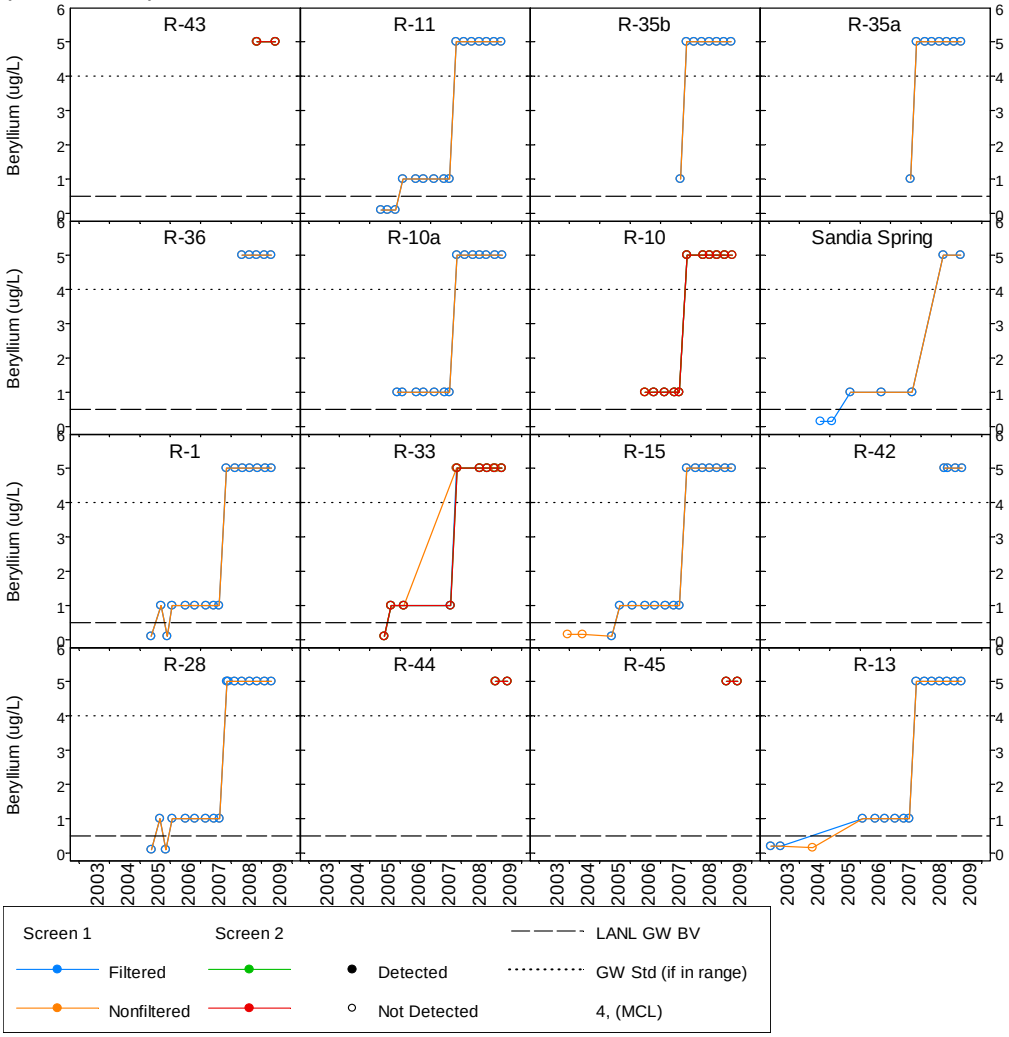


d. Beryllium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

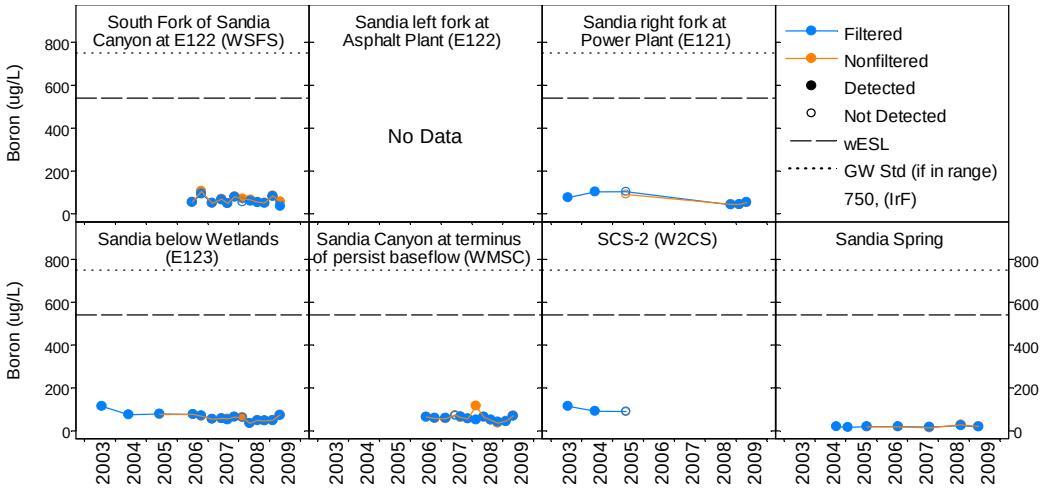


d. Beryllium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

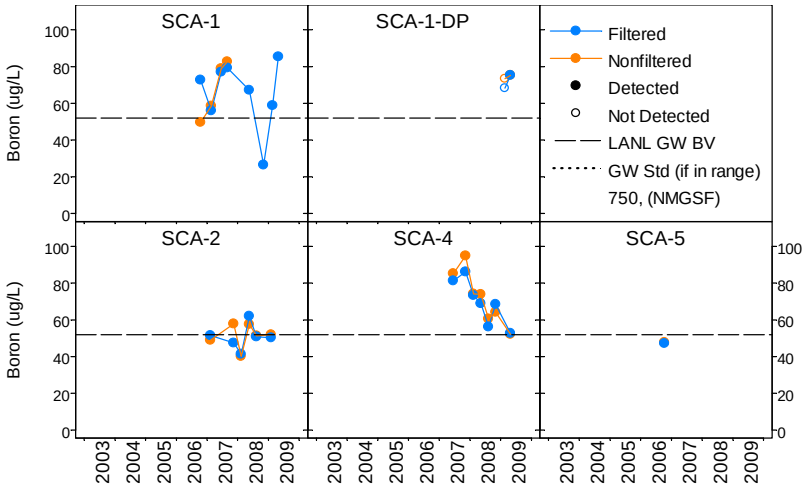


d. Beryllium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

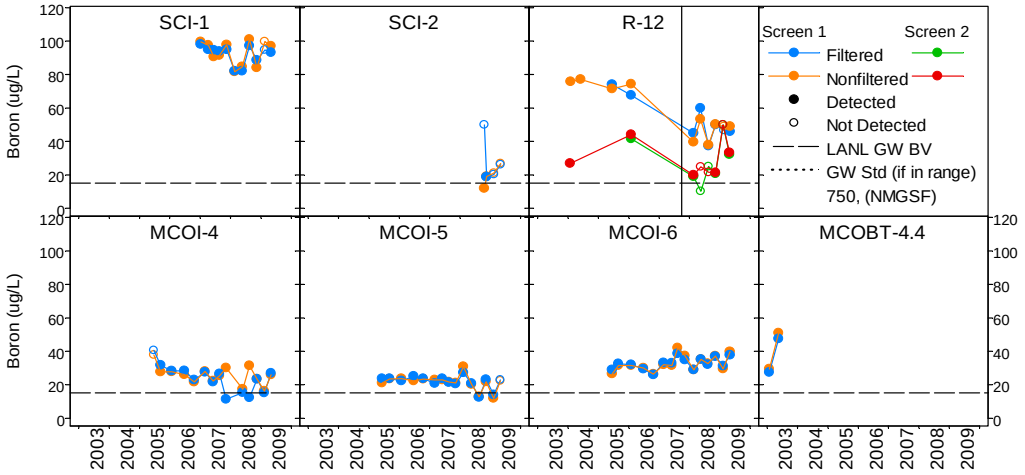


e. Boron in nonstorm-related surface water in Sandia Canyon.

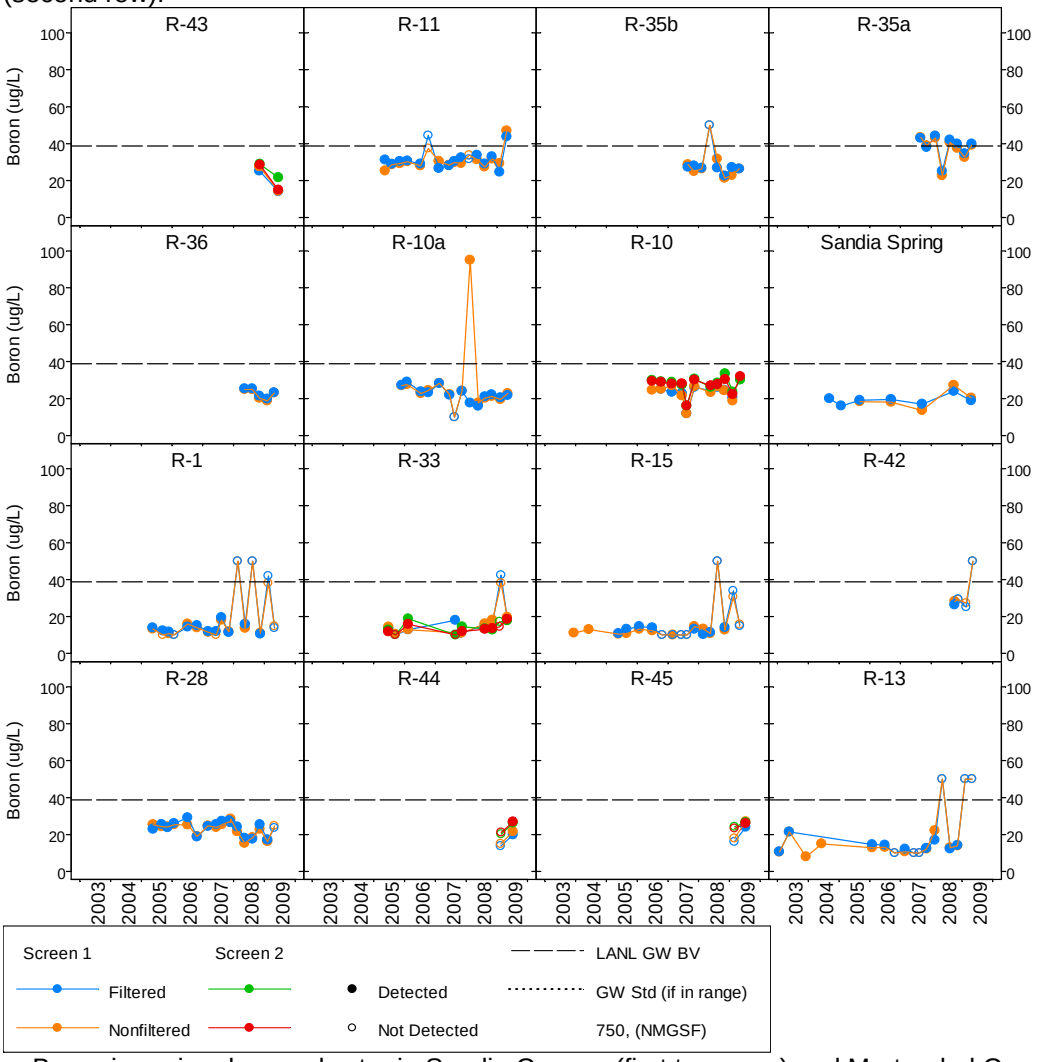


e. Boron in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

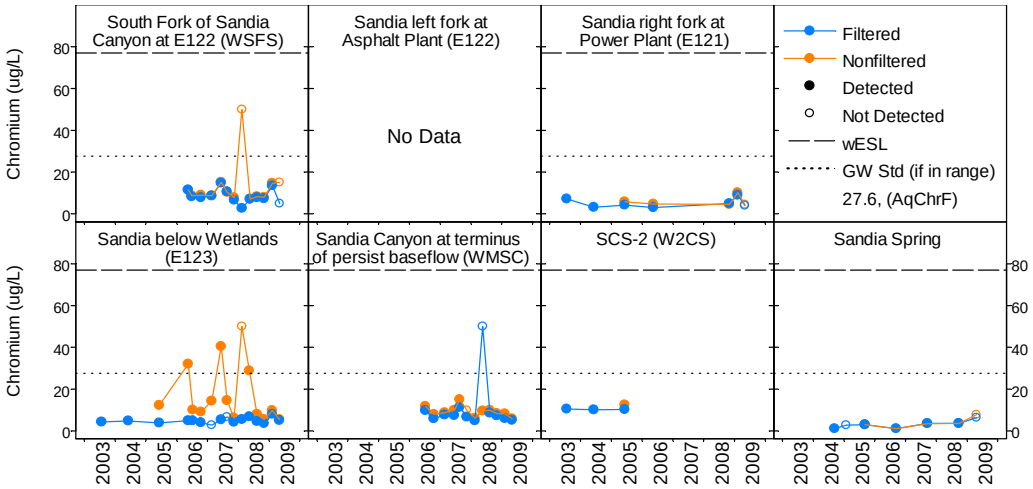


e. Boron in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

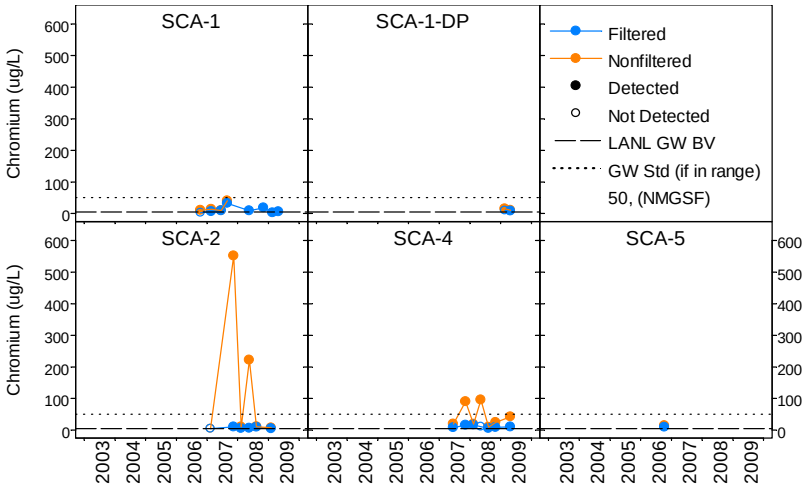


e. Boron in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

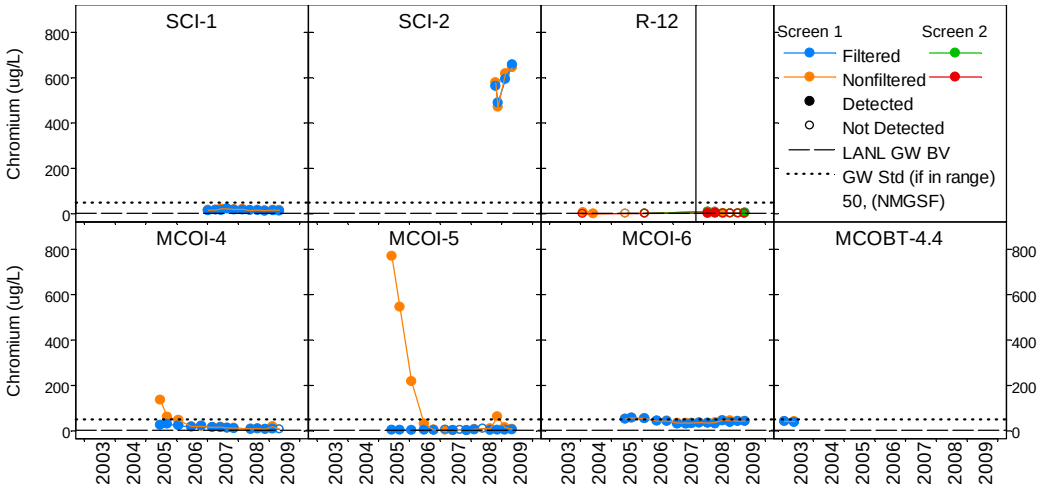


f. Chromium in nonstorm-related surface water in Sandia Canyon.

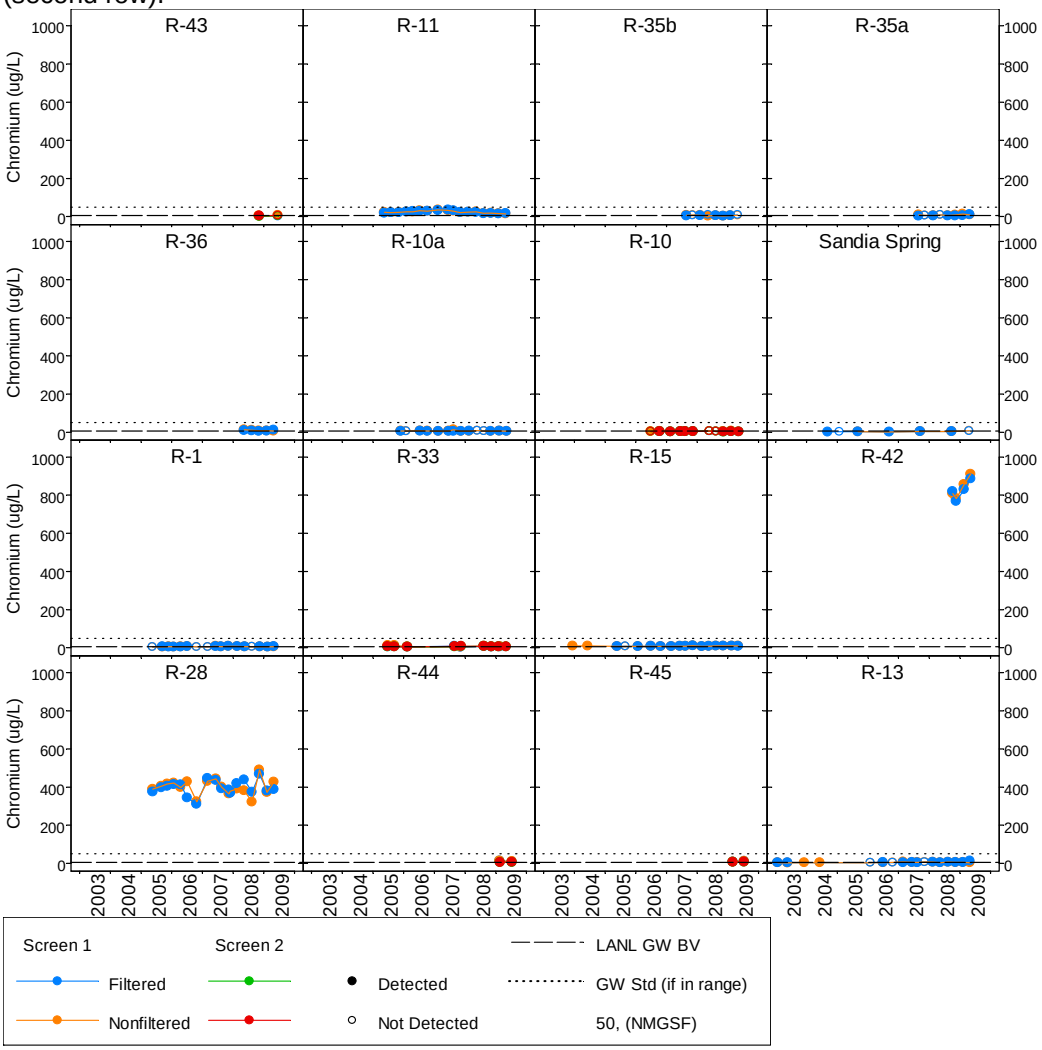


f. Chromium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

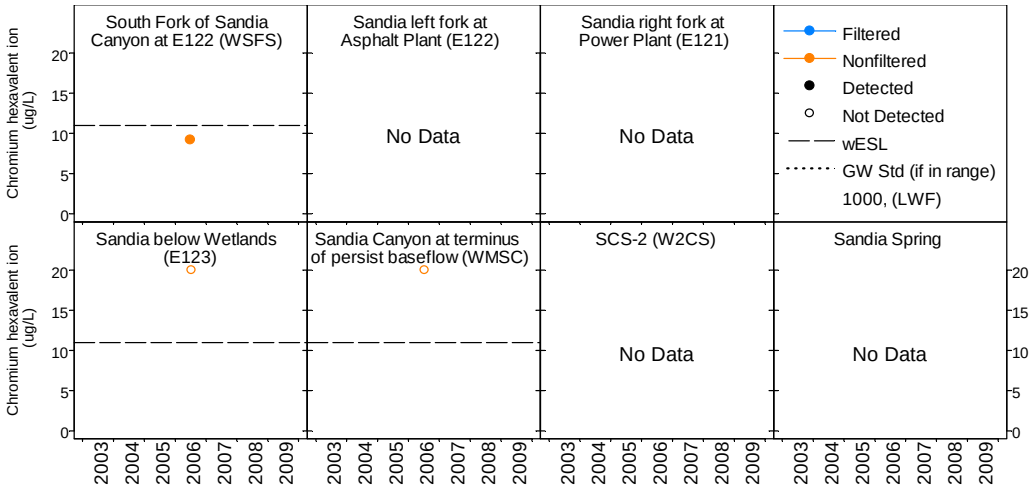


f. Chromium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

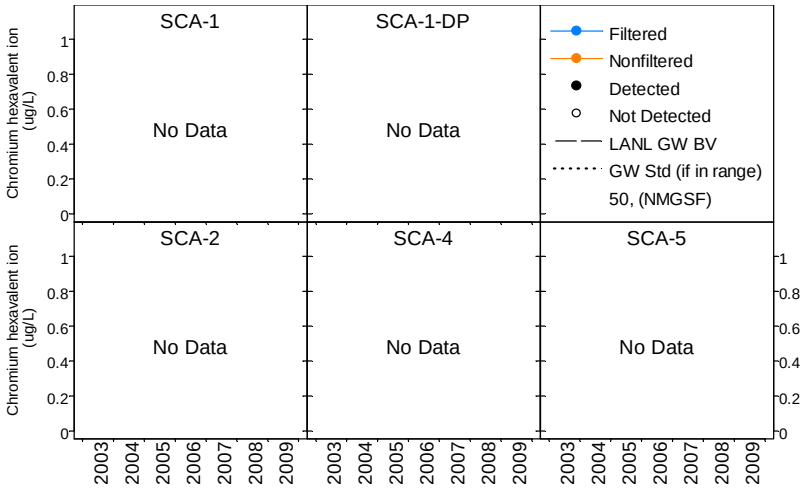


f. Chromium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

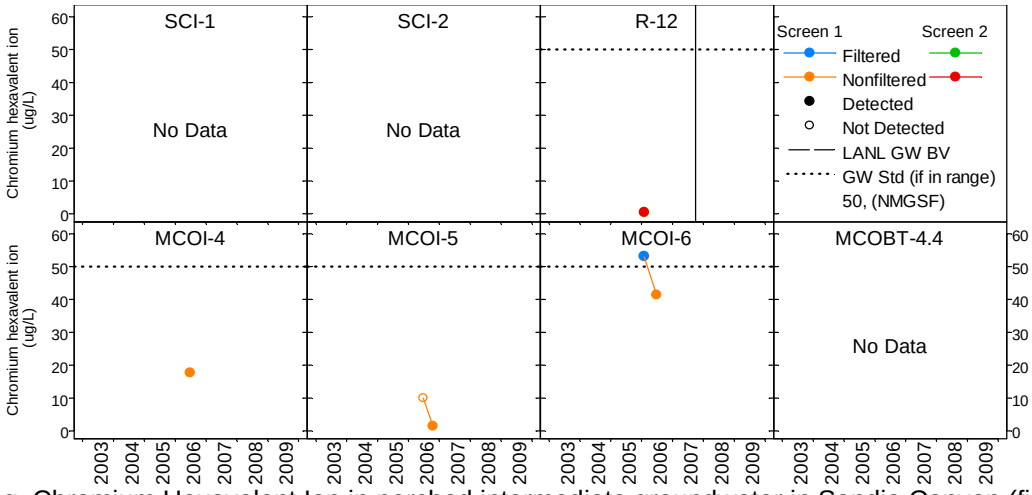


g. Chromium Hexavalent Ion in nonstorm-related surface water in Sandia Canyon.

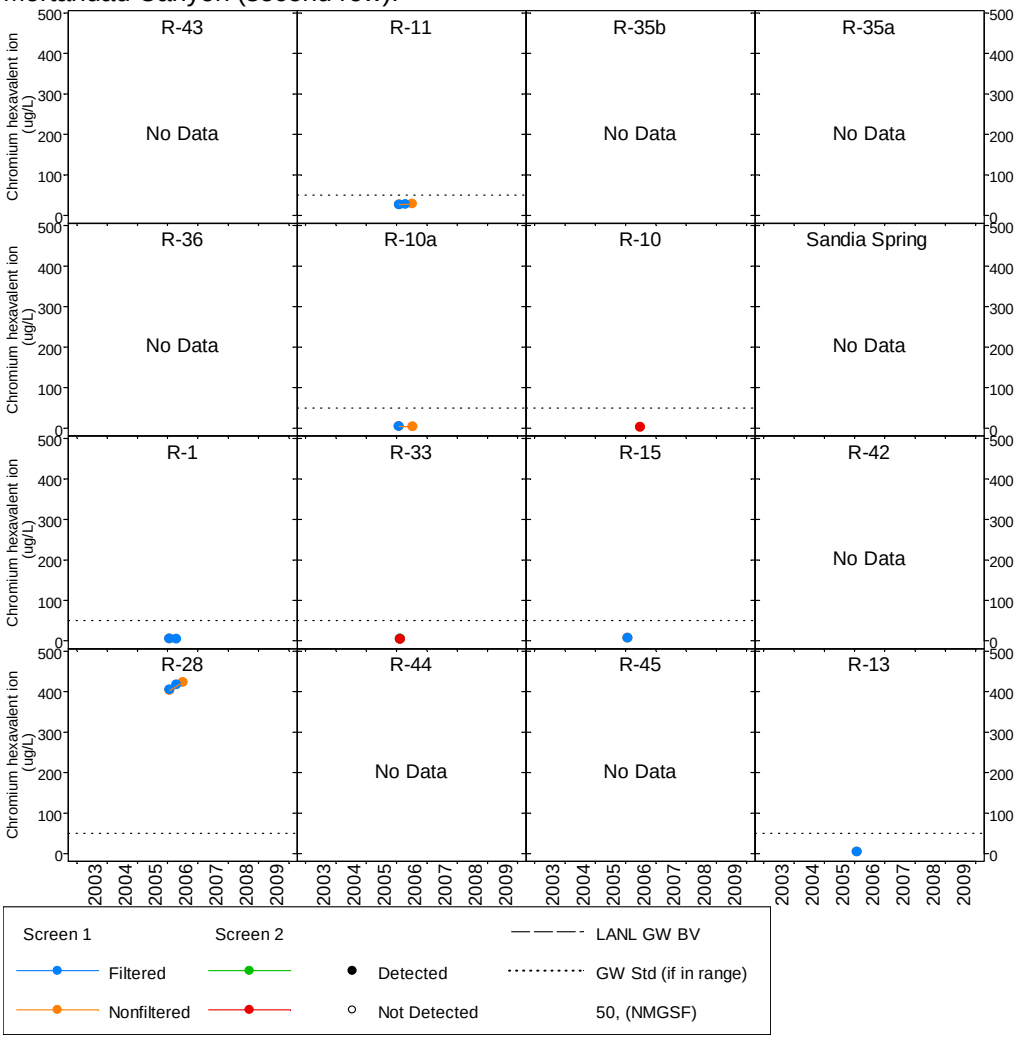


g. Chromium Hexavalent Ion in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

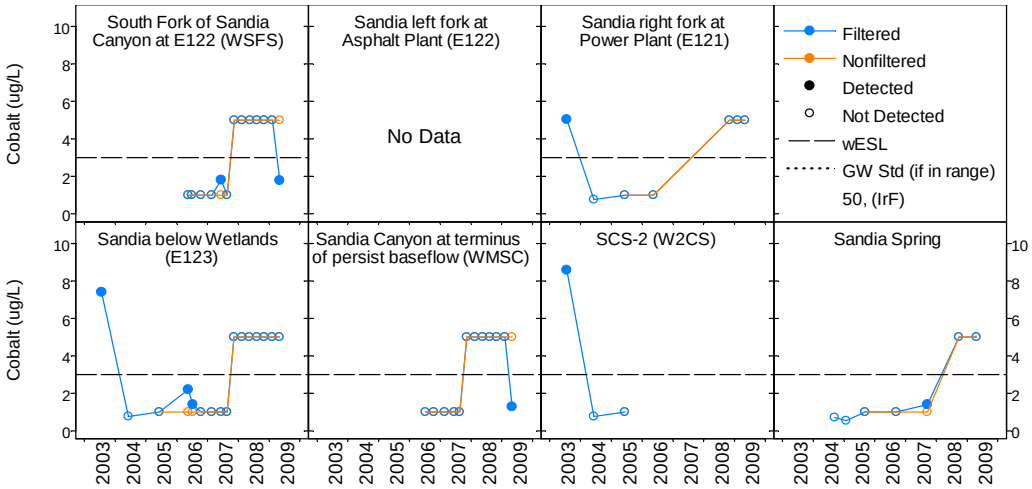


g. Chromium Hexavalent Ion in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

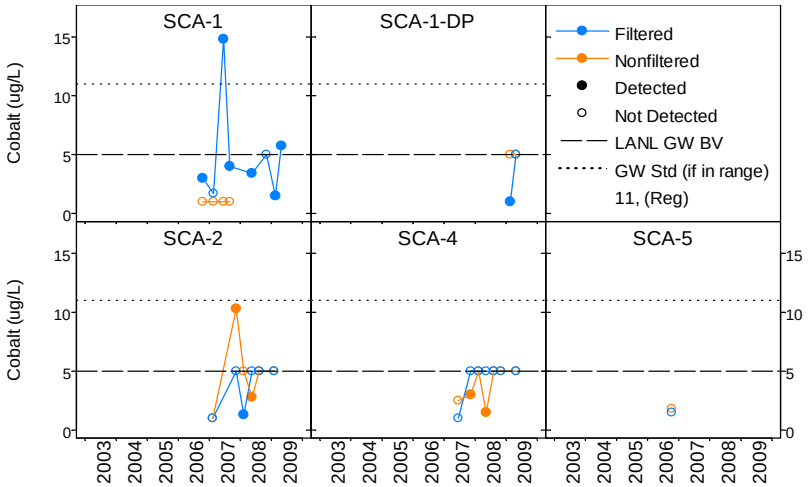


g. Chromium Hexavalent Ion in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

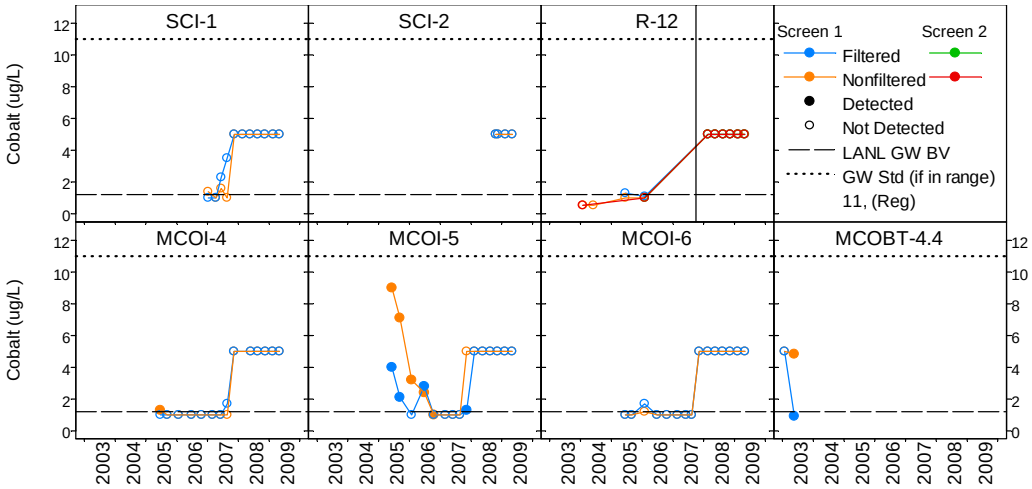


h. Cobalt in nonstorm-related surface water in Sandia Canyon.

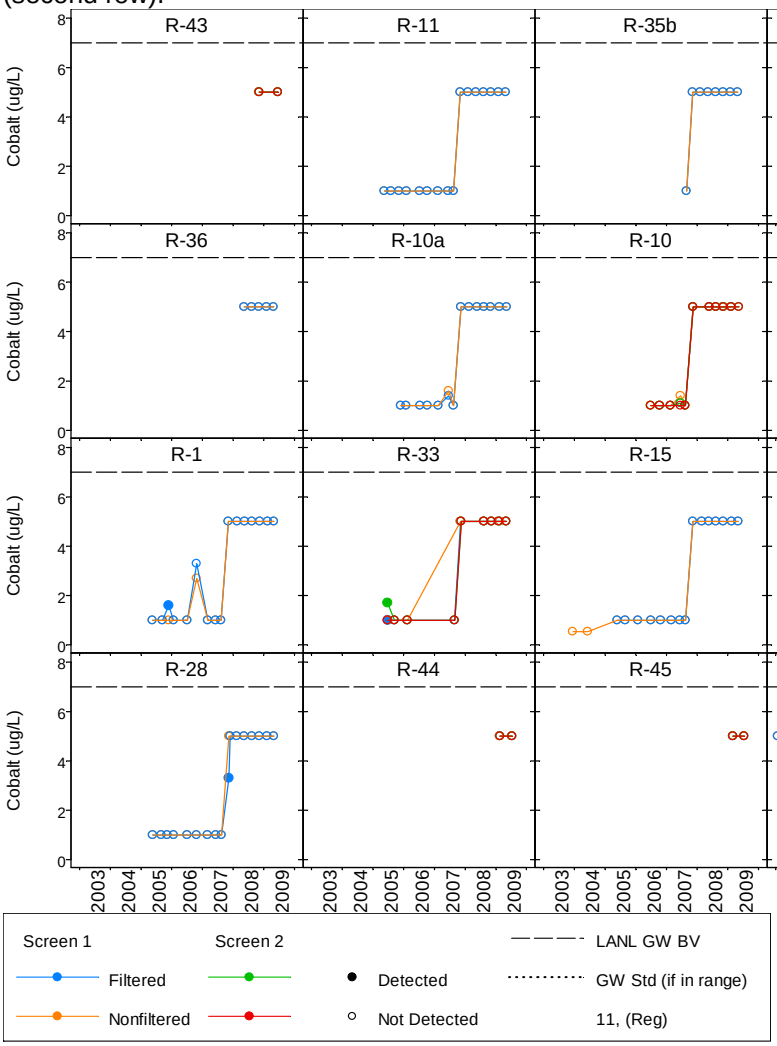


h. Cobalt in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

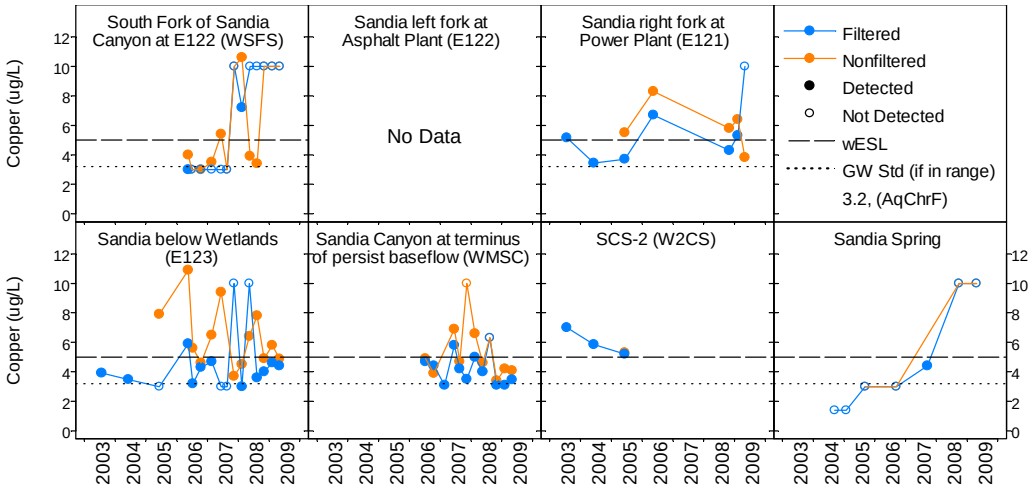


h. Cobalt in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

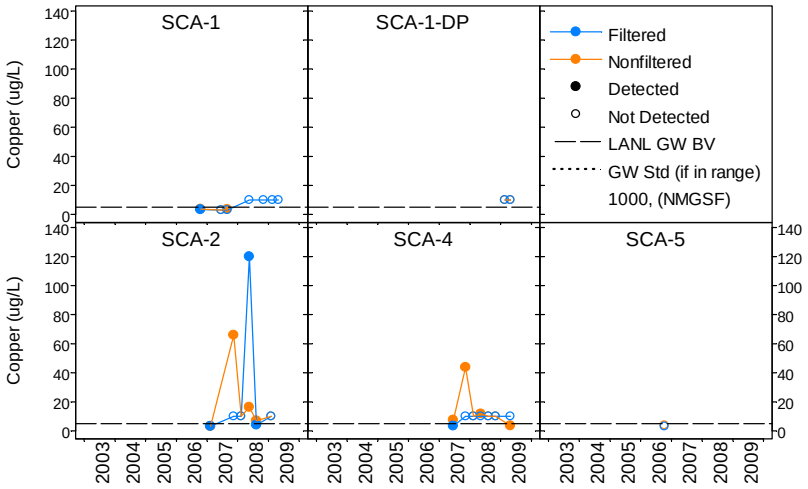


h. Cobalt in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

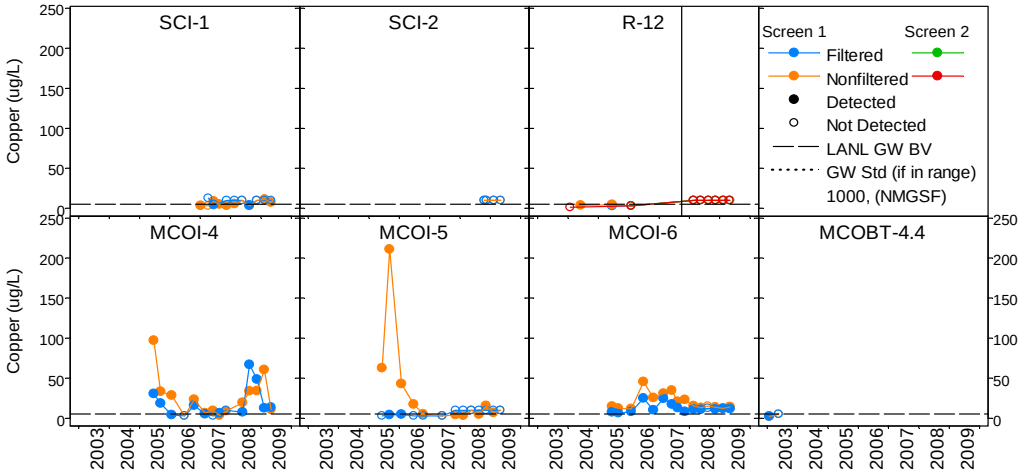


i. Copper in nonstorm-related surface water in Sandia Canyon.

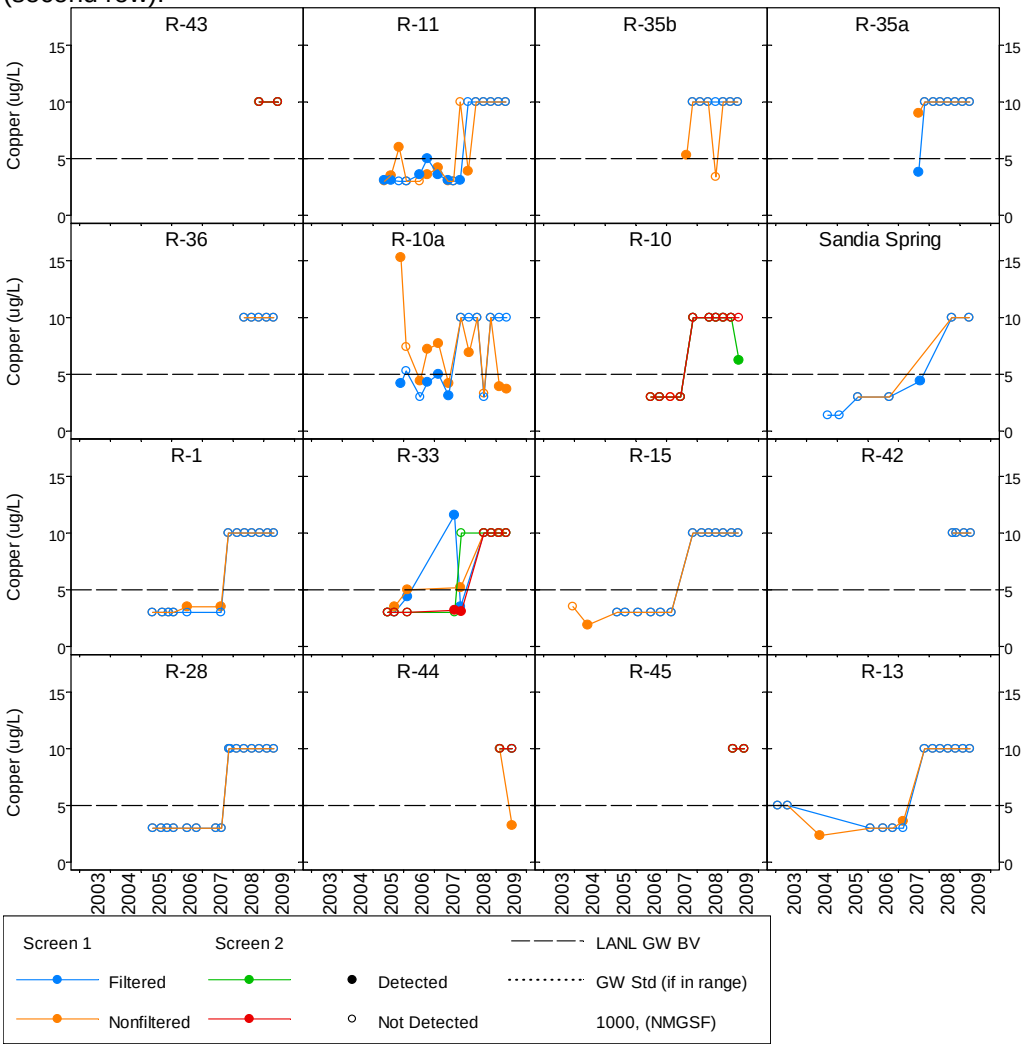


i. Copper in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

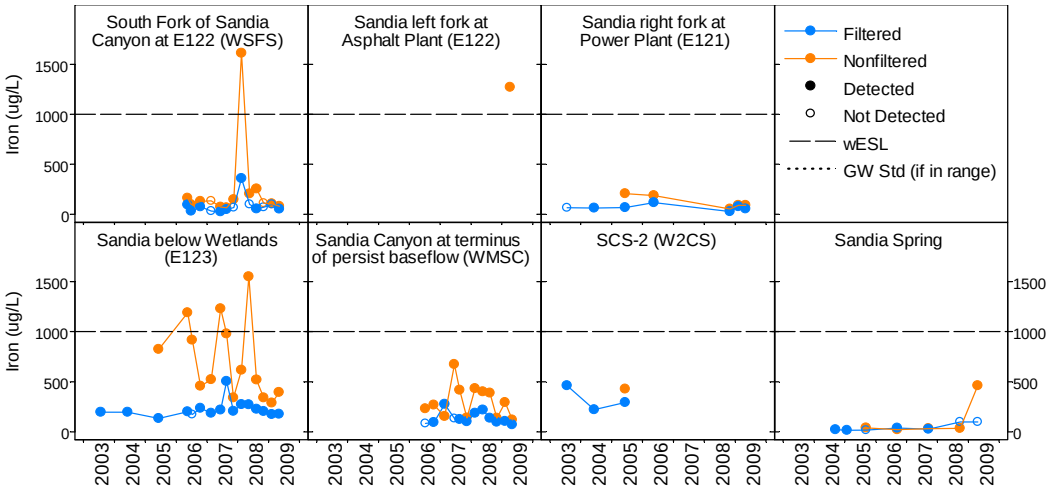


i. Copper in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

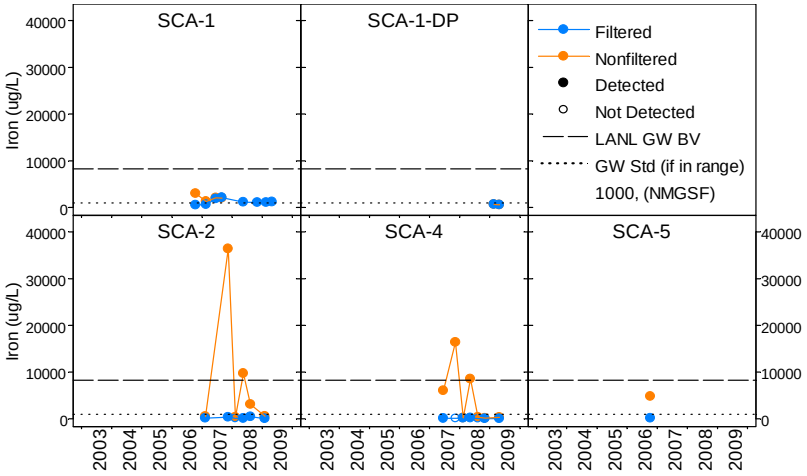


i. Copper in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

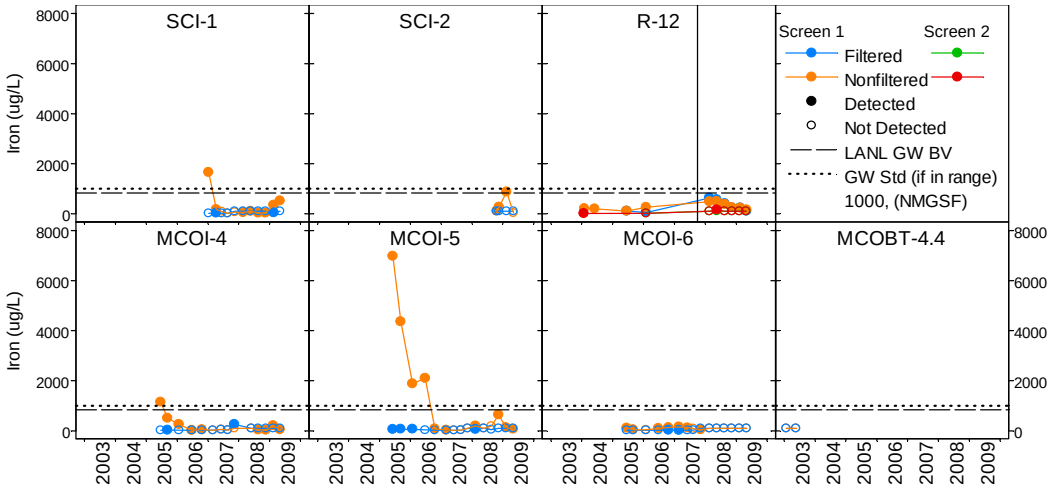


j. Iron in nonstorm-related surface water in Sandia Canyon.

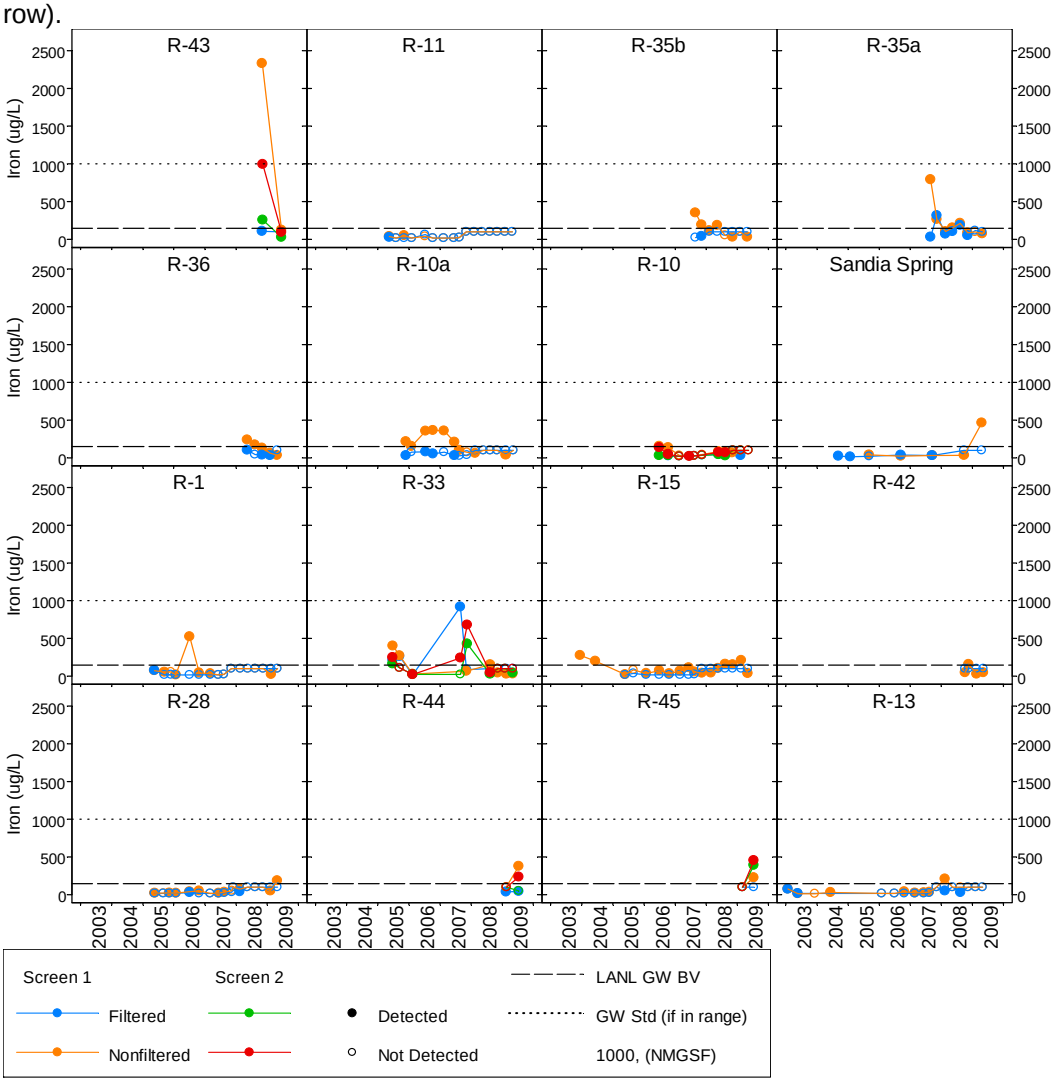


j. Iron in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

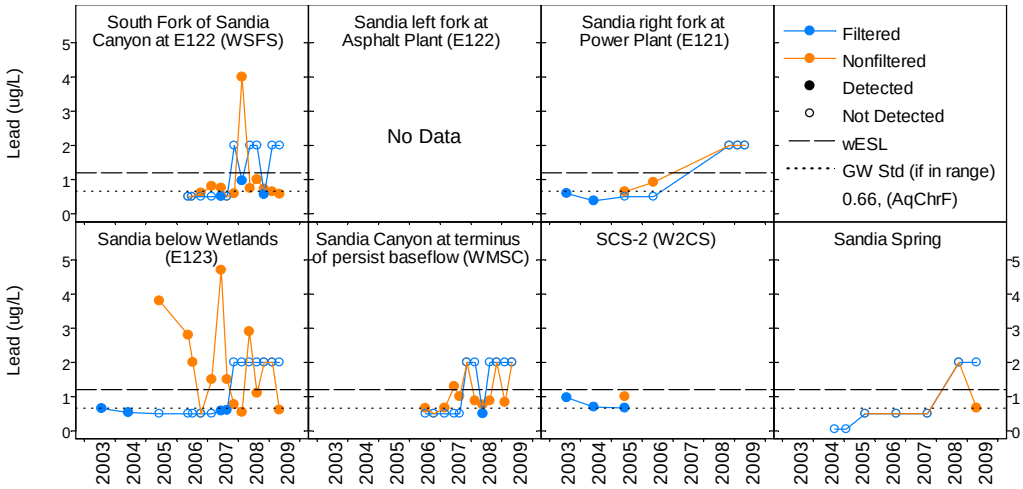


j. Iron in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

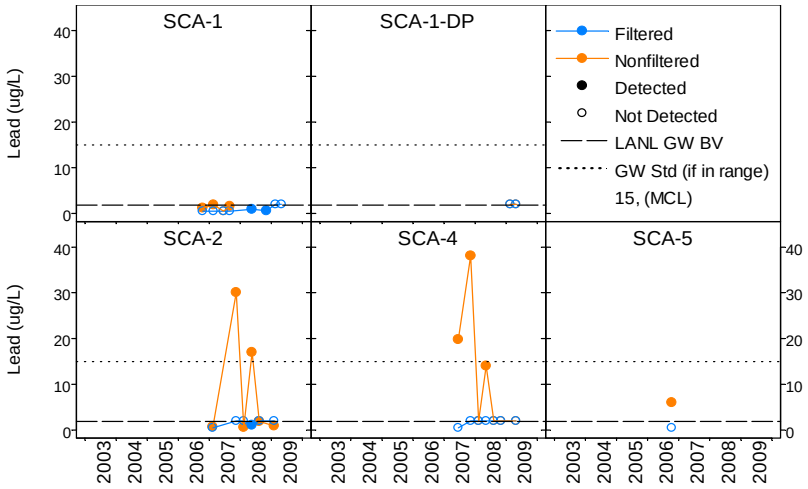


j. Iron in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

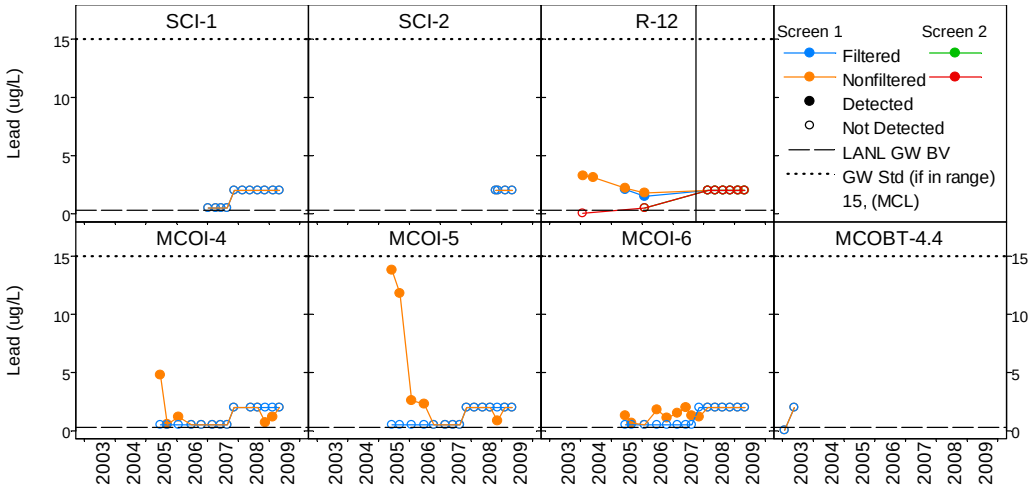


k. Lead in nonstorm-related surface water in Sandia Canyon.

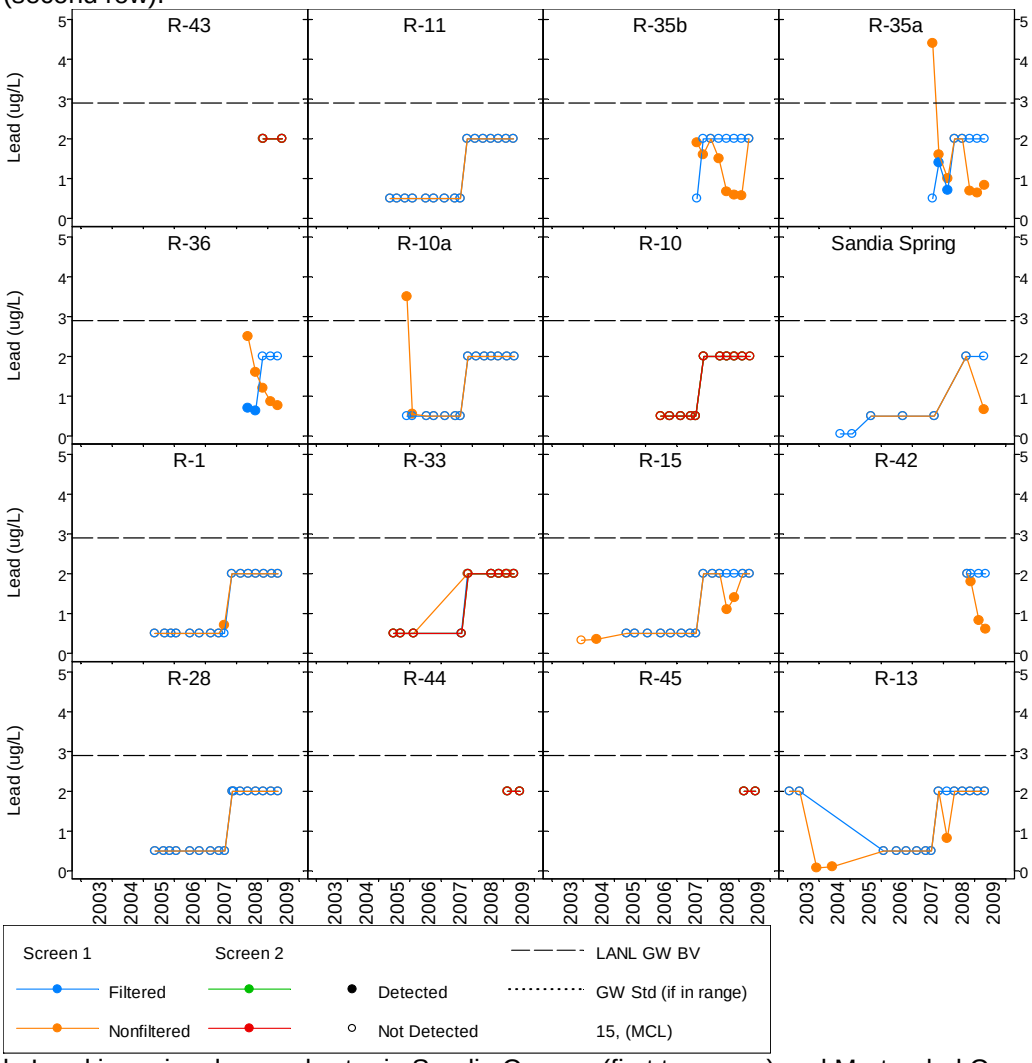


k. Lead in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

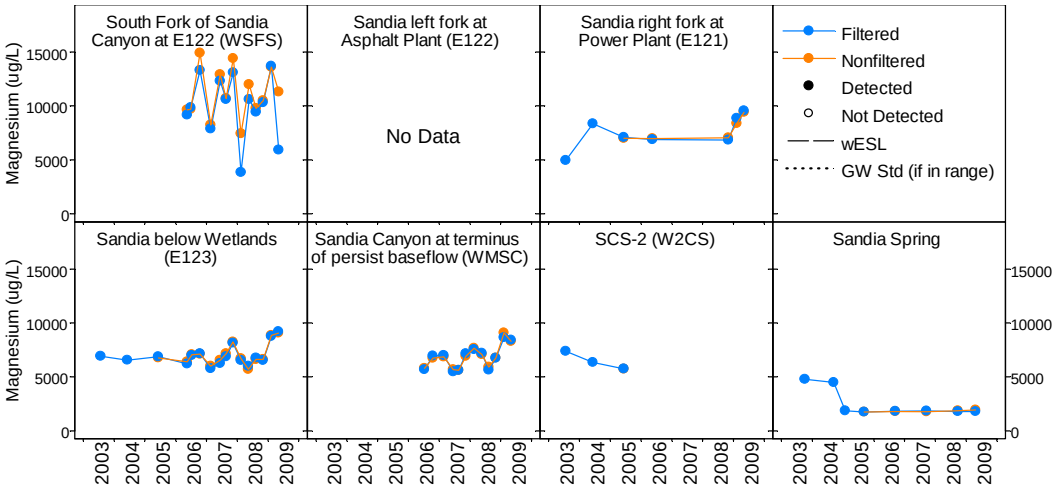


k. Lead in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

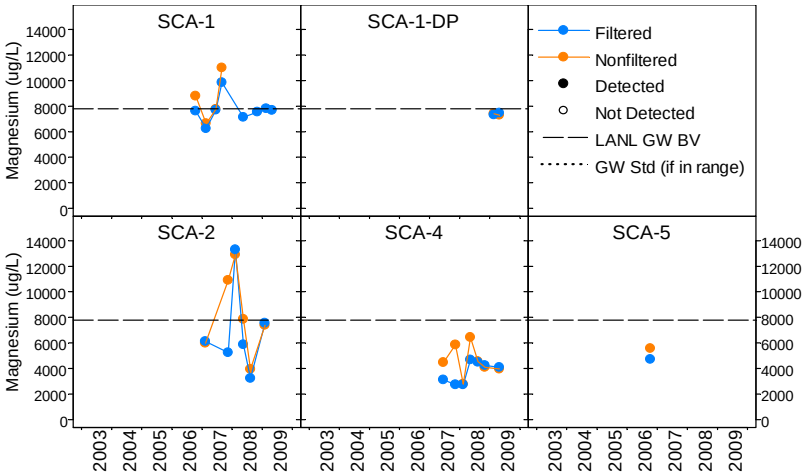


k. Lead in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

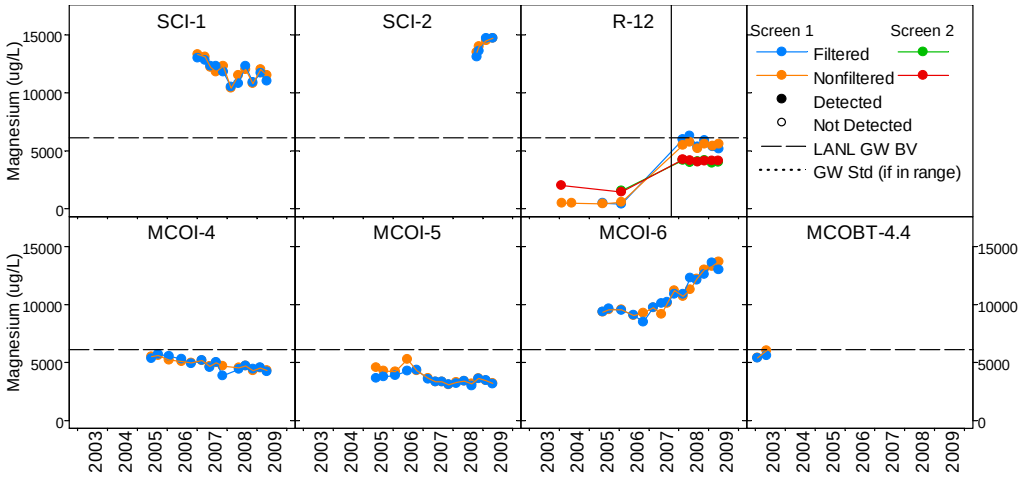


l. Magnesium in nonstorm-related surface water in Sandia Canyon.

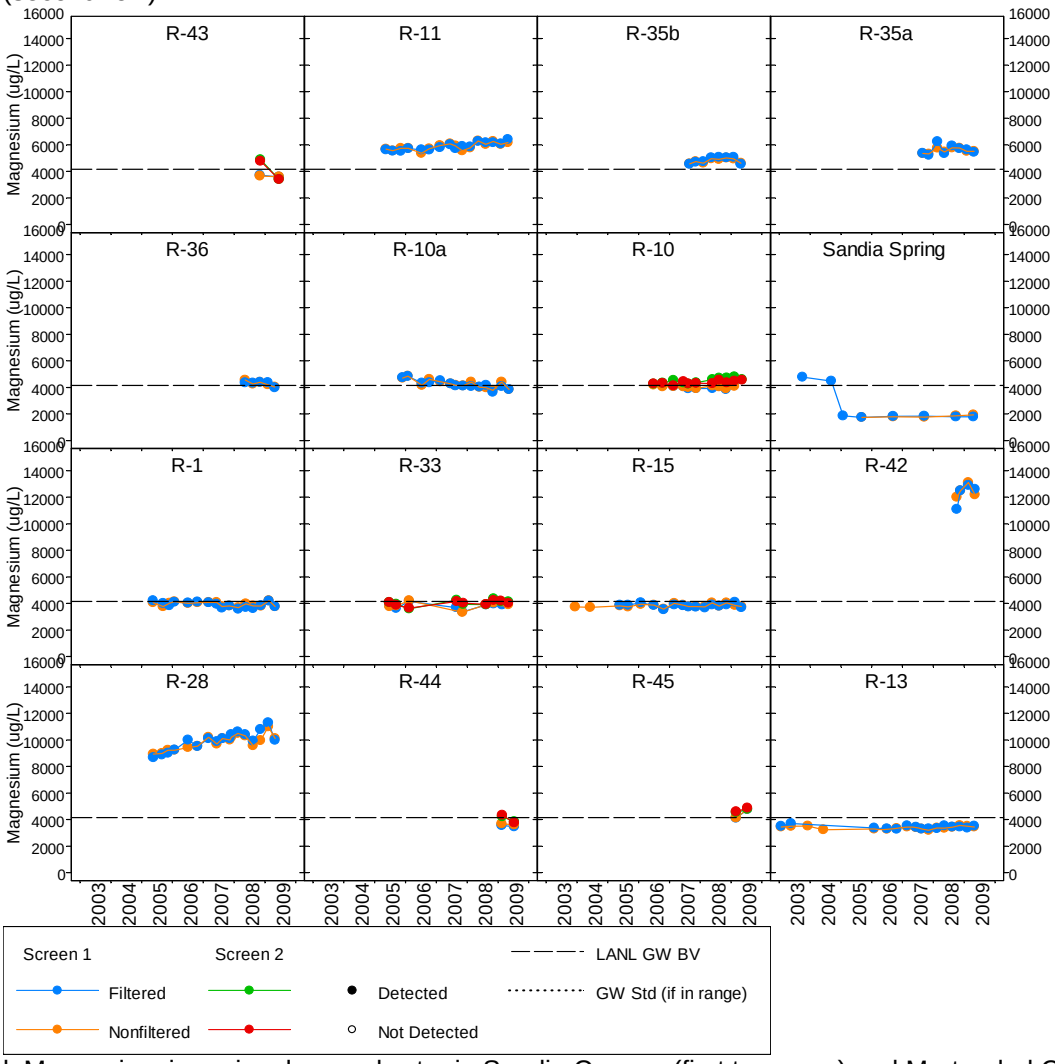


l. Magnesium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

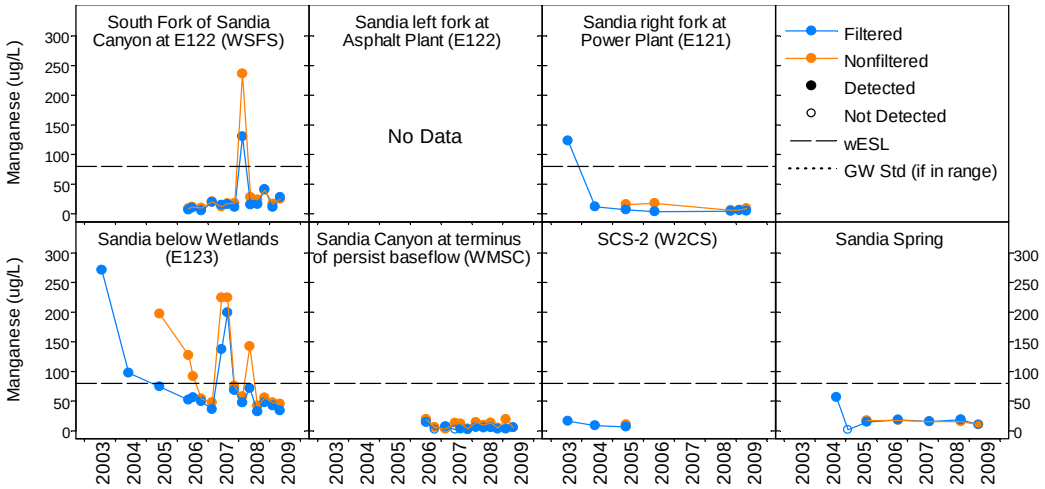


l. Magnesium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

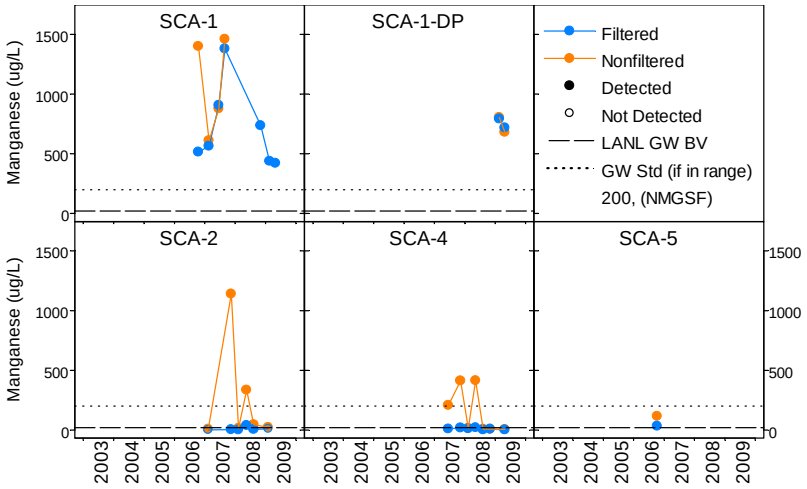


l. Magnesium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

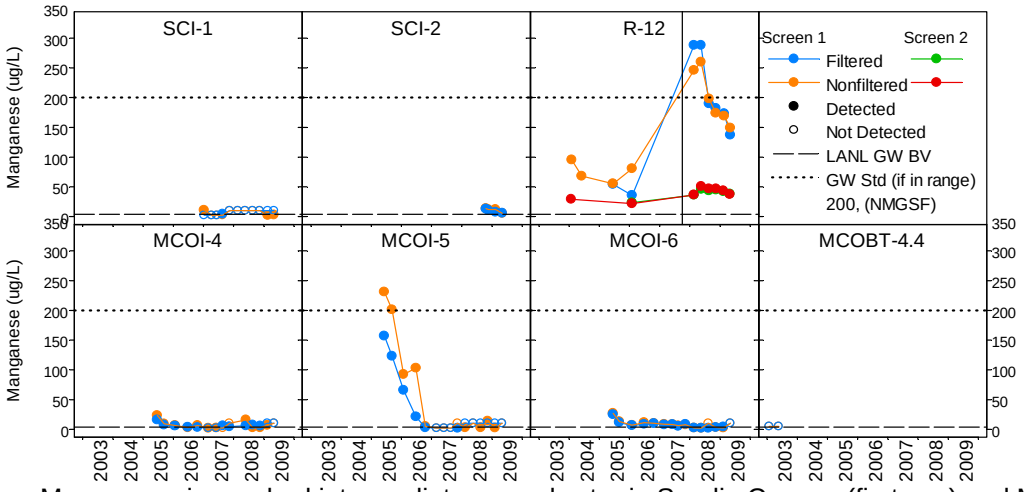


m. Manganese in nonstorm-related surface water in Sandia Canyon.

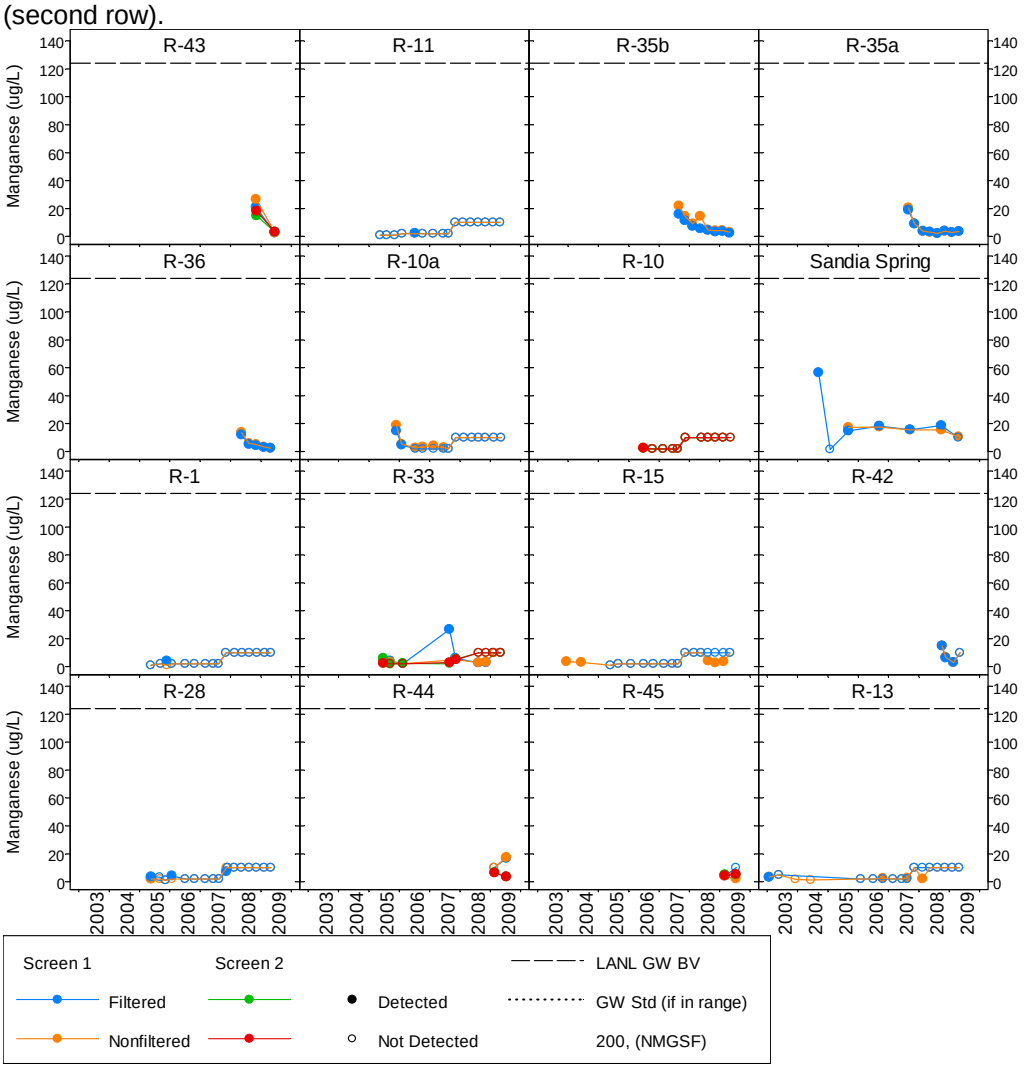


m. Manganese in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

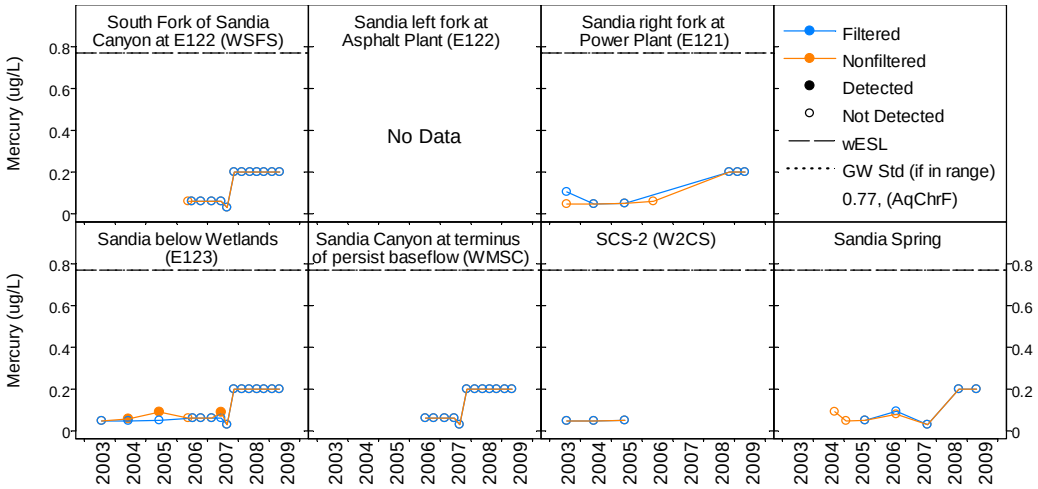


m. Manganese in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

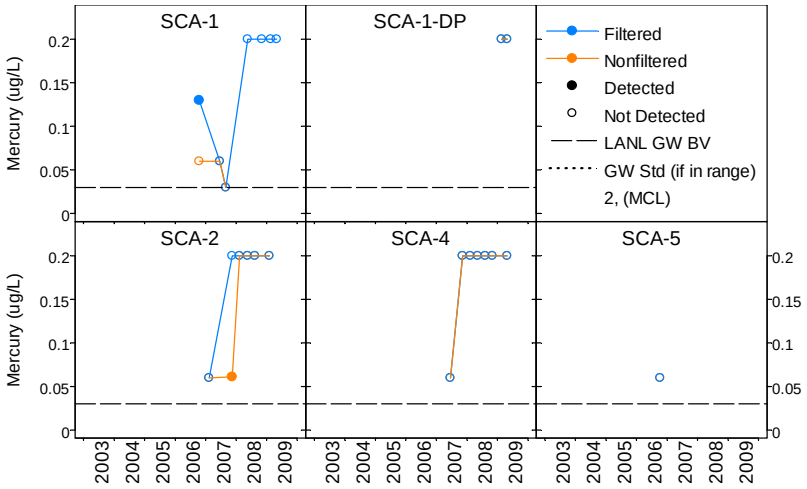


m. Manganese in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

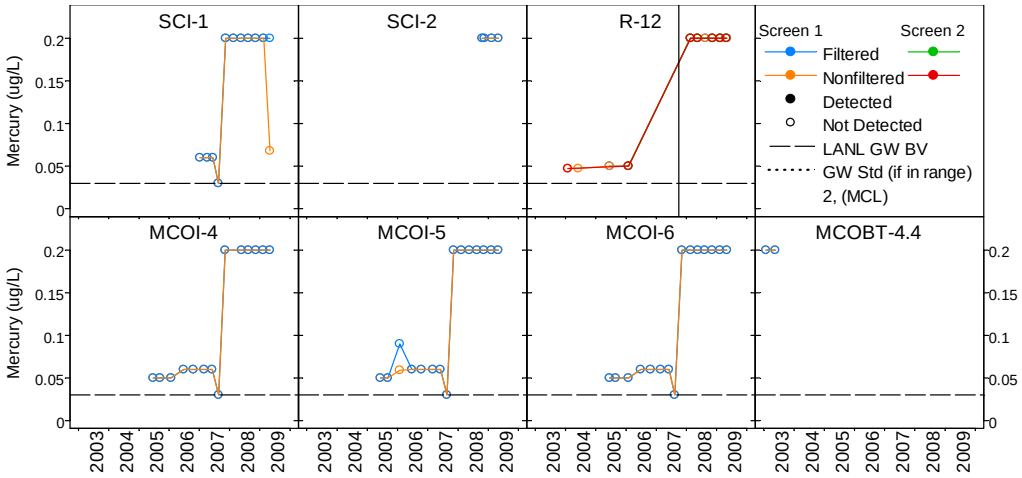


n. Mercury in nonstorm-related surface water in Sandia Canyon.

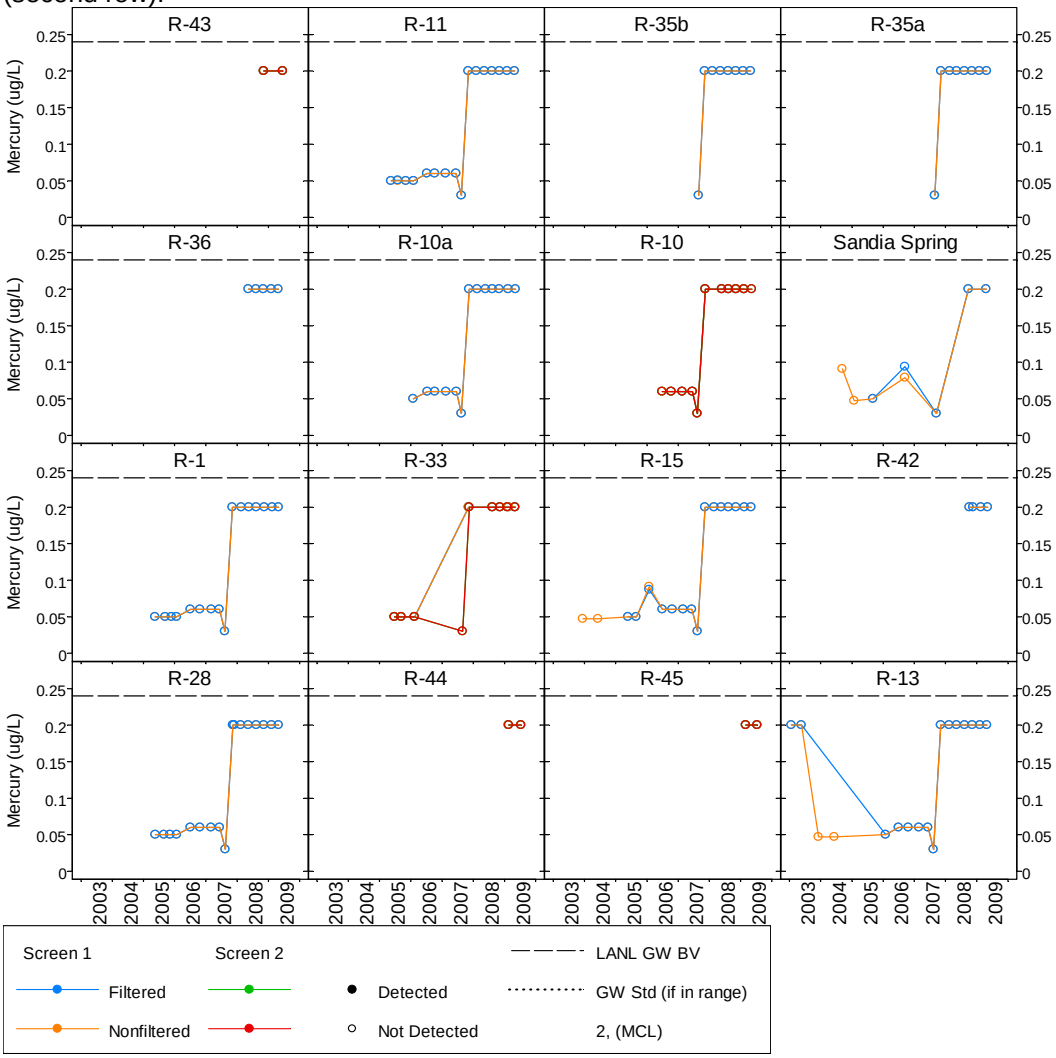


n. Mercury in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

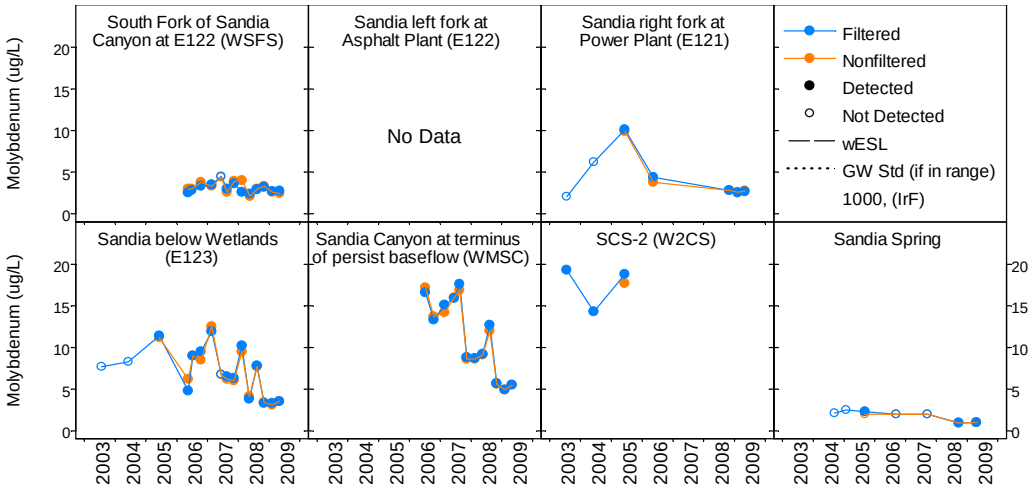


n. Mercury in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

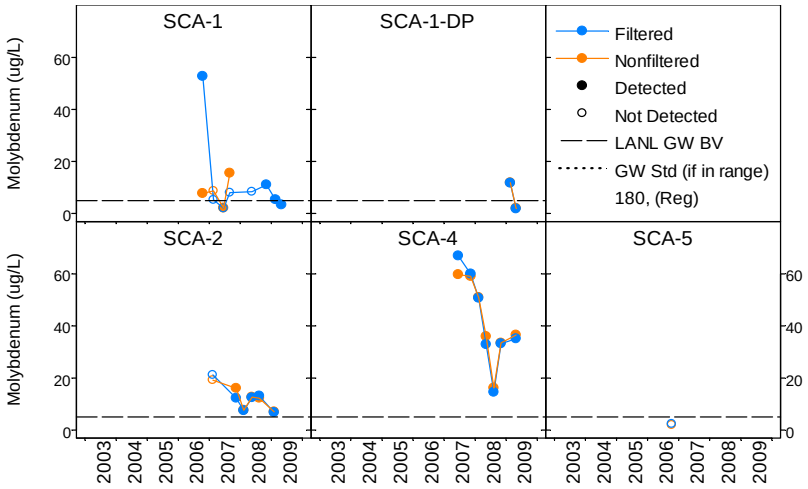


n. Mercury in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

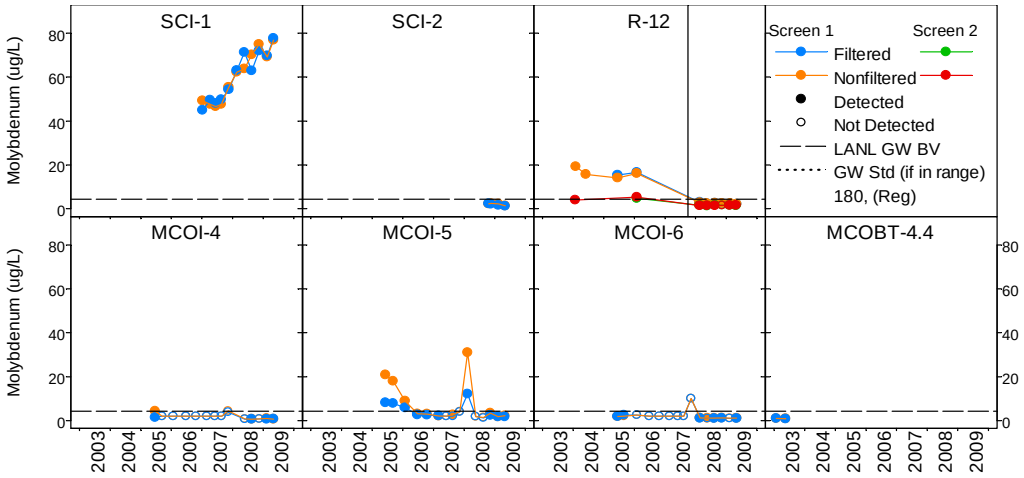


o. Molybdenum in nonstorm-related surface water in Sandia Canyon.

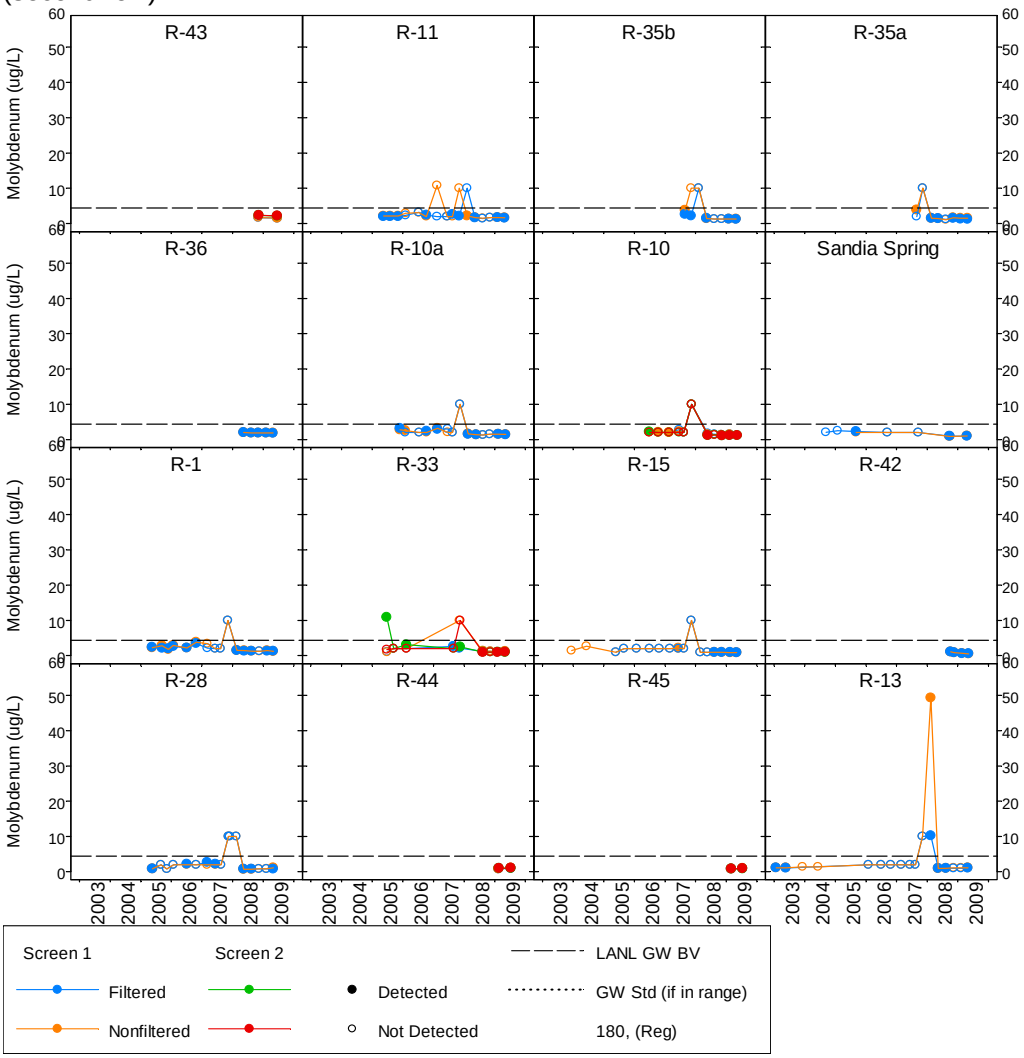


o. Molybdenum in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

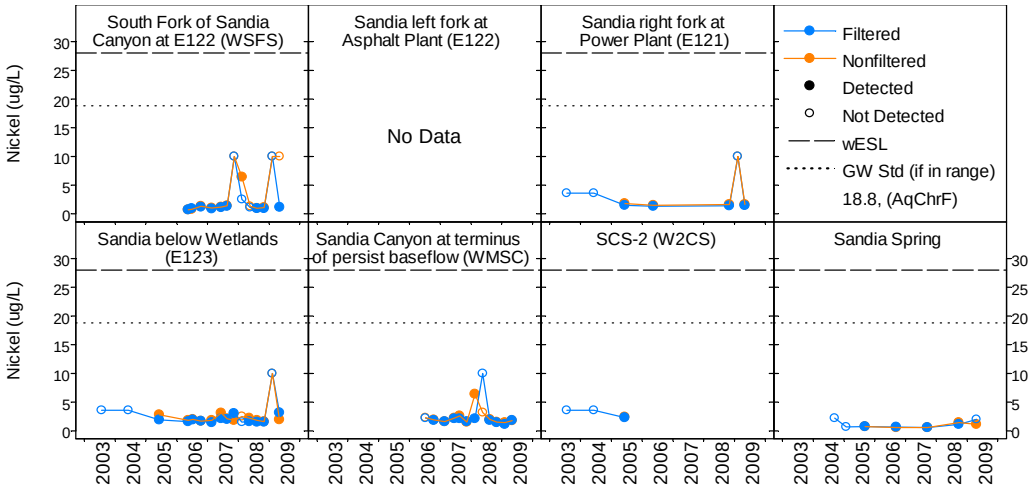


o. Molybdenum in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

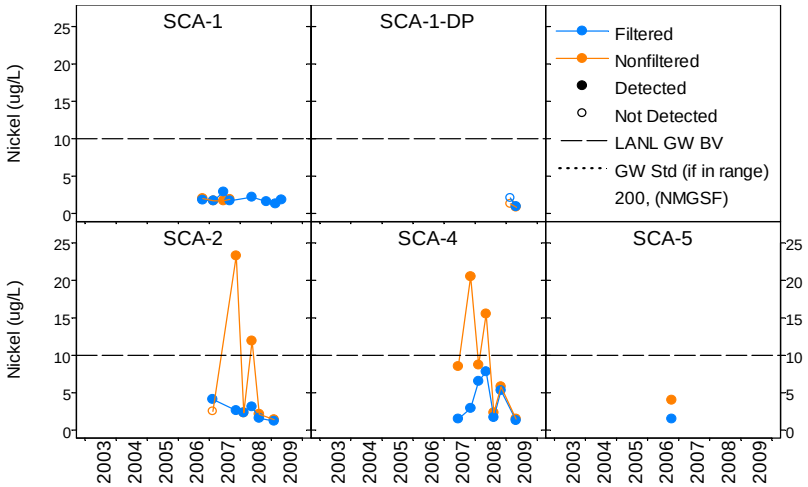


o. Molybdenum in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

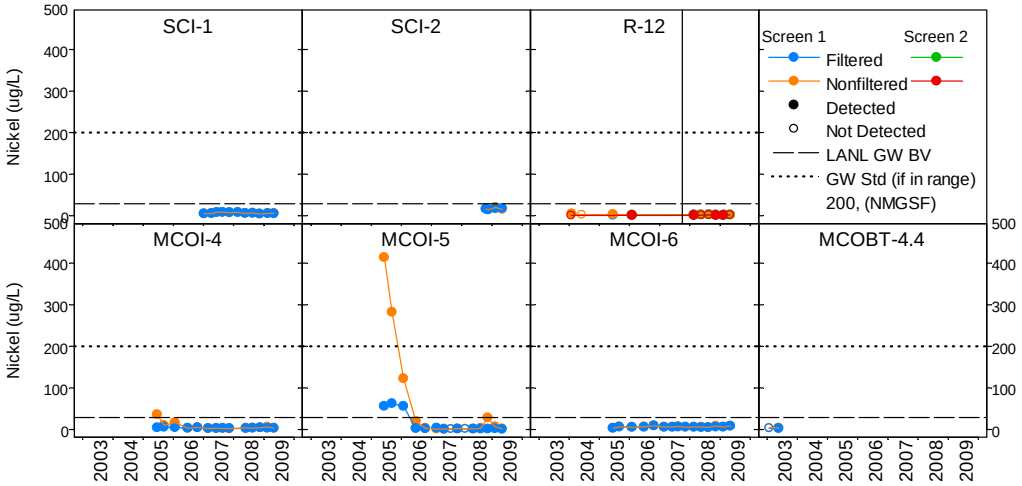


p. Nickel in nonstorm-related surface water in Sandia Canyon.

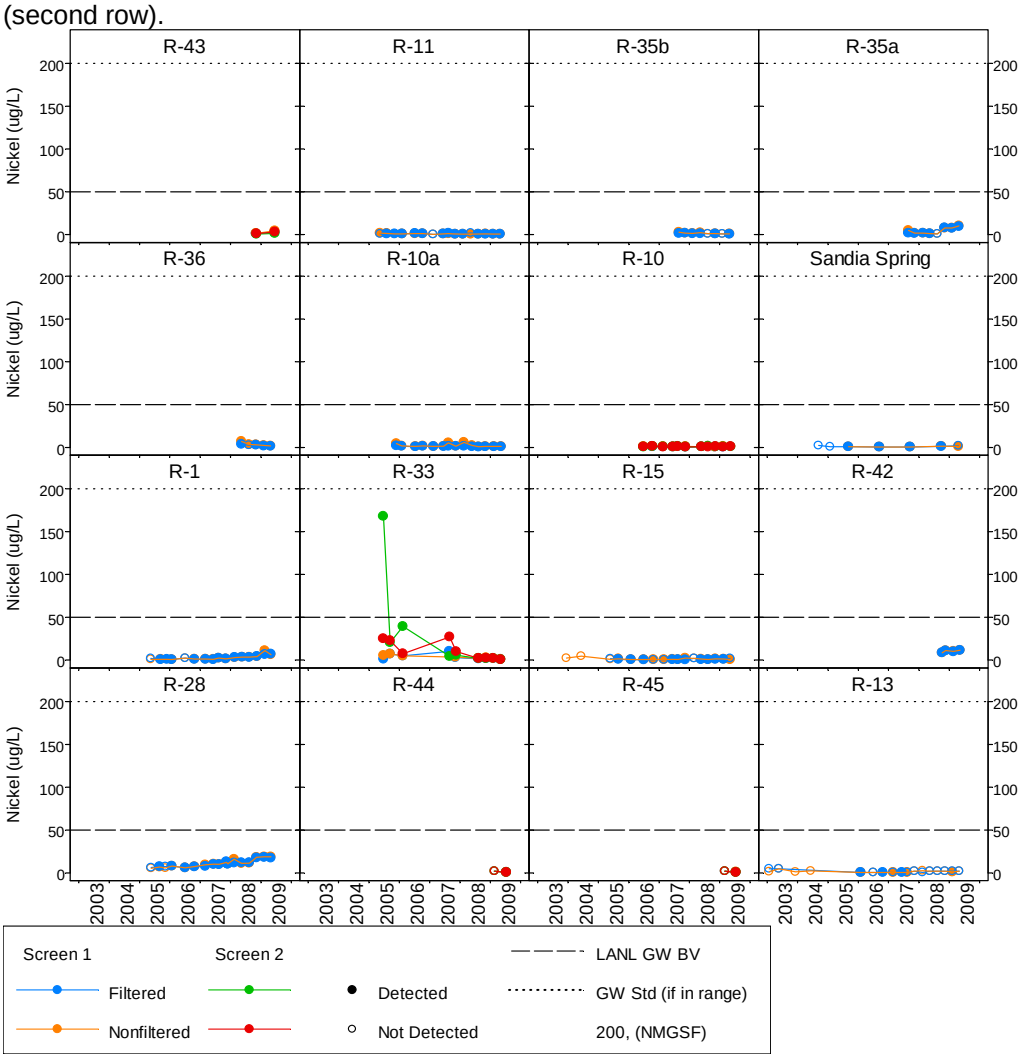


p. Nickel in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

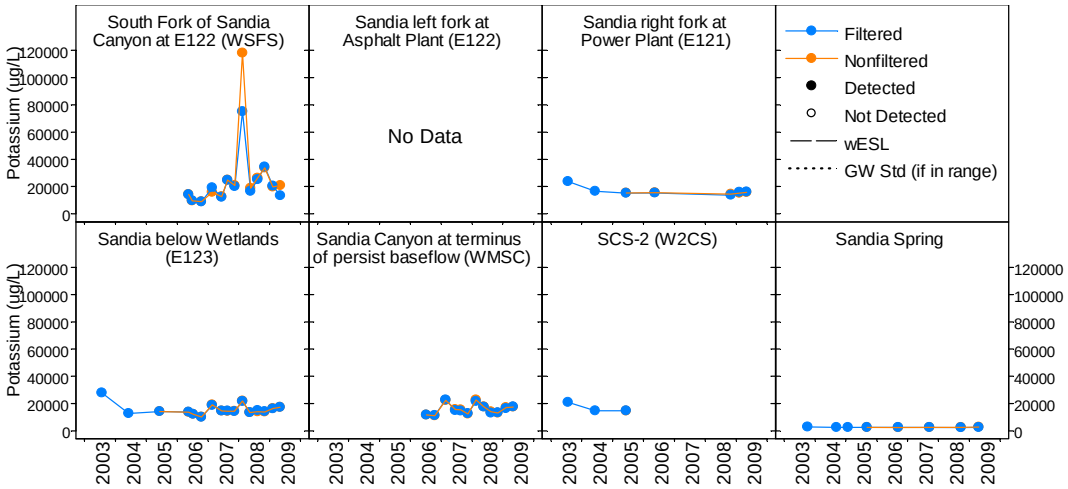


p. Nickel in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

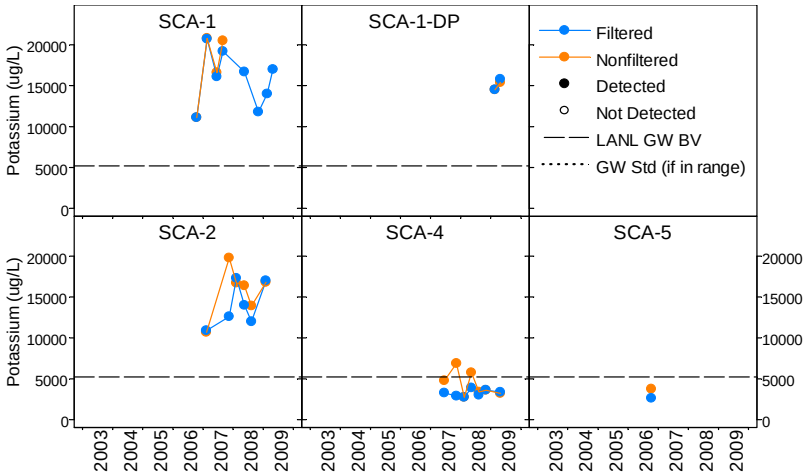


p. Nickel in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

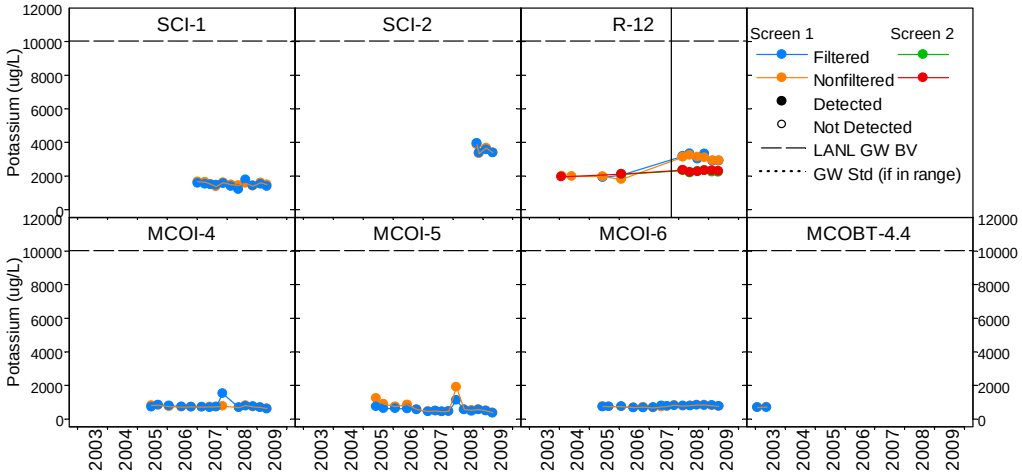


q. Potassium in nonstorm-related surface water in Sandia Canyon.

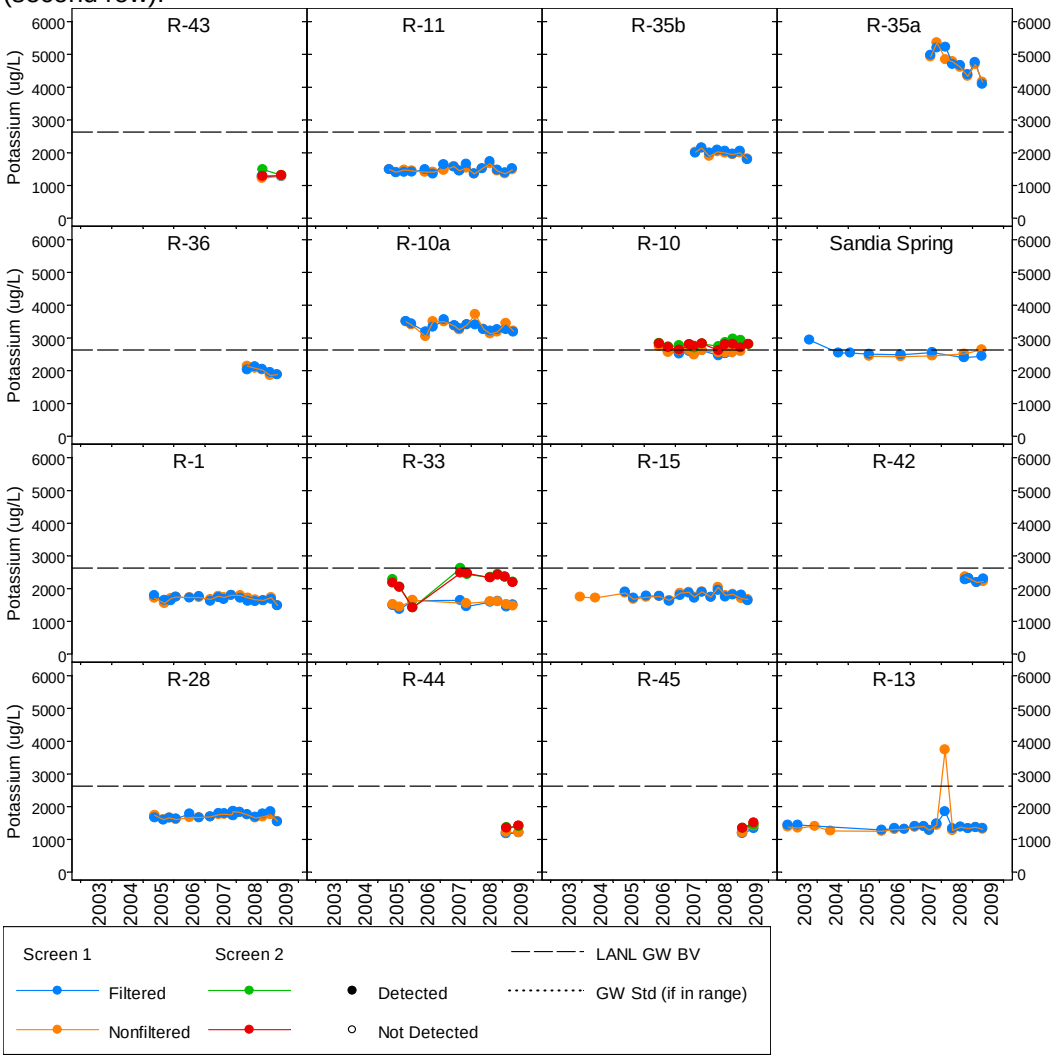


q. Potassium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

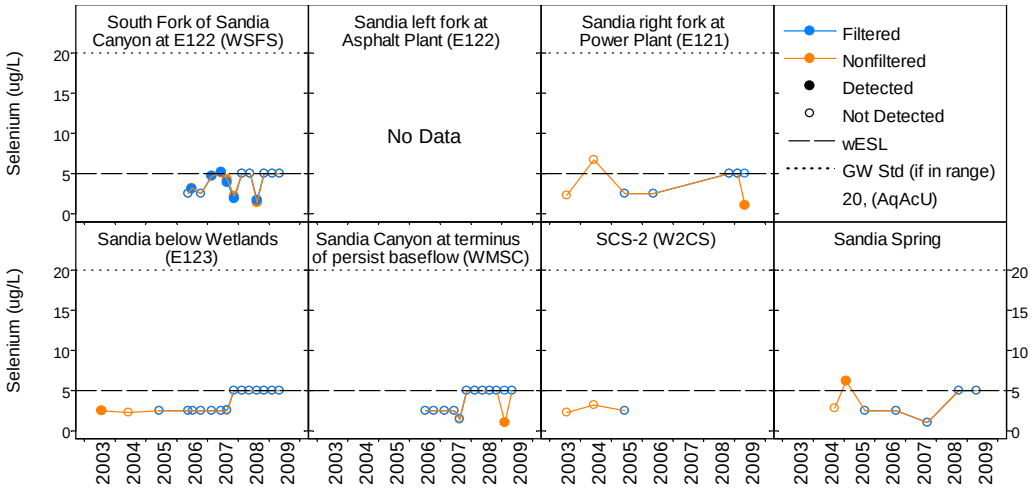


q. Potassium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

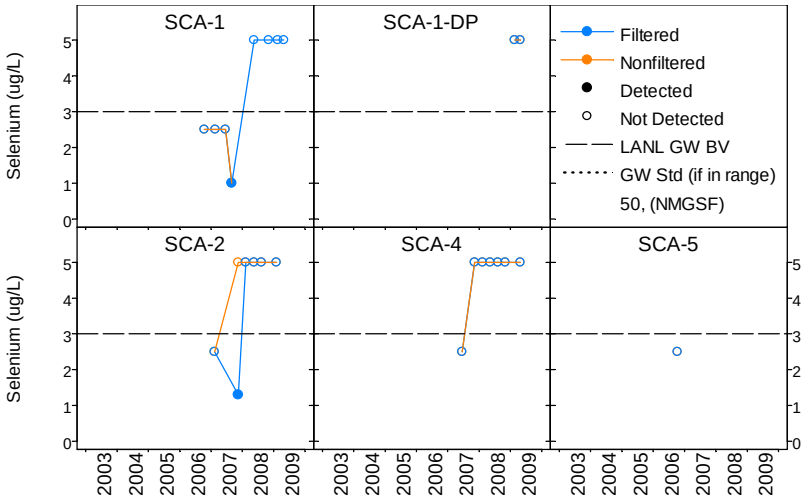


q. Potassium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

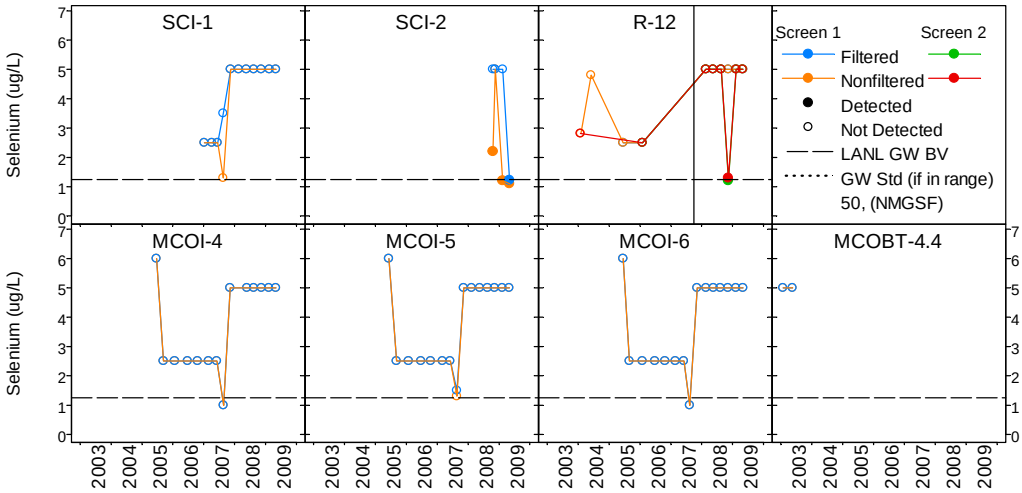


r. Selenium in nonstorm-related surface water in Sandia Canyon.

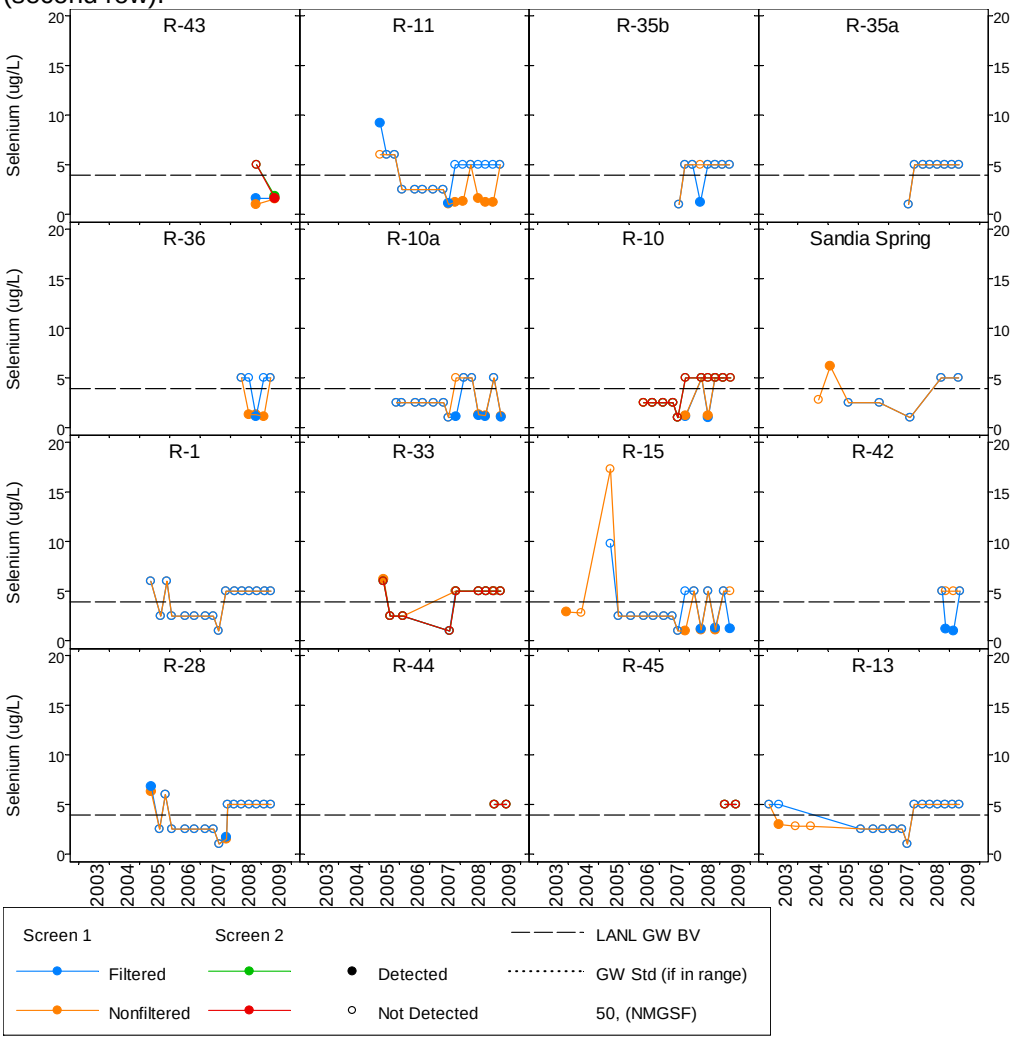


r. Selenium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

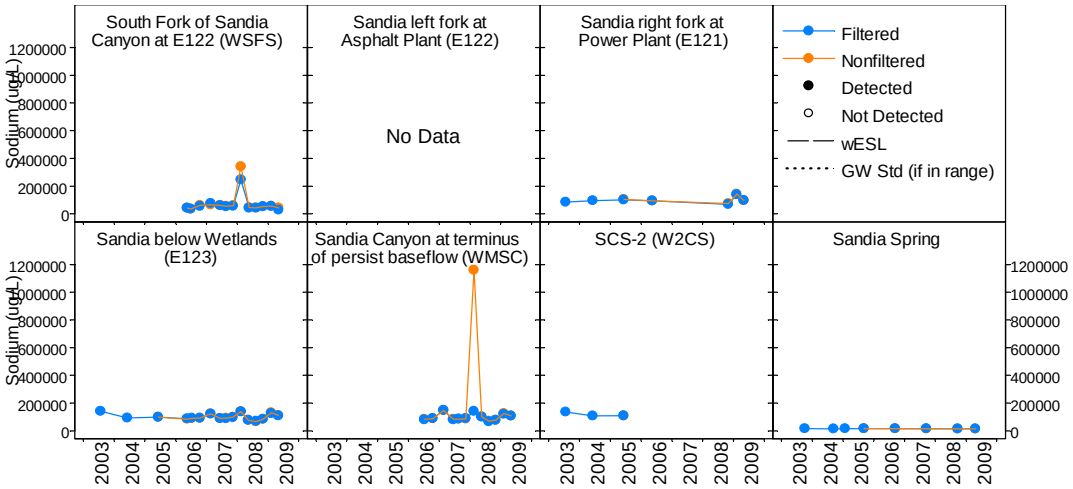


r. Selenium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

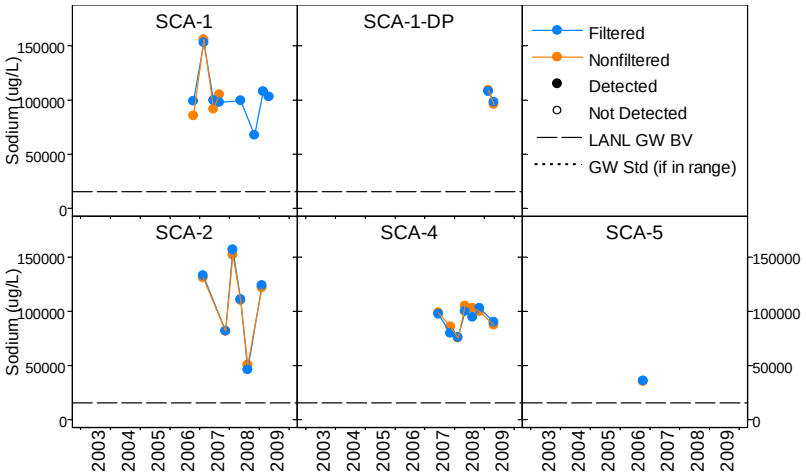


r. Selenium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

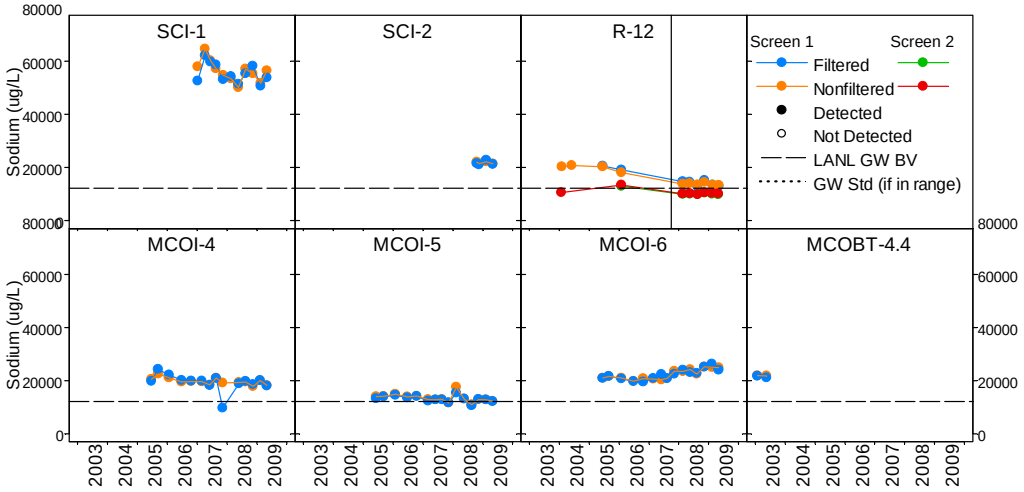


s. Sodium in nonstorm-related surface water in Sandia Canyon.

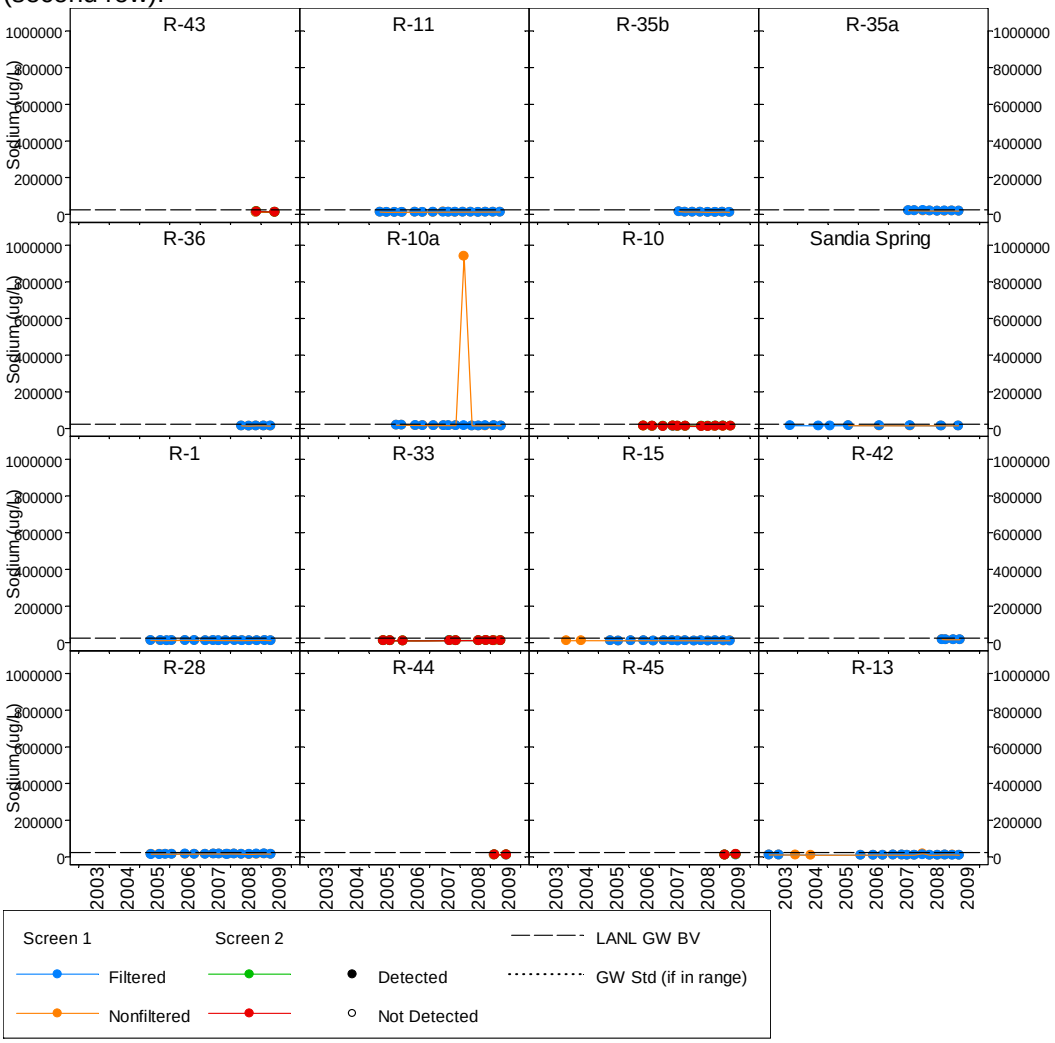


s. Sodium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

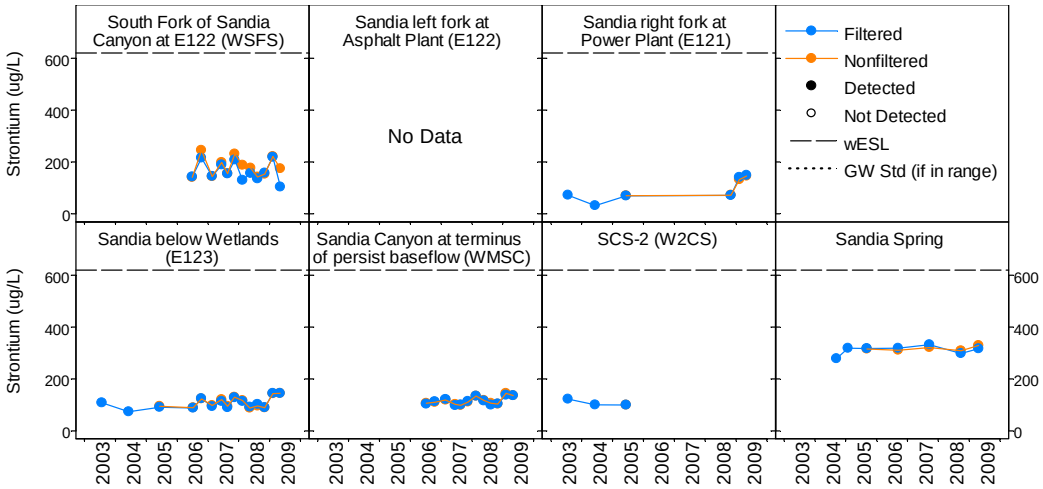


s. Sodium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

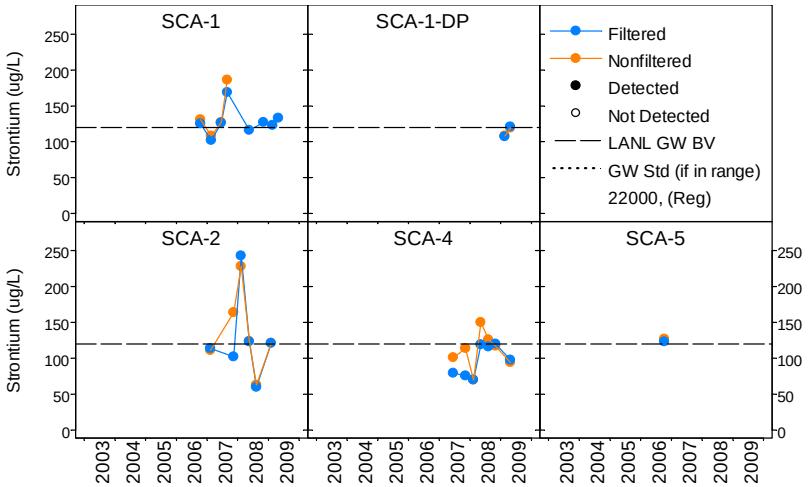


s. Sodium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

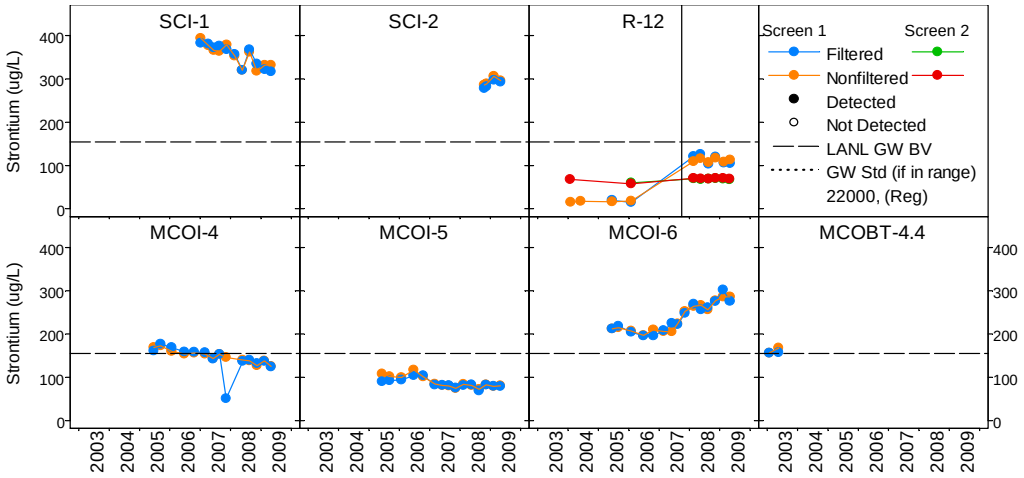


t. Strontium in nonstorm-related surface water in Sandia Canyon.

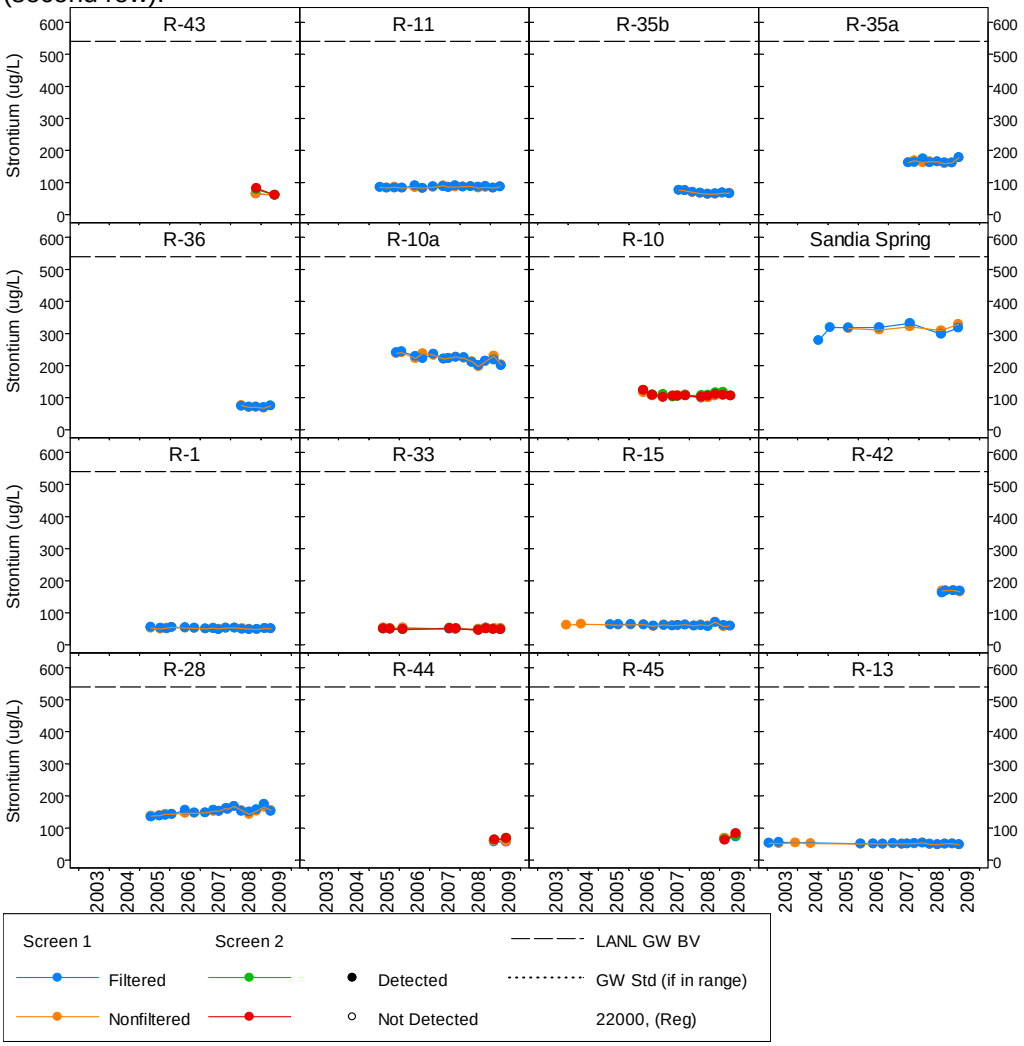


t. Strontium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

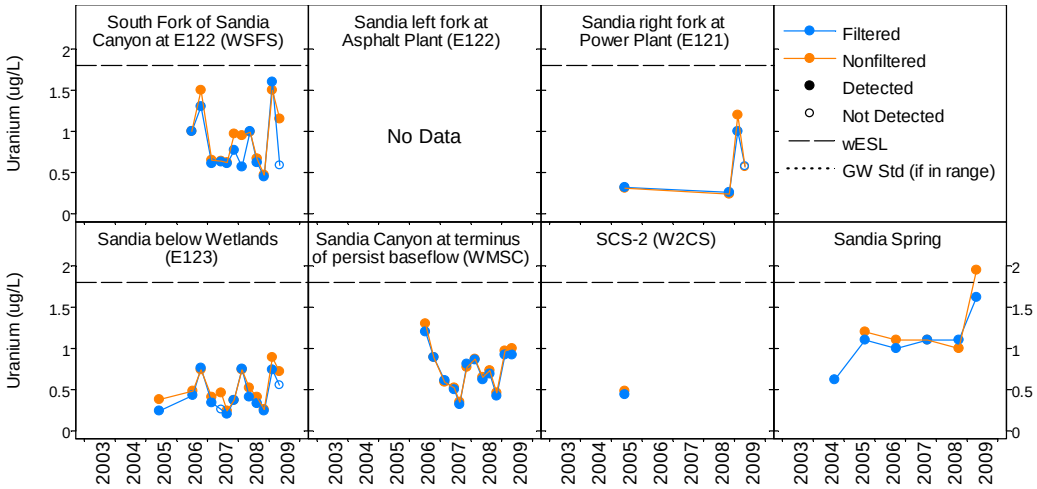


t. Strontium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

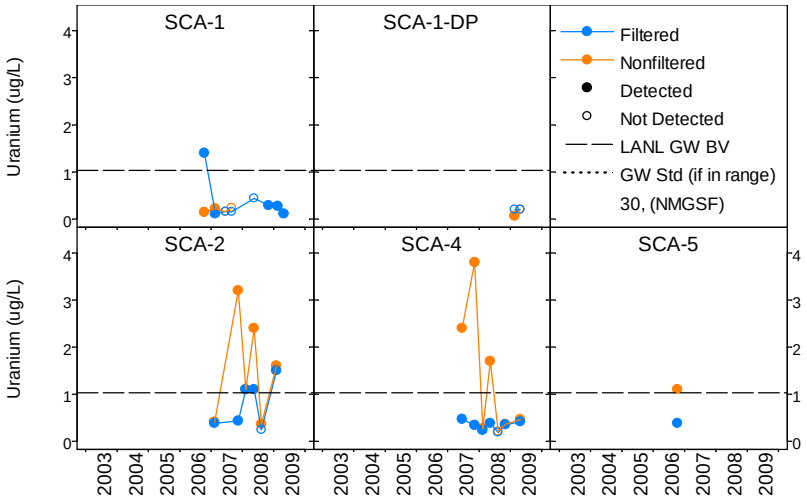


t. Strontium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

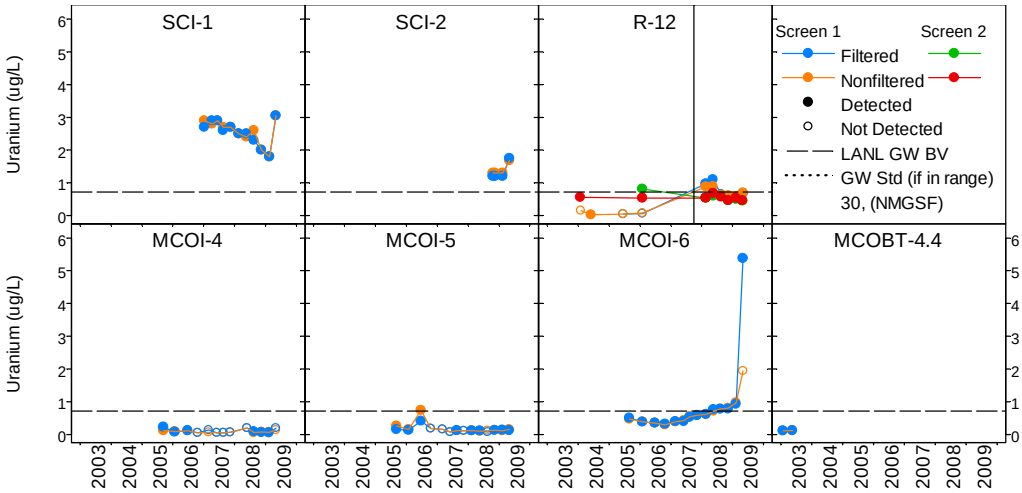


u. Uranium in nonstorm-related surface water in Sandia Canyon.

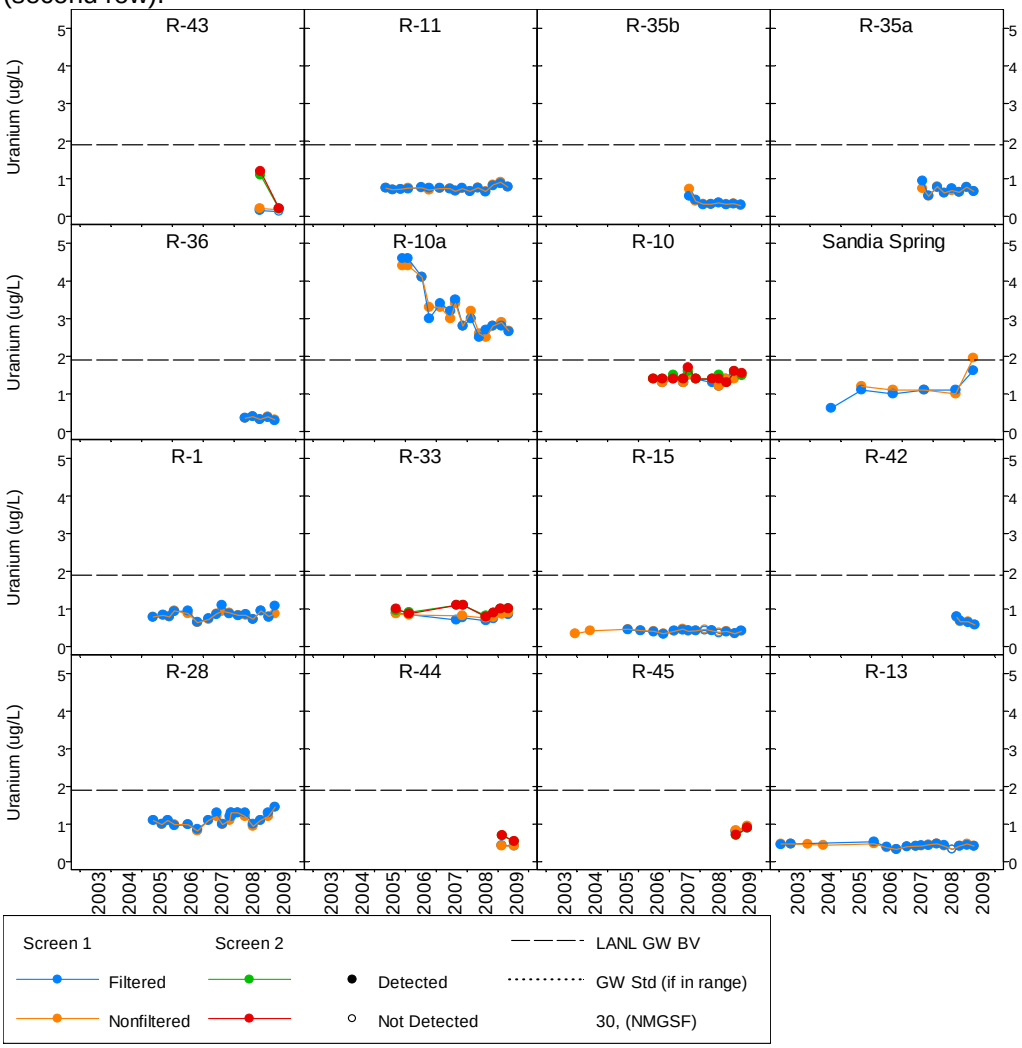


u. Uranium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

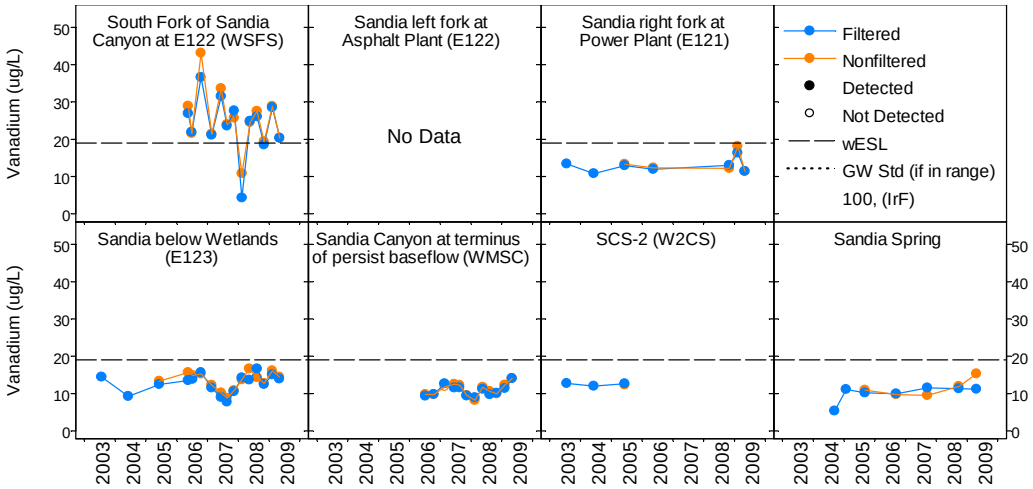


u. Uranium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

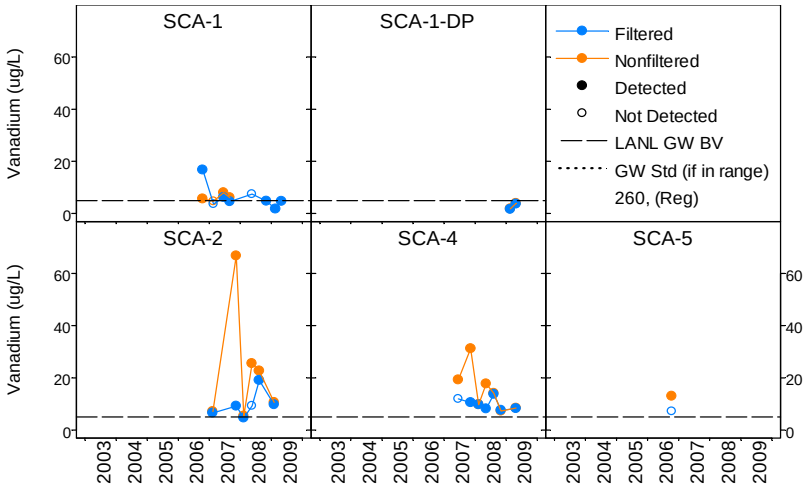


u. Uranium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

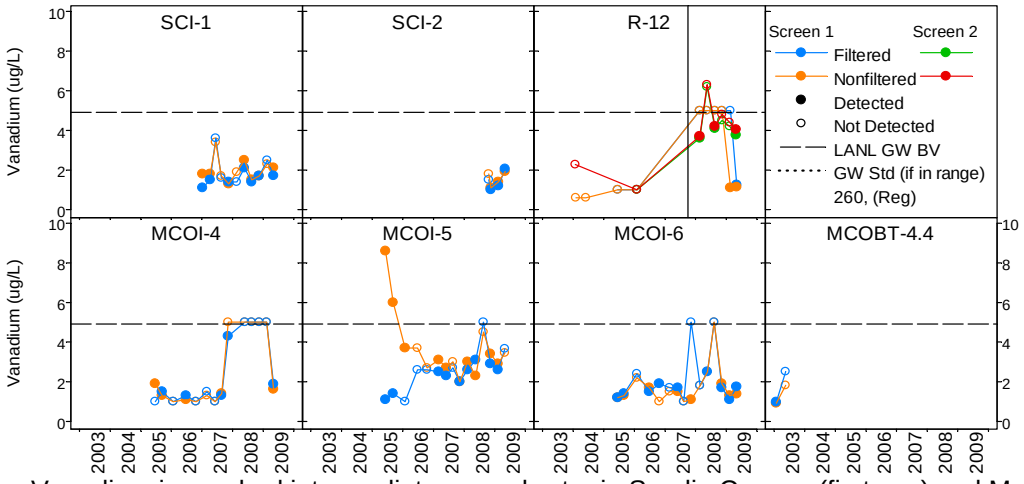


v. Vanadium in nonstorm-related surface water in Sandia Canyon.

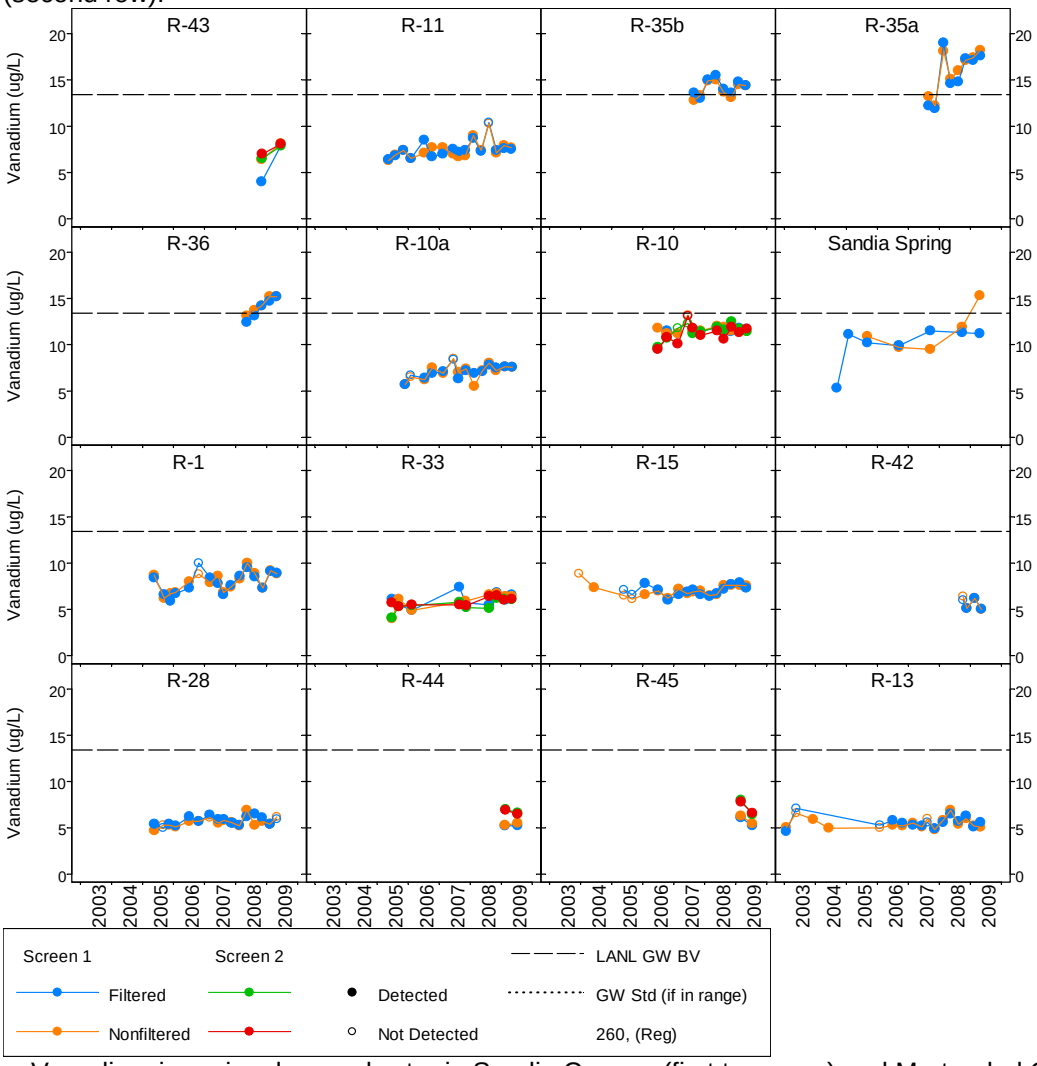


v. Vanadium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

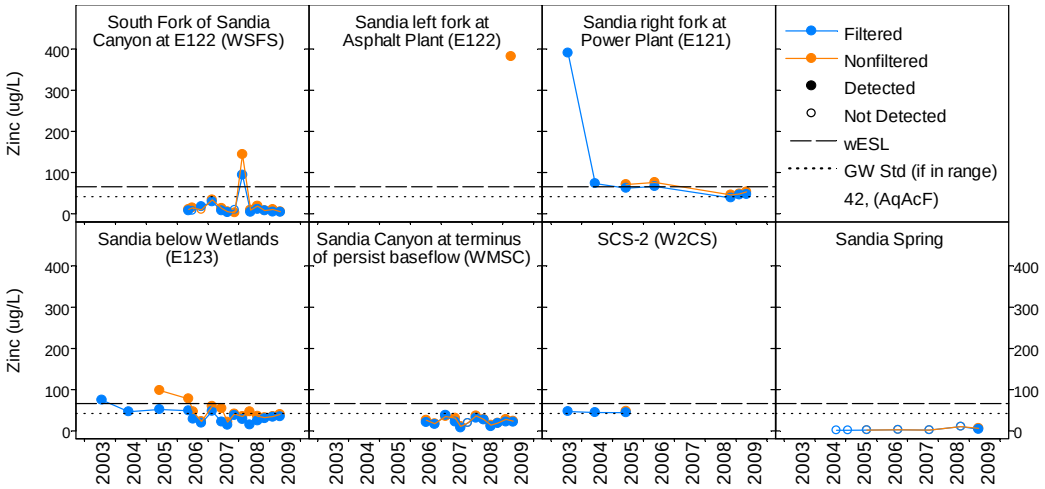


v. Vanadium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

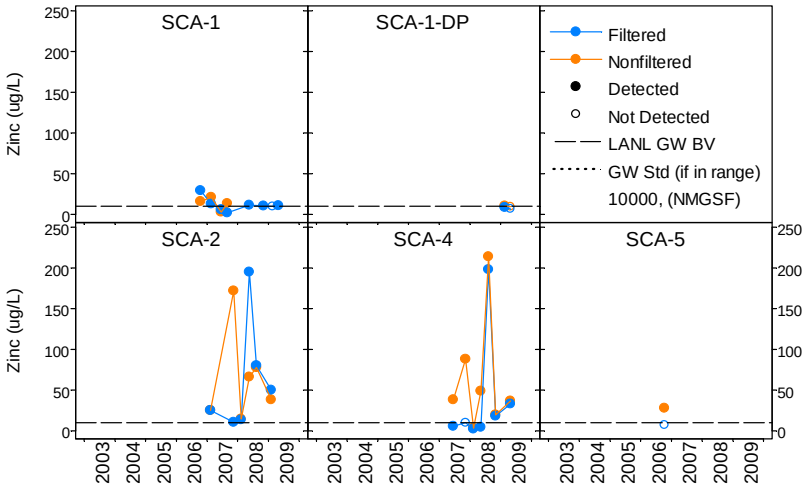


v. Vanadium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

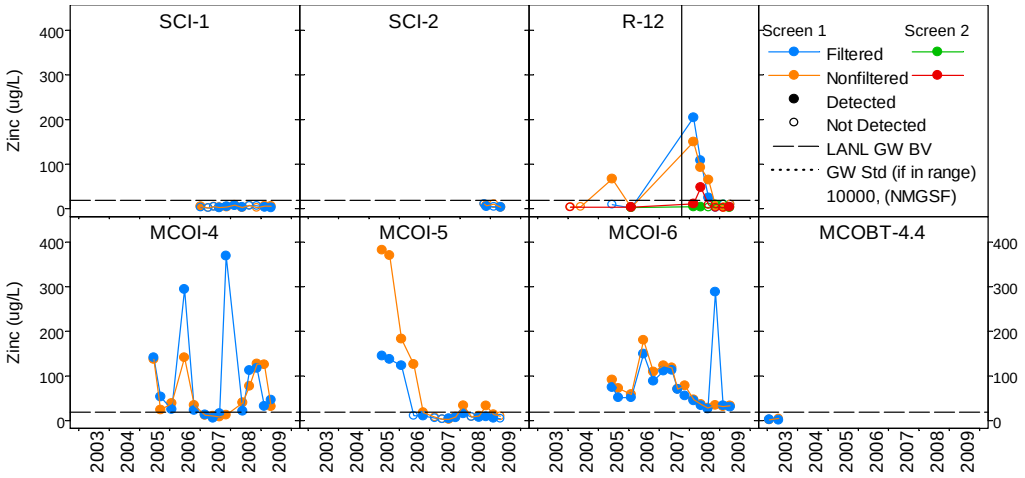


w. Zinc in nonstorm-related surface water in Sandia Canyon.

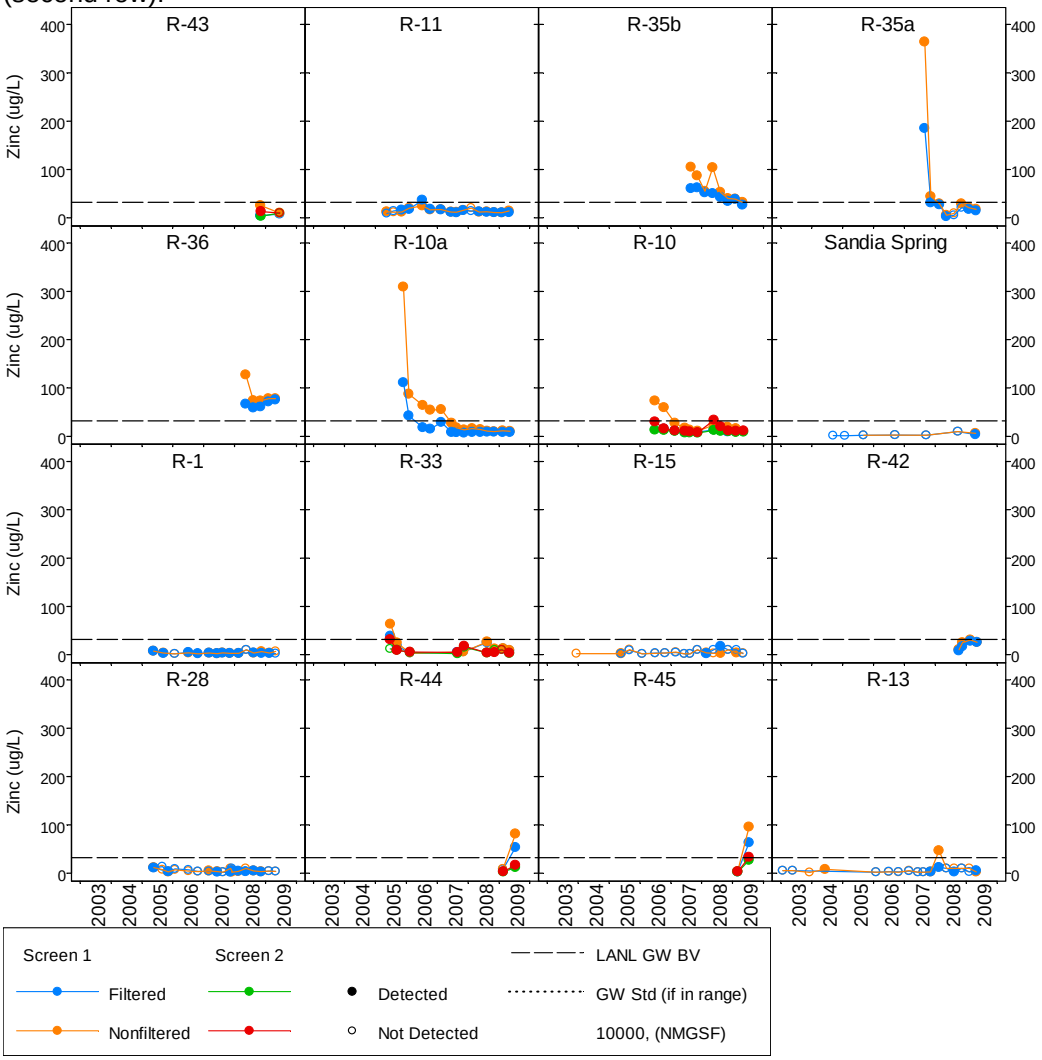


w. Zinc in alluvial groundwater in Sandia Canyon.

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

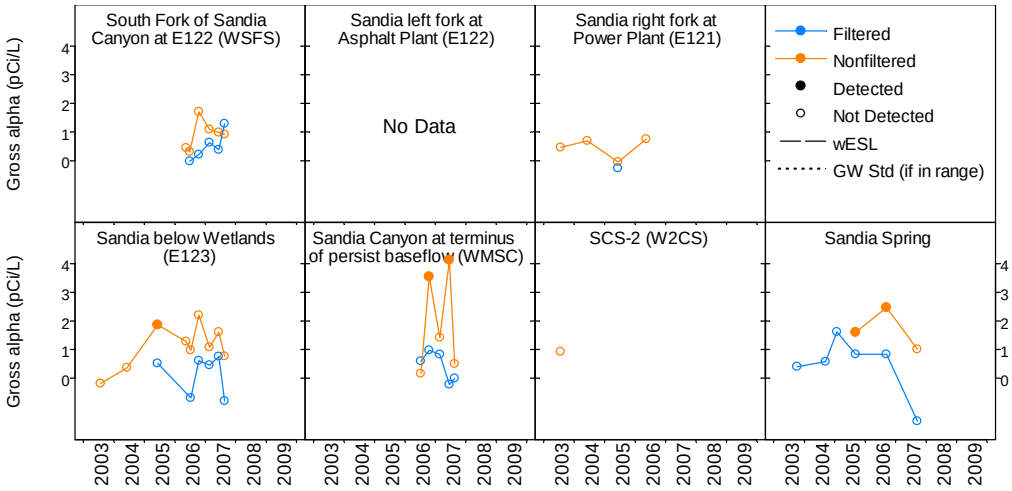


w. Zinc in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

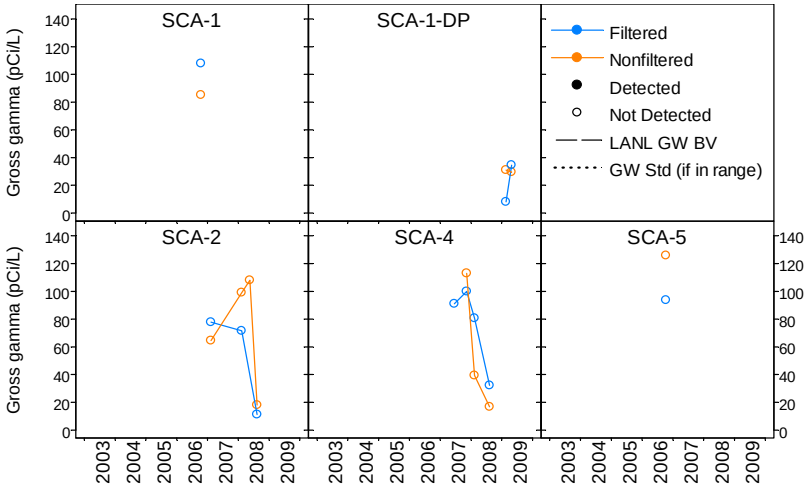


w. Zinc in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-1 (continued) Time-series plots of trace metals in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

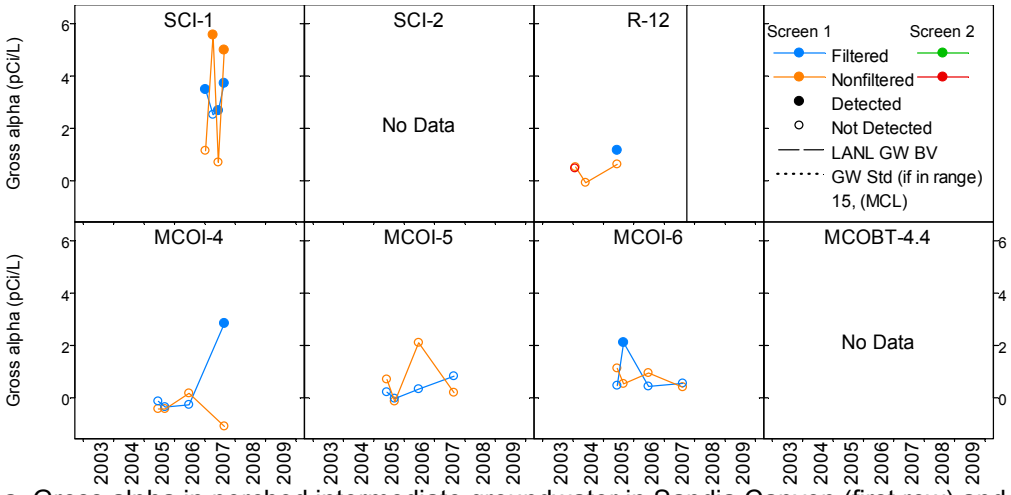


a. Gross alpha in nonstorm-related surface water in Sandia Canyon.

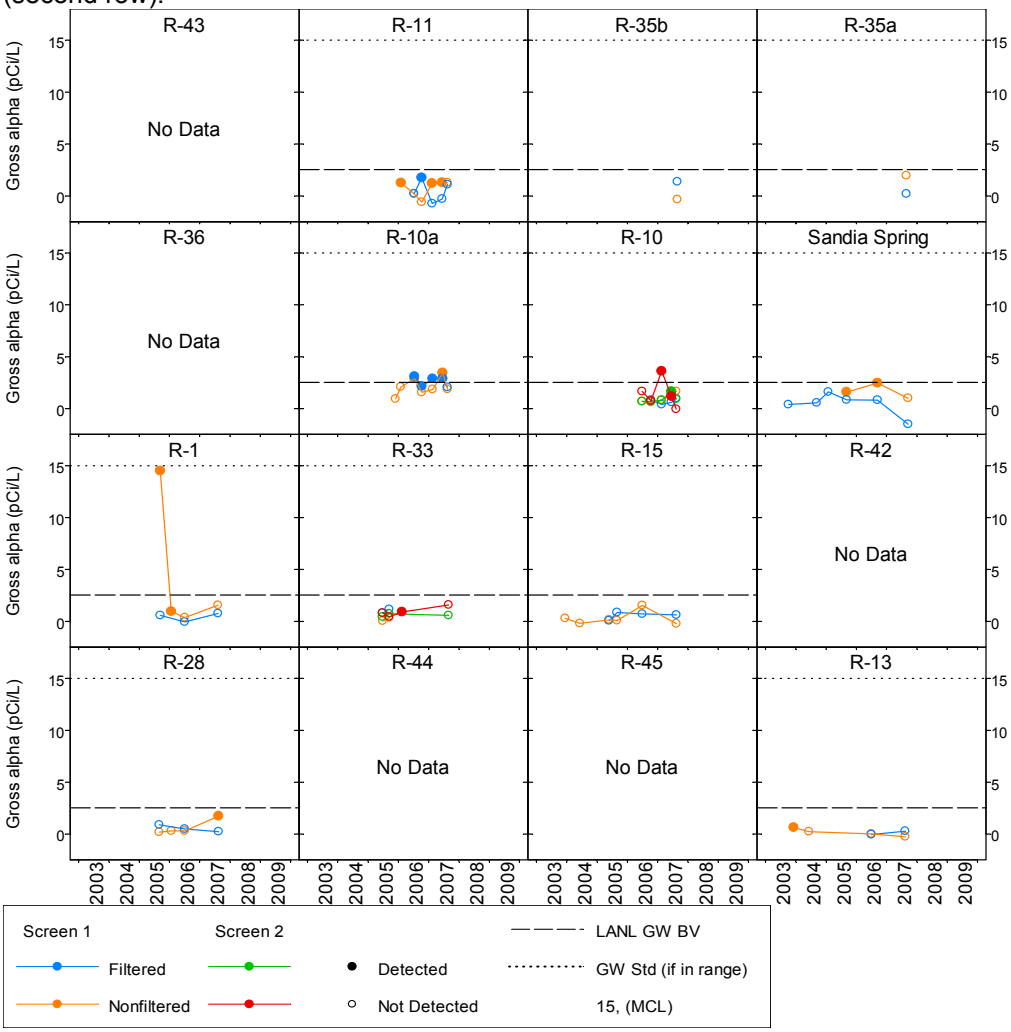


a. Gross alpha in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

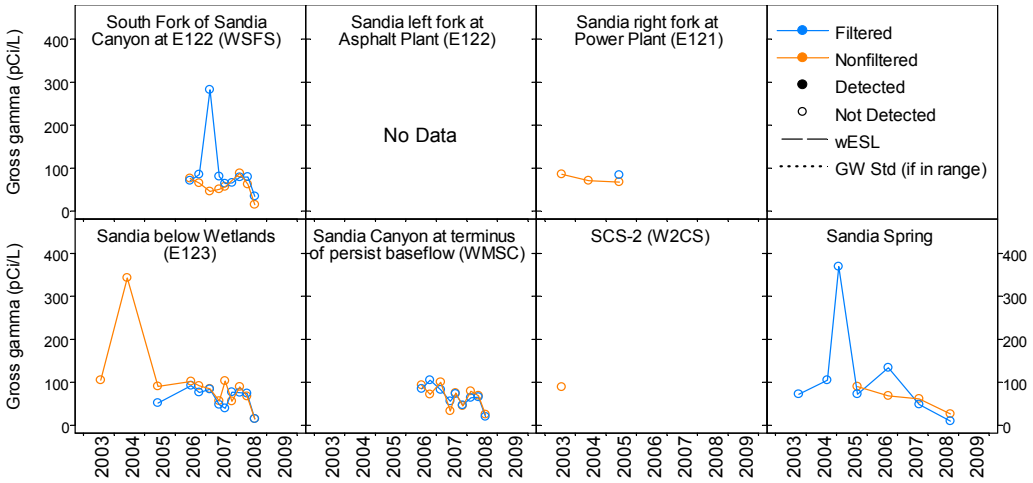


a. Gross alpha in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

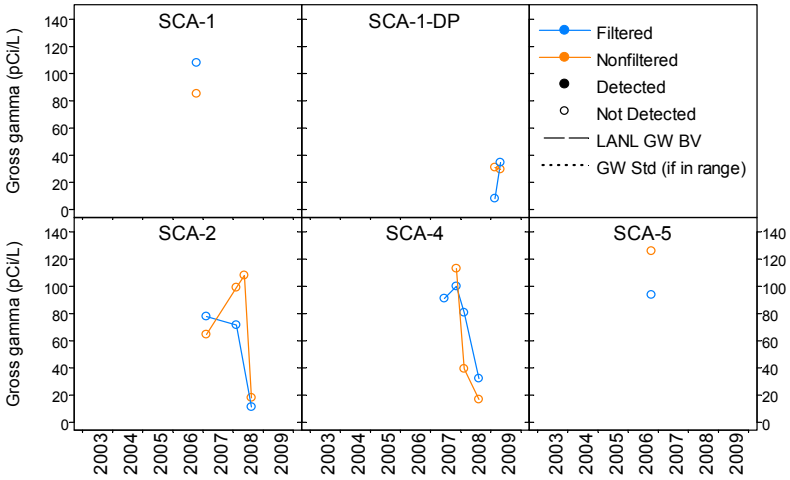


a. Gross alpha in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

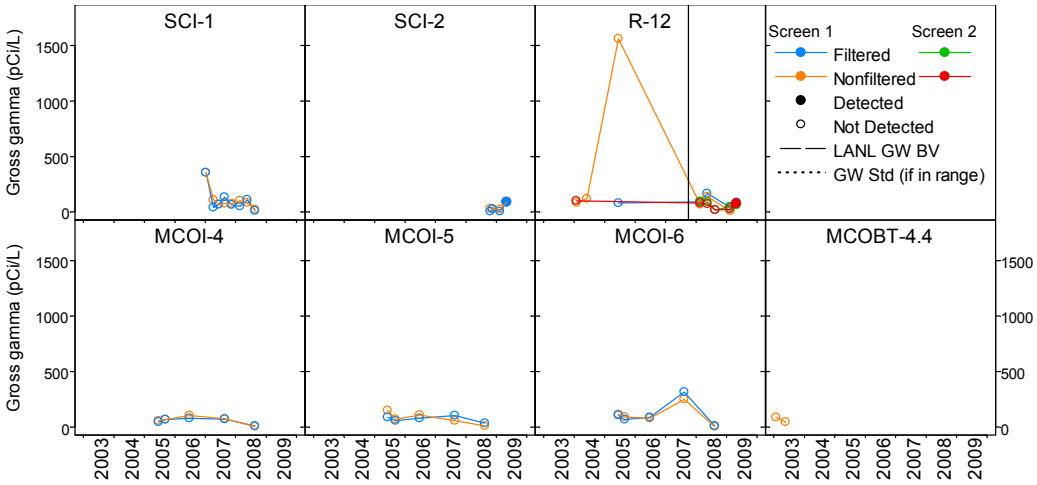


b. Gross gamma in nonstorm-related surface water in Sandia Canyon.

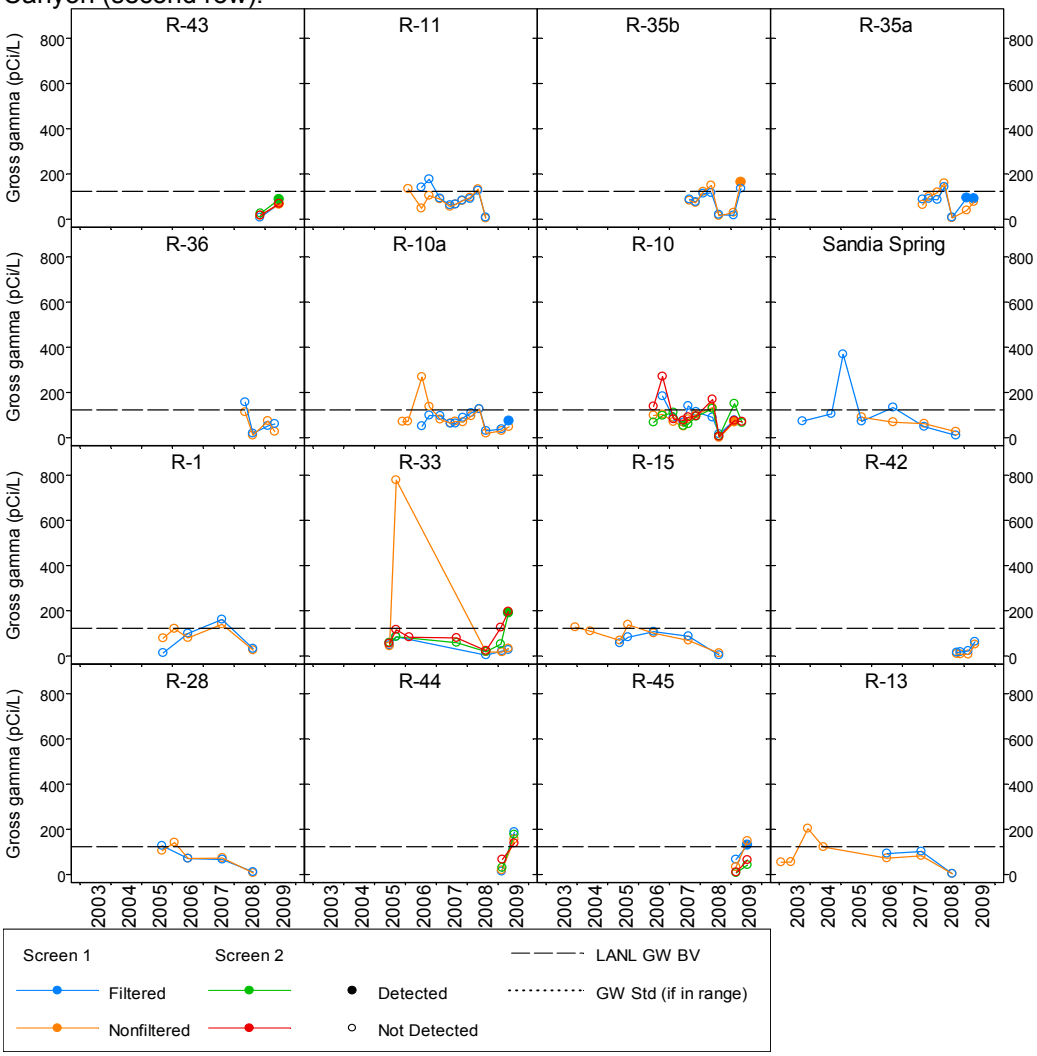


b. Gross gamma in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

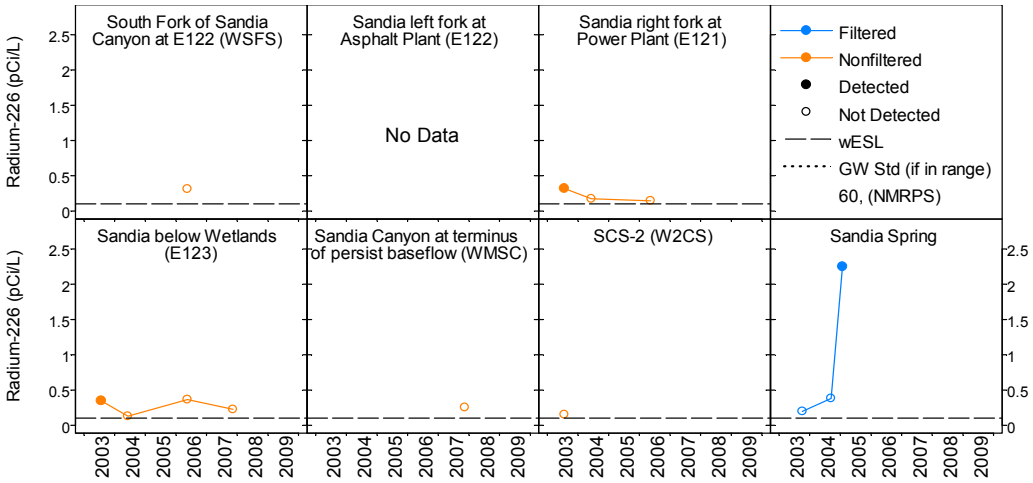


b. Gross gamma in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

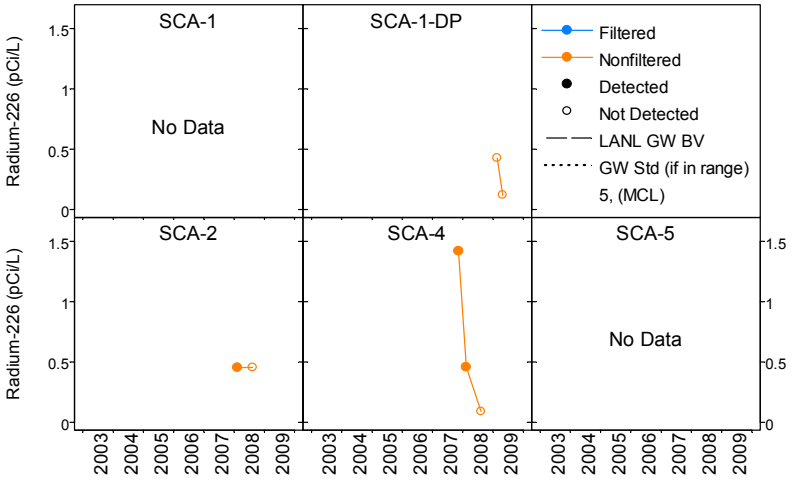


b. Gross gamma in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

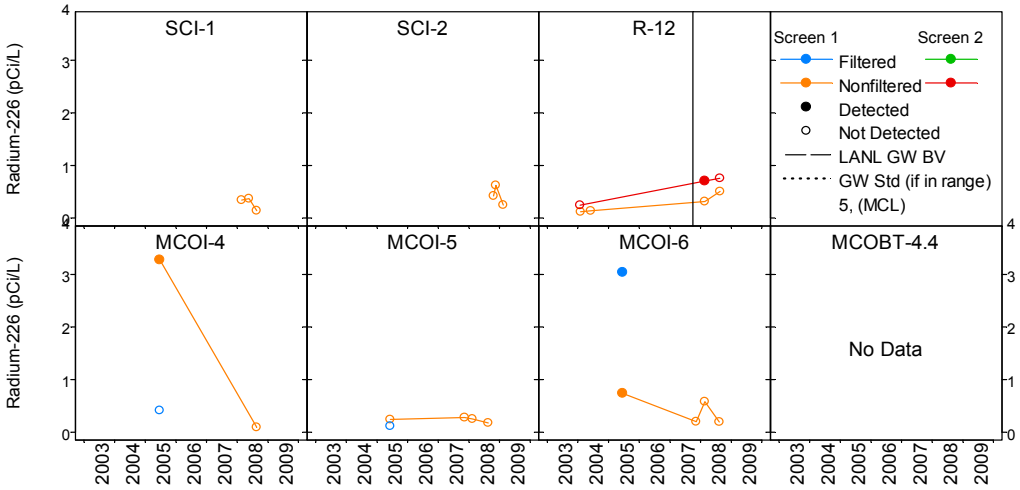


c. Radium-226 in nonstorm-related surface water in Sandia Canyon.

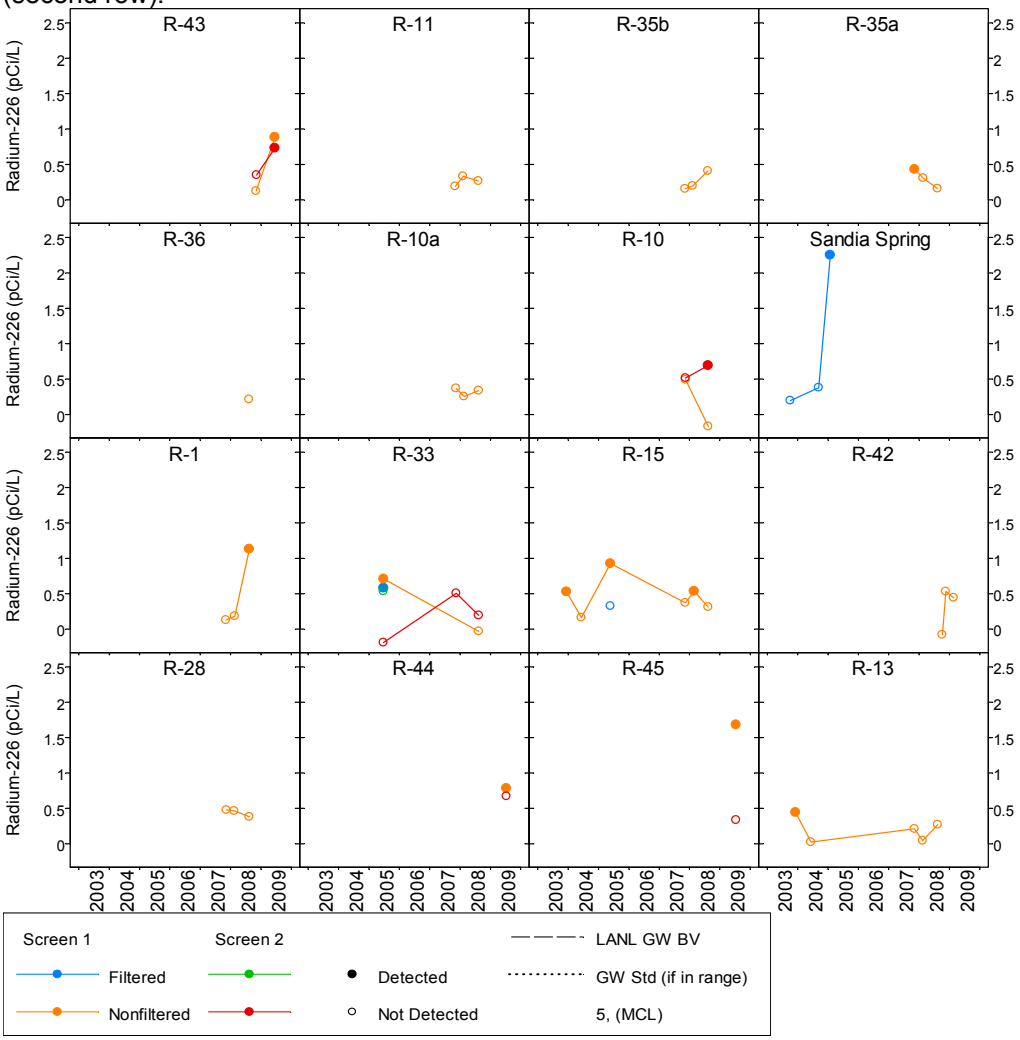


c. Radium-226 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

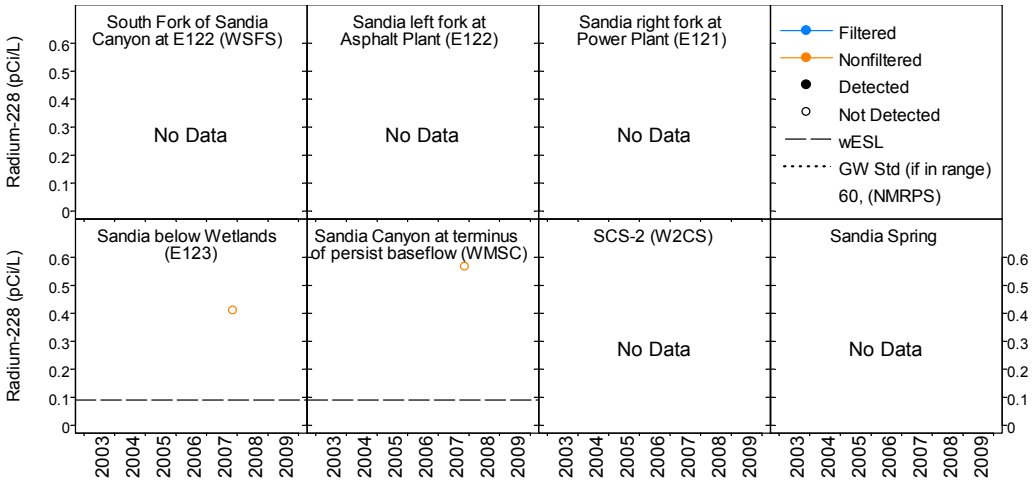


c. Radium-226 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

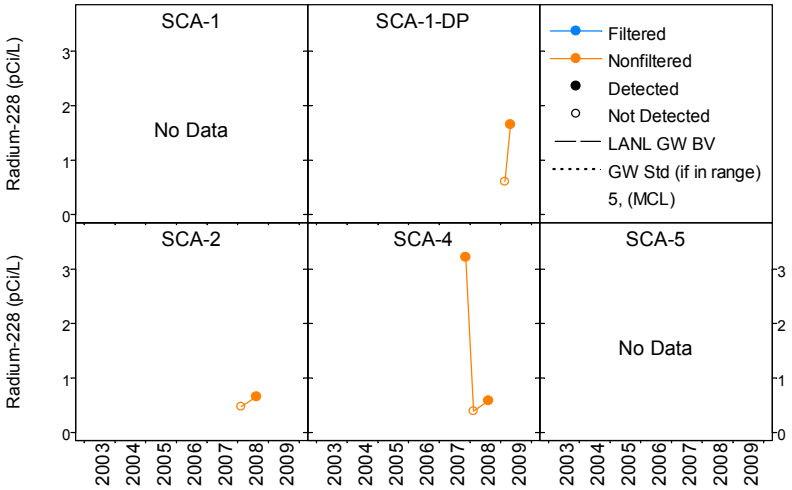


c. Radium-226 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

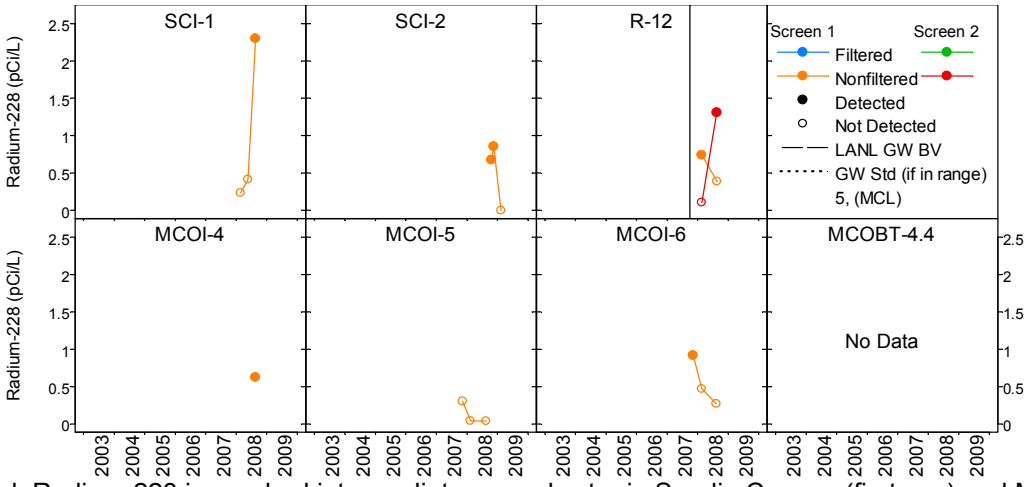


d. Radium-228 in nonstorm-related surface water in Sandia Canyon.

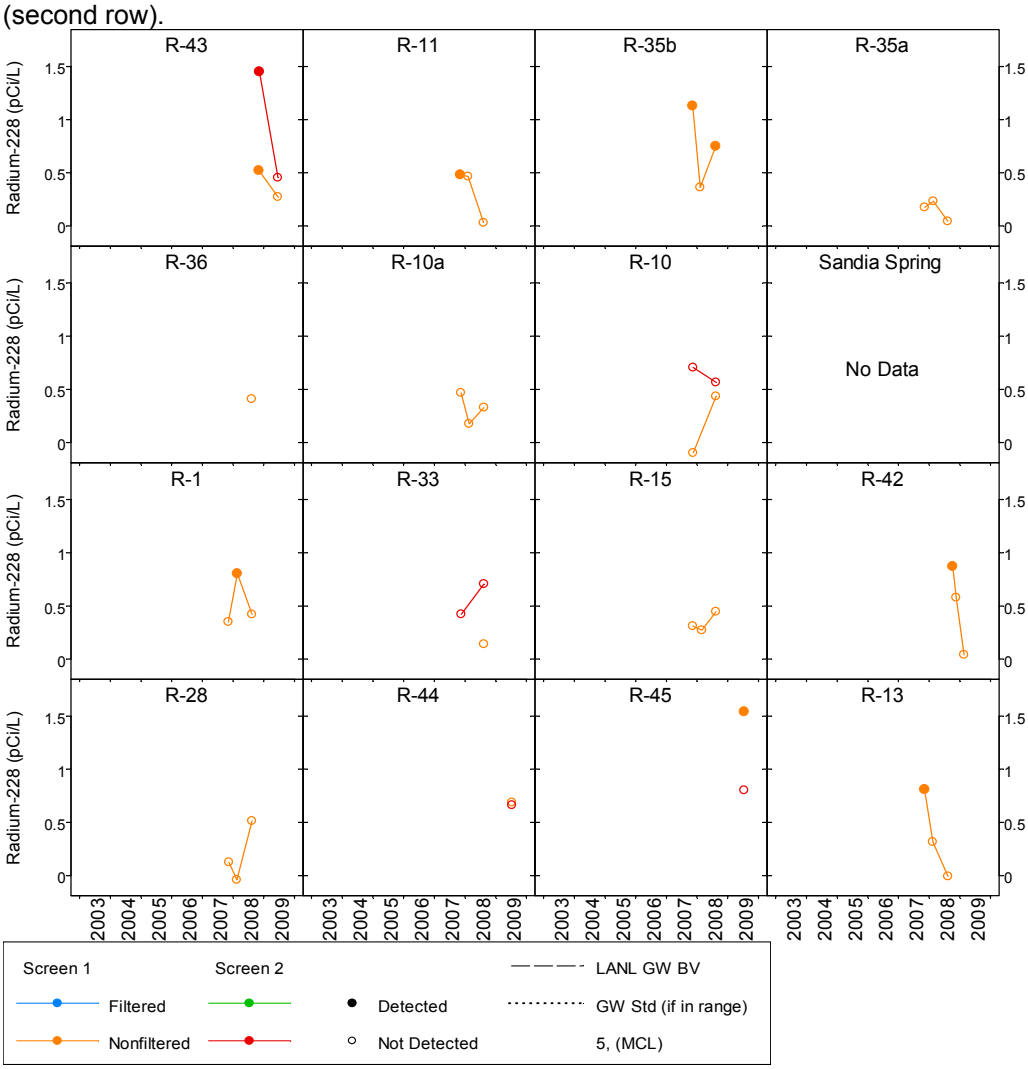


d. Radium-228 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

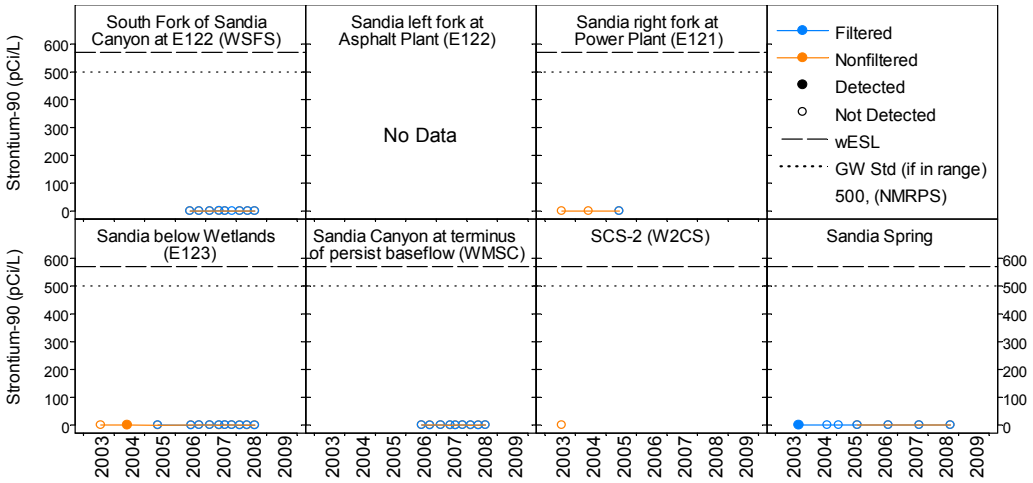


d. Radium-228 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

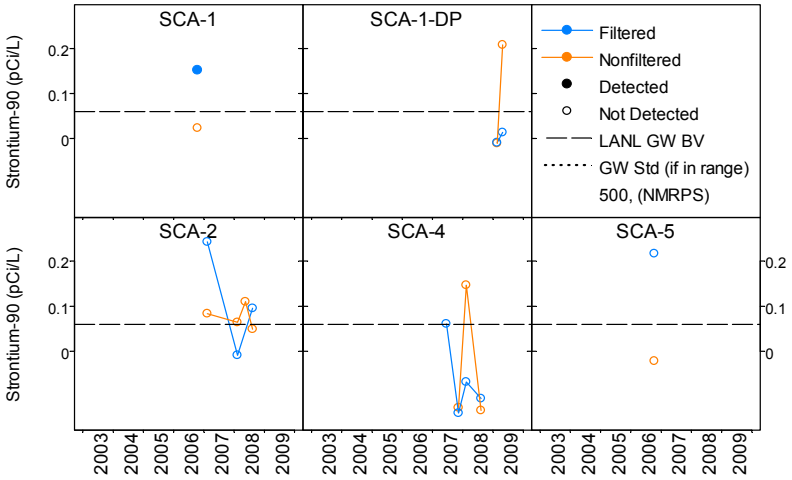


d. Radium-228 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

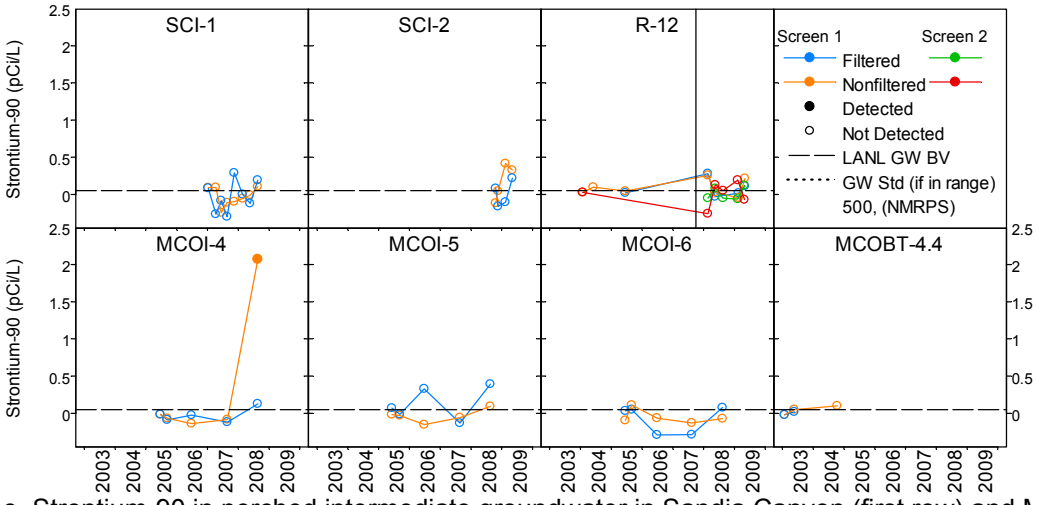


e. Strontium-90 in nonstorm-related surface water in Sandia Canyon.

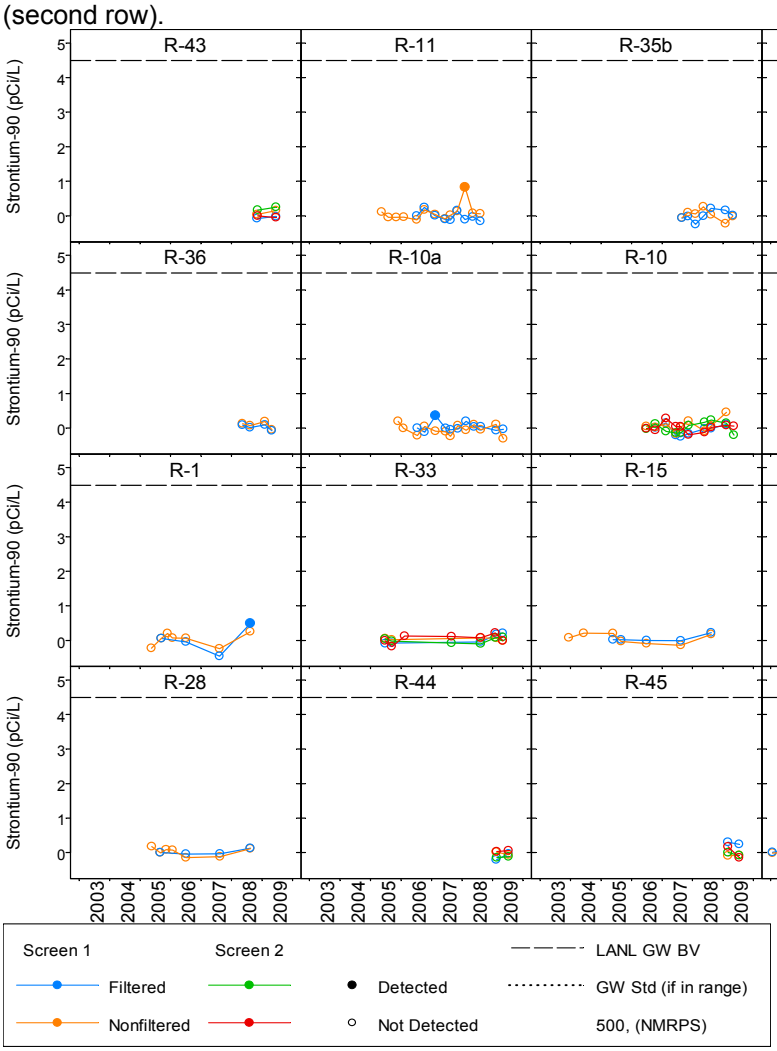


e. Strontium-90 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

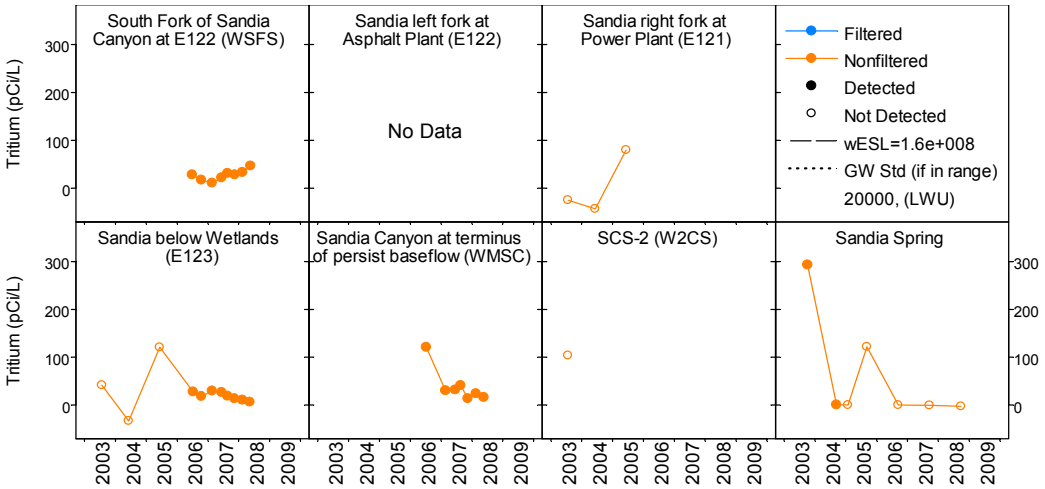


e. Strontium-90 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

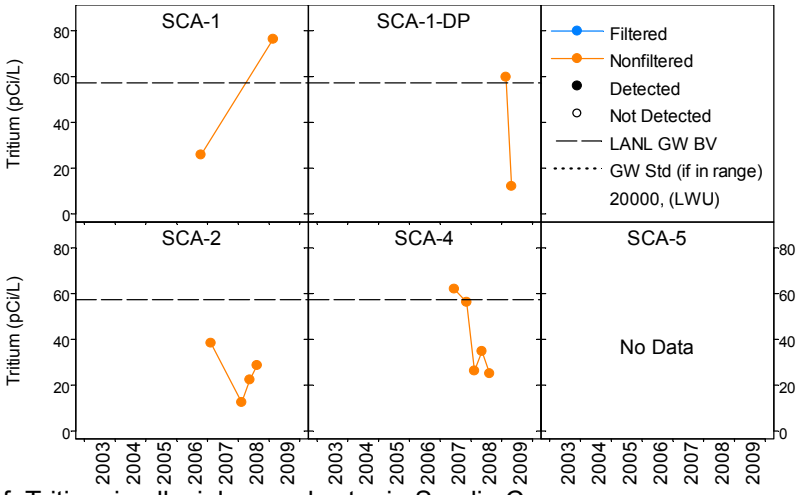


e. Strontium-90 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

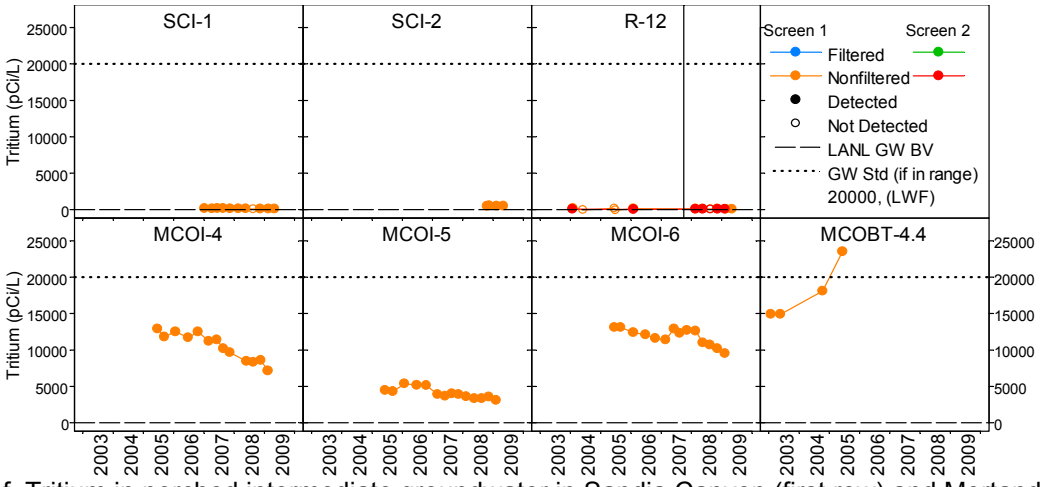


f. Tritium in nonstorm-related surface water in Sandia Canyon.

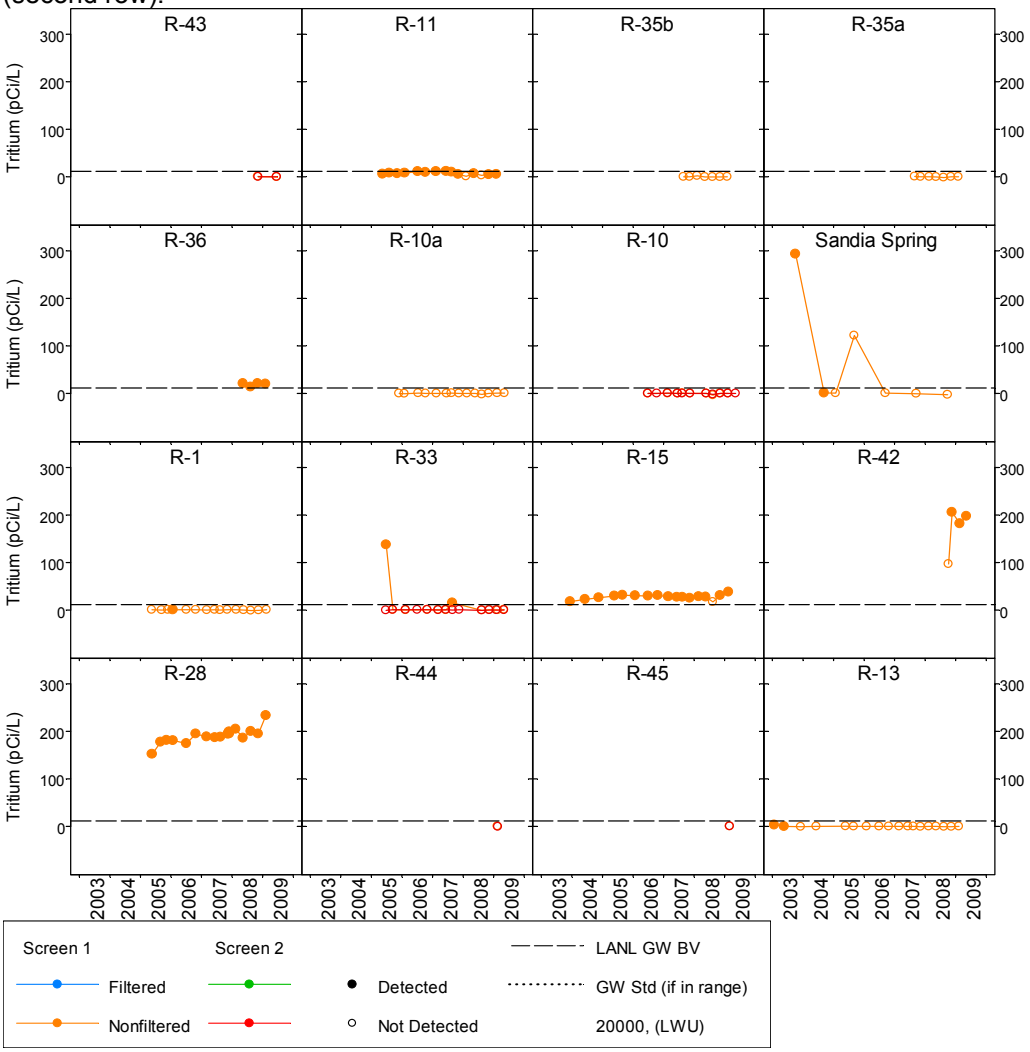


f. Tritium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

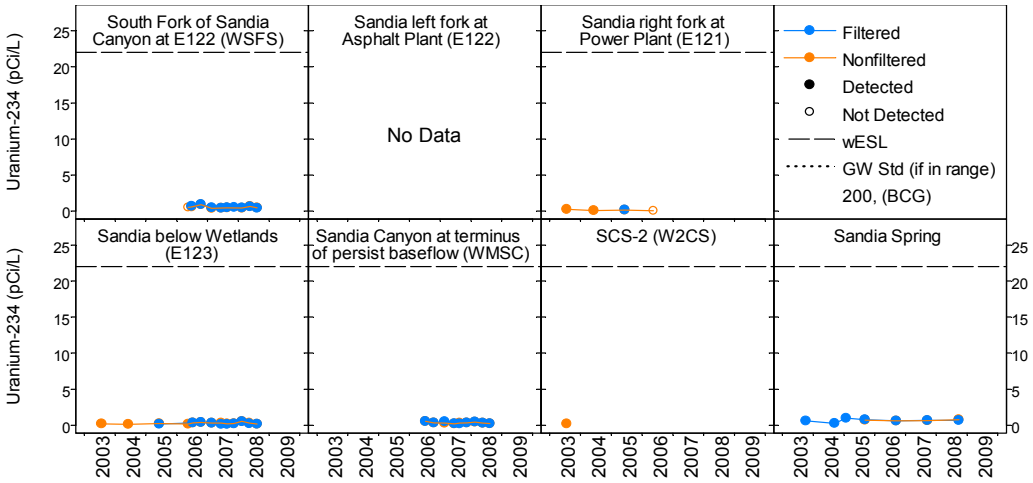


f. Tritium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).



f. Tritium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

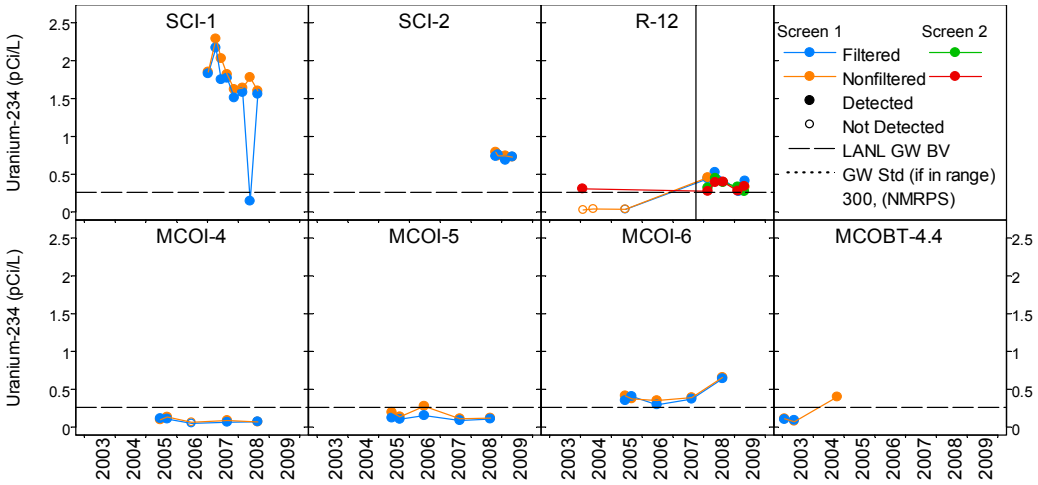
Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009



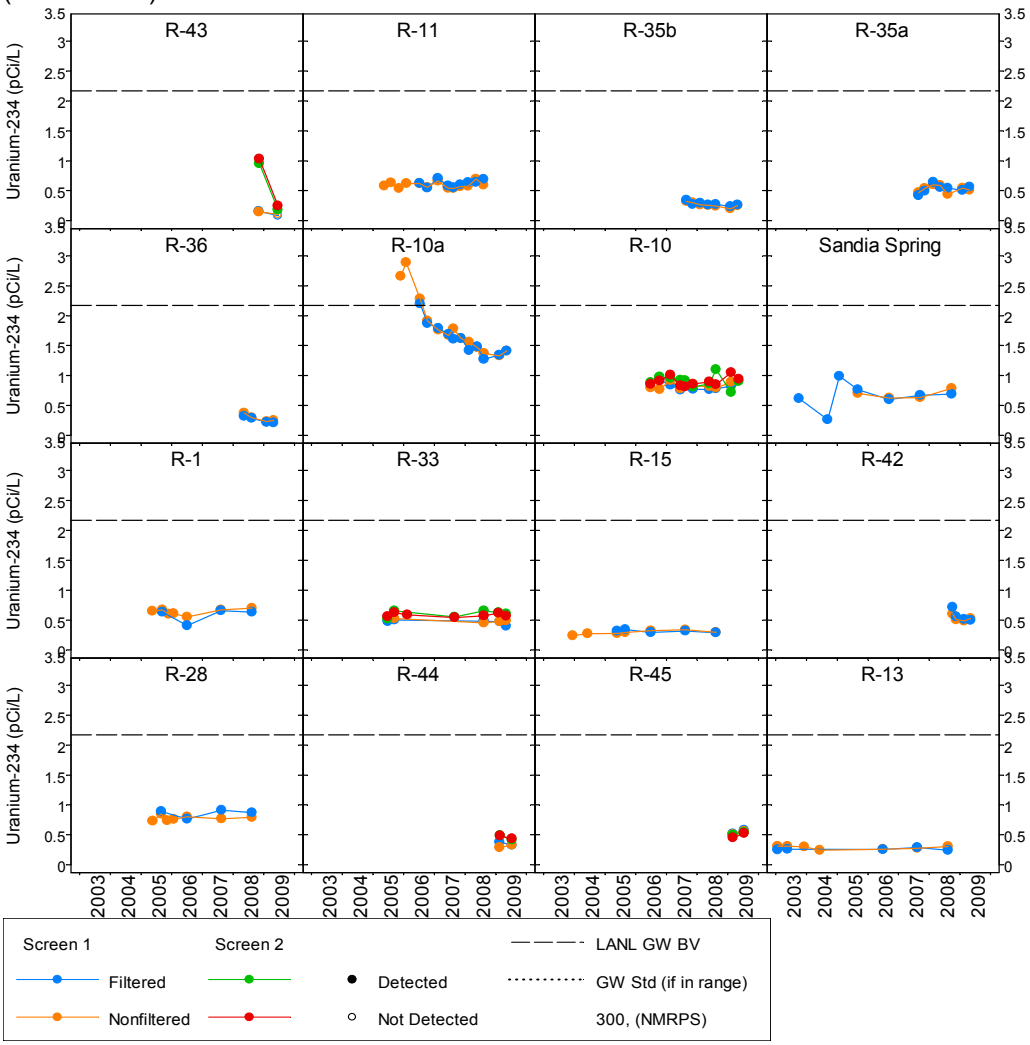
g. Uranium-234 in nonstorm-related surface water in Sandia Canyon.

g. Uranium-234 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

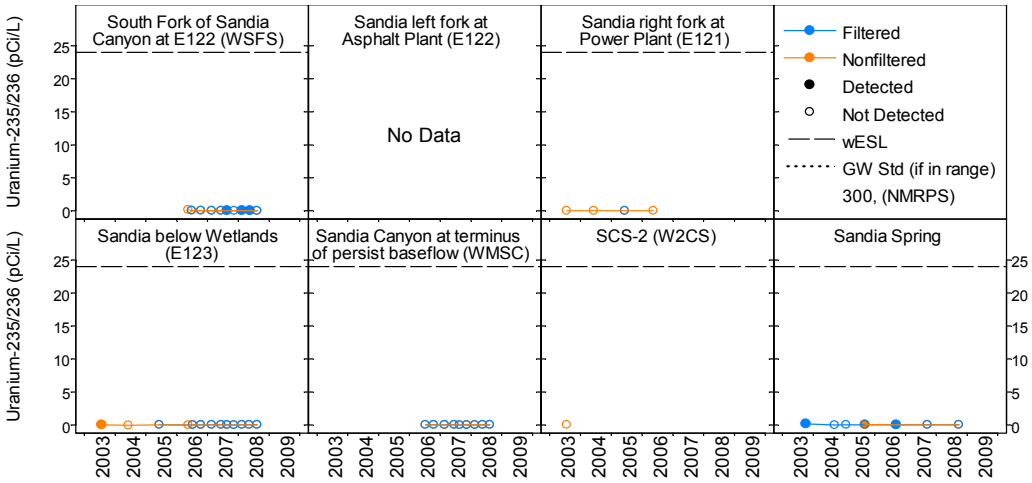


g. Uranium-234 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

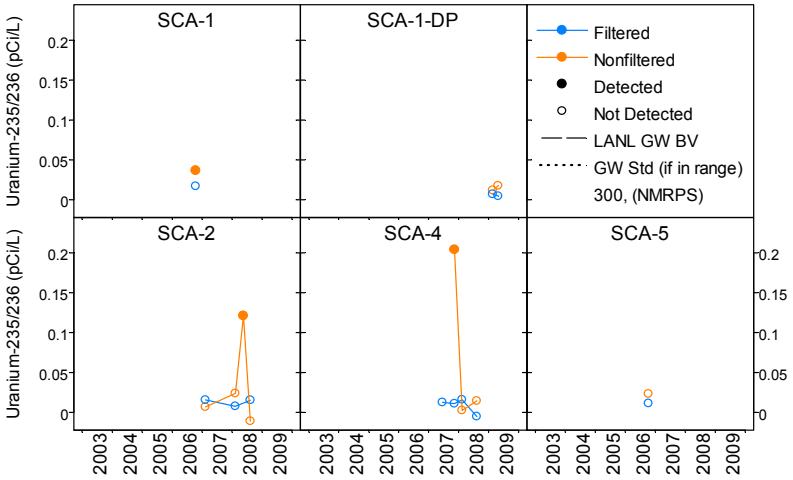


g. Uranium-234 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

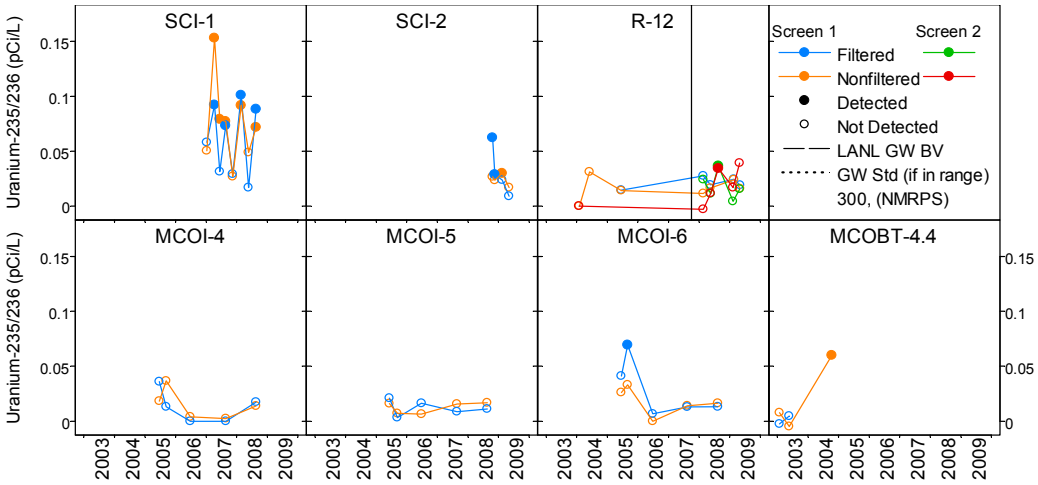


h. Uranium-235/236 in nonstorm-related surface water in Sandia Canyon.

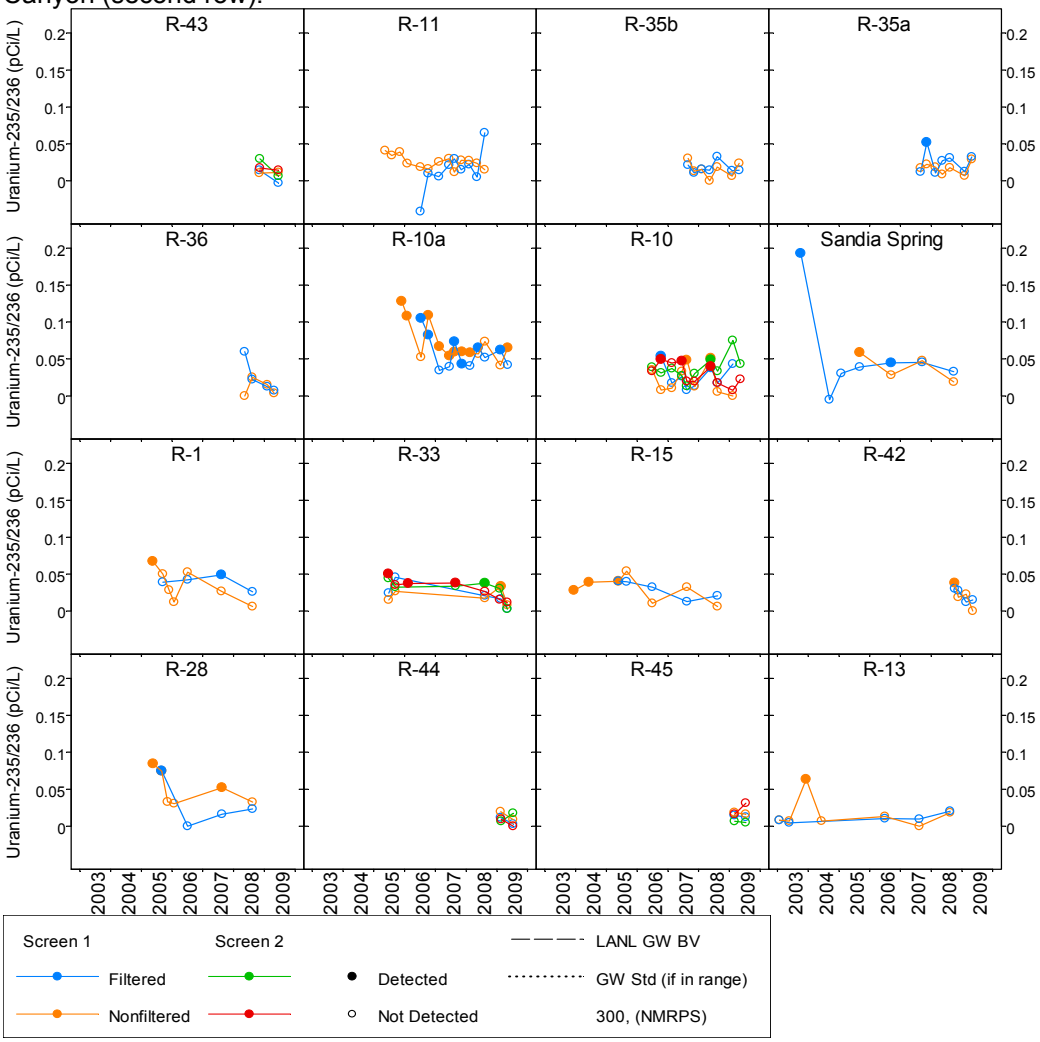


h. Uranium-235/236 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

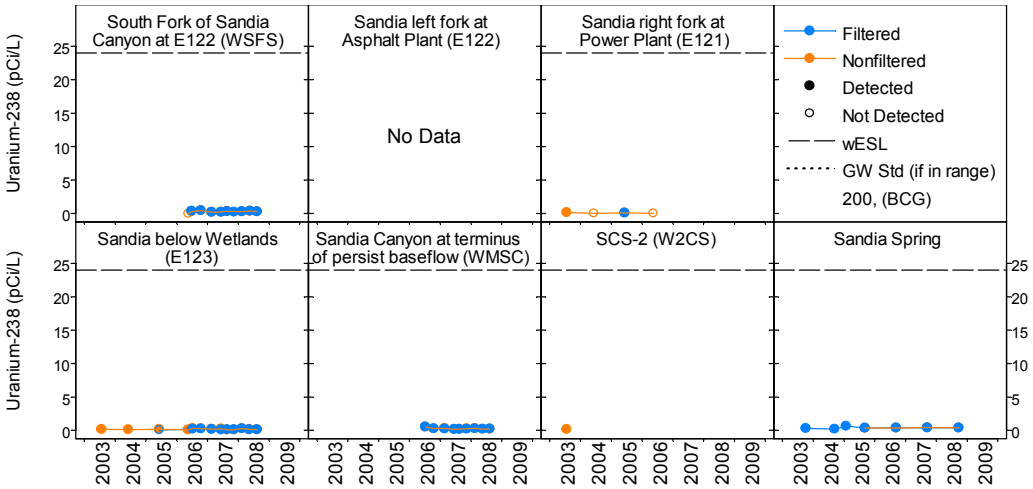


h. Uranium-235/236 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

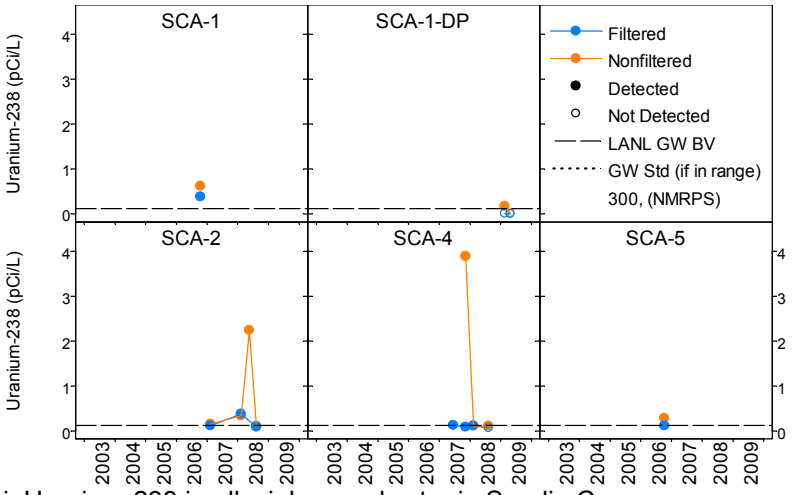


h. Uranium-235/236 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

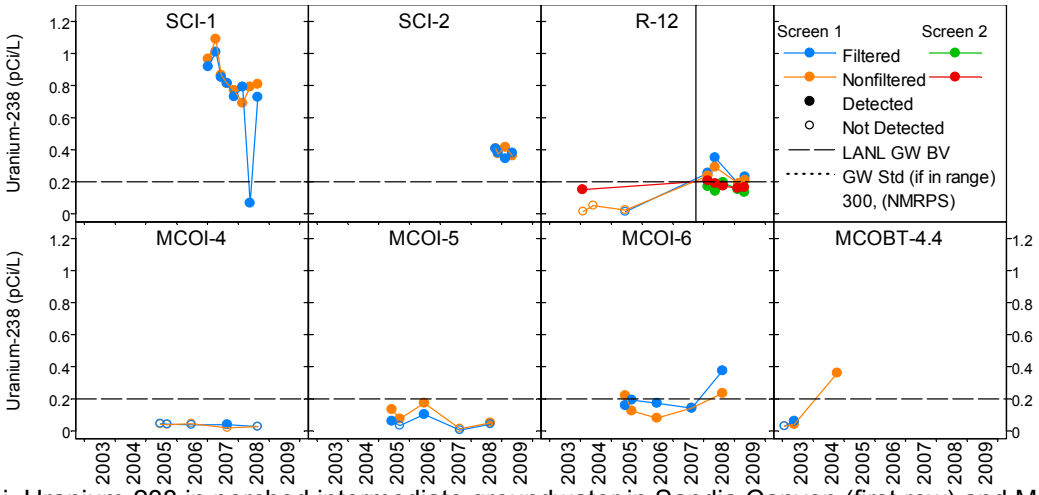


i. Uranium-238 in nonstorm-related surface water in Sandia Canyon.

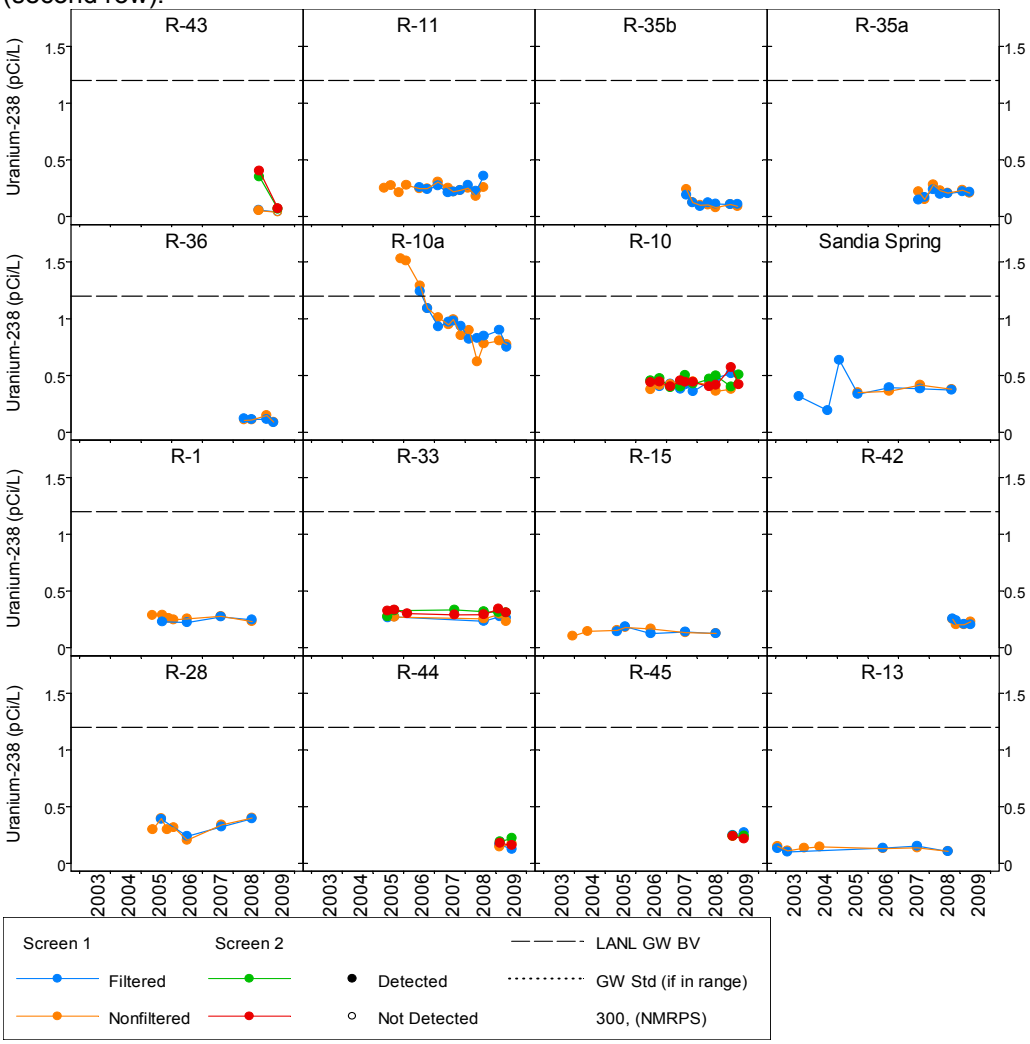


i. Uranium-238 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

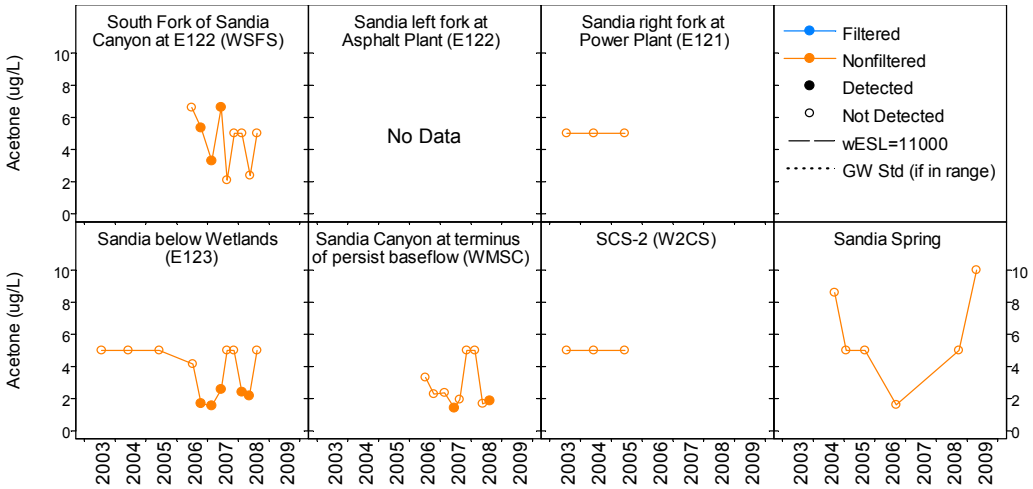


i. Uranium-238 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

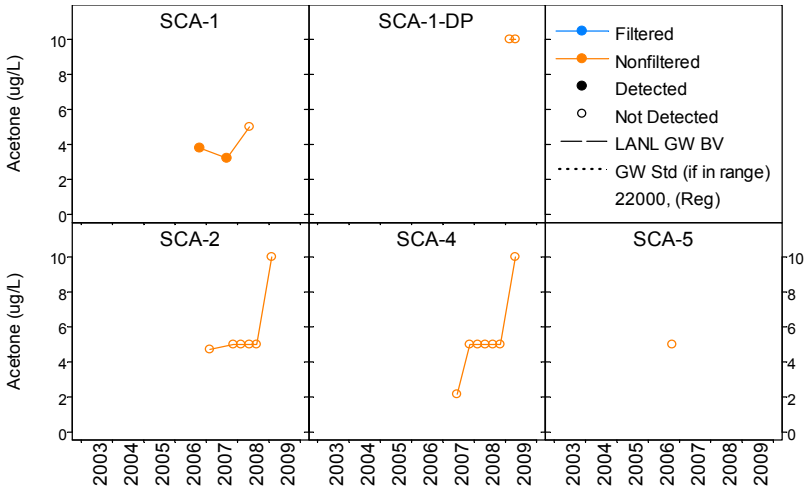


i. Uranium-238 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-2 (continued) Time-series plots of radionuclides in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

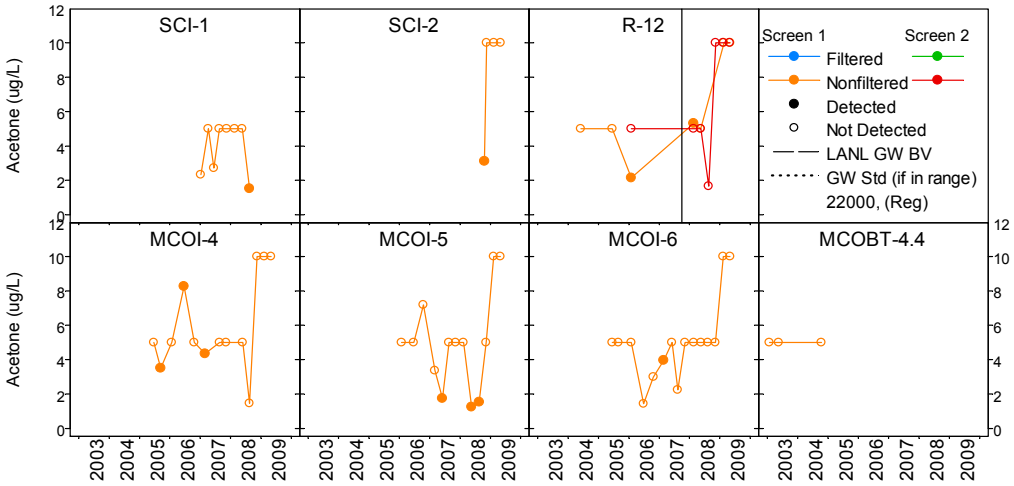


a. Acetone in nonstorm-related surface water in Sandia Canyon.

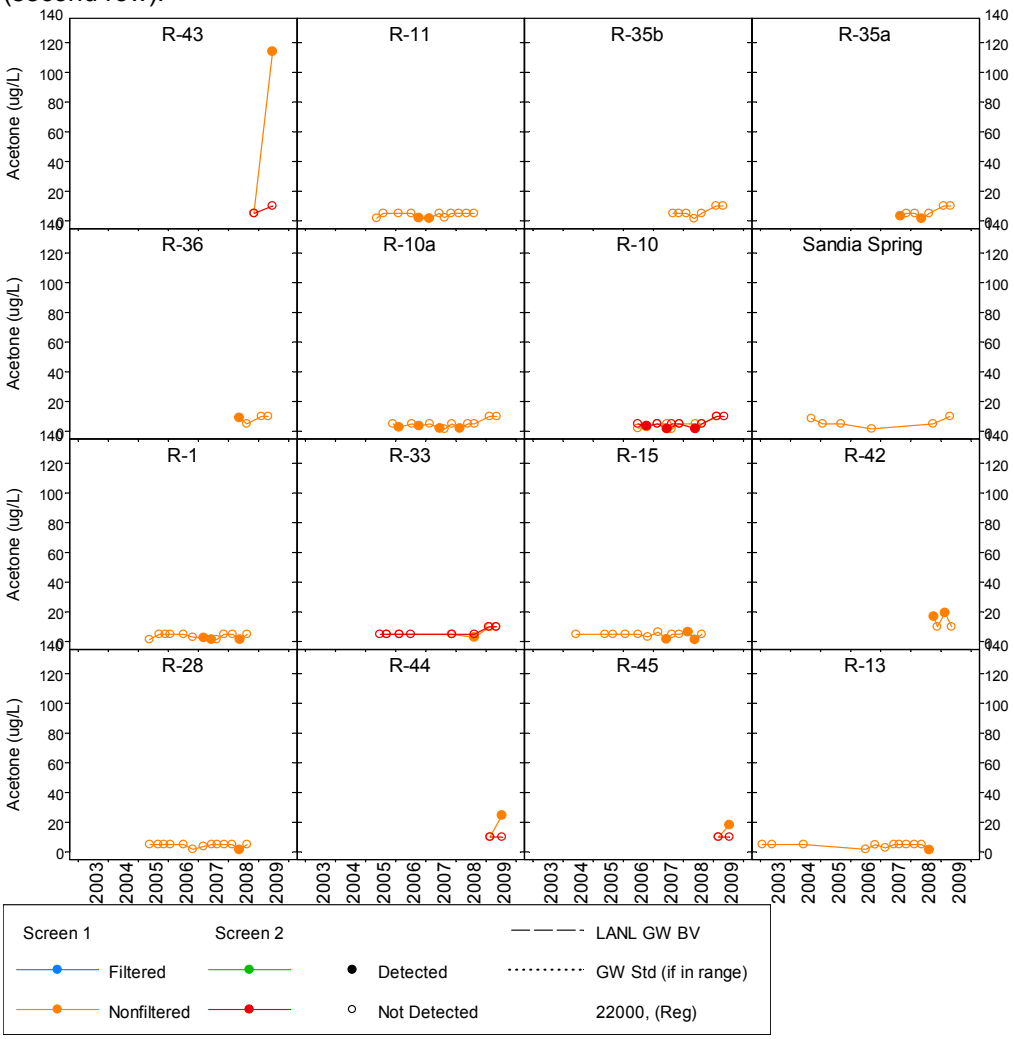


a. Acetone in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

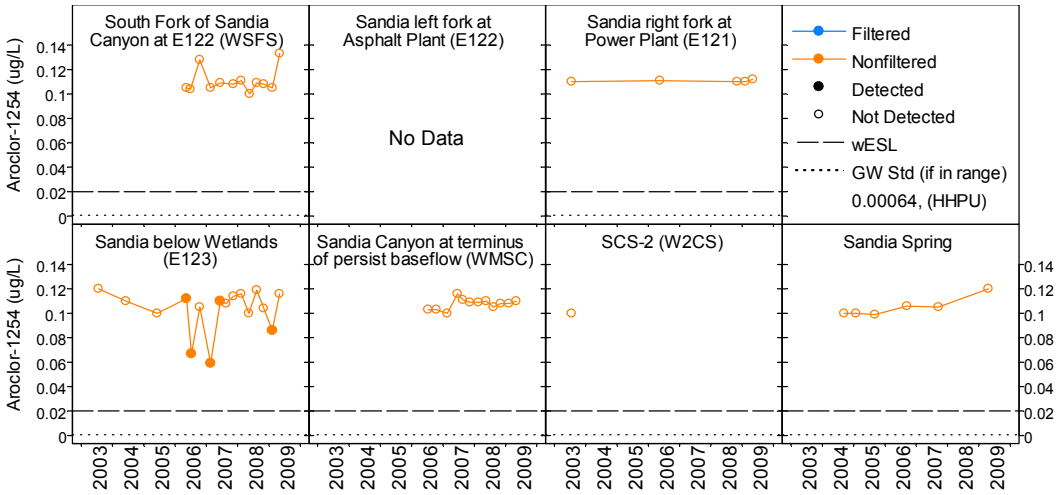


a. Acetone in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

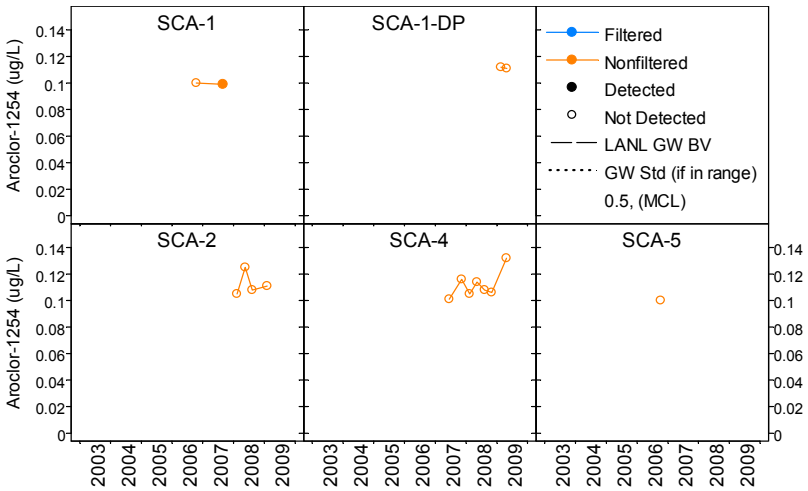


a. Acetone in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

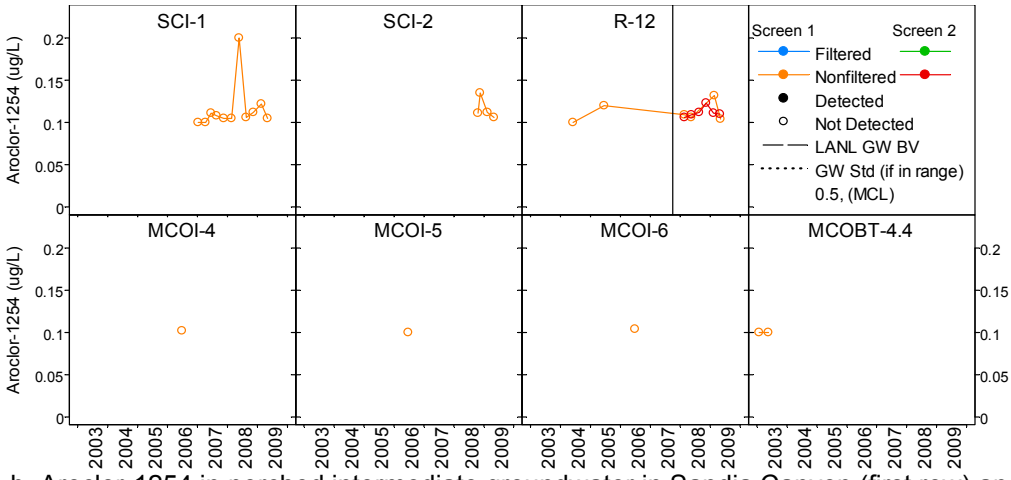


b. Aroclor-1254 in nonstorm-related surface water in Sandia Canyon.

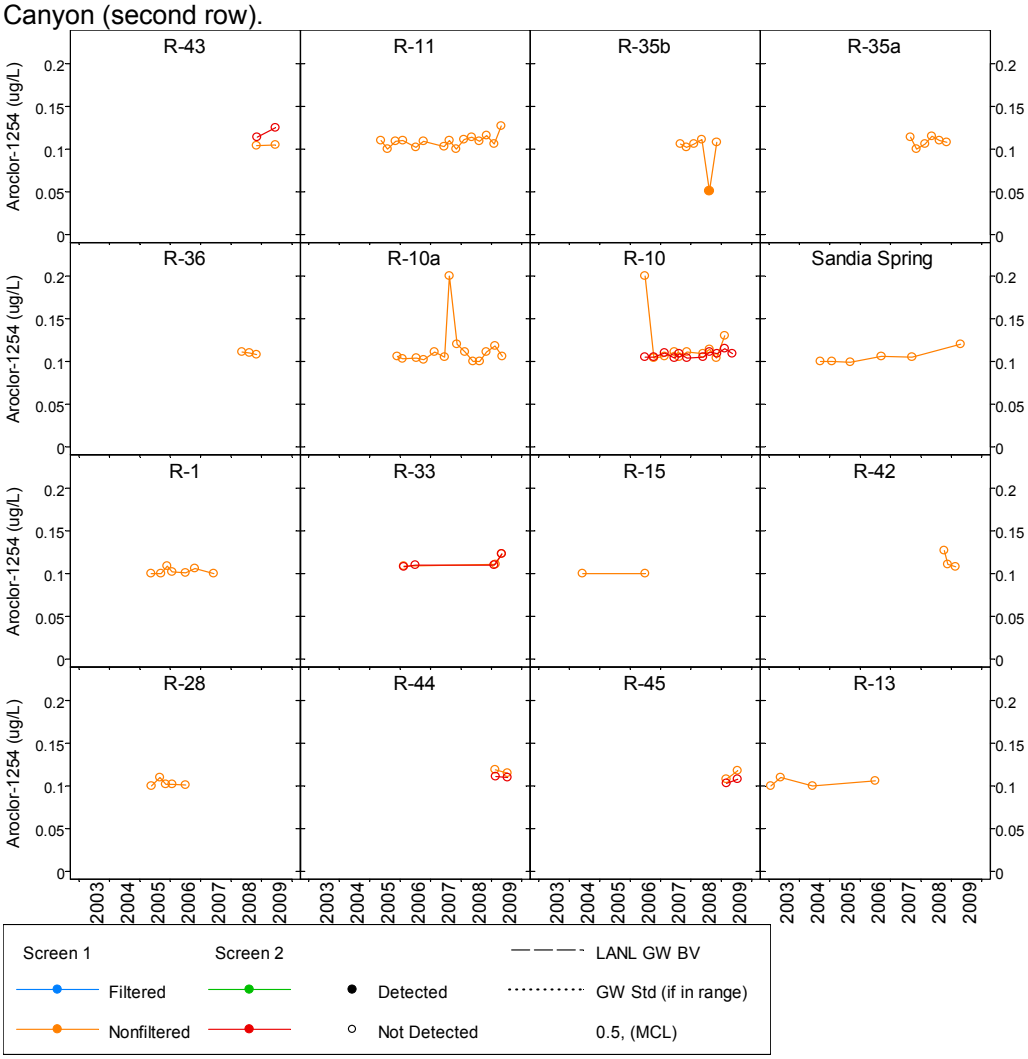


b. Aroclor-1254 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

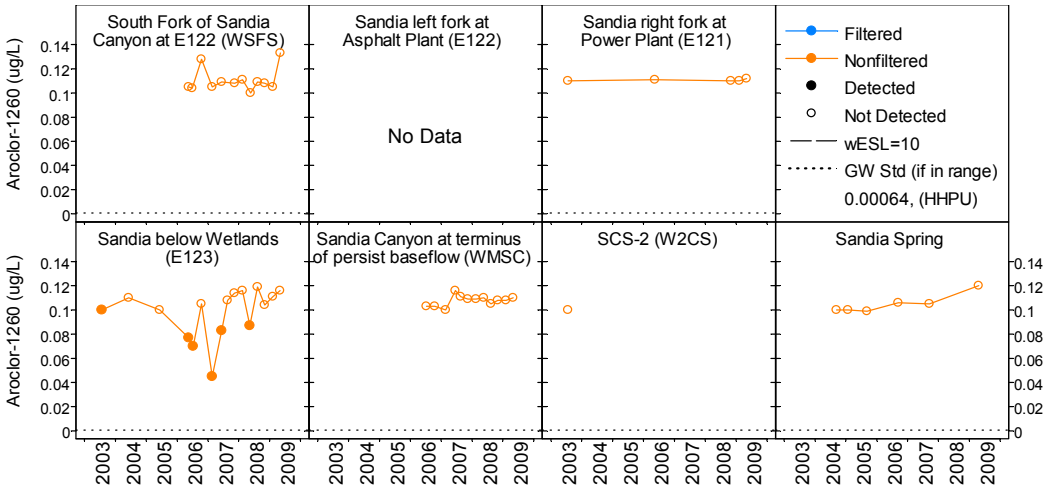


b. Aroclor-1254 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

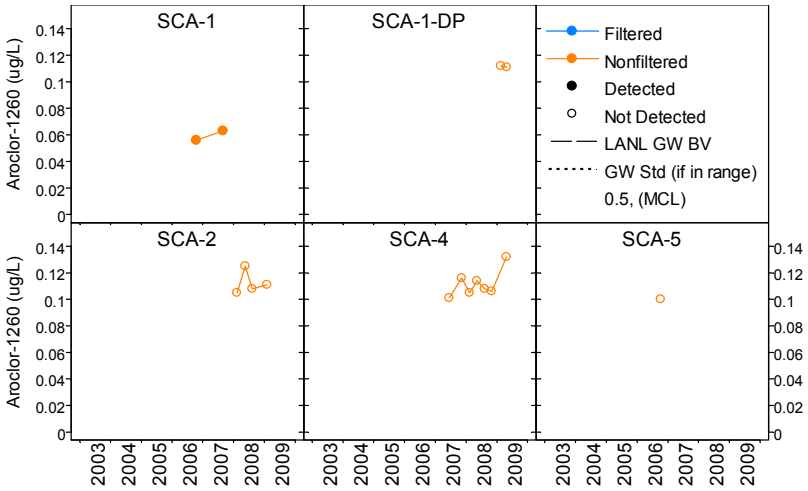


b. Aroclor-1254 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

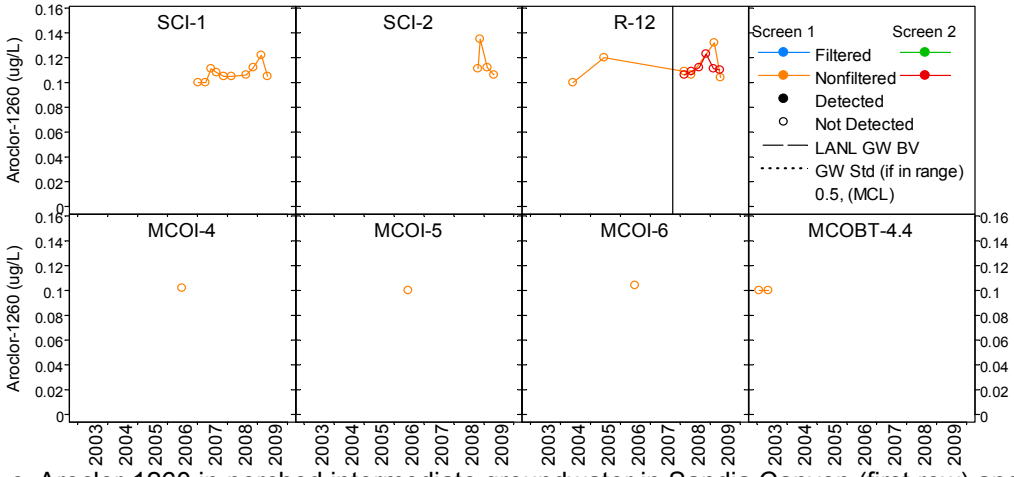


c. Aroclor-1260 in nonstorm-related surface water in Sandia Canyon.

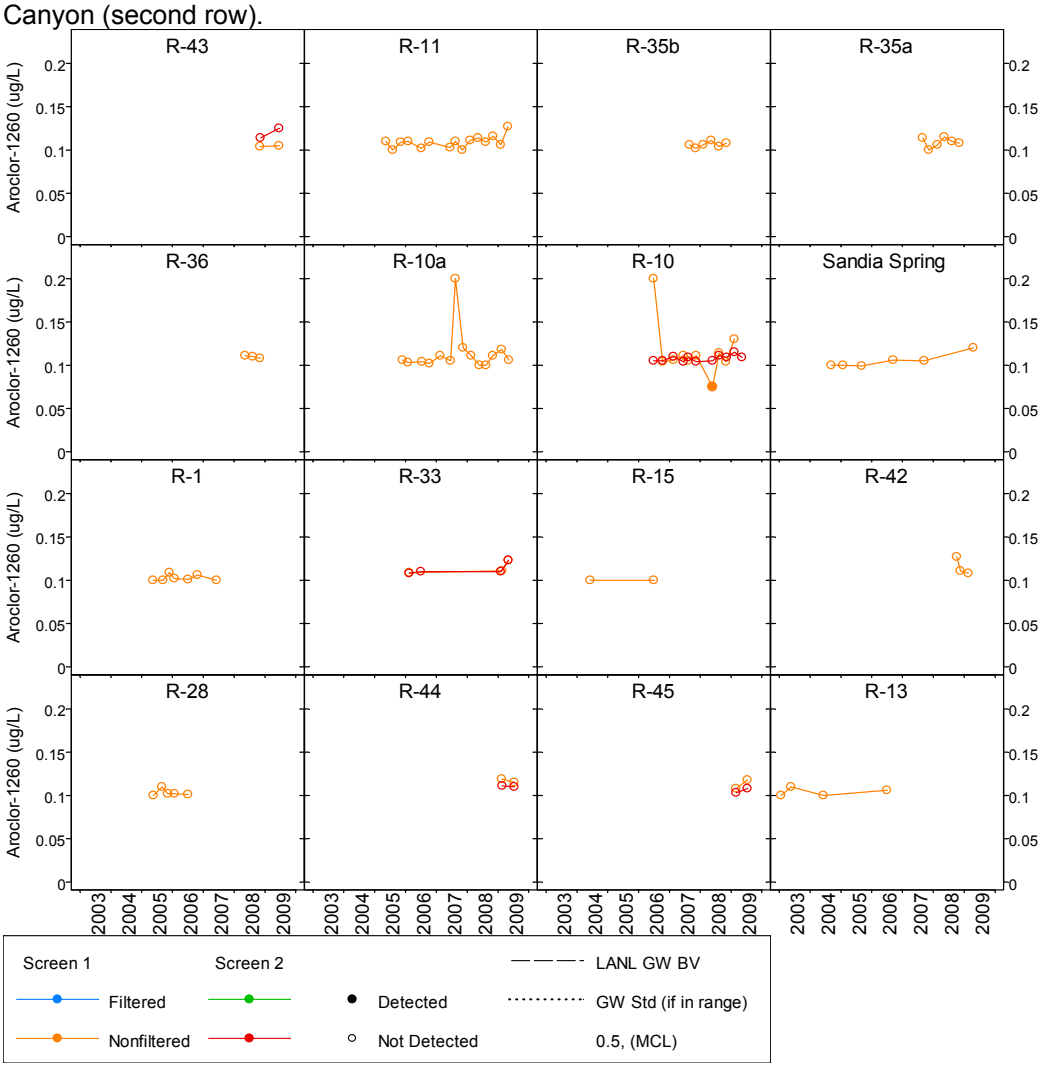


c. Aroclor-1260 in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

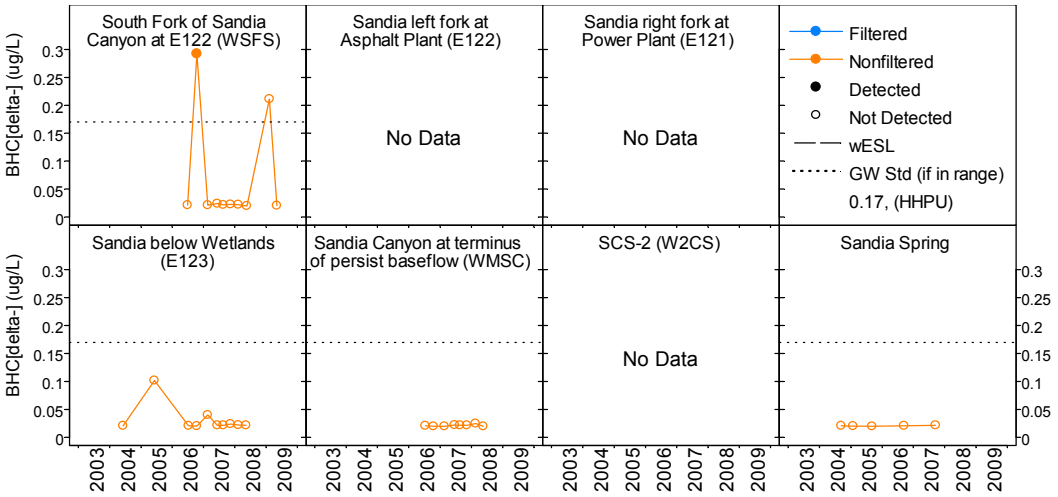


c. Aroclor-1260 in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

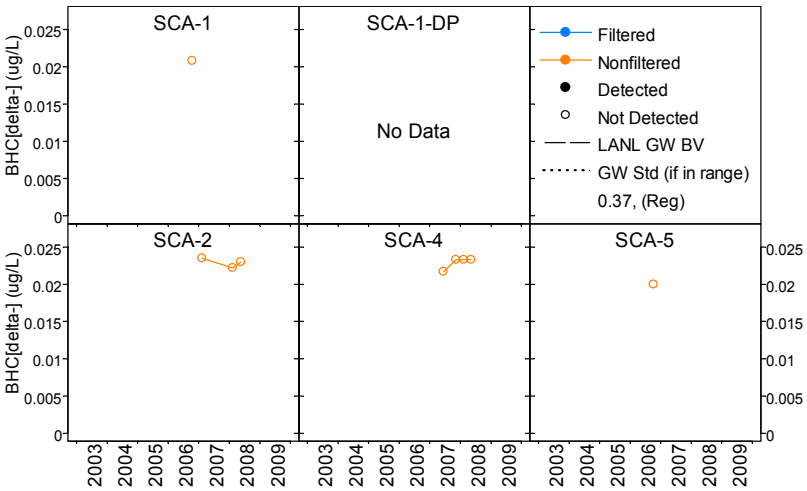


c. Aroclor-1260 in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

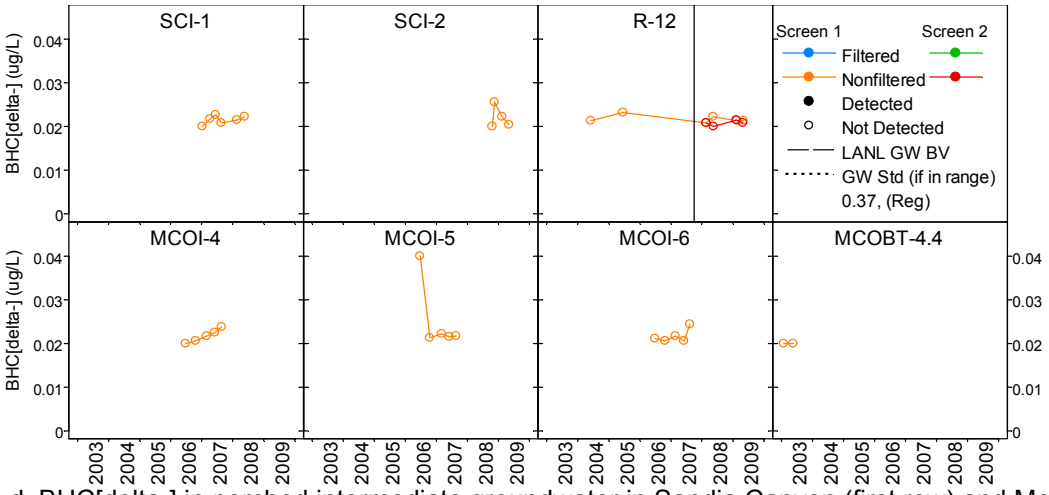


d. BHC[delta-] in nonstorm-related surface water in Sandia Canyon.

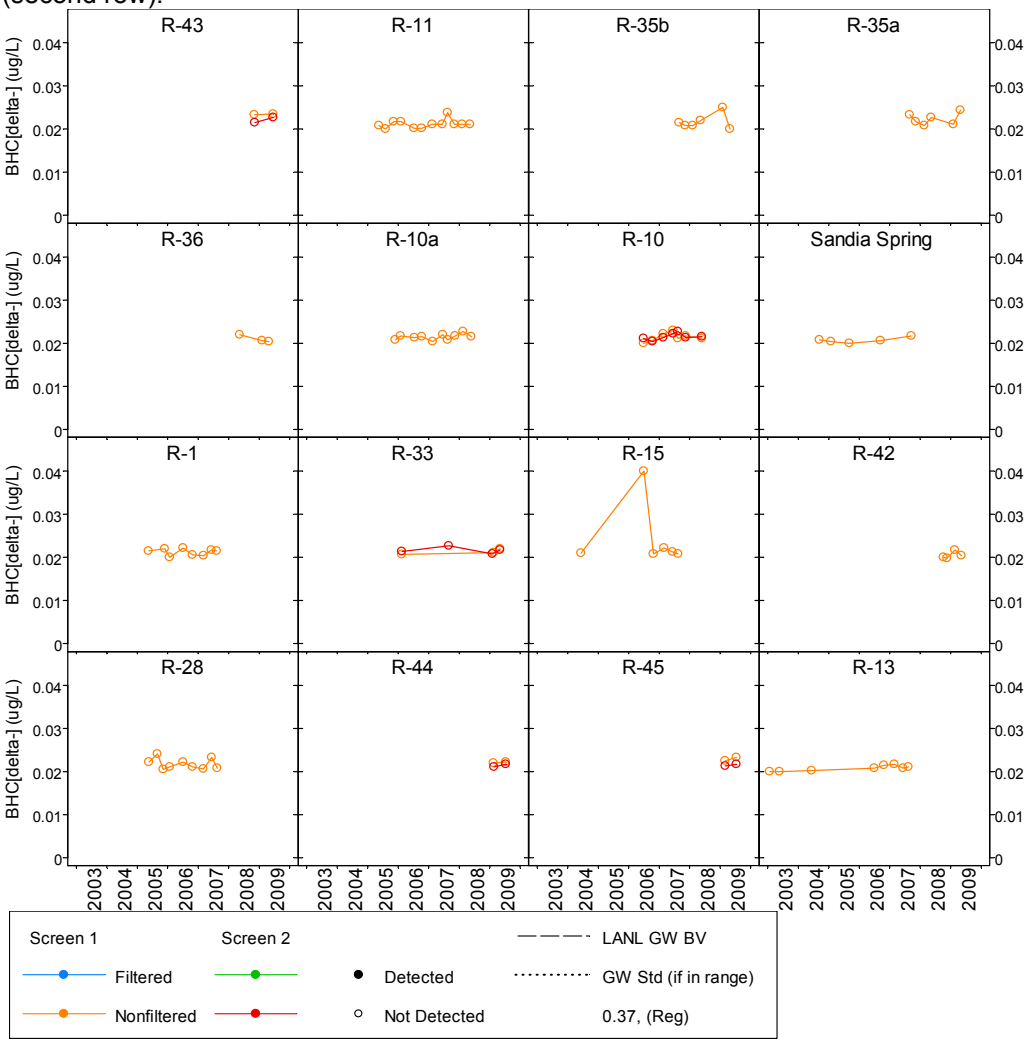


d. BHC[delta-] in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

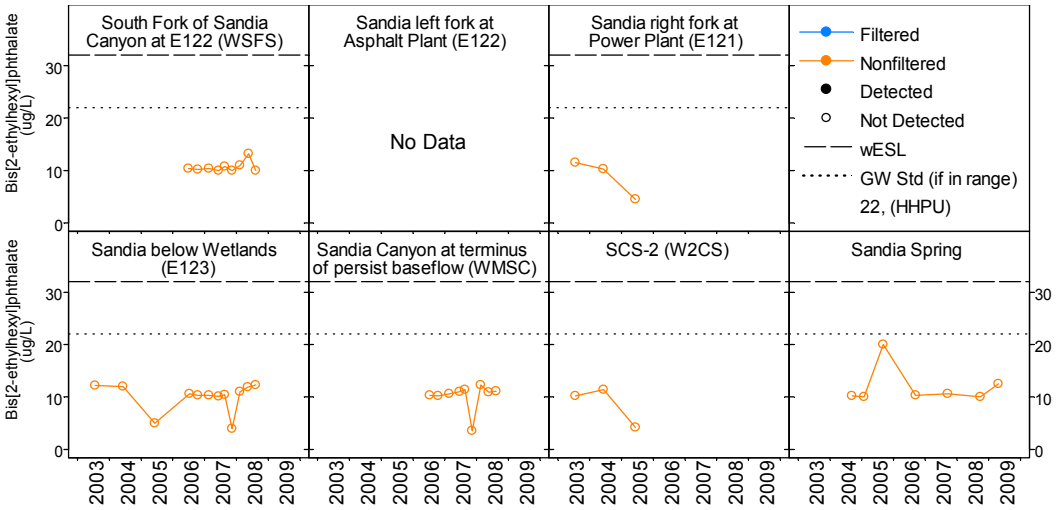


d. BHC[delta-] in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

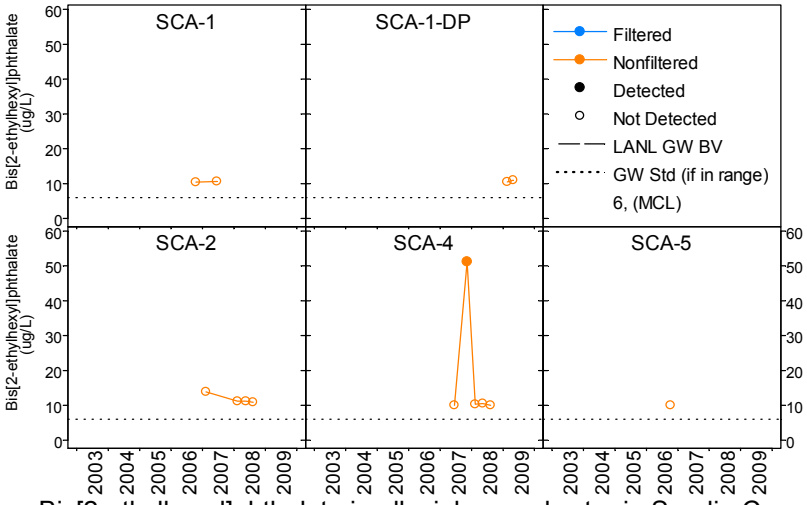


d. BHC[delta-] in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

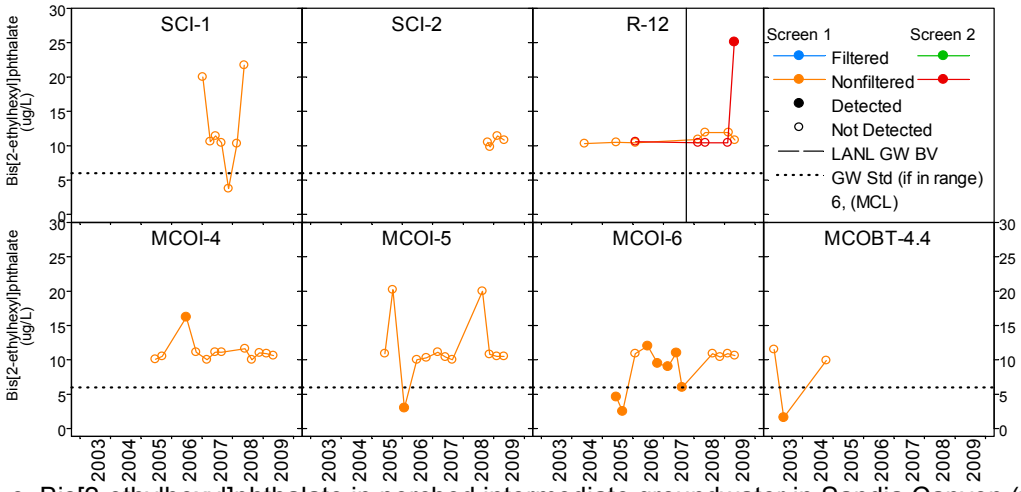


e. Bis[2-ethylhexyl]phthalate in nonstorm-related surface water in Sandia Canyon.

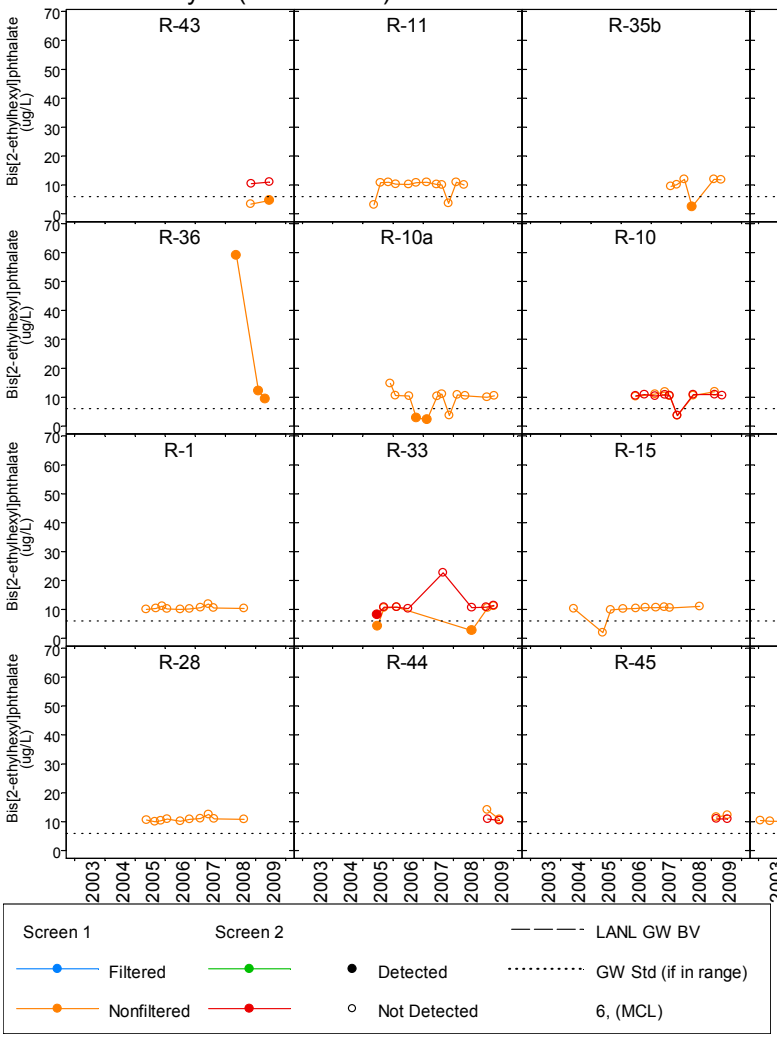


e. Bis[2-ethylhexyl]phthalate in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

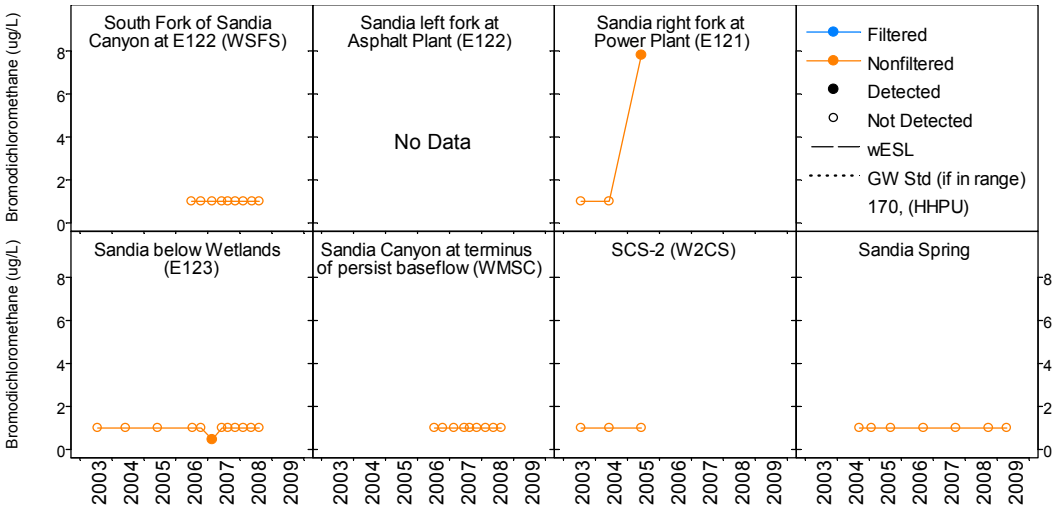


e. Bis[2-ethylhexyl]phthalate in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

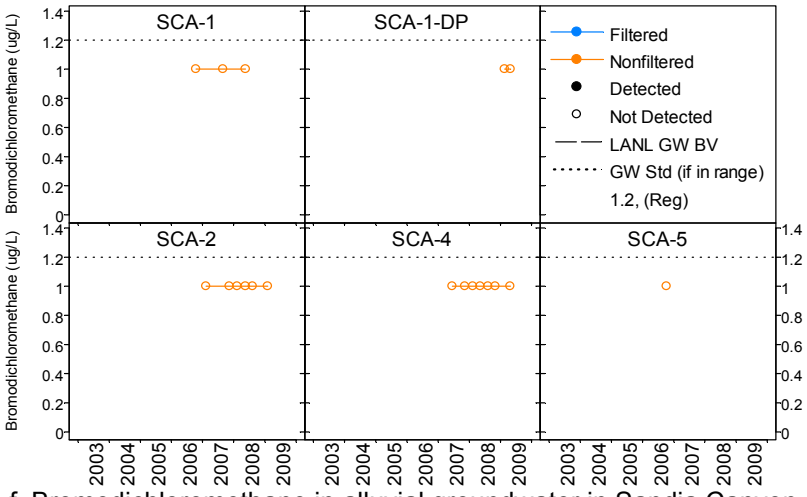


e. Bis[2-ethylhexyl]phthalate in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

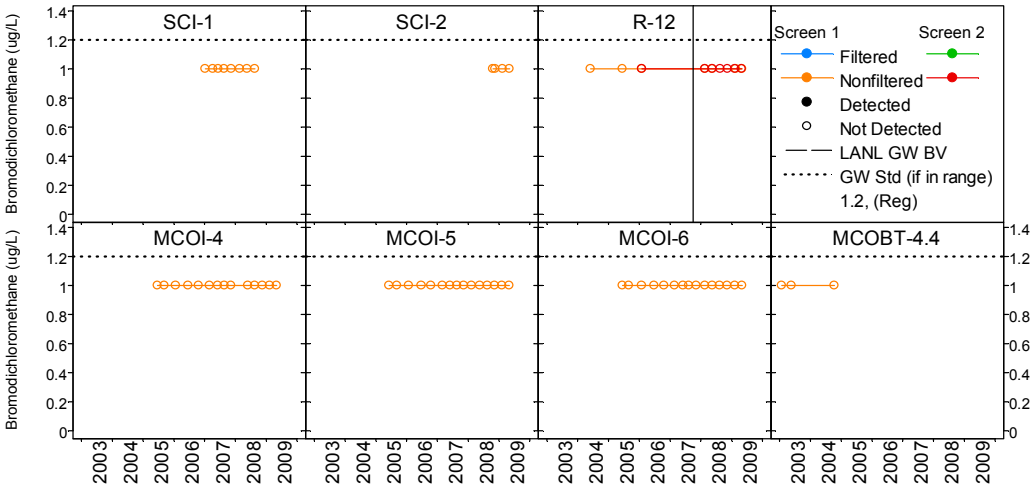


f. Bromodichloromethane in nonstorm-related surface water in Sandia Canyon.

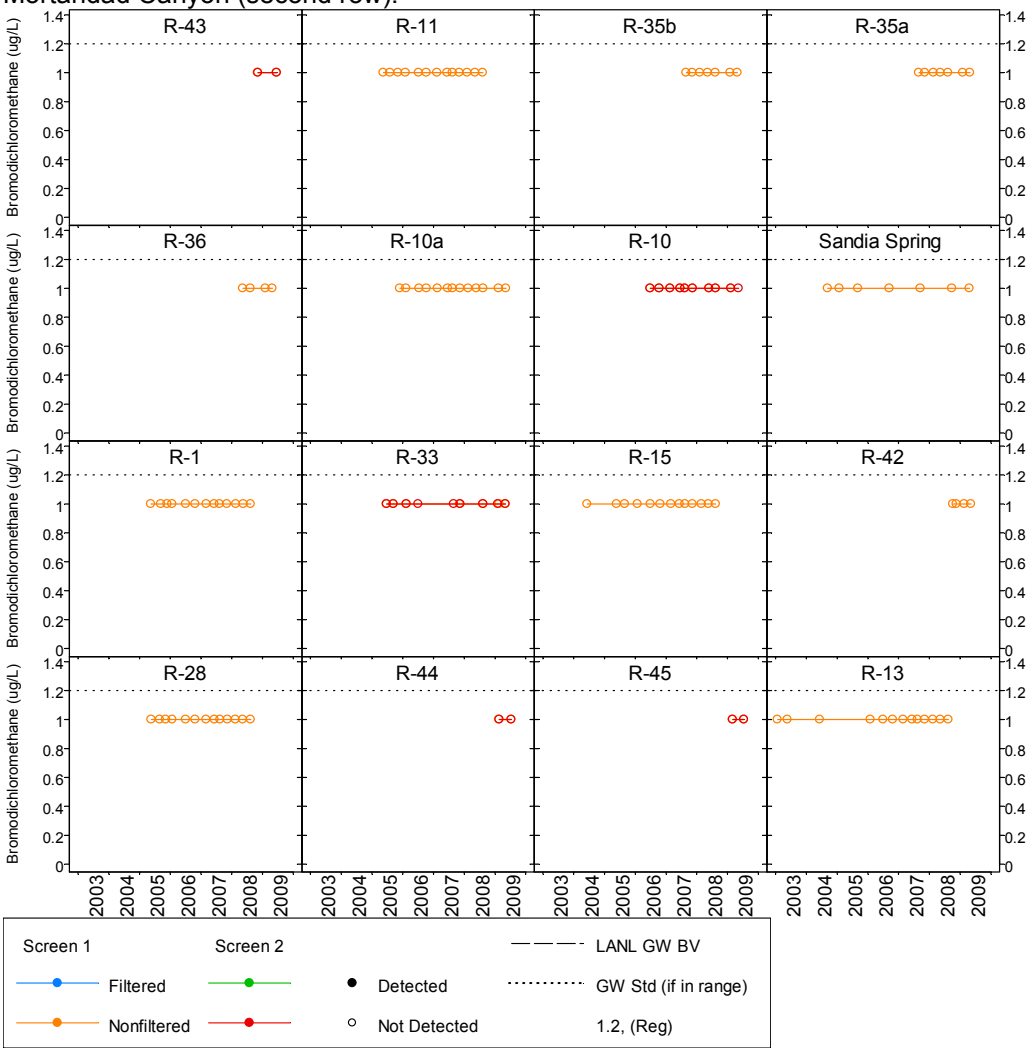


f. Bromodichloromethane in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

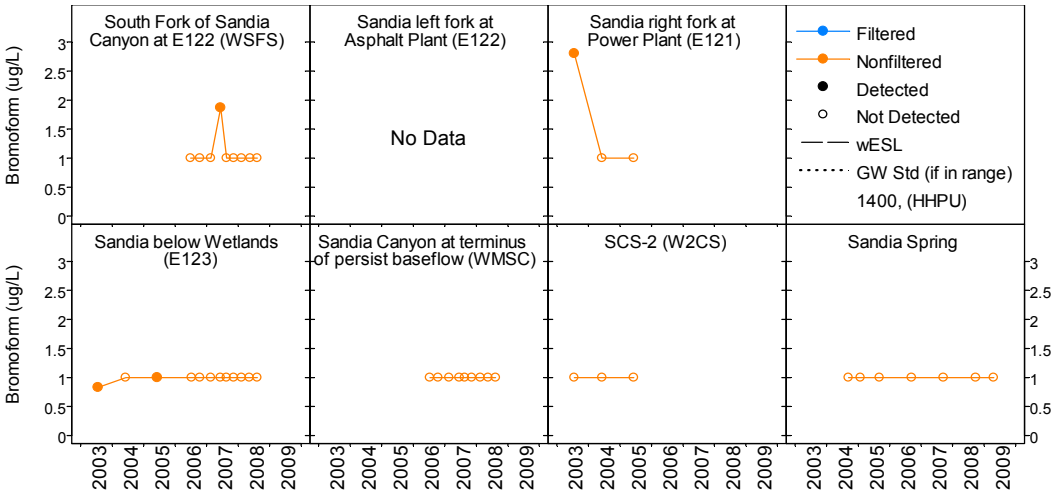


f. Bromodichloromethane in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

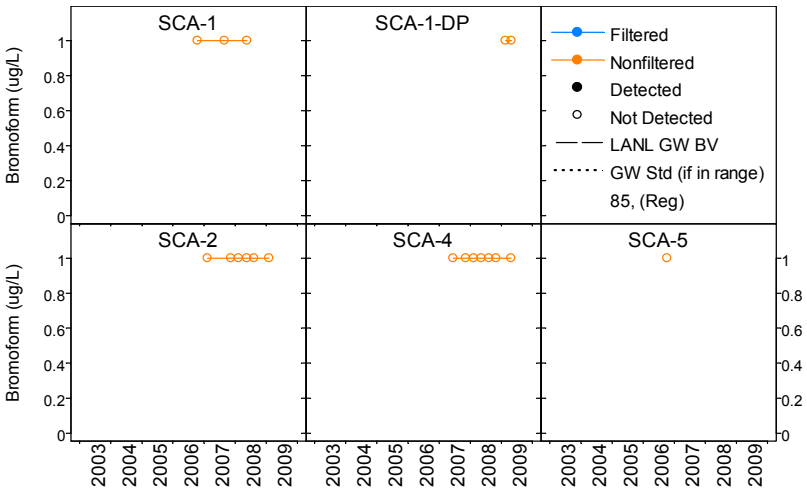


f. Bromodichloromethane in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

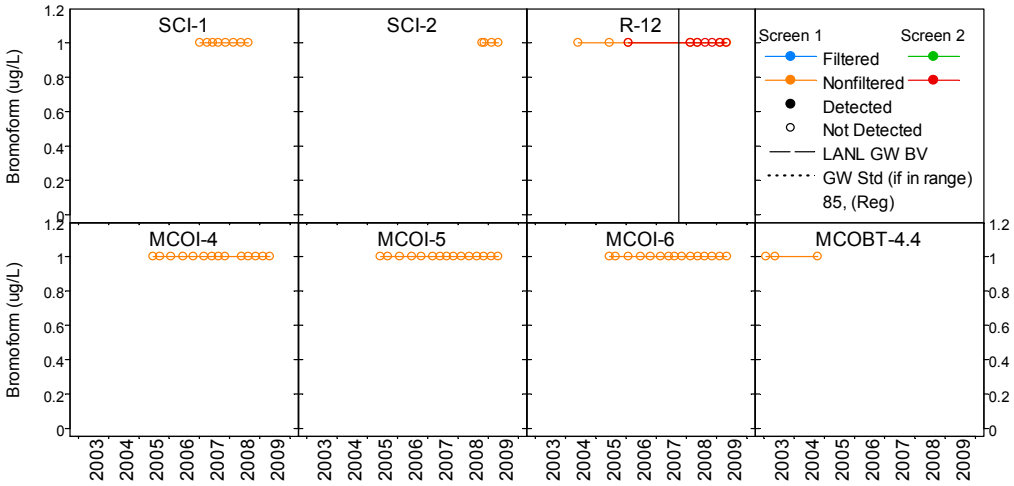


g. Bromoform in nonstorm-related surface water in Sandia Canyon.

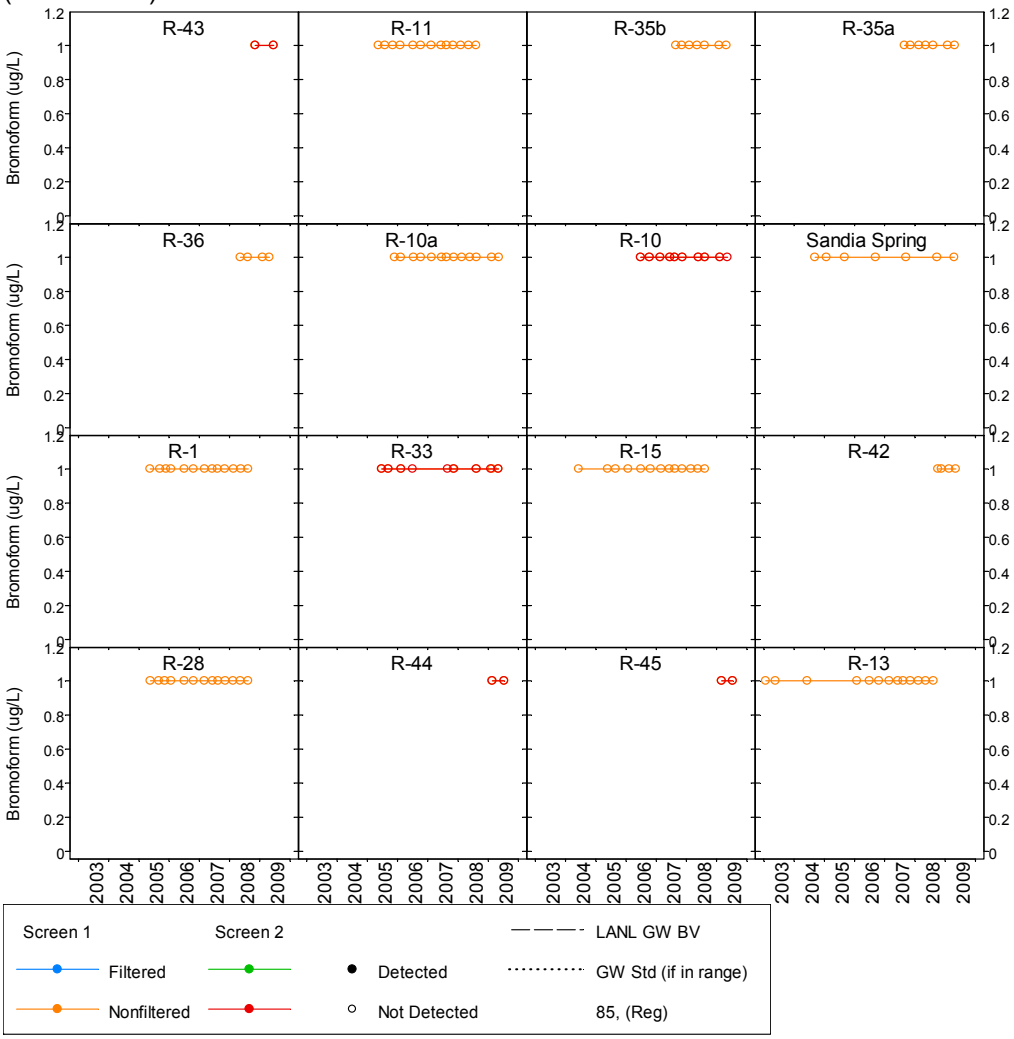


g. Bromoform in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

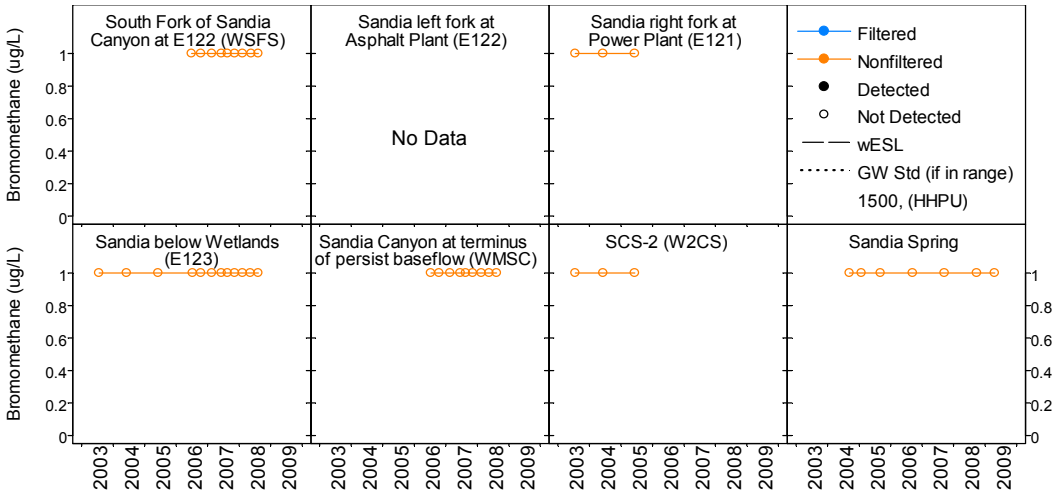


g. Bromoform in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

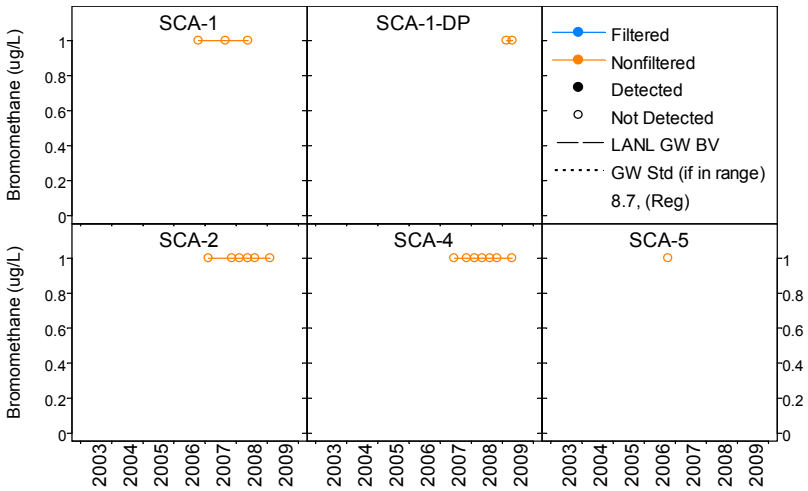


g. Bromoform in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

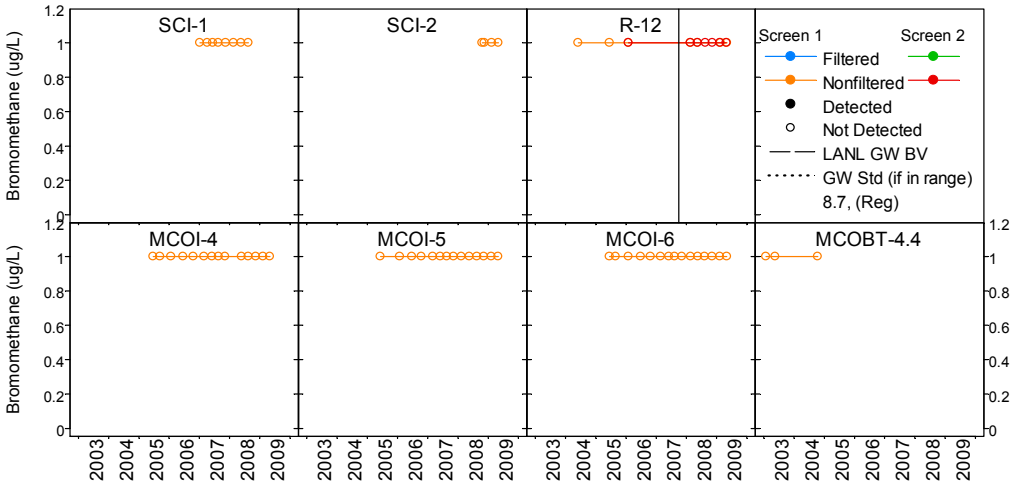


h. Bromomethane in nonstorm-related surface water in Sandia Canyon.

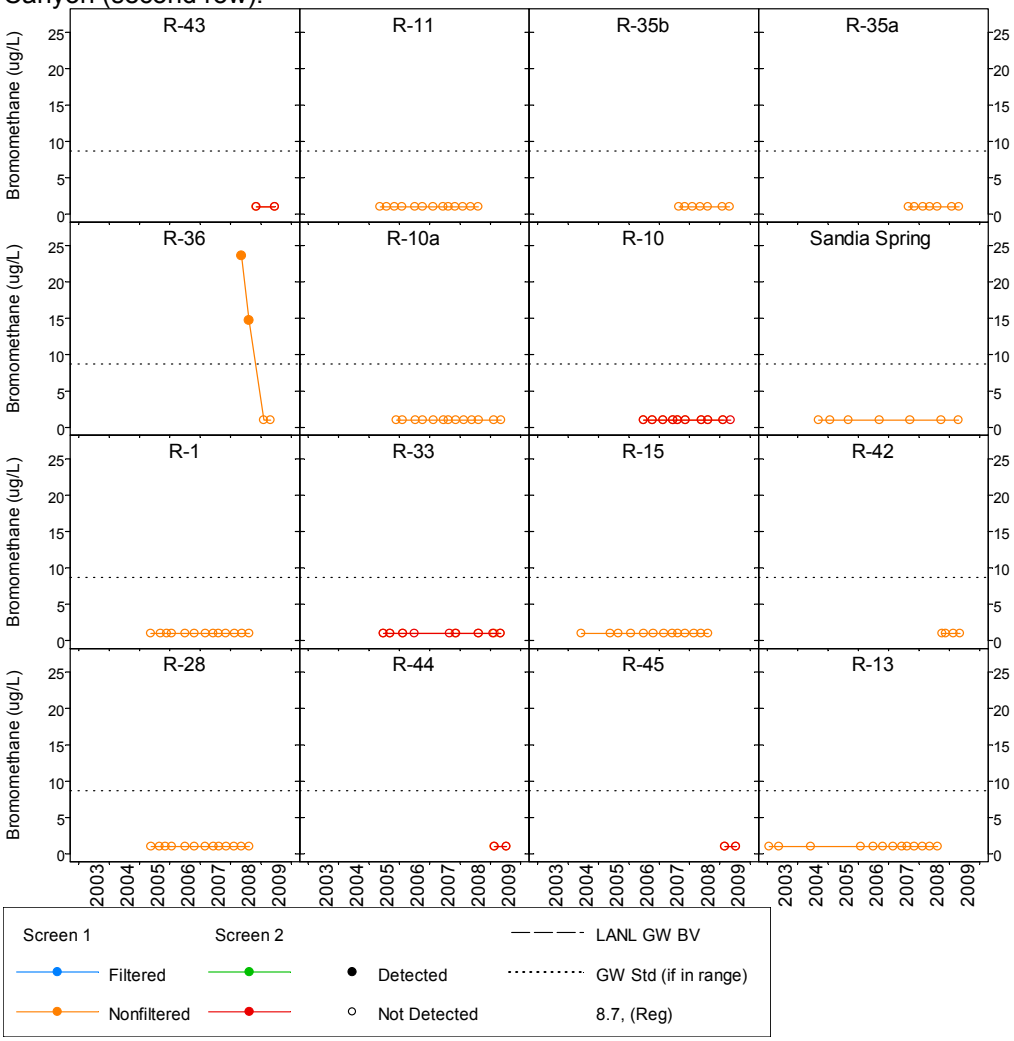


h. Bromomethane in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

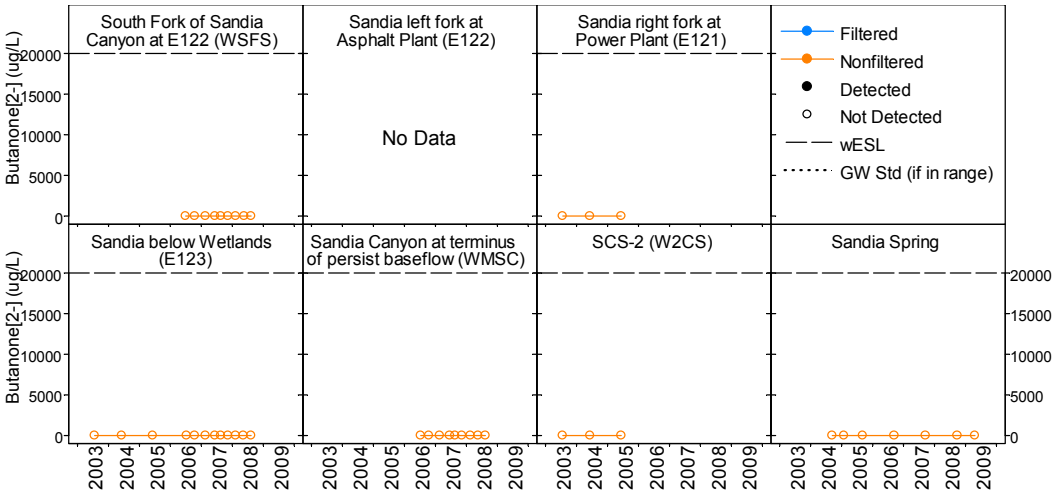


h. Bromomethane in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

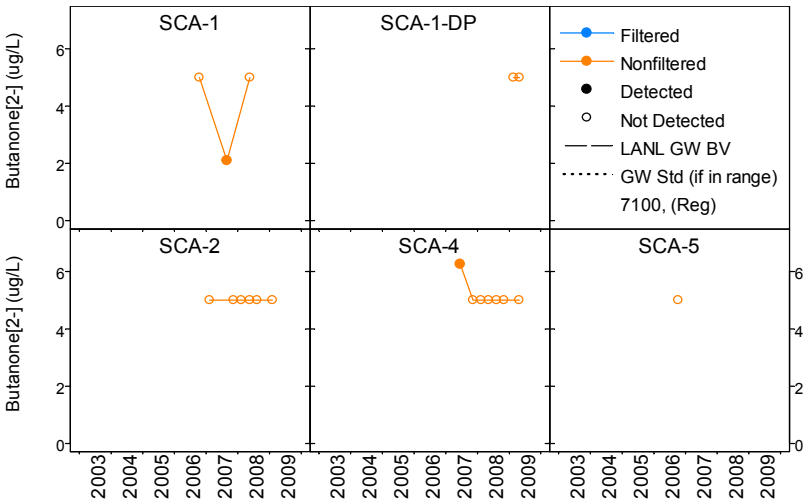


h. Bromomethane in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

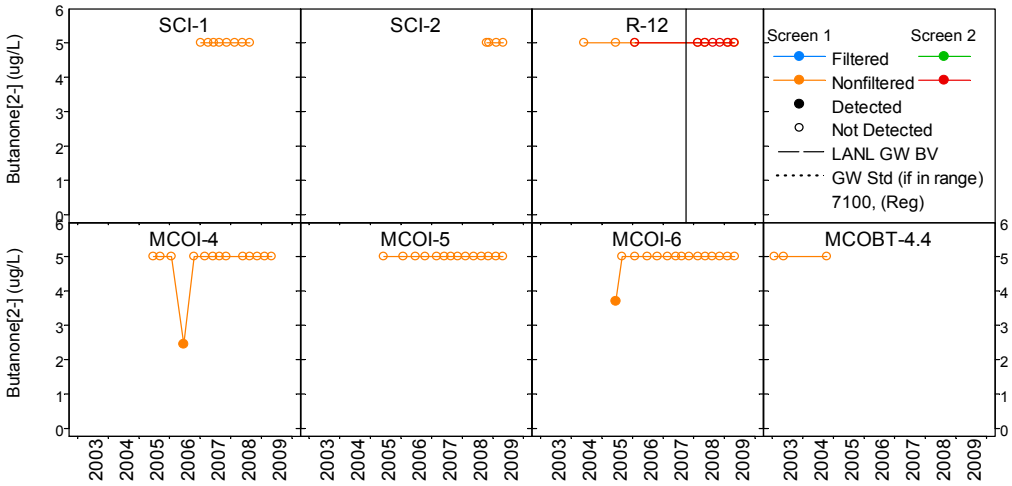


i. Butanone[2-] in nonstorm-related surface water in Sandia Canyon.

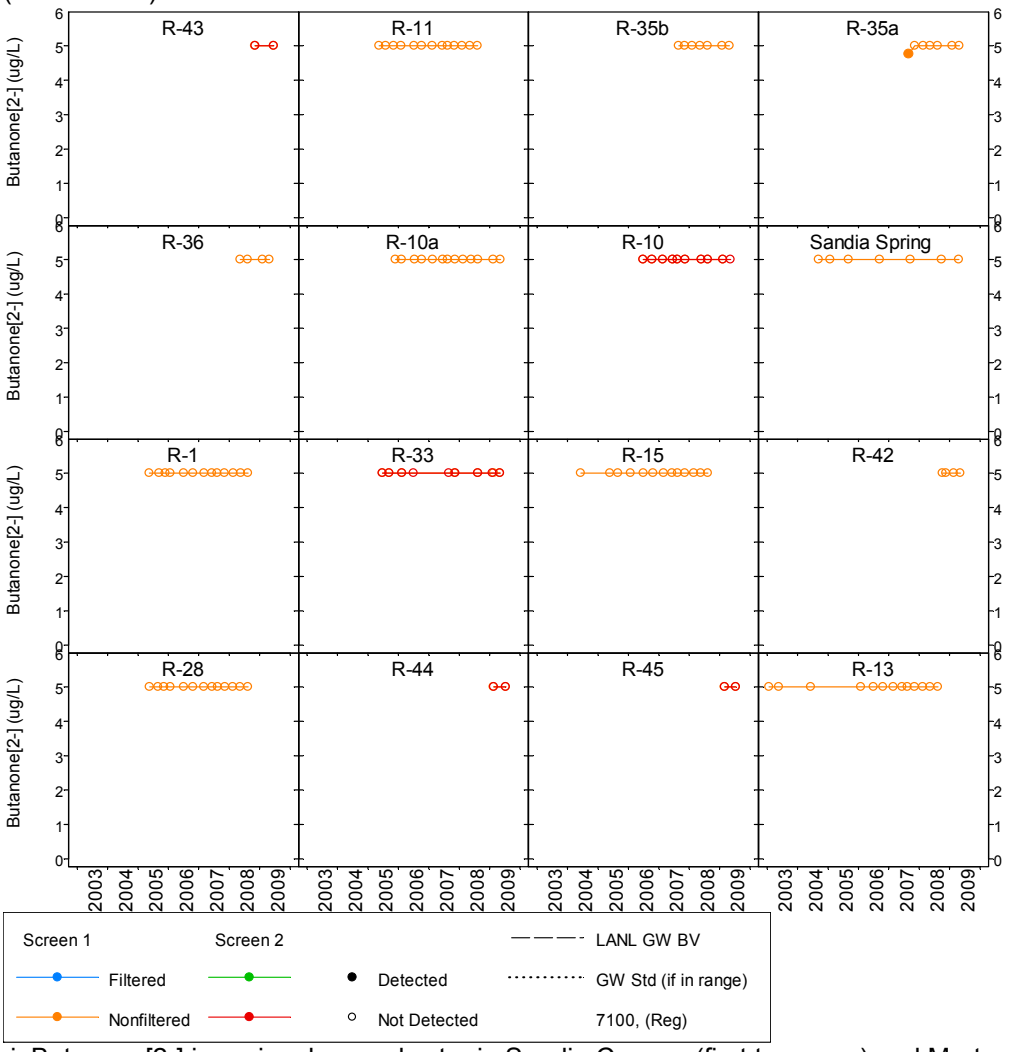


i. Butanone[2-] in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

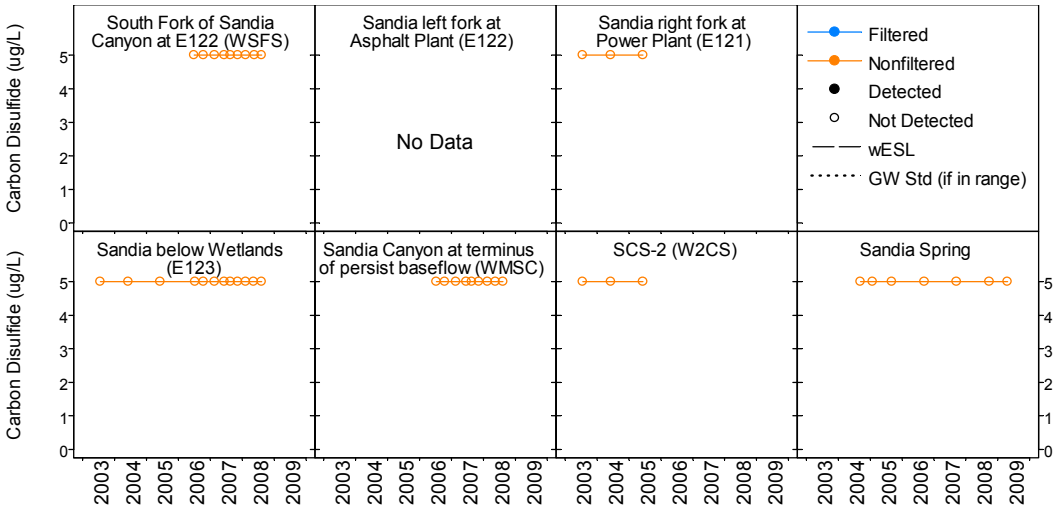


i. Butanone[2-] in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

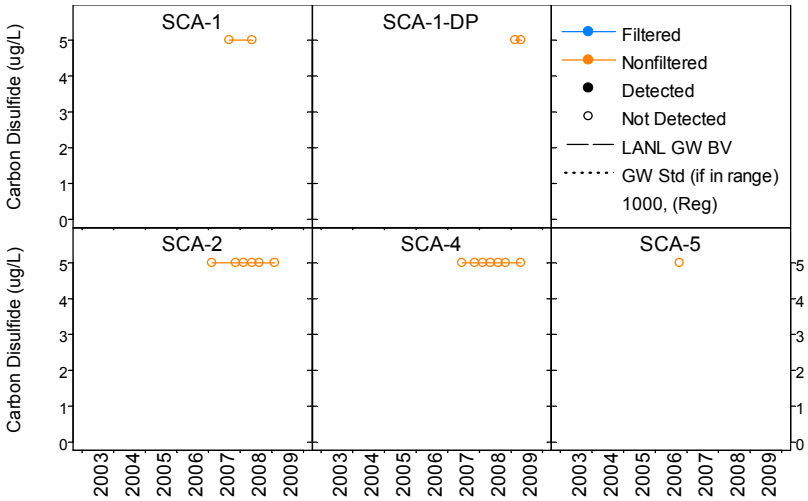


i. Butanone[2-] in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

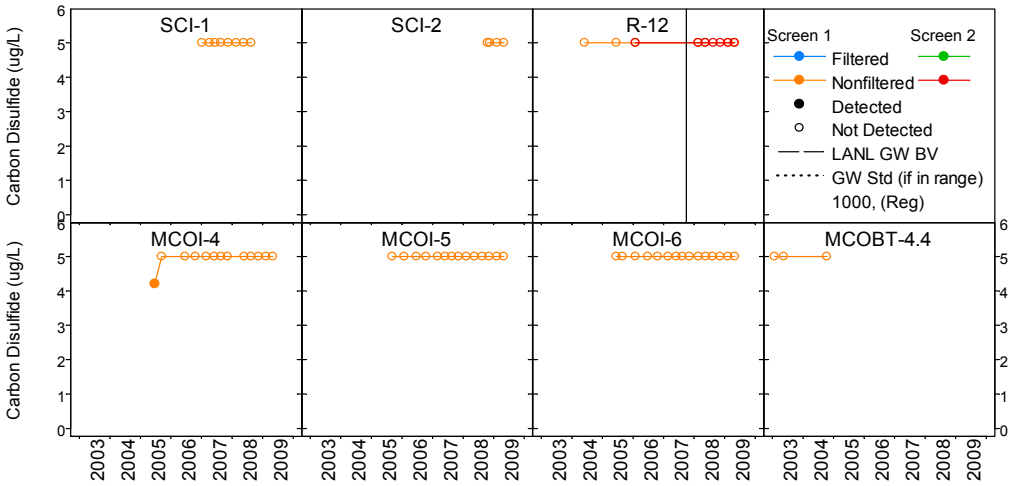


j. Carbon Disulfide in nonstorm-related surface water in Sandia Canyon.

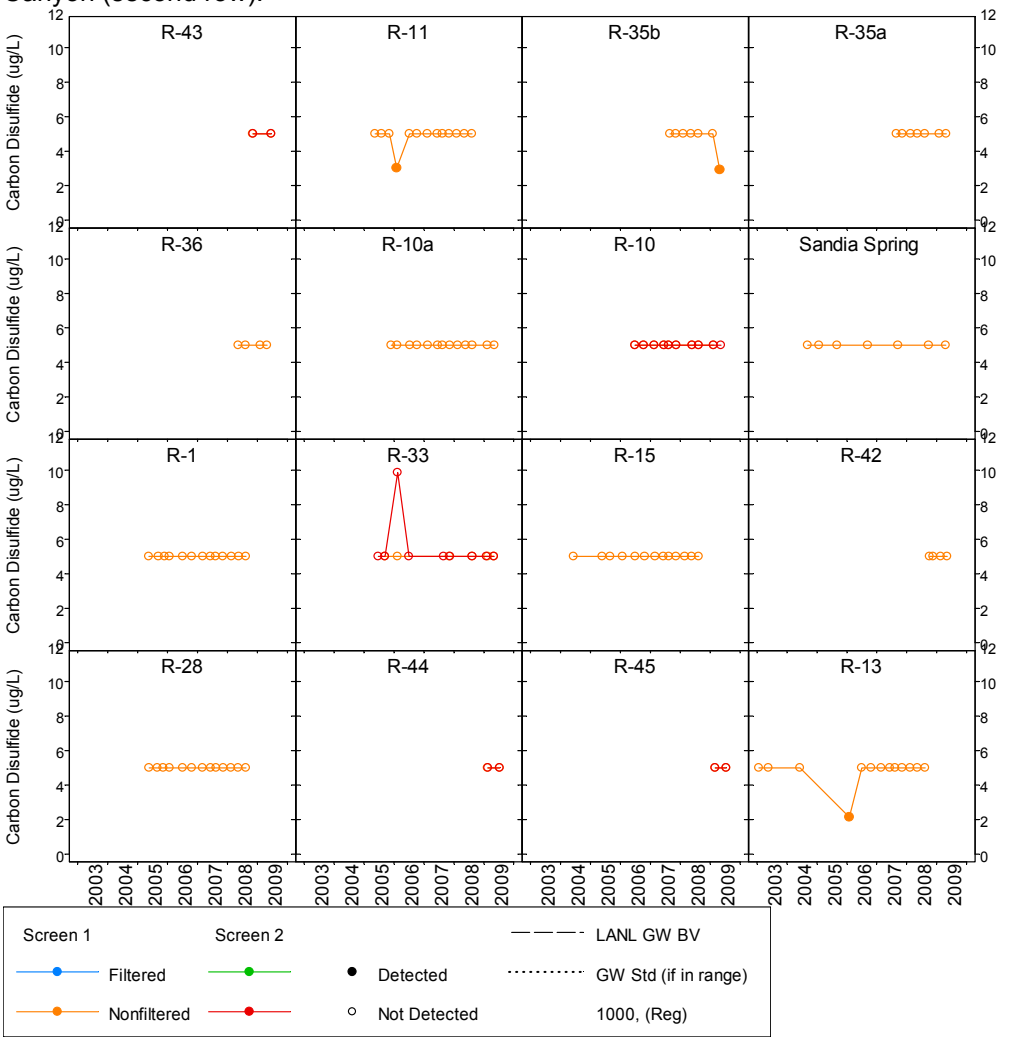


j. Carbon Disulfide in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

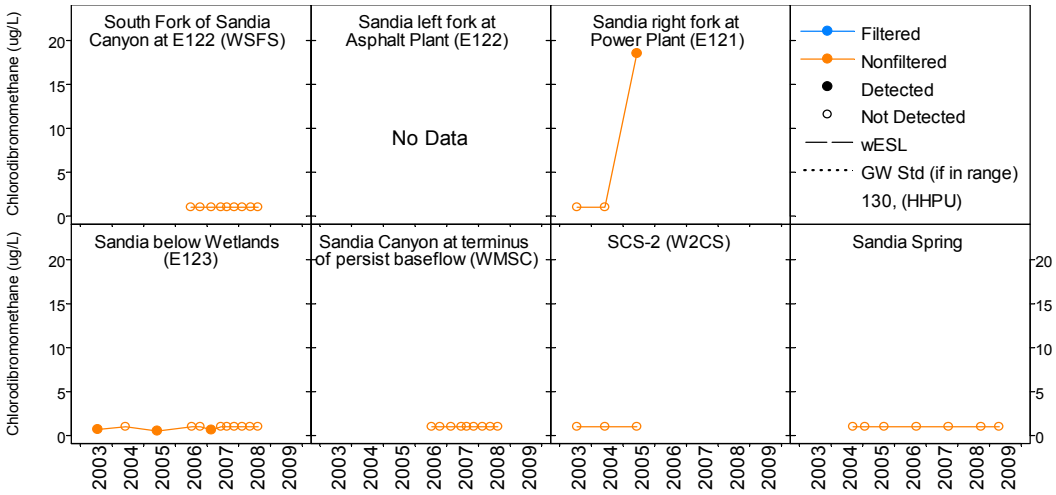


j. Carbon Disulfide in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

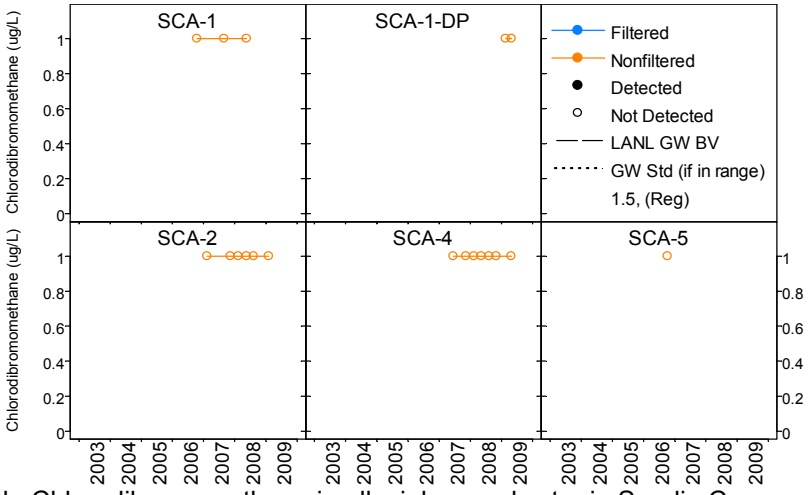


j. Carbon Disulfide in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

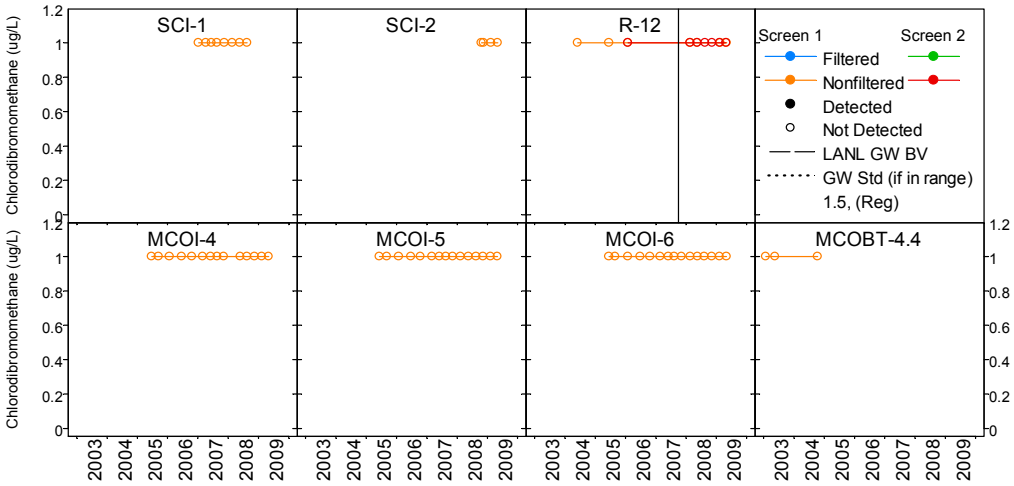


k. Chlorodibromomethane in nonstorm-related surface water in Sandia Canyon.

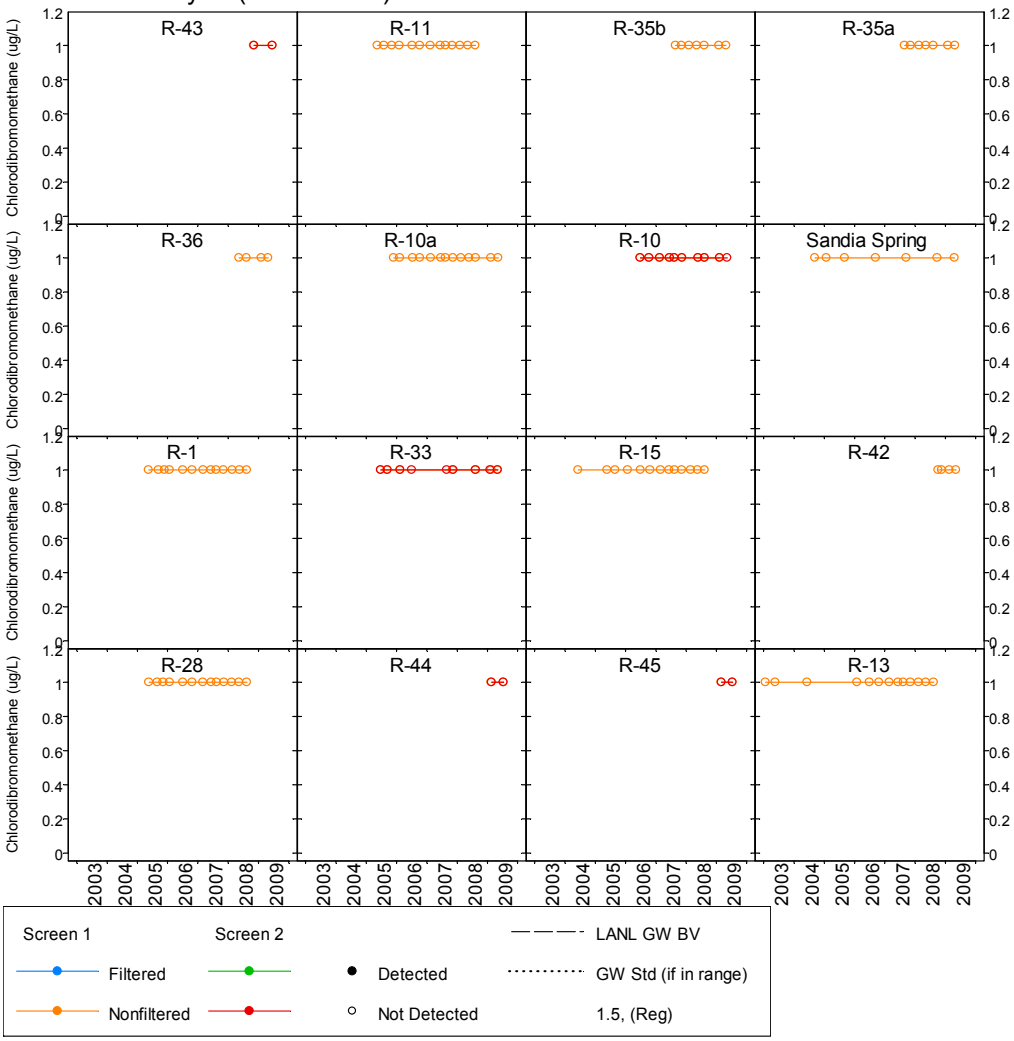


k. Chlorodibromomethane in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

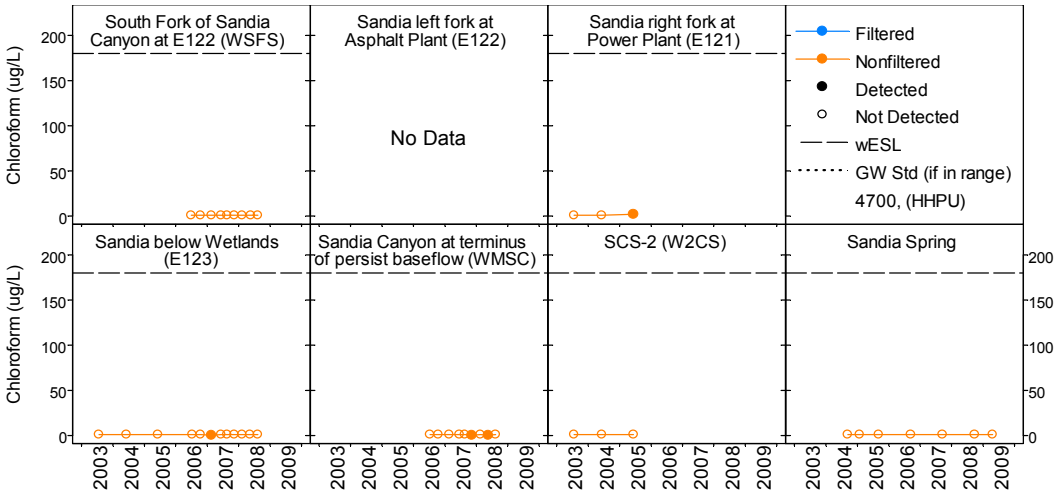


k. Chlorodibromomethane in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

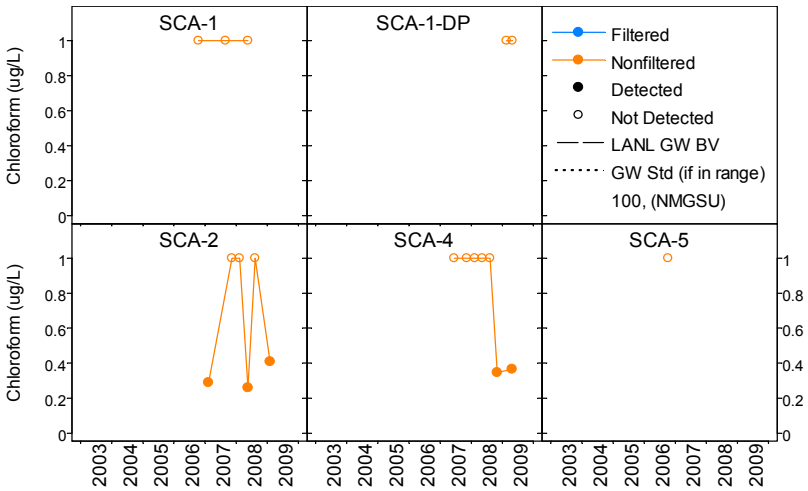


k. Chlorodibromomethane in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

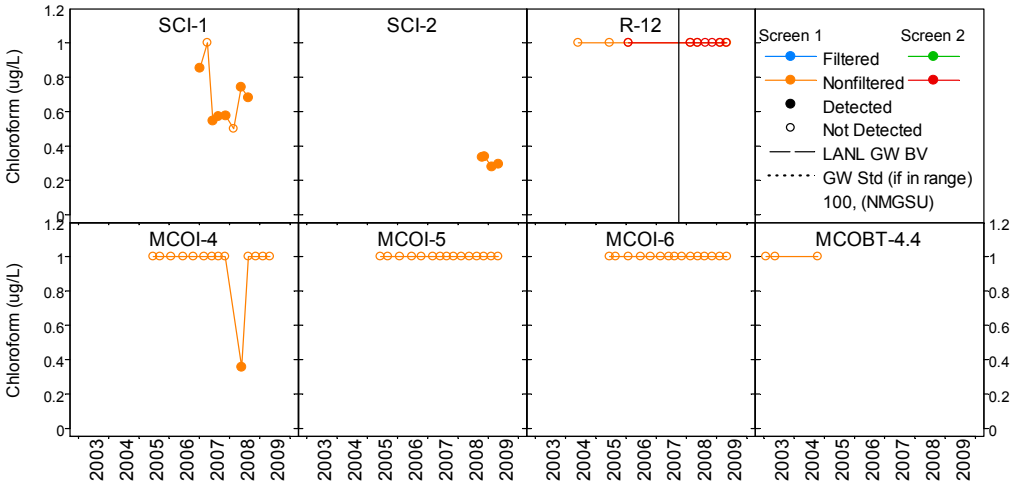


I. Chloroform in nonstorm-related surface water in Sandia Canyon.

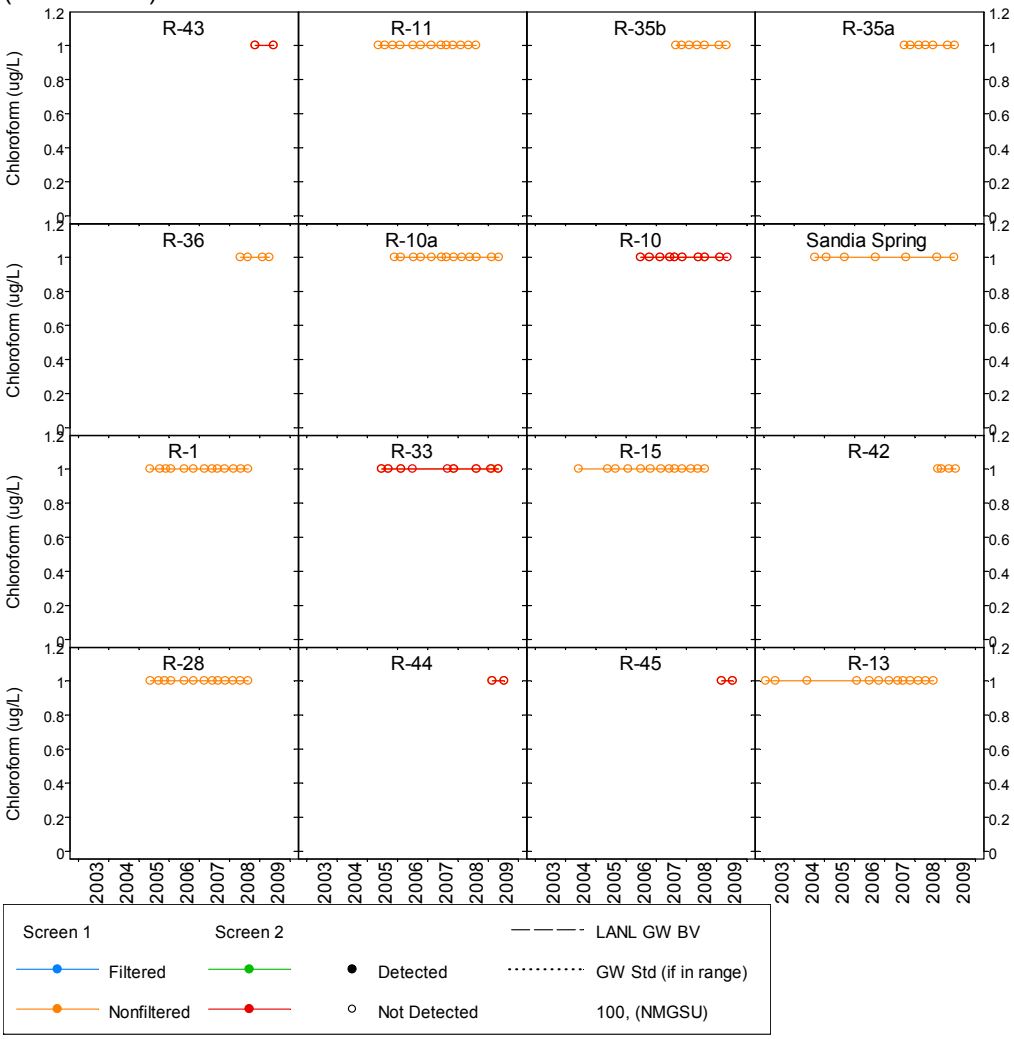


I. Chloroform in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

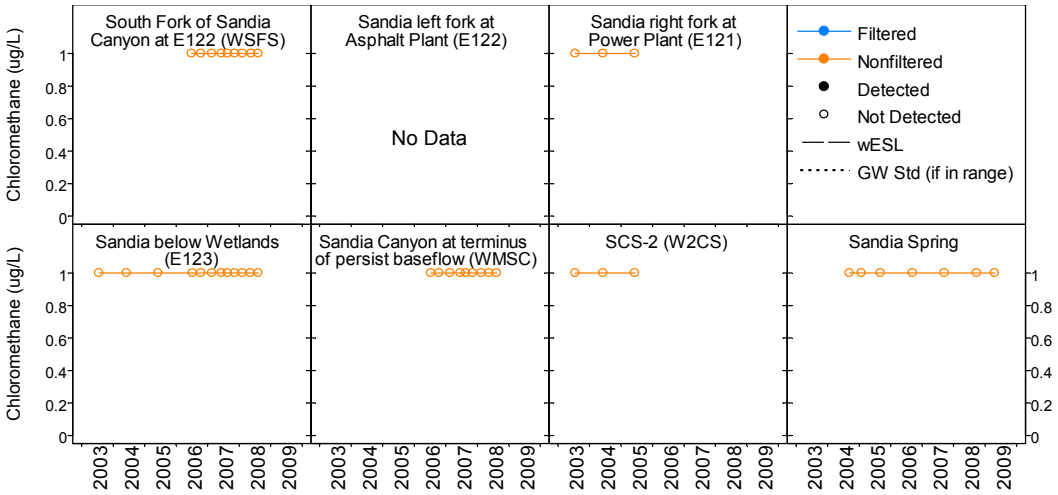


I. Chloroform in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

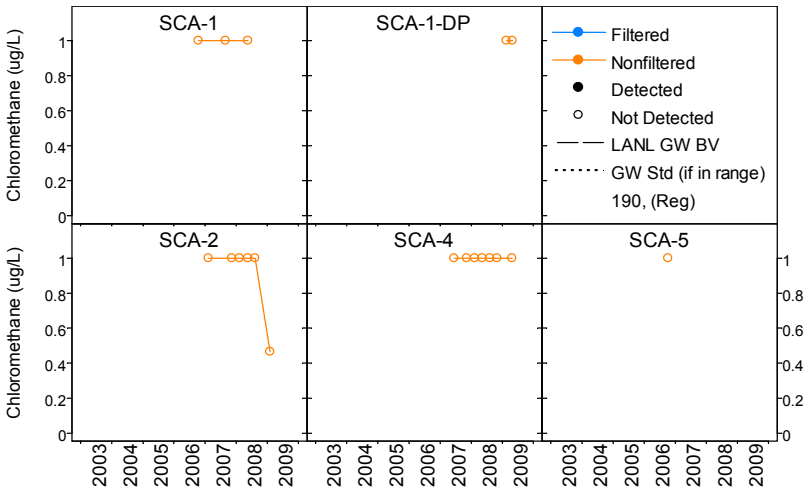


I. Chloroform in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

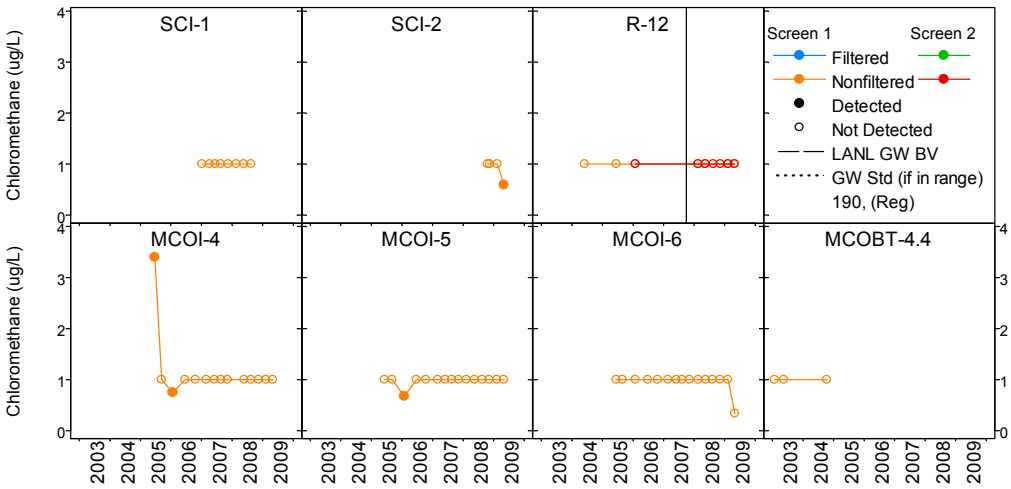


m. Chloromethane in nonstorm-related surface water in Sandia Canyon.

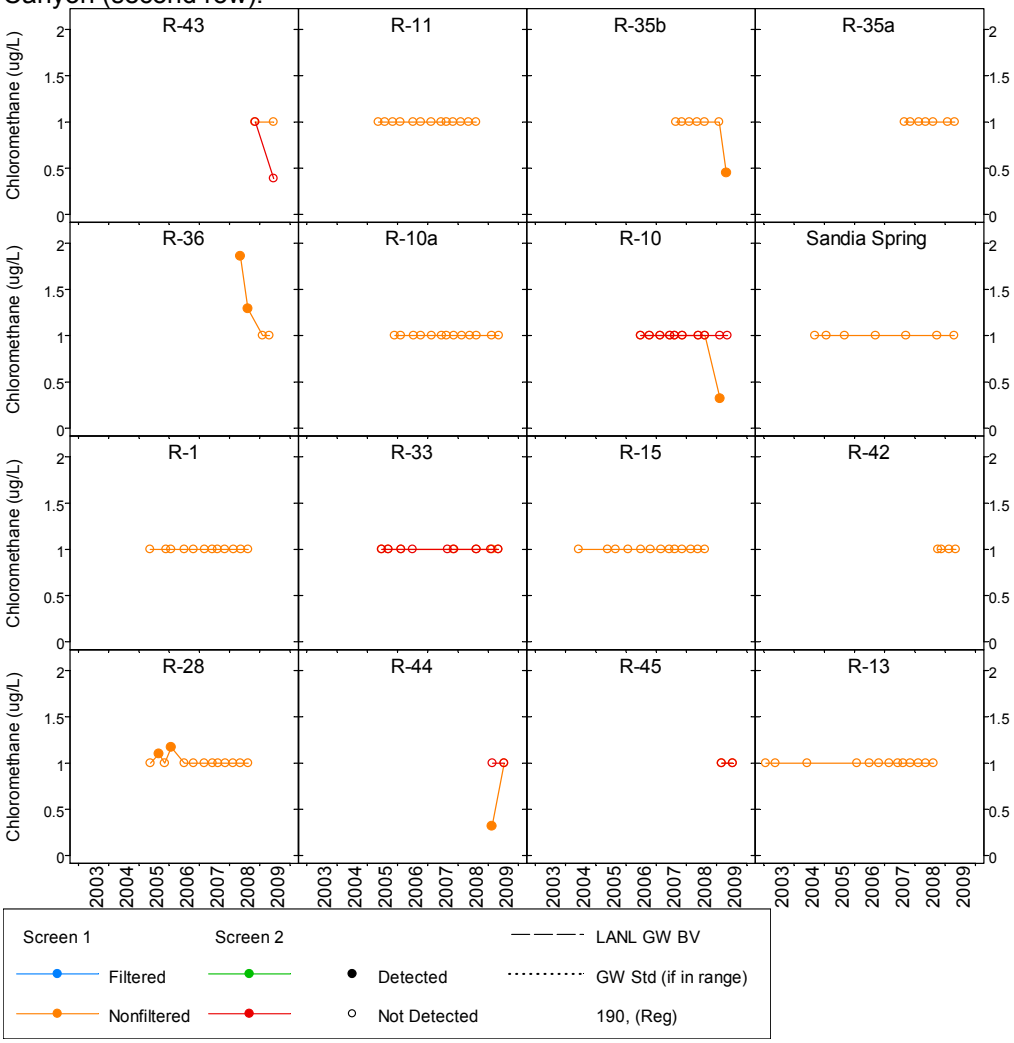


m. Chloromethane in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

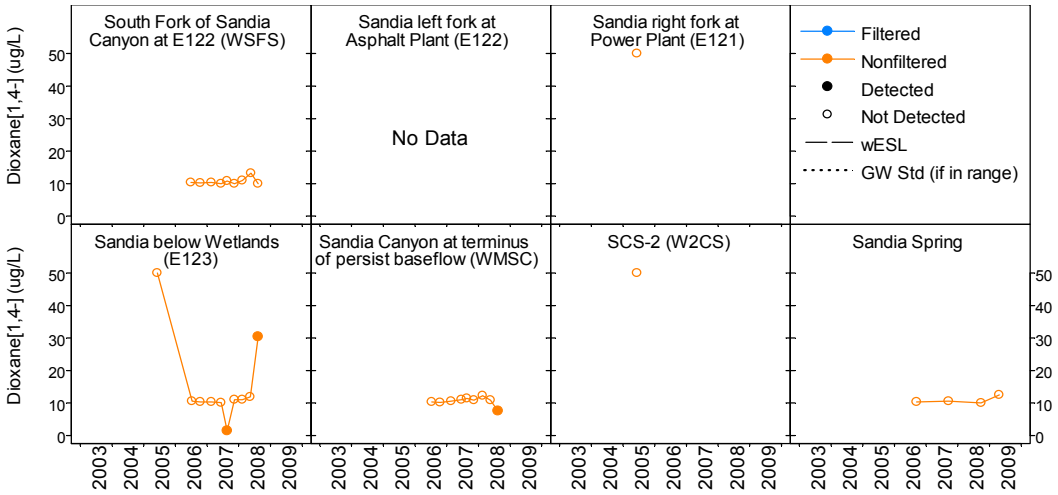


m. Chloromethane in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

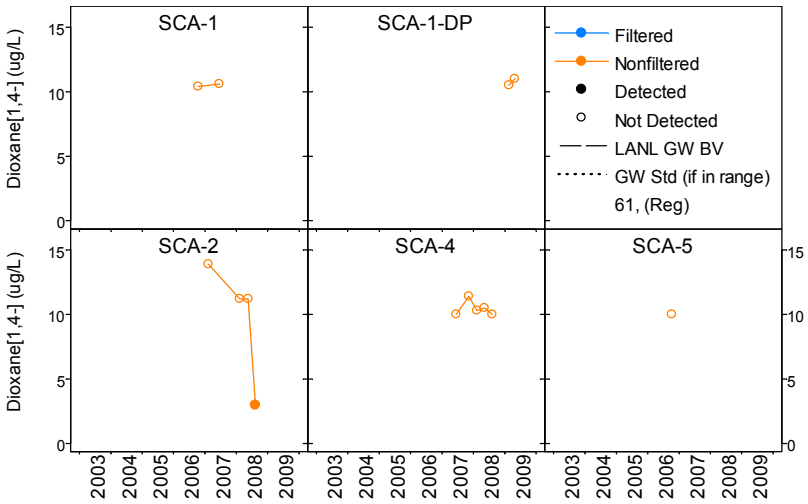


m. Chloromethane in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

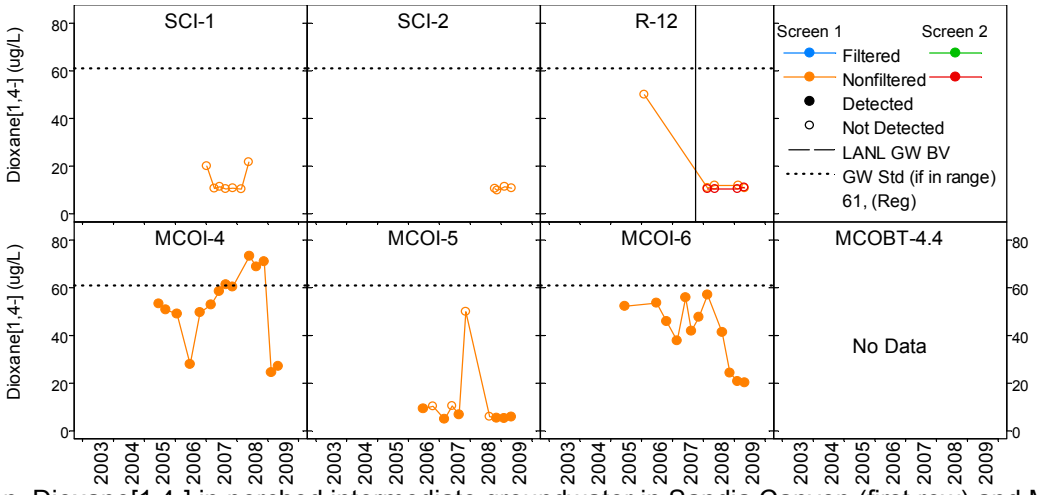


n. Dioxane[1,4-] in nonstorm-related surface water in Sandia Canyon.

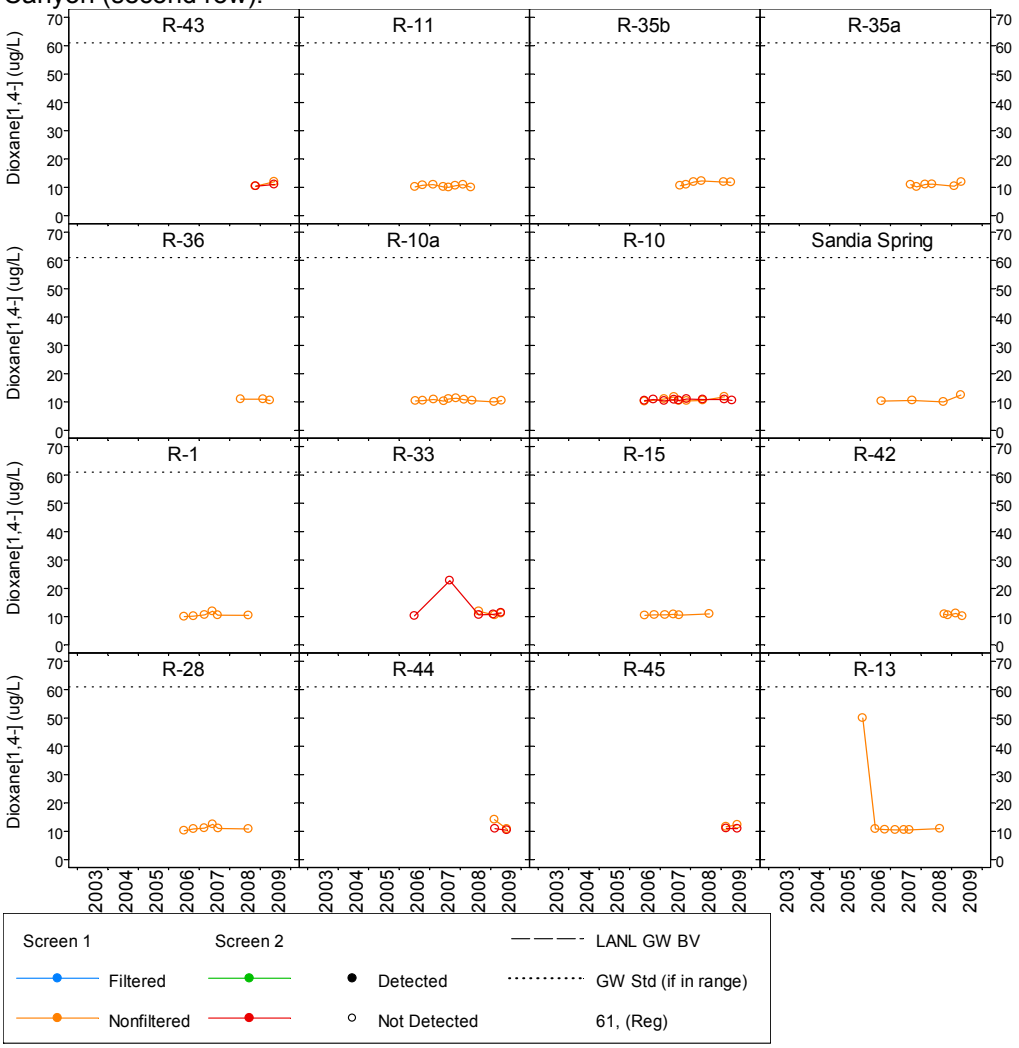


n. Dioxane[1,4-] in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

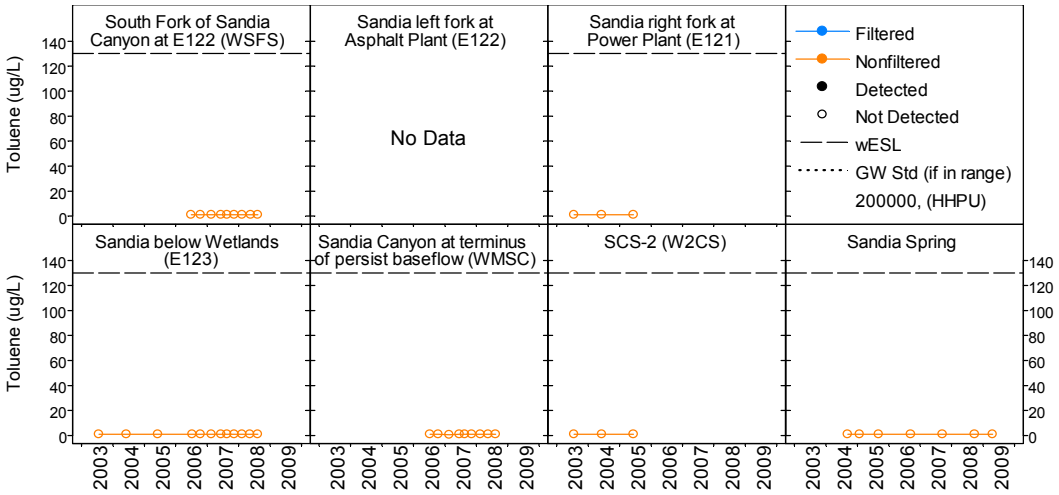


n. Dioxane[1,4-] in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

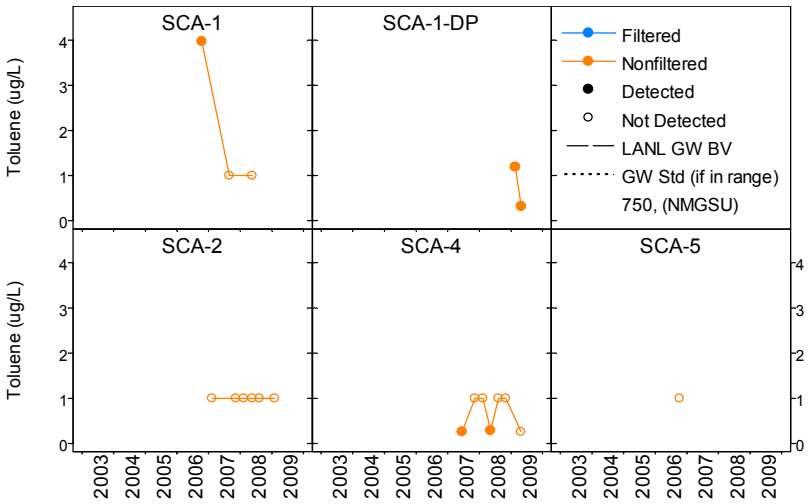


n. Dioxane[1,4-] in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

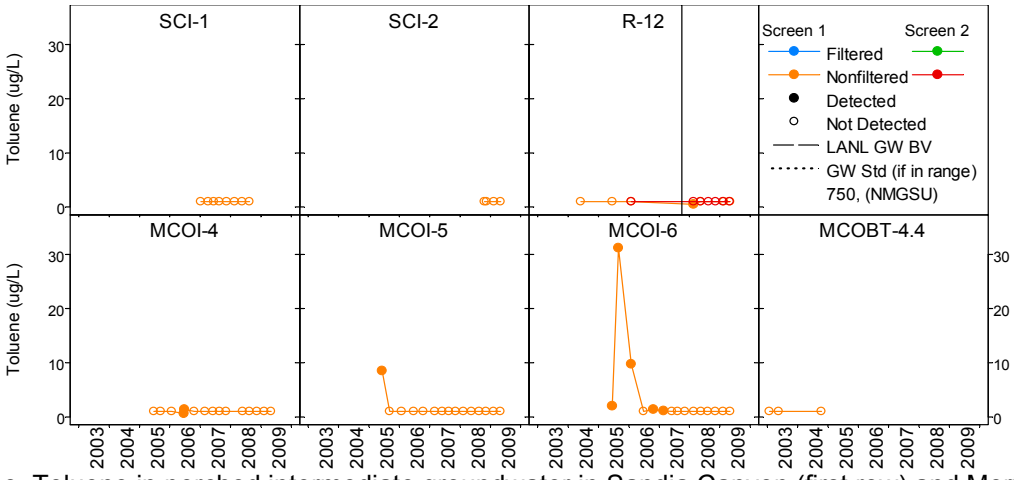


o. Toluene in nonstorm-related surface water in Sandia Canyon.

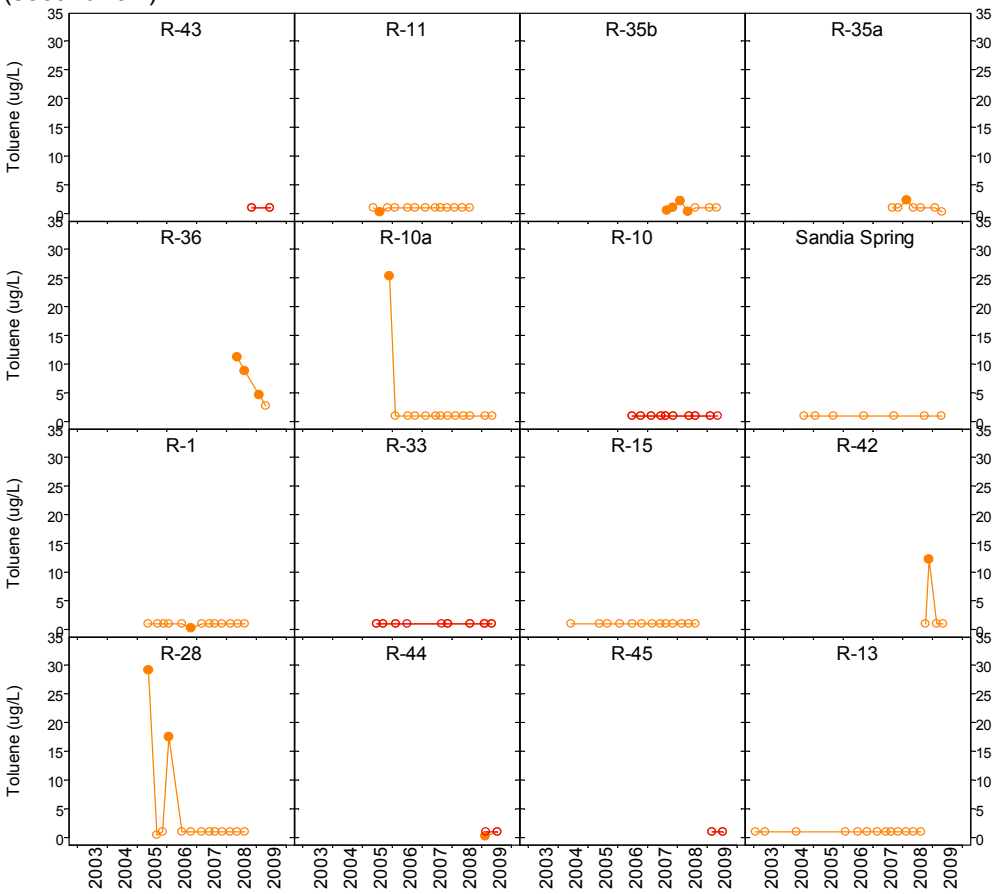


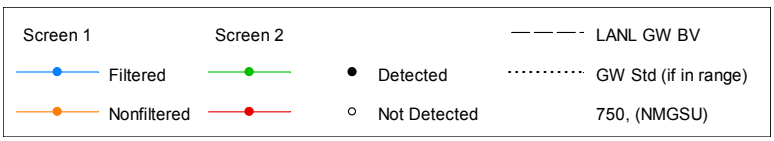
o. Toluene in alluvial groundwater in Sandia Canyon.

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009



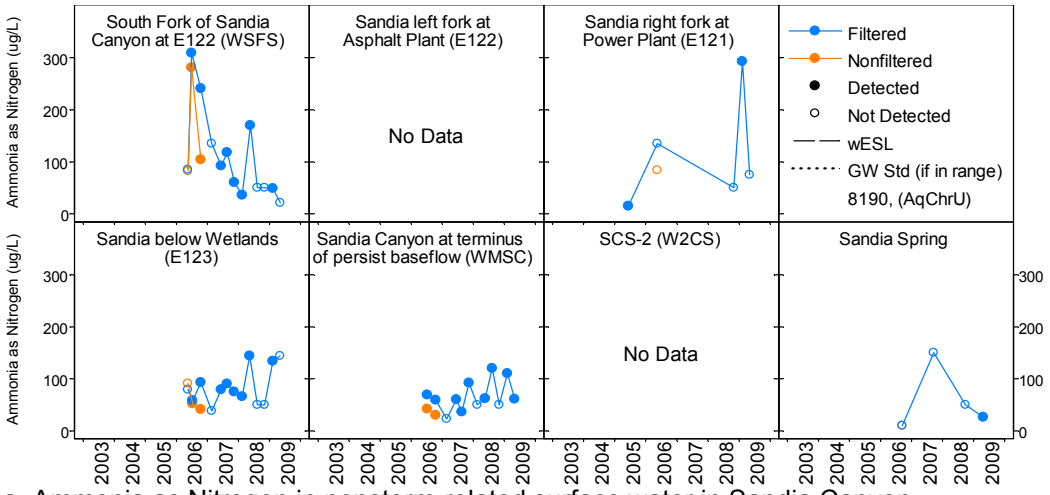
o. Toluene in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).



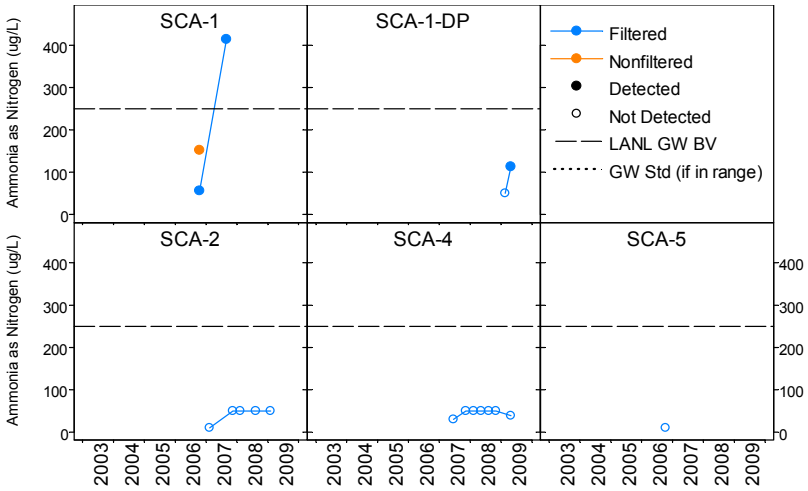


o. Toluene in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-3 (continued) Time-series plots of organic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

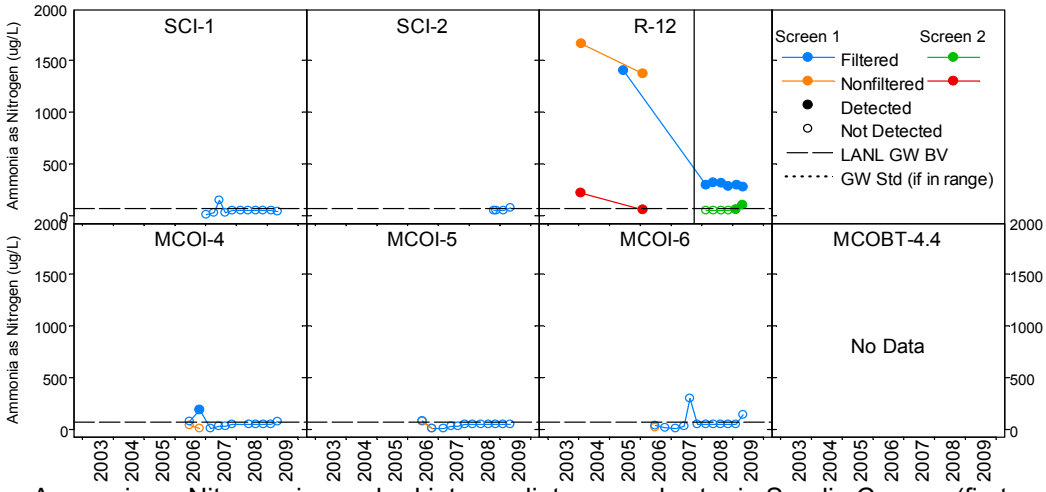


a. Ammonia as Nitrogen in nonstorm-related surface water in Sandia Canyon.

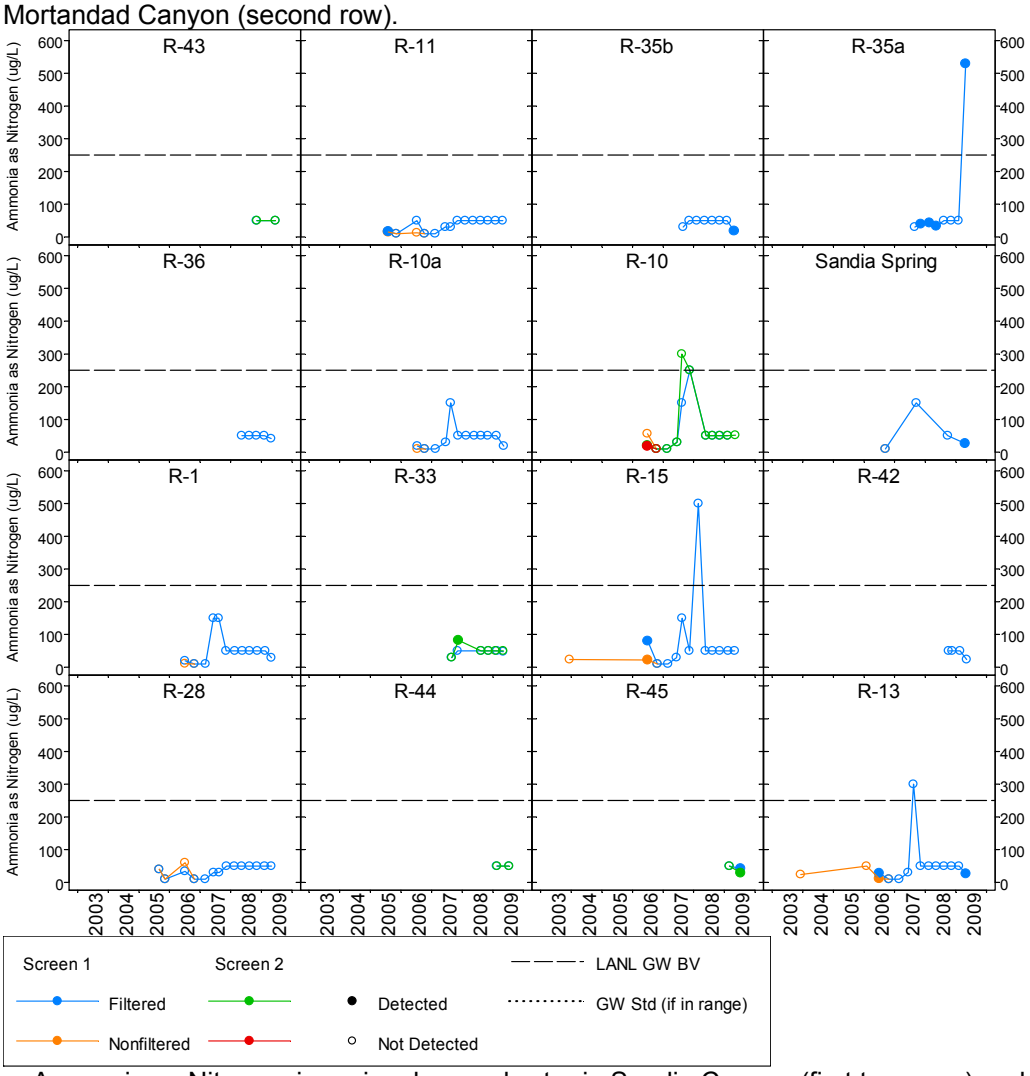


a. Ammonia as Nitrogen in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

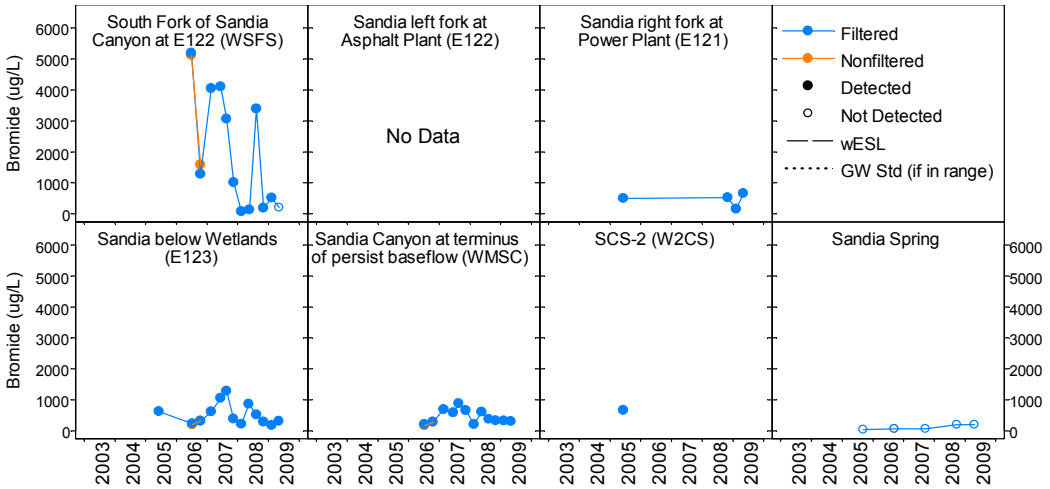


a. Ammonia as Nitrogen in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

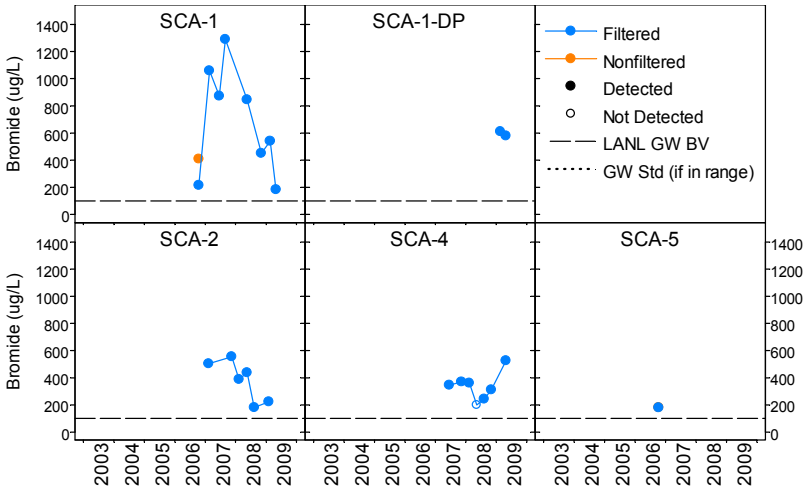


a. Ammonia as Nitrogen in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

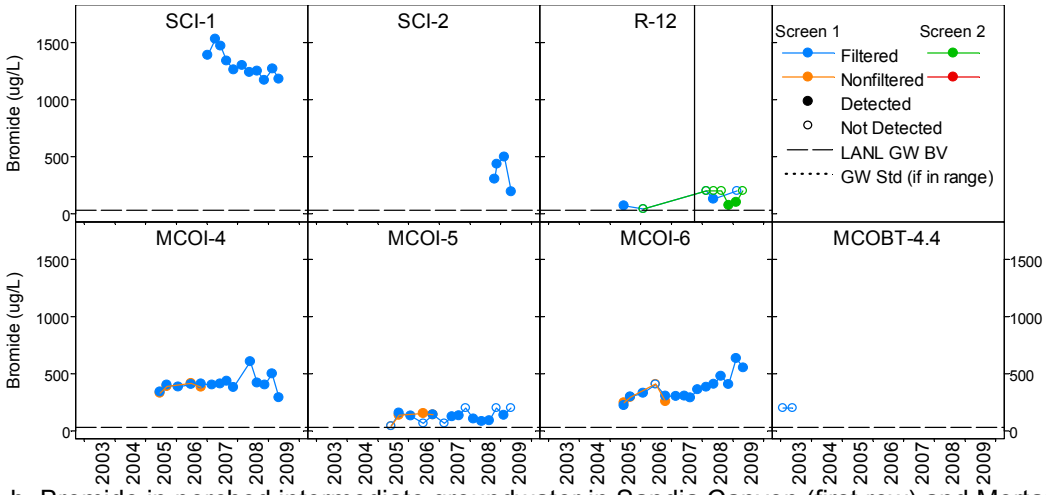


b. Bromide in nonstorm-related surface water in Sandia Canyon.

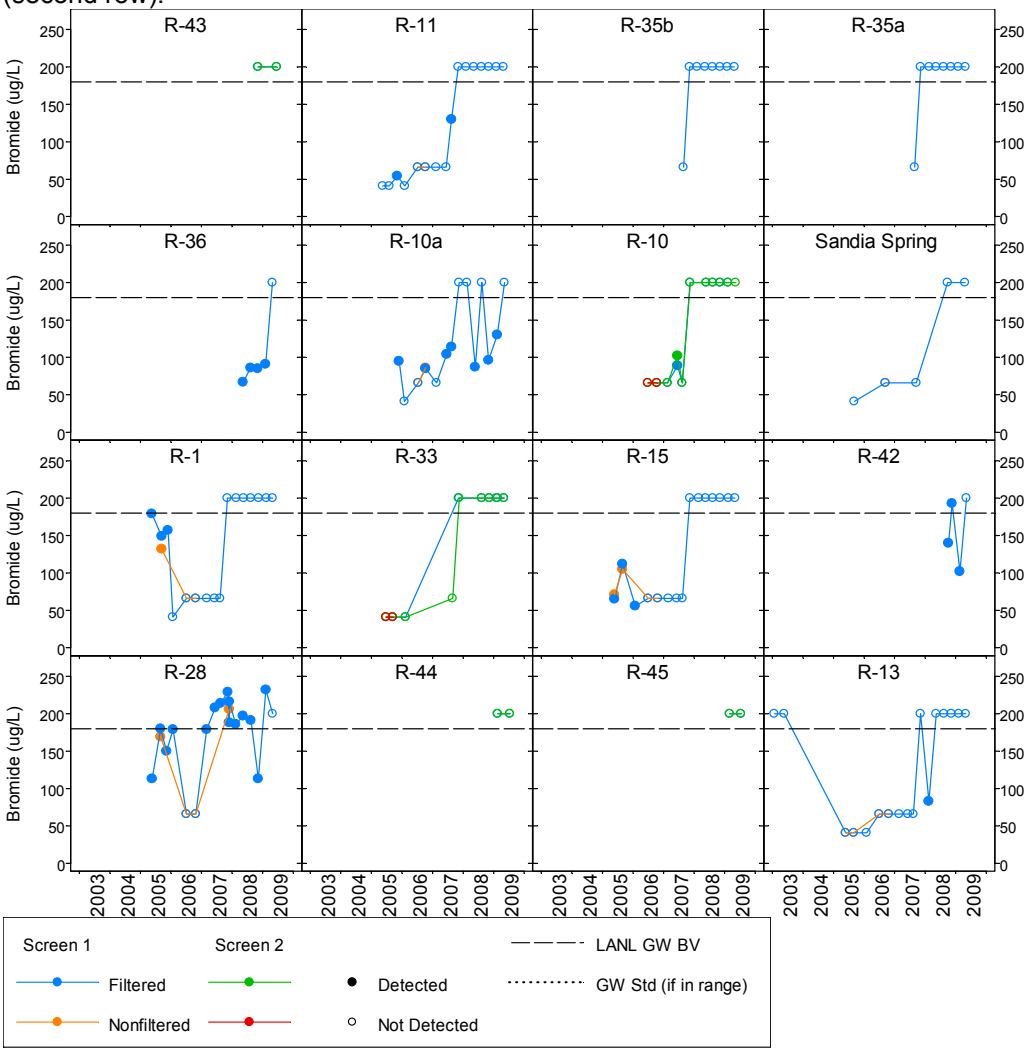


b. Bromide in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

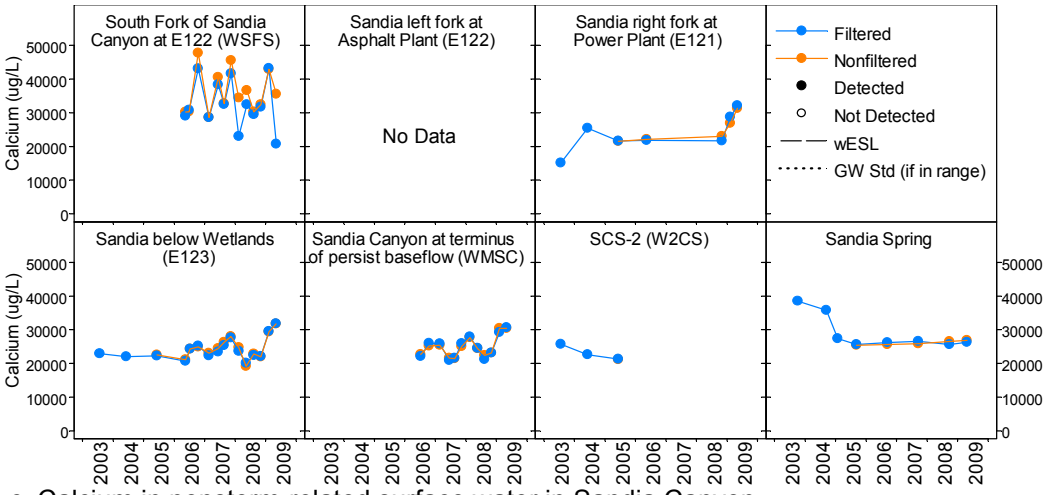


b. Bromide in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

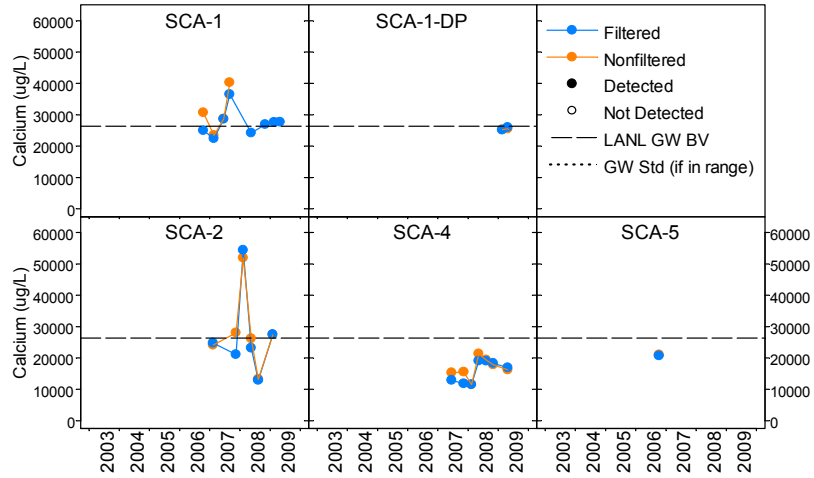


b. Bromide in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

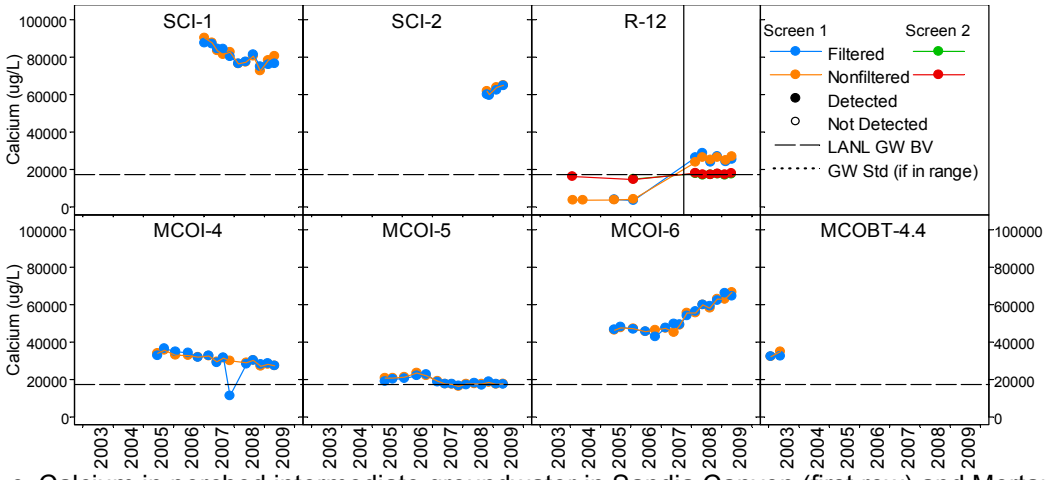


c. Calcium in nonstorm-related surface water in Sandia Canyon.

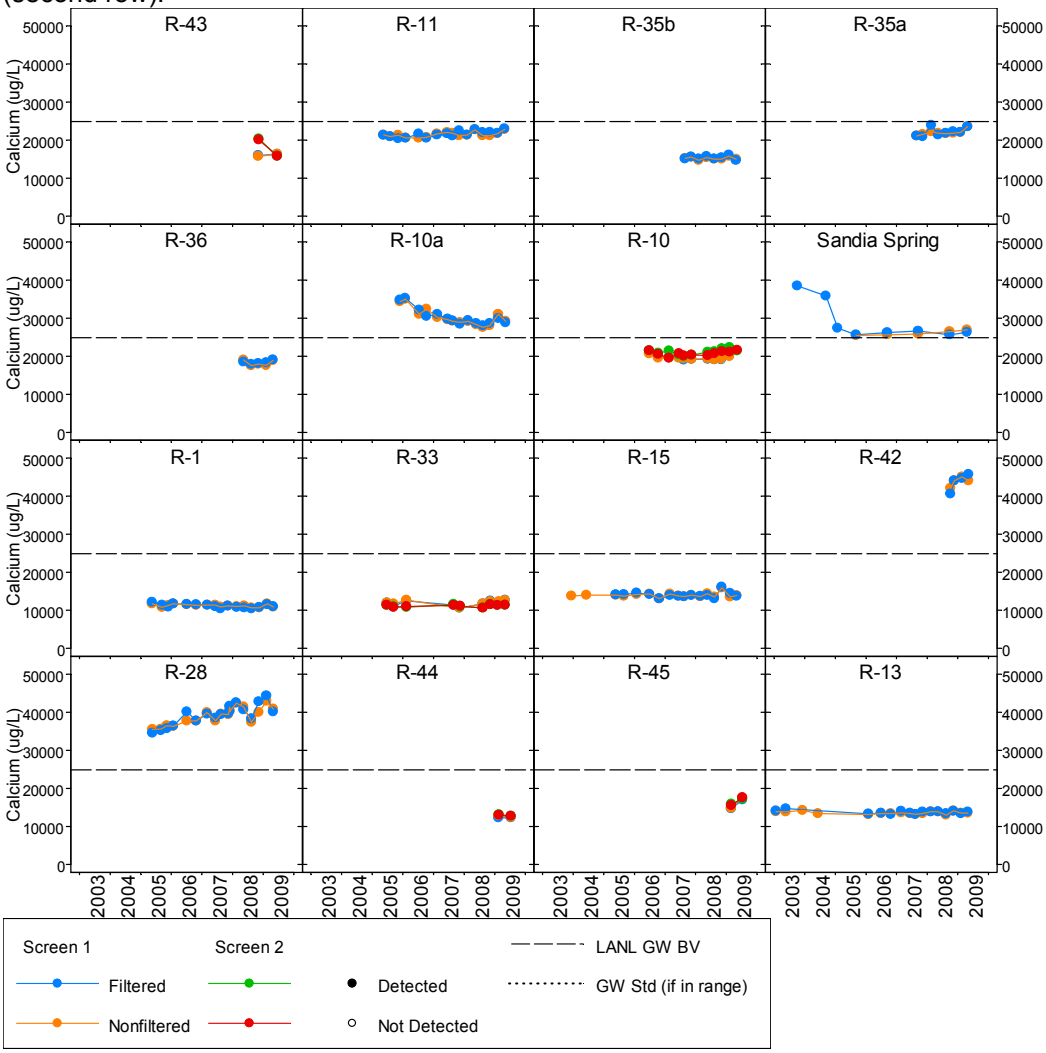


c. Calcium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

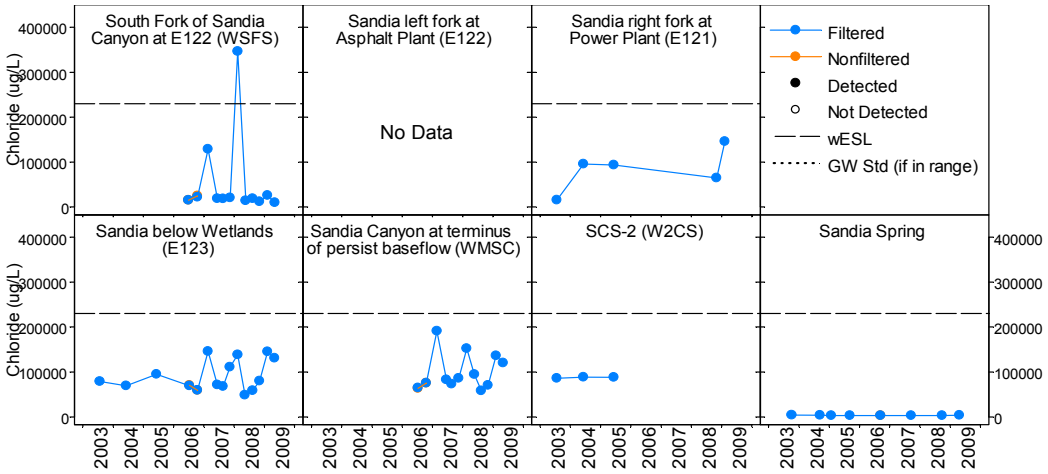


c. Calcium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

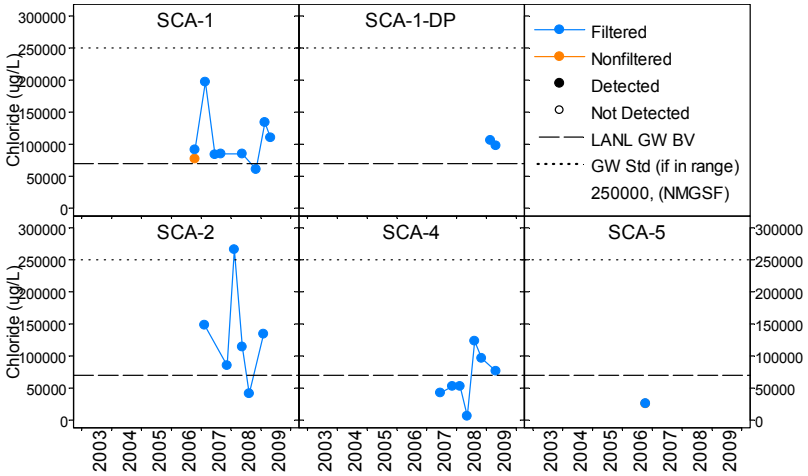


c. Calcium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

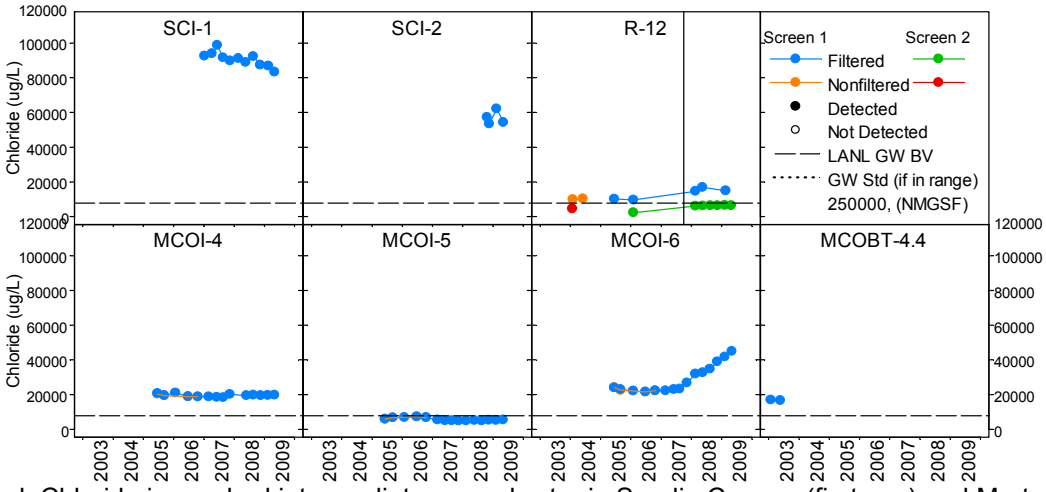


d. Chloride in nonstorm-related surface water in Sandia Canyon.

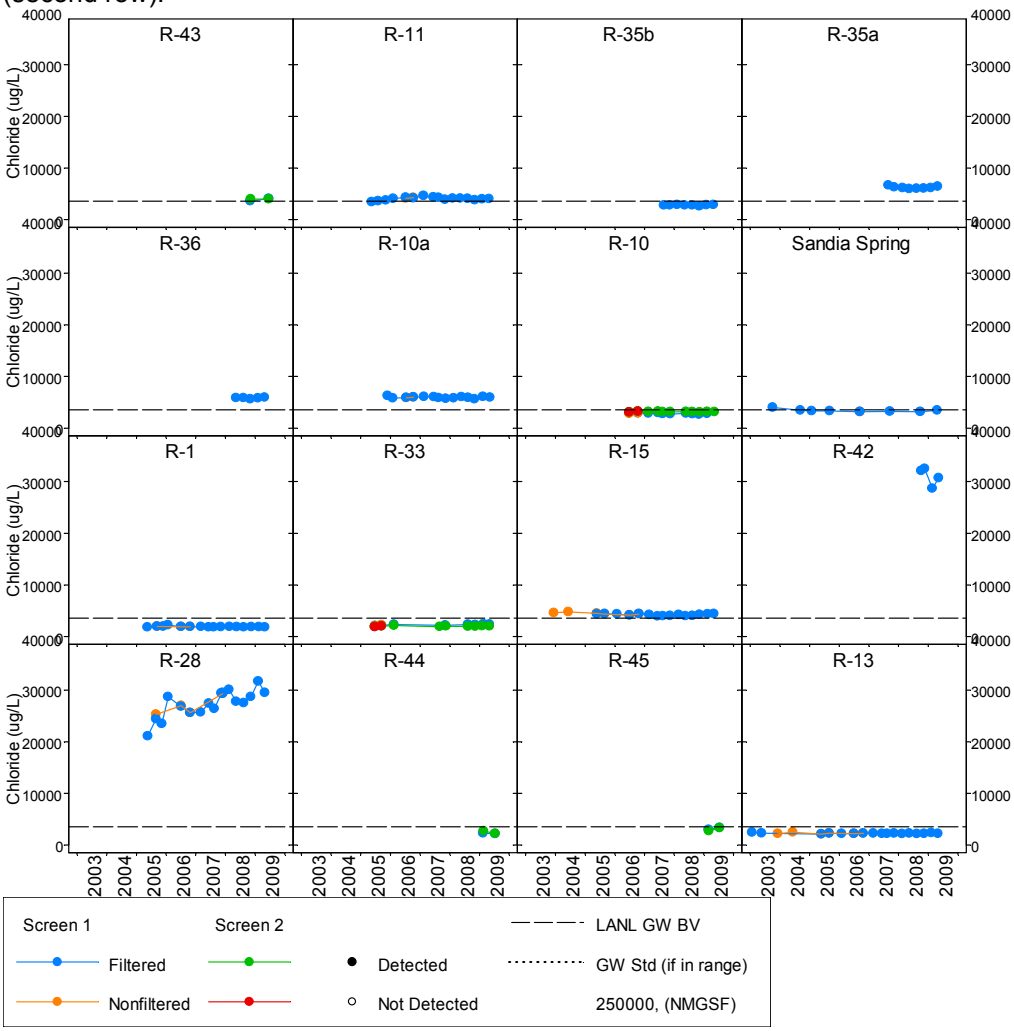


d. Chloride in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

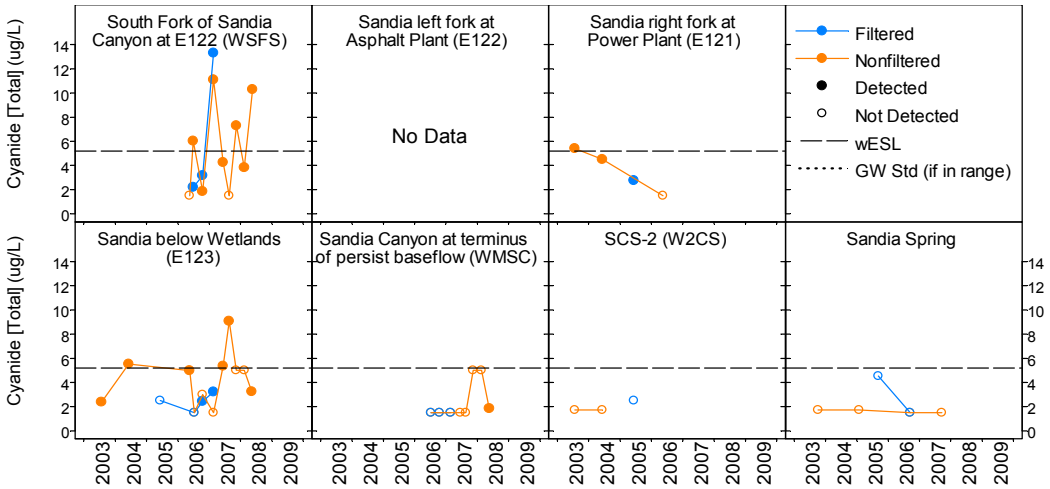


d. Chloride in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

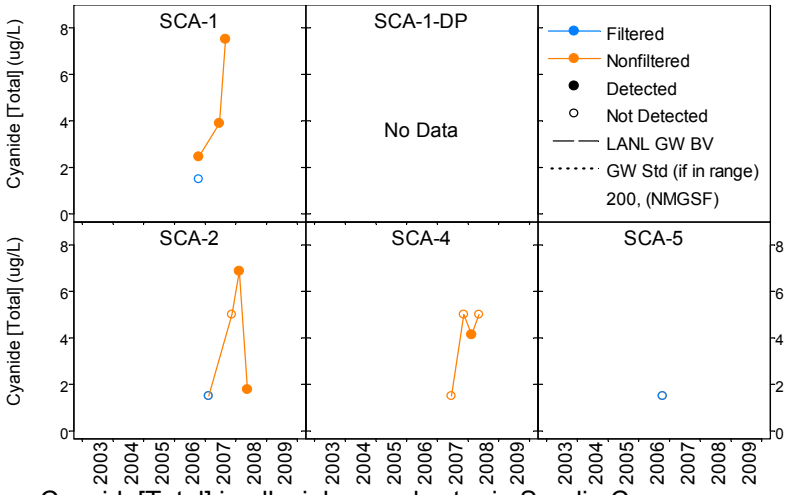


d. Chloride in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

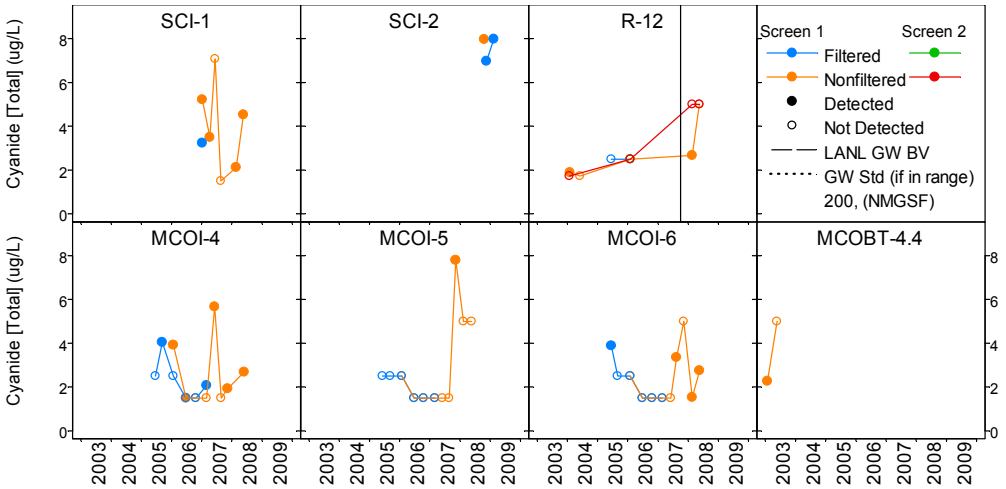


e. Cyanide [Total] in nonstorm-related surface water in Sandia Canyon.

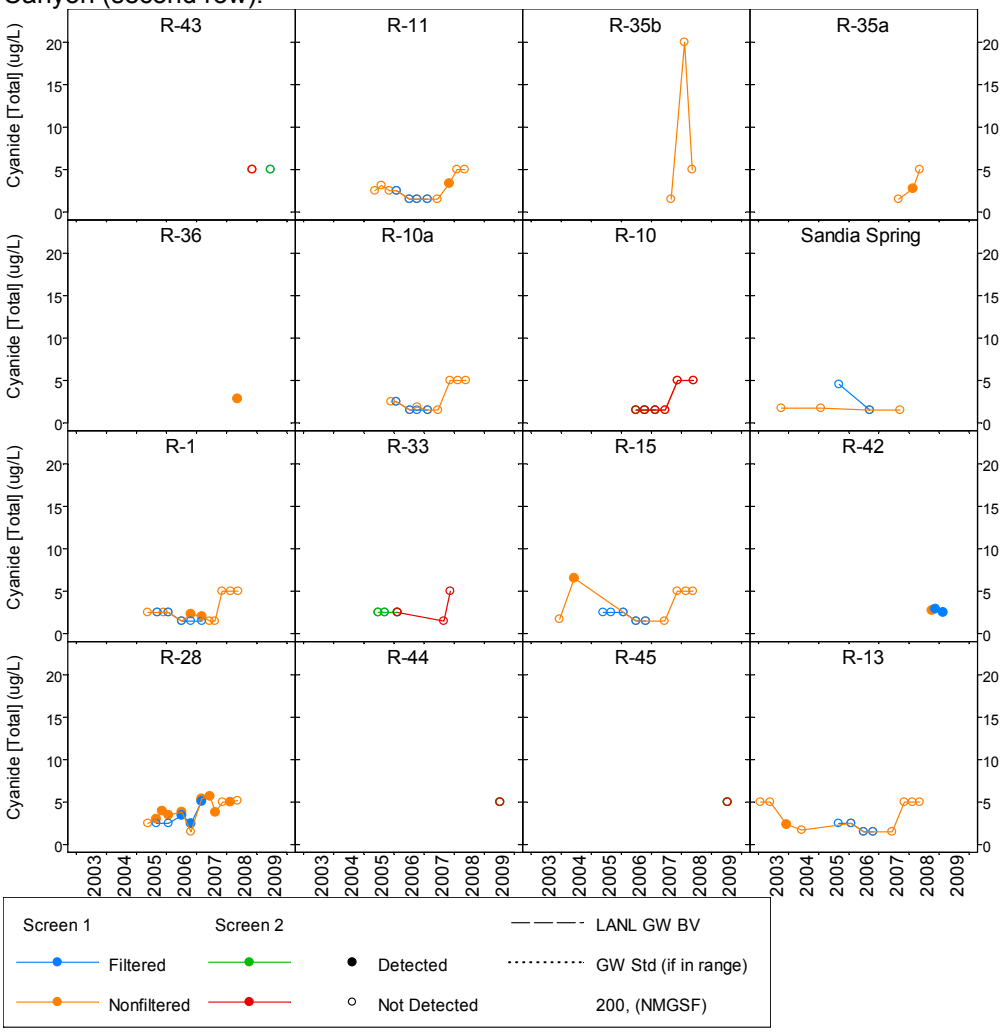


e. Cyanide[Total] in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

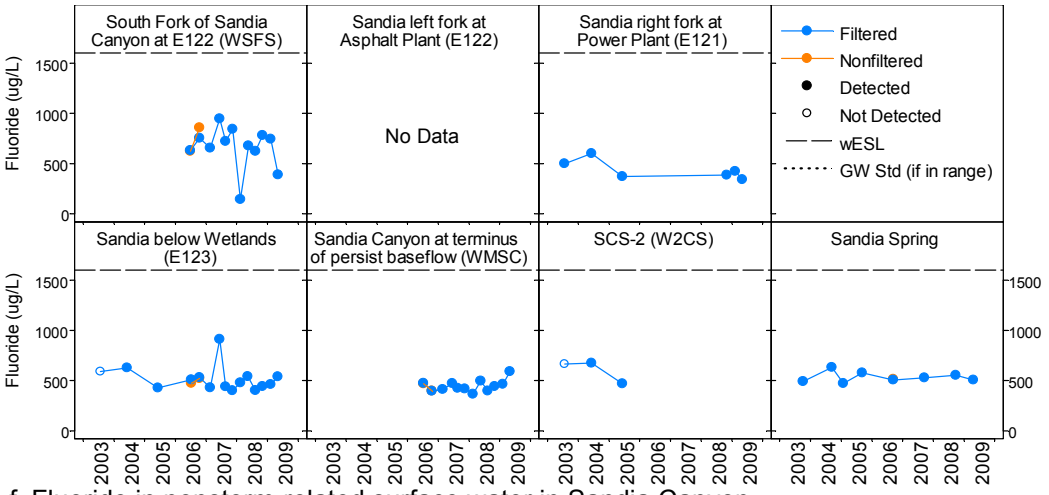


e. Cyanide[Total] in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

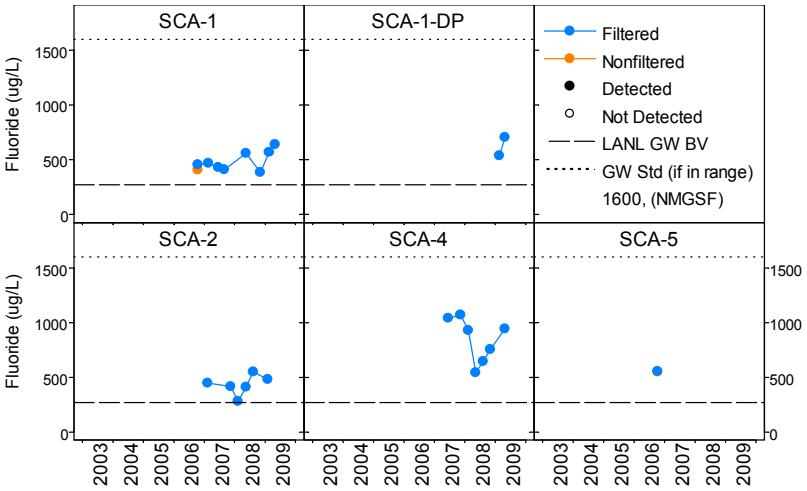


e. Cyanide[Total] in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

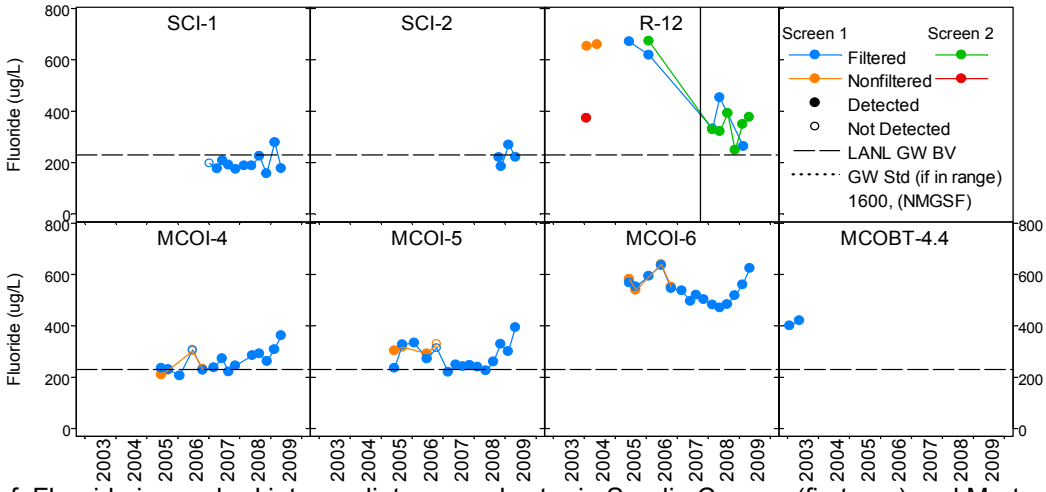


f. Fluoride in nonstorm-related surface water in Sandia Canyon.

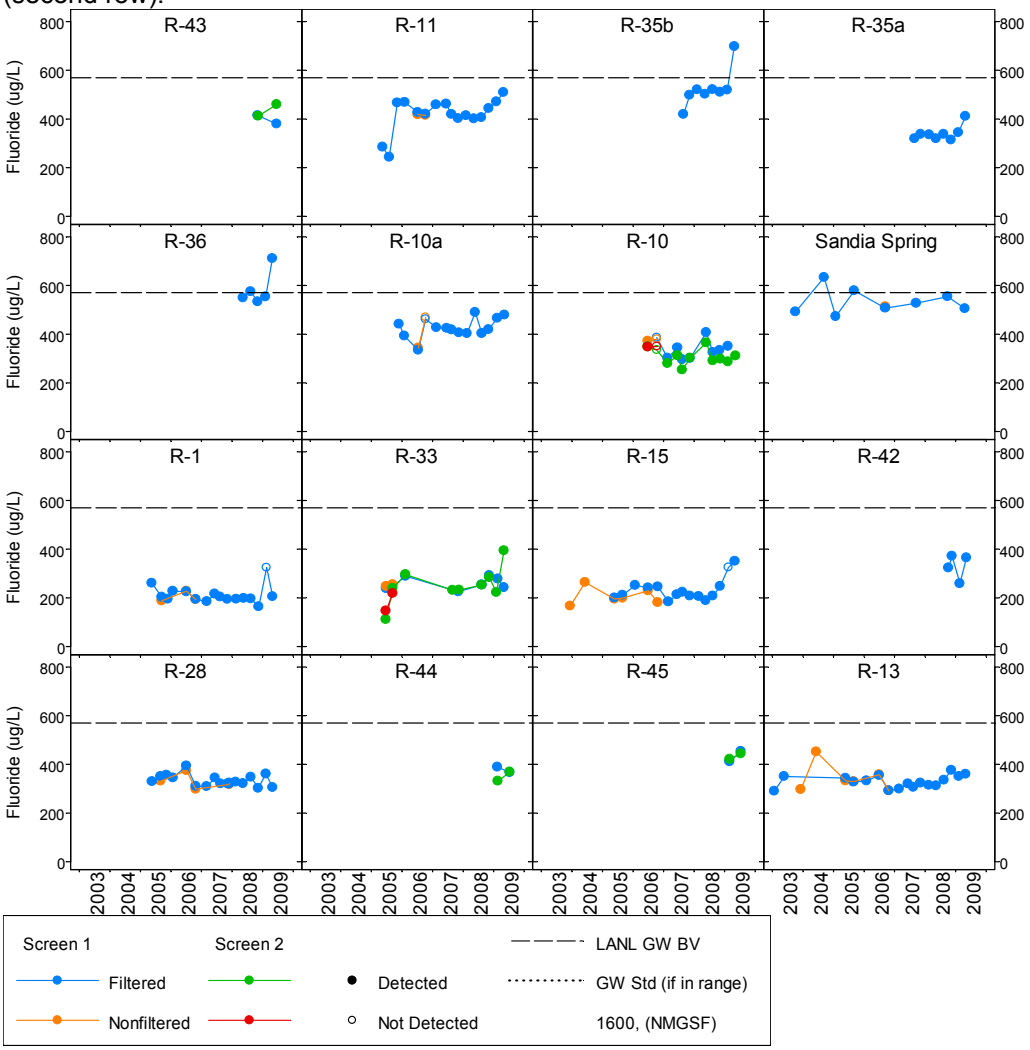


f. Fluoride in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

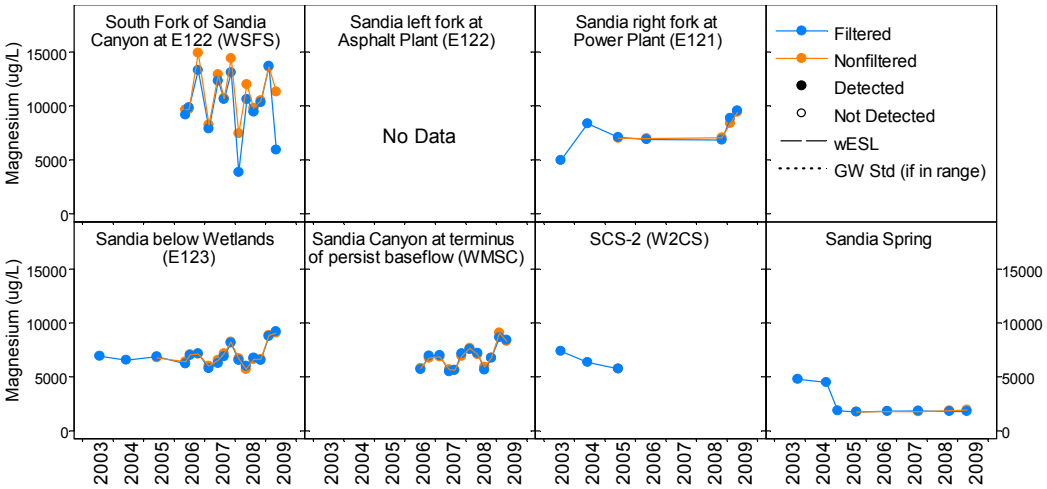


f. Fluoride in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

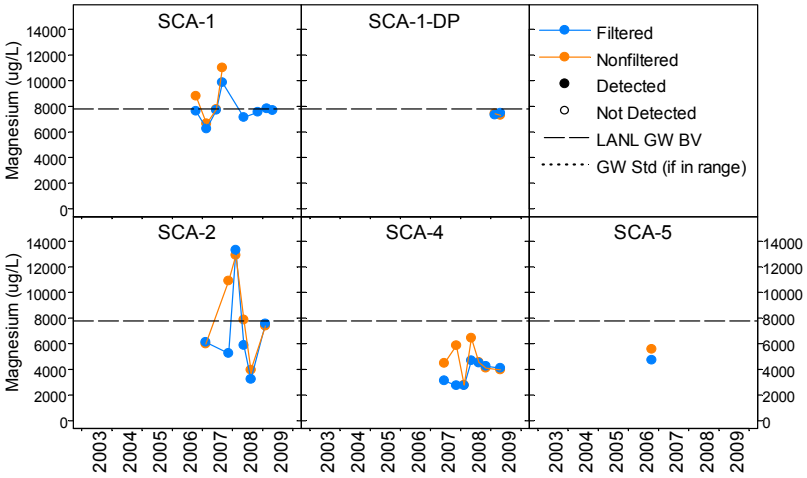


f. Fluoride in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

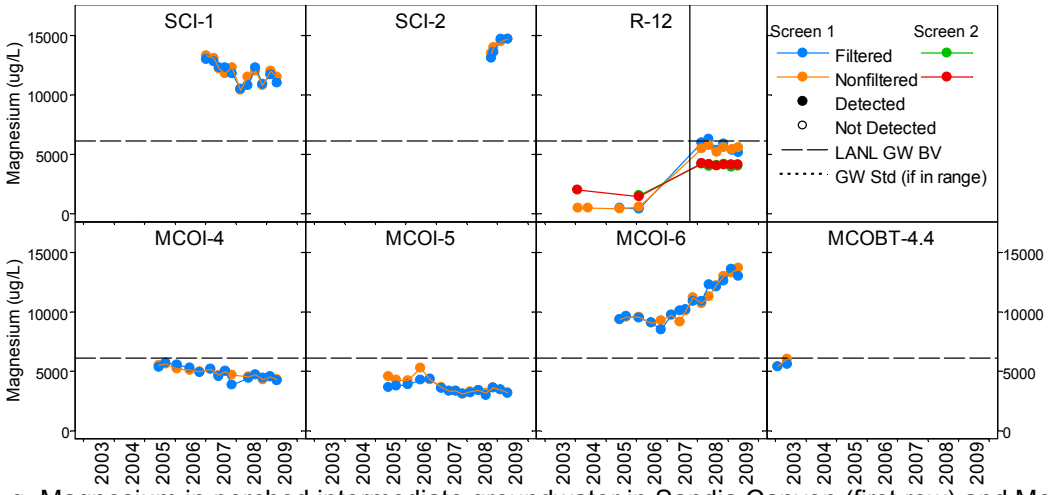


g. Magnesium in nonstorm-related surface water in Sandia Canyon.

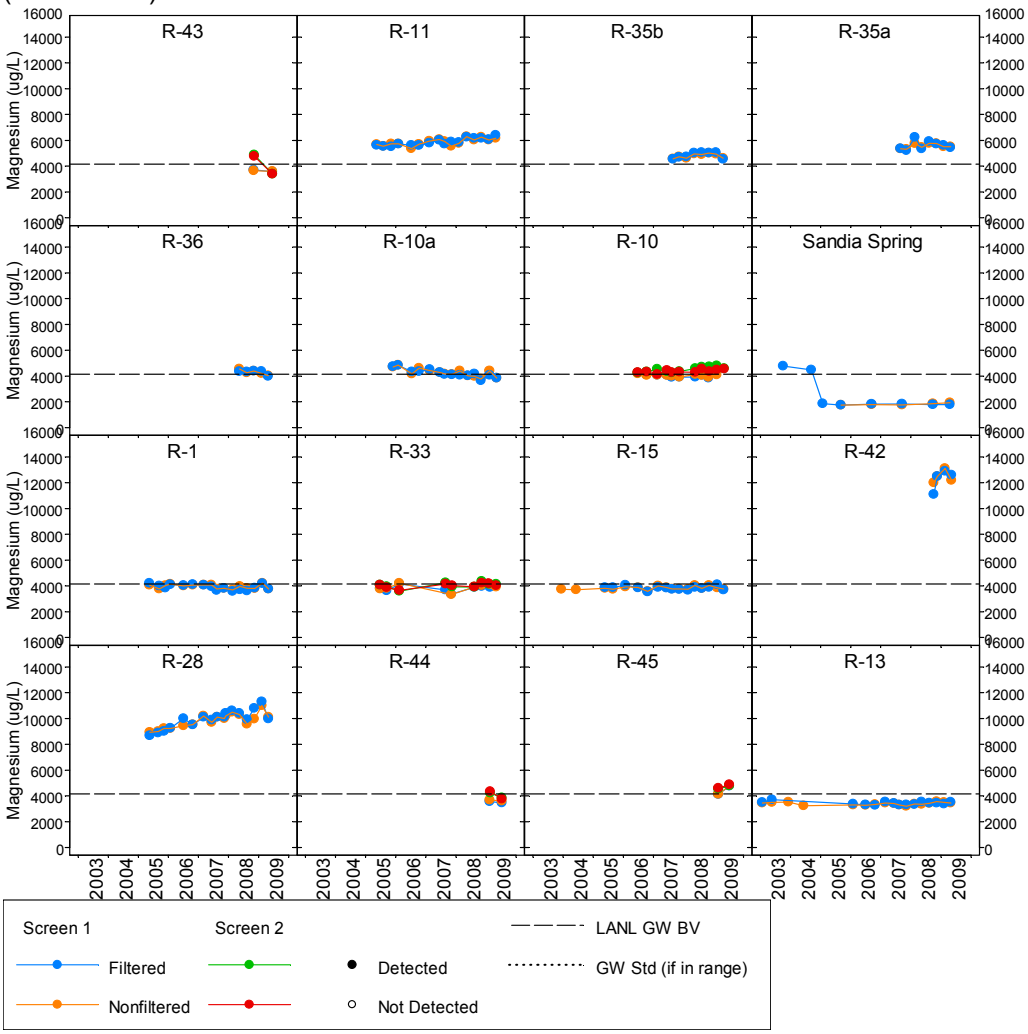


g. Magnesium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

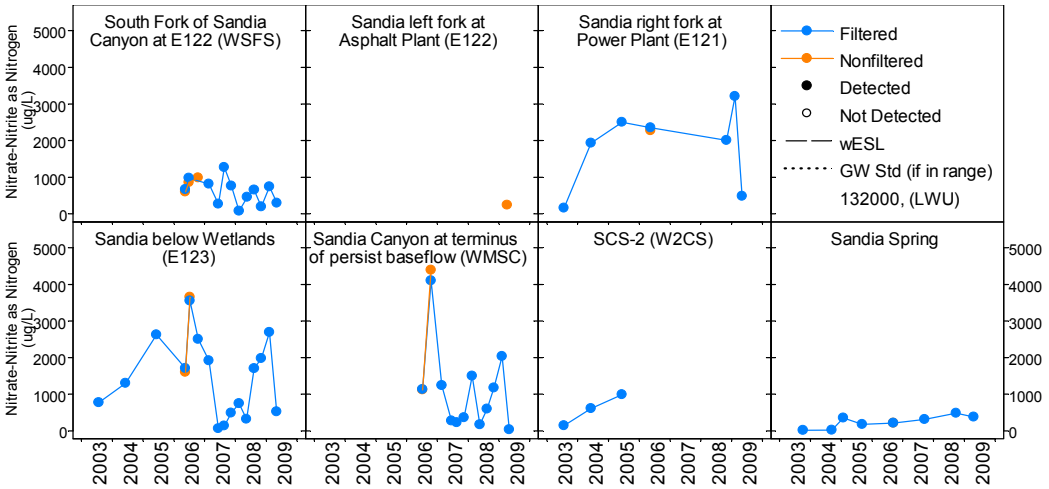


g. Magnesium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

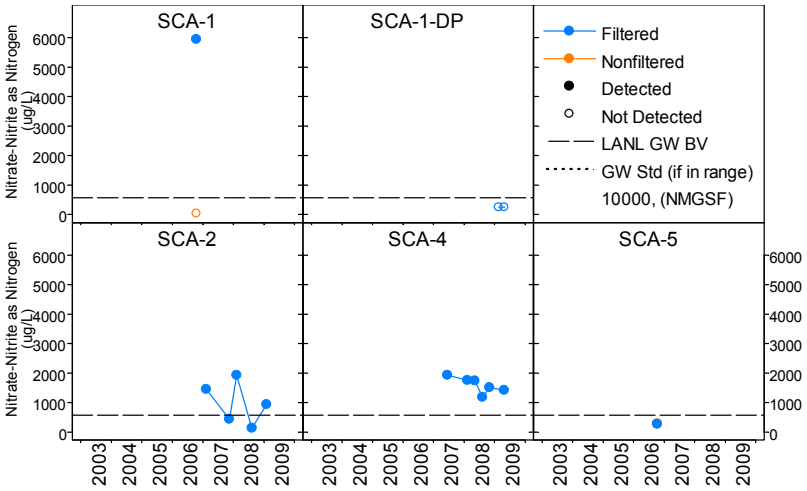


g. Magnesium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

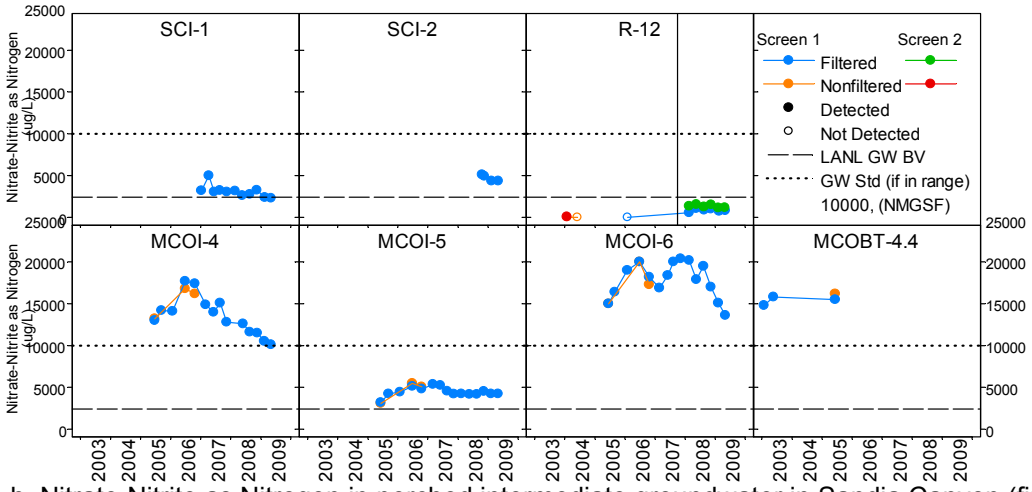


h. Nitrate-Nitrite as Nitrogen in nonstorm-related surface water in Sandia Canyon.

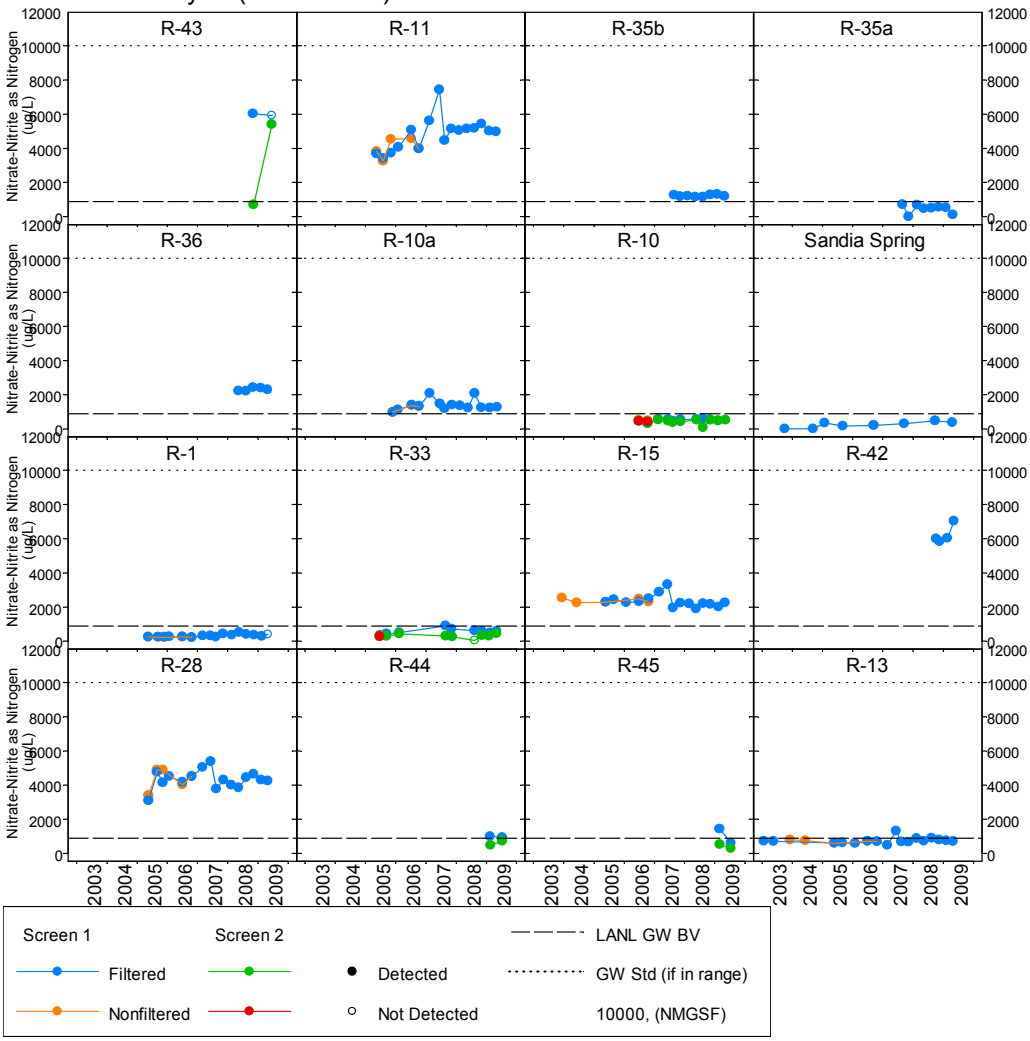


h. Nitrate-Nitrite as Nitrogen in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

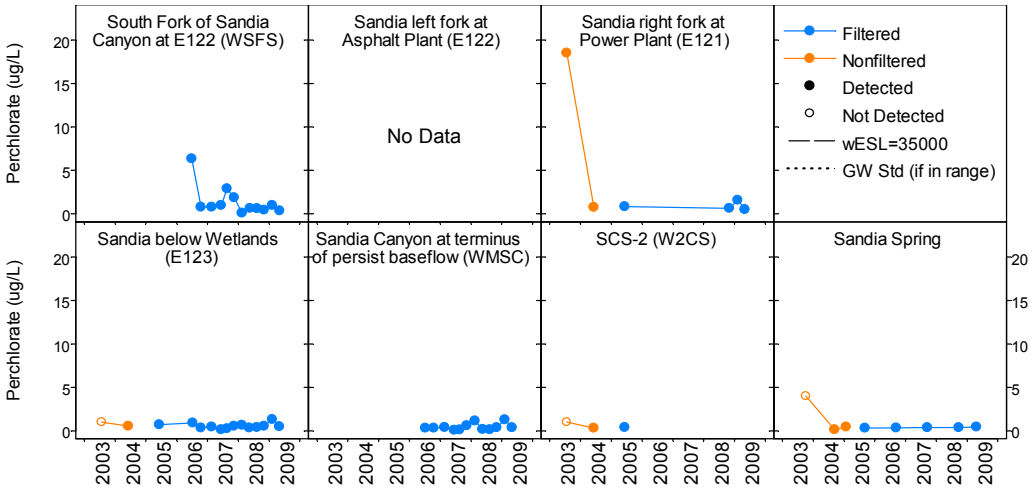


h. Nitrate-Nitrite as Nitrogen in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

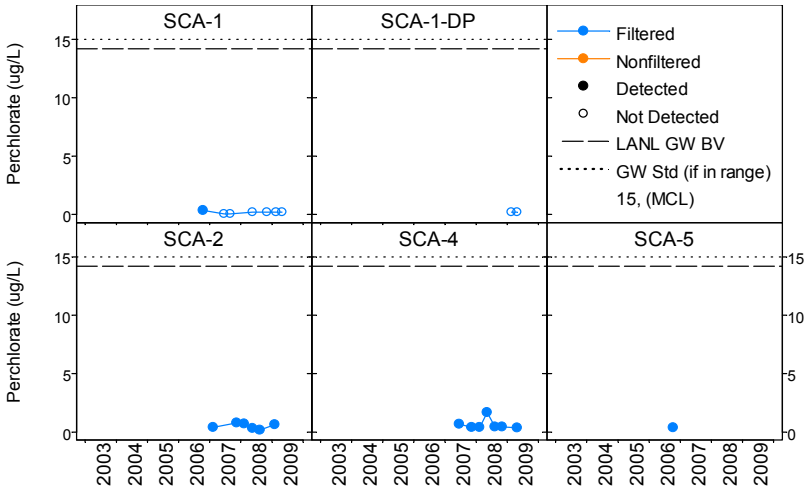


h. Nitrate-Nitrite as Nitrogen in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

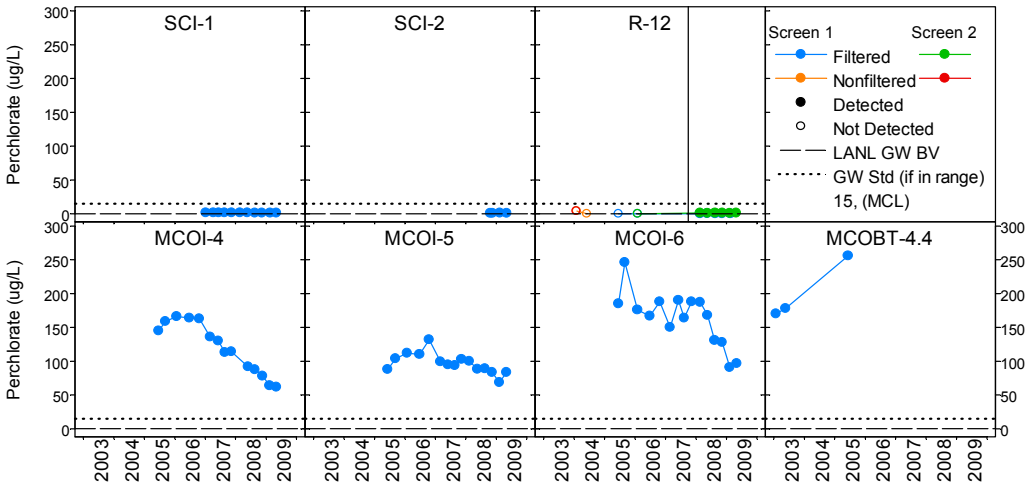


i. Perchlorate in nonstorm-related surface water in Sandia Canyon.

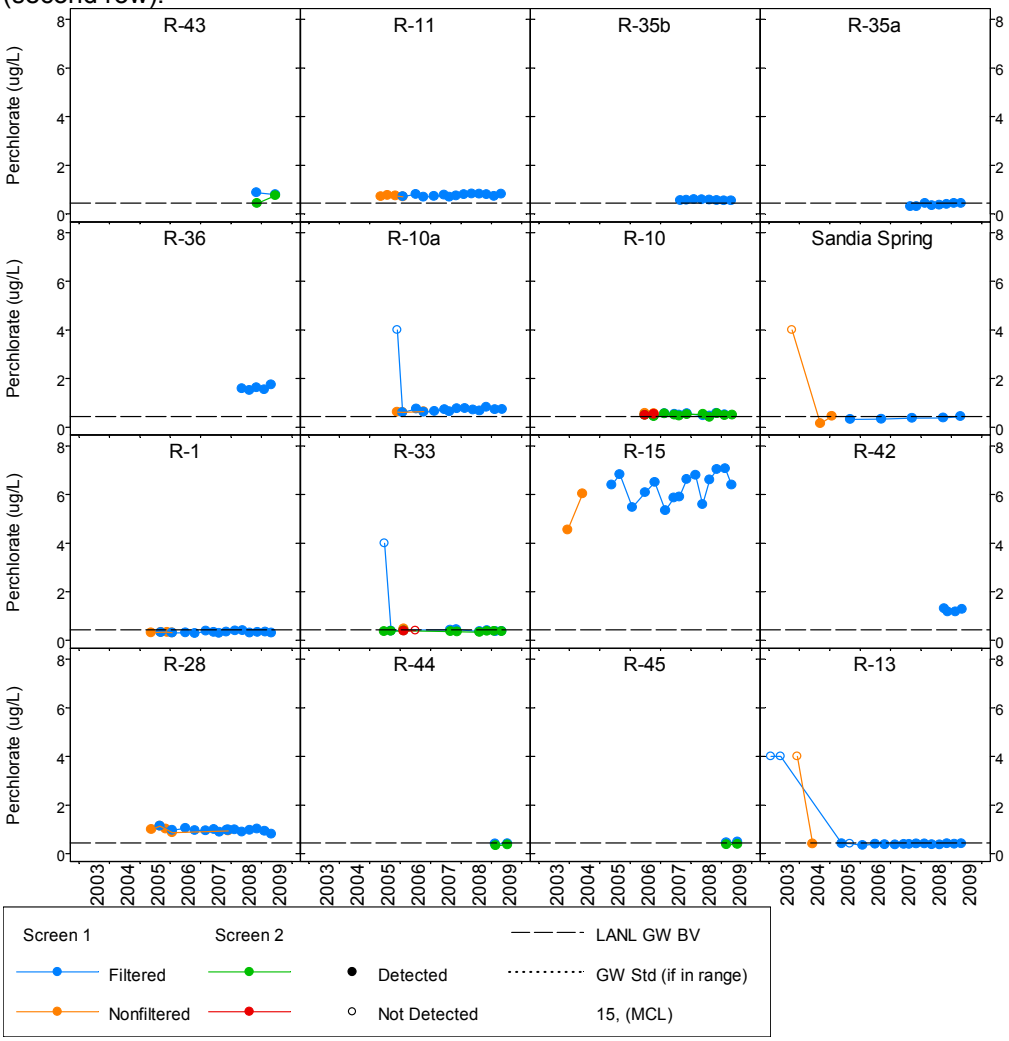


i. Perchlorate in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

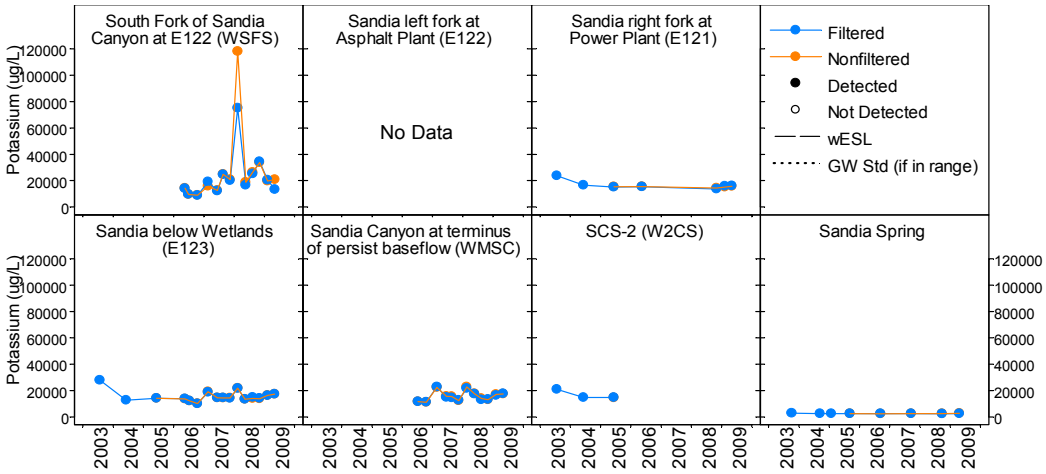


i. Perchlorate in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

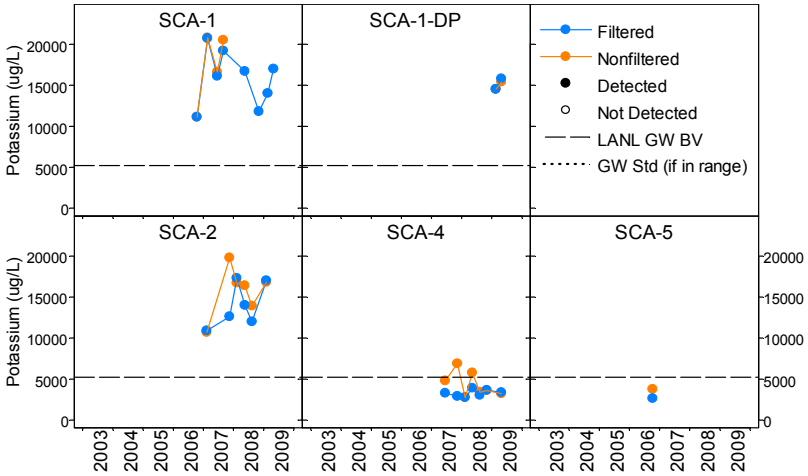


i. Perchlorate in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

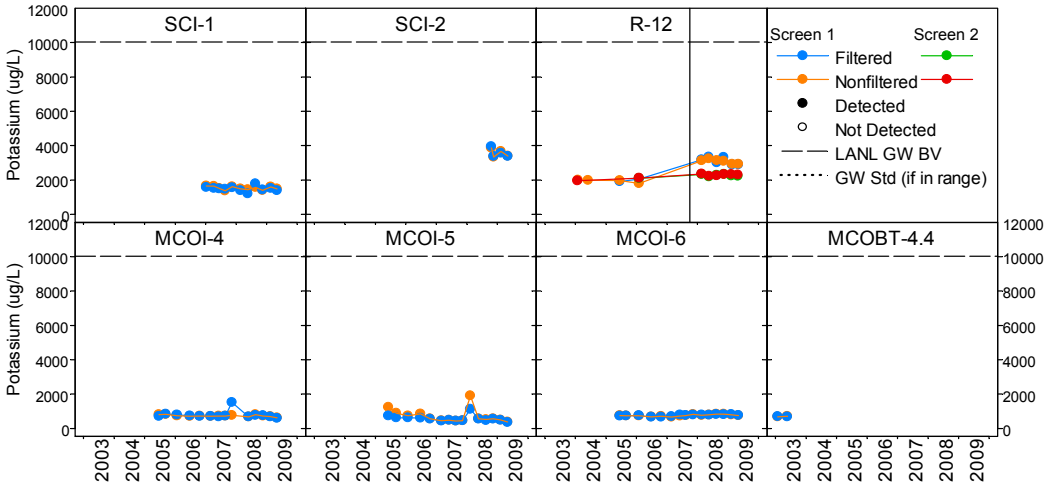


j. Potassium in nonstorm-related surface water in Sandia Canyon.

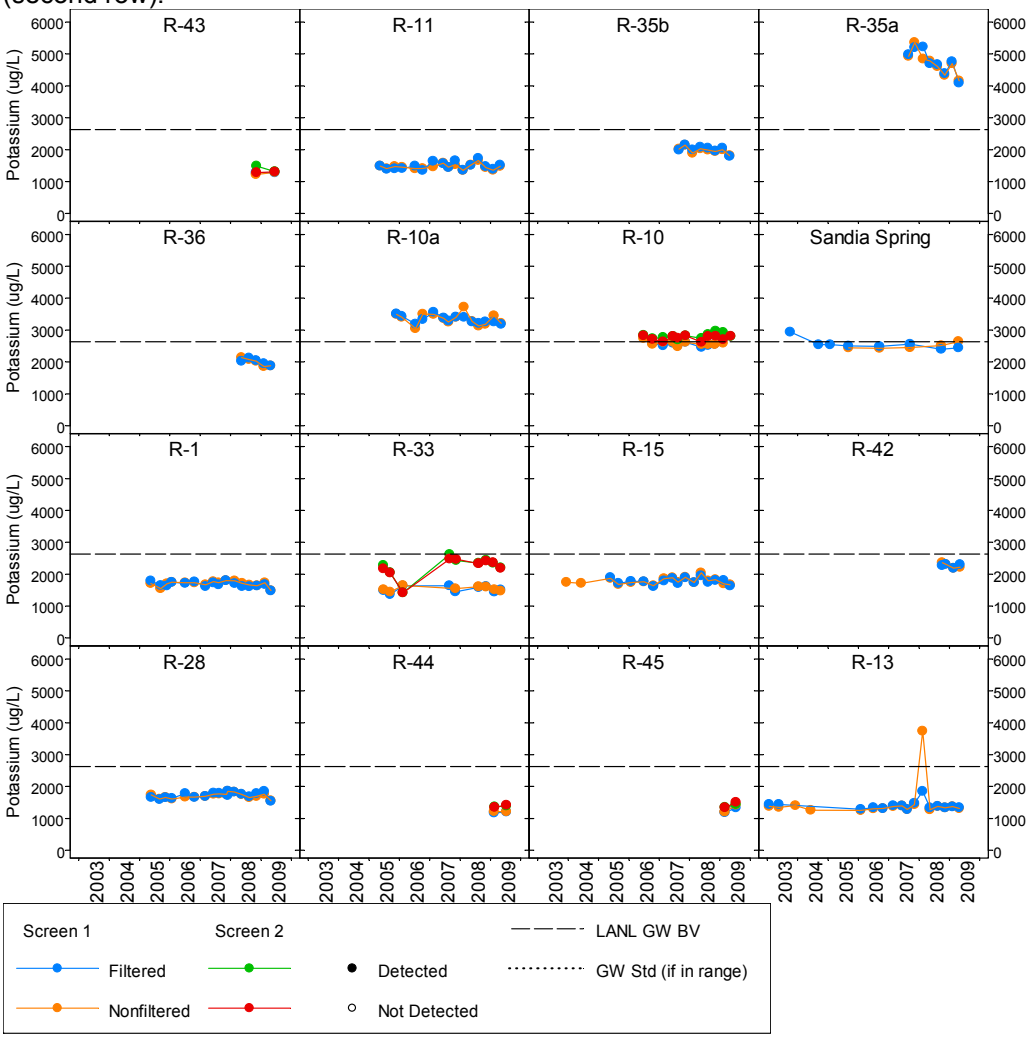


j. Potassium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

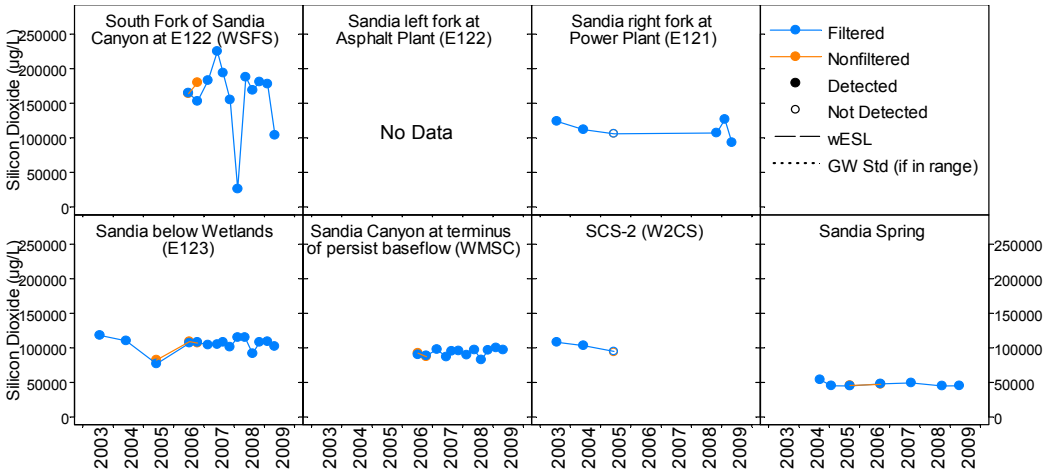


j. Potassium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

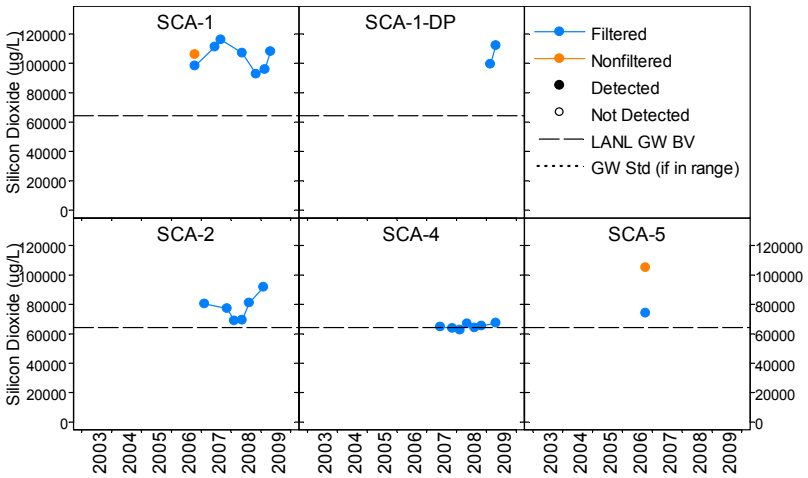


j. Potassium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

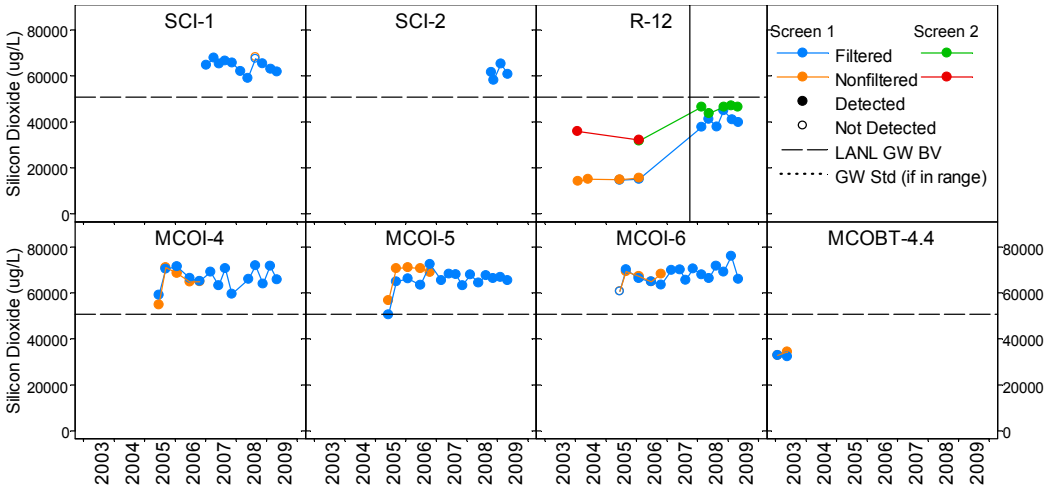


k. Silicon Dioxide in nonstorm-related surface water in Sandia Canyon.

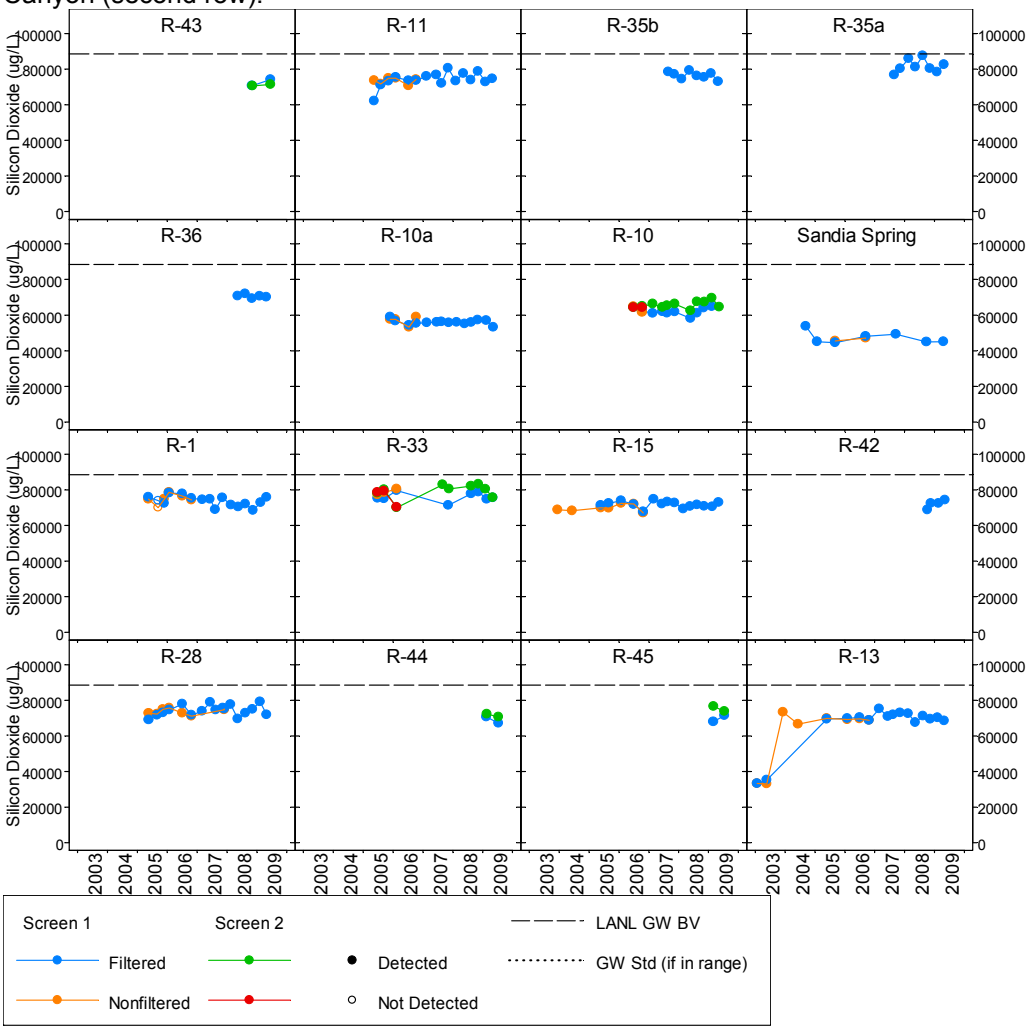


k. Silicon Dioxide in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

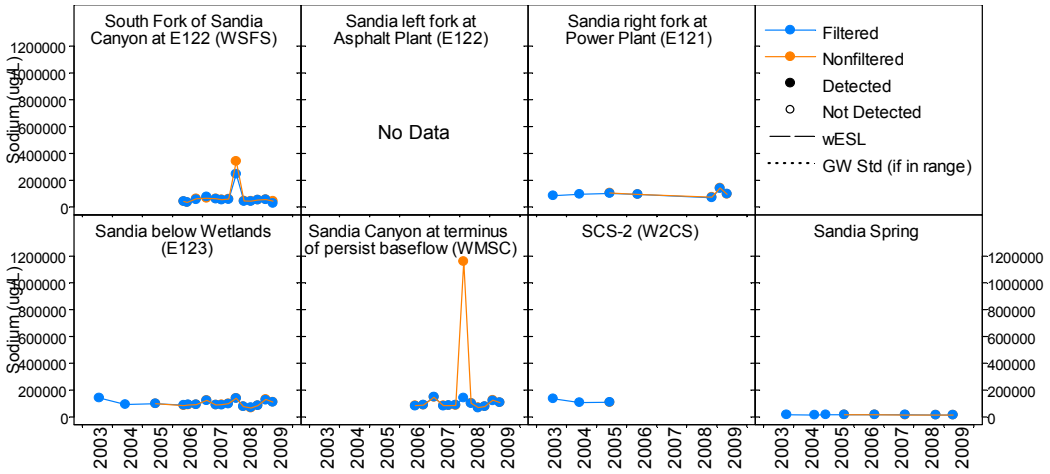


k. Silicon Dioxide in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

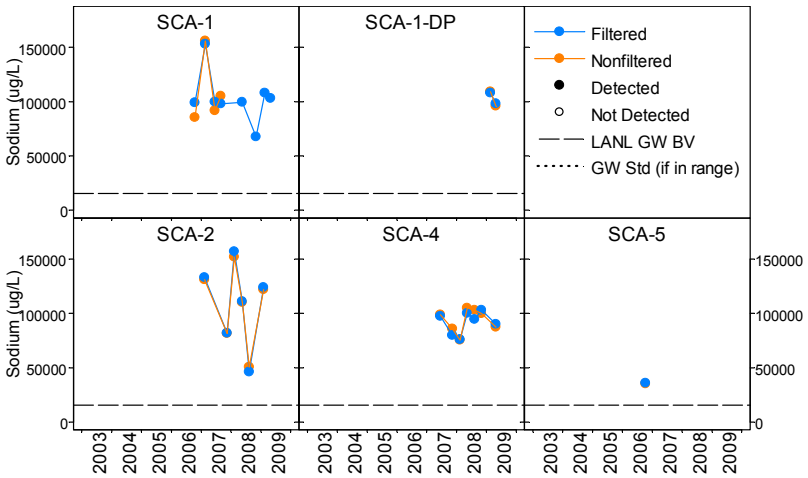


k. Silicon Dioxide in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

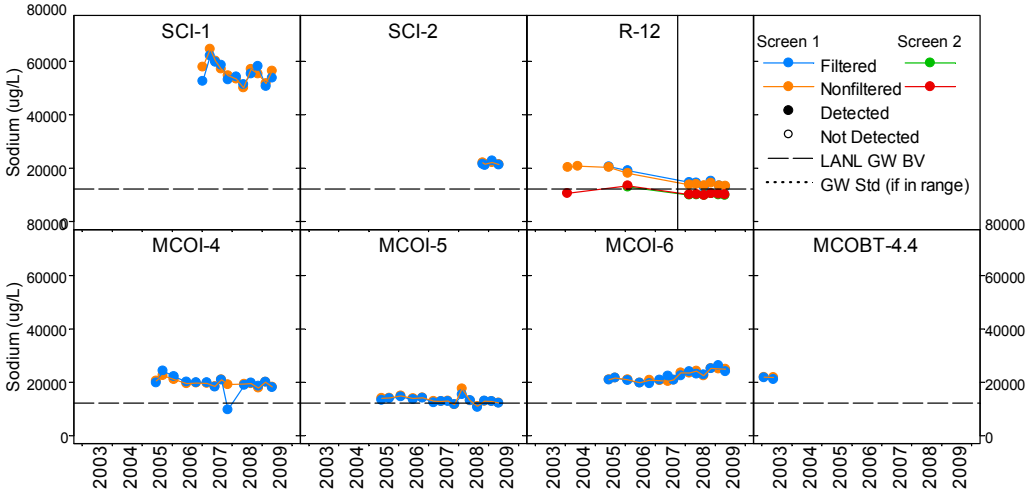


I. Sodium in nonstorm-related surface water in Sandia Canyon.

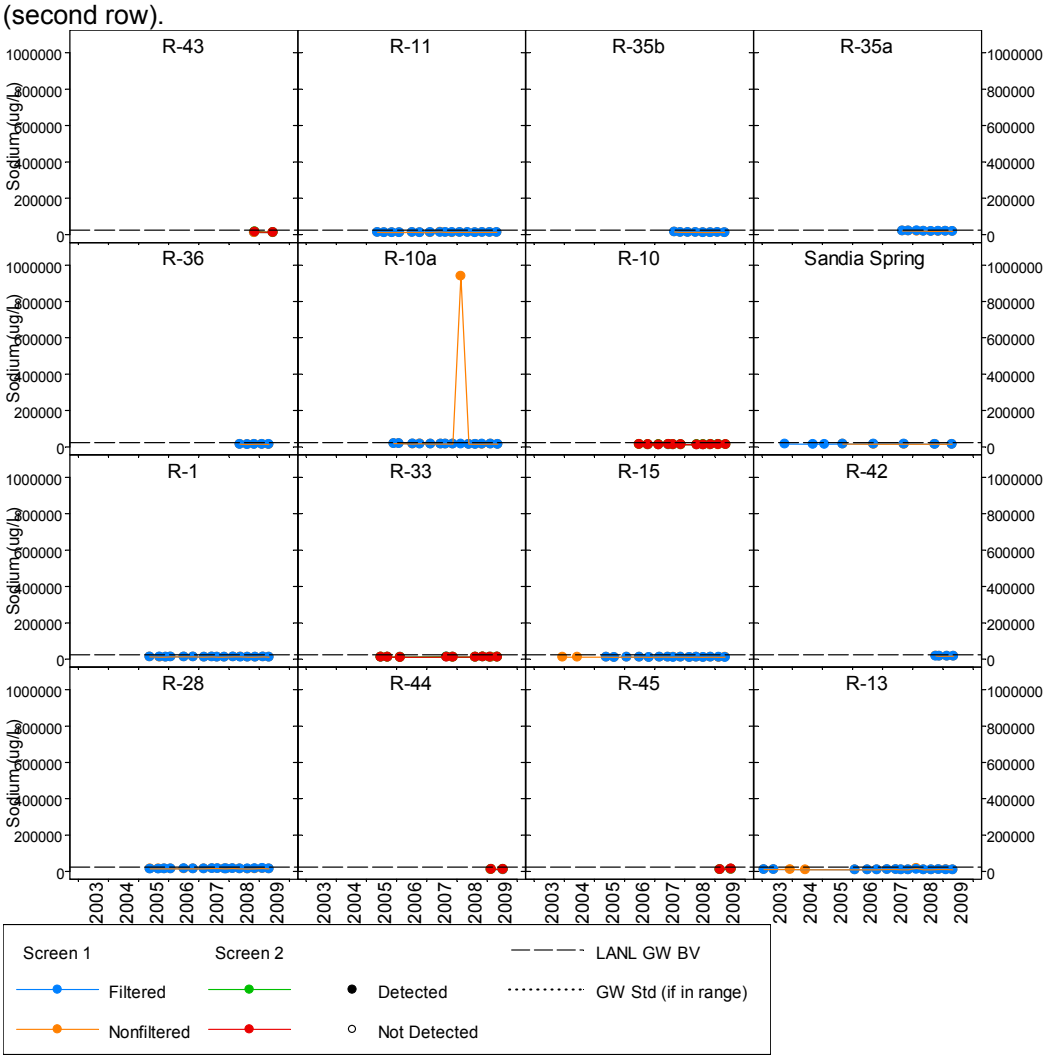


I. Sodium in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

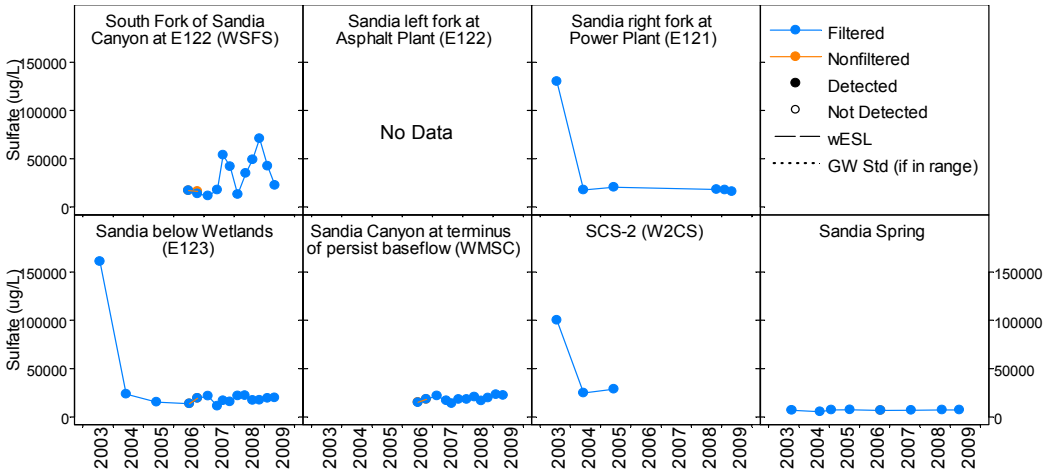


I. Sodium in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

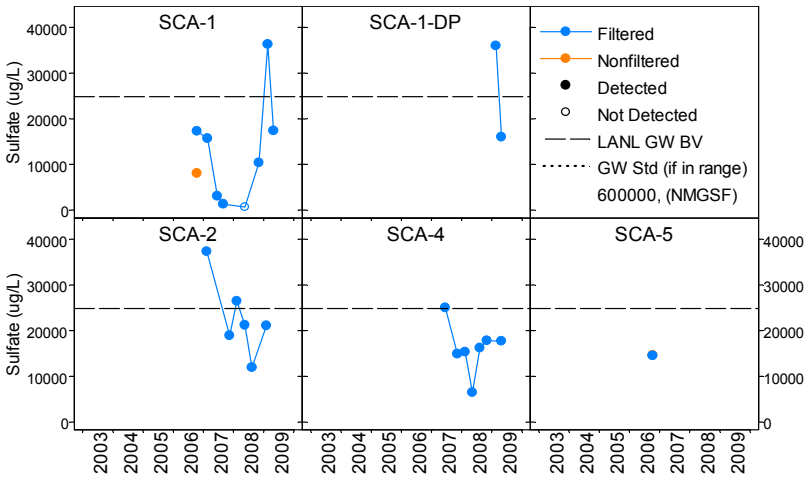


I. Sodium in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

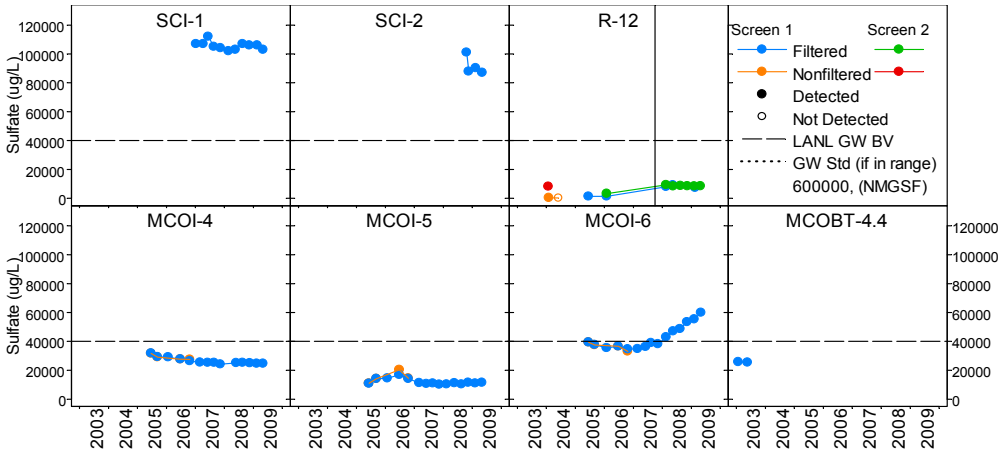


m. Sulfate in nonstorm-related surface water in Sandia Canyon.

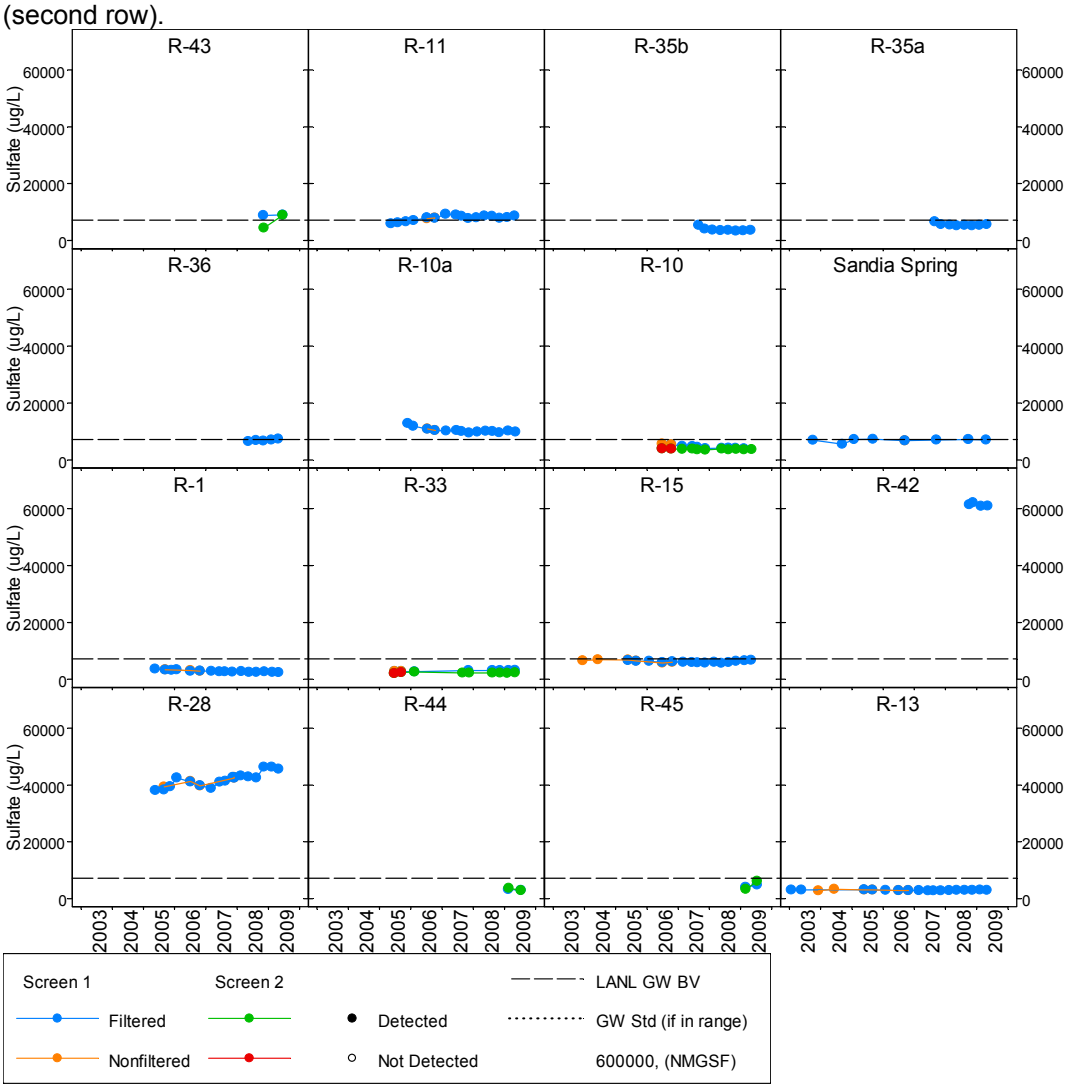


m. Sulfate in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

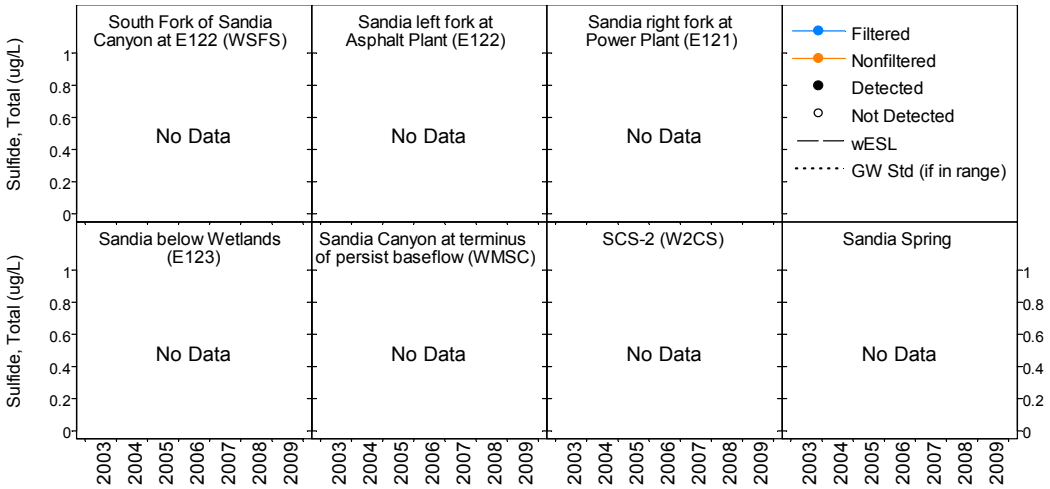


m. Sulfate in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

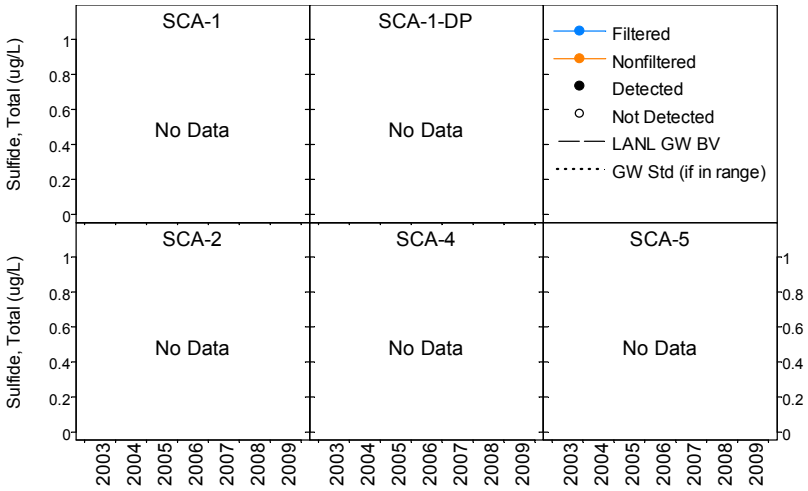


m. Sulfate in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

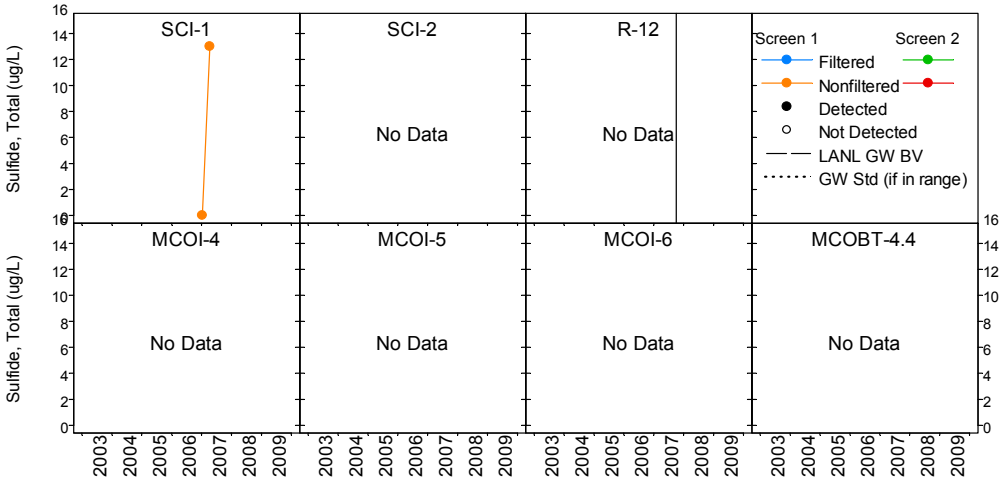


n. Sulfide, Total in nonstorm-related surface water in Sandia Canyon.

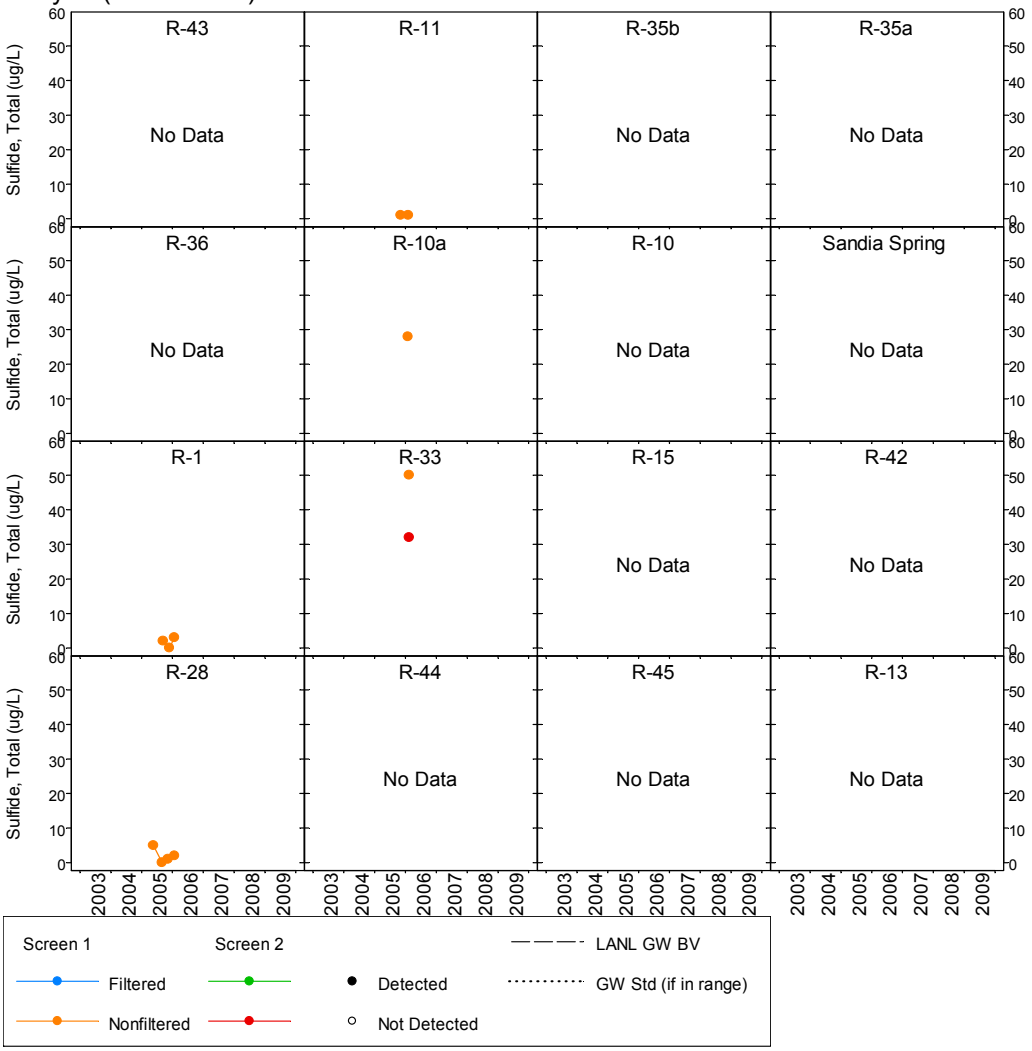


n. Sulfide, Total in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

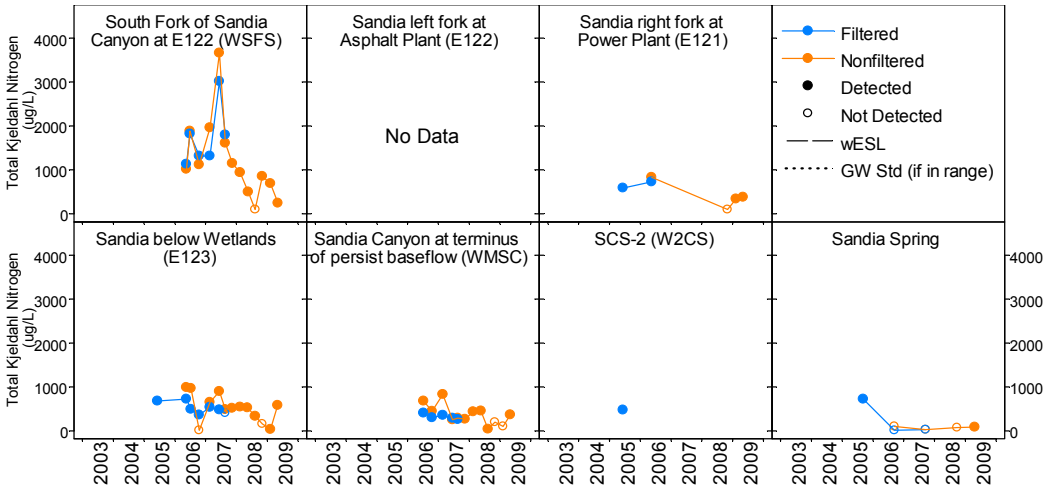


n. Sulfide, Total in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

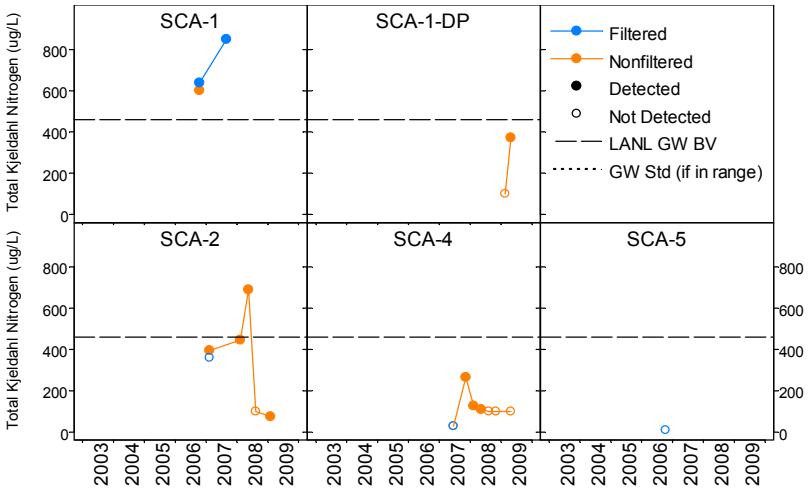


n. Sulfide, Total in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

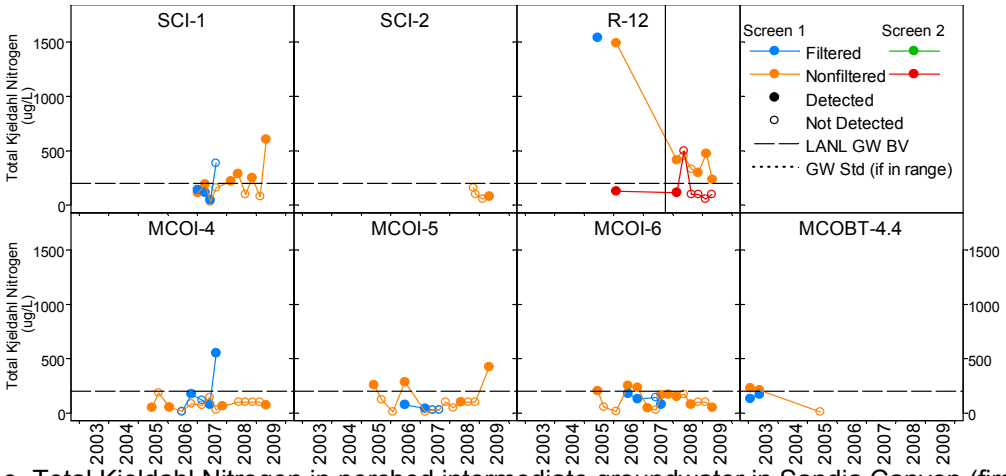


o. Total Kjeldahl Nitrogen in nonstorm-related surface water in Sandia Canyon.

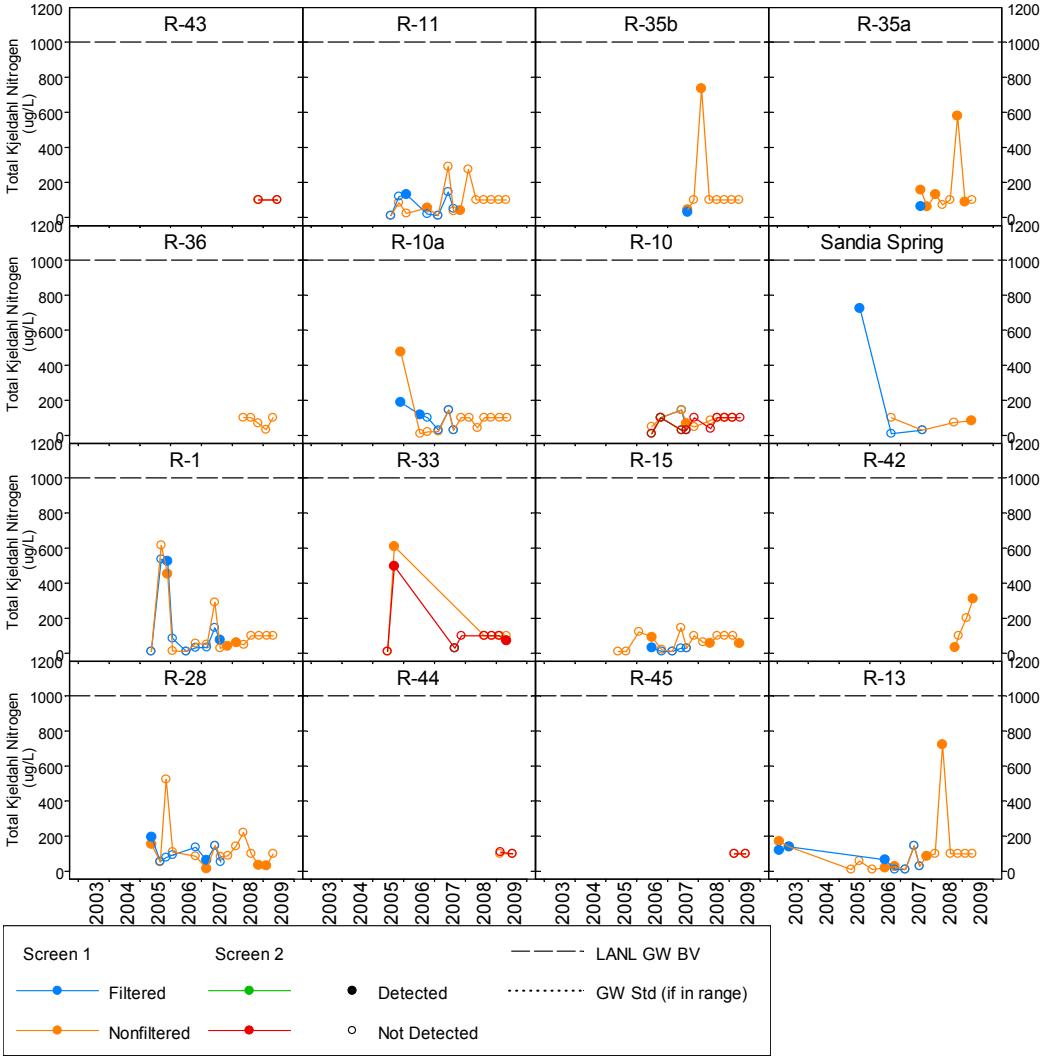


o. Total Kjeldahl Nitrogen in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

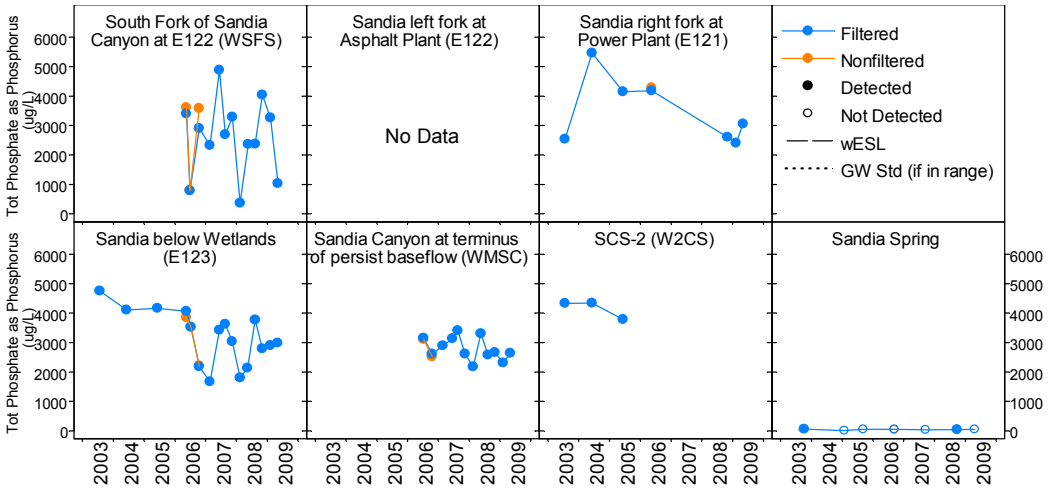


o. Total Kjeldahl Nitrogen in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

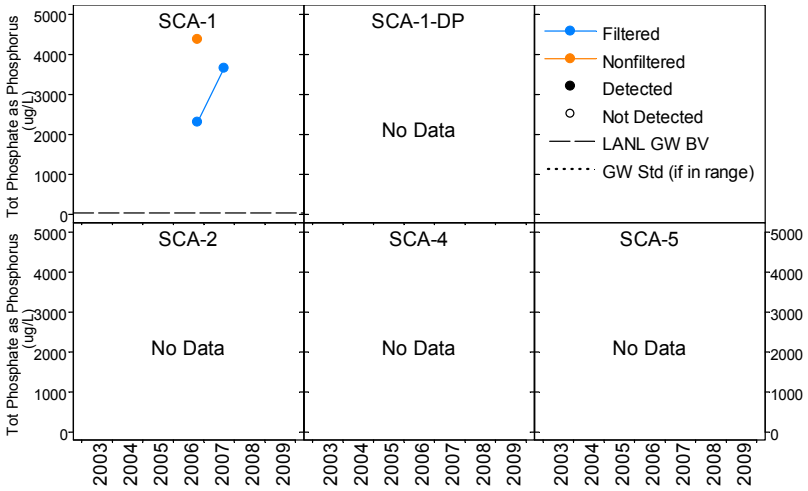


o. Total Kjeldahl Nitrogen in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

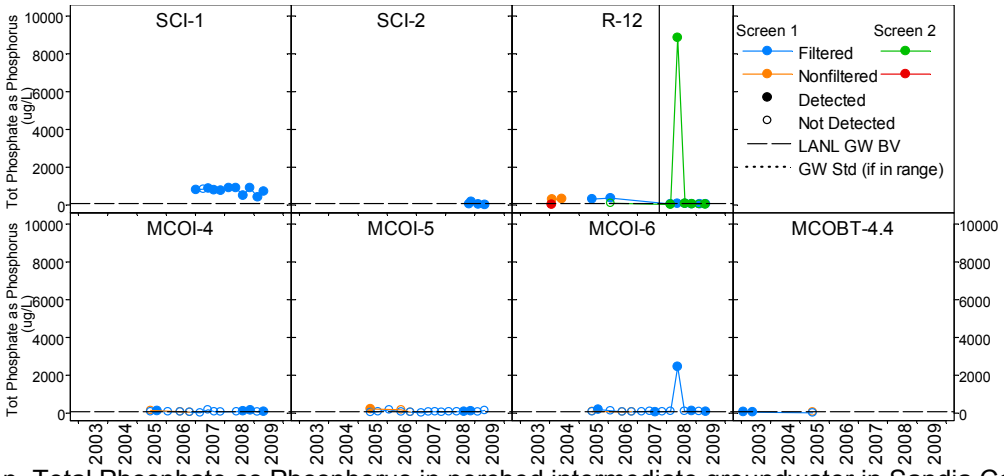


p. Total Phosphate as Phosphorus in nonstorm-related surface water in Sandia Canyon.

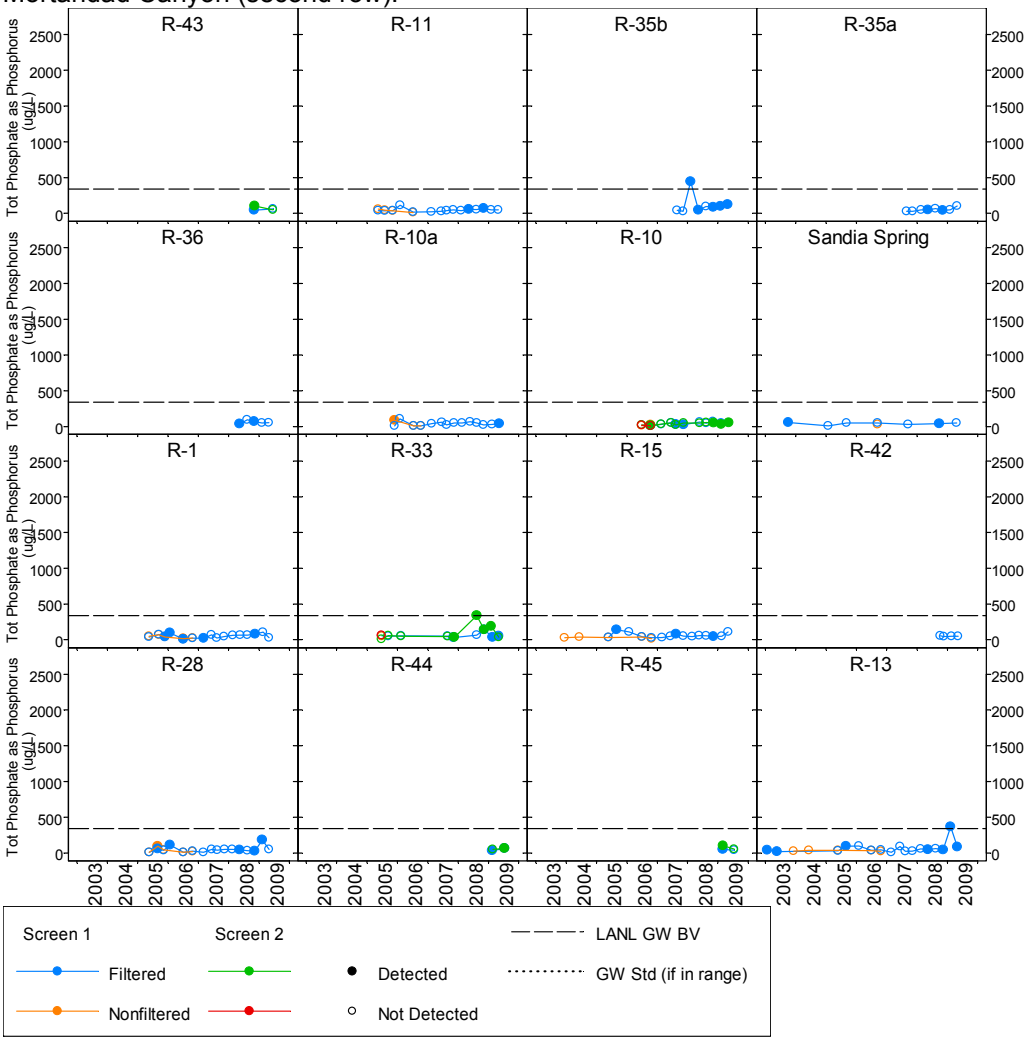


p. Total Phosphate as Phosphorus in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

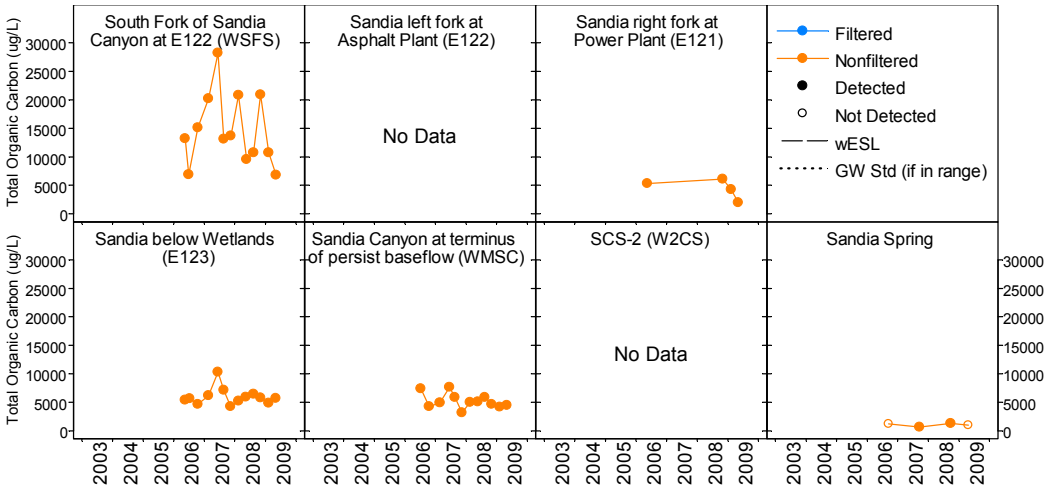


p. Total Phosphate as Phosphorus in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).

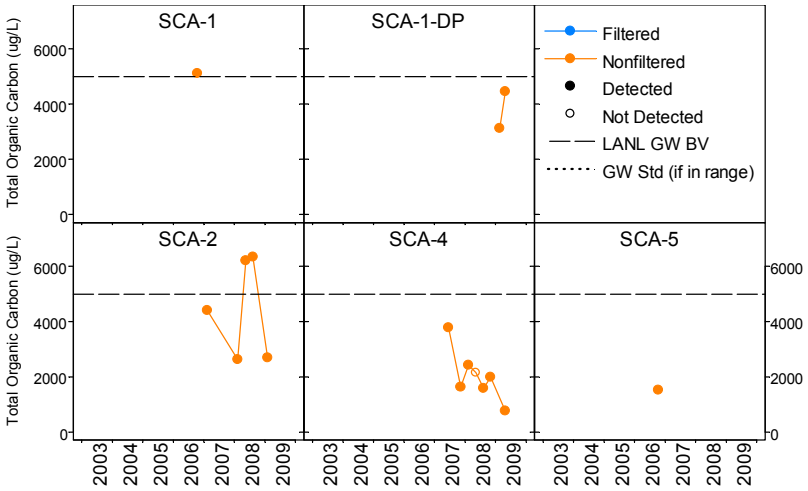


p. Total Phosphate as Phosphorus in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

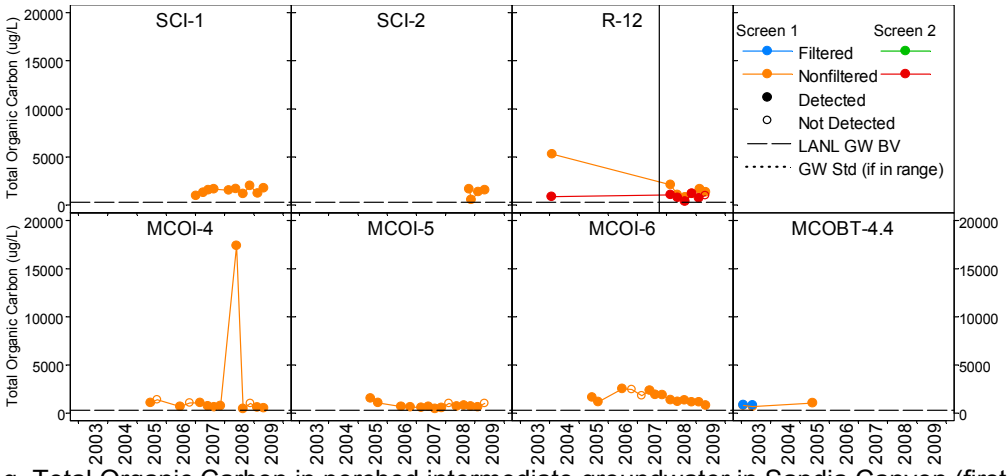


q. Total Organic Carbon in nonstorm-related surface water in Sandia Canyon.

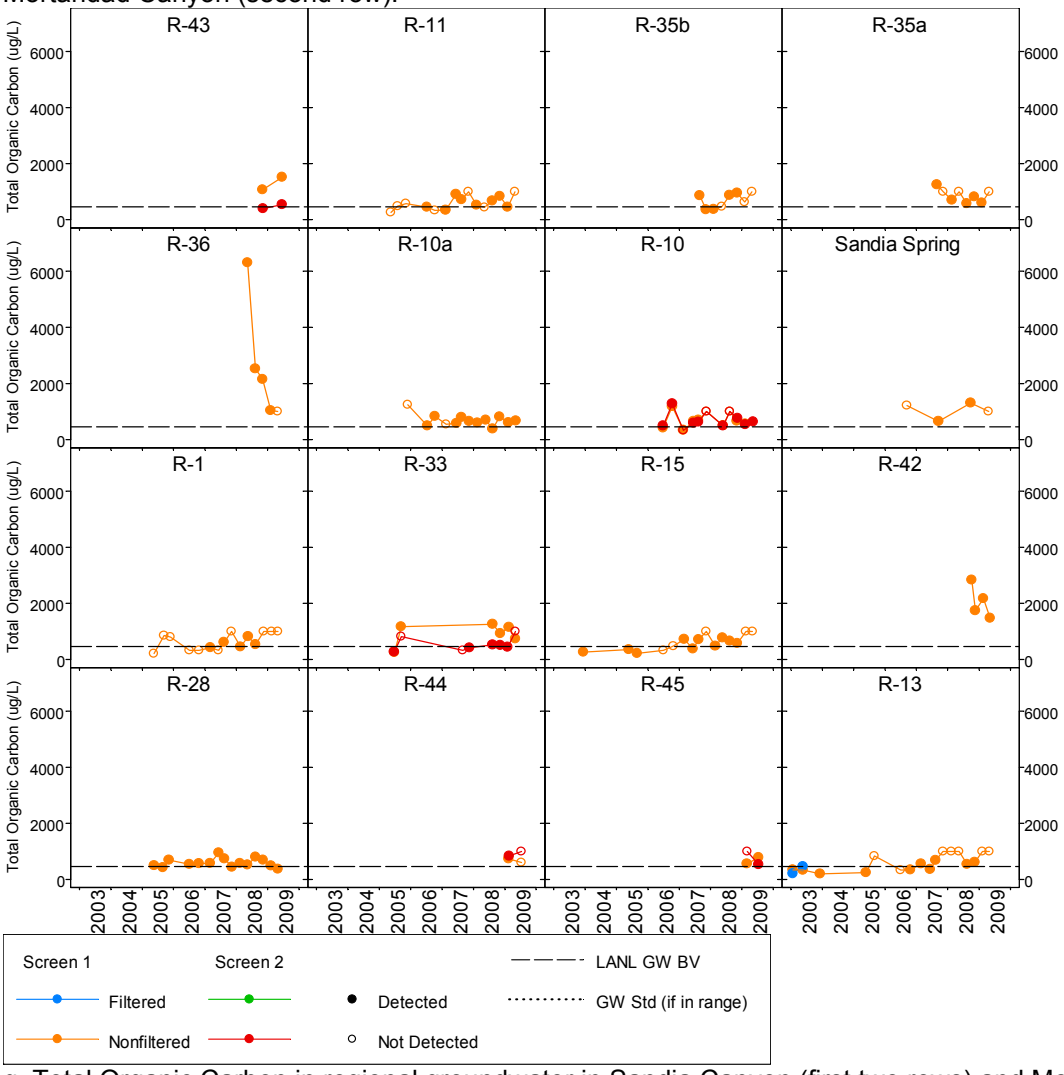


q. Total Organic Carbon in alluvial groundwater in Sandia Canyon.

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009



q. Total Organic Carbon in perched intermediate groundwater in Sandia Canyon (first row) and Mortandad Canyon (second row).



q. Total Organic Carbon in regional groundwater in Sandia Canyon (first two rows) and Mortandad Canyon (last two rows).

Figure D-2.1-4 (continued) Time-series plots of general inorganic analytes in nonstorm-related surface water and groundwater in Sandia Canyon, 2003-2009

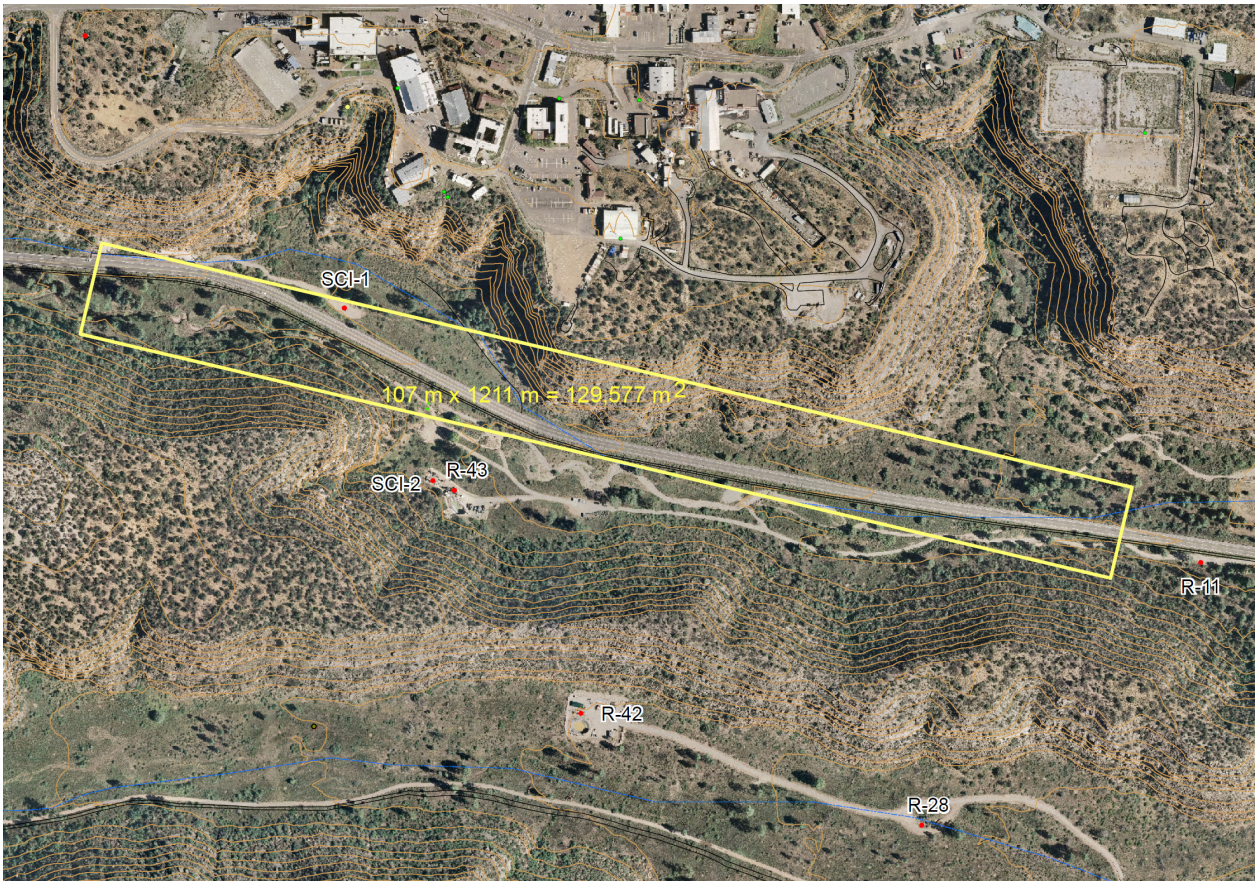


Figure D-2.2-1 Area of infiltration window used for chromium mass balance estimates

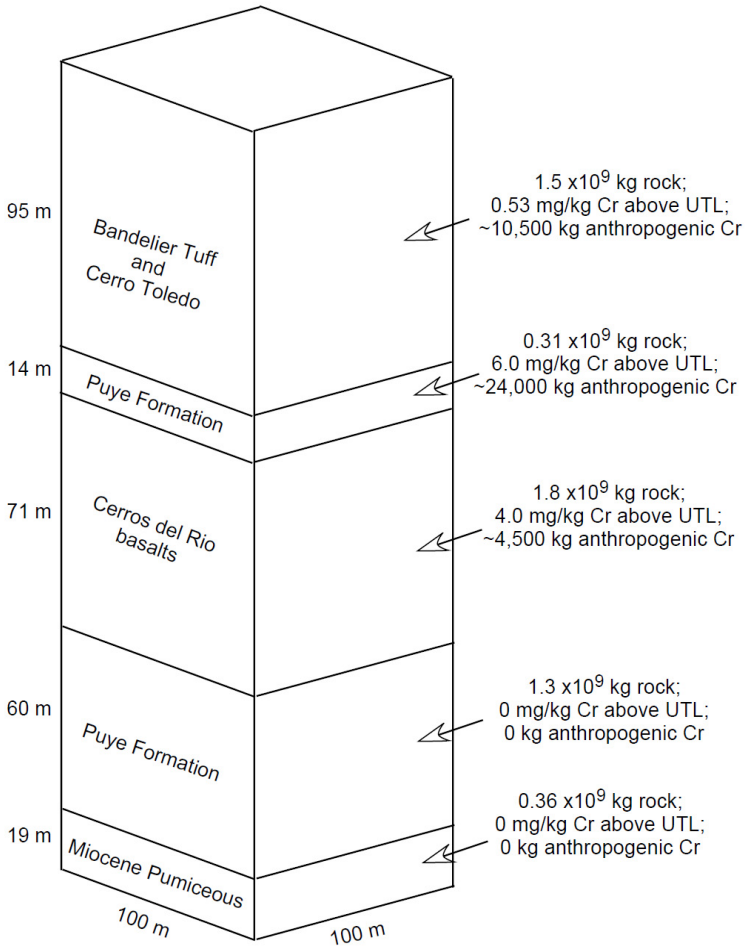
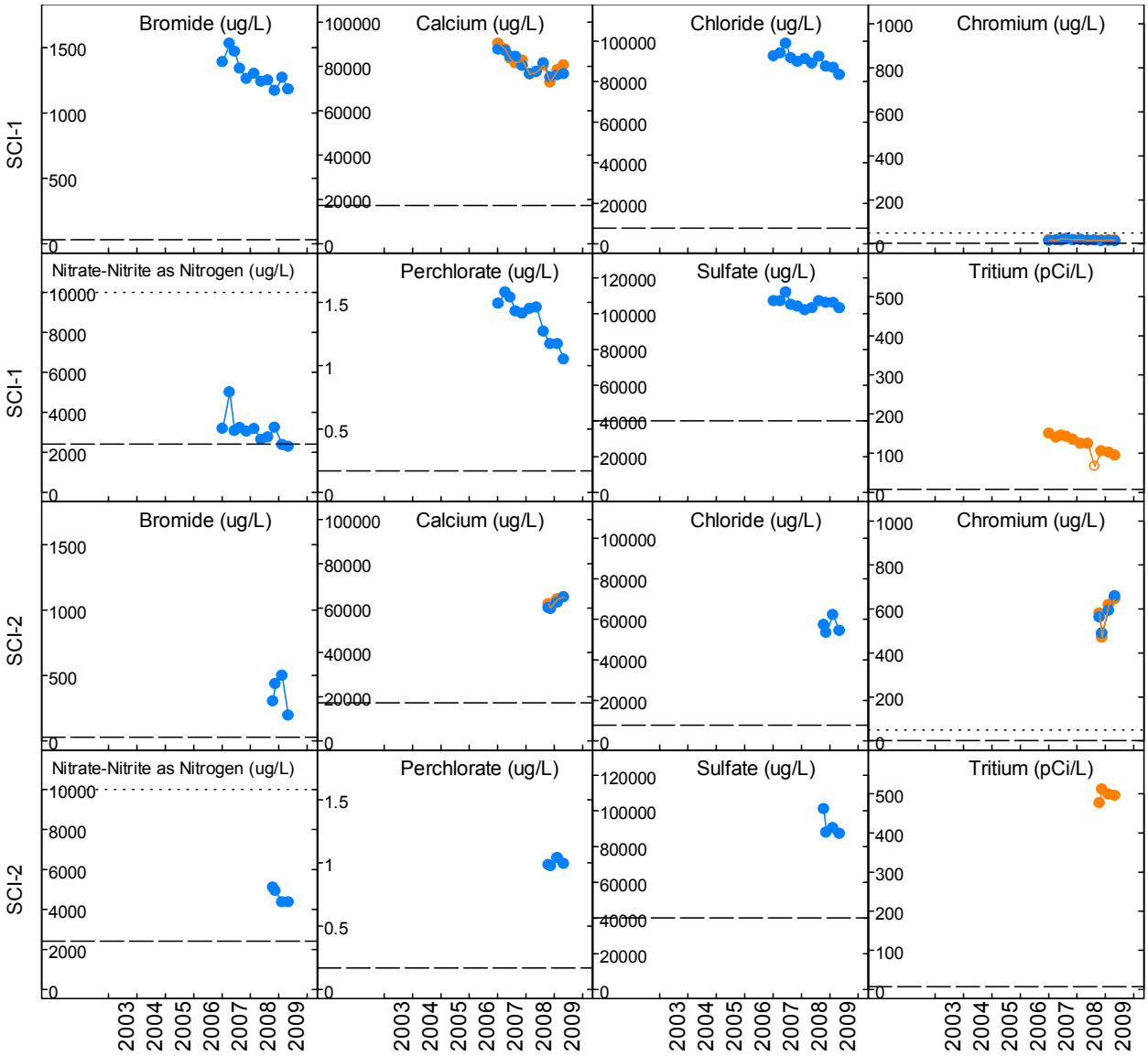
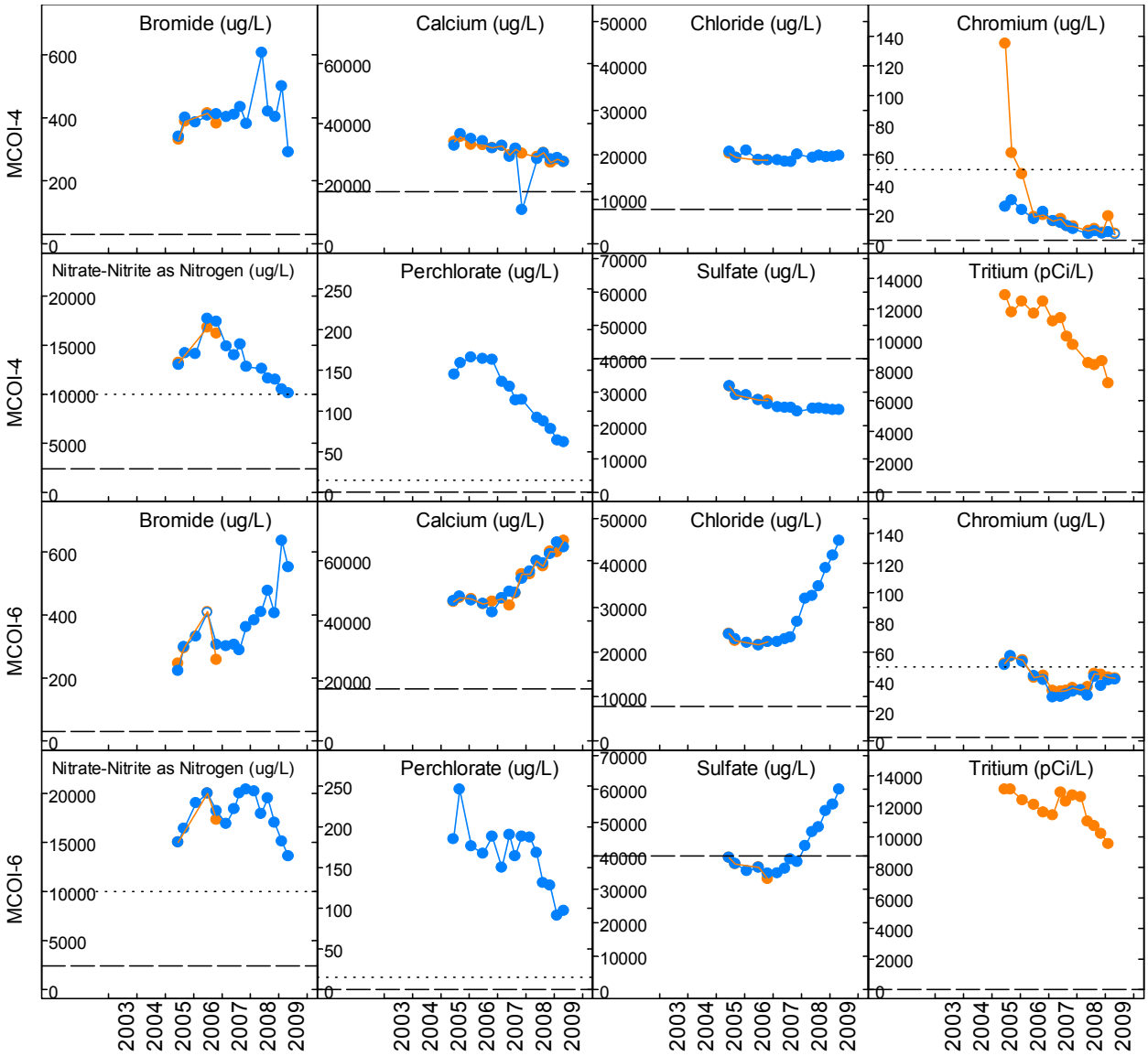


Figure D-2.2-2 Vertical 100 m by 100 m vadose zone column, centered on SCI-2, showing the vadose zone units and estimated mean concentrations for each unit from Table D-2.2-1



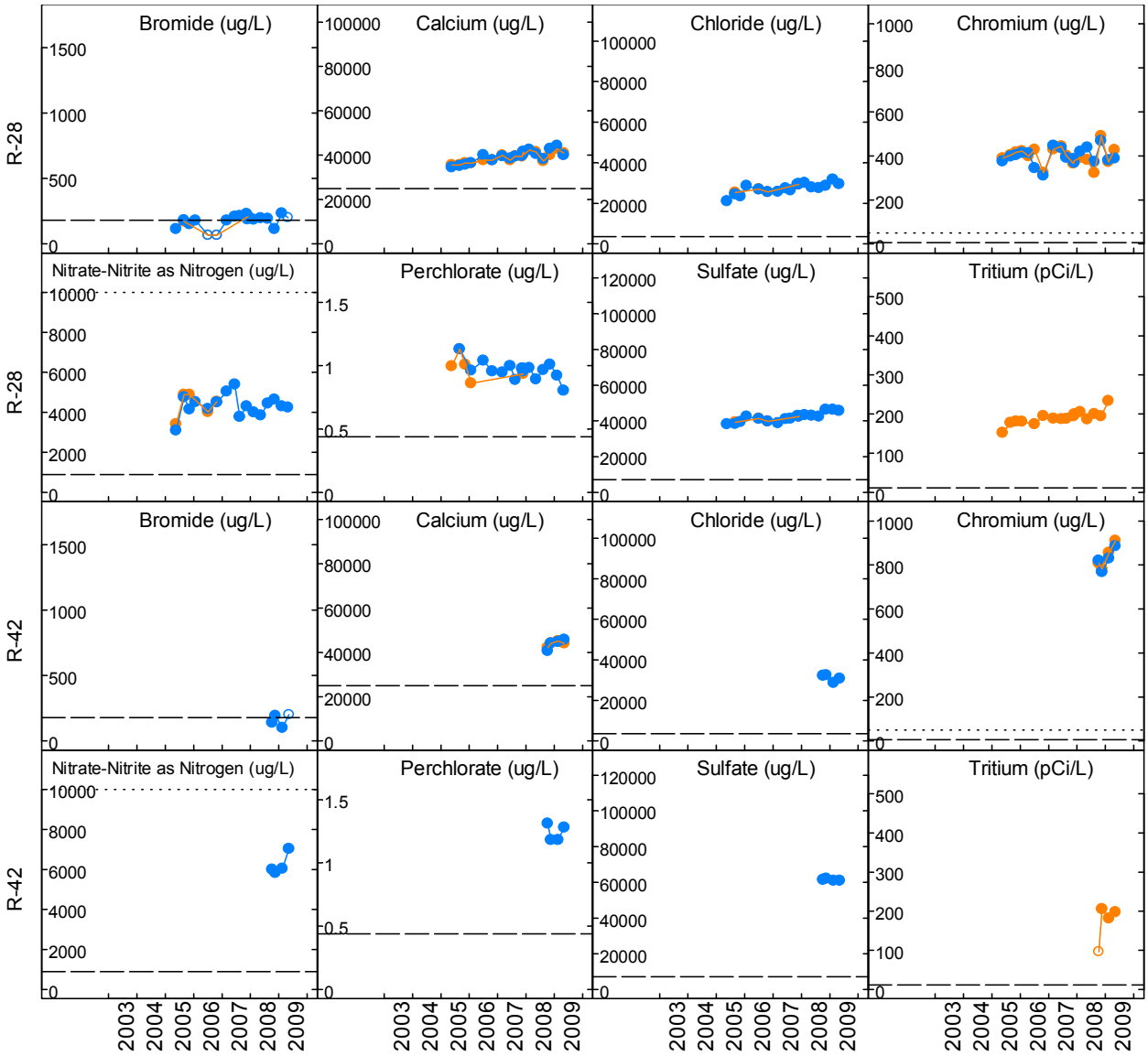
a.

Figure D-2.3-1 Time-series plots of bromide, calcium, chloride, chromium, nitrate, perchlorate, sulfate, and tritium in selected wells, 2003–2009: (a) SCI-1 and SCI-2, (b) MCOI-4 and MCOI-6, (c) R-28 and R-42, (d) R-11 and R-15, and (e) R-44 and R-45



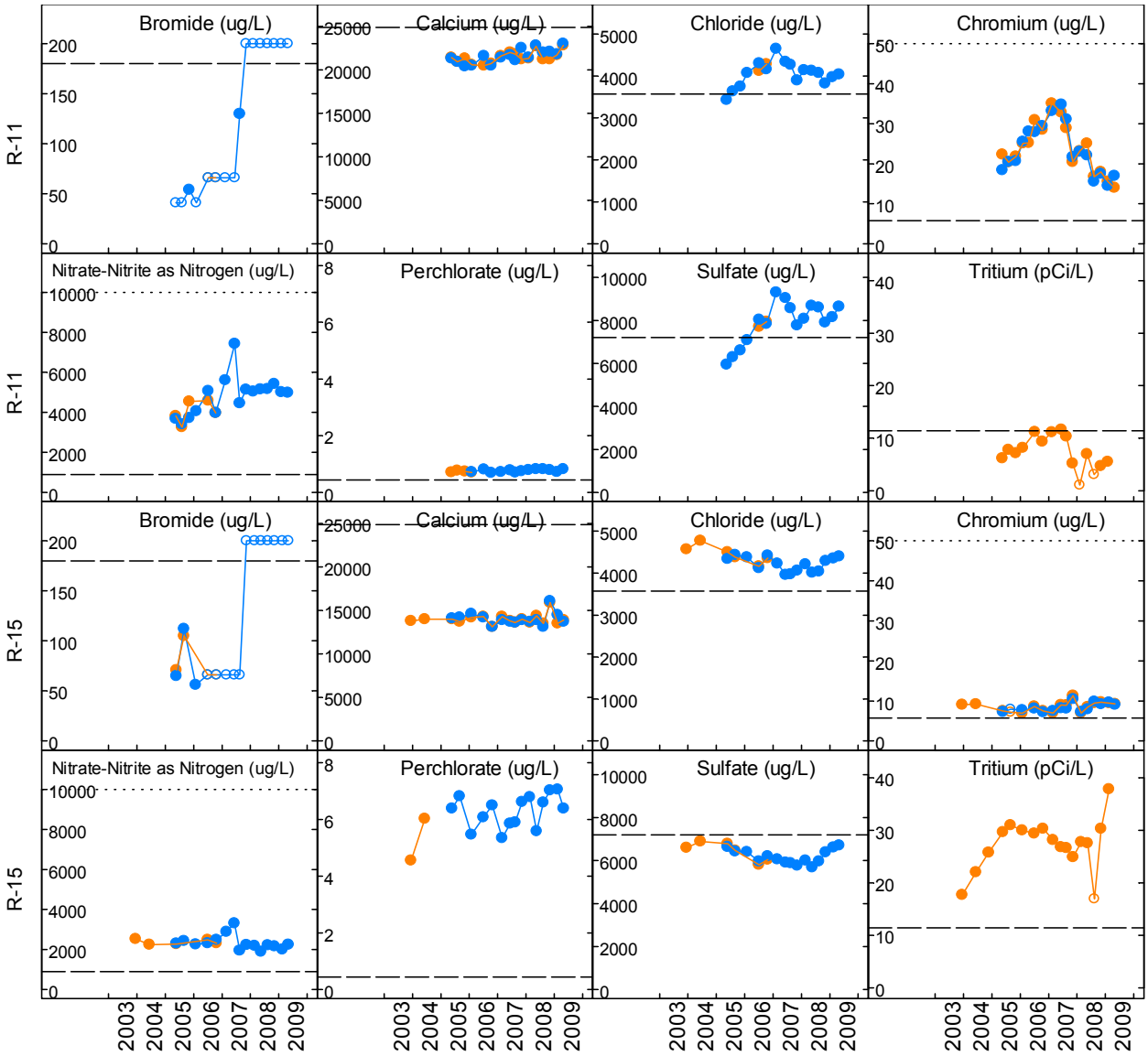
b.

Figure D-2.3-1 (continued) **Time-series plots of bromide, calcium, chloride, chromium, nitrate, perchlorate, sulfate, and tritium in selected wells, 2003–2009: (a) SCI-1 and SCI-2, (b) MCOI-4 and MCOI-6, (c) R-28 and R-42, (d) R-11 and R-15, and (e) R-44 and R-45**



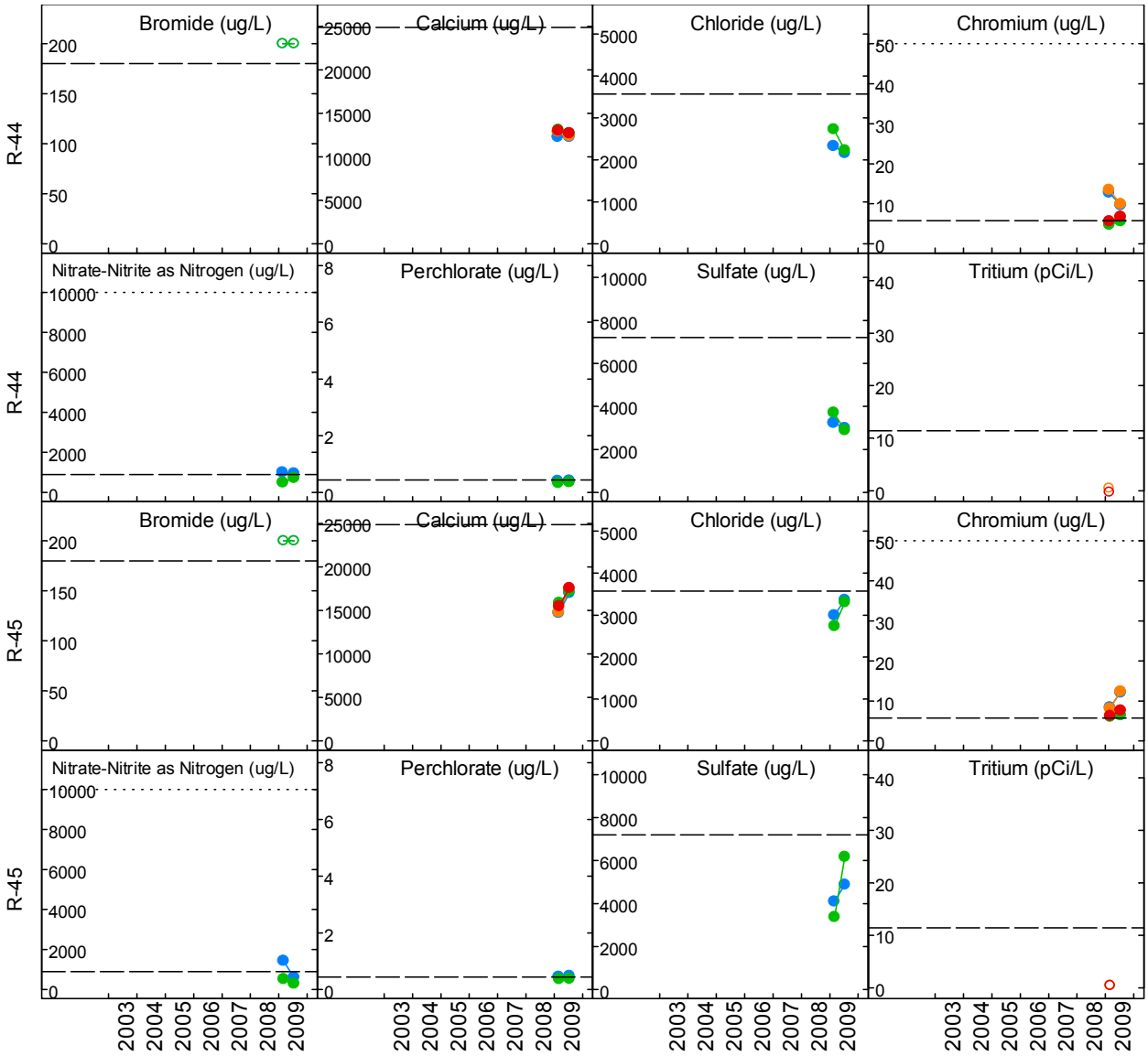
c.

Figure D-2.3-1 (continued) **Time-series plots of bromide, calcium, chloride, chromium, nitrate, perchlorate, sulfate, and tritium in selected wells, 2003–2009: (a) SCI-1 and SCI-2, (b) MCOI-4 and MCOI-6, (c) R-28 and R-42, (d) R-11 and R-15, and (e) R-44 and R-45**



d.

Figure D-2.3-1 (continued) **Time-series plots of bromide, calcium, chloride, chromium, nitrate, perchlorate, sulfate, and tritium in selected wells, 2003–2009: (a) SCI-1 and SCI-2, (b) MCOI-4 and MCOI-6, (c) R-28 and R-42, (d) R-11 and R-15, and (e) R-44 and R-45**



e.

Figure D-2.3-1 (continued) **Time-series plots of bromide, calcium, chloride, chromium, nitrate, perchlorate, sulfate, and tritium in selected wells, 2003–2009: (a) SCI-1 and SCI-2, (b) MCOI-4 and MCOI-6, (c) R-28 and R-42, (d) R-11 and R-15, and (e) R-44 and R-45**

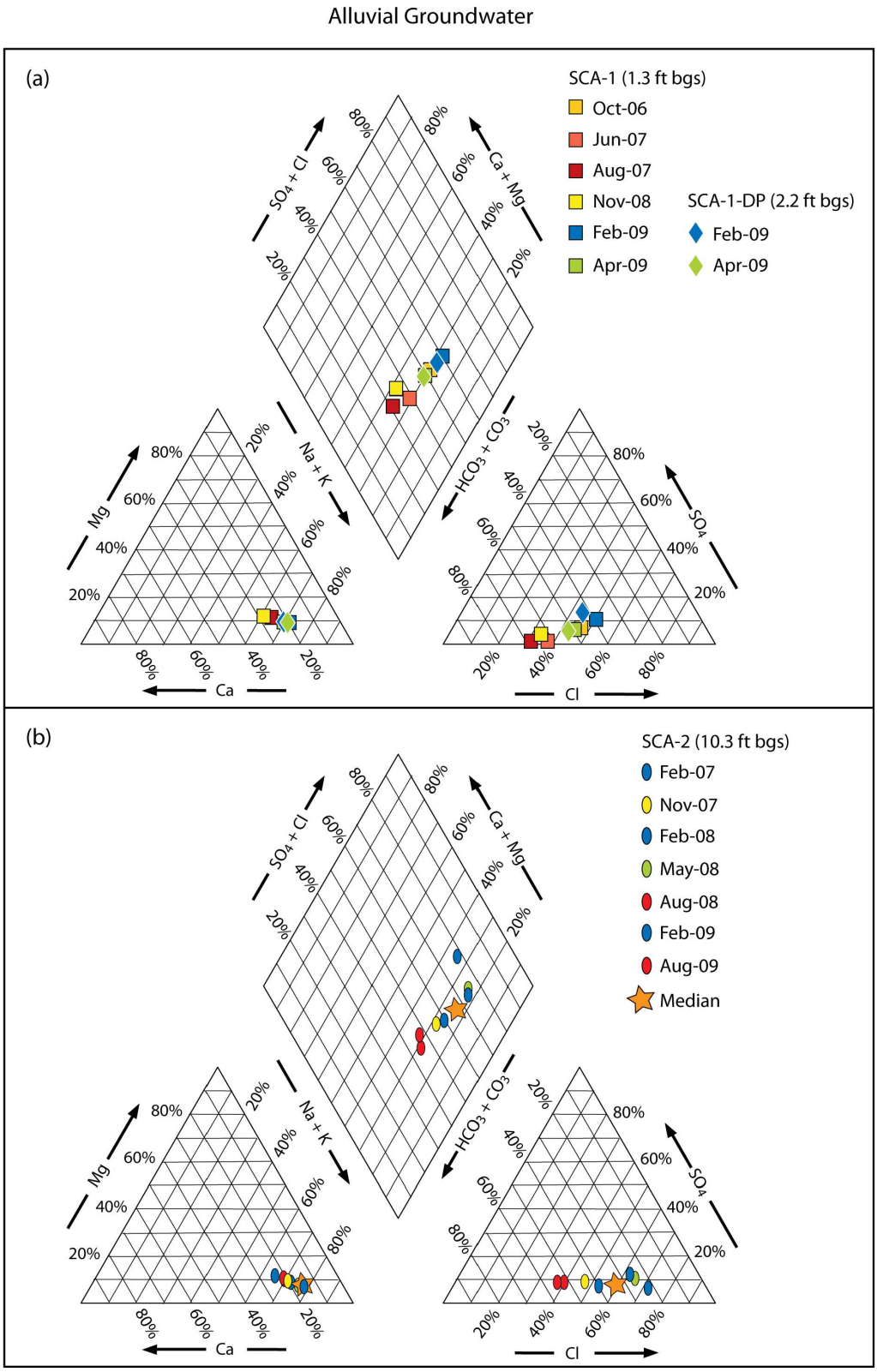


Figure D-2.3-2 Trilinear plots showing relative distributions of major ions in alluvial groundwaters in Sandia Canyon: (a) SCA-1 and SCA-1-DP, (b) SCA-2, (c) SCA-4, and (d) SCA-5

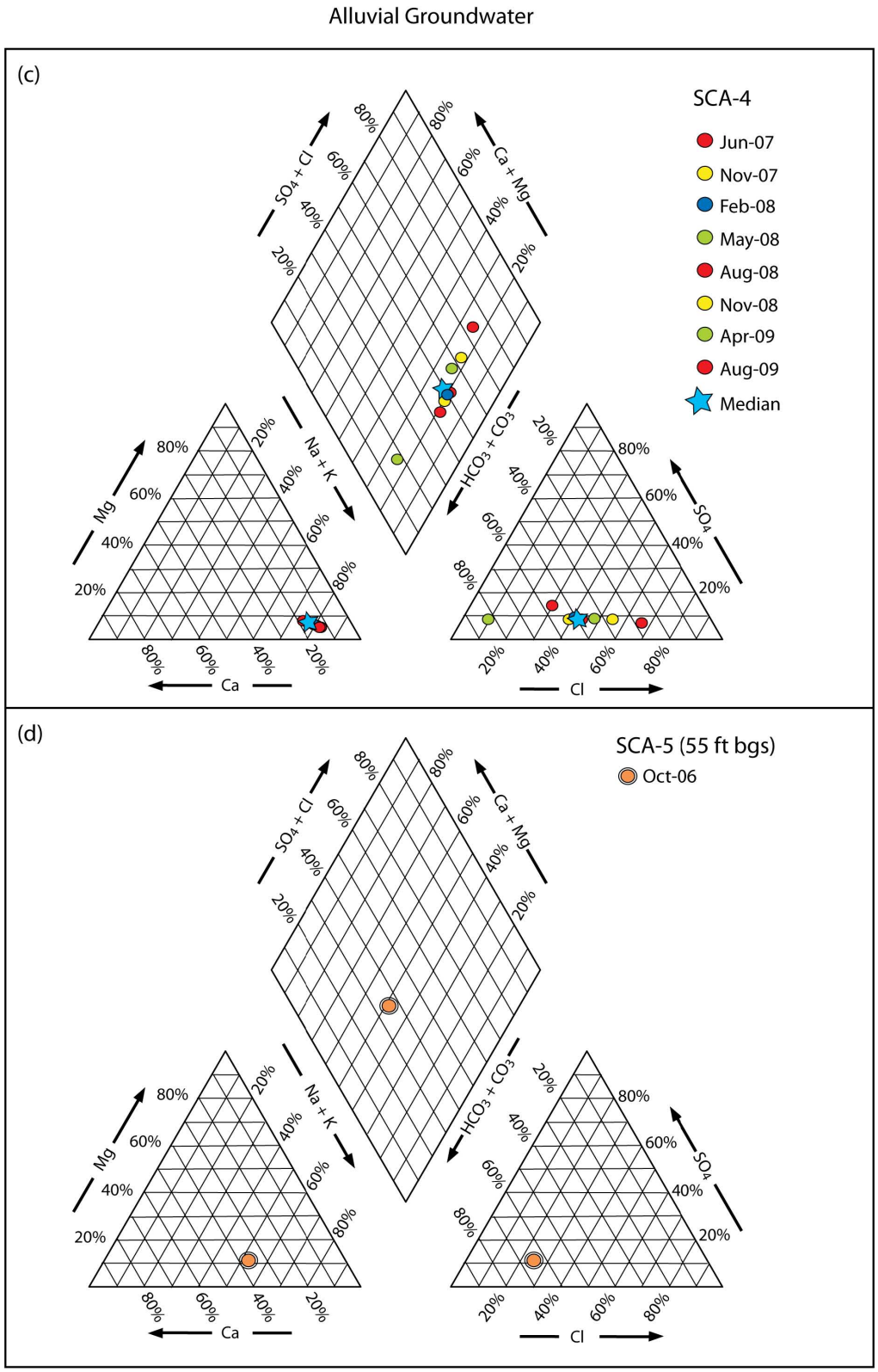


Figure D-2.3-2 (continued) **Trilinear plots showing relative distributions of major ions in alluvial groundwaters in Sandia Canyon: (a) SCA-1 and SCA-1-DP, (b) SCA-2, (c) SCA-4, and (d) SCA-5**

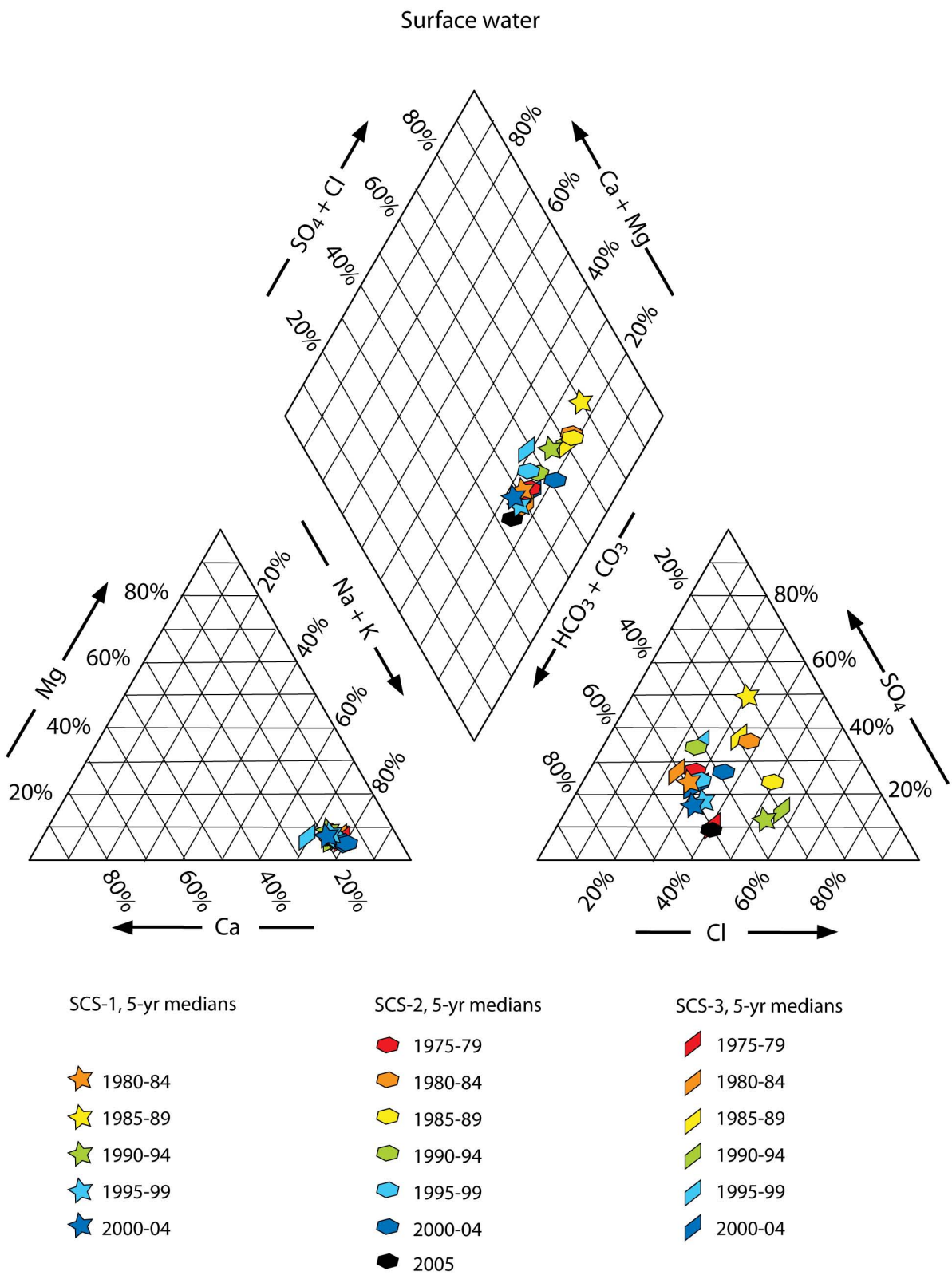


Figure D-2.3-3 Trilinear plot showing relative distributions of major ions in surface waters in Sandia Canyon, 1975–2005

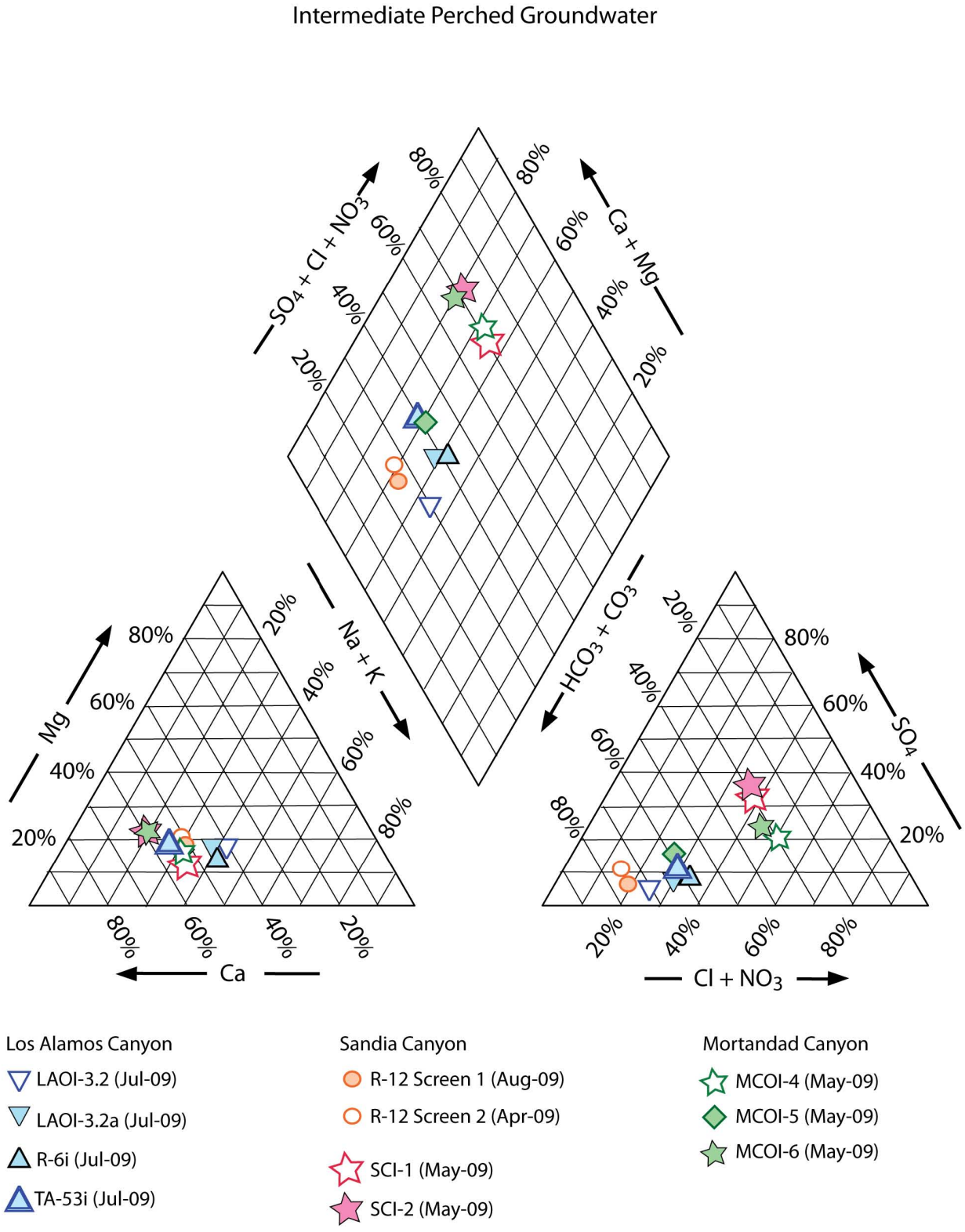


Figure D-2.3-4 Trilinear plot showing relative distributions of major ions in intermediate perched groundwater at selected wells in Los Alamos, Sandia, and Mortandad Canyons

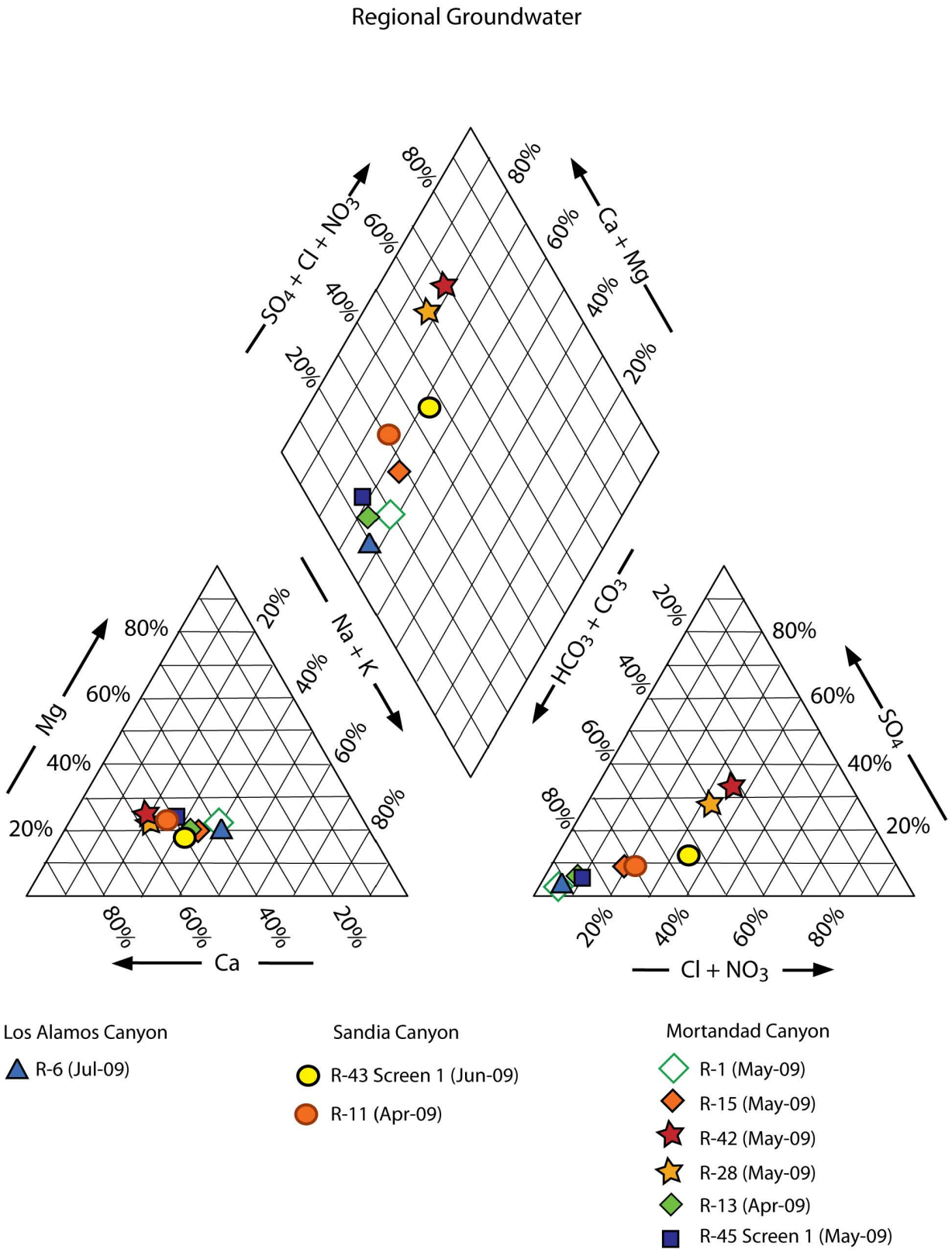


Figure D-2.3-5 Trilinear plot showing relative distributions of major ions in regional groundwater at selected wells in Los Alamos, Sandia, and Mortandad Canyons

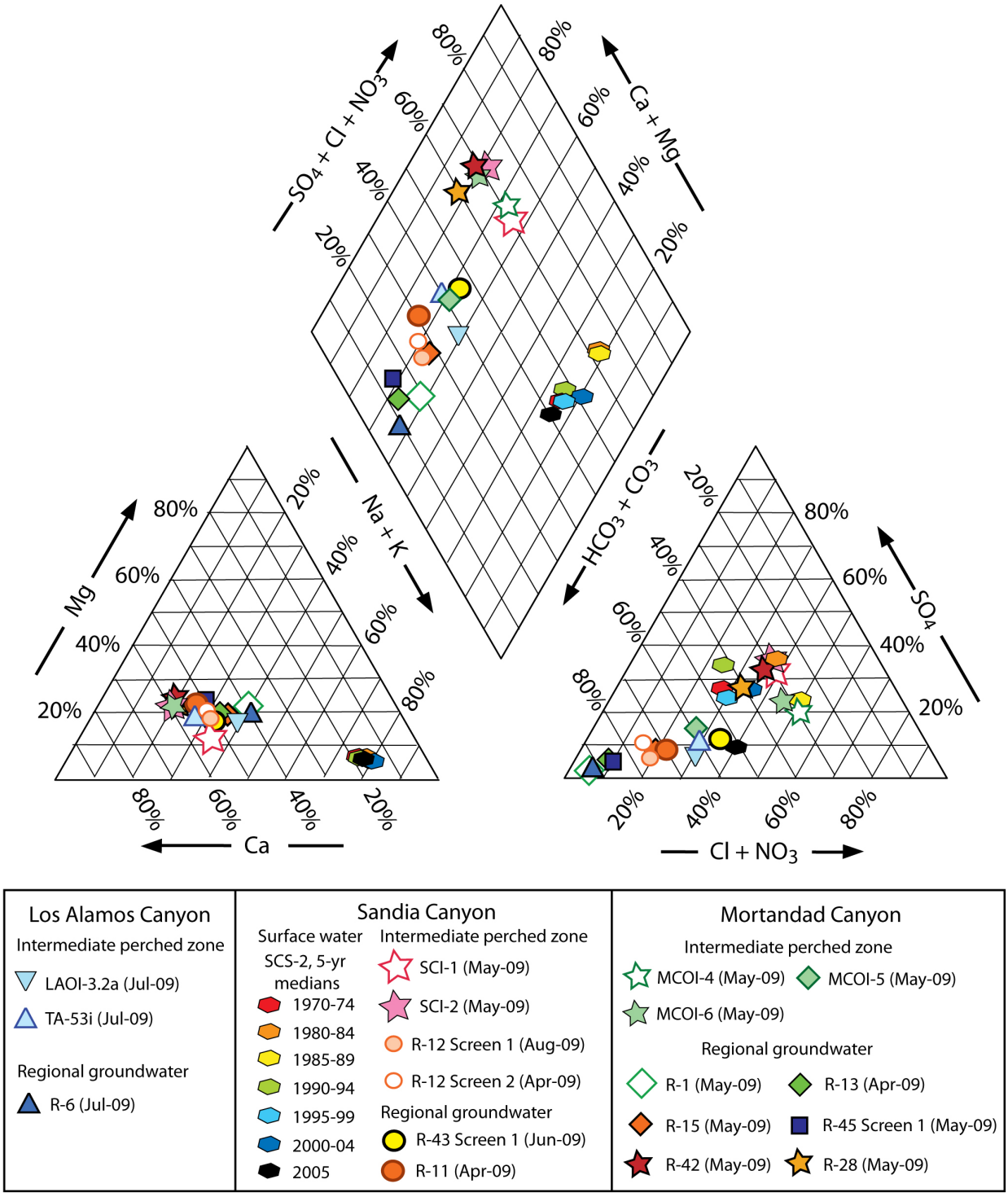


Figure D-2.3-6 Trilinear plot showing relative distributions of major ions in surface water and groundwater at selected monitoring stations and wells in Los Alamos, Sandia, and Mortandad Canyons

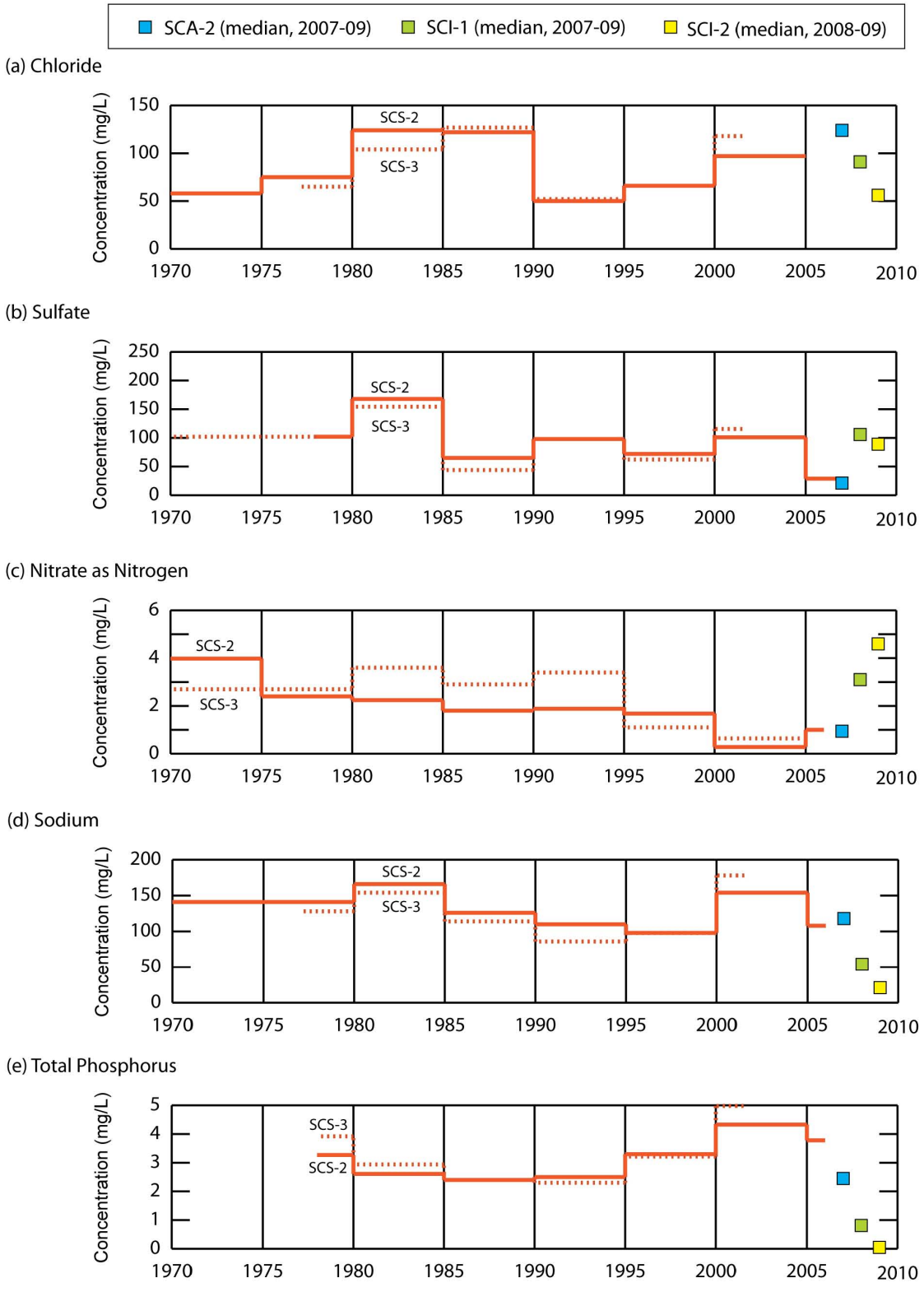


Figure D-2.3-7 Median concentrations of selected analytes in surface waters in Sandia Canyon, 1970 to 2005, and in SCA-2, SCI-1, and SCI-2: (a) chloride, (b) sulfate, (c) nitrate as nitrogen, (d) sodium, (e) total phosphorus, (f) boron, (g) chromium, (h) molybdenum, (i) tritium (as reported), and (h) tritium (decay-corrected)

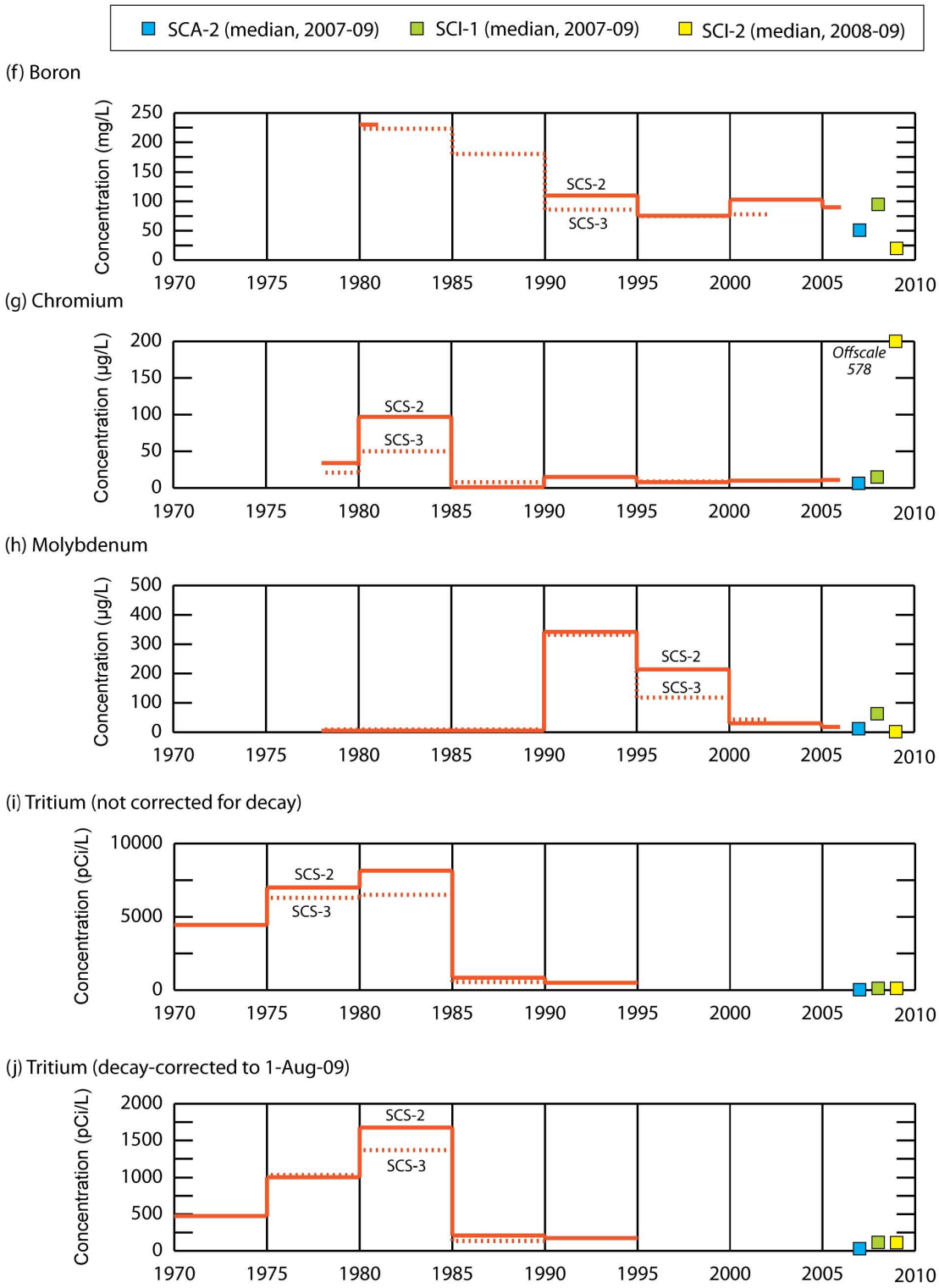
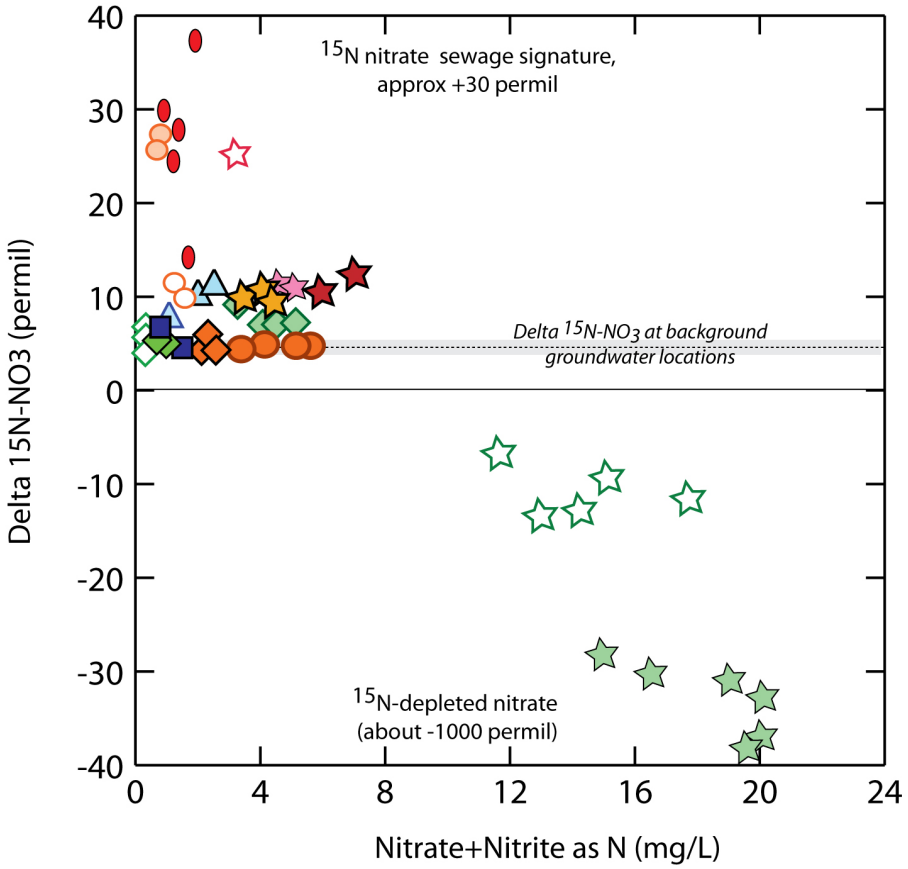


Figure D-2.3-7 (continued) Median concentrations of selected analytes in surface waters in Sandia Canyon, 1970 to 2005, and in SCA-2, SCI-1, and SCI-2: (a) chloride, (b) sulfate, (c) nitrate as nitrogen, (d) sodium, (e) total phosphorus, (f) boron, (g) chromium, (h) molybdenum, (i) tritium (as reported), and (h) tritium (decay-corrected)



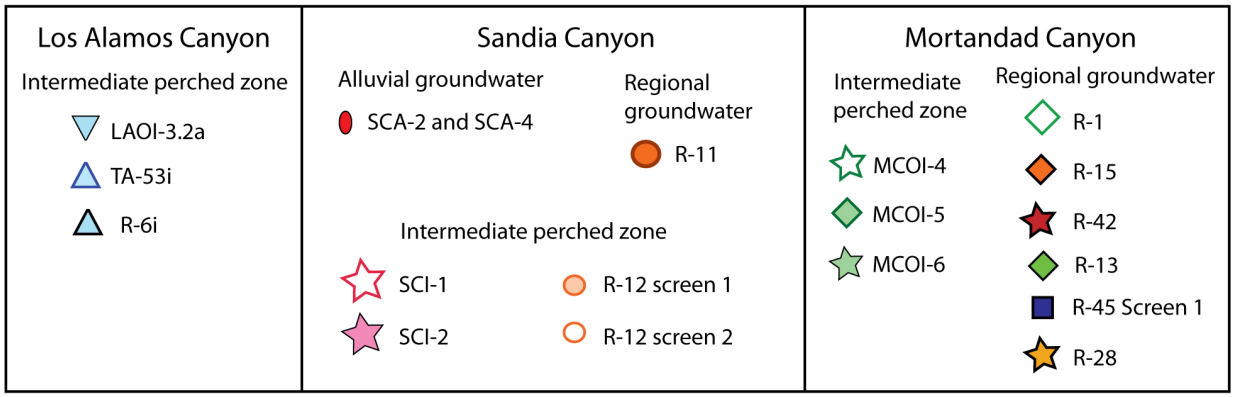


Figure D-2.3-8 Nitrogen-15 to nitrogen-14 ratios in nitrate in groundwater at selected wells in Sandia and Mortandad Canyons, 2003 to 2009: (a) intermediate perched groundwater, and (b) regional groundwater

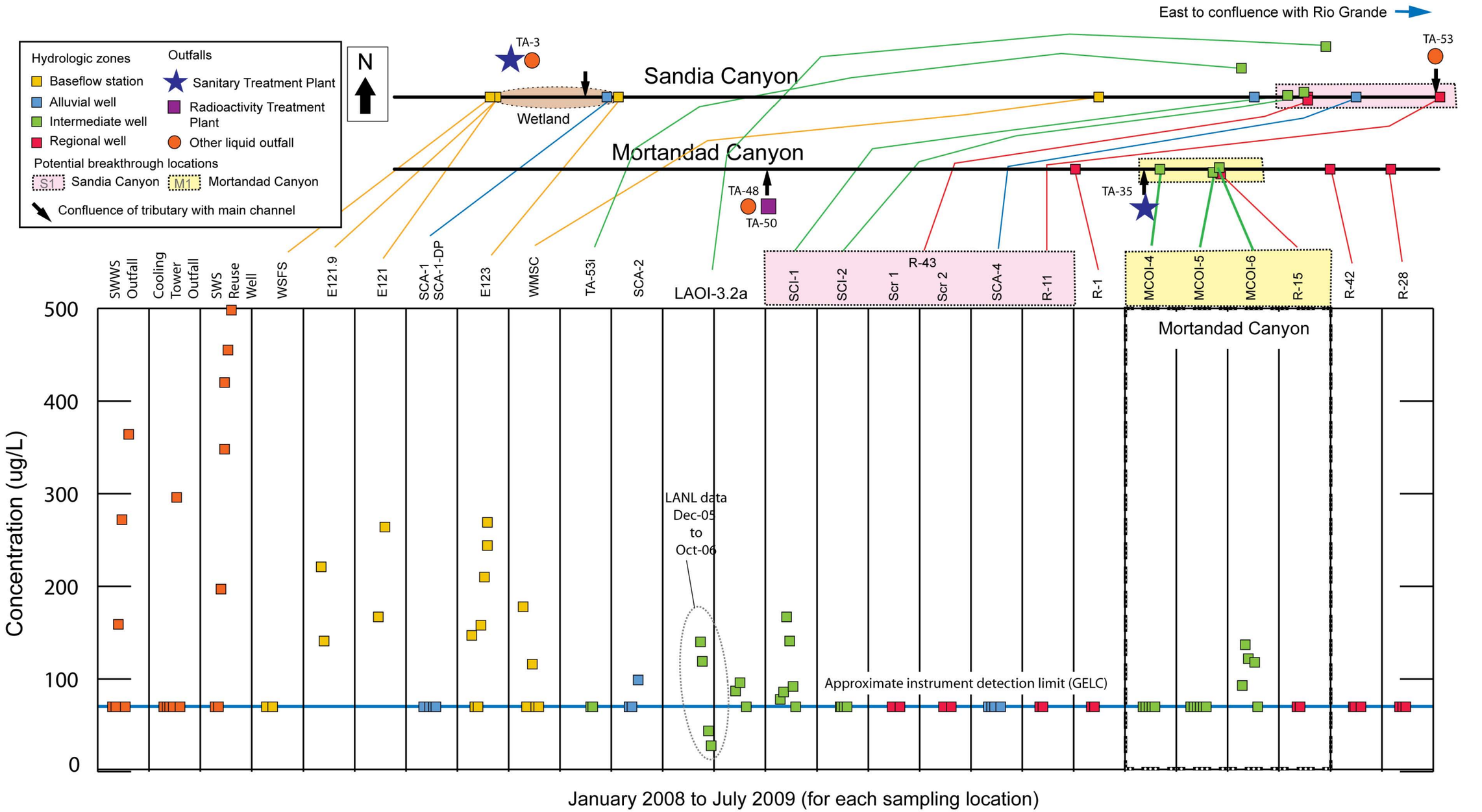


Figure D-2.3-9 Chlorate concentrations in waters collected from Los Alamos, Sandia, and Mortandad Canyons, 2003 to 2009

Table D-1.2-1
Summary of Average Concentrations of Select Inorganic Chemicals in Sandia Canyon Sediment Samples

	Aluminum		Arsenic		Barium		Cadmium						Chromium		Chromium VI						Cobalt						Copper						Cyanide						Iron		Lead	
	Fine Facies	Coarse Facies	Fine Facies	Coarse Facies	Fine Facies	Coarse Facies	Fine Facies			Coarse Facies			Fine Facies	Coarse Facies	Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies	Coarse Facies	Fine Facies	Coarse Facies
Reach	Average	Average	Average	Average	Average	Average	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Average	Average	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Average	Average	Average	Average
BV	**15400**		**3.98**		**127**		**0.40**						**10.5**		**Not available**						**4.73**						**11.2**						**0.82**						**13800**		**19.7**	
S-1N	—[a]	—	4.41	3.27	—	—	0.40	0.25	0.09	0.56	0.28	0.00	12.9	9.8	0.24	0.18	0.12	0.10	0.07	0.05	—	—	—	—	—	—	12.6	12.6	12.6	6.4	6.4	6.4	0.62	0.53	0.43	0.57	0.54	0.51	10192	12415	28.7	10.4
S-1S	—	—	3.37	2.18	189	29	0.26	0.21	0.17	0.49	0.26	0.03	63.0	18.0	0.40	0.35	0.31	0.20	0.11	0.01	—	—	—	—	—	—	27.0	27.0	27.0	9.2	9.2	9.2	2.39	2.39	2.39	0.79	0.74	0.69	—	—	40.6	18.2
S-2	9016	2627	6.01	1.99	111	30	1.59	1.37	1.16	0.58	0.29	0.00	600.9	15.6	0.75	0.53	0.31	0.22	0.22	0.22	2.74	2.59	2.44	1.58	1.45	1.32	49.7	43.3	36.8	6.1	6.1	6.1	3.07	3.03	2.98	0.28	0.14	0.00	11419	6597	26.6	84.2
S-3W	—	—	3.57	1.84	80	49	0.65	0.60	0.56	0.43	0.25	0.07	194.6	100.6	n.d.[b]	n.d.	n.d.	0.55	0.55	0.55	—	—	—	—	—	—	17.0	17.0	17.0	9.1	9.1	9.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	10933	8019	16.6	10.4
S-3E	—	—	—	—	—	—	0.19	0.14	0.08	0.37	0.19	0.00	156.4	21.9	1.12	1.08	1.04	0.67	0.67	0.67	—	—	—	—	—	—	10.9	10.9	10.9	2.2	2.2	2.2	0.46	0.27	0.07	0.32	0.21	0.09	—	—	19.3	6.9
S-4W	—	—	—	—	—	—	0.53	0.28	0.04	0.52	0.26	0.00	50.4	23.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—	—	—	—	10.0	10.0	10.0	1.5	1.5	1.5	—	—	—	—	—	—	—	—	19.7	5.2
S-4E	—	—	—	—	—	—	0.49	0.26	0.04	0.50	0.25	0.00	46.6	3.5	0.90	0.83	0.77	0.11	0.08	0.06	2.50	2.50	2.50	3.01	3.01	3.01	9.9	9.9	9.9	1.6	1.6	1.6	—	—	—	—	—	—	10569	6975	17.9	7.4
S-5C	—	—	—	—	—	—	0.25	0.13	0.00	0.51	0.25	0.00	27.1	4.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—	—	—	—	7.7	7.7	7.7	1.8	1.8	1.8	—	—	—	—	—	—	8847	4085	24.6	6.2
S-5E	—	—	—	—	—	—	0.51	0.26	0.00	0.51	0.26	0.00	13.8	3.4	0.44	0.36	0.28	0.12	0.10	0.08	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15.9	6.1
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—	—
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	—	—	—	—

Table D-1.2-1 (continued)

Reach	Nickel		Mercury						Molybdenum						Perchlorate						Selenium						Silver						Thallium						Zinc	
	Fine Facies	Coarse Facies	Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies	Coarse Facies
	Average	Average	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Average	Average
BV	**9.38**		**0.10**						**Not available**						**Not available**						**0.30**						**1.0**						**0.73**						**60.2**	
S-1N	—	—	—	—	—	—	—	—	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.0022	0.0011	0.0001	0.0023	0.0011	0.0000	2.32	2.32	2.32	1.85	1.63	1.42	—	—	—	—	—	—	—	—	—	—	—	—	111.6	77.6
S-1S	—	—	0.90	0.90	0.90	0.48	0.45	0.42	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.0019	0.0013	0.0007	0.0018	0.0010	0.0002	2.28	2.28	2.28	1.19	1.13	1.07	4.5	4.5	4.5	0.9	0.7	0.5	—	—	—	—	—	—	89.6	60.0
S-2	10.27	3.63	0.73	0.69	0.66	0.10	0.05	0.01	11.87	11.87	11.87	0.99	0.99	0.99	0.0026	0.0014	0.0001	0.0023	0.0012	0.0000	1.21	0.69	0.17	0.89	0.45	0.00	11.6	11.0	10.5	7.9	7.1	6.3	0.34	0.19	0.04	0.30	0.16	0.02	198.0	35.4
S-3W	6.21	3.02	0.15	0.15	0.15	0.08	0.08	0.08	1.88	1.88	1.88	1.04	1.04	1.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.13	1.84	1.56	1.94	1.41	0.88	4.3	4.3	4.3	2.1	2.1	2.1	—	—	—	—	—	—	113.8	65.1
S-3E	—	—	0.08	0.06	0.04	0.02	0.02	0.02	1.03	1.03	1.03	0.75	0.75	0.75	0.0022	0.0012	0.0002	0.0022	0.0011	0.0000	0.78	0.73	0.69	0.95	0.60	0.24	1.5	1.5	1.5	0.4	0.4	0.4	—	—	—	—	—	—	76.0	37.8
S-4W	—	—	—	—	—	—	—	—	0.83	0.83	0.83	0.38	0.38	0.38	0.0019	0.0011	0.0003	0.0022	0.0011	0.0000	1.59	0.86	0.12	1.57	0.78	0.00	1.3	1.3	1.3	0.1	0.1	0.1	—	—	—	—	—	—	97.6	35.4
S-4E	—	—	0.08	0.08	0.08	0.01	0.01	0.00	0.88	0.88	0.88	0.36	0.30	0.24	0.0015	0.0010	0.0004	0.0021	0.0010	0.0000	1.43	0.84	0.26	1.49	0.75	0.00	1.4	1.4	1.4	0.2	0.1	0.1	—	—	—	—	—	—	63.7	36.9
S-5C	—	—	0.04	0.03	0.03	0.01	0.01	0.01	0.80	0.80	0.80	0.45	0.45	0.45	0.0015	0.0012	0.0008	0.0021	0.0010	0.0000	0.73	0.69	0.64	1.32	0.76	0.19	0.9	0.9	0.9	0.2	0.2	0.1	—	—	—	—	—	—	50.9	23.2
S-5E	—	—	—	—	—	—	—	—	0.32	0.32	0.32	0.28	0.25	0.22	0.0016	0.0010	0.0004	0.0021	0.0010	0.0000	1.41	0.75	0.09	1.54	0.77	0.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6W	—	—	—	—	—	—	—	—	0.34	0.26	0.18	0.23	0.11	0.00	0.0050	0.0028	0.0007	0.0051	0.0026	0.0000	0.35	0.22	0.10	0.43	0.24	0.05	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6E	7.35	7.38	—	—	—	—	—	—	0.22	0.14	0.06	0.17	0.08	0.00	0.0047	0.0026	0.0004	0.0051	0.0025	0.0000	0.51	0.26	0.00	0.51	0.25	0.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: All units are in mg/kg.

[a] — = Not a COPC in reach (not detected or no detects > BV).

[b] n.d. = No data; includes rejected data.

Table D-1.2-2
Summary of Average Concentrations of PCBs in Sandia Canyon Sediment Samples

Reach	Aroclor-1242						Aroclor-1248						Aroclor-1254						Aroclor-1260					
	Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies		
	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean
S-1N	—*	—	—	—	—	—	0.099	0.092	0.085	0.014	0.007	0.000	0.091	0.091	0.091	0.124	0.121	0.117	0.143	0.143	0.143	0.328	0.324	0.321
S-1S	—	—	—	—	—	—	—	—	—	—	—	—	0.124	0.106	0.088	0.132	0.099	0.067	1.160	1.160	1.160	0.267	0.243	0.220
S-2	0.098	0.049	0.000	0.087	0.043	0.000	0.100	0.051	0.002	0.087	0.043	0.000	0.220	0.187	0.154	0.103	0.058	0.013	0.349	0.338	0.328	0.151	0.112	0.073
S-3W	—	—	—	—	—	—	—	—	—	—	—	—	0.148	0.144	0.139	0.071	0.063	0.056	0.172	0.172	0.172	0.086	0.079	0.071
S-3E	—	—	—	—	—	—	—	—	—	—	—	—	0.054	0.034	0.013	0.046	0.032	0.018	0.083	0.079	0.076	0.047	0.033	0.020
S-4W	—	—	—	—	—	—	—	—	—	—	—	—	0.051	0.051	0.051	0.026	0.013	0.001	0.059	0.059	0.059	0.026	0.014	0.001
S-4E	—	—	—	—	—	—	—	—	—	—	—	—	0.064	0.064	0.064	0.005	0.004	0.004	0.093	0.093	0.093	0.007	0.006	0.005
S-5C	0.036	0.018	0.000	0.036	0.024	0.011	—	—	—	—	—	—	0.047	0.036	0.025	0.032	0.019	0.006	0.072	0.066	0.060	0.024	0.015	0.007
S-5E	0.009	0.008	0.007	0.003	0.002	0.000	—	—	—	—	—	—	0.012	0.010	0.009	0.004	0.003	0.002	0.021	0.021	0.021	0.006	0.006	0.006
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: All units are in mg/kg.
*— = Not a COPC in reach (not detected).

Table D-1.2-3
Summary of Average Concentrations of Select PAHs in Sandia Canyon Sediment Samples

Reach	Benzo(a)anthracene						Benzo(a)pyrene						Benzo(b)fluoranthene						Indeno(1,2,3-cd)pyrene					
	Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies		
	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean
S-1N	3.864	3.864	3.864	0.845	0.843	0.841	2.464	2.461	2.458	0.602	0.600	0.598	4.321	4.285	4.248	1.121	1.119	1.118	0.863	0.431	0.000	0.309	0.308	0.308
S-1S	1.055	1.055	1.055	0.683	0.473	0.262	0.839	0.810	0.780	0.595	0.381	0.167	1.207	1.005	0.802	0.775	0.387	0.000	0.176	0.173	0.171	0.422	0.211	0.000
S-2	0.889	0.539	0.189	0.275	0.139	0.004	0.874	0.517	0.160	0.274	0.137	0.000	0.969	0.577	0.186	0.277	0.138	0.000	—*	—	—	—	—	—
S-3W	0.094	0.065	0.036	0.017	0.017	0.017	0.045	0.040	0.035	0.014	0.013	0.012	0.079	0.071	0.063	0.029	0.014	0.000	—	—	—	—	—	—
S-3E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-4W	0.032	0.020	0.008	0.002	0.001	0.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-4E	0.017	0.014	0.011	0.002	0.001	0.000	0.016	0.011	0.005	0.003	0.002	0.000	—	—	—	—	—	—	—	—	—	—	—	—
S-5C	0.650	0.330	0.010	0.004	0.003	0.002	0.655	0.329	0.003	0.005	0.004	0.003	—	—	—	—	—	—	—	—	—	—	—	—
S-5E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: All units are in mg/kg.
*— = Not a COPC in reach (not detected).

Table D-1.2-4
Summary of Average Concentrations of DDD, Dieldrin, and TPH-DRO in Sandia Canyon Sediment Samples

Reach	4,4'-DDD						Dieldrin						TPH-DRO					
	Fine Facies			Coarse Facies			Fine Facies			Coarse Facies			Fine Facies			Coarse Facies		
	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean	Upper Bound on Mean	Mid-Point of Range	Lower Bound on Mean
S-1N	—[a]	—	—	—	—	—	—	—	—	—	—	—	1003	1003	1003	1189	1189	1189
S-1S	—	—	—	—	—	—	—	—	—	—	—	—	550	550	550	345	345	345
S-2	0.0356	0.0190	0.0024	0.0163	0.0081	0.0000	0.0356	0.0191	0.0025	0.0163	0.0081	0.0000	61	61	60	13	12	10
S-3W	—	—	—	—	—	—	—	—	—	—	—	—	n.d.[b]	n.d.	n.d.	n.d.	n.d.	n.d.
S-3E	—	—	—	—	—	—	—	—	—	—	—	—	31	31	31	21	21	21
S-4W	—	—	—	—	—	—	—	—	—	—	—	—	21	16	10	13	7	1
S-4E	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	15	15	15
S-5C	—	—	—	—	—	—	—	—	—	—	—	—	49	48	48	3	2	0
S-5E	—	—	—	—	—	—	0.0051	0.0028	0.0004	0.0056	0.0028	0.0000	44	44	44	14	14	14
S-6W	—	—	—	—	—	—	—	—	—	—	—	—	20	20	20	28	18	9
S-6E	—	—	—	—	—	—	—	—	—	—	—	—	20	12	3	25	13	0

Note: All units are in mg/kg.
[a] — = Not a COPC in reach (not detected).
[b] n.d. = No data.

Table D-1.2-5
Summary of Average Concentrations of Thorium-228 and Thorium-232 in Sandia Canyon Sediment Samples

Reach	Thorium-228		Thorium-232	
	Fine Facies	Coarse Facies	Fine Facies	Coarse Facies
BV	**2.28**		**2.33**	
S-1N	n.d.[a]	n.d.	n.d.	n.d.
S-1S	n.d.	n.d.	n.d.	n.d.
S-2	—[b]	—	—	—
S-3W	n.d.	n.d.	n.d.	n.d.
S-3E	—	—	—	—
S-4W	2.08	1.43	1.90	1.34
S-4E	—	—	—	—
S-5C	—	—	—	—
S-5E	1.99	1.31	—	—
S-6W	—	—	—	—
S-6E	—	—	—	—

Note: All units are in pCi/g.
[a] — = Not a COPC in reach; all detects below BVs.
[b] n.d. = No data.

Table D-1.3-1
Estimated Inventory of Select COPCs in Sandia Canyon Investigation Reaches

Geomorphic Unit	Sediment Facies	Area (m^2)	Average Thickness (m)	Estimated Volume (m^3)	Portion Non-gravel	Density (g/cm^3)	Chromium				Aroclor-1242			Aroclor-1248			Aroclor-1254			Aroclor-1260		
							Average Concentration (mg/kg)	Average Concentration in Excess of Background (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach
Reach S-1N																						
c1	coarse	173	0.15	26	0.44	1.23	9.8	4.2	0.06	11%				0.011	0.000	2%	0.195	0.003	30%	0.535	0.008	42%
c2	coarse	164	0.13	21	0.65	1.23	9.8	4.2	0.07	13%				0.002	0.00003	0%	0.008	0.0001	2%	0.008	0.0001	1%
Coarse Facies Subtotal			**m^3**	**47**				**kg**	**0.1**	**24%**				**kg**	**0.000**	**3%**	**kg**	**0.003**	**32%**	**kg**	**0.008**	**43%**
			m^3/km	**236**				**kg/km**	**0.6**					**kg/km**	**0.001**		**kg/km**	**0.01**		**kg/km**	**0.04**	
c1	fine	173	0.15	26	0.98	1.04	12.9	7.3	0.2	35%				0.207	0.005	81%	0.179	0.005	52%	0.330	0.009	49%
c2	fine	164	0.19	31	0.92	1.04	12.9	7.3	0.2	40%				0.034	0.001	15%	0.047	0.001	15%	0.049	0.001	8%
f1	fine	52	0.02	1	0.98	1.04	12.9	7.3	0.01	1%				0.034	0.00004	1%	0.047	0.00005	1%	0.049	0.00005	0%
Fine Facies Subtotal			**m^3**	**58**				**kg**	**0.4**	**76%**				**kg**	**0.007**	**97%**	**kg**	**0.006**	**68%**	**kg**	**0.01**	**57%**
			m^3/km	**291**				**kg/km**	**2**					**kg/km**	**0.03**		**kg/km**	**0.03**		**kg/km**	**0.05**	
Reach Total			**m^3**	**105**				**kg**	**0.5**	**100%**				**kg**	**0.007**	**100%**	**kg**	**0.009**	**100%**	**kg**	**0.02**	**100%**
			m^3/km	**527**				**kg/km**	**3**					**kg/km**	**0.03**		**kg/km**	**0.05**		**kg/km**	**0.09**	
Reach S-1S																						
c1	coarse	357	0.20	71	0.41	1.23	11.4	5.8	0.2	2%							0.099	0.004	15%	0.243	0.009	5%
c2	coarse	371	0.20	74	0.85	1.23	34.5	28.9	2	25%							0.099	0.008	33%	0.243	0.02	12%
f1	coarse	61	0.01	1	0.85	1.23	34.5	28.9	0.02	0.2%							0.099	0.0001	0.3%	0.243	0.0002	0.1%
Coarse Facies Subtotal			**m^3**	**146**				**kg**	**2**	**27%**							**kg**	**0.01**	**48%**	**kg**	**0.03**	**17%**
			m^3/km	**731**				**kg/km**	**12**								**kg/km**	**0.06**		**kg/km**	**0.1**	
c2	fine	371	0.28	104	0.93	1.04	63.0	57.4	6	63%							0.106	0.01	45%	1.160	0.1	72%
f1	fine	61	0.25	15	0.93	1.04	63.0	57.4	0.8	9%							0.106	0.002	7%	1.160	0.02	11%
Fine Facies Subtotal			**m^3**	**119**				**kg**	**7**	**73%**							**kg**	**0.01**	**52%**	**kg**	**0.1**	**83%**
			m^3/km	**596**				**kg/km**	**33**								**kg/km**	**0.06**		**kg/km**	**0.7**	
Reach Total			**m^3**	**265**				**kg**	**9**	**100%**							**kg**	**0.02**	**100%**	**kg**	**0.2**	**100%**
			m^3/km	**1,327**				**kg/km**	**45**								**kg/km**	**0.1**		**kg/km**	**0.8**	
Reach S-2W																						
c1	coarse	46	0.40	18	0.55	1.23	9.0	3.4	0.04	2%				0.043	0.0005	8%	0.050	0.0006	11%	0.061	0.0008	12%
c2	coarse	175	0.49	86	0.75	1.23	21.3	15.7	1	51%				0.043	0.003	54%	0.050	0.004	72%	0.061	0.005	74%
Coarse Facies Subtotal			**m^3**	**104**				**kg**	**1**	**53%**				**kg**	**0.004**	**62%**	**kg**	**0.005**	**84%**	**kg**	**0.006**	**86%**
			m^3/km	**3,472**				**kg/km**	**43**					**kg/km**	**0.1**		**kg/km**	**0.2**		**kg/km**	**0.2**	
c2	fine	175	0.27	47	0.94	1.04	30.4	24.8	1	47%				0.053	0.002	38%	0.020	0.0009	16%	0.020	0.0009	14%
Fine Facies Subtotal			**m^3**	**47**				**kg**	**1**	**47%**				**kg**	**0.002**	**38%**	**kg**	**0.0009**	**16%**	**kg**	**0.0009**	**14%**
			m^3/km	**1,575**				**kg/km**	**38**					**kg/km**	**0.08**		**kg/km**	**0.03**		**kg/km**	**0.03**	
Reach Total			**m^3**	**151**				**kg**	**2**	**100%**				**kg**	**0.006**	**100%**	**kg**	**0.005**	**100%**	**kg**	**0.006**	**100%**
			m^3/km	**5,047**				**kg/km**	**81**					**kg/km**	**0.2**		**kg/km**	**0.2**		**kg/km**	**0.2**	

Table D-1.3-1 (continued)

Geomorphic Unit	Sediment Facies	Area (m^2)	Average Thickness (m)	Estimated Volume (m^3)	Portion Non-gravel	Density (g/cm^3)	Chromium				Aroclor-1242			Aroclor-1248			Aroclor-1254			Aroclor-1260		
							Average Concentration (mg/kg)	Average Concentration in Excess of Background (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach
Reach S-2																						
c1	mixed	867	2.5	2,168	0.86	1.14	216	210	447	3%	0.085	0.2	3%	0.051	0.1	3%	0.473	1	3%	0.370	0.8	3%
c1ct	mixed	9,046	2.5	22,615	0.89	1.14	362	356	8,179	54%	0.085	2	36%	0.051	1	35%	0.473	11	35%	0.370	8	35%
c2a	mixed	2,344	2.5	5,860	0.86	1.14	216	210	1,209	8%	0.085	0.5	9%	0.051	0.3	9%	0.473	3	9%	0.370	2	9%
c2b	mixed	1,664	2.5	4,160	0.86	1.14	216	210	858	6%	0.085	0.3	6%	0.051	0.2	6%	0.473	2	6%	0.370	2	6%
c2cr	mixed	488	0.9	439	0.97	1.14	944	938	456	3%	0.044	0.02	0%	0.044	0.02	1%	1.403	0.7	2%	1.304	0.6	3%
c2ct	mixed	842	2.5	2,105	0.89	1.14	362	356	761	5%	0.085	0.2	3%	0.051	0.1	3%	0.473	1	3%	0.370	0.8	3%
c2w	mixed	247	2.5	618	0.89	1.14	362	356	223	1%	0.085	0.05	1%	0.051	0.03	1%	0.473	0.3	1%	0.370	0.2	1%
c3	mixed	7,987	3.7	29,552	0.79	1.14	118	112	2,993	20%	0.085	2	41%	0.051	1.4	41%	0.473	13	40%	0.370	10	40%
f1	mixed	162	0.5	81	0.79	1.14	118	112	8	0%	0.085	0.006	0%	0.051	0.004	0%	0.473	0.03	0%	0.370	0.03	0%
Reach Total			**m^3**	**67,597**				**kg**	**15,134**	**100%**	**kg**	**6**	**100%**	**kg**	**3**	**100%**	**kg**	**31**	**100%**	**kg**	**24**	**100%**
			m^3/km	**99,408**				**kg/km**	**22,256**		**kg/km**	**8**		**kg/km**	**5**		**kg/km**	**46**		**kg/km**	**36**	
Reach S-3W																						
c1	coarse	440	0.20	88	0.86	1.23	44.8	39.2	4	9%							0.021	0.002	8%	0.021	0.002	5%
c2	coarse	319	0.20	64	0.75	1.23	175	169	10	26%							0.105	0.006	24%	0.136	0.008	22%
Coarse Facies Subtotal			**m^3**	**152**				**kg**	**14**	**35%**							**kg**	**0.008**	**31%**	**kg**	**0.01**	**28%**
			m^3/km	**723**				**kg/km**	**64.8**								**kg/km**	**0.04**		**kg/km**	**0.05**	
c2	fine	319	0.35	112	0.98	1.04	219	213	24	63%							0.149	0.02	64%	0.209	0.02	67%
f1	fine	86	0.26	22	0.97	1.04	22.9	17	0.4	1%							0.046	0.001	4%	0.075	0.002	5%
f2	fine	27	0.28	8	1.00	1.04	22.9	17	0.1	0%							0.019	0.0001	1%	0.029	0.0002	1%
Fine Facies Subtotal			**m^3**	**142**				**kg**	**25**	**65%**							**kg**	**0.02**	**69%**	**kg**	**0.03**	**72%**
			m^3/km	**674**				**kg/km**	**118**								**kg/km**	**0.03**		**kg/km**	**0.04**	
Reach Total			**m^3**	**293**				**kg**	**38**	**100%**							**kg**	**0.03**	**100%**	**kg**	**0.04**	**100%**
			m^3/km	**1,397**				**kg/km**	**183**								**kg/km**	**0.1**		**kg/km**	**0.2**	
Reach S-3E																						
c1	coarse	493	0.50	247	0.60	1.23	8.2	2.6	0.5	1%							0.021	0.004	16%	0.021	0.004	12%
c2	coarse	246	0.40	98	0.8	1.23	32.8	27.2	3	7%							0.058	0.006	24%	0.061	0.006	18%
c3	coarse	92	0.30	28	0.7	1.23	66.1	60.5	1	4%							0.051	0.001	5%	0.056	0.001	4%
f1	coarse	161	0.07	11	0.8	1.23	32.8	27.2	0.3	0.8%							0.051	0.0006	2.4%	0.056	0.0006	2.0%
f2	coarse	160	0.17	27	0.8	1.23	32.8	27.2	0.7	2%							0.051	0.001	6%	0.056	0.002	5%
Coarse Facies Subtotal			**m^3**	**411**				**kg**	**6**	**15%**							**kg**	**0.013**	**53%**	**kg**	**0.013**	**41%**
			m^3/km	**2,055**				**kg/km**	**28**								**kg/km**			**kg/km**		
c2	fine	246	0.43	106	0.99	1.04	66.7	61.1	7	18%							0.036	0.004	17%	0.052	0.006	18%
c3	fine	92	0.49	45	0.99	1.04	201	195	9	24%							0.032	0.001	6%	0.123	0.006	18%
f1	fine	161	0.50	81	0.99	1.04	201	195	16	43%							0.033	0.003	11%	0.043	0.004	11%
f2	fine	160	0.56	90	0.99	1.04	8.2	2.6	0.2	0.6%							0.033	0.003	12.7%	0.043	0.004	12.3%

Table D-1.3-1 (continued)

Geomorphic Unit	Sediment Facies	Area (m^2)	Average Thickness (m)	Estimated Volume (m^3)	Portion Non-gravel	Density (g/cm^3)	Chromium				Aroclor-1242			Aroclor-1248			Aroclor-1254			Aroclor-1260		
							Average Concentration (mg/kg)	Average Concentration in Excess of Background (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach
Fine Facies Subtotal			**m^3**	**321**				**kg**	**32**	**85%**							**kg**	**0.01**	**47%**	**kg**	**0.02**	**59%**
			m^3/km	**1,605**				**kg/km**	**161**								**kg/km**	**0.06**		**kg/km**	**0.09**	
Reach Total			**m^3**	**732**				**kg**	**38**	**100%**							**kg**	**0.02**	**100%**	**kg**	**0.03**	**100%**
			m^3/km	**3,660**				**kg/km**	**189**								**kg/km**	**0.1**		**kg/km**	**0.2**	
Reach S-4W																						
c1	coarse	628	0.50	314	0.70	1.23	4.0	0	0	0%							0.013	0.004	5%	0.014	0.004	5%
c2	coarse	1,560	0.50	780	0.80	1.23	33.0	27.4	21	29%							0.013	0.01	14%	0.014	0.01	13%
c3	coarse	382	0.20	76	0.80	1.23	33.0	27.4	2	3%							0.013	0.001	1%	0.014	0.001	1%
c3a	coarse	31	0.80	25	0.80	1.23	33.0	27.4	0.7	0.9%							0.013	0.0003	0.5%	0.014	0.0003	0.4%
c4	coarse	310	0.10	31	0.80	1.23	33.0	27.4	0.8	1%							0.013	0.0004	1%	0.014	0.0004	1%
Coarse Facies Subtotal			**m^3**	**1,226**				**kg**	**25**	**34%**							**kg**	**0.02**	**22%**	**kg**	**0.02**	**20%**
			m^3/km	**5,331**				**kg/km**	**107**								**kg/km**	**0.07**		**kg/km**	**0.07**	
c2	fine	1,560	0.52	811	0.94	1.04	46.1	40.5	32	45%							0.058	0.05	66%	0.068	0.05	67%
c3	fine	382	0.34	130	0.98	1.04	112	106	14	20%							0.058	0.008	11%	0.068	0.009	11%
c4	fine	310	0.50	155	0.97	1.04	9.9	4.3	0.7	0.9%							0.006	0.0009	1.3%	0.008	0.001	1.6%
Fine Facies Subtotal			**m^3**	**1,096**				**kg**	**47**	**66%**							**kg**	**0.06**	**78%**	**kg**	**0.06**	**80%**
			m^3/km	**4,766**				**kg/km**	**204**								**kg/km**	**0.2**		**kg/km**	**0.3**	
Reach Total			**m^3**	**2,322**				**kg**	**71**	**100%**							**kg**	**0.07**	**100%**	**kg**	**0.08**	**100%**
			m^3/km	**10,097**				**kg/km**	**311**								**kg/km**	**0.3**		**kg/km**	**0.3**	
Reach S-4E																						
c1	coarse	1,290	1.20	1,548	0.90	1.23	3.5	0	0	0%							0.007	0.01	2%	0.011	0.02	3%
c2	coarse	5,580	0.60	3,348	0.90	1.23	3.5	0	0	0%							0.002	0.006	1%	0.002	0.006	1%
f1	coarse	6,234	0.02	125	0.90	1.23	3.5	0	0	0%							0.002	0.0002	0%	0.002	0.0002	0%
Coarse Facies Subtotal			**m^3**	**5,021**				**kg**	**0**	**0%**							**kg**	**0.02**	**4%**	**kg**	**0.02**	**3%**
			m^3/km	**17,931**				**kg/km**	**0**								**kg/km**	**0.07**		**kg/km**	**0.09**	
c2	fine	5,580	0.74	4,129	0.96	1.04	33.7	28.1	116	38%							0.036	0.1	30%	0.065	0.3	37%
f1	fine	6,234	0.55	3,429	0.98	1.04	59.5	53.9	188	62%							0.092	0.3	66%	0.121	0.4	59%
f2	fine	201	0.12	24	0.98	1.04	33.7	28.1	0.7	0.2%							0.092	0.002	0.5%	0.121	0.003	0.4%
Fine Facies Subtotal			**m^3**	**7,582**				**kg**	**305**	**100%**							**kg**	**0.5**	**96%**	**kg**	**0.7**	**97%**
			m^3/km	**27,079**				**kg/km**	**1,088**								**kg/km**	**2**		**kg/km**	**2**	
Reach Total			**m^3**	**12,603**				**kg**	**305**	**100%**							**kg**	**0.5**		**kg**	**0.7**	**100%**
			m^3/km	**45,010**				**kg/km**	**1,088**								**kg/km**	**2**		**kg/km**	**3**	

Table D-1.3-1 (continued)

Geomorphic Unit	Sediment Facies	Area (m^2)	Average Thickness (m)	Estimated Volume (m^3)	Portion Non-gravel	Density (g/cm^3)	Chromium				Aroclor-1242			Aroclor-1248			Aroclor-1254			Aroclor-1260		
							Average Concentration (mg/kg)	Average Concentration in Excess of Background (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach	Average Concentration (mg/kg)	Inventory (kg)	% of Total in Reach
Reach S-5C																						
c1	coarse	487	0.90	438	0.85	1.23	4.3	0	0	0%	0.043	0.02	16%				0.025	0.01	6%	0.014	0.006	2%
c2	coarse	2,158	0.70	1,511	0.85	1.23	4.3	0	0	0%	0.017	0.03	22%				0.017	0.03	14%	0.016	0.03	9%
c3	coarse	1,030	0.50	515	0.85	1.23	4.3	0	0	0%	0.017	0.009	7%				0.017	0.009	5%	0.016	0.009	3%
f1	coarse	8,273	0.03	248	0.85	1.23	4.3	0	0	0%	0.017	0.004	4%				0.017	0.004	2%	0.016	0.004	1%
f1g	coarse	108	0.06	6	0.85	1.23	4.3	0	0	0%	0.017	0.0001	0%				0.017	0.0001	0%	0.016	0.0001	0%
Coarse Facies Subtotal			**m^3**	**2,719**				**kg**	**0**	**0%**	**kg**	**0.06**	**48%**				**kg**	**0.05**	**28%**	**kg**	**0.04**	**15%**
			m^3/km	**11,327**				**kg/km**	**0**		**kg/km**	**0.3**					**kg/km**	**0.2**		**kg/km**	**1**	
c1	fine	487	0.18	88	0.95	1.04	23.0	17.4	2	2%	0.018	0.002	1%				0.029	0.002	1%	0.061	0.005	2%
c2	fine	2,158	0.48	1,036	0.95	1.04	23.0	17.4	18	22%	0.018	0.02	15%				0.029	0.03	16%	0.061	0.06	22%
c3	fine	1,030	0.48	494	0.98	1.04	4.5	0	0	0%	0.020	0.01	8%				0.020	0.01	5%	0.020	0.01	3%
f1	fine	8,273	0.22	1,820	0.98	1.04	38.1	32.5	60	75%	0.018	0.03	26%				0.048	0.09	47%	0.085	0.2	54%
f1g	fine	108	0.16	17	0.98	1.04	38.1	32.5	0.6	0.7%	0.018	0.0003	0.2%				0.048	0.0008	0.4%	0.085	0.001	0.5%
f2	fine	1,938	0.05	97	0.98	1.04	4.5	0	0	0%	0.018	0.002	1%				0.048	0.005	3%	0.085	0.008	3%
Fine Facies Subtotal			**m^3**	**3,552**				**kg**	**80**	**100%**	**kg**	**0.06**	**52%**				**kg**	**0.1**	**72%**	**kg**	**0.2**	**85%**
			m^3/km	**14,801**				**kg/km**	**334**		**kg/km**	**0.3**					**kg/km**	**0.6**		**kg/km**	**1**	
Reach Total			**m^3**	**6,271**				**kg**	**80**	**100%**	**kg**	**0.1**	**100%**				**kg**	**0.2**	**100%**	**kg**	**0.3**	**100%**
			m^3/km	**26,128**				**kg/km**	**334**		**kg/km**	**0.5**					**kg/km**	**0.8**		**kg/km**	**1**	
Reach S-5E																						
c1	coarse	300	0.60	180	0.85	1.23	3.4	0	0	0%	0.002	0.0003	5%				0.002	0.0003	3%	0.003	0.0006	3%
c2	coarse	729	0.50	365	0.85	1.23	3.4	0	0	0%	0.002	0.0007	9%				0.005	0.002	17%	0.008	0.003	13%
f1	coarse	2,054	0.10	205	0.85	1.23	3.4	0	0	0%	0.002	0.0004	5%				0.002	0.0004	3%	0.006	0.001	6%
f2	coarse	195	0.03	6	0.85	1.23	3.4	0	0	0%	0.002	0.0000	0%				0.002	0.00001	0%	0.006	0.00004	0%
Coarse Facies Subtotal			**m^3**	**756**				**kg**	**0**	**0%**	**kg**	**0.001**	**20%**				**kg**	**0.003**	**23%**	**kg**	**0.005**	**22%**
			m^3/km	**3,286**				**kg/km**	**0**		**kg/km**	**0.006**					**kg/km**	**0.01**		**kg/km**	**0.02**	
c1	fine	300	0.12	36	0.96	1.04	13.8	8.2	0.3	4%	0.022	0.0008	11%				0.016	0.0006	5%	0.012	0.0004	2%
c2	fine	729	0.21	153	0.96	1.04	13.8	8.2	1	18%	0.022	0.003	47%				0.016	0.003	22%	0.012	0.002	8%
f1	fine	2,054	0.31	637	0.96	1.04	13.8	8.2	5	75%	0.002	0.002	22%				0.009	0.006	49%	0.025	0.02	67%
f2	fine	195	0.10	20	0.96	1.04	13.8	8	0.2	2%	0.002	0.00005	1%				0.009	0.0002	1%	0.025	0.0005	2%
Fine Facies Subtotal			**m^3**	**845**				**kg**	**7**	**100%**	**kg**	**0.006**	**80%**				**kg**	**0.009**	**77%**	**kg**	**0.02**	**78%**
			m^3/km	**3,675**				**kg/km**	**30**		**kg/km**	**0.02**					**kg/km**	**0.04**		**kg/km**	**0.08**	
Reach Total			**m^3**	**1,601**				**kg**	**7**	**100%**	**kg**	**0.007**	**100%**				**kg**	**0.01**	**100%**	**kg**	**0.02**	**100%**
			m^3/km	**6,961**				**kg/km**	**30**		**kg/km**	**0.03**					**kg/km**	**0.05**		**kg/km**	**0.1**	

Table D-1.3-2
Inventory Estimates For Select COPCs in Sandia Canyon Sediment Deposits

Reach	Distance Above Rio Grande, Upstream End (km)	Length (km)	Sampling Status	Chromium				Aroclor-1242				Aroclor-1248				Aroclor-1254				Aroclor-1260			
				Coarse Facies Inventory (kg)	Fine Facies Inventory (kg)	Total Inventory (kg)	Percent of Total Inventory	Coarse Facies Inventory (kg)	Fine Facies Inventory (kg)	Total Inventory (kg)	Percent of Total Inventory	Coarse Facies Inventory (kg)	Fine Facies Inventory (kg)	Total Inventory (kg)	Percent of Total Inventory	Coarse Facies Inventory (kg)	Fine Facies Inventory (kg)	Total Inventory (kg)	Percent of Total Inventory	Coarse Facies Inventory (kg)	Fine Facies Inventory (kg)	Total Inventory (kg)	Percent of Total Inventory
Outfall 01A001 to S-1S	16.22	0.06	Not sampled	0.6	2	2	0.01%	0	0	0	0%	0	0	0	0	0.004	0.003	0.01	0.02%	0.04	0.01	0.05	0.2%
S-1S	16.16	0.20	Sampled	2	7	9	0.05%	0	0	0	0%	0	0	0	0	0.01	0.01	0.02	0.07%	0.1	0.03	0.2	0.5%
S-1N	16.16	0.20	Sampled	0.1	0.4	0.5	0.003%	0	0	0	0%	0.01	0.0002	0.01	0.2%	0.01	0.003	0.01	0.03%	0.01	0.01	0.02	0.06%
S-2W	15.96	0.03	Sampled	1	1	2	0.01%	0	0	0	0%	0.002	0.004	0.01	0.2%	0.001	0.005	0.01	0.02%	0.001	0.01	0.01	0.02%
culvert, landfill bridge	15.93	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S-2	15.78	0.68	Sampled	5,361	9,773	15,134	84.2%	4.0	1.5	5.5	84.1%	2.4	0.9	3.3	99.6%	21.4	9.7	31.1	87.8%	17.6	6.8	24.4	79.1%
S-2 to S-3W	15.10	0.76	Not sampled	49	90	139	0.8%	0	0	0	0%	0	0	0	0%	0.1	0.03	0.1	0.3%	0.1	0.04	0.1	0.4%
S-3W	14.34	0.21	Sampled	14	25	38	0.2%	0	0	0	0%	0	0	0	0%	0.02	0.01	0.03	0.1%	0.03	0.01	0.04	0.1%
S-3W to S-3E	14.13	1.35	Not sampled	63	188	251	1.4%	0	0	0	0%	0	0	0	0%	0.1	0.1	0.2	0.5%	0.1	0.1	0.2	0.7%
S-3E	12.78	0.20	Sampled	6	32	38	0.2%	0	0	0	0%	0	0	0	0%	0.01	0.01	0.02	0.1%	0.02	0.01	0.03	0.1%
S-3E to S-4W	12.58	1.16	Not sampled	78	211	290	1.6%	0	0	0	0%	0	0	0	0%	0.2	0.1	0.2	0.7%	0.2	0.1	0.3	1.0%
S-4W	11.42	0.23	Sampled	25	47	71	0.4%	0	0	0	0%	0	0	0	0%	0.1	0.02	0.1	0.2%	0.1	0.02	0.1	0.3%
S-4W to S-4E	11.19	1.15	Not sampled	61	682	744	4.1%	0	0	0	0%	0	0	0	0%	1.0	0.1	1.1	3.1%	1.4	0.1	1.5	5.0%
S-4E	10.04	0.31	Sampled	0	305	305	1.7%	0	0	0	0%	0	0	0	0%	0.5	0.02	0.5	1.4%	0.7	0.02	0.7	2.3%
S-4E to S-5C	9.73	0.65	Not sampled	0	428	428	2.4%	0.1	0.1	0.2	2.6%	0	0	0	0%	0.7	0.1	0.8	2.2%	1.1	0.1	1.1	3.7%
S-5C	9.08	0.24	Sampled	0	80	80	0.4%	0.1	0.1	0.1	1.9%	0	0	0	0%	0.1	0.1	0.2	0.5%	0.2	0.04	0.3	0.9%
S-5C to S-5E	8.84	2.14	Not sampled	0	389	389	2.2%	0.3	0.01	0.3	4.9%	0	0	0	0%	0.6	0.1	0.7	2.0%	1.2	0.1	1.3	4.2%
S-5E	6.70	0.23	Sampled	0	7	7	0.04%	0.01	0.001	0.01	0.1%	0	0	0	0%	0.01	0.003	0.01	0.03%	0.02	0.01	0.02	0.1%
S-5E to S-6W	6.47	3.05	Not sampled	0	46	46	0.3%	0.0	0.4	0.4	6.5%	0	0	0	0%	0.1	0.3	0.4	1.1%	0.1	0.3	0.4	1.3%
S-6W	3.42	0.20	Sampled	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%
S-6W to S-6E	3.22	2.77	Not sampled	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%
S-6E	0.45	0.20	Sampled	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%
S-6E to Rio Grande	0.25	0.25	Not sampled	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%	0	0	0	0%
Total		**16.42**		**5,661**	**12,313**	**17,974**	**100%**	**4.5**	**2.1**	**6.5**	**100%**	**2.4**	**0.9**	**3.3**	**100%**	**24.9**	**10.6**	**35.5**	**100%**	**23.1**	**7.8**	**30.9**	**100%**

Table D-2.1-1
Summary of Trace Metal COPCs in Nonstorm-Related Surface Water and Groundwater for the Sandia Watershed

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Aluminum	>Std: WSFS, E123, WMSC, SCS-2	>Std: SCA-2 >Bkd: SCA-2, SCA-4	-	>Bkd: R-11, R-43 sc 1, R-35b, R-10 sc 2, Sandia Spg	>Bkd: R-33 sc 1, R-13	Fig D-2.1-1a
Antimony	All detected values are less than lowest screening value.	-	>Bkd: SCI-1	-	-	Not plotted; low frequency of detection. No exceedances for surface water. One exceedance for groundwater.
Arsenic	>Std: WSFS	>Std: SCA-4 >Bkd: SCA-1, SCA-2, SCA-4	-	-	-	Fig D-2.1-1b
Barium	>wESL: WSFS, E121, E123, SA10005, SCS-2, SA-0007, SA-603204, SA-10005, SA-603205, Sandia Spg	>Bkd: All	-	>Bkd: R-35a, R-10a, Sandia Spg	>Bkd: R-42, R-28	Fig D-2.1-1c
Beryllium	Detected value is less than lowest screening value.	>Std: SCA-2 >Bkd: SCA-2,SCA-4	-	-	-	Fig D-2.1-1d
Boron	All detected values are less than lowest screening value.	>Bkd: SCA-1,SCA-1-DP,SCA-2, SCA-4	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-11, R-35a, R-10a	-	Fig D-2.1-1e
Cadmium	>Std: SCS-2	-	-	-	-	Not plotted; low frequency of detection. One exceedance for surface water. No exceedances for groundwater.
Calcium	Detected in all samples; no screening values are available.	>Bkd: SCA-1,SCA-2	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-10a, Sandia Spg	>Bkd: R-42, R-28	Fig D-2.1-1f

Table D-2.1-1 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Chromium	All detected values are less than lowest screening value.	>Std: SCA-2 >Bkd: All	>Std: SCI-2 >Bkd: All	>Bkd: R-43 sc 1, R-11, R-35b, R-35a, R-36, R-10a, R-10 sc 1	>Std: R-42, R-28 >Bkd: R-1, R-33 sc 1, R-33 sc 2, R-15, R-43 sc 2, R-42, R-28, R-44 sc 1, R-45 sc 1, R-45 sc 2, R-13	Fig D-2.1-1g
Chromium Hexavalent Ion	All detected values are less than lowest screening value.	-	-	-	>Std: R-28	Fig D-2.1-1h
Cobalt	>wESL: E121, E123, SCS-2	>Bkd: SCA-1, SCA-2	-	-	-	Fig D-2.1-1i
Copper	>Std: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg >wESL: WSFS, E121, E123, WMSC, SCS-2	>Bkd: SCA-2, SCA-4	>Bkd: SCI-1	>Bkd: R-11, R-35a, R-35b, R-10a, R-10 sc 2	>Bkd: R-33 sc1	Fig D-2.1-1j
Iron	>wESL: WSFS, E122, E123	>Std: SCA-1, SCA-2 >Bkd: SCA-3,SCA-4	>Bkd: SCI-1, SCI-2	>Bkd: R-43 sc 1, R-43 sc 2, R-35a, R-35b, R-36, R-10a, R-10 sc 1, Sandia Spg	>Bkd: R-33 sc 1, R-33 2, R-45 sc 2, R-1, R-15, R-42, R-28, R-44 sc 1, R-44 sc 2, R-45 sc 1,R-45 sc 2, R-13	Fig D-2.1-1k
Lead	>Std: WSFS, SCS-2 >wESL: WSFS, E123, WMSC	>Std: SCA-2,SCA-4 >Bkd: SCA-1,SCA-3,SCA-4,SCA-5	>Bkd: R-12 sc 1	>Bkd: R-35a, R-10a	-	Fig D-2.1-1l

Table D-2.1-1 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Magnesium	Detected in all samples; no BV or standard values are available for comparison.	>Bkd: SCA-1,SCA-2	>Bkd: SCI-1, SCI-2, R-12 sc 1	>Bkd: R-43 sc 2, R-11, R-35a, R-35b, R-36, R-10a, R-10 sc 1, R-10 sc 2, Sandia Spg	>Bkd: R-1, R-33 sc 1, R-33 sc 2, R-42, R-28, R-44 sc 2, R-45 sc 1, R-45 sc 2	Fig D-2.1-1m
Manganese	>wESL: WSFS, E123, E121, SA-603204	>Std: SCA-1,SCA-1-DP, SCA-2 >Bkd: All	>Std: R-12 sc 1 >Bkd: All	-	-	Fig D-2.1-1n
Mercury	All detected values are less than lowest screening value.	>Bkd: SCA-1, SCA-2	-	-	-	Fig D-2.1-1o
Molybdenum	All detected values are less than lowest standard; no wESL value available.	>Bkd: SCA-1,SCA-1-DP, SCA-2, SCA-4	>Bkd: SCI-1, R-12 sc 1,R-12 sc 2	-	>Bkd: R-13; R-33 sc 2	Fig D-2.1-1p
Nickel	All detected values are less than lowest screening value.	>Bkd: SCA-2,SCA-4	-	-	>Bkd: R-33 sc 2	Fig D-2.1-1q
Potassium	Detected in all samples; no BV or standard values are available for comparison.	>Bkd; All	-	>Bkd: R-35a, R-10a, R-10 sc 1, R-10 sc 2, Sandia Spg	>Bkd: R-13	Fig D-2.1-1r
Selenium	>wESL: WSFS, SA-0007, Sandia Spg	-	-	>Bkd: R-11, Sandia Spg	>Bkd: R-28, R-33 sc 1	Fig D-2.1-1s

Table D-2.1-1 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Silver	>wESL: E123, WMSC	-	-	-	-	Not plotted; low frequency of detection. Two exceedances for nonfiltered surface water. No exceedances for groundwater or for filtered surface water.
Sodium	Detected in all samples; no BV or standard values are available for comparison.	>Bkd; All	>Bkd: SCI-1, SCI-2, R-12 sc 1	>Bkd: R-10a	-	Fig D-2.1-1t
Strontium	All detected values are less than lowest screening value.	>Bkd: All	>Bkd: SCI-1, SCI-2	-	-	Fig D-2.1-1u
Thallium	All detected values are less than lowest screening value.	-	-	-	-	Not plotted; low frequency of detection. No exceedances.
Tin	-	-	>Bkd: SCI-1	>Bkd: R-10 sc 1, R-11	-	Not plotted; low frequency of detection (<2%).
Uranium	>wESL: Sandia Spg	>Bkd: SCA-1 ; SCA-2, SCA-4, SCA-5	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-10a, Sandia Spg	-	Fig D-2.1-1v
Vanadium	>wESL: WSFS	>Bkd: SCA-1 ; SCA-2, SCA-4, SCA-5	-	>Bkd: R-35a, R-35b, R-36, Sandia Spg	-	Fig D-2.1-1w

Table D-2.1-1 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Zinc	>Std: WSFS, E121, E123, SCS-2 >wESL: WSFS, E121, E123, E122	>Bkd: All	>Bkd: R-12 sc 1, R-12 sc 2	>Bkd: R-35a, R-35b, R-36, R-10a, Sandia Spg	>Bkd: R-33 sc 1, R-44 sc 1, R-45 sc 1, R-45 sc 2, R-13	Fig D-2.1-1x

Source: Compiled from Table D-2.0-1, Table D-2.0-5, Table D-2.0-9, and Table D-2.0-13.

Abbreviations: BV = background value; Det = detected; sc = screen; spg = spring; Std = standard; wESL = water ESL

[a] Explanation of column entries for "Locations at which Analyte Exceeds Screening Value"

>Std	This analyte is detected in this media at a concentration exceeding a wateR-quality standard used for screening.
>wESL	This analyte is detected in a surface-water sample at a concentration exceeding the water ESL.
>BV	This analyte is detected in groundwater from this media at a concentration exceeding the BV.
Det	This analyte is detected in this media, and detected concentrations are below any wateR-quality standard, wESL, or BV used for screening. This entry is used for analytes for which wESLs or BVs are not available.
-	This analyte is either not detected in this media or is not detected above the BV or wESL.

Table D-2.1-2
Summary of Radionuclide COPCs in Nonstorm-Related Surface Water and Groundwater for the Sandia Watershed

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Americium-241	All detected values are less than lowest screening value.	-	-	-	-	Not plotted; low frequency of detection (<1%) .
Gross alpha	Det: E123, WMSC, Sandia Spg	Det: SCA-1	Det: SCI-1, R-12 sc 1	>Bkd: R-10a Det: R-10 sc 2, R10a, R-11, Sandia Spg	Det: R-1, R-28, R-33 sc 2, R-13	Fig D-2.1-2a
Gross alpha/beta	-	-	-	-	-	Not plotted; no background values or standards exist for comparison
Gross beta	-	-	-	-	-	Not plotted; no values above lowest applicable standard
Gross gamma	-	-	Det: SCI-2, R-12 sc 2	Det: R-10 sc 1, R-35b, R-43 sc 1	>Bkd: R-33 sc 2, R-45 sc 1	Fig D-2.1-2b
Plutonium-238	Det: WMSC	-	-	-	Det: R-28	Not plotted; low frequency of detection (<1%). No exceedances of standards.
Plutonium-239/240	Det: E123, WMSC	-	-	-	-	Not plotted; low frequency of detection (2 detections in surface water in February 2007). No exceedances of standards.
Potassium-40	Det: E121, WSFS, E123	Det: SCA-2	Det: R-12 sc 1	-	Det: R-33 sc 1	Not plotted; Natural sources.
Radium-226	>wESL: E121, E123, Sandia Spg	Det: SCA-2, SCA-4	Det: R-12 sc 2	Det: R-10 sc 2, R-35a, R-43 sc 1, R-43 sc 2, Sandia Spg	Det: R-1, R-15, R-33 sc 1, R-44 sc 1, R-45 sc 1, R-13	Fig D-2.1-2c

Table D-2.1-2 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Radium-228	-	Det: SCA-2, SCA-4	Det: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	Det: R-11, R-35b, R-43 sc 1, R-43 sc 2	Det: R-1, R-42, R-45 sc 1, R-13	Fig D-2.1-2d
Strontium-90	Detected value is less than lowest screening value.	>Bkd: SCA-1	-	Detected values are less than lowest screening value.	Detected value is less than lowest screening value.	Fig D-2.1-2e
Thorium-230	-	-	-	-	-	Not plotted; low frequency of detection
Tritium	Det: WSFS, E123, WMSC, Sandia Spg	>Bkd: SCA-1, SCA-1-DP, SCA-4	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-11, R-36, Sandia Spg	>Bkd: R-33 sc 1, R-15, R-42, R-28	Fig D-2.1-2f
Uranium-234	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd: SCA-1, SCA-2, SCA-4	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-10a	Det: All	Fig D-2.1-2g
Uranium-235/236	Det: WSFS, E123, Sandia Spg	Det: SCA-1, SCA-2, SCA-4	Det: SCI-1, SCI-2, R-12 sc 2	Det: All	Det: All	Fig D-2.1-2h
Uranium-238	-	>Bkd: SCA-1, SCA-2, SCA-4	>Bkd: SCI-1, SCI-2, R-12 sc 2	>Bkd: R-10a Det: All	Det: All	Fig D-2.1-2i

Source: Compiled from Table D-2.0-2, Table D-2.0-6, Table D-2.0-10, and Table D-2.0-14.

Abbreviations: BV = background value; Det = detected; sc = screen; spg = spring; Std = standard; wESL = water ESL

[a] Explanation of column entries for "Locations at which Analyte Exceeds Screening Value"

>Std This analyte is detected in this media at a concentration exceeding a wateR-quality standard used for screening.

>wESL This analyte is detected in a surface-water sample at a concentration exceeding the water ESL.

>BV This analyte is detected in groundwater from this media at a concentration exceeding the BV.

Det This analyte is detected in this media, and detected concentrations are below any wateR-quality standard, wESL, or BV used for screening. This entry is used for analytes for which wESLs or BVs are not available.

- This analyte is either not detected in this media or is not detected above the BV or wESL

Table D-2.1-3
Summary of Organic COPCs in Nonstorm-Related Surface Water and Groundwater for the Sandia Watershed

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
2,4-Diamino-6-nitrotoluene	Det: WSFS	-	-	-	-	Not plotted; low frequency of detection.
2,6-Diamino-4-nitrotoluene	Det: WSFS	-	-	-	-	Not plotted; low frequency of detection.
Acetone	Det: WSFS, E123, WMSC	Det: SCA-1	Det: SCI-1, SCI-2, R-12 sc 1	Det: R-10 sc 1, R-10 sc 2, R-10a, R-11, R-35a, R-36, R-43 sc 1	Det; R-1, R-15, R-28, R-33 sc 1, R-42, R-44 sc 1, R-45 sc 1, R-13	Fig D-2.1-3a
Aldrin	-	-	Det: SCI-1, SCI-2	-	-	Not plotted; low frequency of detection.
AroclоR-1016	-	-	-	Det: R-10 sc 1	-	Not plotted; low frequency of detection.
AroclоR-1254	>Std: E123	Det: SCA-1	-	Det: R-35b	-	Fig D-2.1-3b
AroclоR-1260	>Std: E123	Det: SCA-1	-	Det: R-10 sc 1	-	Fig D-2.1-3c
Benzene	-	-	-	-	Det: R-15	Not plotted; low frequency of detection.
Benzoic Acid	Det: WMSC	-	Det; R-12 sc 1	Det: R-10 sc 2, R-10a	-	Not plotted; low frequency of detection.
BHC[delta-]	>Std: WSFS	-	-	-	-	Fig D-2.1-3d
Bis[2-ethylhexyl]phthalate	-	>Std: SCA-4	>Std: R-12 sc 2	Det: R-10a, R-35b, R-36, R-43 sc 1	Det: R-33 sc 1, R-33 sc 2, R-42, R-44 sc 1	Fig D-2.1-3e
Bromodichloromethane	Det: WSFS, E123	-	-	-	-	Fig D-2.1-3f
Bromoform	Det: WSFS, E121, E123	-	-	-	-	Fig D-2.1-3g
Bromomethane	-	-	-	Det: R-36	-	Fig D-2.1-3h

Table D-2.1-3 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Butanone[2-]	-	Det: SCA-1, SCA-4	-	Det: R-35a	-	Fig D-2.1-3i
Carbon Disulfide	-	-	-	Det: R-11, R-35b	Det: R-13	Fig D-2.1-3j
Chlorodibromomethane	Det: WSFS, E123	-	-	-	-	Fig D-2.1-3k
Chloroform	Det: WSFS, E123, WMSC	Det: SCA-2, SCA-4	Det: SCI-1, SCI-2	-	-	Fig D-2.1-3l
Chloromethane	-	-	Det: SCI-2	Det: R-10 sc 1, R-35b, R-36	Det: R-28, R-44 sc 1	Fig D-2.1-3m
DDD[4,4'-]	-	-	Det: SCI-1	-	Det: R-1	Not plotted; low frequency of detection.
DDE[4,4'-]	-	-	Det: SCI-1	-	Det: R-1, R-13	Not plotted; low frequency of detection.
DDT[4,4'-]	-	-	Det: SCI-1	-	Det: R-1	Not plotted; low frequency of detection.
Dichlorobenzene[1,3-]	Det: Sandia Spg	Det: SCA-4	-	Det: Sandia Spg	-	Not plotted; low frequency of detection.
Dichlorophenol[2,4-]	Det: Sandia Spg	-	-	Det: Sandia Spg	-	Not plotted; low frequency of detection.
Dieldrin	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Diethylphthalate	-	-	-	-	Det: R-1	Not plotted; low frequency of detection.
Dinitrobenzene[1,3-]	-	-	-	-	Det: R-45 sc 1	Not plotted; low frequency of detection.
Dioxane[1,4-]	Det: E123, WMSC	Det: SCA-1	-	-	-	Fig D-2.1-3n
DNX	-	-	-	Det: R-10 sc 2	-	Not plotted; low frequency of detection.

Table D-2.1-3 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Endosulfan II	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Endosulfan Suflate	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Endrin	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Heptachlorodibenzodioxins [Total]	-	-	-	-	Det: R-15, R-28, R-33 sc 2, R-13	Not plotted; not detected in Sandia waters.
Heptaclor	-	-	Det: SCI-1	-	Det: R-33 sc 1	Not plotted; low frequency of detection.
Heptaclor Epoxide	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Methyl-2-pentanone[4-]	-	-	-	Det: R-10a	-	Not plotted; low frequency of detection.
Methylene Chloride	-	-	-	Det: R-10 sc 1	-	Not plotted; low frequency of detection.
Naphthalene	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Nitrotoluene[3-]	-	-	-	-	Det: R-15	Not plotted; low frequency of detection.
Octachlorodibenzodioxins [1,2,3,4,6,7,8,9-]	-	-	-	Det: R-43 sc 1	Det: R-1, R-45 sc 2	Not plotted; low frequency of detection in Sandia waters.
Pentachlorodibenzodioxins [Totals]	-	-	-	-	Det: R-28, R-13	Not plotted; not detected in Sandia waters.
Phenanthrene	-	-	-	Det: R-11	-	Not plotted; low frequency of detection.

Table D-2.1-3 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Phenol	-	-	-	-	Det: R-33 sc 1	Not plotted; low frequency of detection.
Styrene	-	Det: SCA-4	-	-	-	Not plotted; low frequency of detection.
Toluene	-	Det: SCA-1, SCA-1-DP, SCA-4	Det: R-12, sc 1	Det: R-10a, R-11, R-35a, R-35b, R-36	Det; R-28, R-42, R-44 sc 1	Fig D-2.1-3o
Total Petroleum Hydrocarbons - Diesel Range Organics	-	-	Det: SCI-1	-	-	Not plotted; low frequency of detection.
Trichlorophenol[2,4,5-]	Det: Sandia Spg	-	-	Det: Sandia Spg	-	Not plotted; low frequency of detection.
Trichlorophenol[2,4,6-]	Det: Sandia Spg	-	-	Det: Sandia Spg	-	Not plotted; low frequency of detection.
Xylene[1,3-]+Xylene[1,4-]	-	-	-	-	Det: R-1	Not plotted; low frequency of detection.

Source: Compiled from Table D-2.0-3, Table D-2.0-7, Table D-2.0-11, and Table D-2.0-15.

Abbreviations: BV = background value; Det = detected; n/a = not applicable; sc = screen; spg = spring; Std = standard; wESL = water ESL

Abbreviations: BV = background value; Det = detected; sc = screen; spg = spring; Std = standard; wESL = water ESL

[a] Explanation of column entries for "Locations at which Analyte Exceeds Screening Value"

>Std	This analyte is detected in this media at a concentration exceeding a wateR-quality standard used for screening.
>wESL	This analyte is detected in a surface-water sample at a concentration exceeding the water ESL.
>BV	This analyte is detected in groundwater from this media at a concentration exceeding the BV.
Det	This analyte is detected in this media, and detected concentrations are below any wateR-quality standard, wESL, or BV used for screening. This entry is used for analytes for which wESLs or BVs are not available.
-	This analyte is either not detected in this media or is not detected above the BV or wESL

Table D-2.1-4
Summary of Other General Inorganic COPCs in Nonstorm-Related Surface Water and Groundwater for the Sandia Watershed

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Ammonia as Nitrogen	Det: WSFS, E121, E123, WMSC, Sandia Spg	>Bkd: SCA-1	>Bkd: R-12 sc 1, R-12 sc 2	>Bkd: R-35a	-	Fig D-2.1-4a
Bromide	Det: WSFS, E121, E123, WMSC, Sandia Spg	>Bkd; All	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	-	>Bkd: R-28, R-42	Fig D-2.1-4b
Chloride	>wESL: WSFS	>Std; SCA-2 >Bkd; SCA-1, SCA-1-DP, SCA-4, SCA-5	>Bkd: SCI-1, SCI-2, R-12 sc 1	>Bkd: R-43 sc 1, R-43 sc 2, R-11, R-35a, R-36, R-10a, Sandia Spg	>Bkd: R-15, R-28, R-42	Fig D-2.1-4c
Cyanide[Total]	>wESL: WSFS, E121, E123	Det: SCA-1, SCA-2, SCA-4	>Bkd: SCI-1, SCI-2, R-12 sc 1	Det: R-11, R-35a, R-36	Det: R-1, R-15, R-28, R-42, R-13	Fig D-2.1-4d
Fluoride	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd; All	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-35b, R-36, Sandia Spg	-	Fig D-2.1-4e
Nitrate-Nitrite as Nitrogen	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd: SCA-1, SCA-2, SCA-4	>Bkd: SCI-1, SCI-2	>Bkd: R-43 sc 1, R-43 sc 2, R-11, R-35b, R-36, R-10a	>Bkd: R-33 sc 1, R-15, R-42, R-28, R-44 sc 1, R-45 sc 1, R-13	Fig D-2.1-4f
Perchlorate	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	-	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-43 sc 1, R-43 sc 2, R-11, R-35b, R-36, R-10a, R-10 sc 1, R-10 sc 2	>Bkd: R-33 sc 1, R-15, R-42, R-28, R-45 sc 1	Fig D-2.1-4g
Phosphorus, Orthophosphate	Det: WSFS, E121, E123	-	-	-	-	Not plotted; only 3 measurements; better coverage provided by Total Phosphate as Phosphorus

Table D-2.1-4 (continued)

Analyte	Locations at Which Analyte Exceeds Screening Value[a]					Plot
	Nonstorm-Related Surface Water	Alluvial Groundwater	Intermediate Groundwater	Regional Groundwater (Sandia)	Regional Groundwater (Mortandad)	
Silicon Dioxide	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd; All	>Bkd: SCI-1, SCI-2	-	-	Fig D-2.1-4h
Sulfate	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd; SCA-1, SCA-1-DP, SCA-2, SCA-4	>Bkd: SCI-1, SCI-2	>Bkd: R-43 sc 1, R-43 sc 2, R-11, R-36, R-10a, Sandia Spg	>Bkd: R-42, R-28	Fig D-2.1-4i
Sulfide, Total	-	-	Det: SCI-1	Det: R-11, R-10a	>Bkd: R-1, R-28, R-33 sc 1, R-33 sc 2	Fig D-2.1-4j
Total Kjeldahl Nitrogen	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd: SCA-1, SCA-2	>Bkd: SCI-1, R-12 sc 1	-	-	Fig D-2.1-4k
Total Phosphate as Phosphorus	Det: WSFS, E121, E123, WMSC, SCS-2, Sandia Spg	>Bkd; All	>Bkd: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-35b	>Bkd: R-33 sc 2, R-13	Fig D-2.1-4l
Total Organic Carbon	Det: WSFS, E121, E123, Sandia Spg	>Bkd; All	Det: SCI-1, SCI-2, R-12 sc 1, R-12 sc 2	>Bkd: R-36, R-43 Sc 1	>Bkd: R-42	Fig D-2.1-4m

Source: Compiled from Table D-2.0-4, Table D-2.0-8, Table D-2.0-12, and Table D-2.0-16.

Abbreviations: BV = background value; Det = detected; n/a = not applicable; sc = screen; spg = spring; Std = standard; wESL = water ESL

Abbreviations: BV = background value; Det = detected; sc = screen; spg = spring; Std = standard; wESL = water ESL

[a] Explanation of column entries for "Locations at which Analyte Exceeds Screening Value"

>Std This analyte is detected in this media at a concentration exceeding a wateR-quality standard used for screening.

>wESL This analyte is detected in a surface-water sample at a concentration exceeding the water ESL.

>BV This analyte is detected in groundwater from this media at a concentration exceeding the BV.

Det This analyte is detected in this media, and detected concentrations are below any wateR-quality standard, wESL, or BV used for screening. This entry is used for analytes for which wESLs or BVs are not available.

- This analyte is either not detected in this media or is not detected above the BV or wESL

Table D-2.2-1
Chromium Source Estimates and Reservoirs of Anthropogenic Chromium in the Environment

	Subsection	Mean Estimate (kg)	Range (kg)	Notes
Source	N/A	51,000	31,000 to 72,000	
Sediment	N/A	18,000	5,700 to 27,000 (10^{th} and 90^{th} percentile)	Mean is for entire canyon; range is for reach S-2
Vadose Zone				
	Perched intermediate water	230	100-500	SCI-2 concentration 600 □g/L; assume 30 m depth of perched zone, 129,577 m^2 area, porosity = 0.10. Range is based on porosity ranges of <5% to 20% from Schlumberger density logs for R-42 and R-45.
	In Bandelier Tuff and Cerro Toledo interval	10,500	1,000-51,000	Estimate is based on (1) average rock bulk density of 1.6 g/cm^3, (2) averaging the chromium 3050 digestion values above a upper threshold of 2.6 mg/kg (Ryti et al. 1998, 059730), (3) Qbt/Qct section thickness of 95 m as at SCI-2, (4) infiltration area of 129,577 m^2. Data from SCC 1-6 and SCI-2 used, 17 of 70 samples above threshold, for values above threshold mean = 0.53 mg/kg and s.d. = 2.1 mg/kg. Range is based on 10% of average to average plus 1 s.d.
	In Puye Formation above Cerros del Rio basalts	24,000	2,400-60,000	Estimate is based on (1) average rock bulk density of 2.2 g/cm^3, (2) averaging the chromium 3050 digestion values above a upper threshold of 8 mg/kg (estimated), (3) upper Puye section thickness of 14 m as at SCI-2, (4) canyon-bottom area of 129,577 m^2. Data from SCC 1-6 and SCI-2 used, 11 of 15 samples above threshold, for values above threshold mean = 6.0 mg/kg and s.d. = 9.2 mg/kg. Range is based on 10% of average to average plus 1 s.d.
	In Cerros del Rio basalts	4,500	900-9,000	Estimate is based on (1) average rock bulk density of 2.5 g/cm^3, (2) averaging the chromium 3050 digestion values above a upper threshold of 13 mg/kg (mean plus two standard deviations; Appendix I), (3) Tb4 section thickness of 71 m as at SCI-2, (4) canyon-bottom area of 129,577 m^2. Data from SCC 1-6 and SCI-2 used, 6 of 16 samples above threshold, for values above threshold mean = 4.0 mg/kg and s.d. = 6.5 mg/kg. Range is based on estimates of 1% to 10% effective porous/fractured media.
	In Puye Formation beneath Cerros del Rio basalts	0	0 to ?	An estimated upper threshold of 8 mg/kg chromium in Puye Formation places all four 3050 digestion chromium contents (max. value 6.6 mg/Kg) below threshold. No upper range is given because only a single point analysis (SCI-2) is available.
	In Miocene pumiceous sediments	0	0 to ?	An estimated upper threshold of 5 mg/kg chromium in Miocene Pumiceous sediment places all five 3050 digestion chromium contents (max. value 4.9 mg/kg) below threshold. No upper range is given because only a single point analysis (SCI-2) is available.
Regional Aquifer		555	270 to 3300	Estimate based on simulations presented in Appendix L where the calculated distributions of chromium are calibrated to observations in regional wells.

Appendix E

Statistics and Risk Information

E-1.0 INFORMATION SUPPORTING THE BASELINE ECOLOGICAL RISK ASSESSMENT

This appendix provides plots of various ecological measures to evaluate trends with chemicals of potential ecological concern (COPECs) or associations with other relevant factors at Los Alamos National Laboratory (the Laboratory). Tables of information to support the ecological exposure evaluation are also provided.

E-1.1 Information Supporting COPEC Refinement

There are three sets of tables with concentrations of chemicals of potential concern (COPCs) in sediment and nonstorm-related surface water compared with ecological screening levels (ESLs) for terrestrial and aquatic receptors. The tables summarize the maximum detected concentration by reach or location and the hazard quotient (HQ), which is the ratio of the concentration to the ESL. Tables E-1.1-1 to E-1.1-3 provide information on COPEC refinement for soil COPCs. Tables E-1.1-4 provides information on COPEC refinement for sediment COPCs. Tables E-1.1-5 to E-1.1-8 provide information on COPEC refinement for nonstorm-related surface water COPCs. Tables E-1.1-1 to E-1.1-8 are provided electronically (on CD) in Attachment 1.

E-1.2 Information Supporting the Ecological Exposure Evaluation

The toxicity reference values (TRVs) used in the wildlife exposure evaluation are listed in Table E-1.2-1 for all COPECs. All TRVs are from the ECORISK Database, Version 2.3 (LANL 2008, 103352). The exposure parameters are summarized in Table E-1.2-2 for all wildlife receptors evaluated. COPEC sampling results in exposure media are averaged by location (Table E-1.2-3) to evaluate wildlife receptors with spatially limited home ranges (robin, flycatcher, shrew). COPEC sampling results in exposure media are averaged by reach (Table E-1.2-3) to evaluate wildlife receptors with spatially expansive home ranges (owl, fox, bat). Tables E-1.2-3 and E-1.2-4 are provided electronically (on CD) in Attachment 1.

E-1.3 Plots Supporting Lines of Evidence for Birds

Nest box measurements were collected in Sandia Canyon, at other locations within the Laboratory, and at reference site locations. Reference site locations were selected based on distance from Laboratory sources and are from nest boxes in Cañada del Buey and Guaje Canyon. An evaluation of the home ranges and locations of solid waste management units (SWMUs) and areas of concern (AOCs) was documented by (Colestock 2007, 102994, Table 10, p. 46) and supported the selection of Cañada del Buey and Guaje Canyon as reference site locations. Locations in Rendija Canyon (the Guaje Pines Cemetery and the Los Alamos Municipal Golf Course) were not selected because of the overlap of some bluebird home ranges with SWMUs and AOCs.

Measurements collected at nest boxes included clutch size, number of eggs hatched, percent eggs hatched, number of fledged young, percent fledged young, and percent females observed (Table E-1.3-1 provided electronically on CD in Attachment 1). Egg size and shell thickness were also measured from the nest box monitoring network (Table E-1.3-2 provided electronically on CD in Attachment 1).

Section E-1.3.1 compares bird measures among species, and section E-1.3.2 evaluates temporal trends in bird measures for western bluebirds. Section E-1.3.3 presents an evaluation of differences in bird measures for various data groups.

E-1.3.1 Box Plots Comparing Bird Nest Success and Egg Measures by Species

Figures E-1.3-1 and E-1.3-2 present comparisons of the bird measures of effect (percent of nestlings fledged and percent of nestlings that are female) across species using box plots. Boxes in these figures indicate the interquartile range of the sampling results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values; horizontal lines above and below the boxes represent the 5th and 95th percentiles of the data. These plots demonstrate that there are no significant differences for these measures between species.

As with the measures of the nestlings, egg length may vary between species. Figure E-1.3-3 compares egg length across species, Figure E-1.3-4 compares egg weight across species, and Figure E-1.3-5 compares eggshell thickness across species. As expected, there are differences between these measures for some species. Ash-throated flycatchers, western bluebirds, and mountain bluebirds have very similar ranges of values for these measures. Egg weight and length for the violet-green swallow overlap with the western bluebird as well, although the values cluster at the lower end of the range. Egg lengths for the house finch and the mountain chickadee are smaller than the other species, although the egg weights are closer to those of the other species.

E-1.3.2 Plots of Bird Nest Success and Egg Measures by Year

Measures of nestlings can also potentially be affected by factors such as climate and food supply that vary across years. Figures E-1.3-6 and E-1.3-7 show the time trends for fledging success and the percentage of females for western bluebirds. No biologically relevant trends over time are discernible for either measure, indicating that potential confounding factors did not exert an effect across the time period for the data set.

Measures of egg size can also potentially be affected by factors such as climate and food supply that vary across years. Figure E-1.3-8 compares egg length for all species across years. Figure E-1.3-9 compares egg weight versus time for all species. The same comparison for eggshell thickness is shown in Figure E-1.3-10. None of the three egg measures show a biologically meaningful trend over time, indicating that the potential confounding factors did not exert an effect across the time period for the data set.

E-1.3.3 Comparison of Bird Nest Success among Various Data Groups

Nest box measurements were analyzed for differences in nest success among canyon, data location groups, canyon segments, and reaches. The comparisons are based on results for all species, and the data are presented in box plots. Boxes in these figures indicate the interquartile range of the sample results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values, and horizontal lines above and below the boxes represent the 5th and 95th percentiles of the data. Dunnett's *t*-test results are presented in the right-hand section of each figure. The comparison circles indicate statistical differences between the tests and the reference sites. The reference site sample for the Dunnett's *t*-test is displayed as a heavy red circle, and the text for the reference site is printed in bold red text on the x-axis. Thin red circles represent samples that are not statistically different ($p < 0.05$), and the watershed names are displayed in red on the axis. Heavy grey circles represent samples that are statistically different; these names are printed in black on the x-axis.

Canyon. Nest box measurements were compared for the Sandia Canyon locations to other canyons and reference site locations. Reference site measurements (representing Cañada del Buey, Guaje Pines Cemetery and Los Alamos Municipal Golf Course locations) were plotted for comparison. Nest box

measures were plotted for various canyons in Figures E-1.3-11 to E-1.3-16. There were no statistically significant differences between Sandia Canyon nest box measurements and reference nest box measurements. In summary, none of the canyon nest box measures showed statistical decreases relative to reference site levels; therefore, there is no evidence of impairment of nesting success at Laboratory locations relative to reference locations.

Reach. For Sandia Canyon, nest box observations were analyzed between reaches. Reference site measurements were also plotted for comparison. Nest box measures were plotted for various canyon segments in Figures E-1.3-17 to E-1.3-22. No statistically significant differences between reach and reference location measurements were observed. In summary, none of the reach nest box measures showed statistical decreases relative to reference site levels and therefore no evidence for impairment of nesting success at Laboratory locations relative to reference locations.

E-1.4 Earthworm Bioassay Results versus Confounding Factors and COPECs

To test for relationships of earthworm survival or growth to confounding factors or COPECs, linear regression analyses were compiled (Table E-1.4-1). The table shows if there are statistically relationships of the bioassay results with confounding factors or COPECs for the 10 samples tested with earthworm bioaccumulation test. There are statistically significant relationships for earthworm survival or growth and 10 confounding factors ($p < 0.05$). The confounding factors correlated to earthworm survival or growth were pH, organic matter, clay (<2 µm), fine silt (15-2 µm), total silt + clay, gravel (>2 mm), aluminum, potassium, sodium, and total phosphate as phosphorus. There were no statistically significant relationships with COPECs and earthworm survival or growth.

E-1.5 Seedling Germination Test Results versus Confounding Factors and COPECs

Levels of nutrients in soil exert a strong influence on germination and growth of plants. The pH of soil affects the availability of many nutrients to plants. Soil nutrient parameters and pH values were therefore measured in the soil samples from Sandia Canyon used in the plant laboratory toxicity test. To test for relationships of seedling germination (survival) or growth to confounding factors or COPECs, linear regression analyses were compiled (Table E-1.5-1). Linear regression show if there are relationships of the bioassay results with confounding factors or COPECs for the 10 samples tested with seedling germination test. Statistically significant relationships were noted for both confounding factors and COPECs ($p < 0.05$). The confounding factors correlated to seedling germination (survival) or growth were organic matter, very fine sand (0.125–0.0625 mm), fine sand (0.25–0.125 mm), and sodium. The confounding factors correlated to seedling germination (survival) or growth were perchlorate, selenium, and zinc.

E-1.6 *Chironomus tentans* Toxicity Test Results versus Confounding Factors and COPECs

Particle size and other sediment properties can affect the survival and growth of *Chironomus tentans* (chironomid, Family Chironomidae) larvae. Table E-1.6-1 summarizes the statistically significant linear regression relationships of chironomid survival and measures of growth versus confounding factors for eight pairs (field water and laboratory) of chironomid bioassays Sandia Canyon and reference site results. There are some statistically significant relationships ($p < 0.05$) between sediment texture (organic matter, fine silt [15-2 µm], total silt + clay, very fine sand [0.125-0.0625 mm], and gravel [>2 mm]) and growth. Statistically significant relationships with COPECs (Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260, barium, chromium, copper, cyanide [total], iron, lead, mercury, perchlorate, selenium, and silver) were also found ($p < 0.05$).

E-2.0 SUPPORTING INFORMATION FOR THE HUMAN HEALTH RISK ASSESSMENT

This section provides human health exposure parameters and toxicity information, exposure point concentrations (EPCs), and results of the supplemental human health risk scenario (residential).

E-2.1 Exposure Parameters and Toxicity Information

Exposure parameters used to calculate soil screening levels (SSLs) and screening action levels (SALs) are provided in Table E-2.1-1 (recreational and residential SSLs for inorganic and organic chemicals), Table E-2.1-2 (recreational SALs for radionuclides), Table E-2.1-3 (surface-water ingestion SSLs for inorganic and organic chemicals), and Table E-2.1-4 (residential SALs for radionuclides). Toxicity information for COPCs for which surface-water screening levels (SLs) were calculated is provided in Table E-2.1-5 (inorganic and organic chemicals).

E-2.2 Sediment EPCs

This section provides information on the statistical methods used to calculate EPCs for sediment COPCs used in the human health risk assessment.

The sample results for COPCs fall into three general categories. The first consists of COPCs detected in all of the investigation samples for a data subset of COPCs (radionuclides) that are not censored at the detection limit and reported as the actual measurement value from the instrument with a nondetect qualifier. The second includes inorganic or organic COPCs for which the data are a mixture of detected and nondetected values for a data subset. Nondetect sample results are censored at the detection limits and are reported with a data qualifier starting with "U" (e.g., U or UJ). For inorganic and organic chemicals, ProUCL Version 4.00.04 (http://www.epa.gov/esd/tsc/software.htm) incorporates approaches to representing the censored nondetect values for the calculation of upper confidence limits (UCLs) for use as EPCs. The third category is either an extreme case of the second category where the number of nondetects (the rate of censorship) is so high that methods for the second category are unreliable or the data set is too small to calculate a UCL and the maximum detected sample result is used as the EPC. Section E-2.2.1 describes the methods used to analyze data that fall into the above three categories.

E-2.2.1 UCL Calculation Methods

The statistical methods used to calculate UCLs are consistent with U.S. Environmental Protection Agency (EPA) guidance (EPA 1989, 008021). ProUCL Version 4.00.04, (http://www.epa.gov/esd/tsc/software.htm) was used to calculate UCLs to use as EPCs in the human health risk assessment. Many of the data sets for sediment investigation reaches are censored at the detection limits. ProUCL software includes methods, such as Kaplan–Meier, for calculation of the UCLs when censored data exist. When only small sample data sets were available ($\leq$3 samples) for a specific COPC, the maximum detected sample result was used to represent the EPC.

The first step in calculating a UCL is to determine whether the data fit a probability distribution. The ProUCL software assesses normal, lognormal, and gamma distributions. The possible outcomes and UCL calculation approaches are as follows.

- The data show a normal distribution; normal distribution methods are used.
- The data show a lognormal distribution; lognormal distribution methods are used.
- The data show a gamma distribution; gamma distribution methods are used.

- The data are not different from either distribution; normal distribution methods are used.
- The data are different from all distributions; the Chebyshev or nonparametric methods are used.
- Insufficient data are available to evaluate the distribution; nonparametric methods (such as bootstrapping) are used.
- Three or fewer sample results are available; the maximum detected concentration is used.

Generally speaking, the method ProUCL recommends is based upon the sample size, distribution of the data, sample standard deviation, and level of data censorship (number of nondetects). Details are provided in the "ProUCL Version 4.00.04 User Guide" (EPA 2009, 106601) and "ProUCL Version 4 Technical Guide" (EPA 2007, 106124).

When ProUCL recommended a UCL that exceeded the maximum value for the data, a UCL calculated using one of the alternative methods was used. This approach is consistent with EPA guidance (EPA 2009, 106601). The calculated EPCs based upon the ProUCL UCLs for sediments are provided in Tables 8.2-8 and E-2.2-1. ProUCL results and assorted information are provided in Attachment E-1 on CD.

E-2.3 Nonstorm-Related Surface-Water EPCs

Only nonstorm-related surface-water samples were evaluated and samples collected before 2003 were excluded. The pre-2003 results are not used to calculate EPCs because concentrations in older samples are not representative of current site conditions. Field duplicates (indicated by "FD" in the field quality control [QC] type code column in Appendix C tables) were excluded from EPC calculations. These results are from samples obtained for quality assurance (QA)/QC purposes and not as primary characterization data. Filtered water sample results were excluded, and unfiltered water sample results were used to represent surface water that could be encountered during recreational activities in the canyons. Unfiltered samples provide a protective estimate in that concentrations in unfiltered samples are typically larger than in filtered samples.

Surface-water data were evaluated for each sediment investigation reach. Table E-2.3-1 presents the EPCs for surface-water COPCs retained for the human health risk assessment. Because of the small samples sizes for some of the COPCs evaluated or the small number of detects, maximum detected values were frequently used as the EPCs for water, which are provided in Tables 8.2-9 and E-2.3-1. In other cases, there were sufficient sampling results, and the ProUCL recommend values were used as EPC. The exception, as noted above, is for cases where the recommended UCL was larger than the maximum detected value. The calculated EPCs based upon the ProUCL UCLs for nonstorm-related surface water are also provided in Tables 8.2-9 and E-2.3-1. ProUCL results and assorted information are provided in Attachment E-1 on CD.

E-2.4 Supplemental Human Health Risk Scenario

The SSLs and SALs used for the supplemental human health risk scenario (residential) are provided in Table E-2.4-1. The risk assessment results for the residential scenario are summarized in Table E-2.4-2. The ratios and sum of fraction (SOF) values for the residential scenario are provided in Table E-2.4-3. Sediment EPCs used for this analysis are provided in Tables 8.2-8 and E-2.2-1. Polychlorinated biphenyl (PCB) congener analysis results for the residential scenario are presented in Table E-2.4-4.

E-2.5 Calculation of Surface-Water Recreational Screening Levels

The method used to calculate the surface-water SLs is based upon the methodology used to calculate the recreational SSLs (LANL 2007, 094496) and EPA Risk Assessment Guidance for Superfund, Part E (EPA 2004, 090800). The equations used for noncarcinogens, carcinogens, and radionuclides are detailed below. The parameter values used for the calculations were presented in Table E-2.1-3.

Noncarcinogens

$$SWSL\,(ug/L) = \frac{(1000\,ug/ml)\,x\,(AT_{cnc}\,x\,THQ\,x\,BW_c)}{(EF\,x\,ED)\,x\,[(\frac{Ing}{RfDo}) + (\frac{ET\,x\,SA_c\,x\,Kp\,x\,0.001\,L/cm^3}{RfDd})]}$$

Carcinogens

$$SWSL\,(ug/L) = \frac{(1000\,ug/ml)\,x\,(AT_c\,x\,TR)}{(EF/ET)\,x\,[(IFSW\,x\,SFo) + (DFSW\,x\,Kp\,x\,SFd\,x\,0.001\,L/cm^3)]}$$

Radionuclides

$$SWSL(pCi/L) = \frac{TD}{EF \times Ing \times DCFi}$$

Where, $SFd = SFo / GIAbs\ Factor$

$$RfDd = RfDo\,x\,GIAbs\ Factor$$

$$IFSW = \frac{ED_c\,x\,Ing}{BW_c} + \frac{(ED - ED_c)\,x\,Ing}{BW}$$

$$DFSW = \frac{ED_c\,x\,SA_c}{BW_c} + \frac{(ED - ED_c)\,x\,SA}{BW}$$

and SWSL = surface-water SL

AT_{cnc} = averaging time, child, noncarcinogens

AT_c = averaging time, carcinogens

BW_c = body weight, child

BW = body weight, adult

EF = exposure frequency

ED = exposure duration

ED_c = exposure duration, child

ET = exposure time

GIABs factor = gastrointestinal absorption factor

SA_c = exposure surface area, child

SA = exposed surface area, adult

Kp = dermal permeability constant

Ing = surface-water ingestion quantity per event

IFSW = age-adjusted surface water ingestion factor

DFSW = age-adjusted surface water dermal absorption factor

SFo = oral slope factor

SFd = dermal slope factor

RfDo = oral reference dose

RfDd = dermal reference dose

DCFi = ingestion dose conversion factor

THQ = target hazard quotient

TR = target risk

TD = target dose

E-3.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Colestock, K.L., 2007. "Landscape Scale Assessment of Contaminant Effects on Cavity-Nesting Birds," master's thesis for a Master of Science in Ecology, Utah State University, Logan, Utah. (Colestock 2007, 102994)

EPA (U.S. Environmental Protection Agency), December 1989. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final," EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C. (EPA 1989, 008021)

EPA (U.S. Environmental Protection Agency), August 1997. "Exposure Factors Handbook, Volume I, General Factors," EPA/600/P-95/002Fa, Office of Research and Development, Washington, D.C. (EPA 1997, 066596)

EPA (U.S. Environmental Protection Agency), August 1997. "Exposure Factors Handbook, Volume III, Activity Factors," EPA/600/P-95/002Fc, Office of Research and Development, Washington, D.C. (EPA 1997, 066598)

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EPA (U.S. Environmental Protection Agency), April 2007. "ProUCL Version 4.0 Technical Guide," EPA/600/R-07/041, Office of Research and Development, Washington, D.C. (EPA 2007, 106124)

EPA (U.S. Environmental Protection Agency), February 2009. "ProUCL Version 4.00.04 User Guide (Draft)," EPA/600/R-07/038, Office of Research and Development, Washington, D.C. (EPA 2009, 106601)

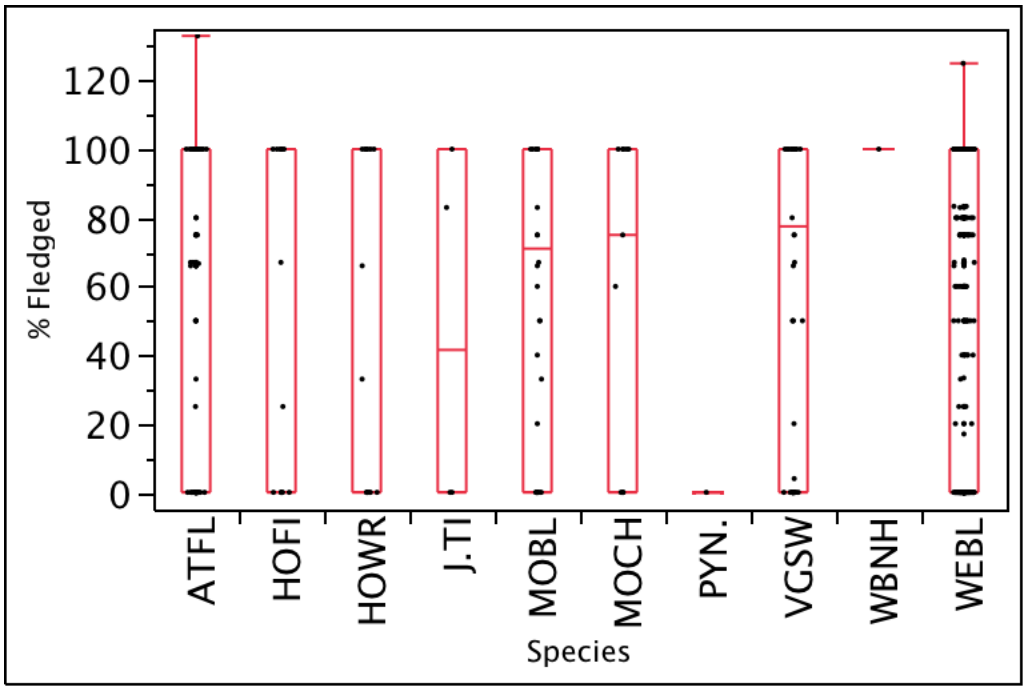
LANL (Los Alamos National Laboratory), May 2005. "Derivation and Use of Radionuclide Screening Action Levels, Revision 1," Los Alamos National Laboratory document LA-UR-05-1849, Los Alamos, New Mexico. (LANL 2005, 088493)

LANL (Los Alamos National Laboratory), January 2007. "Technical Approach for Calculating Recreational Soil Screening Levels for Chemicals," Los Alamos National Laboratory document LA-UR-06-8828, Los Alamos, New Mexico. (LANL 2007, 094496)

LANL (Los Alamos National Laboratory), December 2007. "Standard Human Health Risk Assessment Scenarios, Revision 3," Los Alamos National Laboratory document LA-UR-07-6427, Los Alamos, New Mexico. (LANL 2007, 099829)

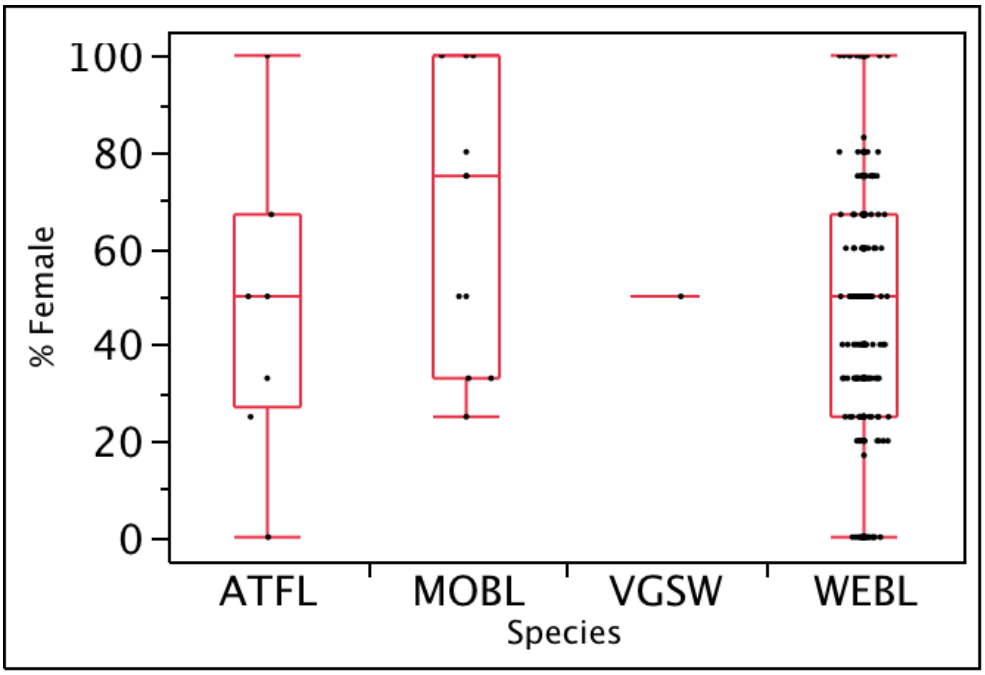
LANL (Los Alamos National Laboratory), October 2008. "Ecorisk Database (Release 2.3)," on CD, LA-UR-08-6673, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2008, 103352)

NMED (New Mexico Environment Department), August 2009. "Technical Background Document for Development of Soil Screening Levels, Revision 5.0," New Mexico Environment Department, Hazardous Waste Bureau and Ground Water Quality Bureau Voluntary Remediation Program, Santa Fe, New Mexico. (NMED 2009, 106420)



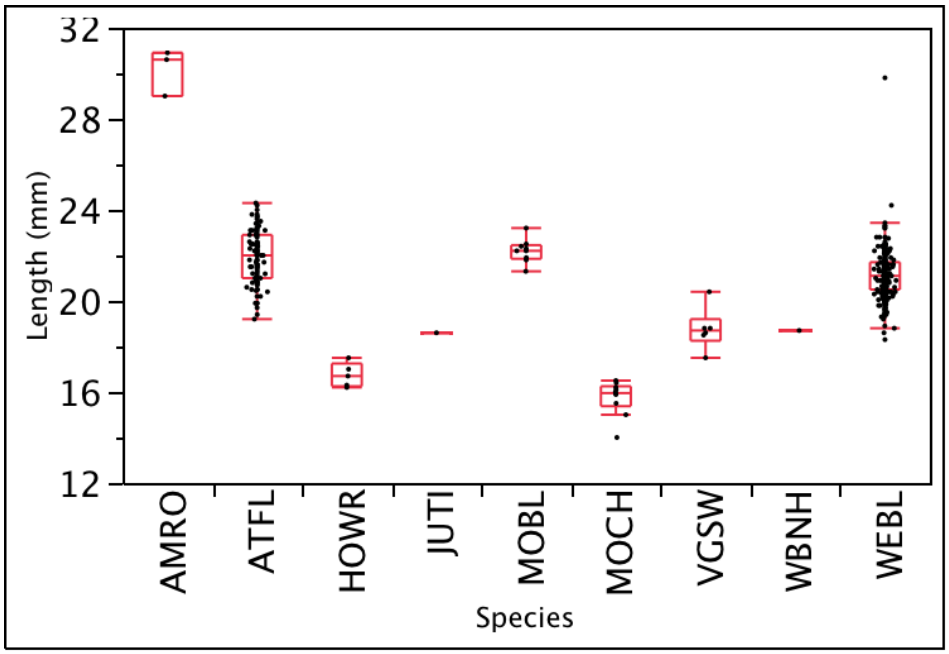
Note: ATFL = ash-throated flycatcher, HOFI = house finch, HOWR = house wren, J.TI = juniper titmouse, MOBL = mountain bluebird, MOCH = mountain chickadee, PYN. = pygmy nuthatch, VGSW = violet-green swallow, and WBNH = white-breasted nuthatch, WEBL = western bluebird.

Figure E-1.3-1 Box plot comparing the percent fledged across avian species



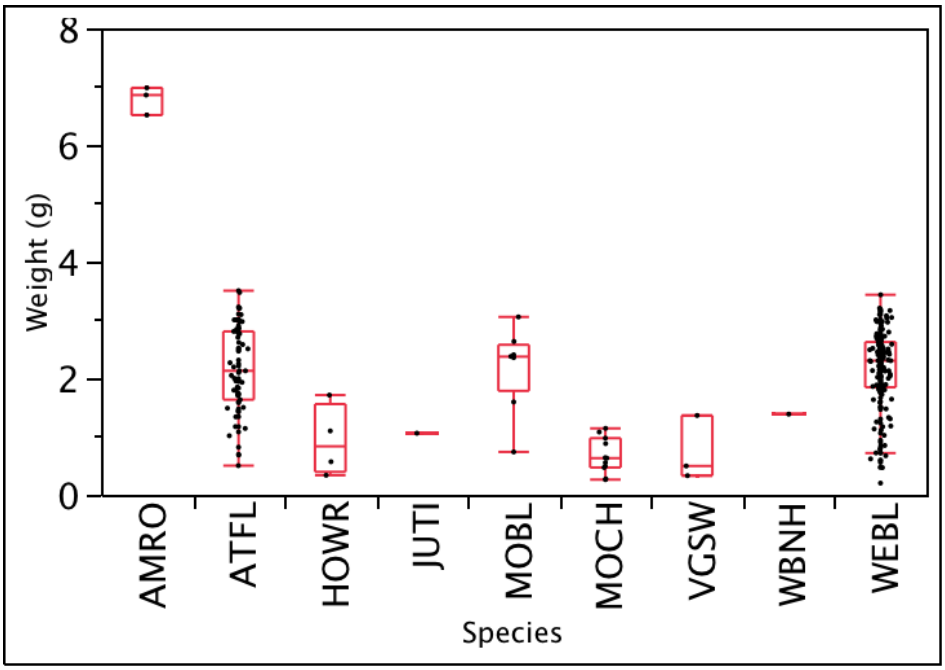
Note: ATFL = ash-throated flycatcher, MOBL = mountain bluebird, VGSW = violet-green swallow, and WEBL = western bluebird.

Figure E-1.3-2 Box plot comparing the percent female nestlings across avian species



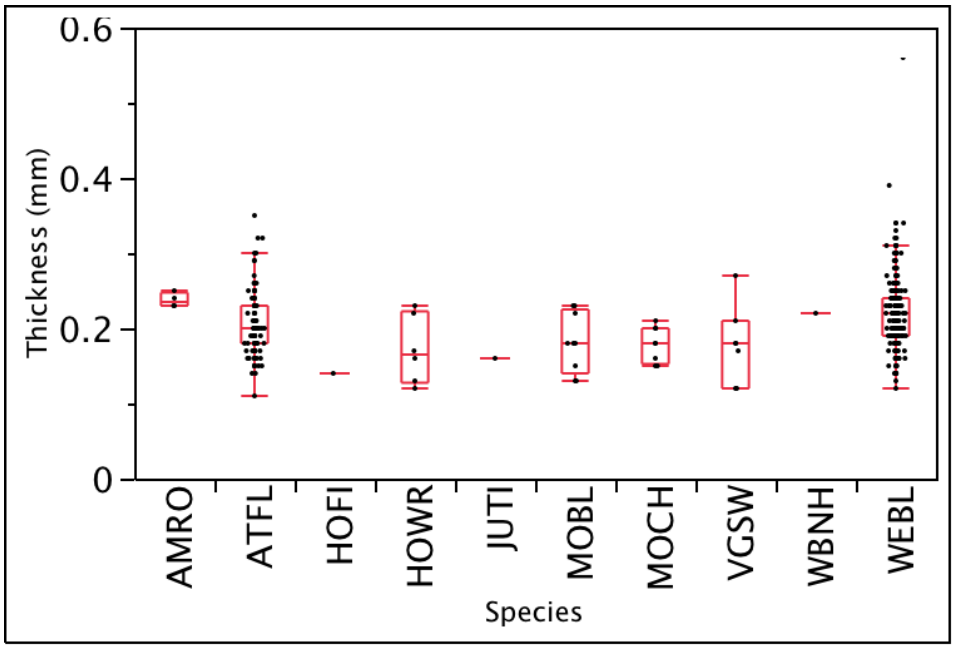
Note: AMRO = American robin, ATFL = ash-throated flycatcher, HOWR = house wren, JUTI = juniper titmouse, MOBL = mountain bluebird, MOCH = mountain chickadee, VGSW = violet-green swallow, WBNH = white-breasted nuthatch, and WEBL = western bluebird.

Figure E-1.3-3 Box plot comparing egg length across species



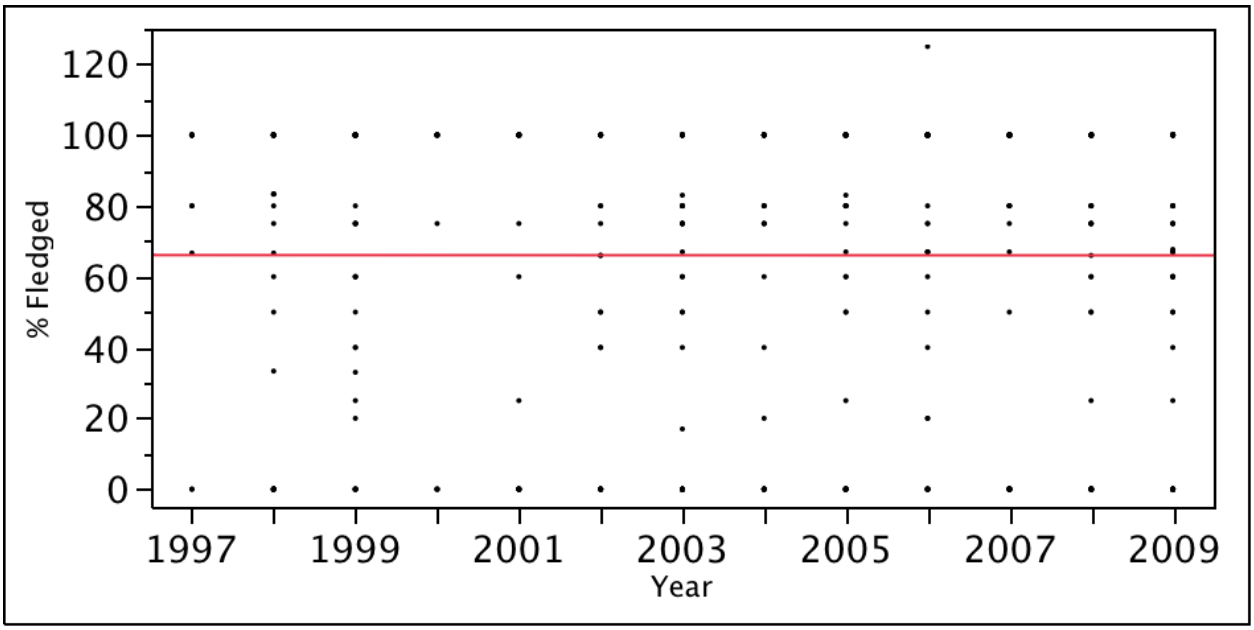
Note: AMRO = American robin, ATFL = ash-throated flycatcher, HOWR = house wren, JUTI = juniper titmouse, MOBL = mountain bluebird, MOCH = mountain chickadee, VGSW = violet-green swallow, WBNH = white-breasted nuthatch, and WEBL = western bluebird.

Figure E-1.3-4 Box plot comparing egg weight across species



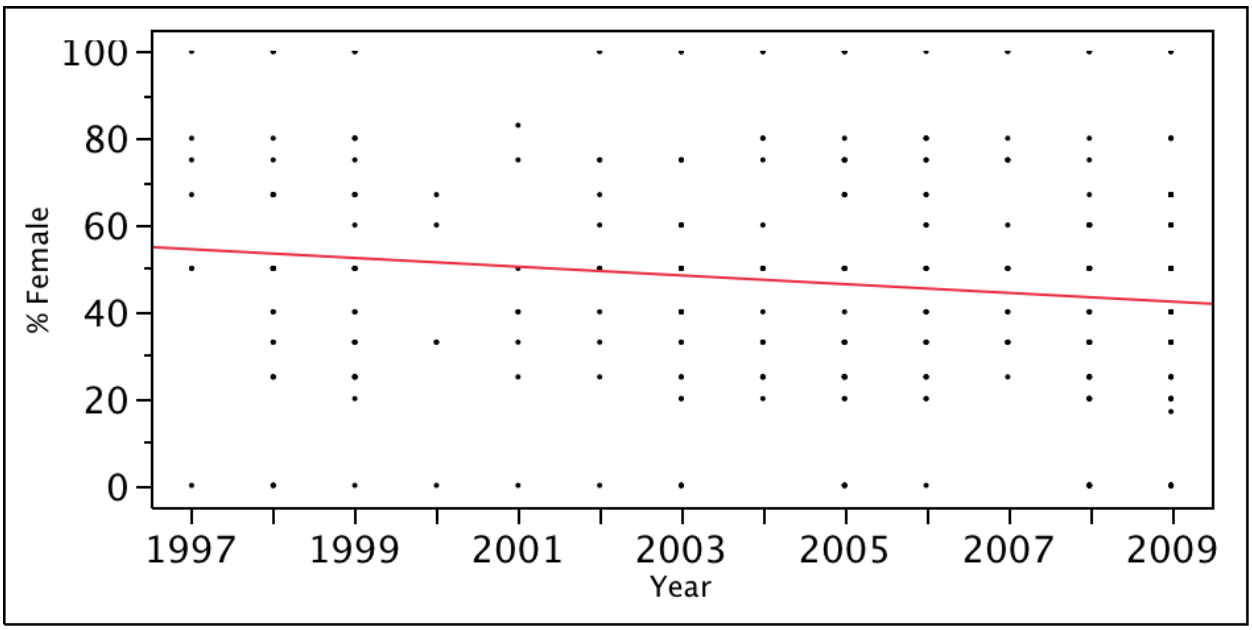
Note: AMRO = American robin, ATFL = ash-throated flycatcher, HOFI = house finch, HOWR = house wren, JUTI = juniper titmouse, MOBL = mountain bluebird, MOCH = mountain chickadee, VGSW = violet-green swallow, WBNH = white-breasted nuthatch, and WEBL = western bluebird.

Figure E-1.3-5 Box plot comparing eggshell thickness across species



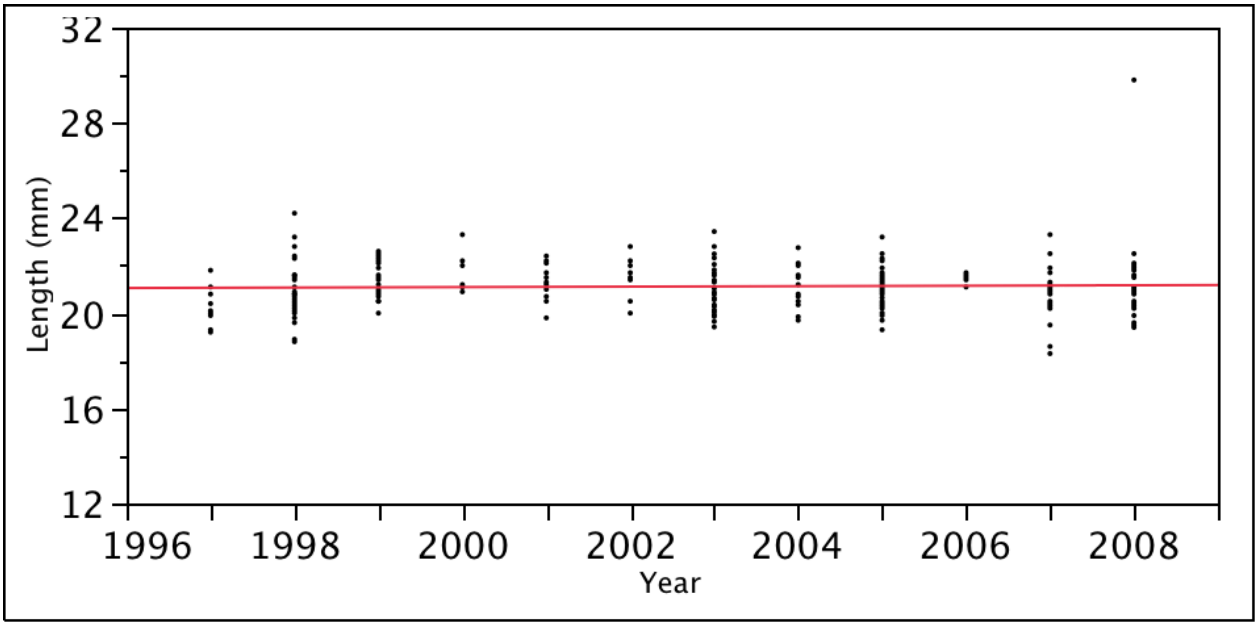
Note: The linear regression line explained variance is <1%, so it is not biologically relevant.

Figure E-1.3-6 Scatter plot of percent of nestlings fledged versus year for western bluebirds



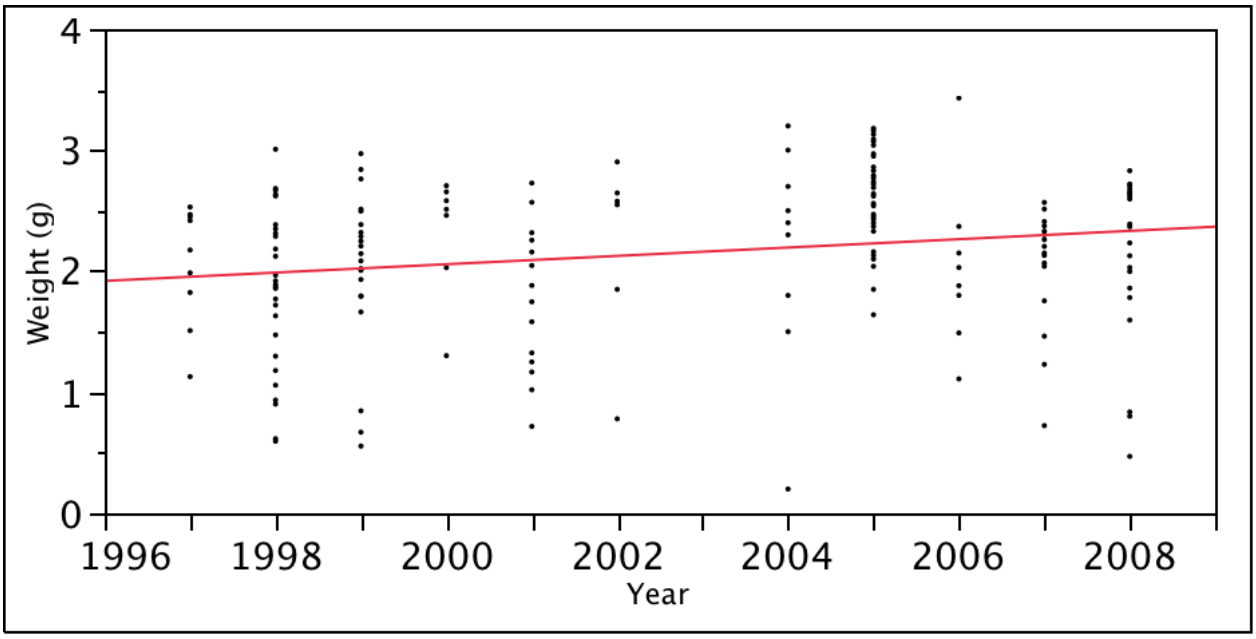
Note: The linear regression line explained variance is 2%, so it is not biologically relevant.

Figure E-1.3-7 Scatter plot of percent nestlings that are female versus year for western bluebirds



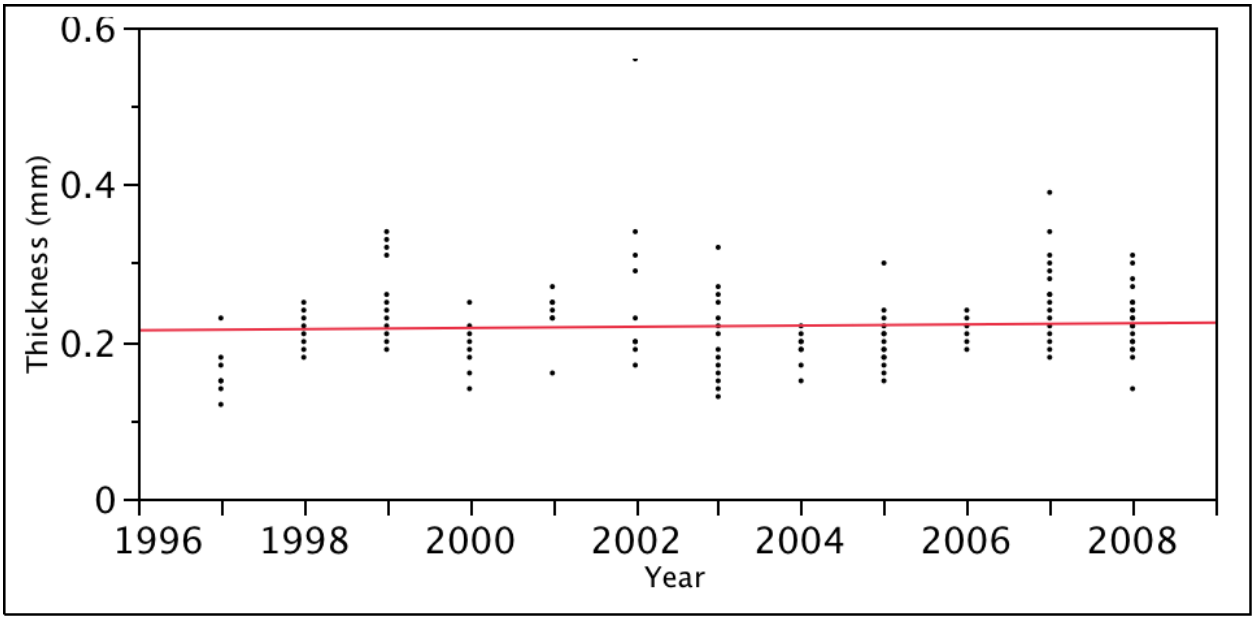
Note: The linear regression line explained variance is <1%, so it is not biologically relevant.

Figure E-1.3-8 Scatter plot of egg length versus year for western bluebirds



Note: The linear regression line explained variance is 3.5%, so it is not biologically relevant.

Figure E-1.3-9 Scatter plot of egg weight versus year for western bluebirds



Note: The linear regression line explained variance is <1%, so it is not biologically relevant.

Figure E-1.3-10 Scatter plot of eggshell thickness versus year for western bluebirds

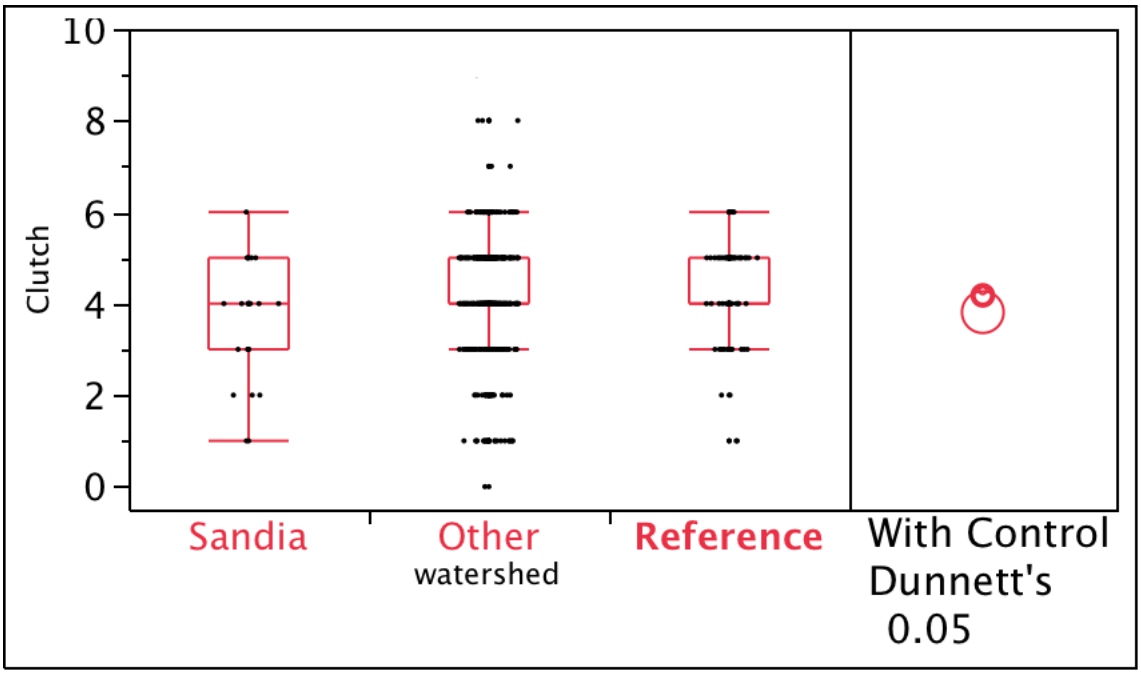


Figure E-1.3-11 Box plots of clutch size for all species by canyon

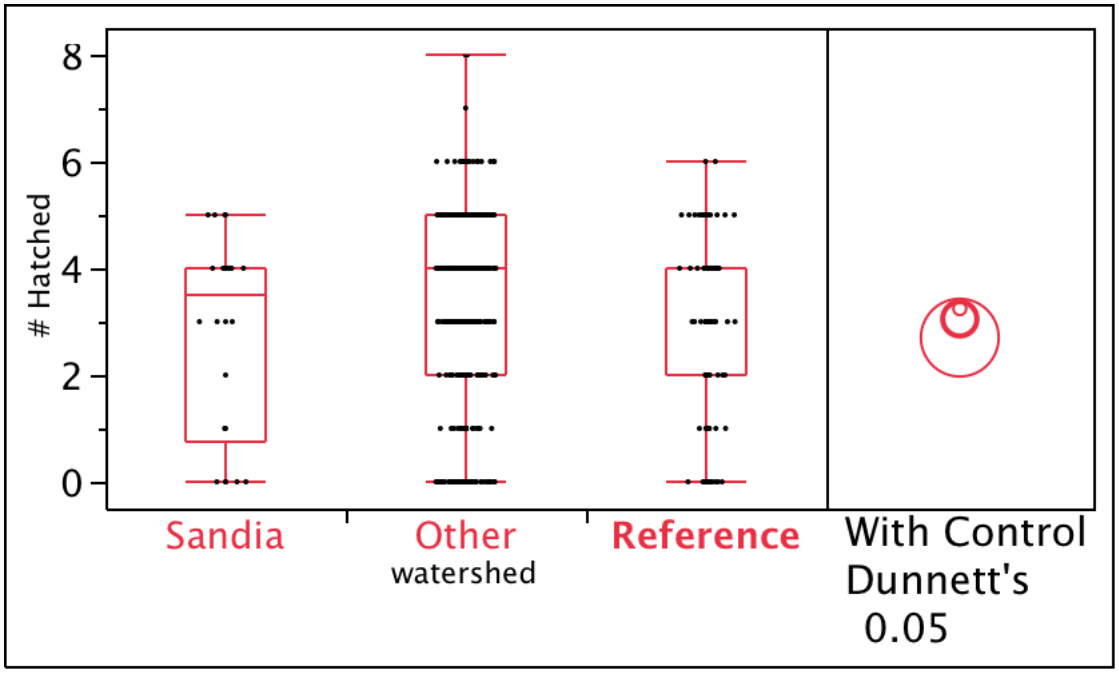


Figure E-1.3-12 Box plots of number hatched for all species by canyon

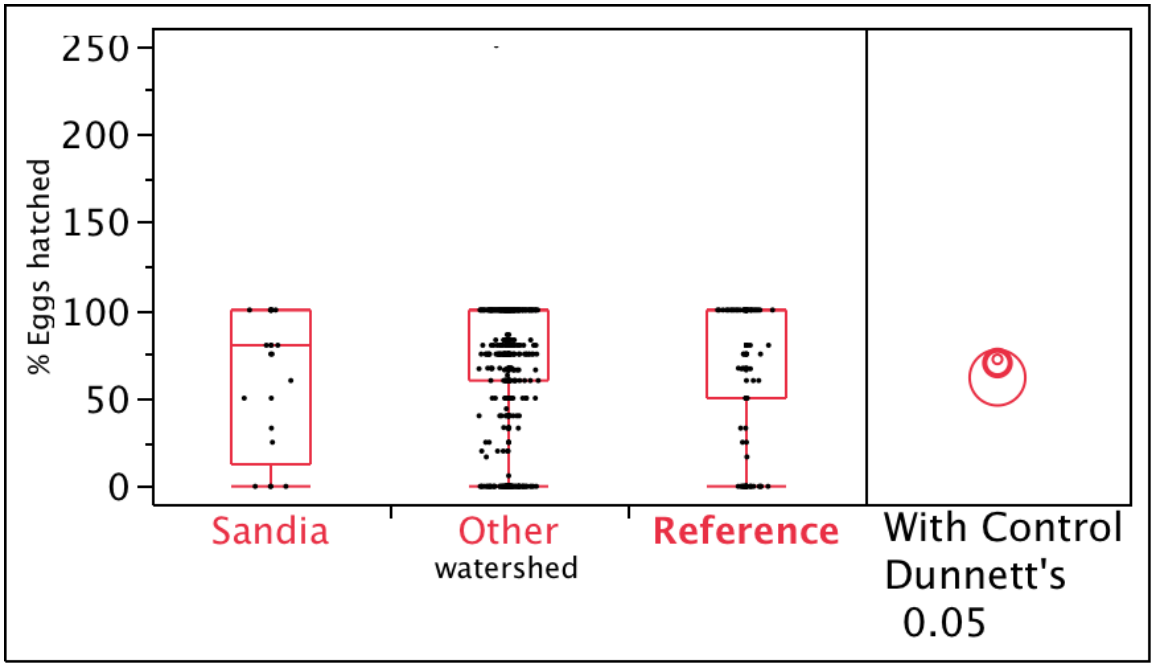


Figure E-1.3-13 Box plots of percentage eggs hatched for all species by canyon

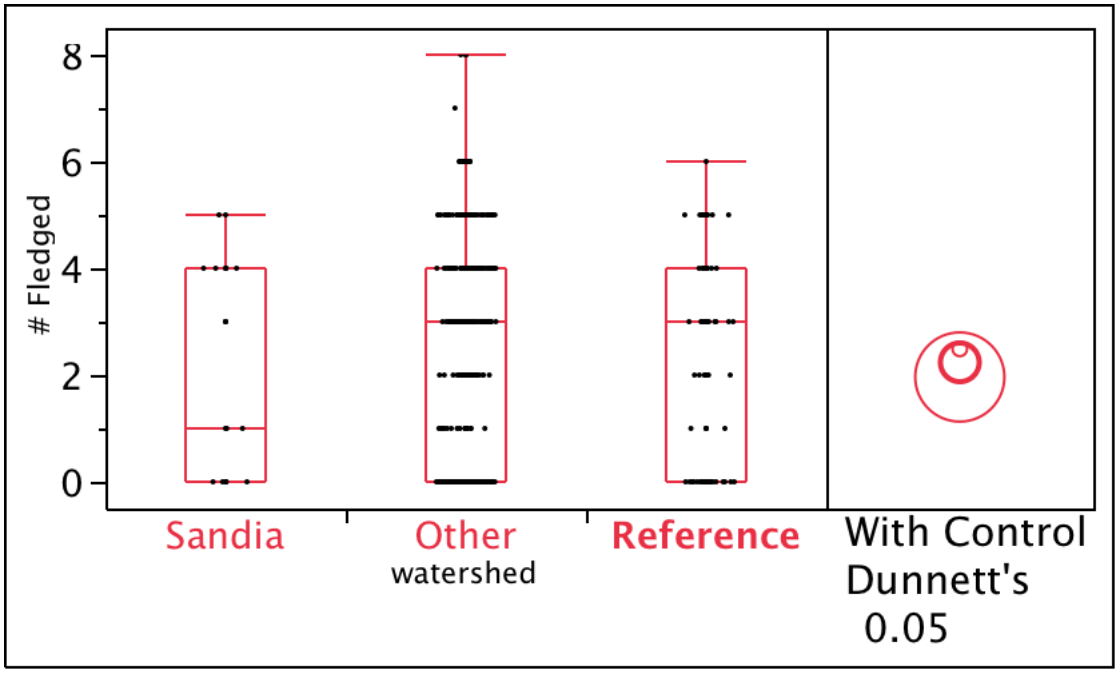


Figure E-1.3-14 Box plots of number fledged for all species by canyon

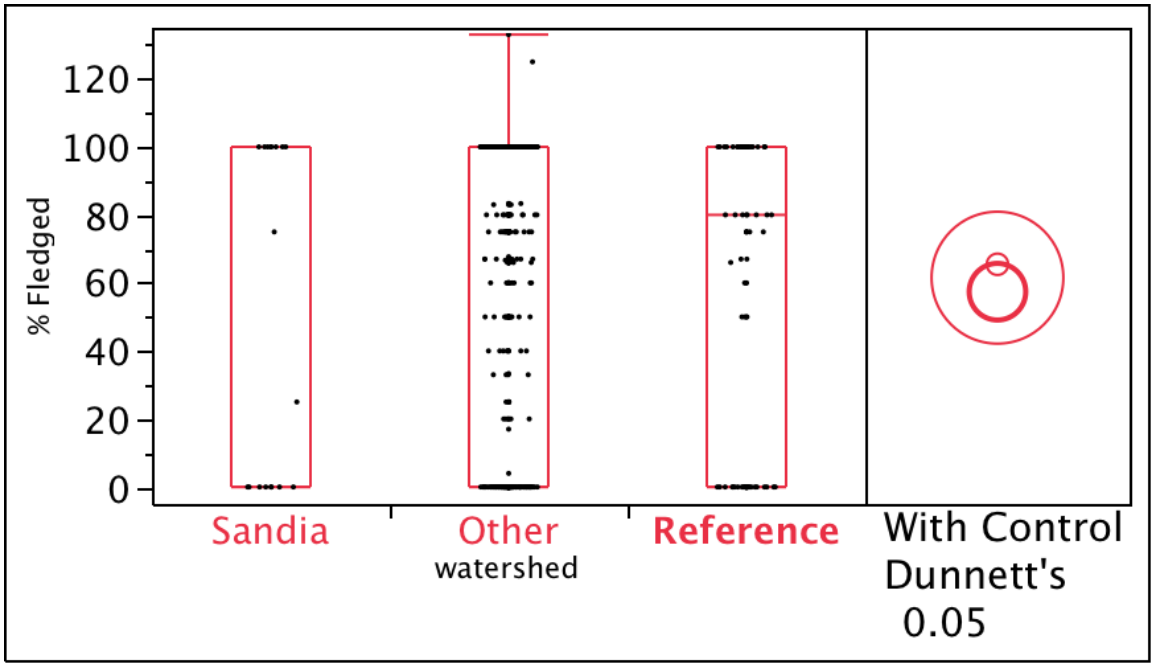


Figure E-1.3-15 Box plots of percentage fledged for all species by canyon

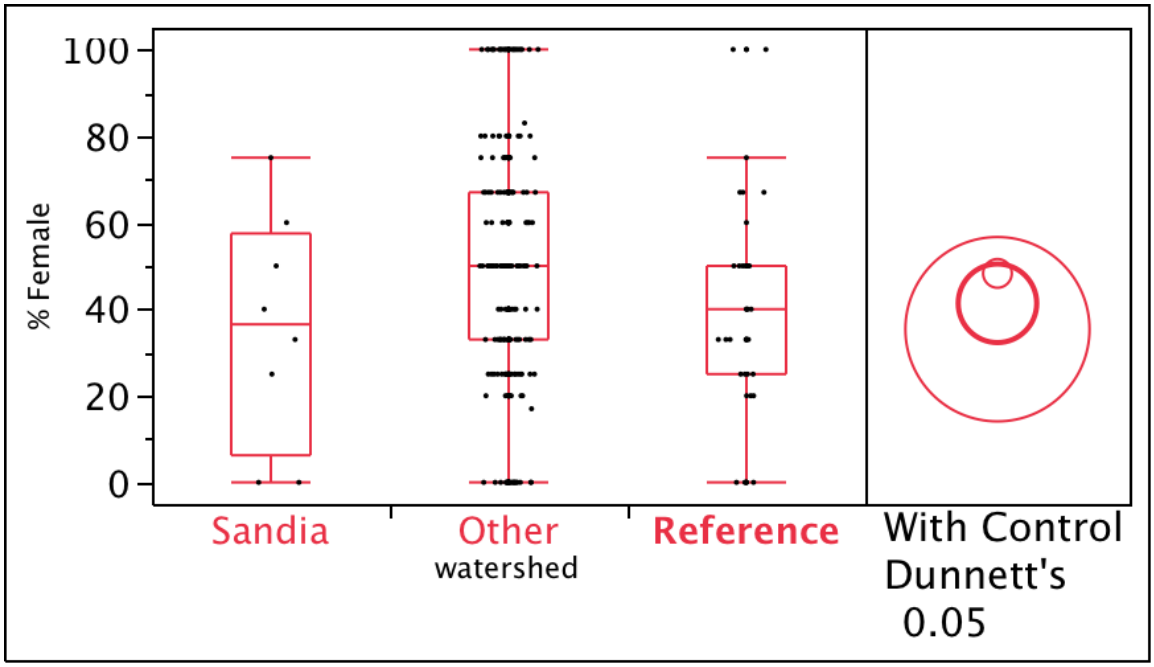


Figure E-1.3-16 Box plots of percentage female for all species by canyon

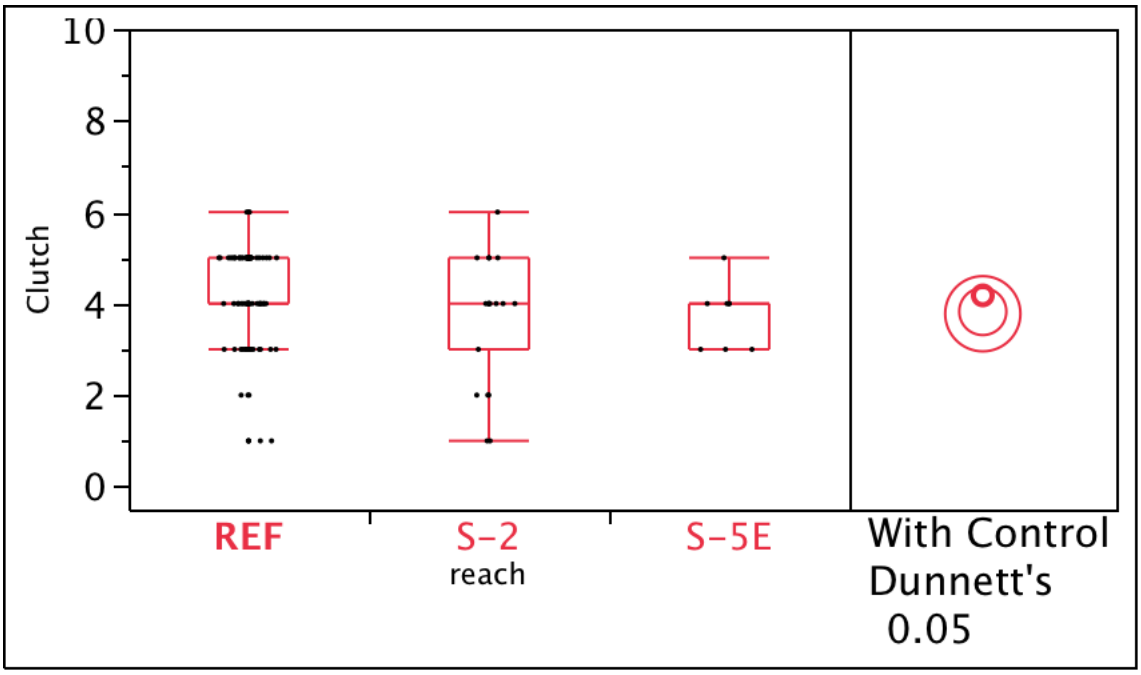


Figure E-1.3-17 Box plots of clutch size for all species by reach

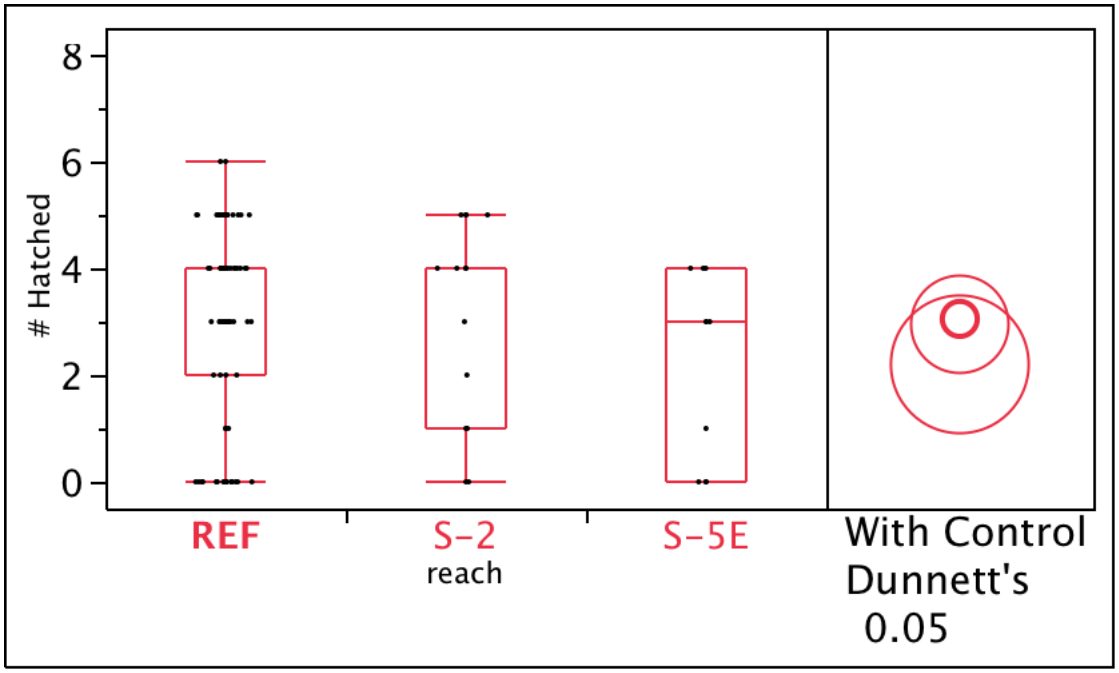


Figure E-1.3-18 Box plots of number hatched for all species by reach

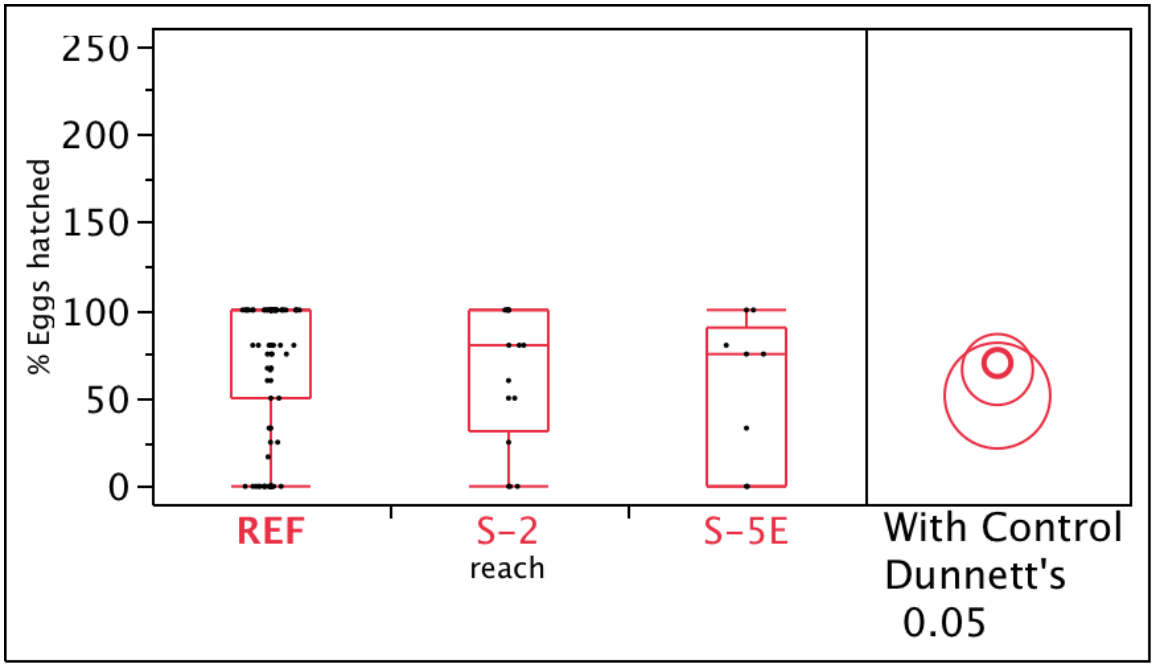


Figure E-1.3-19 Box plots of percentage hatched for all species by reach

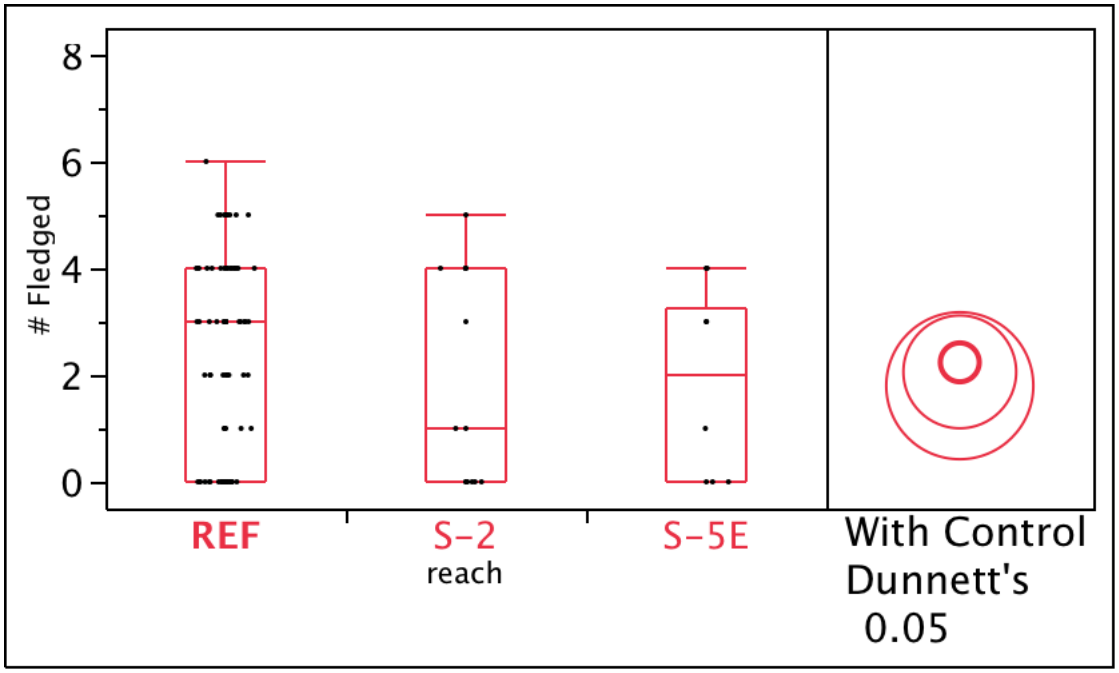


Figure E-1.3-20 Box plots of number fledged for all species by reach

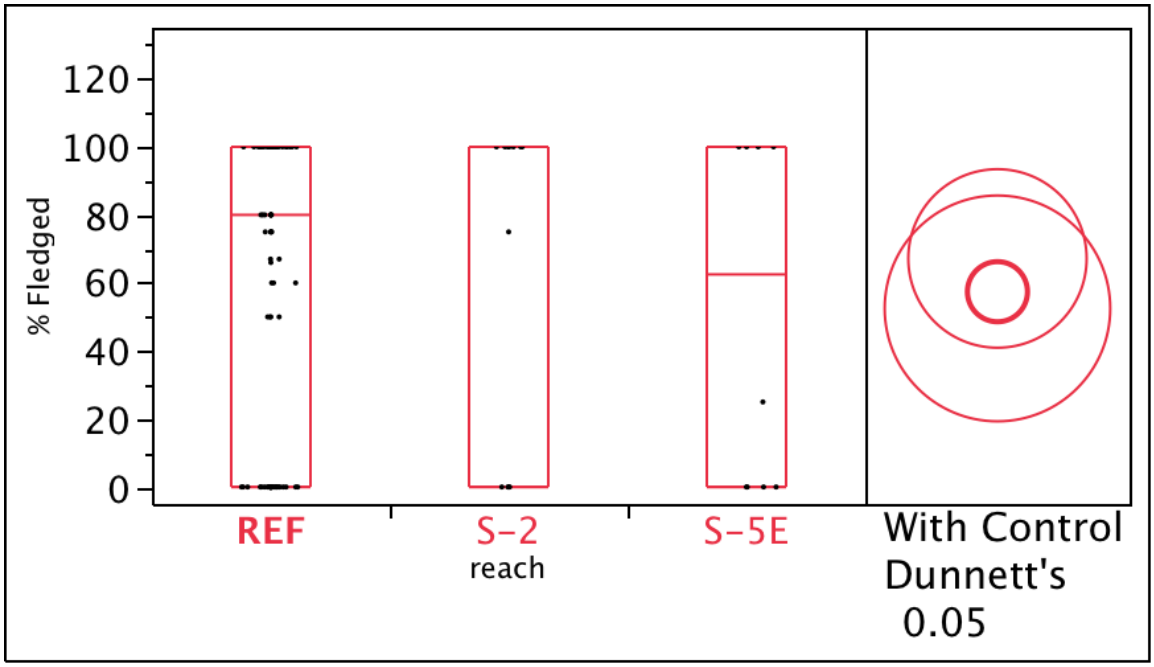


Figure E-1.3-21 Box plots of percentage fledged for all species by reach

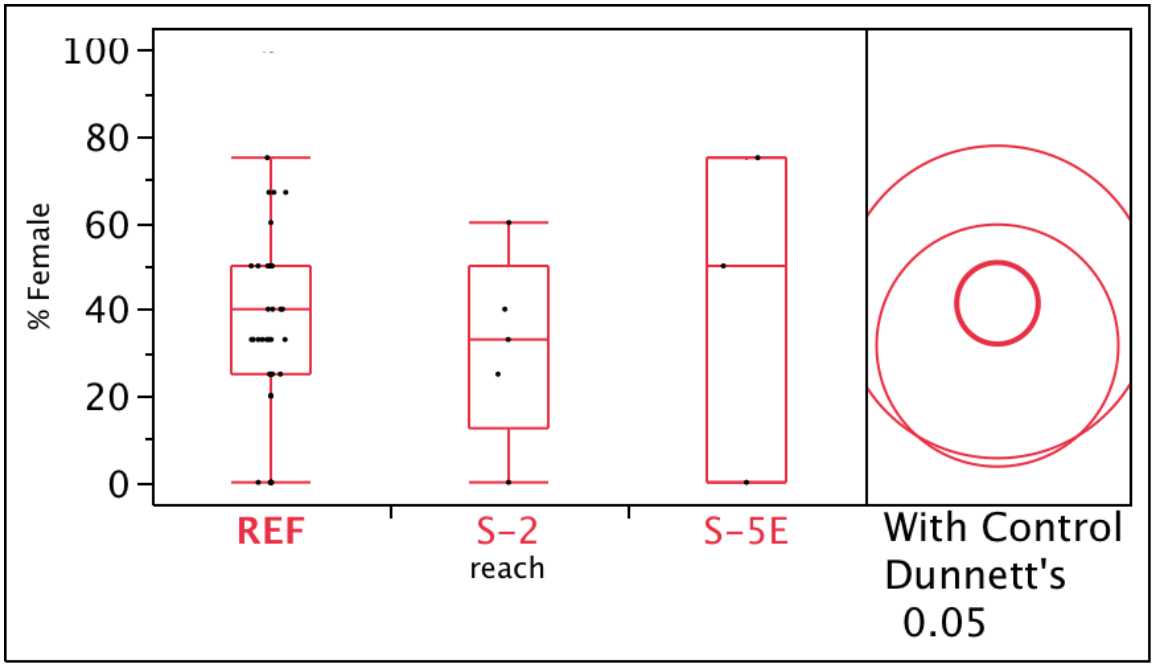


Figure E-1.3-22 Box plots of percentage female for all species by reach

Table E-1.2-1
TRVs for the Ecological Exposure Evaluation

COPEC	Mammalian TRV (mg/kg/d)	Mammalian Carnivore TRV (mg/kg/d)	Bird TRV (mg/kg/d)
Aroclor-1242	0.532	0.532	0.1
Aroclor-1248	0.0099	0.0099	0.1
Aroclor-1254	0.611	0.031	0.1
Aroclor-1260	13.8	0.031	2.15
Barium	51.8	51.8	73.5
Cadmium	0.77	0.77	1.47
Chromium	39.6	39.6	77
Chromium hexavalent ion	9.24	9.24	11
Copper	5.6	5.6	4.05
Cyanide [Total]	68.7	68.7	0.04
DDD[4,4'-]	5.83	5.83	0.016
Dieldrin	0.015	0.015	0.0709
Iron	Na*	na	na
Lead	4.7	4.7	1.63
Mercury	1.41	1.41	0.019
Methyl Mercury	0.032	0.032	0.0064
Nickel	1.7	1.7	6.71
Perchlorate	na	na	na
Selenium	0.143	0.143	0.29
Silver	6.02	6.02	2.02
Thallium	0.0071	0.0071	0.35
Total PCB	na	na	na
Zinc	75.4	75.4	66.1
Tetrachlorodibenzodioxin[2,3,7,8-] is used for Mammal TEC	5.62E-07	5.62E-07	na
Bird TEC	na	na	na

*na = No TRV is available for this receptor class.

Table E-1.2-2
Parameters for the Ecological Exposure Evaluation

Class	Receptor	Exposure Media	Body Weight (kg)	Intake (kg/d)	Normalized Intake (kg/kg/d)
Bird	Mexican spotted owl	Insects	0.58	—*	—
Bird	Mexican spotted owl	Mammal	0.58	0.059	0.102
Bird	Mexican spotted owl	Sed	0.58	0.00118	0.00203
Bird	Mexican spotted owl	Worm	0.58	—	—
Bird	Robin	Insects	0.077	0.117	1.52
Bird	Robin	Mammal	0.077	—	—
Bird	Robin	Sed	0.077	0.0117	0.152
Bird	Robin	Worm	0.077	0.117	1.52
Bird	Southwestern willow flycatcher	Insects	0.0127	0.01	0.79
Bird	Southwestern willow flycatcher	Mammal	0.0127	—	—
Bird	Southwestern willow flycatcher	Sed	0.0127	—	—
Bird	Southwestern willow flycatcher	Worm	0.0127	0.01	0.79
Mammal	Bat	Insects	0.0088	0.0036	0.409
Mammal	Bat	Mammal	0.0088	—	—
Mammal	Bat	Sed	0.0088	—	—
Mammal	Bat	Worm	0.0088	0.0036	0.409
Mammal	Fox	Insects	3.94	—	—
Mammal	Fox	Mammal	3.94	0.55	0.14
Mammal	Fox	Sed	3.94	0.0165	0.00419
Mammal	Fox	Worm	3.94	—	—
Mammal	Shrew	Insects	0.015	0.0093	0.62
Mammal	Shrew	Mammal	0.015	—	—
Mammal	Shrew	Sed	0.015	0.00093	0.062
Mammal	Shrew	Worm	0.015	0.0093	0.62

*— = Exposure media are not evaluated for this receptor.

Table E-1.4-1
Summary of Statistically Significant Regressions between Earthworm Survival and Growth and COPECs and Confounding Factors

X-Variable	Model	Explained Variance of Model (r^2)	Significance of Slope (p-value)	Number of Samples
Confounding Factors				
Aluminum	Eisenia fetida end weight = 0.201 + 0.00000875*Aluminum	0.66	<0.01	10
Fine Silt (15-2 µm)	Eisenia fetida end weight = 0.223 + 0.00175*Fine Silt (15-2 µm)	0.59	<0.01	10
Clay (<2 µm)	Eisenia fetida end weight = 0.214 + 0.00345*Clay (<2 µm)	0.59	<0.01	10
Gravel (> 2 mm)	Eisenia fetida end weight = 0.266 - 0.00138*Gravel (> 2 mm)	0.47	0.03	10
Organic Matter	Eisenia fetida end weight = 0.217 + 0.0120*Organic Matter	0.55	0.01	10
Total Silt + Clay	Eisenia fetida end weight = 0.215 + 0.000700*Total Silt + Clay	0.46	0.03	10
Gravel (> 2 mm)	Eisenia fetida percent survival rate = 84.8 - 0.365*Gravel (> 2 mm)	0.51	0.02	10
pH	Eisenia fetida end weight = 0.356 - 0.0198*pH	0.77	<0.01	10
Potassium	Eisenia fetida end weight = 0.202 + 0.0000515*Potassium	0.52	0.02	10
Sodium	Eisenia fetida end weight = 0.2247534 + 0.000164*Sodium	0.44	0.04	10
Total Phosphate as Phosphorus	Eisenia fetida end weight = 0.2369693 + 0.0000518*Total Phosphate as Phosphorus	0.41	0.05	10

Table E-1.5-1
Summary of Statistically Significant Regressions between Ryegrass Germination and Growth and COPECs and Confounding Factors

X-Variable	Model	Explained Variance of Model (r^2)	Significance of Slope (p-value)	Number of Samples
Confounding Factors				
Fine Sand (0.25–0.125 mm)	Ryegrass Shoot wt surv organism (mg) = 0.500 + 0.0331*Fine Sand (0.25-0.125 mm)	0.48	0.03	10
Organic Matter	Ryegrass Fraction Survival = 1.09 - 0.0647*Organic Matter	0.40	0.05	10
Very Fine Sand (0.125–0.0625 mm)	Ryegrass Shoot wt orig organism (mg) = 0.431 + 0.0326*Very Fine Sand (0.125-0.0625 mm)	0.44	0.04	10
Very Fine Sand (0.125–0.0625 mm)	Ryegrass Shoot wt surv organism (mg) = 0.497 + 0.0303*Very Fine Sand (0.125-0.0625 mm)	0.47	0.03	10
Fine Sand (0.25–0.125 mm)	Ryegrass Shoot wt orig organism (mg) = 0.438 + 0.0350*Fine Sand (0.25-0.125 mm)	0.44	0.04	10
Sodium	Ryegrass Fraction Survival = 1.13 - 0.00132*Sodium	0.72	<0.01	10
Sodium	Ryegrass Root wt orig organism (mg) = 0.441 - 0.000718*Sodium	0.46	0.03	10
Sodium	Ryegrass Shoot wt orig organism (mg) = 0.971 - 0.00172*Sodium	0.51	0.02	10
Sodium	Ryegrass Shoot wt surv organism (mg) = 0.978 - 0.00147*Sodium	0.46	0.03	10
COPECs				
Perchlorate	Ryegrass Fraction Survival = 1.07 - 86.8*Perchlorate	0.53	0.02	10
Perchlorate	Ryegrass Shoot wt orig organism (mg) = 0.949 - 140*Perchlorate	0.59	<0.01	10
Perchlorate	Ryegrass Shoot wt surv organism (mg) = 0.974 - 127*Perchlorate	0.60	<0.01	10
Selenium	Ryegrass Fraction Survival = 1.18 - 0.0477*Selenium	0.60	<0.01	10
Zinc	Ryegrass Fraction Survival = 1.05 - 0.00118*Zinc	0.50	0.02	10

Table E-1.6-1
Summary of Statistically Significant Regressions between Chironomid Survival and Growth and COPECs and Confounding Factors

X-Variable	Model	Explained Variance of Model (r^2)	Significance of Slope (p-value)	Number of Samples
Confounding Factors				
Aluminum	Chironomid Survival = 0.916 - 0.0000284*Aluminum	0.38	0.01	16
Gravel (> 2 mm)	Chironomid Survival = 0.886 - 0.0103*Clay (<2 µm)	0.34	0.02	16
Fine Silt (15-2 µm)	Chironomid Survival = 0.870 - 0.00513*Fine Silt (15-2 µm)	0.35	0.01	16
Gravel (> 2 mm)	Chironomid Ash free dry wt (mg) = 0.395 + 0.00255*Gravel (> 2 mm)	0.28	0.04	16
Organic Matter	Chironomid Survival = 0.874 - 0.0408*Organic Matter	0.33	0.02	16
Potassium	Chironomid Survival = 0.919 - 0.000158*Potassium	0.34	0.02	16
Sodium	Chironomid Ash free dry wt (mg) = 0.557 - 0.000522*Sodium	0.33	0.02	16
Sodium	Chironomid Ratio to CTRL ash free dry wt = 1.39 - 0.00117*Sodium	0.29	0.03	16
Sodium	Chironomid Survival = 0.904 - 0.000472*Sodium	0.31	0.02	16
Total Silt + Clay	Chironomid Survival = 0.869 - 0.00182*Total Silt + Clay	0.29	0.03	16
Very Fine Sand (0.125–0.0625 mm)	Chironomid Ash free dry wt (mg) = 0.310 + 0.0547*Very Fine Sand (0.125-0.0625 mm)	0.26	0.05	16
COPECs				
Aroclor-1242	Chironomid Ratio to CTRL ash free dry wt = 1.41 - 6.12*Aroclor-1242	0.31	0.03	16
Aroclor-1248	Chironomid Ratio to CTRL ash free dry wt = 1.41 - 6.12*Aroclor-1248	0.31	0.03	16
Aroclor-1254	Chironomid Ash free dry wt (mg) = 0.500 - 0.240*Aroclor-1254	0.28	0.04	16
Aroclor-1254	Chironomid Ratio to CTRL ash free dry wt = 1.27 - 0.589*Aroclor-1254	0.29	0.03	16
Aroclor-1254	Chironomid Survival = 0.859 - 0.250*Aroclor-1254	0.35	0.02	16
Aroclor-1260	Chironomid Ash free dry wt (mg) = 0.503 - 0.227*Aroclor-1260	0.28	0.03	16
Aroclor-1260	Chironomid Ratio to CTRL ash free dry wt = 1.27 - 0.549*Aroclor-1260	0.29	0.03	16
Aroclor-1260	Chironomid Survival = 0.861 - 0.234*Aroclor-1260	0.35	0.02	16

Table E-1.6-1 (continued)

X-Variable	Model	Explained Variance of Model (r^2)	Significance of Slope (p-value)	Number of Samples
Barium	Chironomid Survival = 0.879 - 0.000895*Barium	0.33	0.02	16
Chromium	Chironomid Ash free dry wt (mg) = 0.529 - 0.00231*Chromium	0.33	0.02	16
Chromium	Chironomid Ratio to CTRL ash free dry wt = 1.32 - 0.00512*Chromium	0.28	0.03	16
Chromium	Chironomid Survival = 0.879 - 0.00209*Chromium	0.31	0.02	16
Copper	Chironomid Ash free dry wt (mg) = 0.502 - 0.00193*Copper	0.29	0.03	16
Copper	Chironomid Ratio to CTRL ash free dry wt = 1.27 - 0.00466*Copper	0.30	0.03	16
Copper	Chironomid Survival = 0.859 - 0.00192*Copper	0.33	0.02	16
Cyanide [Total]	Chironomid Ash free dry wt (mg) = 0.535 - 0.112*Cyanide [Total]	0.35	0.02	16
Cyanide [Total]	Chironomid Ratio to CTRL ash free dry wt = 1.34 - 0.259*Cyanide [Total]	0.33	0.02	16
Iron	Chironomid Survival = 0.951 - 0.0000131*Iron	0.28	0.03	16
Lead	Chironomid Ash free dry wt (mg) = 0.518 - 0.00352*Lead	0.26	0.04	16
Lead	Chironomid Ratio to CTRL ash free dry wt = 1.31 - 0.00839*Lead	0.26	0.04	16
Lead	Chironomid Survival = 0.884 - 0.00402*Lead	0.40	<0.01	16
Mercury	Chironomid Survival = 0.861 - 0.513*Mercury	0.38	0.01	16
Perchlorate	Chironomid Ash free dry wt (mg) = 0.660 - 67.2*Perchlorate	0.35	0.02	16
Perchlorate	Chironomid Ratio to CTRL ash free dry wt = 1.62 - 151*Perchlorate	0.31	0.02	16
Perchlorate	Chironomid Survival = 0.980 - 55.1*Perchlorate	0.29	0.04	16
Selenium	Chironomid Survival = 0.913 - 0.0310*Selenium	0.30	0.03	16
Silver	Chironomid Ash free dry wt (mg) = 0.496 - 0.00714*Silver	0.30	0.03	16
Silver	Chironomid Ratio to CTRL ash free dry wt = 1.26 - 0.0174*Silver	0.31	0.02	16
Silver	Chironomid Survival = 0.850 - 0.00659*Silver	0.29	0.03	16

Table E-2.1-1
Parameters Used to Calculate Chemical Soil-Screening Levels

Parameters	Residential Values[a]	Recreational Values[b] (Adult Trail User and Child Extended Backyard)
Target HQ	1	1
Target cancer risk	1.00E-05	1.00E-05
Averaging time (carcinogen)	70 yr x 365 days	70 yr x 365 days
Averaging time (noncarcinogen)	ED[c] x 365 days	ED x 365 days
Skin absorption factor	SVOC = 0.1	SVOC = 0.1
	Chemical-specific	Chemical-specific
Adherence factor–child	0.2 mg/cm^2	0.2 mg/cm^2
Body weight–child	15 kg (0–6 years of age)	31 kg (6–11 years of age)
Cancer slope factor–oral (chemical-specific)	mg/kg-day^{-1}	mg/kg-day^{-1}
Cancer slope factor–inhalation (chemical-specific)	mg/kg-day^{-1}	mg/kg-day^{-1}
Exposure frequency	350 day/yr	200 event/yr
Exposure duration–child	6 yr (0–6 years of age)	6 yr (6–11 years of age)
Age-adjusted ingestion factor	114 mg-yr/kg-day	22.6 mg-yr/kg-day
Age-adjusted inhalation factor	11 m^3-yr/kg-day	0.8 m^3-yr/kg-day
Inhalation rate–child	10 m^3/day	1.2 m^3/hr
Soil ingestion rate–child	200 mg/day	71.4 mg/day
Particulate emission factor	6.61 x 10^9 m^3/kg	6.61 x 10^9 m^3/kg
Reference dose–oral (chemical-specific)	mg/kg-day	mg/kg-day
Reference dose–inhalation (chemical-specific)	mg/kg-day	mg/kg-day
Exposed surface area–child	2800 cm^2/day (head, hands, forearms, lower legs, feet)	3525 cm^2/day (face, hands, forearms, lower legs, and feet)
Age-adjusted skin contact factor for carcinogens	361 mg-yr/kg-day	273.3 mg-yr/kg-day
Volatilization factor for soil (chemical-specific)	m^3/kg	m^3/kg
Body weight–adult	70 kg	70 kg
Exposure duration	30 yr[d]	30 yr
Adherence factor–adult	0.07 mg/cm^2	0.07 mg/cm^2
Soil ingestion rate–adult	100 mg/day	25.6 mg/event
Exposed surface area–adult	5700 cm^2/day (head, hands, forearms, lower legs)	5700 cm^2/day (head, hands, forearms, lower legs)
Inhalation rate–adult	20 m^3/day	1.6 m^3/hr
Event time	n/a[e]	1 hr

Note: mg/kg-day^{-1} = kilogram day per milligram; mg-yr/kg-day = milligram year per kilogram day.

[a] Parameter values from NMED (2009, 106420).

[b] Parameter values from LANL (2007, 094496).

[c] ED = Exposure duration.

[d] Exposure duration for lifetime resident is 30 yr. For carcinogens, the exposures are combined for child (6 yr) and adult (24 yr).

[e] n/a = Not applicable.

Table E-2.1-2
Parameters Used in the Screening-Level Calculations for Radionuclides, Recreational

Parameters	Trail User, Adult	Extended Backyard, Child
Inhalation rate (m^3/yr)	14,035[a]	10,526[b]
Mass loading (g/m^3)	0.002[c]	0.002[c]
Outdoor time fraction	0.0228[d]	0.0228[d]
Indoor time fraction	0	0
Soil ingestion (g/yr)	225[e]	605[f]
Surface water ingestion	0.2 L/event	0.2 L/event
Surface water exposure frequency	20 event/yr	20 event/yr

[a] Calculated as [1.6 m^3/h × 200 h/yr] / [indoor + outdoor time fractions], where 1.6 m^3/h is the adult inhalation rate for moderate activity (EPA 1997, 066596, Table 5-23).

[b] Calculated as [1.2 m^3/h × 200 h/yr] / [indoor + outdoor time fractions], where 1.6 m^3/h is the adult inhalation rate for moderate activity (EPA 1997, 066596, Table 5-23).

[c] Calculated as (1 / 6.6 × 10+9 m^3/kg) × 1000 g/kg, where 6.6 × 10+9 m^3/kg is the particulate emission factor used for residential and industrial scenarios (NMED 2009, 106420).

[d] Calculated as (1 h/d × 200 d/yr) / 8766 h/yr, where 1 hr/day is the exposure time for a recreational adult or child (LANL 2005, 088493).

[e] Calculated as [(0.1 g/d / 3.9 h/d) × 200 h/yr)] / [indoor + outdoor time fractions]], where 3.9 h/d is the time-weighted average for "doers" across ages 12–44 (EPA 1997, 066598, Table 15-10, data are from a key activity pattern study for adults), and where 0.1 g/d is the adult soil ingestion rate (NMED 2009, 106420).

[f] Calculated as [(0.2 g/d / 2.9 h/d) × 200 h/yr)] / [indoor + outdoor time fractions] where 2.9 h/d is the time-weighted average across ages 5–11 (EPA 1997, 066598, Table 15-10, data are from a key activity pattern study for adults), and where 0.2 g/d is the child soil ingestion rate (NMED 2009, 106420).

Table E-2.1-3
Parameters Used to Calculate Chemical Surface-Water Screening Levels

Parameters	Recreational (Adult Trail User and Child Extended Backyard) Values[a]
Target HQ	1
Target cancer risk	1.00E-05
Averaging time (carcinogen)	70 yr x 365 days
Averaging time (noncarcinogen)	ED[b] x 365 days
Skin absorption factor	SVOC = 0.1
	Chemical-specific
Cancer slope factor–oral (chemical-specific)	$mg/kg\text{-}day^{-1}$
Cancer slope factor–inhalation (chemical-specific)	$mg/kg\text{-}day^{-1}$
Reference dose–oral (chemical-specific)	mg/kg-day
Reference dose–inhalation (chemical-specific)	mg/kg-day
Body weight–child	31 kg (6-11 years of age)
Exposure duration–child	6 yr (6-11 years of age)
Exposed surface area–child	3140 cm^2 (hands, forearms, lower legs, and feet)
Body weight–adult	70 kg
Surface Water Ingestion	0.2 L/event
Exposure duration–adult	30 yr
Exposed surface area[c]–adult	2130 cm^2 (hands and feet)
Exposure Time	1 hr/d
Exposure Frequency[c]	20 d/yr

Note: $mg/kg\text{-}day^{-1}$ = kilogram day per milligram; mg/kg-day = milligrams per kilogram per day.

[a] Parameter values from LANL (2007, 099829) unless otherwise noted.

[b] ED = Exposure duration,

[c] Parameter value from LANL 2004, 087390.

Table E-2.1-4
Parameters Used in the Screening Level Calculations for Radionuclides, Residential

Parameters	Residential, Child	Residential, Adult
Inhalation rate (m^3/yr)	3652.5[a]	7305[b]
Mass loading (g/m^3)	1.5 x 10^{-7} [c]	1.5 x 10^{-7} [c]
Outdoor time fraction	0.2236[d]	0.0599[e]
Indoor time fraction	0.7347[f]	0.8984[g]
Soil ingestion (g/yr)	73[h]	36.5[i]

[a] Calculated as [10 m^3/day x 350 day/yr] / [indoor + outdoor time fractions], where 10 m^3/day is the daily inhalation rate of a child (NMED 2009, 106420).

[b] Calculated as [20 m^3/day x 350 day/yr] / [indoor + outdoor time fractions], where 20 m^3/day is the daily inhalation rate of an adult (NMED 2009, 106420).

[c] Calculated as [1/ 6.6 x 10^{+9} m^3/kg) x 1000 g/kg, where 6.6 x 10^{+9} m^3/kg is the particulate emission factor (NMED 2009, 106420).

[d] Calculated as [5.6 hr/day x 350 day/yr] / 8766 hr/yr, where 5.6 hr/day is an estimate of time spent outdoors for a 3–11 yr old child (EPA 1997, 066598, Section 15.4-1).

[e] Calculated as [1.5 hr/day x 350 day/yr] / 8766 hr/yr, where 1.5 hr/day is an estimate of time spent outdoors for an adult 12 yr and older (EPA 1997, 066598, Section 15.4-1).

[f] Calculated as [(24-5.6 hr/day x 350 day/yr] / 8766 hr/yr.

[g] Calculated as [(24-1.5 hr/day x 350 day/yr] / 8766 hr/yr.

[h] Calculated as [0.2 g/day x 350 day/yr] / [indoor + outdoor time fractions], where 0.2 g/day is the child soil ingestion rate (NMED 2009, 106420).

[i] Calculated as [0.1 g/day x 350 day/yr] / [indoor + outdoor time fractions], where 0.1 g/day is the adult soil ingestion rate (NMED 2009, 106420).

Table E-2.1-5
Toxicity Values for Chemical COPCs for which
Surface Water Chemical Screening Values Were Calculated

Compound	Oral Slope Factor (mg/kg-day)$^{-1}$	Reference[a]	Reference Dose Oral (mg/kg-day)	Reference[a]
1,4-Dioxane	1.10E-02	IRIS	na[b]	na
Aroclor-1254	na	na	2.00E-05	IRIS
Aroclor-1260	2.00E+00	IRIS	na	na
Arsenic	1.50E+00	IRIS	3.00E-04	IRIS
BHC[delta-][c]	1.80E+00	IRIS	na	na
Bromodichloromethane	6.20E-02	IRIS	2.00E-02	IRIS
Chlorodibromomethane	8.40E-02	IRIS	2.00E-02	IRIS
Chloroform	3.10E-02	IRIS	1.00E-02	IRIS
Chloride	na	na	3.89E-01	IRIS
Chromium	na	na	3.00E-03	IRIS
Fluoride	na	na	6.00E-02	IRIS
Manganese	na	na	1.40E-01	IRIS
Perchlorate	na	na	7.00E-04	IRIS
Thallium	na	na	6.60E-05	IRIS
Vanadium	na	na	5.00E-03	IRIS

Note: mg/kg-day^{-1} = kilogram day per milligram; mg-yr/kg-day = milligram year per kilogram day.

[a] IRIS = Integrated Risk Information System.

[b] na = Not available.

[c] beta-BHC surrogate.

Table E-2.2-1
EPCs for Sediment COPCs

Reach	Analyte	Number Detects	Number Nondetects	% NDs	Minimum Detected (µg/L)	Maximum Detected (µg/L)	Mean (µg/L)	Median (µg/L)	Standard Deviation	Skewness	Coefficient of Variation	UCL	Units	UCL Method
S-1N	Aroclor-1248	3	8	73%	0.0604	0.354	0.17	0.0942	0.161	1.646	0.948	0.146	mg/kg	95% KM (t) UCL
S-1N	Aroclor-1254	10	1	9%	0.0046	0.559	0.113	0.0392	0.183	2.102	1.62	0.337	mg/kg	95% KM (Chebyshev) UCL
S-1N	Aroclor-1260	10	1	9%	0.0027	1.58	0.246	0.0316	0.508	2.49	2.068	1.147	mg/kg	97.5% KM (Chebyshev) UCL
S-1N	Arsenic	10	0	0%	2.02	6.05	3.951	3.965	1.264	0.204	0.32	4.684	mg/kg	95% Student's-t UCL
S-1N	Benzo[a]anthracene	8	2	20%	0.0549	17	3.318	1.48	5.668	2.562	1.708	9.914	mg/kg	95% KM (Chebyshev) UCL
S-1N	Benzo(a)pyrene	7	3	30%	0.083	10.4	2.448	1.14	3.605	2.351	1.472	3.681	mg/kg	95% KM (BCA) UCL
S-1N	Benzo[b]fluoranthene	6	4	40%	0.18	18.2	4.993	2.58	6.605	2.226	1.323	7.072	mg/kg	95% KM (BCA) UCL
S-1N	Indeno[1,2,3-cd]pyrene	1	9	90%	1.23	1.23	1.23	1.23	—*	—	—	1.23	mg/kg	Maximum Detected
S-1N	Iron	10	0	0%	3720	29500	11081	9490	6837	2.514	0.617	16138	mg/kg	95% H-UCL
S-1N	Lead	10	0	0%	6.89	46.3	21.37	20.95	12.05	0.74	0.564	28.35	mg/kg	95% Student's-t UCL
S-1S	Aroclor-1260	22	1	4%	0.04	11	0.828	0.327	2.287	4.588	2.763	3.719	mg/kg	97.5% KM (Chebyshev) UCL
S-1S	Arsenic	15	0	0%	1.43	4.61	2.811	2.65	0.859	0.588	0.306	3.201	mg/kg	95% Student's-t UCL
S-1S	Benzo[a]anthracene	10	1	9%	0.0427	3.6	0.869	0.594	1.004	2.661	1.155	2.09	mg/kg	95% KM (Chebyshev) UCL
S-1S	Benzo(a)pyrene	8	4	33%	0.206	3.3	0.787	0.447	1.029	2.684	1.308	1.106	mg/kg	95% KM (BCA) UCL
S-1S	Benzo[b]fluoranthene	4	8	67%	0.555	3	1.404	1.03	1.099	1.645	0.783	1.281	mg/kg	95% KM (t) UCL
S-1S	Indeno[1,2,3-cd]pyrene	1	11	92%	1.2	1.2	1.2	1.2	—	—	—	1.2	mg/kg	Maximum Detected
S-2	Aluminum	65	0	0%	1220	20000	6209	4410	4387	1.346	0.707	7349	mg/kg	95% H-UCL
S-2	Aroclor-1242	1	73	99%	0.366	0.366	0.366	0.366	—	—	—	0.366	mg/kg	Maximum Detected
S-2	Aroclor-1254	21	53	72%	0.0297	2.53	0.591	0.318	0.774	1.847	1.31	0.326	mg/kg	95% KM (BCA) UCL
S-2	Aroclor-1260	55	19	26%	0.0388	2.08	0.379	0.209	0.488	2.454	1.287	0.522	mg/kg	95% KM (Chebyshev) UCL
S-2	Arsenic	64	1	2%	0.773	15.6	4.264	3	3.559	2.03	0.835	6.153	mg/kg	95% KM (Chebyshev) UCL
S-2	Benzo[a]anthracene	18	13	42%	0.0258	0.615	0.226	0.135	0.193	1.044	0.852	0.245	mg/kg	95% KM (t) UCL

Table E-2.2-1 (continued)

Reach	Analyte	Number Detects	Number Nondetects	% NDs	Minimum Detected (µg/L)	Maximum Detected (µg/L)	Mean (µg/L)	Median (µg/L)	Standard Deviation	Skewness	Coefficient of Variation	UCL	Units	UCL Method
S-2	Benzo(a)pyrene	14	17	55%	0.0477	0.545	0.222	0.108	0.198	0.87	0.892	0.215	mg/kg	95% KM (t) UCL
S-2	Benzo[b]fluoranthene	6	25	81%	0.119	0.884	0.516	0.515	0.328	-0.018	0.637	0.287	mg/kg	95% KM (t) UCL
S-2	Cadmium	31	32	51%	0.126	8.69	1.585	0.753	2.056	2.091	1.297	1.278	mg/kg	95% KM (BCA) UCL
S-2	Chromium	65	0	0%	5	3740	358.7	55.4	823.5	3.179	2.296	567.5	mg/kg	95% H-UCL
S-2	Cobalt	58	7	11%	0.639	8.2	2.519	2.125	1.233	2.144	0.489	2.653	mg/kg	95% KM (BCA) UCL
S-2	Dieldrin	1	20	95%	0.037	0.037	0.037	0.037	—	—	—	0.037	mg/kg	Maximum Detected
S-2	Iron	65	0	0%	3460	21000	9742	9000	3937	0.968	0.404	10557	mg/kg	95% Student's-t UCL
S-2	Lead	65	0	0%	4.3	690	32	17	84.32	7.658	2.635	77.59	mg/kg	95% Chebyshev (Mean, Sd) UCL
S-2	Mercury	44	21	32%	0.0234	5.57	0.792	0.312	1.214	2.752	1.534	1.129	mg/kg	95% KM (Chebyshev) UCL
S-2	Molybdenum	9	0	0%	0.671	44.4	10.71	3.47	14.78	1.794	1.38	27.97	mg/kg	95% Approximate Gamma UCL
S-2	Silver	47	19	29%	0.182	87.3	12.56	4.92	17.34	2.485	1.38	17.58	mg/kg	95% KM (Chebyshev) UCL
S-2	Thallium	23	42	65%	0.105	1.06	0.259	0.161	0.241	2.607	0.932	0.228	mg/kg	95% KM (% Bootstrap) UCL
S-2	Vanadium	65	0	0%	6	40	17.55	15	8.669	1.232	0.494	19.39	mg/kg	95% H-UCL
S-3W	Aroclor-1260	18	2	10%	0.0054	0.308	0.146	0.123	0.0954	0.158	0.653	0.172	mg/kg	95% KM (t) UCL
S-3W	Arsenic	20	0	0%	0.909	5.85	2.876	2.86	1.212	0.665	0.421	3.345	mg/kg	95% Student's-t UCL
S-3W	Benzo(a)pyrene	5	5	50%	0.0366	0.0697	0.0562	0.0555	0.0127	-0.879	0.227	0.0546	mg/kg	95% KM (t) UCL
S-3W	Chromium	15	0	0%	16.7	398	150.7	124	118.9	0.979	0.789	204.8	mg/kg	95% Student's-t UCL
S-4W	Thorium-228	10	0	0%	0.873	2.47	1.884	2.02	0.462	-1.286	0.245	2.152	pCi/g	95% Student's-t UCL
S-4W	Thorium-232	10	0	0%	0.867	2.37	1.729	1.805	0.427	-0.71	0.247	1.976	pCi/g	95% Student's-t UCL

*— = Not available or not applicable.

Table E-2.3-1
EPCs for Surface Water COPCs

Reach	Analyte	Number Detects	Number non-Detects	% NDs	Minimum Detected (µg/L)	Maximum Detected (µg/L)	Mean (µg/L)	Median (µg/L)	Standard Deviation	Skewness	Coefficient of Variation	UCL (µg/L)	UCL Method
S-1N	Arsenic	7	6	46%	1.8	10.1	4.729	3.2	3.077	0.919	0.651	5	95% KM (t) UCL
S-1N	BHC[delta-]	1	9	90%	0.292	0.292	0.292	0.292	—*	—	—	0.292	Maximum
S-1N	Chromium	11	2	15%	7.1	15.1	9.909	8.7	2.76	1.184	0.278	11.13	95% KM (BCA) UCL
S-1N	Fluoride	2	0	0%	622	857	739.5	739.5	166.2	—	0.225	857	Maximum
S-1N	Lead	10	3	23%	0.578	4	1.047	0.735	1.045	3.079	0.999	1.455	95% KM (BCA) UCL
S-1N	Manganese	13	0	0%	8.9	236	35.79	17.8	60.76	3.483	1.697	109.2	Use 95% Chebyshev (Mean, Sd) UCL
S-1N	Thallium	1	12	92%	0.54	0.54	0.54	0.54	—	—	—	0.54	Maximum
S-1N	Vanadium	13	0	0%	10.8	43.1	25.35	24.5	7.731	0.576	0.305	29.18	Use 95% Student's-t UCL
S-1S	Arsenic	1	4	80%	4.8	4.8	4.8	4.8	—	—	—	4.8	Maximum
S-1S	Bromodichloromethane	1	2	67%	7.8	7.8	7.8	7.8	—	—	—	7.8	Maximum
S-1S	Chlorodibromomethane	1	2	67%	18.5	18.5	18.5	18.5	—	—	—	18.5	Maximum
S-1S	Chloroform	1	2	67%	1.9	1.9	1.9	1.9	—	—	—	1.9	Maximum
S-1S	Chromium	4	1	20%	4.6	10.1	6.275	5.2	2.598	1.793	0.414	8.275	95% KM (t) UCL
S-1S	Perchlorate	2	0	0%	0.741	18.5	9.621	9.621	12.56	—	1.305	18.5	Maximum
S-2	Aroclor-1254	5	15	75%	0.059	0.112	0.0868	0.086	0.0242	-0.0223	0.279	0.089	95% KM (t) UCL
S-2	Aroclor-1260	6	14	70%	0.045	0.1	0.077	0.08	0.0186	-0.913	0.242	0.0872	95% KM (t) UCL
S-2	Arsenic	24	24	50%	1.8	9.3	4.438	3.15	2.932	0.865	0.661	4.127	95% KM (% Bootstrap) UCL
S-2	Bromodichloromethane	1	12	92%	0.458	0.458	0.458	0.458	—	—	—	0.458	Maximum
S-2	Chloride	2	0	0%	59400	70300	64850	64850	7707	—	0.119	70300	Maximum
S-2	Chlorodibromomethane	3	10	77%	0.52	0.68	0.605	0.615	0.0805	-0.551	0.133	0.68	Maximum Detected
S-2	Chloroform	1	12	92%	0.278	0.278	0.278	0.278	—	—	—	0.278	Maximum
S-2	Chromium	15	1	6%	3.6	40.4	13.67	9.7	11.08	1.524	0.811	26.14	95% KM (Chebyshev) UCL

Table E-2.3-1 (continued)

Reach	Analyte	Number Detects	Number non-Detects	% NDs	Minimum Detected (µg/L)	Maximum Detected (µg/L)	Mean (µg/L)	Median (µg/L)	Standard Deviation	Skewness	Coefficient of Variation	UCL (µg/L)	UCL Method
S-2	1,4-Dioxane	2	8	80%	1.46	30.4	15.93	15.93	20.46	—	1.285	24.8	95% KM (jackknife) UCL
S-2	Fluoride	2	0	0%	474	520	497	497	32.53	—	0.0654	520	Maximum
S-2	Lead	11	5	31%	0.54	4.7	2.02	1.5	1.373	0.802	0.68	2.234	95% KM (t) UCL
S-2	Manganese	32	0	0%	13.1	224	96.19	66.45	66.46	0.942	0.691	147.4	95% Chebyshev (Mean, Sd) UCL
S-2	Thallium	4	28	88%	0.4	0.81	0.605	0.605	0.237	1.40E-15	0.391	0.505	95% KM (t) UCL
S-3E	Arsenic	26	32	55%	2.3	8.6	4.415	4.6	1.646	1.012	0.373	4.492	95% KM (t) UCL
S-3E	Chloride	4	0	0%	63300	75000	69150	69150	6755	0	0.0977	75000	Maximum
S-3E	Chloroform	3	20	87%	0.289	0.326	0.314	0.326	0.0214	-1.732	0.0681	0.326	Maximum Detected
S-3E	Chromium	54	4	7%	5.79	15	9.147	8.7	2.547	0.776	0.278	10.51	95% KM (Chebyshev) UCL
S-3E	1,4-Dioxane	2	18	90%	7.53	7.53	7.53	7.53	—	—	—	7.53	Maximum
S-3E	Fluoride	4	0	0%	397	470	433.5	433.5	42.15	0	0.0972	470	Maximum
S-4W	Arsenic	12	16	57%	2.3	5.3	4.067	4.2	1.164	-0.35	0.286	4.449	95% KM (t) UCL
S-4W	Chloride	4	0	0%	63300	75000	69150	69150	6755	0	0.0977	75000	Maximum
S-4W	Chloroform	3	22	88%	0.289	0.326	0.314	0.326	0.0214	-1.732	0.0681	0.326	Maximum Detected
S-4W	Chromium	54	4	7%	5.79	15	9.147	8.7	2.547	0.776	0.278	10.51	95% KM (Chebyshev) UCL
S-4W	1,4-Dioxane	2	18	90%	7.53	7.53	7.53	7.53	—	—	—	7.53	Maximum
S-4W	Fluoride	4	0	0%	397	470	433.5	433.5	42.15	0	0.0972	470	Maximum

*— = Not available or not applicable.

Table E-2.4-1
Screening Levels for the Residential Scenario

Medium	COPC	End Point*	Target Adverse-Effect Level	Residential SL	Units	Reference
Sediment	Aluminum	nc	HQ=1	78100	mg/kg	NMED (2009, 106420)
Sediment	Aroclor-1242	ca	risk=10-5	1.7	mg/kg	NMED (2009, 106420)
Sediment	Aroclor-1248	ca	risk=10-5	1.7	mg/kg	NMED (2009, 106420)
Sediment	Aroclor-1254	nc	HQ=1	1.12	mg/kg	NMED (2009, 106420)
Sediment	Aroclor-1254	ca	risk=10-5	1.7	mg/kg	NMED (2009, 106420)
Sediment	Aroclor-1260	ca	risk=10-5	1.7	mg/kg	NMED (2009, 106420)
Sediment	Arsenic	ca	risk=10-5	3.59	mg/kg	NMED (2009, 106420)
Sediment	Benzo[a]anthracene	ca	risk=10-5	4.81	mg/kg	NMED (2009, 106420)
Sediment	Benzo[a]pyrene	ca	risk=10-5	0.481	mg/kg	NMED (2009, 106420)
Sediment	Benzo[b]fluoranthene	ca	risk=10-5	4.81	mg/kg	NMED (2009, 106420)
Sediment	Cadmium	nc	HQ=1	77.9	mg/kg	NMED (2009, 106420)
Sediment	Chromium	ca	risk=10-5	2800	mg/kg	EPA Regional SSLs
Sediment	Cobalt	nc	HQ=1	23	mg/kg	EPA Regional SSLs
Sediment	Dieldrin	ca	risk=10-5	0.245	mg/kg	NMED (2009, 106420)
Sediment	Indeno[1,2,3-cd]pyrene	ca	risk=10-5	4.81	mg/kg	NMED (2009, 106420)
Sediment	Iron	nc	HQ=1	54800	mg/kg	NMED (2009, 106420)
Sediment	Lead	nc	HQ=1	400	mg/kg	NMED (2009, 106420)
Sediment	Mercury	nc	HQ=1	23	mg/kg	EPA Regional SSLs
Sediment	Molybdenum	nc	HQ=1	391	mg/kg	NMED (2009, 106420)
Sediment	Silver	nc	HQ=1	391	mg/kg	NMED (2009, 106420)
Sediment	Thallium	nc	HQ=1	5.16	mg/kg	NMED (2009, 106420)
Sediment	Thorium-228	RAD	15 mrem/yr	2.3	pCi/g	LANL (2005, 088493)
Sediment	Thorium-232	RAD	15 mrem/yr	5	pCi/g	LANL (2005, 088493)

*nc = Noncarcinogen, ca = carcinogen, RAD = radionuclide dose.

Table E-2.4-2
Summary of Residential Risk Assessment Results

Reach	Carcinogenic ILCR[a]	Noncarcinogenic Hazard Index	Total Radionuclide Dose
S-1N	1.4E-04	0.67	—[b]
S-1S	6.3E-05	—	—
S-2	3.3E-05	1.2	—
S-3W	1.2E-05	—	—
S-4W	—	—	20

Note: Shaded exceeds 1 x 10^{-5} carcinogenic risk, hazard index of 1.0, or dose of 15 mrem/yr.

[a] ICLR = Incremental lifetime cancer risk.

[b] — = Incomplete pathway.

Table E-2.4-3
Risk Ratios Based on EPCs for Sediment, Residential Scenario

Carcinogens													
Reach	**Aroclor-1242**	**Aroclor-1248**	**Aroclor-1254**	**Aroclor-1260**	**Arsenic**	**Benzo(a)pyrene**	**Benzo[a]anthracene**	**Benzo[b]fluoranthene**	**Chromium**	**Dieldrin**	**Indeno[1,2,3-cd]pyrene**	**Total Risk Ratio**	**Total Risk**
Residential SL (mg/kg)	1.7	1.7	1.7	1.7	3.59	0.481	4.81	4.81	2800	0.245	4.81		
S-1N	—*	0.086	0.20	0.67	1.3	7.7	2.1	1.5	—	—	0.26	14	1.4E-04
S-1S	—	—	—	2.2	0.89	2.3	0.44	0.27	—	—	0.25	6.3	6.3E-05
S-2	0.22	—	0.19	0.31	1.7	0.45	0.051	0.060	0.20	0.15	—	3.3	3.3E-05
S-3W	—	—	—	0.10	0.93	0.11	—	—	0.073		—	1.2	1.2E-05
Noncarcinogens													
Reach	**Aluminum**	**Aroclor-1254**	**Cadmium**	**Cobalt**	**Iron**	**Lead**	**Mercury**	**Molybdenum**	**Silver**	**Thallium**	**Vanadium**	**Total Risk Ratio**	**Hazard Index**
Residential SL (mg/kg)	78100	1.12	77.9	23	54800	400	23	391	391	5.16	391		
S-1N	—	0.30	—	—	0.29	0.071	—	—	—	—	—	0.67	0.67
S-2	0.094	0.29	0.016	0.12	0.19	0.19	0.049	0.072	0.045	0.044	0.050	1.2	1.2
Radionuclides													
Reach	**Thorium-228**	**Thorium-232**	**Total Dose Ratio**	**Total Dose**									
Residential SL (pCi/g)	2.3	5											
S-4W	0.94	0.40	1.3	20									

Note: Values in shaded cells exceed 1 x 10^{-5} carcinogenic risk, hazard index of 1.0, dose of 15 mrem/yr, or risk ratio for individual COPC and/or reach greater than one.
*— = Not a COPC.

Table E-2.4-4
Reach S-2 PCB Congener Analysis, Residential Scenario

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Residential Risk Ratio[d]
SA-600108	CASA-08-13546	3.54–4.36	PCB-105	0.0299	0.00003	8.97E-07	1.79E-04	4.3
			PCB-106/118	0.0954	0.00003	2.86E-06		
			PCB-114	0.000958	0.00003	2.87E-08		
			PCB-123	0.00135	0.00003	4.05E-08		
			PCB-126	0.00171	0.1	1.71E-04		
			PCB-156	0.0204	0.00003	6.12E-07		
			PCB-157	0.00488	0.00003	1.46E-07		
			PCB-167	0.011	0.00003	3.30E-07		
			PCB-169	0.0000752	0.03	2.26E-06		
			PCB-189	0.00385	0.00003	1.16E-07		
			PCB-77	0.0026	0.0001	2.60E-07		
			PCB-81	0.0000439	0.0003	1.32E-08		
SA-600110	CASA-08-13547	0–0.85	PCB-105	0.00593	0.00003	1.78E-07	3.13E-05	0.76
			PCB-106/118	0.0212	0.00003	6.36E-07		
			PCB-114	0.000169	0.00003	5.07E-09		
			PCB-123	0.000241	0.00003	7.23E-09		
			PCB-126	0.000294	0.1	2.94E-05		
			PCB-156	0.00456	0.00003	1.37E-07		
			PCB-157	0.000929	0.00003	2.79E-08		
			PCB-167	0.00227	0.00003	6.81E-08		
			PCB-169	0.0000255	0.03	7.65E-07		
			PCB-189	0.00098	0.00003	2.94E-08		
			PCB-77	0.000489	0.0001	4.89E-08		
			PCB-81	0.00011	0.0003	3.30E-08		

Table E-2.4-4 (continued)

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Residential Risk Ratio[d]
SA-600113	CASA-08-13548	0.3–2.33	PCB-105	0.222	0.00003	6.66E-06	5.50E-04	13
			PCB-106/118	0.796	0.00003	2.39E-05		
			PCB-114	0.0095	0.00003	2.85E-07		
			PCB-123	0.00926	0.00003	2.78E-07		
			PCB-126	0.00509	0.1	5.09E-04		
			PCB-156	0.0959	0.00003	2.88E-06		
			PCB-157	0.0208	0.00003	6.24E-07		
			PCB-167	0.0386	0.00003	1.16E-06		
			PCB-169	0.000119	0.03	3.57E-06		
			PCB-189	0.00805	0.00003	2.42E-07		
			PCB-77	0.0127	0.0001	1.27E-06		
			PCB-81	0.000404	0.0003	1.21E-07		
	CASA-08-13552	2.33–3.31	PCB-105	0.00515	0.00003	1.55E-07	1.79E-05	0.4
			PCB-106/118	0.0172	0.00003	5.16E-07		
			PCB-114	0.000192	0.00003	5.76E-09		
			PCB-123	0.000182	0.00003	5.46E-09		
			PCB-126	0.000167	0.1	1.67E-05		
			PCB-156	0.00265	0.00003	7.95E-08		
			PCB-157	0.000591	0.00003	1.77E-08		
			PCB-167	0.00125	0.00003	3.75E-08		
			PCB-169	0.000011	0.03	3.30E-07		
			PCB-189	0.000458	0.00003	1.37E-08		
			PCB-77	0.000281	0.0001	2.81E-08		
			PCB-81	0.0000863	0.0003	2.59E-08		

Table E-2.4-4 (continued)

Location ID	Sample ID	Depth Interval (ft)	Analyte	Result (mg/kg)	TEF[a]	TEQ[b]	Total TEQ[c]	Residential Risk Ratio[d]
SA-600115	CASA-08-13549	0–0.98	PCB-105	0.0771	0.00003	2.31E-06	2.94E-04	7.09
			PCB-106/118	0.285	0.00003	8.55E-06		
			PCB-114	0.00287	0.00003	8.61E-08		
			PCB-123	0.00382	0.00003	1.15E-07		
			PCB-126	0.00275	0.1	2.75E-04		
			PCB-156	0.0493	0.00003	1.48E-06		
			PCB-157	0.01	0.00003	3.00E-07		
			PCB-167	0.0212	0.00003	6.36E-07		
			PCB-169	0.0000978	0.03	2.93E-06		
			PCB-189	0.00661	0.00003	1.98E-07		
			PCB-77	0.00418	0.0001	4.18E-07		
			PCB-81	0.0054	0.0003	1.62E-06		
	CASA-08-13553	0.98–2.2	PCB-105	0.011	0.00003	3.30E-07	2.94E-05	0.71
			PCB-106/118	0.0362	0.00003	1.09E-06		
			PCB-114	0.000344	0.00003	1.03E-08		
			PCB-123	0.000476	0.00003	1.43E-08		
			PCB-126	0.000272	0.1	2.72E-05		
			PCB-156	0.00513	0.00003	1.54E-07		
			PCB-157	0.00125	0.00003	3.75E-08		
			PCB-167	0.00234	0.00003	7.02E-08		
			PCB-169	0.0000121	0.03	3.63E-07		
			PCB-189	0.000649	0.00003	1.95E-08		
			PCB-77	0.000591	0.0001	5.91E-08		
			PCB-81	0.0000763	0.0003	2.29E-08		
						95th UCL	3.56E-04	8.6

[a] TEFs from WHO (http://www.who.int/entity/ipcs/assessment/tef_values.pdf).

[b] TEQ = [conc] x TEF.

[c] 2,3,7,8-TCDD SL = 4.14E-05 mg/kg from NMED (2009, 106420).

[d] Risk Ratio = [Total TEQ] x [TCCD SL].

Attachment E-1

ProUCL Files
(on CD included with this document)

Appendix F

Sandia Canyon Surface-Water Balance and Alluvial and Perched-Intermediate Groundwater Level Responses

F-1.0 SURFACE-WATER STUDY

Los Alamos National Laboratory (the Laboratory or LANL) conducted a surface-water investigation in Sandia Canyon from July 2007 to June 2008 to determine surface water losses along the length of the canyon. The results of that study are presented in Appendix C of the "Fate and Transport Investigations Update for Chromium Contamination from Sandia Canyon" (hereafter, the Chromium Fate and Transport Update Report) (LANL 2008, 102996). Briefly, the investigation used permanent and temporary gaging stations to focus on canyon segments with perennial or common surface water supplied from effluent discharges. These segments are shown in Figure 7.2-1 of the investigation report as SW1 through SW4. Table F-1.0-1 shows the approximate surface-water budget in the Sandia watershed for the study period. The significant findings of that study are that little infiltration of surface water occurs in the wetland area (SW1), and little to no infiltration occurs in the steep section of the canyon directly below the wetland (SW2). Greater infiltration occurs in SW3, but the majority occurs in SW4 where alluvium is present in the canyon floor (Figure 7.2-1). This water budget excluded periods with significant runoff so that input to the watershed was based on recorded outfall volumes. During the study period, National Pollutant Discharge Elimination System (NPDES) outfalls contributed approximately 75% of the total flow into the canyon, with stormwater runoff and snowmelt contributing the remainder. When runoff contributes to the water budget, flow past gage E124 (Plate 1) becomes more likely.

F-2.0 ALLUVIAL GROUNDWATER-LEVEL RESPONSES TO SURFACE-WATER FLOW

This appendix summarizes alluvial groundwater-level responses to surface-water flow in Sandia Canyon for the period from October 1, 2006, to June 30, 2009. Alluvial wells SCA-1, SCA-2, SCA-3, SCA-4 and SCA-5 and piezometer nests SCP-1a,b,c and SCP-2a,b were installed in Sandia Canyon in October 2006 as part of the chromium investigation work defined in the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 091987). The locations of these wells and piezometers are shown in Figure 3.2-2 and Plate 1 of this report. Completion information is included in Appendix B of the "Interim Measures Investigation Report for Chromium Contamination in Groundwater" (LANL 2006, 094431). Groundwater-level (transducer) data from these wells and piezometers have been gathered since October 2006. Sandia Canyon alluvial groundwater level responses to surface-water flow through April 2008 were discussed previously in the Chromium Fate and Transport Update Report (LANL 2008, 102996). That report analyzed both mean daily groundwater levels for the entire period and hourly groundwater levels for focused short periods. The shorter time period illustrated hourly water levels and 5-min gage flow rates; it was chosen to better illustrate alluvial water-level responses during active storm periods. Both time periods are useful for understanding transients in the alluvial system and their potential spatial and time-dependent effects on deeper percolation to the underlying bedrock units. The hourly data are not included here, but the previous findings based on those data are summarized in the sections that follow. That report also estimated infiltration rates (for segment SW4, Figure 7.2-1) from the alluvial groundwater into bedrock of 2.4 m/yr (7.9 ft/yr) to 4.9 m/yr (16 ft/yr). The estimated infiltration rates are quite high compared to other estimates for net infiltration rates across that Pajarito Plateau (Birdsell et al. 2005, 092048; Kwicklis et al. 2005, 090069), but they are required to accommodate the approximately 1100 m^3/d (300,000 gal./d) of effluent discharged to the canyon.

This current report presents an update for the alluvial groundwater and surface flow data available through June 30, 2009, and mean daily levels are shown in Figure F-2.0-1. In addition to the alluvial groundwater levels, corresponding mean daily outfall discharge volumes, mean daily surface-water flow rates measured at gaging stations E123 and E124, and daily maximum and minimum temperatures at Laboratory meteorological tower Technical Area 06 (TA-06), are also shown in Figure F-2.0-1 to assess

the response of the alluvial groundwater system in relation to surface flow and runoff events. Additionally, groundwater-levels of two perched-intermediate zones beneath Sandia Canyon intercepted by monitoring wells SCI-1 and SCI-2 (Figure 3.2-2) are plotted in Figure F-2.0-1 to assess the hydrologic response of the deeper groundwater (approximately 300 ft to 500 ft below ground) to surface and near-surface events.

F-2.1 Water Sources

Figure F-2.0-1a shows daily and running-average outfall volumes recorded for NPDES outfall 01A001 in upper Sandia Canyon (Plate 1) from October 1, 2006, to June 30, 2009. This outfall discharges effluent, predominantly from the Laboratory's TA-46 Sanitary Wastewater Systems Consolidation (SWSC) plant and the TA-03 steam plant (TA-3-SM22), once daily. Effluent for cooling of the TA-03 power plant is also discharged here, but currently the power plant produces power only infrequently and adds little to the effluent volume. Outfall 01A001 is the main effluent source of water to Sandia Canyon, and average discharges are close to 290,000 gal./d. It is noteworthy that the TA-03 steam plant was taken out of service for maintenance of the steam system from May 31, 2007, to early August 2007. During that period, the discharge rate dropped to roughly 160,000 gal./d, which is close to the estimated discharge rate that occurred while chromium was being released from the outfall in the late 1950s to early 1970s (LANL 2007, 098938, Appendix A). Also, discharges were greatest, averaging nearly 400,000 gal./d, from mid-January to mid-March 2008, probably from an increase in the steam-heating requirements. These observations indicate that the steam plant discharges add significantly to the outfall 01A001 releases. Daily records for NPDES outfalls 03A027 and 03A199 associated with facility cooling of the Strategic Computing Complex (SCC) and the LANL Data Communications Center (LDCC), both at TA-03, from August 1, 2008, through June 30, 2009, are also plotted in Figure F-2.0-1. Together, these outfalls generally contribute less than 100,000 gal./d of cooling water effluent to the canyon. Runoff from summer thunderstorm events is also shown for selected stream gages in Sandia Canyon in Figure F-2.0-1a; runoff contributes a significant volume of surface water as compared to effluent volume, as described in section F-1.0.

F-2.2 Stream Gage Data

Stream gaging station data for permanent gages E121, E122, E123, and E124 and temporary gage D123 (Figure 3.2-2 and Plate 1) are shown in Figure F-2.0-1b. These data are used to understand the relative magnitude and timing of flow variations rather than their absolute magnitudes. In terms of the alluvial water-level responses to surface flow events, E123, D123, and E124 are most informative because they describe surface-water flow out of the wetland (E/D123) and farther downcanyon where the canyon bottom has a significant thickness of alluvium (E124). These data are repeated on the plots for SCA-2 and SCA-4 (Figures F-2.0-1d and F-2.0-1f) to better illustrate alluvial-water-level responses to surface-flow events observed at these two gage locations. In general, surface flow at the eastern end of the wetland responds about 1.5 h after the daily release at Outfall 01A001. The stream gages respond quickly to larger storm runoff events as well. Surface flow at gage E124 generally occurs only as a result of storm runoff (or sustained heavy snowmelt runoff), but not all precipitation events yield runoff at the gage. During storm runoff events in September 2007, the runoff front arrived at gage E124 about 1.5 h after arriving at gage E123.

F-2.3 Alluvial Groundwater

Alluvial groundwater monitoring well SCA-1 (Plate 1) is located in upper Sandia Canyon in the eastern part of the wetland. The well is shallow and fully saturated (LANL 2006, 094431). The mean daily water level reported at this location is shown in Figure F-2.0-1c; the water level is effectively the surface-water

level because the well is fully saturated to above the ground surface. Over the full period of record, the mean water level has declined just over 1 ft. Hourly data show that the water level at SCA-1 rises and falls diurnally in concert with flow at gage E123 with approximately a 0.5-ft variation (LANL 2008, 102996). The water-level variations at this location are minor, suggesting that storage volume and/or conductive capacity of the wetland area are sufficiently large to dampen out the transients.

Alluvial well SCA-2 is located in the narrow stretch of Sandia Canyon just west (upstream) of where the alluvium in the canyon floor begins to widen and thicken; the well is situated 2.3 m above the active stream channel (LANL 2006, 094431). The mean daily groundwater level at this location is shown in Figure F-2.0-1d. Over the full period of record, 4-ft variations have occurred over time periods of approximately 2 mo. The highest levels at SCA-2 occur in response to storm runoff and also during cold weather, as seen by the temperature data in Figure F-2.0-1c. The cold weather may cause icing in the upstream channel, which, in turn, routes surface water farther down the canyon, resulting in greater infiltration into the alluvium near SCA-2. Hourly data show that the groundwater level at SCA-2 rises and falls diurnally, with the peak occurring approximately a half-day after peak flow occurs at gage E123, and daily variations are 1 ft or more (LANL 2008, 102996). The lag suggests that water movement downstream of E123 predominantly occurs as lateral groundwater flow through the alluvial system. When runoff events reach gage E124, SCA-2 groundwater levels rise more quickly (about one-quarter-day lag) because, in this case, the alluvium is recharged by two water sources: the usual (delayed) lateral groundwater flow through the alluvium and the additional (more rapid) infiltration of local runoff close to SCA-2. The peak response to runoff events is broader under this condition because the two pathways contribute to the groundwater level at different time scales. At SCA-2, the rapid, diurnal fluctuations in groundwater level imply little storage and high conductive capacity of the alluvial system. The high conductive capacity might be enhanced by the steeper slope of the canyon bottom in this section (Figure 7.2-1), which likely promotes lateral downcanyon flow in the alluvium over infiltration into bedrock.

Alluvial monitoring well SCA-3 and the two nested piezometers SCP-2a and SCP-2b are located next to each other in a broad stretch of Sandia Canyon about 1140 ft east of SCA-2 and adjacent to the active stream channel near stream gage E124 (LANL 2006, 094431) (Figure 3.2-1 and Plate 1). Mean daily groundwater levels for these are shown in Figure F-2.0-1e. There was considerable difficulty during drilling of SCA-3, and the screen placement is generally too high to measure alluvial groundwater levels, except for relatively brief periods when levels are elevated after large runoff events. However, the screens in the two nested piezometers are deeper and have complete records that adequately cover the water-level fluctuations. The groundwater level in SCA-3 is approximately the same as that measured in piezometer SCP-2a. For the period of record, alluvial groundwater-level fluctuations in this part of Sandia Canyon vary over longer time scales (months) than farther up the canyon and overall by up to 12 ft. This behavior is significantly different than that observed at SCA-2. It appears that long-term groundwater rises at SCP-2a and SCP-2b correspond to similar long-term rises at SCA-2 (e.g., during December 2006 through January 2007, late August and September 2007, December 2007 to January 2008). Again, icing in the upstream portion of the channel may cause more infiltration into the alluvium downstream. The lowest groundwater levels were measured during August 2007, following the approximately 2-mo, low-release period at the 01A001 outfall. Hourly data show that the water levels at SCP-2a and SCP-2b rise in response to runoff after summer storm runoff events (LANL 2008, 102996). When runoff reaches gage E124, the groundwater levels in the alluvium rise at a faster rate (steep inflections in the hydrographs), often within a day, because the surface water seeps into the alluvium closer to the wells than under conditions when runoff does not reach stream gage E124. However the response in the alluvial groundwater to storm runoff events is subdued. At this location, response times are slower because a significant volume of surface water and runoff generally infiltrates into the alluvium between SCA-2 and SCA-3/SCP-2. The groundwater at SCA-3/SCP-2 also responds to lateral flow through the alluvium, which has a larger storage volume, and its base is fairly flat at this location in the canyon (Figures 7.2-1).

Near SCP-2a and SCP-2b, groundwater levels decline during periods of low runoff, indicating that infiltration into bedrock probably occurs in this part of the canyon.

Alluvial groundwater monitoring well SCA-4 and the three nested piezometers SCP-1a, SCP-1b, and SCP-1c are located next to each other in a broad stretch of Sandia Canyon downstream of SCA-3 and about 1200 ft east of E124 (Figure 3.2-1 and Plate 1) (LANL 2006, 094431). Mean daily groundwater levels for these wells are shown in Figure F-2.0-1f. SCA-4 and the three piezometers have similar groundwater levels and nearly complete records. Groundwater levels in these wells have varied by up to 6 ft. The fluctuations at SCA-4 occur over longer time periods than at SCA-2, but response to runoff events at E124 is quicker than at upstream piezometers SCP-2a and SCP-2b, despite SCA-4's location farther down the canyon. The long-term groundwater rises and falls follow those at SCA-2, although lag times are not consistent. Here also, low groundwater levels were measured during August 2007, following the low release period at the 01A001 outfall and a period when significant runoff did not reach E124. Hourly data indicate the overall groundwater levels rise during the summer runoff period in discrete steps (LANL 2008, 102996). When runoff reaches gage E124, the water levels rise steeply (1.5 to 2-ft abrupt change) within a day, apparently because of nearby surface-water recharge. Between runoff events, however, the water levels decline more slowly than at SCA-2 and SCA-3. This behavior shows the alluvial groundwater at this location is tied more directly to the surface-water system than near SCA-3/SCP-2. Overall, however, groundwater levels do not increase and response times are slow when runoff does not reach E124; this segment of the canyon alluvium is generally recharged by lateral flow through the extensive alluvium. The decline in the alluvial groundwater level between runoff events suggests slow leakage of the groundwater from the alluvium into deeper bedrock units. Because alluvial groundwater does not extend much farther down the canyon, it can be expected that most of the alluvial groundwater loss is from seepage into underlying units rather than laterally down canyon. Therefore, infiltration into bedrock is very likely in this part of Sandia Canyon.

Mean daily groundwater levels for alluvial groundwater monitoring well SCA-5 are shown in Figure F-2.0-1f. Monitoring well SCA-5 is located about 1600 ft downstream of SCA-4 (Figure 3.2-1 and Plate 1). SCA-5 is typically dry, but after large runoff events has contained groundwater in October 2006, December 2007, and the fall of 2008. The groundwater level at SCA-5 is about 60 ft lower than at SCA-4. After significant precipitation and runoff on 12/1/07, SCA-4 had a large, immediate groundwater level increase, while the groundwater at SCA-5 did not respond for about 2 wk. Similarly, after large runoff events in August and October 2008, the groundwater at SCA-5 showed responses about 1 mo later than at SCA-4. The response time at SCA-5 appears to depend on how far downstream and how close to SCA-5 the runoff extends. Alluvial groundwater monitoring wells SCO-1 and SCO-2 located farther downstream in Sandia Canyon have never measured water.

F-2.4 Perched Intermediate Groundwater Levels

Perched intermediate monitoring well SCI-1 (Figure 3.2-1 and Plate 1) is located on the north side of the road in Sandia Canyon between alluvial wells SCA-2 and SCA-3 (LANL 2006, 094431). SCI-1 is screened in the Puye Formation just above the contact with the Cerros del Rio basalt at approximately 300 ft depth below the base of the alluvium. Monitoring well SCI-2 is located about 270 ft south of SCA-3 and near regional well R-43; this well is screened in the Cerros del Rio basalt where the perched intermediate groundwater is about 500 ft below the base of the alluvium. The mean daily groundwater levels at SCI-1 and SCI-2 are shown in Figure F-2.0-1g for the periods from February 2007 to June 2009 and from February 2009 to June 2009, respectively. The groundwater level at SCI-1 has fluctuated approximately 7 ft over the period of record. The water-level fluctuation is smooth and shows a gradual groundwater rise from October 2007 to November 2008 of about 7 ft. The groundwater level at SCI-2 has fluctuated approximately 1 ft over its short period of record. The intermediate groundwater does not

indicate a correlation with runoff events or alluvial groundwater fluctuations in Sandia Canyon. However, the relatively short period of groundwater-level data for both SCI wells precludes additional analyses at this time.

Perched-intermediate groundwater is present within the Cerros del Rio basalt farther down the canyon at monitoring well R-12 (Figure 7.2-1 and Plate 1). Significant infiltration from alluvial groundwater is highly unlikely at this location because of the lack of local saturation in the alluvium. The perched-intermediate groundwater at R-12 may result from snowmelt runoff in Los Alamos Canyon instead (Koch and Schmeer 2009, 105181).

F-2.5 Groundwater Temperature

The alluvial and intermediate groundwater temperature time series for the period from October 2006 to June 2009 is shown in Figure F-2.5-1, and the data are summarized in Table F-2.5-1. The largest groundwater temperature fluctuations are at monitoring well SCA-1 where the shallow well is located next to the stream channel. Here the groundwater temperature reflects the seasonal air temperatures and has a seasonal variation of about 17°C, with a standard deviation of about 6°C. The groundwater temperature at SCA-2 shows similar seasonal trends as at SCA-1, but in the summer of 2007 the higher groundwater temperatures at SCA-2 were delayed about 10 wk, while in 2008 the SCA-2 groundwater temperature more closely paralleled that of SCA-1. The large fluctuations in groundwater temperatures at SCA-1 and SCA-2 likely indicate that the groundwater at SCA-1 and SCA-2 is recharged by surface water near the wells.

Monitoring well SCA-3 has been dry much of the time because the screen is relatively shallow at 32 ft below ground surface (bgs); the available alluvial groundwater temperatures from this location appear to show a muted and delayed response to seasonal temperatures when compared with SCA-1 and SCA-2. The apparent groundwater temperature variation at SCA-3 is about 7°C (std dev 1.9°C) with an apparent delay of 2 to 3 mo to seasonal fluctuations. The groundwater temperature fluctuations at SCA-3 may indicate lateral movement of groundwater through the alluvium downstream to SCA-3 rather than recharge from the stream channel. The nearby piezometers SCP-2a and SCP-2b have screens 13 to 18 ft deeper than SCA-3 and show significantly more muted groundwater temperature fluctuations and delayed responses. The temperature fluctuations in the two piezometers are about 5° C with a 5- to 6-mo seasonal delay in temperature trends when compared with SCA-1 and SCA-2. The higher screen at SCP-2a shows slightly more temperature variation that the deeper screen at SCP-2b.

The groundwater temperature at SCA-4 and nearby piezometers SCP-1abc are nearly coincident in the figure and show seasonal fluctuations of about 2°C that lag about 6 mo behind SCA-2. The groundwater temperatures at SCA-4 are 2° to 3°C higher than at SCA-3 and SCP-2a and SCP-2b, although the screen depth at SCA-4 is similar to that at SCP-2a. The groundwater temperature at SCA-5, where the screen is deepest at 55 to 64 ft bgs, is about 2°C higher than at SCA-4. Because SCA-5 is dry much of the time, seasonal temperature variations are inconclusive; however, the available data indicate a fluctuation of about 1°C.

The groundwater temperature at intermediate monitoring well SCI-1 is similar to that of SCA-4 at an average of 11°C. The groundwater temperature at SCI-1 does not show an apparent seasonal trend but has shown a temperature decline of about 0.4°C from 2007 to 2009 while its groundwater level has risen (Figure F-2.0-1g). The similarity in the groundwater temperatures at SCI-1 and SCA-4 may indicate that the intermediate groundwater is sourced from the alluvium in middle Sandia Canyon. SCI-1 groundwater level is approximately 300 ft lower than at SCA-4. Based on a local geothermal gradient of 33°C/km

(1°C/100ft) (Kron and Heiken 1980, 097415), SCI-1 would be approximately 3°C warmer than SCA-4 if the geothermal gradient controlled its temperature.

The intermediate groundwater temperature in the Cerros del Rio Basalt at SCI-2 is about 16°C, about 5°C higher than at SCI-1 and SCA-4; the groundwater at SCI-2 is about 160 ft deeper than at SCI-1 and 460 ft deeper than at SCA-4. The short period of record for SCI-2 precludes seasonal or trend analysis. However, the difference in temperature between SCA-4 and SCI-2 is very close to 4.6 °C dictated by the geothermal gradient. This implies that the temperature of the perched intermediate groundwater at SCI-2 is in thermal equilibrium with the surrounding rock and perhaps the groundwater is not actively being recharged by alluvial water.

F-3.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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LANL (Los Alamos National Laboratory), September 2007. "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon," Los Alamos National Laboratory document LA-UR-07-6018, Los Alamos, New Mexico. (LANL 2007, 098938)

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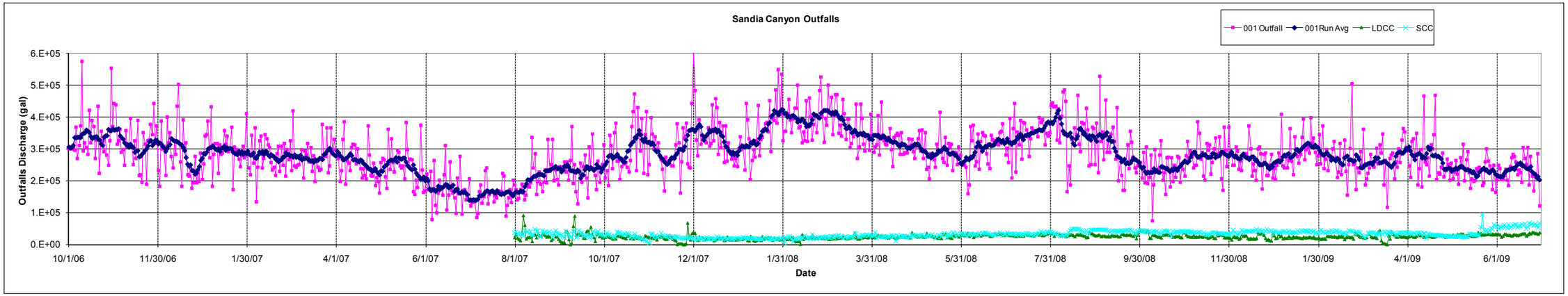
a.



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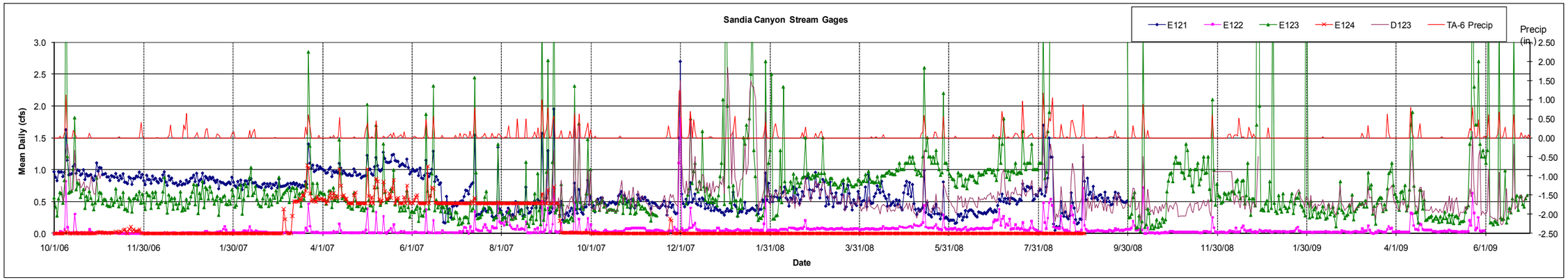

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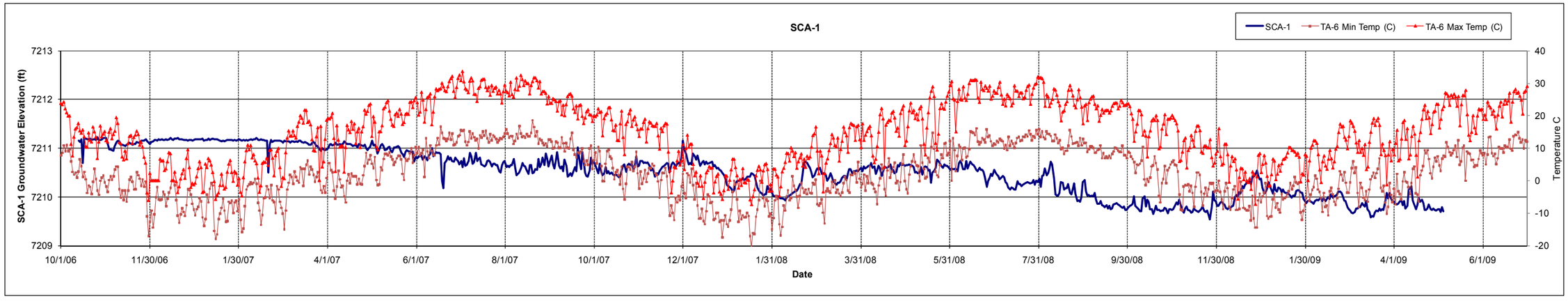
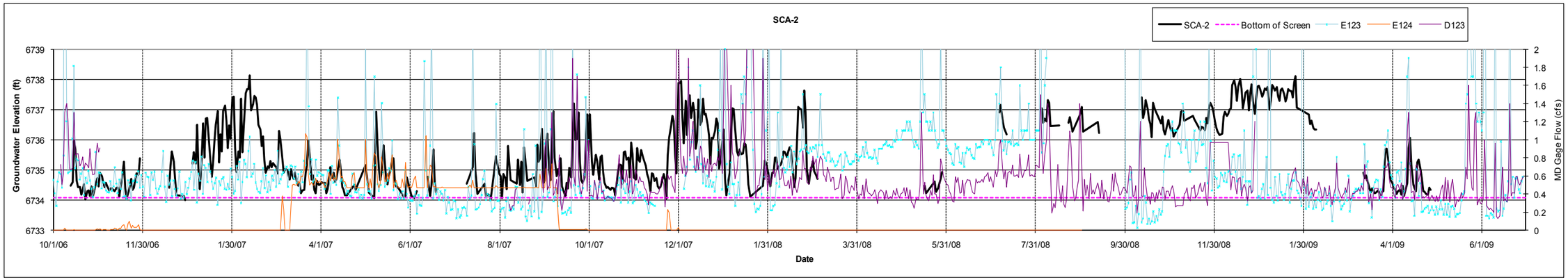


Note: Also shown are data for Sandia Canyon outfall volumes and stream gage and TA-06 precipitation and temperature records.

Figure F-2.0-1 Mean daily alluvial water levels measured in wells SCI-1, SCI-2, SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5 and piezometers SCP-1a,b,c and SCP-2a,b for the period of record from October 2006 to June 2009

d.



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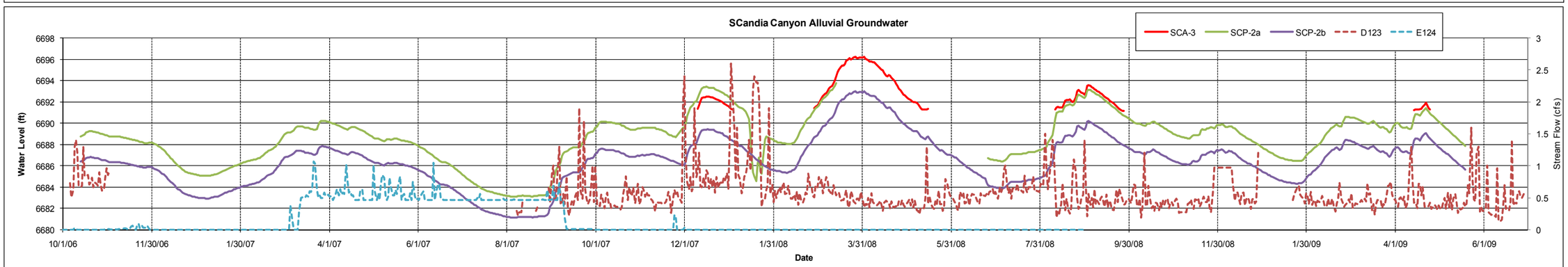

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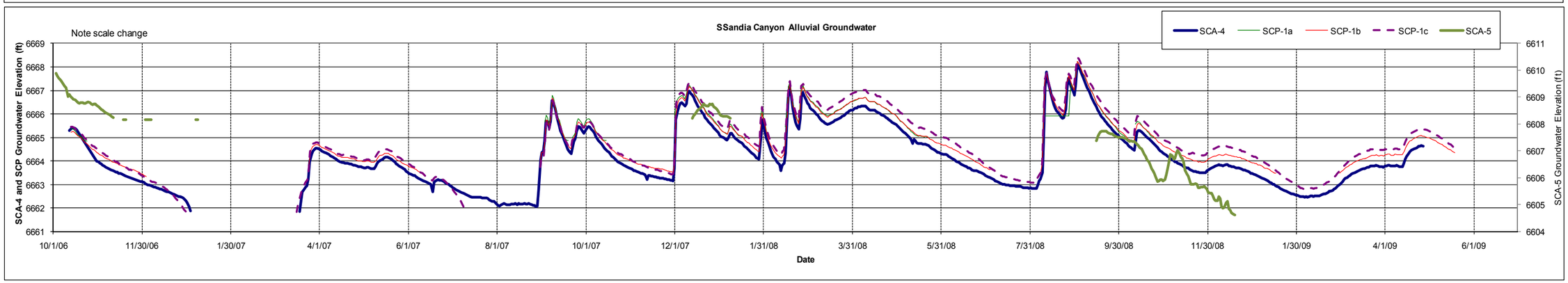

Figure F-2.0-1 (continued) **Mean daily alluvial water levels measured in wells SCI-1, SCI-2, SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5 and piezometers SCP-1a,b,c and SCP-2a,b for the period of record, October 2006 to June 2009**

g.

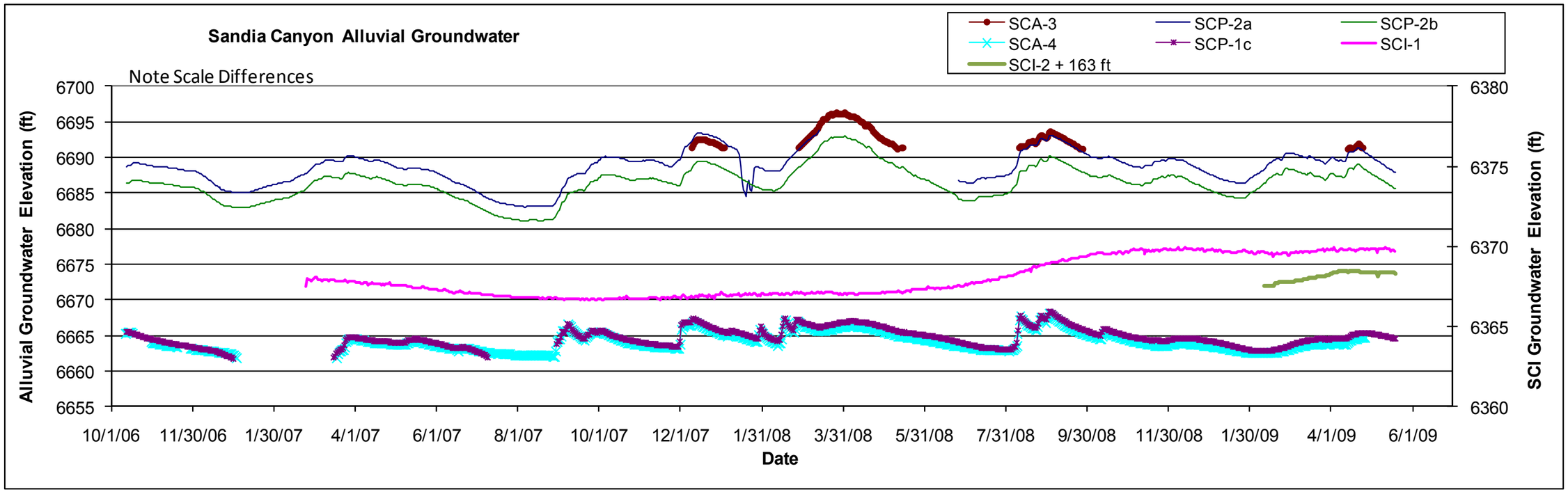

Figure F-2.0-1 (continued) **Mean daily alluvial water levels measured in wells SCI-1, SCI-2, SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5 and piezometers SCP-1a,b,c and SCP-2a,b for the period of record from October 2006 to June 2009**

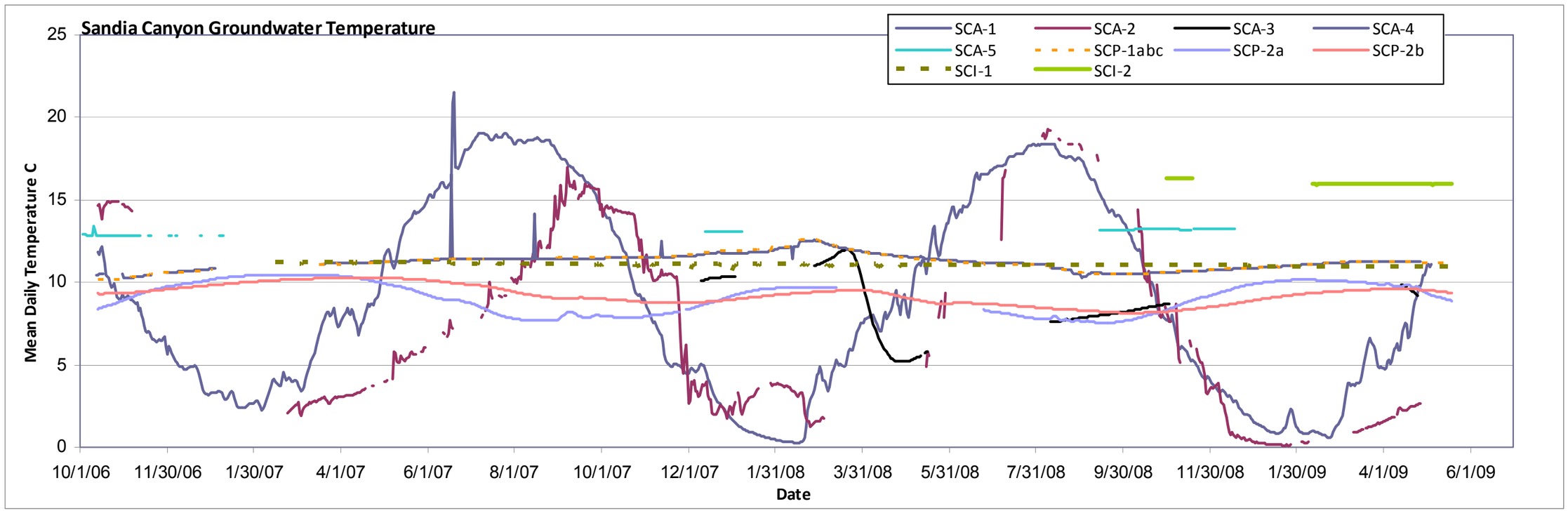

Figure F-2.5-1 Mean daily groundwater temperature measured in wells SCI-1, SCI-2, SCA-1, SCA-2, SCA-3, SCA-4, and SCA-5 and piezometers SCP-1a,b,c and SCP-2a,b for the period of record from October 2006 to June 2009

Table F-1.0-1
Approximate Surface-Water Budget in
Upper Sandia Canyon from July 2007 to June 2008

Process and Area	Estimated Gain or Loss (acre-ft/yr)	Percent of Total
Discharges from outfalls	389	75%
Runoff above E123	130	25%
ET in wetland	–18	–3%
Deep infiltration beneath wetland, SW1	–12	–2%
Deep infiltration between wetland and D123.6, SW2	0	0%
Surface water loss between D123.6 and D123.8, SW3	–119	–23%
Surface water loss between D123.8 and E124, SW4 upper	–334	–64%
Surface water loss between E124 and E125, SW4 lower	–36	–7%
Total	**0**	**0**

Source: From LANL 2008, 102996.
Note: SW1 through SW4 shown in Figure 7.2-1

Table F-2.5-1
Summary of Alluvial and Intermediate
Groundwater Temperature Data in Sandia Canyon

Well Name	Port Name	Average Temp C	Count	Std Dev C
SCA-1	SINGLE COMPLETION	8.86	22411	5.957
SCA-2	SINGLE COMPLETION	6.38	10126	5.450
SCA-3	SINGLE COMPLETION	8.61	4638	1.916
SCA-4	SINGLE COMPLETION	11.26	19869	0.699
SCA-5	SINGLE COMPLETION	13.08	3981	0.194
SCP-1abc	SCP-1a	11.51	6543	0.767
SCP-1abc	SCP-1b	11.27	16408	0.531
SCP-1abc	SCP-1c	11.18	19782	0.479
SCP-2a	SINGLE COMPLETION	9.10	20175	0.957
SCP-2b	SINGLE COMPLETION	9.24	22772	0.600
SCI-1	SINGLE COMPLETION	11.04	19771	0.090
SCI-2	SINGLE COMPLETION	16.27	27884	0.093

Appendix G

Analysis of Regional Aquifer Water Levels
Observed at Monitoring Wells near Sandia Canyon

G-1.0 MAPS OF THE REGIONAL AQUIFER WATER-TABLE NEAR SANDIA CANYON

G-1.1 Regional Water-Table Map

The regional aquifer beneath Los Alamos National Laboratory (LANL or the Laboratory) is a complex hydrogeological system. The top of the aquifer is predominantly under phreatic (water-table) conditions. However, areas of local confinement are also caused by local hydrogeological conditions. In general, the top of the regional aquifer is defined by the elevation of the regional water table. In the areas of local confinement, a regional piezometric surface represents the elevation of hydraulic heads in the confined zones. In general, the regional piezometric surface can be considered to represent a spatial continuation of the water table in the confined areas. Because the aquifer is predominantly under phreatic conditions, the term “regional water table” is used even though in some areas of the aquifer the term “regional piezometric surface” is more appropriate.

The general shape of the regional water table is predominantly controlled by the areas of regional recharge to the west (flanks of Sierra de los Valles) and discharge to the east (the Rio Grande and the White Rock Canyon springs). The structure of the regional phreatic flow is also expected to be impacted by (1) local infiltration zones (e.g., beneath wet canyons), (2) heterogeneity of aquifer properties, and (3) discharge zones (water-supply wells and springs).

Information about the elevation of the regional water table is provided by existing data from monitoring wells (water levels) and selected springs (discharge elevations). Well data are primarily used to map the elevation of the regional water-table; spring discharge elevations are used only in the vicinity of White Rock Canyon to provide additional constraints on the water-table elevation.

Water-table elevations vary in time because of transient effects that include pumping of the water-supply wells, and large- and small-scale variability in aquifer recharge. Therefore, water-level maps represent specific periods of time. Averaged water levels for February and March 2009 are computed for the regional aquifer wells and presented in Figure G-1.1-1. For wells H-19, TW-1, TW-2, TW-3, and TW-4, historical water-level data that are considered to be uncertain but important for constraining the water-table map in the northern portion of the Laboratory are used. Figure G-1.1-1 includes new water-level data from a series of recently drilled wells (R-42, R-43, R-44, R-45, R-46, and R-49), but the measurements are difficult to interpret, because the water-level data are preliminary and for a different time period. These data are considered in the construction of the regional water table map, but this analysis is preliminary.

In addition to the transients, many other factors complicated the contouring of the regional water table. For example, differences in well screen placements and local hydrogeologic conditions also complicate the interpretation of the water-level data.

1. Some screens are substantially below the top of regional saturation (more than 60 ft); as a result, the collected water-level data may not be representative of the actual water-table elevations (for example, R-10a, R-13, R-18, R-20, R-21, R-26, R-28, R-32, and R-34).
2. Some screens are long (more than 50 ft) and may represent composite water-levels within the aquifer (DT wells, R-8, R-13, and R-15, a total of 6 wells).
3. Some screens are under confined conditions and represent piezometric surface elevations (R-4 and R-24).
4. Well R-25 is drilled in a complicated hydrogeological setting, and it is uncertain which of the R-25 screens (screen 4 or 5) provides information about the water-table elevation.

5. Well R-9 is screened in a zone (basalts within Santa Fe Group, Tb 2) that is potentially disconnected from the regional aquifer.

Water-table screens are located in various hydrostratigraphic units, including sedimentary and volcanic rocks with contrasting hydrogeologic properties; it is expected that the structure of the regional water table is impacted by groundwater flow through hydrostratigraphic units with contrasting properties.

The process of water-table contouring is theoretically constrained by conformity rules (Freeze and Cherry 1979, 088742): (1) the contour lines should be perpendicular to the flowpaths; (2) the length and the width of the flownet cells formed by the contour lines between two adjacent flowpaths should have the same ratios. These rules are theoretically valid only for the case of a uniform isotropic aquifer with no recharge/discharge sources within flownet cells. Deviations from the conformity rules are caused by aquifer heterogeneity and anisotropy as well as by recharge/discharge sources within flownet cells.

The regional water table is contoured by attempting to achieve three goals simultaneously: (1) match the water-level data at the monitoring wells, (2) account for issues of data representativeness, and (3) preserve flownet conformity. Figure G-1.1-1 is a contour map of the regional water table that attempts to satisfy those three goals. The actual contouring is performed using a combination of manual and automated techniques. The automated contouring is performed using the minimum curvature method (Smith and Wessel 1990, 107000).

The existing water-level data and the contoured map (Figure G-1.1-1) suggest potential mounding of the regional water-table near TW-1, R-8, and R-36. The water level at R-36 is slightly higher than the water levels at R-28, R-45, R-11, R-13, and R-34. The mounding may result from local recharge of the regional aquifer along Los Alamos, Pueblo, and Sandia Canyons.

The existing water-level data represented by the contour map suggest that thick lavas in the area between R-32 and R-22 may be the cause of the increased phreatic hydraulic gradients in this area, resulting from the lower transmissive properties of lava flows compared to more transmissive properties of the Puye Formation and Santa Fe Group sediments. The hydrogeologic properties associated with the lava flows may also be responsible for diverting the flow of phreatic groundwater to the north. The increased hydraulic gradients in the area between R-32 and R-22 may also be an indication of recharge in the lower Pajarito Canyon area that causes local mounding in the lavas, which are expected to be of low storativity when compared to the Puye Formation fanglomerates and Santa Fe Group sediments.

G-1.2 Local-Scale Water-Table Map Near Sandia Canyon

Figure G-1.2-1 shows a small-scale version of the water-table map near Sandia Canyon. The water-level data represent averages of the January 2009 water levels. The data for R-42, R-43, R-44, and R-45 are preliminary and were collected during well construction and development. New water-level data are currently collected at these wells using pressure transducers and will be a subject of future analyses in documents such as the “General Facility Investigation” reports (e.g., LANL 2008, 101932) and the annual “Groundwater Level Status” reports (e.g., Koch and Schmeer 2009, 105181). It is important to note that the water-level data presented in Figure G-1.2-1 suggest an eastern-southeastern groundwater flow direction. The presented contour lines are obtained by spatially fitting the data points with a plane; the slope and orientation of the plane is computed using a simple regression analysis. However, Figure G-1.2-1 shows that there is no perfect planar match between observed and estimated (presented as contour lines) water levels. It is especially difficult to reconcile the elevated water level at R-36 (higher than levels at R-42 R-28, R-45, R-11, R-13, and R-34) and at R-35b (higher than level at R-45). Future analysis will address the spatial distribution of the water levels and hydraulic gradients in this area. Related to analyses presented in Appendix L of this investigation report, it is important to note that

currently groundwater flow directions are uncertain, but the flow is most likely oriented as presented in Figure G-1.2-1. The hydraulic gradient is on the order of 0.001 with an uncertainty range from 0.0005 to 0.002.

G-2.0 ANALYSIS OF TRANSIENT WATER LEVELS OBSERVED AT REGIONAL AQUIFER MONITORING WELLS NEAR SANDIA CANYON

Analysis of transient water levels observed in the regional aquifer at the monitoring wells near Sandia Canyon provides information about the magnitude of pumping drawdowns caused by the water-supply wells in the vicinity. The analysis also provides information about the hydrogeologic properties of the regional aquifer, the potential effect of local infiltration recharging the aquifer beneath Sandia Canyon, water-supply pumping on groundwater flow directions, and long-term groundwater-level elevation trends. The complex hydrogeology beneath the Laboratory, coupled with the relatively small magnitude of the observed water-level transients in the shallow portion of the regional aquifer, presents particular challenges for this analysis. This appendix discusses a hydraulic survey of transient water levels observed at 16 monitoring wells (or 19 observation locations including multiple screens for some monitoring wells) using an analytical flow model and linear regression analysis.

G-2.1 Water-Level Data

The monitoring wells in and near Sandia Canyon monitor groundwater-level elevations in the shallow portion of the regional aquifer, which is predominantly under phreatic (unconfined) conditions. Water-supply wells in the vicinity pump from the deeper portion of the aquifer, which is primarily under confined conditions. The drawdown at the supply wells varies from 10 to 25 m. The gradients and flow directions in the phreatic zone exhibit a predominant influence from ambient flow, with a less-pronounced influence from water-supply pumping. The ambient flow is controlled by areas of mountain-front and canyon-bottom recharge and discharge at the river and springs to the east. Maps of the regional water table are presented and discussed in section G-1.0.

Figure G-2.1-1 presents groundwater levels (as absolute water-level elevations above sea level) for the observation wells near Sandia Canyon. The total fluctuation in groundwater levels over the approximately 3-yr period presented is small, from approximately 0.25 m to 4.0 m. Figure G-2.1-1 also presents the daily pumping (production) volumes from wells in the vicinity (PM-1, PM-2, PM-3, PM-4, PM-5, and O-4). Note that the pumping at all the wells, except PM-4, is cycled on a daily basis. PM-4 is pumped continuously during the summer season.

A visual comparison between the fluctuations in the groundwater levels and in the pumping volumes shows a correlation between R-15 and PM-4, R-35a and PM-3, R-33 and PM-4, and R-8 and PM-3. However, correlations associated with the other monitoring and pumping wells are not readily apparent. A subtle correlation between general seasonal trends in water levels and pumping rates can be observed at many of the monitoring wells, suggesting these water-level changes are probably caused by water-supply pumping.

Other influences that may be present in the water-level records include (1) barometric effects, (2) variability in the ambient flux, (3) variability in local recharge beneath Sandia Canyon or other canyons (identification of such transients typically requires much longer observation periods than the existing 3-yr water-level record), and (4) subsidence (pore-elastic effects) from water-supply pumping.

The following analysis includes the modeling of transient water-level responses at monitoring wells by estimating pumping drawdown using simple analytical techniques that account for pumping influences.

This approach allows "fingerprinting" of pumping influences at observation well locations, given contrasting pumping records, estimation of potential drawdown effects associated with individual pumping wells, and estimation of effective hydraulic properties of the aquifer between pumping and observation wells. While the use of a simple analytical model does not allow the accurate estimation of the spatial properties of aquifer heterogeneity, it can provide information about the aquifer properties, for example non-uniform aquifer properties or aquifer anisotropy. A linear regression analysis is used to provide estimates of the rate of groundwater-level elevation decline in the monitoring wells.

G-2.2 Analytical Estimation of Potential Pumping Effects

Pumping drawdown effects have been simulated using the Theis solution (Freeze and Cherry 1979, 088742, p. 317) defined as

$$s = \frac{Q}{4\pi T} W(u) = \frac{Q}{4\pi T} W\left(\frac{r^2 S}{4Tt}\right),$$

where s is the transient drawdown (L), Q is the discharge from the well (L^3T^{-1}), T is the transmissivity (L^2T^{-1}), $W(u)$ is the well function where $u = r^2S/4Tt$, where r is the distance to the pumping well (L), S is the specific storage coefficient, and t is time since pumping commenced (T). The Theis solution is intended for homogeneous formations, precluding its ability to characterize spatial variation of hydraulic properties. Nevertheless, the equation can provide estimates for the pumping effects in heterogeneous formations if the effective properties of the aquifer are known.

The principle of superposition is used to represent transient effects in pumping rates and to combine drawdown contributions from multiple water-supply wells to predict observed drawdown at a given monitoring well. In this way, the predicted drawdown at a monitoring well is a sum of drawdowns created by each production well during each pumping period:

$$s = \sum_{i=1}^{N} \sum_{j=1}^{M_i} \frac{Q_{ij} - Q_{ij-1}}{4\pi T_i} W\left(\frac{r_i^2 S_i}{4T_i\left(t - t_{Qij}\right)}\right),$$

where N is the number of pumping wells, M_i is the number of pumping periods (i.e., number of pumping rate changes), Q_{ij} is the pumping rate of well i during pumping period j, and t_{Qij} is the time when the pumping rate changed at well i during pumping period j. In these analyses, seven pumping wells are considered, and the maximum number of pumping rate changes (M_i) is 2035 (for O-4). The principle of superposition allows for different effective hydraulic properties between different water supply/observation well pairs (T_i, S_i), referred to as cross-hole effective hydraulic properties. In this way, it is possible to estimate the extent that the heterogeneity affects the observed drawdowns in the monitoring wells. Furthermore, discrepancies between the simulated and observed pressures may suggest additional transients or heterogeneities that are currently not included in this model (e.g., transients in the ambient fluxes).

Inverse modeling is employed to identify effective hydraulic properties (transmissivity T and specific storage S), resulting in model predictions that are consistent with observed water-level elevations (calibration targets). The daily variations in the water-supply production record, which include the daily pumping and recovery periods, are explicitly represented in the model.

This inverse analysis is similar to the analysis of pumping tests. However, in this case, the pumping test includes multiple pumping wells that have transient pumping records. The benefits of this approach are

that (1) specially designed field tests are not needed (testing should include a prolonged cessation of pumping at all the production wells before the test, although this might not be feasible), and (2) the effects of measurement errors may be mitigated given long water-level and pumping records.

Rates of decline in the groundwater-level elevations since 2006 are estimated using a linear regression analysis performed using a least-squares Levenberg-Marquardt algorithm to fit a straight line to the observed water levels. The slope of the line provides an optimal estimate of the water-level trend in a least-squares sense.

G-2.3 Results and Discussion

Figure G-2.3-1 presents plots of the observed (plotted in red) and simulated groundwater-level elevations (plotted in black) at the monitoring wells considering the influence of water-supply pumping. By inspecting the plots, it is apparent that for most wells the water-level transients can be simulated with the analytical model. In other cases, the general trend is simulated, while the higher frequency transients are not replicated by the model (e.g., R-9, R-36). For each inversion model, the effective cross-hole transmissivities and storativities between the observation and pumping wells are estimated. The cross-hole property inferences that demonstrate the ability to produce simulations correlated with the observed water levels are presented in Tables G-2.3-1 and G-2.3-2, respectively. It is important to note that the various transmissivity estimates listed in Table G-2.3-1 are within 2 orders of magnitude of each other, indicating a degree of consistency in the estimates of this effective property. Some of the variation in this parameter may be attributed to early-time behavior of Theis solution parameter (Wu et al. 2005, 106998). Variations in the transmissivity estimates suggest unique aquifer heterogeneity between each of the supply wells and monitoring wells. The specific storage estimates vary by over 3 orders of magnitude (Table G-2.3-2), indicating various degrees of interwell connectivity between pumping/monitoring well pairs (Meier et al. 1998, 106999). As with the transmissivity estimates, some of this variability may be attributed to early-time behavior of Theis solution parameters.

Table G-2.3-3 summarizes the results of the calibrations by indicating the pumping wells that the model identified as influencing the water-level fluctuations at each monitoring well. In most cases, the model clearly attributes the water-level transients to particular water-supply wells. In the cases of R-6 and R-13, one well is clearly identified as contributing to the water-level transients; however, other wells could also potentially contribute. It is important to note that the observed water levels in these two cases present seasonal trends (resulting from high pumping rates in the summer and low pumping rates in the winter months), but little high frequency transients that could be attributed to a particular water-supply well. In the cases of R-7, R-9, R-34, R-35b, and R-36, the water levels do not appear to be correlated with pumping transients. For R-7, R-34, and R-35b, this effect is probably because the water levels demonstrate a smooth temporal trend without high frequency transients, making the fingerprinting of water-supply well influences difficult. For wells R-9 and R-36, while there are significant high frequency transients, the model simulates a relatively smooth temporal trend, the water-level fluctuations cannot be attributed to any of the pumping wells. The fluctuations may have another source not considered in the analysis or the propagation of the transients from the pumping well to these monitoring wells is more complex than the current model can simulate. Also, R-7, R-9, R-34, R-35b, and R-36 screen zones at the top of the regional aquifer are not well connected with the deep aquifer zones pumped by the water-supply wells.

Table G-2.3-4 presents the rate of groundwater-level change during the approximately 3-yr period considered here determined by linear regression of the barometrically corrected groundwater levels. It is apparent a declining trend in water levels occurs near Sandia Canyon, with an average decline of approximately 0.177 m/yr with a standard deviation of 0.104 m/yr about this average. While it is clear

water levels are declining, the rate of decline varies spatially. High rates of decline are observed at R-8 and R-15; the lowest rates are observed at R-5, screen 4, R-9, and R-14 (Table G-2.3-4). The water-level declines are observed at screens located at various depths below the regional aquifer water table; therefore, the data do not provide direct observation of the decline of the regional water table in the study area.

G-2.4 Summary of Pumping Effects

A simple analytical model was used to extract groundwater information from production and water-level records about the properties of the regional aquifer beneath the Sandia Canyon area. The inverse analysis of pressure responses from pumping suggests that there may be large-scale hydrogeologic structures with properties that are different from the rest of the aquifer. Fingerprinting of water-supply pumping influences at the monitoring wells indicates the complicated connections within the aquifer resulting from large-scale heterogeneities. The water levels at the monitoring wells are declining in a nonuniform manner within the area. Currently, the transient water-level records for wells R-42, R-43, R-44, and R-45 are not sufficient to perform the analyses presented here.

The presented analyses are important because they provide information about (1) effective hydrogeological properties of the aquifer (in a manner similar to standard pumping tests), (2) hydraulic connections between water-supply and monitoring wells (as well as the hydrostratigraphic sections screened by these wells), (3) potential impact of water-level transients on directions of groundwater flow and contaminant transport in the area. In summary, the pumping wells appear to have a small impact on the regional water table near Sandia Canyon; as a result, pumping wells are expected to have little influence on the groundwater flow and contaminant transport.

G-3.0 TRANSIENTS IN WATER LEVELS AND CONCENTRATIONS OF GEOCHEMICAL CONSTITUENTS OBSERVED AT R-28

Figure G-3.0-1 compares transients in the water-level elevation and concentrations of key geochemical constituents observed at R-28. The figure suggests some correlation exists between the water levels and chromium, nitrate, and tritium concentrations. In addition, chromium, nitrate, and tritium concentration also seem to be well correlated. This correlation could indicate that the fluctuations of the regional water table affect the contaminant fate and transport. This behavior may be caused by various hydrogeological and geochemical processes. For example, geochemical constituents in the lowermost part of the vadose zone (adjacent to the regional water-table) could be mobilized during times of higher water levels. In this way, chromium, nitrate, and tritium mass residing in the vadose zone may be flushed by rising regional-aquifer groundwater, resulting in a higher measured concentration at the monitoring wells. Conversely, when the water table drops, chromium, nitrate, and tritium come from continuously saturated strata, which potentially results in more dilute concentrations.

G-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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Koch, R.J., and S. Schmeer, March 2009. "Groundwater Level Status Report for 2008, Los Alamos National Laboratory," Los Alamos National Laboratory report LA-14397-PR, Los Alamos, New Mexico. (Koch and Schmeer 2009, 105181)

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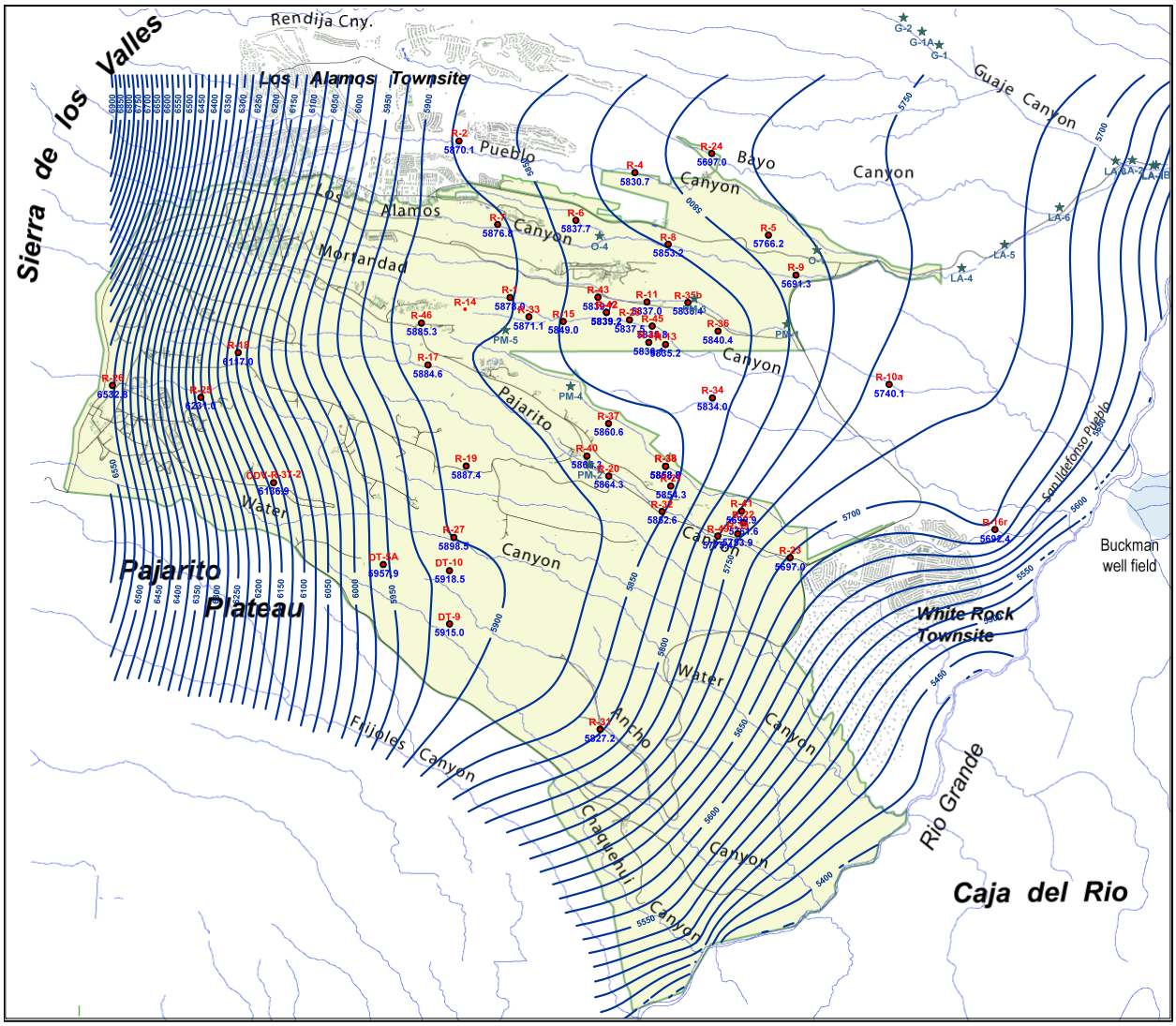
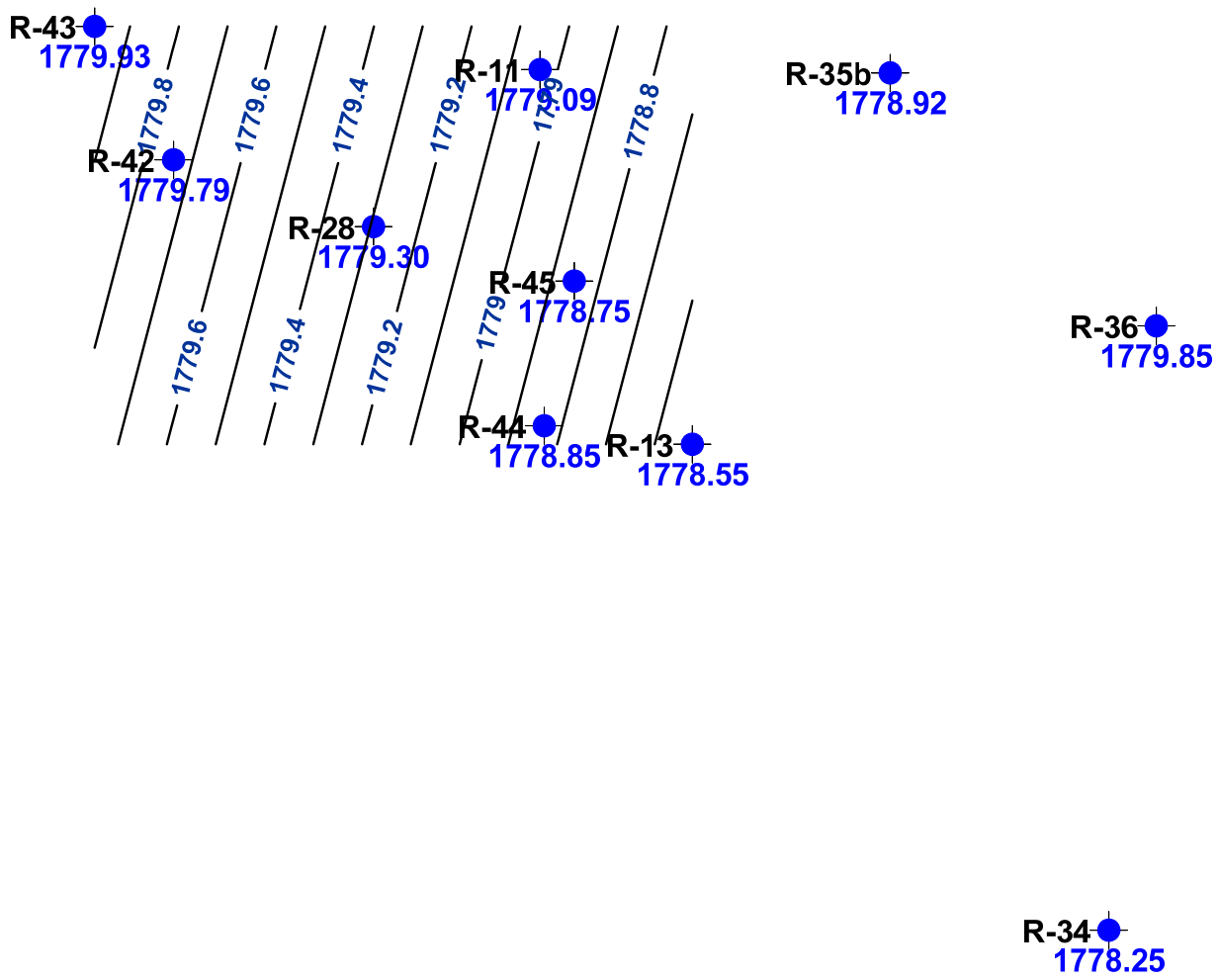


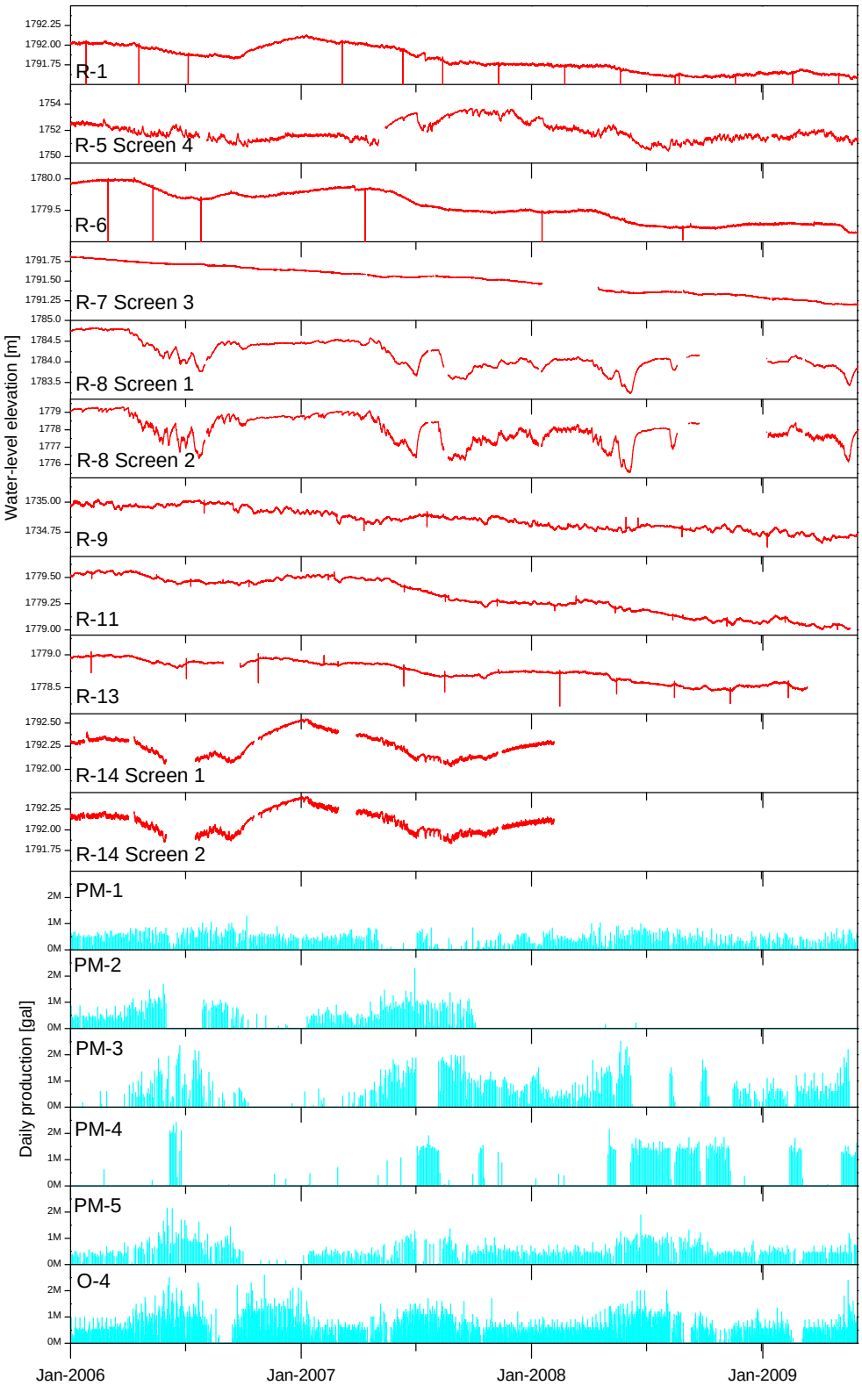
Note: Water levels are shown in feet above mean sea level.

Figure G-1.1-1 Regional water-table map representing the average regional water levels observed in February and March 2009



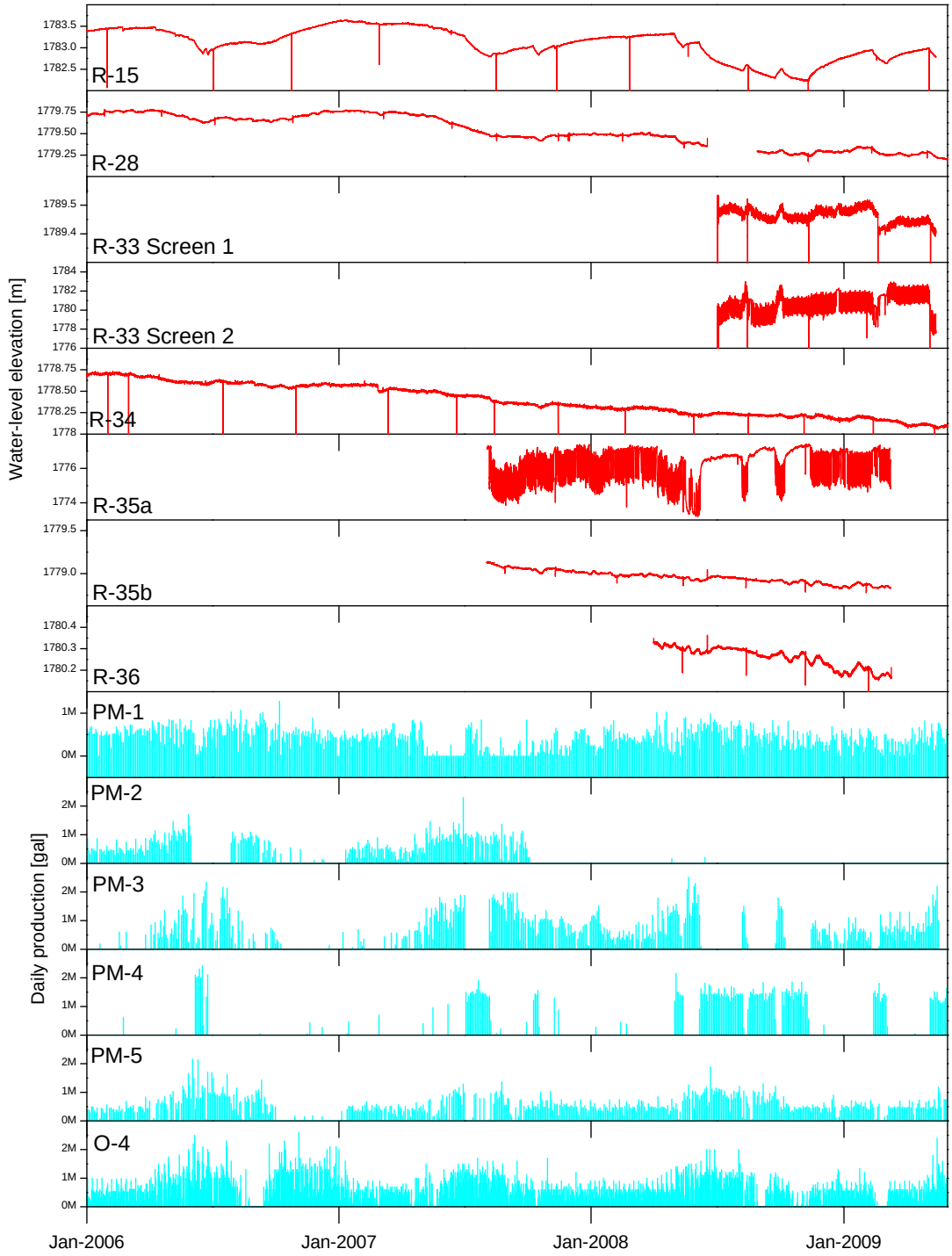
Note: Water levels are shown in meters above mean sea level.

Figure G-1.2-1 Water-table map representing the general trend in the water levels near Sandia Canyon based on observations made in January 2009 (water levels for the new wells R-42, R-43, R-44 and R-45 were observed during well installation and development)



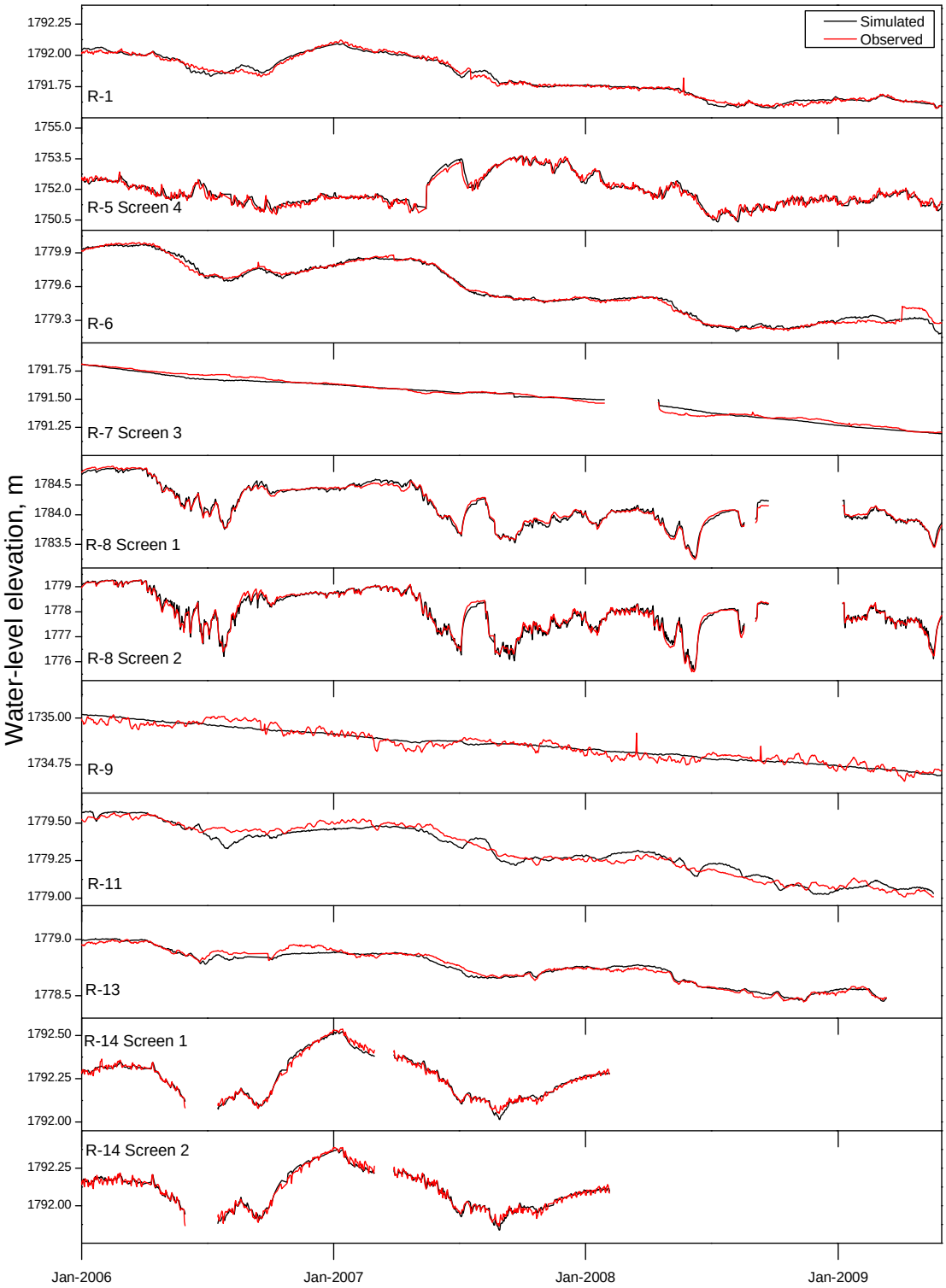
a.

Figure G-2.1-1 Groundwater-level elevations at observation wells and supply-well pumping volumes for production wells near Sandia Canyon



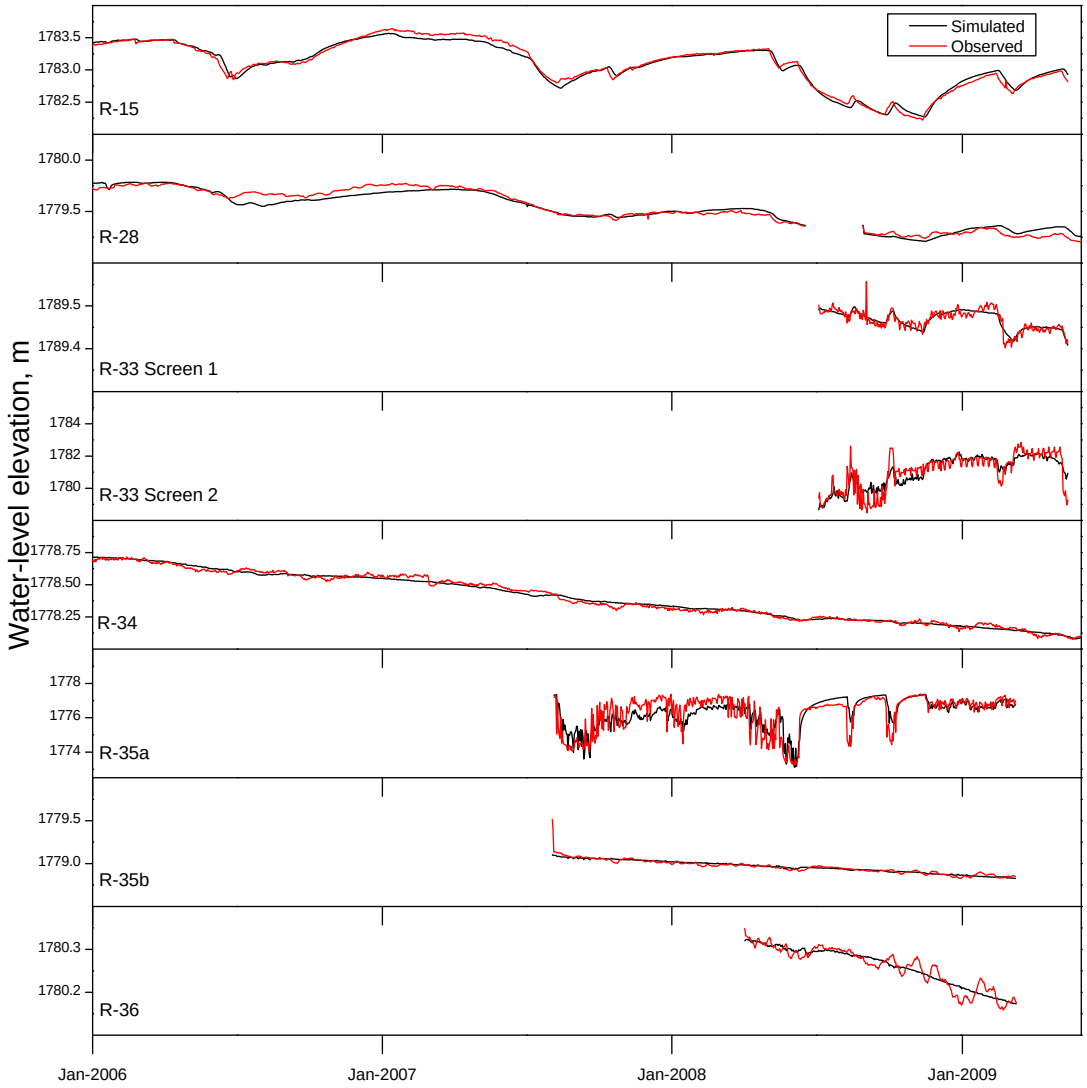
b.

Figure G-2.1-1 (continued) Groundwater-level elevations at observation wells and supply-well pumping volumes for production wells near Sandia Canyon



Notes: Each plot presents the results from a separate model inversion. In each case, the model simulates water elevations at a single observation well using pumping records for all seven water-supply wells. Note differences in the y-axis scales on each plot.

Figure G-2.3-1 Barometrically corrected observed (red line) and model-simulated (black line) water levels at individual monitoring wells



Notes: Each plot presents the results from a separate model inversion. In each case, the model simulates water elevations at a single observation well using pumping records for all seven water-supply wells. Note differences in the y-axis scales on each plot.

Figure G-2.3-1 (continued) Barometrically corrected observed (red line) and model-simulated (black line) water levels at individual monitoring wells

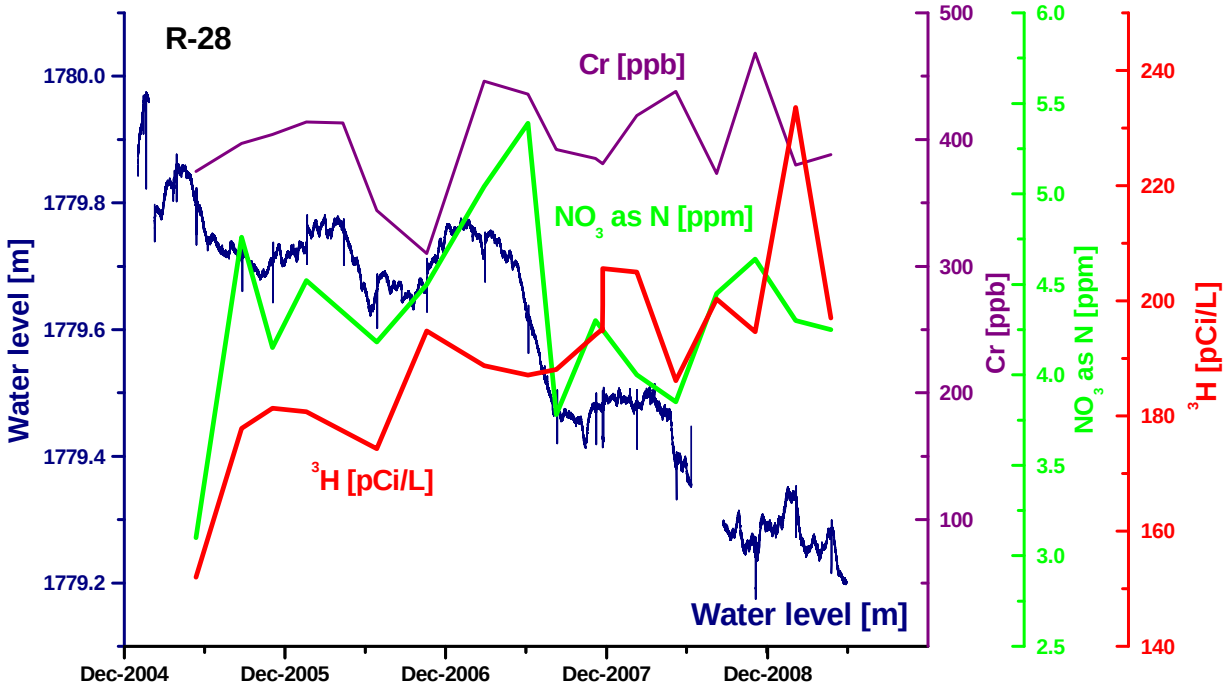


Figure G-3.0-1 Transients in water-level elevation and concentrations of key geochemical constituencies observed at well R-28

Table G-2.3-1
Estimates of Effective Cross-Hole Transmissivity (m^2/day)
between Pumping Wells and Monitoring Wells Based on Model Calibration

Well	Screen	PM-1	PM-2	PM-3	PM-4	PM-5	O-1	O-4
R-1	Single	—*	—	—	—	3.80E+03	—	—
R-5	4	1.91E+02	—	—	—	—	—	—
R-6	Single	—	—	2.51E+03	3.98E+03	1.78E+03	—	—
R-7	Single	—	—	—	—	—	—	—
R-8	1	—	—	2.04E+03	—	—	—	3.09E+03
R-8	2	—	—	9.12E+02	—	—	—	3.47E+03
R-9	Single	—	—	—	—	—	—	—
R-11	Single	—	3.39E+03	5.01E+03	5.13E+03	—	—	—
R-13	Single	—	1.26E+04	6.92E+03	6.17E+03	—	—	—
R-14	1	—	2.19E+03	—	3.89E+03	3.02E+03	—	—
R-14	2	—	2.34E+03	—	4.37E+03	3.09E+03	—	—
R-15	Single	—	3.63E+03	3.02E+03	9.77E+02	2.88E+03	—	—
R-28	Single	—	3.09E+03	4.79E+03	6.31E+03	—	—	—
R-33	1	—	—	—	1.58E+04	—	—	—
R-33	2	—	—	—	1.91E+03	—	—	—
R-34	Single	—	—	—	—	—	—	—
R-35a	Single	—	—	8.91E+02	—	—	—	—
R-35b	Single	—	—	—	—	—	—	—
R-36	Single	—	—	—	—	—	—	—

*— = Transmissivity was not estimated because of a lack of discernable pumping influence by the particular pumping well at the particular monitoring well.

Table G-2.3-2
Estimates of Effective Cross-Hole Storativity (Unitless)
between Pumping Wells and Monitoring Wells Based on Model Calibration

Well	Screen	PM-1	PM-2	PM-3	PM-4	PM-5	O-1	O-4
R-1	Single	—*	—	—	—	0.100	—	—
R-5	4	0.001	—	—	—	—	—	—
R-6	Single	—	—	0.028	0.018	0.062	—	—
R-7	Single	—	—	—	—	—	—	—
R-8	1	—	—	0.005	—	—	—	0.019
R-8	2	—	—	0.001	—	—	—	0.005
R-9	Single	—	—	—	—	—	—	—
R-11	Single	—	0.069	0.676	0.110	—	—	—
R-13	Single	—	0.010	0.100	0.017	—	—	—
R-14	1	—	0.006	—	0.025	0.030	—	—
R-14	2	—	0.007	—	0.022	0.016	—	—
R-15	Single	—	0.009	0.042	0.022	0.058	—	—
R-28	Single	—	0.050	0.263	0.056	—	—	—
R-33	1	—	—	—	0.047	—	—	—
R-33	2	—	—	—	0.0002	—	—	—
R-34	Single	—	—	—	—	—	—	—
R-35a	Single	—	—	0.011	—	—	—	—
R-35b	Single	—	—	—	—	—	—	—
R-36	Single	—	—	—	—	—	—	—

*— = Storativity was not estimated because of a lack of discernable pumping influence by the particular pumping well at the particular monitoring well.

Table G-2.3-3
Identification of the Influence of Pumping Wells (Columns)
on Monitoring Wells (Rows) Water Levels Near Sandia Canyon

Well	Screen	PM-1	PM-2	PM-3	PM-4	PM-5	O-1	O-4
R-1	Single	No	No	No	No	Yes	No	No
R-5	4	Yes	No	No	No	No	No	No
R-6	Single	No	No	Yes	?	?	No	No
R-7	Single	No	No	No	No	No	No	No
R-8	1	No	No	Yes	No	No	No	Yes
R-8	2	No	No	Yes	No	No	No	Yes
R-9	Single	No	No	No	No	No	No	No
R-11	Single	No	No	Yes	Yes	Yes	No	No
R-13	Single	No	?	?	Yes	No	No	No
R-14	1	No	Yes	No	Yes	Yes	No	No
R-14	2	No	Yes	No	Yes	Yes	No	No
R-15	Single	No	Yes	Yes	Yes	Yes	No	No
R-28	Single	No	No	Yes	Yes	Yes	No	No
R-33	1	No	No	No	Yes	No	No	No
R-33	2	No	No	No	Yes	No	No	No
R-34	Single	No	No	No	No	No	No	No
R-35a	Single	No	No	Yes	No	No	No	No
R-35b	Single	No	No	No	No	No	No	No
R-36	Single	No	No	No	No	No	No	No

Notes: "Yes" indicates a positive identification of the ability of the model to simulate a component of the water-level fluctuations at a well. "No" indicates the model was not able to attribute a component of the water-level fluctuations to the pumping well. A question mark indicates the results are inconclusive.

Table G-2.3-4
Estimated Rate of Groundwater-Level Elevation Decline Since 2006

Well	Screen	Linear Rate of Water-Level Decline (m/yr)	Comment
R-1	Single	0.153	None
R-5	4	0.028	None
R-6	Single	0.240	None
R-7	3	0.172	No pumping influences identified
R-8	1	0.239	Water-level decline influenced by pumping
R-8	2	0.390	Water-level decline influenced by pumping
R-9	Single	0.083	No pumping influences identified
R-11	Single	0.174	None
R-13	Single	0.182	None
R-14	1	0.046	Water-level decline influenced by pumping
R-14	2	0.051	Water-level decline influenced by pumping
R-15	Single	0.323	None
R-28	Single	0.220	None
R-33	1	Not analyzed	Short record to perform the analysis
R-33	2	Not analyzed	Short record to perform the analysis
R-34	Single	0.175	No pumping influences identified
R-35a	Single	Not analyzed	Short record to perform the analysis; water level heavily influenced by pumping
R-35b	Single	0.168	No pumping influences identified
R-36	Single	0.158	No pumping influences identified

Appendix H

Chromium Isotope Investigation

H-1.0 INTRODUCTION

Samples of surface water and groundwater in Mortandad and Sandia Canyons and Cañada del Buey were collected and analyzed for stable isotopes of chromium (^{52}Cr and ^{53}Cr, δ^{53}Cr). The purpose of this investigation, conducted by Los Alamos National Laboratory (the Laboratory) is to evaluate possible reduction of Cr(VI) to Cr(III) along surface water and groundwater flow paths. Stable isotopes of chromium may provide quantitative information on biological and/or chemical conditions that control the extent of Cr(VI) reduction in surface and subsurface environments. Key reductants include solid organic matter (SOM) (especially abundant in the Sandia Canyon wetland) and ferrous iron [Fe(II)] concentrated in reactive minerals and glass, which is particularly abundant at depth within the Cerros del Rio basalt. Analyses of δ^{53}Cr in water samples should advance the geochemical conceptual model for chromium, particularly with regard to where in the system reduction of Cr(VI) may be occurring.

H-2.0 CHROMIUM ISOTOPE FRACTIONATION

Chromium has four stable isotopes: ^{50}Cr (4.35%), ^{52}Cr (83.8%), ^{53}Cr (9.50%), and ^{54}Cr (2.37%).

The delta (δ) notation is as follows:

$$\delta^{53}Cr = \{[(^{53}Cr/^{52}Cr_{sample})/(^{53}Cr/^{52}Cr_{standard})-1]*1000\} \quad \textbf{Equation H-1}$$

in units of per mil (‰) or parts per thousand.

The standard used in this study was National Institute of Standards and Technology (NIST) SRM 979, a chromium nitrate compound sold by the NIST as an isotopic standard.

Ratios of ^{53}Cr to ^{52}Cr have been demonstrated to reflect the degree of reduction of dissolved Cr(VI) to Cr(III) along surface water and groundwater flow paths (Ellis et al. 2002, 098081; Kitchen et al. 2004, 098088; Sikora et al. 2008, 102411). During both abiotic and biotic reduction of Cr(VI) to Cr(III), a kinetic isotope effect occurs in which the lighter isotope, ^{52}Cr, reacts preferentially, leaving the remaining dissolved Cr(VI) enriched in the heavier isotope, ^{53}Cr.

This process is represented mathematically as follows (Ellis et al. 2002, 098081):

$$\delta^{53}Cr = [(\delta^{53}Cr_{ini} + 10^3)f^{(\alpha-1)}]-10^3 \quad \textbf{Equation H-2}$$

where δ^{53}Cr is the isotopic composition of residual dissolved Cr(VI), and f is the fraction of Cr(VI) remaining. In Equation H-2, alpha (α) is the instantaneous fractionation factor. Before any reduction of Cr(VI) takes place, f is equal to 1, and δ^{53}Cr is equal to $\delta^{53}Cr_{ini}$. Equation H-2 can be used to calculate f, the fraction of Cr(VI) remaining. This value, in turn, can be subtracted from unity and converted to a percentage to calculate the percentage of Cr(VI) reduction occurring along a flow path.

A range of environmentally relevant fractionation factors from approximately 0.9957 (i.e., a fractionation of -4.3‰ resulting from microbial reduction [Sikora et al. 2008, 102411]) to 0.9975 (i.e., a fractionation of -2.5‰, abiotic reduction [Ellis et al. 2002, 098081; Kitchen et al. 2004, 098088; Johnson and Berna 2008, 102464]) has been observed. Fractionation factors do not appear to vary with Cr(VI) concentration, at least in the case of microbial reduction (Sikora et al. 2008, 102411). The isotopic fractionation factor for oxidation of solid Cr(III) to Cr(VI) was previously considered to be negligible (Ellis et al. 2004, 098086); however, recent work suggests the weathering of mafic rocks results in the production of Cr(VI) with δ^{53}Cr of ~ 1 ‰ (Izbicki et al., 2008, 102412; Johnson 2009, 106997). Dr. Johnson, of the University of Illinois

Urbana-Champaign, believes that "weathering-produced Cr(VI), immediately after its formation, has a good chance of going back toward the reduced zone it came from (e.g., Fe(II)-bearing leached layer on mineral surface). [As a result] some of the Cr(VI) is lost to back-reaction and the remainder is isotopically heavy" (Johnson 2009, 106997). Chromium isotopes are not fractionated significantly by adsorption processes (Ellis et al. 2004, 098086).

The initial Cr isotope composition of dissolved chromate before reduction is $\delta^{53}Cr_{ini}$. Chromite ores, from which industrial chromium is derived, have an average $\delta^{53}Cr$ of -0.082 ± 0.058 ‰ (2 σ) (Schoenberg et al. 2008, 102413). Because of the high temperature and efficiency of extraction, industrial chromium should have very similar $\delta^{53}Cr$ values (Ellis et al. 2002, 098081; Schoenberg et al. 2008, 102413). The highest value measured for industrial reagent chromium is 0.37 ‰ (Ellis et al. 2002, 098081).

In this study of Sandia Canyon and Mortandad Canyon, a set of decision rules was developed to determine $\delta^{53}Cr_{ini}$.

1. $\delta^{53}Cr_{ini}$ of locations determined to be background with respect to Cr was set at 1 ‰, with the exception of R-16r, for which a value of 0.68 ‰ was used. These values were determined empirically. $\delta^{53}Cr$ values from Ancho Spring, Spring 10, Spring 9b, R-14 (data were only considered post-well rehabilitation), R-1, R-34, R-16r, R-10, and R-10a were used to determine variation in background concentrations and $\delta^{53}Cr$. These sites were chosen because of their location relative to Cr contaminant inputs, lack of temporal trends in Cr concentrations (i.e., Cr concentrations were not higher in the past or are not currently increasing), lack of evidence for other contaminants that would have been associated with Cr releases, and flow and transport considerations. The mean value of $\delta^{53}Cr$ for these locations is 1.18 ± 0.26 ‰. This value is very similar to that associated with weathering-produced Cr(VI) (Izbicki et al., 2008, 102412; Johnson 2009, 106997). Groundwater samples from R-16r had the lowest $\delta^{53}Cr$ (minimum of 0.68 ‰), so $\delta^{53}Cr_{ini}$ for this location was set at 0.68 ‰ to prevent calculation of negative percentage reduction (See Equation H-2). Any location not considered in calculating background $\delta^{53}Cr_{ini}$ that had concentrations and $\delta^{53}Cr$ values within the range defined by the above locations ($\delta^{53}Cr$ of 0.68 to 1.55 ‰ and total filtered Cr of 1.5 to 9.9 μg/L) were also assigned $\delta^{53}Cr_{ini}$ of 1 ‰ as the data cannot be distinguished from background values. If any contaminant Cr(VI) is present at such locations, $\delta^{53}Cr_{ini}$ will be overestimated and the calculated percentage reduction of Cr(VI) will be underestimated (see Equation H-2 above). Assuming a 1 ‰ value for these locations, therefore, results in a conservative estimation of percentage reduction of Cr(VI).
2. For locations with total dissolved Cr concentrations greater than 20 μg/L, a $\delta^{53}Cr_{ini}$ value of 0 ‰ was assigned because of the predominance of Cr(VI) derived from potassium dichromate. Though the exact $\delta^{53}Cr$ value of potassium dichromate released from Laboratory cooling towers is unknown, most industrial sources of Cr have values similar to 0 ‰. The lowest $\delta^{53}Cr$ value seen in our data set is 0.14 ‰, which is within analytical error of 0 ‰.
3. Only one location, SCI-1, had $\delta^{53}Cr$ values less than 0.68 ‰ (the lowest value in our range of background $\delta^{53}Cr$). Given this observation, and the fact that SCI-1 is located above the Cerros del Rio basalt from which background Cr(VI) could be produced by weathering, it can be assumed that all Cr(VI) is from releases of potassium dichromate and that $\delta^{53}Cr_{ini}$ can be assigned a value of 0 ‰ . A value of 0 ‰ was also chosen for all surface water and alluvial locations, which are similarly located above basalts.
4. For locations that do not fit any of the above categories, a mixture of background and anthropogenic Cr sources was assumed. The value for $\delta^{53}Cr_{ini}$ was set at 0.35 ‰, half way between the anthropogenic end member and the lowest $\delta^{53}Cr$ value at a background location (R-16r; 0.68 ‰). It should be noted that uncertainty associated with picking a value for $\delta^{53}Cr_{ini}$

(choosing a value between 0.2 and 0.5 ‰, for example) is typically less than that associated with use of different fractionation factors.

H-3.0 SAMPLE COLLECTION AND PRESERVATION

Surface and groundwater samples were collected in 1-L high-density polypropylene bottles for Cr isotope analyses. Before November, 2008, the nonacidified samples were filtered through 0.45-micrometer membranes. During the course of Cr investigations it was recognized that, for some samples, colloidal Cr(III) passed through 0.45 and 0.22-micrometer membranes (see Appendix J, section J-4.9, for a discussion of colloidal Cr). This Cr-bearing colloidal material is larger than 0.02 micrometers. As a result, samples collected from November 2008 onwards were filtered through 0.02-micrometer membranes. The Cr isotope analyses were conducted at the University of Illinois Urbana-Champaign, Department of Geology.

H-4.0 ANALYTICAL METHODOLOGY

The sample preparation process consisted of purifying Cr and removing interfering elements such as titanium (Ti), vanadium (V), and iron. A measured amount of the ^{50}Cr+^{54}Cr double isotope spike solution (see section H-4.1) was added and thoroughly mixed with an aliquot of the water. Cr(VI) was separated from the sample matrix and purified using an anion exchange process. Cr(VI) was adsorbed onto an anion exchange resin, sample matrix species were rinsed from the resin with hydrochloric acid, the Cr was converted to Cr(III), and Cr(III) was eluted from the resin. With most of the samples containing less than 30 μg/L of Cr, some iron (Fe) was not fully separated from Cr in the purification process described above. It is possible that the Fe(II, III) occurred as complexed ions bound to dissolved and suspended organic carbon. Excessive Fe was removed using a second ion exchange step in which Fe was adsorbed onto anion exchange resin as $FeCl_4$ and Cr passed through.

H-4.1 Double Isotope Spike

Multicollector inductively coupled plasma mass spectrometer (ICPMS) instruments impart a large bias to the measured ratios; measured $^{53}Cr/^{52}Cr$ ratios differ from true ratios by approximately 3%. This measurement bias was determined precisely and corrected for using the double isotope spike approach. A solution containing ^{50}Cr and ^{54}Cr in a known ratio was added to each sample and mixed thoroughly. When the sample-spike mixture was analyzed, the measured $^{50}Cr/^{54}Cr$ ratio was used to determine the measurement bias. The measured $^{53}Cr/^{52}Cr$ was then corrected for this bias. Any isotopic fractionation that occurred during sample preparation after addition of the double spike was corrected for as part of the overall bias. More detail about the double spike approach can be found in recent publications (Beard and Johnson 1999, 098076; Johnson et al. 1999, 098087) and references therein.

H-4.2 Mass Spectrometry

Isotopic ratios for Cr were determined using a Nu Plasma HR multicollector ICP-MS. The argon-based inductively coupled plasma generates ArC^+, ArN^+ and ArO^+ ions with masses close to, but slightly greater than, those of ^{52}Cr, ^{53}Cr, ^{54}Cr, and ^{56}Fe. The instrument is operated in a high-resolution mode that allows measurement of ^{50}Cr, ^{52}Cr, ^{53}Cr, ^{54}Cr, and ^{56}Fe while excluding ArC^+, ArN^+, and ArO^+. Interferences from ^{54}Fe, ^{50}Ti, and ^{50}V were corrected for by measuring ^{56}Fe, ^{49}Ti, and ^{51}V, calculating the ^{54}Fe, ^{50}Ti, and ^{50}V interference intensities using natural $^{54}Fe/^{56}Fe$, $^{50}Ti/^{49}Ti$, and $^{50}V/^{51}V$ ratios, and subtracting the calculated interference intensities from the measured chromium isotope intensities. A thoroughly tested calculation routine was used to correct for interferences, determine the instrumental bias, mathematically subtract the

double-spike chromium from the sample chromium, and calculate a final $^{53}Cr/^{52}Cr$ result. Because the measured changes in the $^{53}Cr/^{52}Cr$ ratios are small (<1%), the isotopic composition is reported in δ notation. $\delta^{53}Cr$ expresses the parts-per-thousand (per mil or ‰) deviation of a measured isotope ratio relative to the NIST SRM 979 standard (see Equation H-1).

H-4.3 Quality Control and Precision

Standard solutions were run through the sample preparation procedure along with batches of samples. The results from these standards all differed from unprocessed standards by less than 0.1‰ and show no statistically significant offset from unprocessed standards. Typical analytical precision is ± 0.2 ‰ (2 σ), though samples with high organic or iron contents can have lower precision of up to ± 0.5 ‰ (2 σ). Offsets between duplicate pairs of field samples were always less than 0.2 ‰, except for a surface water sample from location E123.4, which ran at lower precision (2 σ precision of 0.5 ‰) because of the high concentrations of dissolved organics and one sample from R-35a where the difference in duplicates was 0.23 ‰ (Table H-4.3-1). Between sampling rounds, $\delta^{53}Cr$ also appears to be quite consistent, particularly for most regional aquifer locations (see for example, data from R-28 [Table H-4.3-1]). Several samples were analyzed following filtration at different filter sizes. Three samples from SCI-1, analyzed for $\delta^{53}Cr$ after filtering through 0.45-, 0.22- and 0.02-micrometer membranes, yielded values of 0.281 ‰, 0.205 ‰ and 0.234 ‰, respectively. (Note: the latter two data points are not in the Water Quality Database because they were accidently assigned the same sample identification values as the 0.45-micrometer filtered sample.) Similar tests performed on samples from R-35a and R-36 (see Table H-4.3-1) also produced results that were identical within analytical error. These results suggest that any colloidal Cr(III) in the samples is not affecting column extraction of Cr(VI) and interfering with analytical results. However, samples collected after November 2008 continue to be filtered through 0.02-micrometer membranes as a good practice.

H-5.0 RESULTS AND DISCUSSION

The analytical results provided in Table H-4.3-1 are listed by watershed, generally organized from upgradient to downgradient along the flow path within each aquifer zone. The $\delta^{53}Cr$ values and percentage of Cr(VI) reduced are presented in Table H-4.3-1 for a range of potential fractionation factors. All values for percentage Cr(VI) reduced discussed herein assume a fractionation factor of -3.5 ‰ (i.e., an alpha of 0.9965). The average percentage reduction of Cr(VI) for all intermediate and regional aquifer locations sampled in Mortandad and Sandia Canyon is shown in Figure H-5.0-1.

It is expected that Cr isotopic enrichment will be highest where the supply of reductants [e.g., Fe(II) and dissolved organic carbon] is highest relative to the mass of Cr(VI) available for reduction. The lateral and leading edges of a plume, therefore, are expected to have the highest $\delta^{53}Cr$ values, whereas the core of a plume, where Cr(VI) concentrations are highest, may show lower $\delta^{53}Cr$ values. Because of the heterogeneous nature of the subsurface beneath Sandia and Mortandad Canyons, the complexity of the conceptual model, and uncertainty associated with whether particular locations are located in the core of a Cr contaminant mass or more towards the periphery, flow paths from Cr isotope data were not inferred. Rather, the data were used to understand where in the system Cr reduction is occurring, while taking into account that in some cases mixing of water with different Cr isotopic compositions related to differing amounts of Cr(VI) reduction may occur. It should be emphasized that a single $\delta^{53}Cr$ value only yields the total amount of reduction that occurred *somewhere* along the upgradient flow path. Measurements at different locations along flow paths are needed to determine where in the system reduction actually occurs.

H-5.1 Surface Water and Alluvial Aquifer

In general, surface water and alluvial water samples were the least amenable to analysis, with many samples failing to yield δ^{53}Cr data because of interferences associated with the presence of organic matter and high dissolved/colloidal Fe. Samples that did yield data typically have lower precision (on the order of ± 0.5 ‰). For those samples that yielded results, calculated percentage Cr(VI) reduction values range from ~4% to 34% (Table H-4.3-1). Potential reductants present in alluvial groundwater and associated surface water include dissolved organic carbon (DOC) in the form of humic and fulvic acids and dissolved organic nitrogen in the form of amino acids and total Kjeldahl nitrogen (TKN), as well as Fe(II).

It is interesting that samples from alluvial well SCA-1DP, located at the distal end of the Sandia wetland, and from the terminus of persistent baseflow in Sandia Canyon have δ^{53}Cr values within error of 0 ‰, suggesting no reduction. It is extremely unlikely that any Cr(VI) has escaped reduction in the Sandia wetland (Appendix J) or that nonreduced contaminant Cr(VI) has been stored in the downgradient alluvial system since 1972 to only now be released with a primary potassium dichromate isotopic signature. It is possible, however, that Cr(VI) measured at these locations results from reoxidation of Cr(III) within the dewatered portion of the Sandia wetland. The chromium isotopic composition of Cr(III) in the Sandia wetland is not known, but it could be equal to the source potassium dichromate, provided all Cr(VI) entering the wetland alluvial system was reduced. Near-quantitative reduction is possible given the large Cr(III) inventories (LANL 2007, 098127) and the prevalence of reducing conditions maintained by SOM concentrated within the wetland. It is also possible, however, that the δ^{53}Cr value of Cr(III) in wetland sediments is lighter than the source isotopic composition if only a portion of the Cr(VI) entering the alluvial system of the wetland was reduced. During Cr(VI) reduction, the light isotope (^{52}Cr) preferentially accumulates in the reduced form of Cr, Cr(III). Isotopic analysis of Cr(III) in wetland sediments could be performed to distinguish among these possibilities. It is unknown why the SCA-1DP and terminus locations have different isotopic values compared to the Sandia Below Wetlands and E123.45 surface water locations, which are also downgradient of the Sandia wetland.

H-5.2 Intermediate-Depth and Regional Groundwater

Background locations, or locations with total dissolved Cr concentrations and δ^{53}Cr within the background range, have among the lowest percentage Cr(VI) reduction values observed in this study (Table H-4.3-1 and yellow circles in Figure H-5.0-1). Chemical weathering or oxidation of the Cerros del Rio basalt is the likely source of background Cr(VI). There may be less opportunity for significant subsequent reduction within the basalt, although clearly some subsequent reduction does occur [calculated percentage Cr(VI) reduction values are not zero].

Samples from SCI-1 also have low percentage Cr(VI) reduction (green circle in Figure H-5.0-1). This likely reflects the fact that this well is completed above the Fe(II)-rich Cerros del Rio basalt. In this case, Cr(VI) reduction along flow paths to SCI-1 would likely only have occurred in the Sandia wetland. As drying and oxidation of wetland sediments (with potentially lower δ^{53}Cr as discussed in section H-5.1) is a relatively recent phenomenon, an alternative explanation for low observed levels of reduction at SCI-1 is that significant amounts of Cr(VI) discharged from the cooling tower essentially bypassed the Sandia wetland (in terms of chemical interaction and reduction) as surface flow, with subsequent storage in the vadose zone.

Locations for which an approximately 1:1 mixture of anthropogenic and background Cr(VI) was assumed (purple circles in Figure H-5.0-1) had percentage Cr(VI) reduction values ranging from approximately 17% to 45%. The higher end of this range represents the maximum Cr(VI) reduction noted in this study and

primarily derives from intermediate wells completed in the Cerros del Rio basalt (note that MCOI-4, located in Mortandad Canyon, is completed in the Cerros del Rio basalt even though it appears to be above the basalt when well locations are projected to Sandia Canyon as in Figure H-5.0-1). The combination of lower concentrations [even after taking into account reduction from initial Cr(VI) concentrations relative to other locations (i.e. orange circles in Figure H-5.0-1)] and readily available reductant [Fe(II)] appears to maximize the potential for reduction. Those wells completed below the Cerros del Rio basalt in the regional aquifer show lower percentage Cr(VI) reduction, perhaps because of flow paths with shorter residence times within the basalt. One exception to this pattern is well R-35a, which has the average highest percentage reduction observed in Mortandad and Sandia Canyons. The δ^{53}Cr values for this well have failed to stabilize (Table H-4.3-1), so interpretation of these high values may be premature. It is unknown if the observed reduction reflects a greater percentage of Cr(VI) that interacted with overlying basalt, subsequent reduction occurring in the Miocene sediments in which the well is completed, or some other factor that has yet to be recognized.

Wells that show a clear predominance of anthropogenic Cr(VI) (>20 μg/L; orange circles in Figure H-5.0-1) have intermediate values of percentage Cr(VI) reduction. Despite higher observed concentrations of Cr(VI), the fact that dissolved Cr reaching these locations still shows a significant degree of reduction [Cr(VI) concentrations would have been ~25% to 30 % higher in the absence of reduction] suggests that the main Cr contaminant mass has experienced significant interaction with overlying basalts. It is not unexpected that somewhat lower percentage Cr(VI) reduction is observed in these more highly contaminated wells, as compared with wells with lower anthropogenic Cr(VI) concentrations, as the mass of Cr(VI) may overwhelm the amount of available reactive reductant along the flow paths to these locations. The relatively consistent percentage Cr(VI) reduction values found in contaminated or potentially contaminated locations within the regional aquifer (with the exception of R-35a) suggest that most reduction occurs in the surface/alluvial system and in the vadose zone as opposed to in the regional aquifer proper.

The fact that the average percentage Cr reduction calculated for surface locations E122, E123.45, and Sandia below Wetlands (~31 %) are higher than the values for R-42 and R-28 (~26 %) appears contrary to the flow path for Cr(VI) transport from the surface system to the regional aquifer. This apparent contradiction has three possible explanations.

1. Cr(VI) observed at R-28 and R-42 essentially bypassed the wetland (in terms of chemical interaction) as surface flow during the period of Cr(VI) release to Sandia Canyon. All the reduction indicated by the associated δ^{53}Cr values at these locations occurred in the Cerros del Rio basalt. Conversely, the Cr(VI) observed in current day surface water has interacted with the strong reducing capacity of the wetland.
2. Cr(VI) observed in current-day surface water may result from oxidation of Cr(III) in the dewatered portion of the Sandia wetland, and therefore initial δ^{53}Cr may be underestimated and percentage reduction overestimated at surface water locations.
3. There may be no contradiction: all of the edges of a plume (leading, lateral and trailing) may show higher percentage reduction values as a result of low concentrations of Cr(VI) to be reduced relative to available reductant. Cr(VI) in current-day surface waters may represent the trailing edge of the Cr(VI) contaminant mass.

Chromium isotope values for the four groupings identified in Figure H-5.0-1 were analyzed by an analysis of variance (ANOVA) procedure accompanied by a Tukey's pairwise comparison analysis with a family error rate of 5 %. The ANOVA indicated that at least one of the groupings had significantly different mean

δ^{53}Cr than the others (p<0.001). The means and standard deviations for percentage Cr(VI) reduction for the four groups are as follows:

- δ^{53}Cr < 0.7 ‰ (green circle above Cerros del Rio basalt in Figure H-5.0-1): 9.5 ± 2.6 %
- Total filtered Cr > 20 μg/L (orange circles in Figure H-5.0-1): 27.8 ± 3.2 %
- Background or δ^{53}Cr within background range (yellow circles in Figure H-5.0-1): 10.1 ± 10.3 %
- Other (purple circles in Figure H-5.0-1): 31.1 ± 12.4 %

Tukey's pairwise comparison analysis indicates that the mean δ^{53}Cr for SCI-1 (δ^{53}Cr < 0.7 ‰; completed above the basalt) is statistically lower than the mean values for sites with total filtered Cr greater than 20 μg/L and "other" sites (purple circles in Figure H-5.0-1) but not different than background locations or locations with δ^{53}Cr within the background range (yellow circles in Figure H-5.0-1). This finding supports the conclusion that much of the observed reduction of Cr(VI) occurs in the Cerros del Rio basalt. Both locations with total filtered Cr greater than 20 μg/L and "other" sites have means statistically higher than background locations or locations with δ^{53}Cr within the background range. Mean δ^{53}Cr for these two groups, however, is not statistically distinguishable.

H-6.0 SUMMARY

Ferrous iron present in aquifer material is hypothesized to be the most important naturally occurring reductant for removing Cr(VI) from intermediate and regional groundwater at Los Alamos. Reduction of Cr(VI) by Fe(II) leads to the precipitation of insoluble $Cr(OH)_3$ under circumneutral pH conditions. Ferrous iron is concentrated in magnetite and silicate minerals, including biotite, amphiboles, and pyroxenes, and silicate glass present in the Cerros del Rio basalt, the Puye Formation, and the Santa Fe Group, with Fe concentrations being markedly higher in the Cerros del Rio basalt. Reduction of Cr(VI) to Cr(III) occurs as Fe(II) oxidizes to Fe(III), forming amorphous ferric hydroxide, a common alteration product of Fe(II)-bearing minerals. Most of the reduction appears to occur in the Fe(II)-rich Cerros del Rio basalt, with the degree of reduction depending on contaminant concentration and residence time within the basalt. To a first approximation, it appears that roughly one-quarter of the main mass of Cr(VI) has been reduced before it reached the regional aquifer. Constant δ^{53}Cr values at most contaminated regional aquifer locations may suggest a steady-state scenario in which Cr(VI) is constantly resupplied from drip points in the overlying vadose zone.

H-7.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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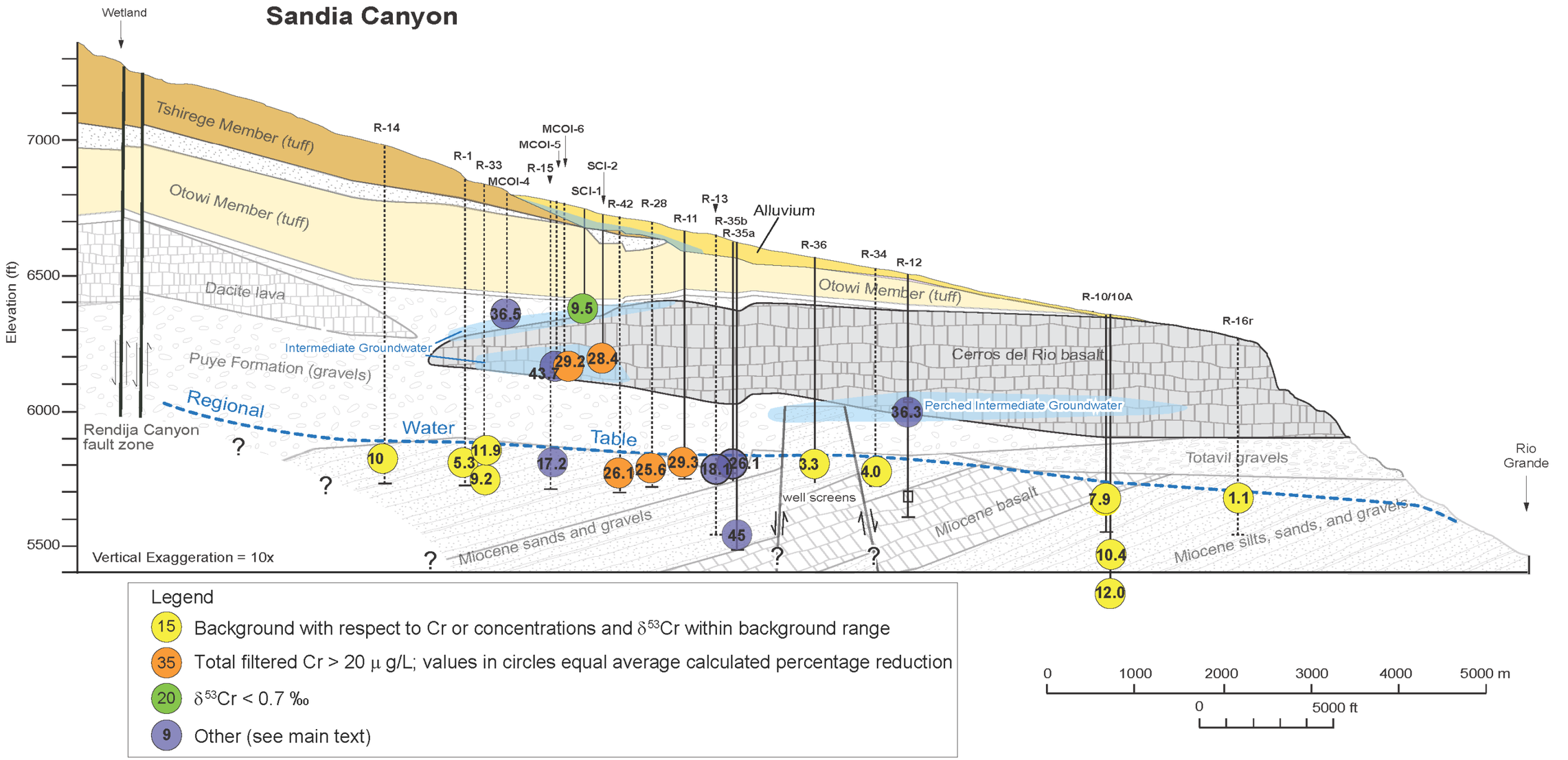

Note: Dashed lines represent well locations projected into Sandia Canyon from adjacent canyons.

Figure H-5.0-1 Average percentage Cr(VI) reduction

Table H-4.3-1
δ^{53}Cr, Cr Concentrations, and Calculated %Cr(VI) Reduction for Locations in Sandia and Mortandad Canyons and Cañada del Buey

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	δ^{53}Cr (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Mortandad	MCO-7.5	Alluvial	02-Mar-07	GF070200G57M01	2.4	—[d]	—	—	—	—	—	
	MCO-7.5	Alluvial		UF070200G57M01	—	—	1.47	0	34.3	28.9	44.4	34.3
	MCOI-4	Intermediate	12-Nov-07	CAMO-08-8619	10.1	—	1.85	0.35	34.8	29.4	45.1	
	MCOI-4	Intermediate	29-May-08	CAMO-08-12733	6.7	—	1.79	0.35	33.7	28.4	43.8	
	MCOI-4	Intermediate		CAMO-08-12734	—	5.6	—	—	—	—	—	
	MCOI-4	Intermediate	19-Aug-08	CAMO-08-14494	8.4	—	1.93	0.35	36.3	30.7	46.8	
	MCOI-4	Intermediate	18-Nov-08	CAMO-09-778	6.9	—	2.04	0.35	38.3	32.5	49.1	
	MCOI-4	Intermediate	05-May-09	CAMO-09-8155	< 6.47	—	2.12	0.35	39.7	33.7	50.7	36.5
	MCOI-5	Intermediate	05-Mar-07	GF070200GMC501	< 5	—	—	—	—	—	—	
	MCOI-5	Intermediate		UF070200GMC501	—	—	2.93	0.35	52.1	45.1	64.3	
	MCOI-5	Intermediate	12-Nov-07	CAMO-08-8625	1.1	—	2.00	0.35	37.6	31.8	48.3	
	MCOI-5	Intermediate	13-Feb-08	CAMO-08-10422	4.6	—	2.84	0.35	50.9	43.9	63.0	
	MCOI-5	Intermediate	20-May-08	CAMO-08-12737	—	1.8	—	—	—	—	—	
	MCOI-5	Intermediate		CAMO-08-12738	< 10	—	2.42	0.35	44.6	38.2	56.3	
	MCOI-5	Intermediate	18-Aug-08	CAMO-08-14499	2.2	—	2.22	0.35	41.4	35.2	52.6	
	MCOI-5	Intermediate	11-Nov-08	CAMO-09-781	3.3	—	2.16	0.35	40.3	34.3	51.5	
	MCOI-5	Intermediate		CAMO-09-8162	4.49	—	2.08	0.35	39.0	33.1	49.9	43.7
	MCOI-6	Intermediate	26-Feb-07	GF070200GMC601	29.4	—	—	—	—	—	—	
	MCOI-6	Intermediate		GF070200GMC620	30.3	—	—	—	—	—	—	
	MCOI-6	Intermediate		UF070200GMC601	—	—	1.60	0	36.7	31.1	47.2	
	MCOI-6	Intermediate		UF070200GMC620 FD[e]	—	—	1.44	0	33.7	28.4	43.8	
	MCOI-6	Intermediate	09-Nov-07	CASA-08-7612	33.3	—	1.55	0	35.8	30.2	46.2	
	MCOI-6	Intermediate	22-Feb-08	CAMO-08-10425	34.2	—	1.00	0	24.8	20.7	33.0	
	MCOI-6	Intermediate	20-May-08	CAMO-08-12739	—	5.3	—	—	—	—	—	
	MCOI-6	Intermediate		CAMO-08-12741	30.5	—	1.01	0	25.1	20.9	33.2	
	MCOI-6	Intermediate	12-Aug-08	CAMO-08-14501	43.3	—	0.99	0	24.6	20.6	32.7	
	MCOI-6	Intermediate	10-Nov-08	CAMO-09-785	37	—	1.16	0	28.2	23.6	37.1	
	MCOI-6	Intermediate	05-May-09	CAMO-09-8167	41.5	—	0.99	0	24.6	20.6	32.7	29.2
	R-14 port depth 1204.5 ft	Regional	01-Mar-07	GF07020G14R101	2.4	—	—	—	—	—	—	
	R-14 port depth 1204.5 ft	Regional		UF07020G14R101	—	—	1.11	1	3.1	2.5	4.3	11
	R-14 port depth 1200.6 ft	Regional	13-Nov-08	CAMO-09-792	3.6	—	1.31	1	8.5	6.9	11.6	
	R-14 port depth 1200.6 ft	Regional	07-May-09	CAMO-09-8206	< 4.92	—	1.43	1	11.5	9.5	15.8	10.0

Table H-4.3-1 (continued)

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	$\delta^{53}Cr$ (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Mortandad (continued)	R-1	Regional	07-Mar-07	GF070200G01R01	< 4.6	—	—	—	—	—	—	
	R-1	Regional		UF070200G01R01	—	—	1.24	1	6.6	5.4	9.1	
	R-1	Regional	22-Feb-08	CAMO-08-10453	7.2	—	1.22	1	6.1	5.0	8.4	
	R-1	Regional		CAMO-08-10455 FD	7.2	—	1.13	1	3.6	3.0	5.1	
	R-1	Regional	20-May-08	CAMO-08-12742	5.5	—	1.17	1	4.7	3.9	6.6	
	R-1	Regional		CAMO-08-12744	—	7.9	—	—	—	—	—	5.3
	R-33 port depth 995.5 ft	Regional	13-Mar-07	EF07020G33R101	9.72	—	—	—	—	—	—	
	R-33 port depth 995.5 ft	Regional		UF07020G33R101	—	—	1.79	1	20.2	16.8	27.1	
	R-33 port depth 995.5 ft	Regional	11-Nov-08	CAMO-09-794	4.5	—	1.34	1	9.2	7.6	12.7	
	R-33 port depth 995.5 ft	Regional	05-May-09	CAMO-09-8203	5.52	—	1.39	1	10.5	8.7	14.4	
	R-33 port depth 995.5 ft	Regional	06-May-09	CAMO-09-8199	< 4.62	—	1.28	1	7.7	6.3	10.6	11.9
	R-33 port depth 1112.4 ft	Regional	13-Mar-07	EF07020G33R201	6.18	—	—	—	—	—	—	
	R-33 port depth 1112.4 ft	Regional		UF07020G33R201	—	—	1.36	1	9.8	8.0	13.4	
	R-33 port depth 1112.4 ft	Regional	11-Nov-08	CAMO-09-795	5.2	—	1.32	1	8.7	7.2	12.0	9.2
	R-15	Regional	28-Feb-07	GF070200G15R01	7.5	—	—	—	—	—	—	
	R-15	Regional		UF070200G15R01	—	—	1.02	0.35	17.4	14.4	23.5	
	R-15	Regional	25-Feb-08	CAMO-08-10436	7.3	—	1.02	0.35	17.4	14.4	23.5	
	R-15	Regional	20-May-08	CAMO-08-12752	7.9	—	1.03	0.35	17.6	14.6	23.8	
	R-15	Regional		CAMO-08-12753	—	38.4	—	—	—	—	—	
	R-15	Regional	15-Aug-08	CAMO-08-14540	9.8	—	0.97	0.35	16.2	13.4	22.0	17.2
	R-42	Regional	09-Oct-08	CAMO-08-16441	820	—	1.05	0	25.9	21.7	34.3	
	R-42	Regional		CAMO-09-201 FD	798	—	1.05	0	25.9	21.7	34.3	
	R-42	Regional	20-Nov-08	CAMO-09-826	768	—	1.06	0	26.1	21.8	34.5	
	R-42	Regional	20-Feb-09	CAMO-09-2871	830	—	1.06	0	26.1	21.8	34.5	
	R-42	Regional	11-May-09	CAMO-09-8210	886	—	1.07	0	26.3	22.0	34.8	26.1
	R-28	Regional	06-Mar-07	GF070200G28R01	446	—	—	—	—	—	—	
	R-28	Regional		GF070200G28R20	425	—	—	—	—	—	—	
	R-28	Regional		UF070200G28R01	—	—	1.00	0	24.8	20.7	33.0	
	R-28	Regional		UF070200G28R20 FD	—	—	0.90	0	22.7	18.9	30.2	
	R-28	Regional	14-Nov-07	CAMO-08-8712	385	—	1.00	0	24.8	20.7	33.0	
	R-28	Regional	15-Feb-08	CAMO-08-10441	419	—	1.08	0	26.5	22.2	35.1	
	R-28	Regional	14-May-08	CAMO-08-12767	438	—	1.01	0	25.1	20.9	33.2	
	R-28	Regional		CAMO-08-12768	—	428.6	—	—	—	—	—	
	R-28	Regional	15-Aug-08	CAMO-08-14542	373	—	1.05	0	25.9	21.7	34.3	
	R-28	Regional	10-Nov-08	CAMO-09-809	468	—	1.13	0	27.6	23.1	36.3	
	R-28	Regional	01-May-09	CAMO-09-8178	388	—	1.12	0	27.4	22.9	36.1	25.6

Table H-4.3-1 (continued)

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	$\delta^{53}Cr$ (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Mortandad (continued)	R-13	Regional	28-Feb-07	GF070200G13R01	3.8	—	—	—	—	—	—	
	R-13	Regional		UF070200G13R01	—	—	1.00	0.35	16.9	14.0	22.9	
	R-13	Regional	14-Feb-08	CAMO-08-10444	6.2	—	1.14	0.35	20.2	16.8	27.1	
	R-13	Regional	14-May-08	CAMO-08-12770 FD	4	—	1.01	0.35	17.2	14.2	23.2	
	R-13	Regional		CAMO-08-12771	—	3.6	—	—	—	—	—	
	R-13	Regional		CAMO-08-12772	3.6	—	1.07	0.35	18.6	15.4	25.0	
	R-13	Regional		CAMO-08-12773	—	3.8	—	—	—	—	—	
	R-13	Regional	14-Aug-08	CAMO-08-14534	6.3	—	0.84	0.35	13.1	10.8	17.8	
	R-13	Regional		CAMO-08-14535 FD	6.2	—	0.92	0.35	15.0	12.4	20.4	
	R-13	Regional	10-Nov-08	CAMO-09-810	4.8	—	1.09	0.35	19.0	15.8	25.6	
	R-13	Regional		CAMO-09-813 FD	4.8	—	1.18	0.35	21.1	17.5	28.2	
	R-13	Regional	30-Apr-09	CAMO-09-8179	12.7	—	1.15	0.35	20.4	17.0	27.4	
	R-13	Regional		CAMO-09-8182 FD	11.4	—	1.13	0.35	20.0	16.6	26.8	
	R-34	Regional	13-Mar-07	GF070200G34R01	5	—	—	—	—	—	—	18.1
	R-34	Regional		UF070200G34R01	—	—	1.18	1	5.0	4.1	6.9	
	R-34	Regional	19-Feb-08	CAMO-08-10450	4.6	—	1.17	1	4.7	3.9	6.6	
	R-34	Regional	28-May-08	CAMO-08-12779	—	3.7	—	—	—	—	—	
	R-34	Regional		CAMO-08-12781	3	—	1.01	1	0.3	0.2	0.4	
	R-34	Regional	15-Aug-08	CAMO-08-14545	< 6.1	—	1.21	1	5.8	4.8	8.0	4.0
Sandia (continued)	South Fork of Sandia Canyon at E122	Surface water	21-May-08	CASA-08-12814	—	7.4	—	—	—	—	—	
	South Fork of Sandia Canyon at E122	Surface water		CASA-08-12815	7	—	1.34	0	31.8	26.8	41.5	
	South Fork of Sandia Canyon at E122	Surface water		CASA-08-12817 FD	< 50	—	1.43	0	33.5	28.3	43.5	
	South Fork of Sandia Canyon at E122	Surface water		CASA-08-12818	—	7.6	—	—	—	—	—	32.7
	Sandia below Wetlands	Surface water	20-Feb-07	GF070200P12301	< 2.7	—	—	—	—	—	—	
	Sandia below Wetlands	Surface water		UF070200P12301	—	—	1.43	0	33.5	28.3	43.5	
	Sandia below Wetlands	Surface water	14-Feb-08	CASA-08-10856	5.4	—	1.32	0	31.4	26.4	41.0	32.5
	E123.45	Surface water	20-Feb-07	UF0702E123.401	—	—	1.59	0	36.5	30.9	47.0	
	E123.45	Surface water		UF0702E123.420 FD	—	—	1.01	0	25.1	20.9	33.2	30.8
	Middle Sandia Canyon at terminus of persistent baseflow	Surface water	22-Feb-07	GF070200PMSC01	7.6	—	—	—	—	—	—	
	Middle Sandia Canyon at terminus of persistent baseflow	Surface water		UF070200PMSC01	—	—	0.30	0	8.2	6.7	11.3	
	Middle Sandia Canyon at terminus of persistent baseflow	Surface water	19-Feb-08	CASA-08-10858	4.9	—	0.14	0	3.9	3.2	5.4	6.1
	SCA-1-DP	Alluvial	20-Feb-09	CASA-09-2858	< 9.5	—	0.14	0	3.9	3.2	5.4	3.9

Table H-4.3-1 (continued)

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	$\delta^{53}Cr$ (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Sandia (continued)	SCI-1	Intermediate	22-Aug-07	GF070800SCI101	22.1	—	—	—	—	—	—	
	SCI-1	Intermediate		UF070800SCI101	—	—	0.44	0	11.8	9.7	16.1	
	SCI-1	Intermediate	16-Nov-07	CASA-08-7412	16.5	—	0.35	0	9.5	7.8	13.1	
	SCI-1	Intermediate	22-Feb-08	CASA-08-10569	17.1	—	0.51	0	13.6	11.2	18.4	
	SCI-1	Intermediate	21-May-08	CASA-08-12860	15.2	—	0.28	0	7.7	6.3	10.6	
	SCI-1	Intermediate		CASA-08-16501	—	—	0.21	0	5.7	4.7	7.9	
	SCI-1	Intermediate		CASA-08-16502	—	—	0.23	0	6.5	5.3	8.9	
	SCI-1	Intermediate	19-Aug-08	CASA-08-14367	15	—	0.37	0	10.0	8.2	13.8	
	SCI-1	Intermediate	13-Nov-08	CASA-09-872	11.7	—	0.32	0	8.7	7.2	12.0	
	SCI-1	Intermediate	06-May-09	CASA-09-8267	12.6	—	0.43	0	11.6	9.5	15.8	9.5
	SCI-2	Intermediate	21-Oct-08	CASA-09-502	562	628	1.17	0	28.4	23.8	37.4	
	SCI-2	Intermediate		CASA-09-507 FD	562	628	1.17	0	28.4	23.8	37.4	
	SCI-2	Intermediate	18-Nov-08	CASA-09-960	489	—	1.22	0	29.4	24.7	38.6	
	SCI-2	Intermediate	13-Feb-09	CASA-09-2991	593	—	1.22	0	29.4	24.7	38.6	
	SCI-2	Intermediate	06-May-09	CASA-09-8315	658	—	1.06	0	26.1	21.8	34.5	28.4
	R-12 port depth 504.5 ft	Intermediate	21-Feb-08	CASA-08-10578	< 10	—	1.77	0.35	33.3	28.1	43.3	
	R-12 port depth 504.5 ft	Intermediate	19-Aug-08	CASA-08-14363	< 3	—	1.73	0.35	32.6	27.4	42.4	
	R-12 port depth 504.5 ft	Intermediate	13-Nov-08	CASA-09-867	< 3	—	2.14	0.35	40.0	34.0	51.1	
	R-12 port depth 504.5 ft	Intermediate		CASA-09-868 FD	< 3	—	2.05	0.35	38.4	32.6	49.3	
	R-12 port depth 504.5 ft	Intermediate	29-Apr-09	CASA-09-8281	< 3	—	1.98	0.35	37.2	31.5	47.9	36.3
	R-11	Regional	13-Feb-07	GF070200G11R01	33.2	—	—	—	—	—	—	
	R-11	Regional		GF070200G11R20	34.9	—	—	—	—	—	—	
	R-11	Regional		UF070200G11R01	—	—	1.18	0	28.6	24.0	37.6	
	R-11	Regional		UF070200G11R20 FD	—	—	1.13	0	27.6	23.1	36.3	
	R-11	Regional	07-Nov-07	CASA-08-7433	21.7	—	1.12	0	27.4	22.9	36.1	
	R-11	Regional	06-Feb-08	CASA-08-10546	23	—	1.36	0	32.2	27.1	41.9	
	R-11	Regional		CASA-08-10553 FD	20.7	—	1.30	0	31.0	26.1	40.5	
	R-11	Regional	12-May-08	CASA-08-12870	22.1	—	1.07	0	26.3	22.0	34.8	
	R-11	Regional		CASA-08-12871	—	22.2	—	—	—	—	—	
	R-11	Regional	11-Aug-08	CASA-08-14383	15.6	—	1.22	0	29.4	24.7	38.6	
	R-11	Regional	05-Nov-08	CASA-09-883	17.5	—	1.34	0	31.8	26.8	41.5	
	R-11	Regional		CASA-09-904	17.8	—	—	—	—	—	—	
	R-11	Regional	29-Apr-09	CASA-09-8275	13.5	—	1.21	0	29.2	24.5	38.4	29.3

Table H-4.3-1 (continued)

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	$\delta^{53}Cr$ (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Sandia (continued)	R-35a	Regional	30-Aug-07	GF07080GR35a01	2.4	—	—	—	—	—	—	
	R-35a	Regional		UF07080GR35a01	—	—	3.93	0.35	64.0	56.4	76.0	
	R-35a	Regional	21-Feb-08	CASA-08-10557	4.7	—	2.10	0.35	39.3	33.4	50.3	
	R-35a	Regional	13-May-08	CASA-08-12874	< 10	—	3.17	0.35	55.3	48.0	67.6	
	R-35a	Regional		CASA-08-12875	—	1.6	—	—	—	—	—	
	R-35a	Regional		CASA-08-12879	—	1.7	—	—	—	—	—	
	R-35a	Regional		CASA-08-12880 FD	< 10	—	2.94	0.35	52.2	45.2	64.5	
	R-35a	Regional	12-Aug-08	CASA-08-14389	4.7	—	2.03	0.35	38.1	32.3	48.9	
	R-35a	Regional		CASA-08-14392[f]	—	—	1.75	0.35	32.9	27.8	42.8	
	R-35a	Regional	06-Nov-08	CASA-09-884	3.6	—	2.24	0.35	41.7	35.5	53.0	
	R-35a	Regional	04-Feb-09	CASA-09-3014	4.9	—	2.02	0.35	37.9	32.2	48.7	
	R-35a	Regional	28-Apr-09	CASA-09-8304	3.42	—	2.37	0.35	43.8	37.4	55.4	45.0
	R-35b	Regional	29-Aug-07	GF07080GR35b01	4.8	—	—	—	—	—	—	
	R-35b	Regional		GF07080GR35b20	4.1	—	—	—	—	—	—	
	R-35b	Regional		UF07080GR35b01	—	—	1.23	0.35	22.2	18.5	29.7	
	R-35b	Regional		UF07080GR35b20 FD	—	—	1.29	0.35	23.5	19.6	31.3	
	R-35b	Regional	10-Nov-07	GWR35b-08-8639	< 7.4	—	1.42	0.35	26.3	22.0	34.8	
	R-35b	Regional	07-Feb-08	CASA-08-10558	5.9	—	1.51	0.35	28.2	23.6	37.1	
	R-35b	Regional	13-May-08	CASA-08-12877	—	3.6	—	—	—	—	—	
	R-35b	Regional		CASA-08-12878	< 10	—	1.80	0.35	33.9	28.6	44.0	
	R-35b	Regional	12-Aug-08	CASA-08-14385	5.6	—	1.31	0.35	24.0	20.0	31.9	
	R-35b	Regional		CASA-08-14464 FD	5.6	—	1.23	0.35	22.2	18.5	29.7	
	R-35b	Regional	06-Nov-08	CASA-09-886	3.2	—	1.35	0.35	24.8	20.7	32.9	
	R-35b	Regional		CASA-09-888 FD	3	—	1.41	0.35	26.1	21.8	34.5	
	R-35b	Regional	02-Feb-09	CASA-09-3017	5.1	—	1.48	0.35	27.6	23.1	36.3	
	R-35b	Regional	27-Apr-09	CASA-09-8307	< 7.48	—	1.49	0.35	27.8	23.3	36.6	26.1
	R-36	Regional	12-May-08	CASA-08-12884	—	4.1	—	—	—	—	—	
	R-36	Regional		CASA-08-12885	8.8	—	0.90	1	-2.9	-2.4	-4.1	
	R-36	Regional	12-Aug-08	CASA-08-14397	7.5	—	1.09	1	2.5	2.1	3.5	
	R-36	Regional	13-Aug-08	CASA-08-14398[f]	—	—	1.10	1	2.8	2.3	3.9	
	R-36	Regional	06-Nov-08	CASA-09-892	5.6	—	1.16	1	4.5	3.6	6.2	
	R-36	Regional	05-Feb-09	CASA-09-3024	6.2	—	1.27	1	7.4	6.1	10.2	
	R-36	Regional	28-Apr-09	CASA-09-8312	4.66	—	1.19	1	5.3	4.3	7.3	3.27

Table H-4.3-1 (continued)

Canyon	Location	Aquifer Type	Collection Date	Sample ID	Total Dissolved Cr (µg/L)	Cr(VI) (µg/L)	$\delta^{53}Cr$ (‰)	Estimated $\delta^{53}Cr_{ini}$	%Reduction[a]	%Reduction (min)[b]	%Reduction (max)[c]	Average % Reduction
Sandia (continued)	R-10 port depth 874 ft	Regional	21-Feb-07	GF07020GR10101	2.7	—	—	—	—	—	—	
	R-10 port depth 874 ft	Regional		UF07020GR10101	—	—	1.26	1	7.2	5.9	9.9	
	R-10 port depth 874 ft	Regional	27-May-08	CASA-08-12861	< 4.7	—	1.42	1	11.3	9.3	15.4	
	R-10 port depth 874 ft	Regional		CASA-08-12863	—	2.1	—	—	—	—	—	
	R-10 port depth 874 ft	Regional	13-Aug-08	CASA-08-14372	< 5.5	—	1.45	1	12.1	9.9	16.5	
	R-10 port depth 874 ft	Regional	03-Nov-08	CASA-09-877	2.5	—	1.42	1	11.3	9.3	15.4	10.4
	R-10 port depth 1042 ft	Regional	21-Feb-07	UF07020GR10201	—	—	1.37	1	10.0	8.2	13.7	
	R-10 port depth 1042 ft	Regional		GF07020GR10201	2.7	—	—	—	—	—	—	
	R-10 port depth 1042 ft	Regional	27-May-08	CASA-08-12865	—	2.2	—	—	—	—	—	
	R-10 port depth 1042 ft	Regional		CASA-08-12866	< 5.7	—	1.37	1	10.0	8.2	13.7	
	R-10 port depth 1042 ft	Regional	13-Aug-08	CASA-08-14375	< 4.2	—	1.55	1	14.5	12.0	19.7	
	R-10 port depth 1042 ft	Regional	12-Nov-08	CASA-09-878	1.5	—	1.36	1	9.8	8.0	13.4	
	R-10 port depth 1042 ft	Regional	12-May-09	CASA-09-8271	2.47	—	1.52	1	13.8	11.4	18.8	12.0
	R-10a	Regional	20-Feb-07	GF07020GR10A01	5.6	—	—	—	—	—	—	
	R-10a	Regional		UF07020GR10A01	—	—	1.32	1	8.7	7.2	12.0	
	R-10a	Regional	19-Feb-08	CASA-08-10564	5.8	—	1.33	1	9.0	7.4	12.4	
	R-10a	Regional	27-May-08	CASA-08-12868	—	4.4	—	—	—	—	—	
	R-10a	Regional		CASA-08-12869	< 7.9	—	1.29	1	7.9	6.5	10.9	
	R-10a	Regional	13-Aug-08	CASA-08-14378	< 5.9	—	1.22	1	6.1	5.0	8.4	7.9
Cañada del Buey	R-16r	Regional	14-Mar-07	GF07020GR16A01	6.3	—	—	—	—	—	—	
	R-16r	Regional		GF07020GR16A20	6.4	—	—	—	—	—	—	
	R-16r	Regional		UF07020GR16A01	—	—	0.74	0.68	1.7	1.4	2.4	
	R-16r	Regional		UF07020GR16A20 FD	—	—	0.77	0.68	2.5	2.1	3.5	
	R-16r	Regional	06-Feb-08	CAMO-08-10459	8	—	0.70	0.68	0.6	0.5	0.8	
	R-16r	Regional		CAMO-08-10460 FD	9.9	—	0.68	0.68	0.0	0.0	0.0	
	R-16r	Regional	19-May-08	CAMO-08-12758	9.4	—	0.69	0.68	0.3	0.2	0.4	
	R-16r	Regional		CAMO-08-12759	—	4.5	—	—	—	—	—	
	R-16r	Regional		CAMO-08-12760 FD	9.9	—	0.72	0.68	1.1	0.9	1.6	
	R-16r	Regional		CAMO-08-12761	—	4.5	—	—	—	—	—	1.0

[a] Fractionation factor of 3.5 ‰.

[b] Fractionation factor of 4.3 ‰.

[c] Fractionation factor of 2.5 ‰. Not determined for this sample

[d] — = Not determined for this sample.

[e] FD = Field duplicate sample.

[f] Sample filtered with a 0.02-micrometer membrane; compare with previous sample in table filtered with a 0.45-micrometer membrane.

Appendix I

Experimental Investigations of Hexavalent Chromium Attenuation in Vadose Zone and Regional Aquifer Materials

I-1.0 INTRODUCTION

I-1.1 Background, Significance, and Objectives

Geochemical characterization and remediation of soil and groundwater contaminated by chromium (Cr) at Los Alamos National Laboratory (the Laboratory) requires knowledge of chromium-migration processes in both vadose zone and regional aquifer materials. Like all transition metals, chromium can exist under several oxidation states from Cr(0) (the metallic form) to Cr(VI) (Richard and Bourg 1991, 107034). However, only the trivalent [Cr(III)] and hexavalent [Cr(VI)] forms are important in the Eh-pH range of natural aquatic systems (Richard and Bourg 1991, 107034; Palmer and Puls 1994, 107032; Peterson et al. 1997, 107033). As reported in these studies, Cr(VI) to be relatively mobile, acutely toxic, carcinogenic, and therefore of major environmental concern. Cr(III), on the other hand, is immobile and has a relatively low toxicity. Previous investigations of chromium contamination from Sandia Canyon (LANL 2007, 098938) have suggested that it occurs primarily in the hexavalent form in the groundwater samples collected from regional well R-28. High concentrations of dissolved chromium, most likely stable as $HCrO_4^-$ and CrO_4^{2-}, have also been detected in one of the recently installed regional monitoring wells, R-42 (LANL 2009, 101559).

Studies directed at delineating and quantifying migration of haxavalent chromium in the vadose zone and regional aquifer beneath Sandia Canyon will serve to (1) refine conceptual and numerical models of chromium fate and transport, (2) evaluate the potential retention capacity of the groundwater system along flow paths from source to regional aquifer, (3) reveal the geochemical processes affecting hexavalent chromium distribution throughout the vadose zone and regional aquifer, and (4) assess the limits of natural attenuation of Cr(VI) by potential reductants in the groundwater system.

The broad objective of the studies presented in this appendix is to gain site-specific knowledge from confirmatory laboratory studies of the migration of hexavalent chromium and to reveal geochemical processes controlling Cr(VI) transport in the vadose zone and regional aquifer in Sandia Canyon. Findings of these studies provide initial information for assessment of long-term stabilization and remediation approaches for contaminated chromium in Sandia and Mortandad Canyons along flow paths from the source to the regional aquifer.

I-1.2 Measurements and Purpose

To accomplish the primary objective of this investigation, several experimental studies and geochemical modeling calculations were carried out. These consist of the following.

- Site-specific geochemistry of chromium: Geochemical modeling using the computer code PHREEQC was applied to calculate and verify the speciation and mineral stability of dissolved chromium in groundwater used for chromium experiments.
- Mass of total chromium and its leachability from background rock samples: deionized (DI) water leaching and U.S. Environmental Protection Agency (EPA) Method 3050 digestion tests were conducted on core samples of the most chromium-rich groundwater host rock, Cerros del Rio basalt, to investigate chromium content, availability, and feasibility from background rock releasing to groundwater.
- Retention capacities of the vadose zone and regional aquifer materials for Cr(VI): Conventional static (batch) and flow-through (column) experiments were conducted to investigate retention capacities of geomedia for Cr(VI) using site-specific groundwater and hydrogeological materials

that are representative of potential flow pathways in the vadose zone and regional aquifer beneath Sandia and Mortandad Canyons.

- Nature of geochemical processes controlling migration of Cr(VI): Synchrotron-based X-ray absorption spectroscopy was applied to identify Cr(III)/Cr(VI) speciation and oxidation state of chromium surface complexes of Cr(VI) reacted with vadose zone and regional aquifer materials.
- Characterization of geological materials: scanning electron microscope (SEM) and x-ray diffraction (XRD) analyses were conducted to characterize materials used in the above experiments.

This appendix presents analytical, experimental, and modeling methods and results of the studies listed above. The findings from this study provide the data and interpretation necessary to assess potential site-specific geochemical effects on the long-term fate and transport of chromium beneath Sandia and Mortandad Canyons.

I-2.0 EXPERIMENTAL MATERIALS AND METHODS

I-2.1 Rocks and Sediments

I-2.1.1 Geologic Context of Samples Used in Cr(VI) Batch and Column Experiments

Understanding and quantifying chromium inventories, environmental geochemistry, and contaminant movement in groundwater at the Laboratory require information on natural retardation of Cr(III/VI) in groundwater by adsorption and by mineral precipitation. The primary cause of chromium retardation will likely be through reduction of soluble Cr(VI) by chemical reduction taking place at the interface between reactive-mineral surfaces and groundwater. Mineral surfaces that contain electron donors such as Fe(II) are capable of reducing Cr(VI) to Cr(III) followed by fixation of Cr(III) complexes and precipitation of amorphous $Cr(OH)_3$, which significantly retard chromium transport.

For the designed chromium experiments, site-specific rock samples from beneath the Laboratory were selected. Core and cuttings samples were collected from units that are either commonly associated with perching horizons (the Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff; Cerros del Rio lavas) or from sedimentary units that commonly host regional saturation (Puye Formation and Santa Fe Group). Most samples were selected from boreholes beneath dry mesas (e.g., samples from borehole MCOI-10) or boreholes in canyon locations at depths where chromium contamination has not been observed (R-9, LAOI-7, R-35a, and R-35b). These samples are believed to be free of anthropogenic chromium that, if present, could affect data interpretation. Core and cuttings samples were also collected, however, from depths corresponding to the perched zone in lower Cerros del Rio basalts at borehole SCI-2 where significant chromium contamination is documented in groundwater. Concentrations of soluble chromium above 100 ppb, and some higher than 300 ppb, were leached with deionized water using SCI-2 core samples. The SCI-2 samples provide data from fracture materials in an interval of known chromium contamination, where fracture transmission is believed to be dominant and questions of past and future chromium retardation may be addressed.

Wherever possible, core samples free from drilling-induced effects, which might yield samples that do not represent native or predrilling conditions, such as extensive exposure to drilling additives and circulation fluid used during drilling, and loss of potentially reactive fines during cuttings collection. Unfortunately, no core samples were available for the Puye Formation and Santa Fe Group sediments, and cuttings were used during the batch and column experiments on those materials. For these samples, special bulk samples of cuttings were collected by bucket during drilling at R-35a (Santa Fe Group) and R-35b (Puye

Formation). This collection method avoids problems related to loss of fines. Moreover, because the cuttings were collected from beneath the water table, the circulation fluid for these samples is in situ regional groundwater to which the samples were naturally exposed.

I-2.1.2 Characterization of Samples for Cr(VI) Batch and Column Experiments

Samples used for Cr(VI) static and column experiments were examined by optical methods (at hand-lens and binocular microscope magnification), by XRD, and by SEM with secondary electron imaging and energy dispersive spectroscopy (EDS).

The XRD analyses were performed with an automated Siemens D500 diffractometer using Cu Kα radiation, incident- and diffracted-beam Soller slits, and a Kevex Si(Li) solid-state detector, measuring from 2° to 70° 2θ. The XRD analyses were run on either bulk material (nonsieved) or sieved (<75 µm) splits of the samples studied. Magnetic separates were collected (by bar magnet, separated from the sample by weighing paper) to concentrate and better characterize iron-bearing minerals, because one of the suggested modes of chromium retardation is reduction at the surfaces of minerals containing ferrous iron. Some of the <75 µm splits were obtained by sieving unprocessed bulk samples, but others were obtained from samples that were crushed before sieving, exposing new mineral surfaces.

In some of the core and cuttings samples, small amounts of iron-metal contamination was subsequently noted in magnetic separates. The descriptions below note which samples contain such contamination and the amount present. Presence of iron metal in several samples potentially influences or positively biases the magnitude or degree of Cr(VI) retention, resulting from reduction of Cr(VI) to Cr(III). Fortunately, several samples free of iron metal have similar distribution coefficients (K_d) to those that contain small amounts of iron metal. Table I-2.1-1 summarizes the XRD data for all Cr(VI) attenuation tests samples, including whether or not iron metal was detected. The source of iron metal was traced back to original samples (e.g., bags of cuttings or Lexan sleeves for core), and it is apparent that the metal contamination comes from drilling tools and is difficult to avoid. The amount of iron metal is small, but the potential impact could be significant; the effects of iron metal contamination are discussed below.

The SEM analyses were collected from grains mounted with carbon tape on aluminum stubs. Samples were carbon-coated before analysis. A Quanta 400 FEG from FEI Company Environmental SEM was used in secondary-electron mode with EDS spectra obtained on a Si(Li) detector. All of the samples analyzed by SEM were examined after exposure to Cr(VI) solutions as used in the static experiments. The goal of this analysis was to seek evidence of specific minerals that may have accumulated chromium from solution greater than the amount of chromium expected in natural minerals (e.g., olivine and spinel).

I-2.1.2.1 Sample Descriptions: Representative Lithology Samples Used in Cr(VI) Batch and Column Experiments

As discussed in Section I-2.1.1, background rock samples were selected for the Cr(VI) retention tests. These core and cuttings samples were collected from several units from boreholes MCOI-10, R-9, LAOI-7, R-35a, and R-35b. These samples are believed to be free of anthropogenic chromium. A total of 10 samples of core or cuttings samples from four lithologies was collected and are described below.

Otowi Member of the Bandelier Tuff (Guaje Pumice Bed): Two Samples

Core from MCOI-10 at 675.9–676.4-ft depth

Description: Bag sample of Guaje Pumice Bed; clean core rubble zone from mesa locality away from contaminant sources; clean, relatively intact core, moderately cohesive, with no evidence of alteration.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is ~80% glass plus quartz, feldspar, and trace biotite. Magnetic separate is 0.6% of the bulk and is predominantly iron metal.

Core from MCOI-10 at 680.5–682.0 ft depth

Description: Lexan-contained sample of Guaje Pumice Bed; clean, relatively intact core from below-mesa locality away from contaminant sources.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is ~75% glass plus quartz, feldspar, and trace biotite. No magnetic separate was obtainable from the crushed sample, and this sample showed no contamination by iron metal.

Cerros del Rio Basaltic Lavas: Six Samples

Core from MCOI-10 at 713.0–714.2-ft depth

Description: Core from the altered flow top (soil zone) of the Cerros del Rio lavas. This locality is under the mesa south of Mortandad Canyon, away from contaminant sources.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly plagioclase and quartz, plus lesser amounts of smectite, cristobalite, and mica with traces of augite, kaolinite, magnetite, hematite, and zeolite. Magnetic separate is 1.7% of the bulk and is predominantly magnetite and augite, with adhering feldspar, plus iron metal.

Core from MCOI-10 at 714.6–715.0-ft depth

Description: Core of unaltered Cerros del Rio lava at a below-mesa locality away from contaminant sources.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly plagioclase feldspar and augite with minor olivine and magnetite. Magnetic separate is 3.6% of the bulk and is predominantly magnetite plus iron metal.

SEM analysis of grains exposed to chromium in solution: (1) Mount of bulk sample at 15 kV: No detectable chromium in wide-field EDS. Spot imaging of olivine shows no chromium detection in EDS; (2) mount of magnetic separate at 30 kV: in wide-field EDS, the spectrum shows stronger chromium signal than the R-9 and LAOI-7 samples. Spot imaging of olivine indicates only trace chromium, as does spot imaging of augite.

Core from R-9 at 183.0–183.7-ft depth

Description: Bag sample of Cerros del Rio altered rubble zone, within upper perched aquifer.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly plagioclase feldspar and augite with minor olivine and trace magnetite and smectite. Magnetic separate is 5.7% of the bulk and is predominantly magnetite/maghemite with iron metal and lesser amounts of augite; small amounts of plagioclase are included in the magnetic separate.

Core from R-9 at 245.2–245.5-ft depth

Description: Core sample of intact massive, unaltered basalt from beneath upper perched zone.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly plagioclase feldspar and augite with trace olivine and magnetite. Magnetic separate is 1.0% of the bulk and is predominantly titanomagnetite with iron metal and lesser amounts of olivine and augite; small amounts of plagioclase are included in the magnetic separate.

SEM analysis of grains exposed to chromium in solution: (1) Mount of bulk sample at 15 kV: No detectable chromium in wide-field EDS; grains are mostly plagioclase lacking chromium. (2) Mount of magnetic separate at 30 kV: in wide-field EDS, the spectrum shows a stronger titanium signal than LAOI-7 samples. Imaging of high-titanium cluster (pyroxene-plagioclase-iron, titanium oxides) has trace chromium. Spot imaging of limonite grain shows less chromium than the cluster EDS.

Core from LAOI-7 at 83.3–85.6-ft depth

Description: Rubble zone from the upper surface of the Cerros del Rio with clay and possible pedogenic coatings.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly smectite, plagioclase and quartz with minor mica. Magnetic separate is 0.8% of the bulk and is predominantly titanomagnetite with iron metal.

SEM analysis of grains exposed to chromium in solution: (1) Mount of bulk sample at 15 kV: No detectable chromium in wide-field EDS; grains are mostly plagioclase lacking chromium. (2) Mount of magnetic separate at 30 kV: In wide-field EDS, the spectrum shows only trace chromium. Spot imaging of clinopyroxene grain shows no detectable chromium.

Core from LAOI-7 at 234.3–236.2-ft depth

Description: Intact massive, unaltered basalt from dense lava beneath upper perched zone.

Mineralogy by XRD: The <75-µm-size fraction, mechanically crushed, is predominantly plagioclase and augite with minor olivine and maghemite. Magnetic separate is 2.5% of the bulk and is predominantly maghemite; this sample showed no contamination by iron metal.

SEM analysis of grains exposed to chromium in solution: (1) Mount of bulk sample at 15 kV: No detectable chromium in wide-field EDS; grains are mostly plagioclase lacking chromium. (2) Mount of magnetic separate at 30 kV: In wide-field EDS, the spectrum shows only trace chromium. Spot imaging of clinopyroxene and plagioclase grains shows no detectable chromium.

Puye Formation: One Combined Sample

Total cuttings samples of R-35b at 820–825-ft depth and 840-845-ft depth (combined)

Description: Bulk sample from 820–825 ft depth with borehole groundwater represents well-sorted pea gravel, with abundant dark silt fraction, from a depth interval equivalent to the upper part of the well screen at R-35b. Bulk sample from 840–845-ft depth represents coarser, angular gravels typical of lower part of the screen. These samples were combined for this study.

Mineralogy by XRD: The <75-µm-size fraction, sieved without crushing, is predominantly quartz and plagioclase, with mica with only trace smectite. Magnetic separate is 1.5% of the bulk and is predominantly magnetite with some adhering quartz and plagioclase; no iron metal was detected in the

<75-µm split. However, visual examination of a magnetic separate from the 75–500-µm sample at 840–845-ft depth showed a small amount of iron metal contamination.

SEM analysis of grains exposed to chromium in solution: (1) Mount of bulk sample at 15 kV: No detectable chromium in wide-field EDS; grains are mostly plagioclase lacking chromium. (2) Mount of magnetic separate at 15 kV: In wide-field EDS, the sample has a small chromium peak. Spot analysis of an etched orthopyroxene grain shows no detectable chromium. Spot analysis of clinopyroxene grain also shows no chromium. A fine-grained mineral cluster does show detectable chromium. Arcuate fragment of ~40 µm with desiccation cracks and submicron layering, interpreted as a clay body, has most significant chromium peak yet observed. Clay body has Na-Mg-Al-Si-K-Ca-Fe-base composition, with some F.

Santa Fe Group: One Sample

Total cuttings sample of R-35a at 1060–1065-ft depth

Description: Bulk sample with borehole groundwater; sample represents tuffaceous sands and gravels typical of lower part of the well screen at R-35a.

Mineralogy by XRD: The bulk sample (unsieved) is predominantly smectite and plagioclase with amphibole. The <75-µm-size fraction, sieved without crushing, contains well-crystallized smectite, plagioclase, and amphibole. Magnetic separate is 0.8% of the bulk and is predominantly magnetite; no iron metal was detected in this sample.

I-2.1.2.2 Descriptions of Fracture Samples from SCI-2 Used in Static Experiments

Fractured core samples were collected from a chromium-contaminated location, the perched zone in lower Cerros del Rio basalts at borehole SCI-2 where significant chromium is documented in groundwater. These samples provide data from fracture materials that have been exposed to chromium contamination. The perched intermediate zone at SCI-2 extends from ~509–627-ft depth; the screen at SCI-2 extends from 548–568-ft depth. Throughout most of this interval, perched groundwater is stored in and migrates through fractures. Extensive fracture coatings and local fillings of fine silt were noted. The matrix porosity is exceedingly small and groundwater flow dominantly occurs within fractures. Fracture samples were collected from immediately above the screen interval to characterize these fracture-associated materials.

Fracture coating in core from SCI-2 at 540-ft depth, Cerros del Rio basalt

Description: Near-vertical fracture in dense, poorly vesicular Cerros del Rio lava. Fracture fill is silty, light brown, and thin (~2–3 mm), coating all fracture walls.

Mineralogy by XRD: The bulk sample contains abundant quartz and plagioclase with lesser mica and zeolite; smectite is present but is not abundant. Magnetic separate has maghemite associated with quartz, plagioclase, mica, and trace smectite. No iron metal was detected in this sample.

Fracture coating in core from SCI-2 at 548-ft depth, Cerros del Rio basalt

Description: Oblique fracture in dense, moderately vesicular Cerros del Rio lava. Fracture fill is silty, light brown, and can be found in adjacent cm-scale vesicles as a geopetal fill. Fracture dip is ~70 degrees.

Mineralogy by XRD: The bulk sample contains abundant plagioclase and quartz, with lesser mica and zeolite (possibly phillipsite) and a minor amount of poorly crystalline smectite. This sample contained insufficient magnetic material for separation and analysis. No iron metal was detected in this sample.

I-2.2 Groundwaters

Chromium-contaminant-free groundwater collected from Los Alamos Canyon intermediate well LAOI-7 was used for experiments conducted using rock samples from wells LAOI-7, MCOI-10, R-9, and SCI-2. Groundwater collected from Sandia Canyon regional well R-35a was used for experiments conducted using samples from R-35a and R-35b.

Chemical compositions of groundwater at LAOI-7 and R-35a are summarized in Table I-2.2-1. Analytical results provided in Table I-2.2-1 indicate that groundwater within the Cerros del Rio lavas at LAOI-7 is relatively oxidizing and is characterized by measurable dissolved oxygen (DO), nitrate-nitrite(N), and sulfate. Concentrations of DO ranging from 4.5 mg/L to 7.3 mg/L confirm that the groundwater is oxic at LAOI-7. Concentrations of total organic carbon (TOC) range from 0.4 mg/L to 1.7 mg/L at LAOI-7, possibly consisting of humic acids and other forms of organic carbon derived from alluvial groundwater providing recharge to this saturated zone. Inorganic carbon, in the form of bicarbonate, is the dominant anion in groundwater samples collected from LAOI-7 and other wells across the Pajarito Plateau. Dissolved concentrations of iron and manganese are less than 50 µg/L and 6 µg/L, respectively, suggesting that reductive dissolution of Fe(III) and Mn(IV) (oxy)hydroxides is not extensive under these relatively oxidizing conditions. Dissolved background chromium concentrations at LAOI-7 ranged from 1 mg/L to 2 µg/L.

The analytical results presented in Table I-2.2-1 indicate groundwater within the Santa Fe Group (R-35a) is also relatively oxidizing and is characterized by measurable DO, nitrate-nitrite(N), and sulfate. Concentrations of DO measured at R-35a range from 3.0 to 5.2 mg/L. Concentrations of TOC range from 0.4 mg/L to 1.2 mg/L at R-35a. Dissolved concentrations of iron and manganese at R-35a range from 32 µg/L to 315 µg/L and from 3 µg/L to 20 µg/L, respectively. Dissolved background chromium concentrations at R-35a ranged from 2 µg/L to 6 µg/L.

Cr(VI) is stable in groundwater that is relatively oxidizing, including wells LAOI-7 and R-35a. The low chromium concentrations ($\leq$6 µg/L) in these groundwaters indicate chromium is at background concentrations rather than elevated from an anthropogenic source.

I-2.3 Chromium (III)/(VI) Compounds and Other Chemical Agents

Analytical grade Cr_2O_3 and K_2CrO_4 were used in the experiments as the Cr(III) and Cr(VI) sources, respectively. Analytical-grade lithium bromide was used as a nonreacting tracer for column flow-through experiments.

I-2.4 Leaching and Digestion Experiments

Two methods were used in determining mass of total chromium and its leachability from the background rock samples: DI water-leaching tests and EPA Method 3050 acid digestion.

I-2.4.1 DI Water-Leaching Tests

All samples for DI water leaching were lightly crushed to approximately 1-mm particle size (PS). The ratio of solid samples to DI water was 2 to 3, typically consisting of 100 g solid to 150 mL of DI water. The

samples were placed on a shaker table for 48 h before they are filtered using 0.45-µm membranes and acidified with concentrated nitric acid to pH 2 before analysis. Total chromium concentrations in all DI water leachates were analyzed by inductively coupled plasma mass spectrometry (ICPMS) at the Earth and Environmental Sciences 14 (EES-14) laboratory.

I-2.4.2 EPA Method 3050

Samples selected for EPA Method 3050 digestion were supplied coarse-crushed to General Engineering Laboratory (GEL). This process uses both concentrated HCl (variable mL/g of sample) and HNO_3 (≤15 mL/g of sample) to partially digest the rock samples. The digestions were not filtered before analysis. Metal oxides and (oxy)hydroxides and clay minerals partially or completely dissolve during the EPA 3050 digestion. Total chromium concentrations in EPA Method 3050 digestions were analyzed by ICPMS at GEL.

I-2.5 Static (Batch) Experiments

Conventional static (batch) experiments were conducted to determine distribution coefficients of chromium between the vadose zone and regional aquifer materials and groundwater. The test results will allow for evaluation of the attenuation-retention capacities of these rock samples for Cr(VI).

Batch experiments were carried out by weighing a certain amount of solid sample into a preweighed and cleaned polyethylene tube (tube 1) with a cap, adding ~35 mL of groundwater containing spiked Cr(VI) at known concentration to the tube, shaking the mixture, and placing the tube in a shaker to be agitated at a speed of ~120 rpm for a designated period of time. Afterwards, each sample was removed from the shaker and centrifuged for 30 min at ~1200 rpm. A portion of the liquid phase (the top ~30 mL) was pipetted to a clean polyethylene tube (tube 2) and capped. Before analyses, the liquid phase in tube 2 was filtered through a 0.2-µm filter. The total concentrations of chromium, as well as other solutes in the filtered solution, were determined using ICPMS (EPA Method SW-846-6020).

I-2.6 Flow-Through Column Experiments

To better characterize retention or transport of Cr(VI) in vadose zone and regional aquifer materials under flowing conditions, flow-through column experiments were performed using the same groundwater and solid materials as in some of the batch experiments.

In all of the column experiments, lithium bromide was used as a conservative tracer. The solid samples used to pack the columns were wet-sieved to remove fine particles that can clog the columns. The dried wet-sieved solid samples were then packed into the columns. Saturated flow conditions within the columns were achieved by drawing tracer-free groundwater into the flow system in a slow and controlled manner under vacuum. The entire system was then placed under water and under vacuum to ensure fluid saturation, as shown in Figure I-2.6-1. The vacuum was cycled on the submerged flow system until it no longer evolved gas bubbles. The system was then removed from the submersion bath and placed in a vertical orientation, and a steady flow of degassed groundwater was pumped through the column from bottom to top. This flow of degassed groundwater was continued until all visible gas bubbles had been flushed out or dissolved. The Cr(VI)- and bromide-containing tracer solution was then injected in finite-duration pulses (approximately 30 mL, Table I-2.6-1), followed immediately and without any flow interruption by tracer-free groundwater. Syringe pumps were used to achieve constant flow rates through the flow system, and fraction collectors were used to collect column effluent samples at specified intervals for total concentration of chromium and bromide analyses. Figure I-2.6-1 shows a schematic illustration of a column-flow experiment. The volume associated with the inlet and outlet tubing for each of the columns

is listed in Table I-2.6-1 as dead volume. Table I-2.6-1 lists each column used and the respective experimental conditions.

I-2.7 X-ray Absorption Near Edge Spectroscopy Measurements

X-ray absorption near-edge spectroscopy (XANES) is the canonical spectroscopic method for obtaining molecular-scale information on reaction mechanisms in solid-solute systems, especially for providing the oxidation states of the element of interest at relatively low concentration in both solid and solution forms (Peterson et al. 1997, 107033). Measurements use synchrotron-based x-ray absorption spectroscopy and x-ray scattering techniques to determine oxidation states of chromium and its surface complexes on vadose zone and regional aquifer materials. These measurements reveal the chemical nature of chromium-retention processes within geomedia of interest.

Additional batch adsorption experiments were conducted (distinct from those described in section I-2.5) for the XANES analyses to maximize adsorption onto the solid phase. The batch experiments were carried out by weighing approximately 0.3 g of solid sample (Table I-3.2-1 presents detailed information on solid samples used) into a weighed and cleaned polyethylene tube (denoted as tube 1) with a cap, adding ~35 mL of noncontaminated groundwater to which 1 ppm of Cr(VI) was added, shaking the mixture, and putting the tube in a shaker to be agitated at a speed of approximately 120 revolutions per minute (rpm). After 1 d, the sample was removed from the shaker and centrifuged for 30 min at approximately 1200 rpm. A portion of the liquid phase (the top 30 mL) was pipetted to a clean polyethylene tube (denoted as tube 2) and capped. Approximately 30 mL more of noncontaminated groundwater containing 1 ppm of Cr(VI) was added to the residue in tube 1, shaking the mixture and again putting the tube in a shaker to be agitated at a speed of approximately 120 rpm. This procedure was repeated until the total chromium concentration in solution removed from tube 1 remained constant, which indicated that accumulation of chromium onto the solid sample had reached a maximum. About 100 mg of the residual solid material was transferred from tube 1 to a sample holder and sealed with Kapton tape for XANES measurement. The results of these measurements determine the speciation and oxidation state of chromium in these solid samples.

Solutions from tube 2 were subsequently analyzed for chromium content by ICPMS to determine total dissolved concentrations of chromium remaining in solution.

The XANES spectra were collected at ambient laboratory conditions at beam line 11 of the Stanford Synchrotron Radiation Laboratory, and the analyses were performed by Dr. S. Webb and Dr. J. Bargar.

I-2.8 PHREEQC Geochemical Modeling of Chromium Speciation and Mineral Saturation

PHREEQC v2.14.3, a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations (Parkhurst and Appelo 1999, 095402) was used to calculate chromium speciation and saturation indices (SI) for chromium-bearing solids for groundwater collected at wells LAOI-7 and R-35a. The MINTEQ.v4_DATABASE file included in the PHREEQC software was used as the thermodynamic database for the simulations. This database contains the required thermodynamic data for Cr(III, VI) including aqueous speciation and mineral SI calculations.

Figure I-2.8-1 illustrates the procedure used for calculating chromium speciation and SI.

I-3.0 RESULTS AND DISCUSSIONS

I-3.1 Geochemical Modeling of LAOI-7 and R-35a Groundwaters

I-3.1.1 Background and Objectives

This section presents a summary of a geochemical modeling analysis of noncontaminated groundwater collected from perched intermediate-depth well LAOI-7 and regional aquifer well R-35a that was used for batch and column experiments. Wells LAOI-7 and R-35a are completed within the Cerros del Rio basalt and Santa Fe Group, respectively. The computer code PHREEQC (Parkhurst and Appelo 1999, 095402) was used for this analysis.

The objectives of this geochemical modeling analysis for LAOI-7 and R-35a influent groundwater are twofold:

1. Geochemical calculation of oxidation state and speciation of dissolved chromium in the groundwater used for Cr(VI) migration experiments and determine the predominant chromium species present in the groundwater in the relevant to the field conditions;
2. Determine saturation indices of Cr(III, VI) solids to evaluate potential precipitation processes.

Groundwater is a solution composed of numerous solutes that may be in equilibrium with a large variety of reactive minerals and amorphous solids, including silica glass, amorphous chromium hydroxide, and amorphous ferric hydroxide. Geochemical modeling allows calculation of the distribution of aqueous species in a given solution or solute and the saturation states of solutes relative to a set of minerals and amorphous solids. Thus, using geochemical calculations, the distribution of dissolved chromium species can be determined in LAOI-7 and R-35a groundwater and spiked-chromium groundwater samples used in experimental studies. Results of geochemical calculations can also help identify mineral and amorphous phases that likely contribute to or control the solubility of dissolved chromium in the groundwater. Field parameters such as pH, temperature and DO, as well as complete and accurate groundwater analyses, are required for accurate calculation of aqueous speciation and saturation indices for reactive solid phases.

Geochemical modeling calculations increase our understanding of Cr(III, VI) speciation and mineral equilibria within perched intermediate-depth aquifers (Cerros del Rio basalt) and the regional aquifer system (Puye Formation and Santa Fe Group) at the Laboratory.

I-3.1.2 Geochemical Modeling Approach

Median chemical compositions of the LAOI-7 and R-35a groundwater (Table I-3.1-1) serve as input to PHREEQC to calculate concentrations of different aqueous species of Cr(III, VI) potentially present in the groundwater. Chromium(VI) is stable under relatively oxidizing conditions and typically forms bichromate ($HCrO_4^-$) below pH 6.5 and chromate (CrO_4^{2-}) at higher pH values at 25°C. Dissolved Cr(III) species are stable under relatively reducing conditions, forming a free or uncomplexed cation and hydrolysis species including Cr^{3+} (stable under most acidic pH), $CrOH^{2+}$, $Cr(OH)_2^+$, $Cr(OH)_3^0$, and $Cr(OH)_4^-$ (stable under most basic pH). Hydrolysis reactions are important in controlling the solubility of amorphous $Cr(OH)_3$ under reducing and variable pH conditions. For example, the solubility minimum for amorphous and crystalline $Cr(OH)_3$ in equilibrium with dissolved $Cr(OH)_3^0$ occurs under circumneutral pH (6.0 to 9.0) conditions. Adsorption of Cr(III) hydrolysis species onto hydrous ferric oxide (HFO) is controlled by aqueous speciation and pH (Richard and Bourg 1991, 107034). Adsorption of Cr(III) species onto HFO and other adsorbents occurs before precipitation of Cr(III) solids, and precipitation dominates as groundwater becomes saturated or in equilibrium with crystalline and amorphous $Cr(OH)_3$.

Speciation calculations were performed using PHREEQC for both natural chromium concentrations in LAOI-7 (1.40 µg/L) and R-35a (4.90 µg/L) and spiked (50 µg/L) chromium concentrations. Groundwater at LAOI-7 and R-35a is relatively oxidizing with median DO concentrations of 6.83 mg/L and 4.48 mg/L, respectively. Chromium(VI) aqueous species are stable in the presence of measurable DO characteristic of these two groundwaters.

Chromium(VI) species can be adsorbed to a greater extent onto HFO under acidic pH conditions enhanced by a net-positive surface charge on HFO. In addition to adsorption, Cr(VI) reduces to Cr(III) and precipitates from solution as amorphous $Cr(OH)_3$ in the presence of mineral and aqueous reductants. Important solid reductants for Cr(VI) may include minerals with abundant ferrous iron such as olivine, magnetite, and augite present in the Cerros del Rio basalt. For example, the abundance of olivine within the Cerros del Rio basalt at borehole R-9 varies from 2.4 to 8.8 weight percent (wt %) or 24,000 mg/kg to 88,000 mg/kg rock (Broxton et al. 2001, 071250). Ferrous iron contained in olivine is a potential electron donor that can oxidizes to ferric iron and form amorphous $Fe(OH)_3$ or ferrihydrite. Co-precipitation of both Cr(III) and Fe(III) within ferrihydrite can result in additional scavenging of chromium from solution. Additional geochemical calculations using PHREEQC or an equivalent computer program evaluating the adsorption and reduction capacities of perched intermediate and regional aquifer systems will be conducted in the future to address monitored natural attenuation (MNA) of chromium contamination at the Laboratory.

I-3.1.3 Speciation Analysis and Saturation Index Calculations for LAOI-7 and R-35a Groundwaters

Results of the PHREEQC speciation and mineral-SI calculations for the LAOI-7 and R-35a median groundwater compositions are shown in Table I-3.1-1. Calculated Eh and pe values, based on the O_2^0/H_2O redox couple for LAOI-7 and R-35a, are 781 millivolts (mV) and 13.21 and 752 mV and 12.71, respectively. The parameter pe is the negative $\log_{10}$ of the electron activity, in which oxidizing conditions are characterized by positive pe values. Concentrations of measured and calculated total dissolved chromium species are in units of molality (moles of solute/kg H_2O).

The results of geochemical modeling calculations suggest that chromate (CrO_4^{2-}) and bichromate ($HCrO_4^-$) are the dominant aqueous species of Cr(VI) in the initial and spiked LAOI-7 and R-35a groundwaters. The results also indicate that Cr(III) aqueous species are not stable in the strongly oxidizing LAOI-7 and R-35a groundwaters, having calculated concentrations less than 1e-20 molal. In addition, the LAOI-7 and R-35a groundwaters are undersaturated with respect to metal-chromate and Cr(III) solids. These solids are not expected to precipitate from the influent solutions prior to the batch and column experiments. The calculations suggest that dissolved Cr(VI) species are stable, and geochemical reactions leading to the precipitation of Cr(III, VI) solids are not likely in the groundwaters without exposure to ferrous iron at mineral surfaces. These results imply that retention of Cr(VI) during the batch and column experiments is from rock-water interactions rather than from precipitation.

I-3.2 Leaching and Digestion Experiments to Constrain Maximum Chromium Background in Groundwater Exposed to Cerros del Rio Basalts

I-3.2.1 Objectives and Sample Selection for Leaching Experiments

High concentrations of dissolved chromium (500–600 ppb) in groundwater, as in the perched water within Cerros del Rio basalts at SCI-2, are clearly of anthropogenic origin. At low concentrations of chromium (<5 ppb), it may be difficult to determine whether anthropogenic contamination is present. Important to this determination is an understanding of how readily chromium can be leached from various minerals

contained in host rocks beneath the Laboratory. Chromium(III) is the stable oxidation state of this octahedrally bound trace metal within crystallographic lattices of iron-rich oxide and silicate minerals. Mineral hosts for natural chromium are typically those that readily incorporate other transition metals (especially iron and nickel). Common minerals with this character include olivine and spinels (such as magnetite); at high temperatures and early in magmatic crystallization sequences, these minerals readily incorporate chromium from the melt and deplete it from more evolved compositions. Thus, chromium is typically more abundant in basalts than in compositions such as dacite or rhyolite. Figure I-3.2-1 shows chromium concentrations in common lithologies beneath the Pajarito Plateau plotted against another minor element, strontium, that is also concentrated in more mafic igneous rocks but is accumulated by feldspar rather than olivine or magnetite. The highest chromium concentrations and thus the likeliest contributors to relatively high background chromium are in basalts. Basalts were the focus of DI water leaching experiments and partial digestion primarily because of their high chromium content but also because they commonly host perched aquifers or, in the southern portion of the Laboratory, the regional aquifer.

A suite of samples from the Cerros del Rio basalts in MCOI-10 and LAOI-7 was selected to provide constraints on extractable chromium concentrations at sites without chromium contamination. MCOI-10 is located beneath the mesa south of Mortandad Canyon; core and cuttings collected through the Cerros del Rio at this location showed no evidence of water saturation and indicate no possible exposure to anthropogenic chromium. At MCOI-10, only the very top of the Cerros del Rio was cored, so core samples were supplemented by cuttings from greater depth. LAOI-7 is located in Los Alamos Canyon and contains a perched interval in the lower Cerros del Rio, but perched water here does not contain chromium contamination.

Separate splits, as core or cuttings fragments, were leached with either (1) DI water on a shaker table and/or (2) following the EPA Method 3050 process using both HCl and HNO_3 to partially digest the rock samples. Other sample splits were shatterbox or ball-mill pulverized to produce fine powders for x-ray fluorescence (XRF) analysis. The XRF analyses provide total sample chromium content to compare with the amount of chromium released by DI leaching or by the EPA Method 3050. Table I-3.2-1 summarizes the suite of background basalt samples used for leaching experiments.

Two of the samples selected for leaching (LAOI-7 242.9-245.9-ft and MCOI-10 714.6-715.0-ft) are close to or collocated with samples used for batch and column experiments and described above. Eight of the samples leached are from very fresh unweathered basalt; these eight were analyzed by XRF to obtain total major-element compositions plus key trace elements, including chromium (Table I-3.2-2). Total chromium contents of the basalt samples used range from 184 to 235 ppm, a range typical of the basalts beneath the Laboratory (Figure I-3.2-1). The XRF data also provide information relating each sample to either the tholeiitic or alkalic basaltic series typical of the north-central portion of the Laboratory. A sample of altered flow-top material with likely soil components (MCOI-10 713.0-714.2 ft) and a fracture fill from a perched zone in the Cerros del Rio lavas (LAOI-7 242.9-245.9 ft) were also leached but were not analyzed by XRF.

I-3.2.2 Results of Leaching and Digestion Experiments

Results of DI water leaching and EPA Method 3050 digestion experiments are summarized in Table I-3.2-3. Notable in the results is a general lack of detectable dissolved chromium in the DI water leachates, with only a few samples producing detectable chromium at the 1 ppb level. Much more chromium was obtained by the more aggressive low-pH EPA Method 3050 digestion process, but even at pH values of 1 to 2 the amount of chromium extracted was limited to ~1% to 5% of the rock inventory. Short-term aqueous leaching under circumneutral pH conditions is ineffective at removing and

accumulating chromium from basaltic host rocks, including weathered and nonweathered samples. The DI water leaching results are consistent with low background concentrations of dissolved chromium measured at Spring 9B (2 to 4 ppb) discharging from the Cerros del Rio basalt in White Rock Canyon.

Figure I-3.2-2 shows results of the DI water leaching and digestion experiments (Table I-3.2-3) plotted as "background" fields against the leach data obtained from collocated core holes SCC-2 and SCI-2. These core holes are located in Sandia Canyon; the Cerros del Rio basalts in SCI-2 host a perched zone with chromium contamination. The DI water leach profiles are significantly higher in the Cerros del Rio basalts than were obtained by DI water leaching of crushed, uncontaminated basalt. The EPA Method 3050 digestion chromium profile for the Cerros del Rio interval at SCI-2 indicates several samples with 2 to 3 times the maximum value seen in 3050 digestion of the background chromium samples, and 2 orders of magnitude more chromium extraction than the SCI-2 DI water leach values, probably indicating some of the accumulated chromium in core at SCI-2 is a Cr(III) precipitate coating the basalt that is not leached by DI water but is acid soluble.

I-3.3 Retention of Cr(VI) in the Vadose Zone and Regional Aquifer Materials

I-3.3.1 Solute/Solid Interactions and Distribution Coefficients (K_d, mL/g)

In the vadose zone and regional aquifer, chemical interactions occur between groundwater and solid phases. Solids are important to the geochemistry of the groundwater system because they are the primary sources and sinks of dissolved chemical constituents by two geochemical processes:

1. Mineral precipitation: if the solubility of a mineral containing the solute is reached, precipitation of the mineral will occur. In this case, the concentration of the dissolved solute will be limited by the solubility of the mineral.
2. The interactions between a solute and solids can also affect its mobility in the groundwater system. Such interactions include adsorption/desorption, oxidation/reduction, and acid/base neutralization.

As discussed in section I-3.1.3, precipitation of chromium-containing minerals in groundwater did not occur before and during batch and column experiments. Therefore, observation of retention of chromium in the vadose zone and regional aquifer materials from static and column tests should be the result of solute/solid interactions depending on redox state of the solute and reductive capacity of aquifer material, mainly Fe(II) minerals.

The degree of solute removal by solid is commonly studied in the laboratory by two types of experiments. One type is static (batch) experiments in which solid material is mixed with groundwater of known concentration of the solute of interest. Another is flow-through (column) experiments in which groundwater with a known concentration of the solute of interest is brought through a column containing solid material at designed flow rates (Figure I-2.6.1). For static experiments, the final solute concentration is measured and the difference between initial and the final solution concentration is used to calculate the amount of a solute is removed by the solids. A distribution coefficient K_d can be derived from such experiments:

$$K_d = S_i / C_i \qquad \textbf{Equation I-1}$$

Where, S_i (in mg/kg) and C_i (in mg/L) represent the concentrations of constituent i in solid and solution, respectively.

K_d describes the partitioning of solute i in solid and solution from the interaction between solute/solids. K_d is an empirically derived parameter and is not a thermodynamic equilibrium constant; thus, it may vary as the experimental conditions change. Based on its definition (Equation I-1), experimentally derived K_d can be expressed as

$$K_d = \frac{C_{init.} - C_{eq.}}{C_{eq.}} \frac{V}{M} \qquad \textbf{Equation I-2}$$

where V and M are the volume of solution and the mass of solid used in the test, respectively; $C_{init.}$ is the initial concentration/activity of a solute in the solution; and $C_{eq.}$ is the final (equilibrium) concentration/activity of a solute in solution.

It is important to note that distribution coefficients, K_d by definition, do not provide explicit information on what geochemical process occurred between solid and solute.

I-3.3.2 Measured Distribution Coefficients (K_ds) of Cr(VI) in the Vadose Zone and Regional Aquifer Materials

Table I-3.3-1 lists all the borehole samples and groundwaters used for batch experiments and their preparation methods.

Tables I-3.3-2 to I-3.3-6 present experimentally derived distribution coefficients (K_ds) of samples from MCOI-10, R-9c, LAOI-7, R-35a, R-35b, and SCI-2, respectively.

The results of the static batch experiments indicate the following.

- The K_d values for Cr(VI) within the vadose zone and regional aquifer at Sandia Canyon differ from sample to sample and range from zero to ~950 mL/g, which suggests the retention capacities of vadose zone and aquifer materials for Cr(VI) significantly vary depending on mineralogy of the solid samples, sample preparation method, and particle size.
- The particle size of the sample plays an important role with respect to K_d value. In general, the smaller the particle size, the larger the K_d value.
- Samples that have undergone grinding and crushing have significantly larger K_d values. Increased surface area and exposure of fresh mineral surfaces containing Fe(II) are two main reasons for these large experimentally derived K_d values for the ground and crushed samples.
- K_d values obtained using noncrushed rock samples are most representative of in situ geochemical conditions. Distribution coefficients determined from noncrushed samples should be considered in flow and transport modeling of chromium.
- Field evidence has shown that Cr(VI) has migrated from alluvial groundwater to the regional aquifer, which is consistent with small K_d (less than 5 mL/g) values measured with larger, noncrushed rock samples.
- Samples with greater amounts of Fe(II) minerals including olivine, magnetite, amphiboles, and pyroxenes in addition to clay minerals tend to attenuate Cr(VI) to a greater extent than do those samples consisting mainly of quartz and feldspars. The association of Fe(II)-bearing minerals with increasing retention capacity suggests that chemical reduction of Cr(VI) to Cr(III), followed by precipitation of amorphous $Cr(OH)_3$, may occur and is a plausible attenuation mechanism for Cr(VI) retention in vadose zone and regional aquifer materials, as shown in our follow up column tests and XANES measurement results discussed in section I-3.3.3 and I-3.4 of this appendix.

- The relatively low K_d values (0 to 5.9 mL/g) for Cr(VI) from SCI-2 core suggest short groundwater residence times in lined-fractured systems may significantly limit the extent of chromium reduction and/or adsorption onto the Cerros del Rio basalt or the reaction sites on the lined fracture material may be saturated with respect to chromium. In other words, the different adsorbents comprising fracture coatings may have reached their maximum adsorption capacity for chromium at SCI-2. This is consistent with the observed elevated, above-background concentrations of total dissolved chromium at SCI-2.
- Core samples from SCI-2 contain fractures lined mainly with quartz and feldspar with small amounts of zeolite and mica with only trace amounts of magnetite and smectite, as determined from XRD analyses. Optical examination of these materials as grains in oil shows them to be very fine silts (<50 μm and mostly ~5 μm) that include minute grains of pyroxene, olivine, and amphibole as well as those minerals determined by XRD. This fracture material most likely was translocated from hydrostratigraphic units overlying the Cerros del Rio basalt beneath Sandia Canyon. These fracture-lined samples were included as part of the batch experiments to determine their attenuation capacity for Cr(III, VI). Results of the batch experiments show that the distribution coefficients for chromium were less than 6 mL/g, suggesting that the reductive capacity of the Cerros del Rio basalt is significantly diminished at SCI-2 because fracture materials coat the abundant Fe(II)-oxide and -silicate minerals contained in the basalt. It is very likely Cr(VI) was not reduced to Cr(III) and adsorption and precipitation of Cr(III, VI) solids did not occur during the experiments. Specific surface areas of quartz and feldspar are less than 5 m^2/g and the pH of point of zero charge (pH_{pzc}) for quartz and Na-rich feldspar are 3 and 6.8, respectively (Langmuir 1997, 056037). The specific surface area of smectite (only a trace constituent in these samples) exceeds 500 m^2/g; however, its pH_{pzc} is 2 (Langmuir 1997, 056037) and adsorption of Cr(VI) species onto this adsorbent is not likely under both experimental and field conditions at SCI-2. Adsorption of chromate (CrO_4^{2-}) and bichromate (CrO_4^{2-}) onto these adsorbents under oxidizing and basic pH conditions is not likely to occur. Exchange capacity for chromium in the zeolites is also expected to be very small. Groundwater at well SCI-2 is oxic with dissolved chromium stable as $HCrO_4^-$ and CrO_4^{2-} in concentrations ranging from 500 to 600 ppb. The mineralogy, aqueous chemistry, and results of the batch experiments are entirely consistent with each other. Depending on the extent of fracture filling and fracture wall modification, the reduction capacity of the Cerros del Rio basalt is likely to vary considerably and be site-specific at the Laboratory.

I-3.3.3 Column Tests

The chromium and bromide breakthrough curves from five flow-through column experiments are presented in Figures I-3.3-1 to I-3.3-5. These breakthrough curves show chromium and bromide concentrations normalized to their injection concentrations as a function of the volume of groundwater eluted from the columns since the start of the chromium and bromide injection (pore volume zero is when the injections started).

The key inferences from the chromium and bromide breakthrough curves can be summarized as follows.

- Transport behavior of chromium in samples from wells R-35a (Santa Fe Group) and R-35b (Puye Formation), LAOI-7 (altered basalt flow top), and R-9c (basalt rubble zone) is consistent; total chromium was not recovered from the columns. The exception is the Guaje Pumice Bed sample from MCOI-10 where total chromium was recovered from the column.
- Retention of chromium by samples from wells R-35a and R-35b, LAOI-7, and R-9c was almost 100% complete. No detectable total dissolved chromium (<1 ppb) was found in their eluted fluids

during the experimental period. This high retention of chromium in column experiments appears to be typical of the Santa Fe Group sediments, Puye Formation sediments, altered Cerros del Rio flow top, and transmissive rubble zones of the Cerros del Rio basalts.

- Weak retention of chromium using MCOI-10 core was observed, as suggested by the peak of the chromium breakthrough curve slightly below that of bromide. Additionally, the shape of the chromium breakthrough curve was identical to that of bromide, and no delayed breakthrough of chromium and/or extended tail of its breakthrough curve was observed, suggesting that retention of chromium in this sample of the Guaje Pumice Bed from MCOI-10 is limited. In contrast, retention of chromium is likely from reduction of Cr(VI) to Cr(III) by ferrous iron-bearing minerals present in the Cerros del Rio basalt. Hence, desorption of Cr(VI) that has been reduced to Cr(III) by vadose zone and regional aquifer materials is insignificant. Reduced Cr(III) is rapidly, strongly and specifically adsorbed by iron and manganese oxides and some clay minerals.
- Adsorption/precipitation of reduced Cr(III) in the vadose zone and regional aquifer materials is an important geochemical process in determining the fate and transport of chromium in the Laboratory groundwater system, although quantification of this process will require a more robust dataset based on uncrushed samples known to be free of metal contamination. For example, more experiments should be conducted to evaluate dissolution of Cr(III) solids in the presence of DI water, local rain water, and effluent from the Sanitary Effluent Reclamation Facility (SERF), which may treat sanitary waste effluent by reverse osmosis in the future. Geochemical modeling of both batch and column experiments should help in distinguishing precipitation from adsorption. Quantifying the long-term reductive capacities of the Puye Formation, Cerros del Rio basalt, and Santa Fe Group is essential for remediation options including MNA at the Laboratory,
- Determination of rates of Cr(VI) reduction along vadose zone and regional aquifer flow paths is essential to evaluate whether natural attenuation is to be considered as a viable remediation option (Palmer and Puls 1994, 107032).
- More work is required to determine whether chromium currently accumulated in the vadose zone and regional aquifer can act as significant second sources of groundwater contamination in the future. This analysis includes quantifying the mass of chromium and transport mechanisms within the vadose zone beneath Sandia Canyon.

I-3.4 XANES Measurements

I-3.4.1 XANES for Chromium (III)/(VI) Compounds

XANES spectra of the two chromium calibration compounds (Cr_2O_3 and K_2CrO_4 standards) were measured before the XANES method was used to analyze field samples. Figure I-3.4-1 presents the normalized XANES spectra for mixtures of Cr_2O_3 and K_2CrO_4, varying from 100% Cr_2O_3 to 100% K_2CrO_4. The initial peak in the spectrum, just above 5990 eV, is known as the normalized pre-edge peak, while the entire spectrum is known as the normalized pre-edge region. As Figure I-3.4-1 shows, increasing pre-edge height reflects increasing Cr(VI) content. The information in the pre-edge region helps determine the oxidation states of chromium and the relative Cr(III)/Cr(VI) ratio in the sample.

I-3.4.2 XANES for Surface Complex of Chromium in the Vadose Zone and Regional Aquifer Materials

Figures I-3.4-2 and I-3.4-3 present XANES measurements of chromium adsorbed onto various core and cuttings samples collected from boreholes from Sandia Canyon. These spectra suggest that reduction of Cr(VI) to Cr(III) occurred after the Cr(VI) solution was exposed to these rock and sediment materials (as

described in section I-2.7), indicating that natural attenuation of anthropogenic chromium in Sandia Canyon sediments has occurred in both vadose zone and regional aquifer materials. The spectrum from R-35a (Figure I-3.4-3) shows the signature pre-edge peak just above 5990 eV associated with Cr(VI), while the other samples do not show this feature. Spectroscopic results show a range of reduction capacities for Cr(VI), from strong reduction potential within wetlands to moderate within vadose zone basalts and regional aquifer sediments. Table I-3.4-1 summarizes Cr(III)/Cr(VI) content calculated by XANES fitting relative to total chromium in various solid samples after exposure to Cr(VI) solution.

I-4.0 EFFECT OF IRON METAL ON MEASURED OF DISTRIBUTION COEFFICIENTS

A complicating factor in the experimental procedure was the late discovery that small amounts (generally <1%) of iron metal are present in some of the experimental samples. Investigation into the source of this iron metal first focused on the sample processing chain (particularly splitting and crushing equipment), but it was determined by returning to the source samples and containers that the major source is drilling-steel contamination. In some cases the steel is visible if concentrated magnetically and examined at high magnification; it is characteristically jagged and curved, with gold to blue iridescence that may result from high-temperature oxidation induced by friction during drilling. The extent of oxidation and hence the impact of this contaminant on the results is a subject for further analysis. However, the fact that it is not present in all samples allows an assessment of whether the metal fragments impact the results reported here.

- Two samples of the Guaje Pumice Bed from MCOI-10 were used in these experiments: one from 675.9–676.40-ft depth (with ~0.6% metal contamination) and one from 680.5–682-ft depth (without metal contamination). Table I-4.0-1 compares the K_d values obtained from these samples.
- The comparison in Table I-4.0-1 suggests the iron metal does have some effect, but the differences between results with and without iron metal are far less significant than the differences between crushed and uncrushed samples. This supports the conclusion reached in this study that crushing and exposure of fresh mineral surfaces greatly increases chromium retention by reduction of Cr(VI) to Cr(III) followed by precipitation of amorphous $Cr(OH)_3$.
- Other samples in which no iron metal was found include the Cerros del Rio lava from LAOI-7 at the 234.3–236.2-ft depth, with an uncrushed <75-µm split K_d of 3.7 and a crushed <75-µm split K_d of 340. Here again, metal contamination is not a factor, and the K_d increases significantly with crushing and exposure of fresh mineral surfaces. It is also worth noting that none of the Santa Fe Group sediments from R-35a had any iron metal contamination, and the crushed <75-µm split K_d determination of 362 is not affected by any metal content. Experiments with an uncrushed sample from R-35a are yet to be done.
- Drilling steel is a fairly common contaminant in the core and cuttings samples needed for these migration experiments. The steel particles are generally too small and dispersed to be removed by hand-picking. Simple magnetic cleaning of experimental materials is not possible in sample preparation since that would remove many of the natural iron-bearing minerals as well. The lesson learned from the migration experiments summarized here is that multiple samples should be prepared for each test, and all samples should be tested for metal contamination prior to experimentation.

I-5.0 CONCLUSIONS

This appendix summarizes a broad range of experimental work directed at understanding the behavior of dissolved chromium movement or retention in natural samples that host vadose zone and regional aquifer groundwater at the Laboratory. The combination of XANES speciation studies, batch and column transport experiments, and modeling has provided data needed for understanding the basic processes involved.

Groundwaters within Cerros del Rio lavas are relatively unaffected by any leaching of natural chromium from these relatively chromium-rich rocks. Chromate (CrO_4^{2-}) and bichromate ($HCrO_4^-$) are the dominant aqueous species stable in the LAOI-7 and R-35a oxidizing groundwaters. Noncontaminated groundwaters at the Laboratory are undersaturated with respect to Cr(III, VI) solids, and precipitation of chromium phases was unlikely before and during batch and column experiments.

Both vadose zone and regional aquifer materials have variable attenuation capacities for Cr(VI), reflecting large variations in measured distribution coefficients (K_d values). Higher K_d values tend to be associated with crushed rocks and reduced particle sizes, where increased surface area and exposure of fresh mineral surfaces provides more reactive sites containing ferrous iron that acts as a chemical reductant. Lower K_d values associated with noncrushed samples are more representative of Cr(VI) retention capacities of various in situ vadose zone and aquifer materials. The smaller K_d values associated with noncrushed samples should be used in flow and transport modeling of chromium at the Laboratory.

Synchrotron-based XANES measurements enable determination of the chromium oxidation state and speciation of its surface complex after reacting with aquifer materials. The results of XANES measurements combined with static and flow-through column tests, as well as geochemical modeling calculations, suggest that reduction of Cr(VI) to Cr(III) occurs naturally from strong to moderate depending on mineralogy, particularly with respect to the amount of ferrous iron-bearing minerals, and is the primarily geochemical process controlling retention of Cr(VI) in the vadose zone and regional aquifer.

The relatively low K_d values (0 to 5.9 mL/g) for Cr(VI) obtained from SCI-2 core suggest that short groundwater residence times in fractured systems significantly limit the extent of chromium adsorption onto fractures in Cerros del Rio basalt that contain large amounts of translocated silt. Chemical saturation of chromium adsorption sites on fracture fill adsorbents is another process contributing to limited attenuation of Cr(VI) at SCI-2. This finding is consistent with the observed high concentrations of total dissolved chromium at SCI-2.

Adsorption/precipitation of reduced Cr(III) in the vadose zone and regional aquifer materials is an important geochemical process in determining the fate and transport of chromium in the Laboratory groundwater system, although quantification of this process will require a more robust data set based on uncrushed samples known to be free of metal contamination. There is uncertainty related to the reduction rate of Cr(VI) and of Cr(III) solids in the presence of DI water, local rain water, and effluent that may be treated by reverse osmosis at the SERF plant and discharged to Sandia Canyon in the future. Geochemical modeling of both batch and column experiments should help in distinguishing precipitation from adsorption. Quantifying the long-term reductive capacities of the Puye Formation, Cerros del Rio basalt, and Santa Fe Group would reduce uncertainty related to remediation options including MNA at the Laboratory,

More work is required to determine whether chromium currently accumulated in the vadose zone and regional aquifer can act as significant second sources of groundwater contamination in the future. This includes quantifying the mass of chromium and transport mechanisms within the vadose zone beneath Sandia Canyon.

I-6.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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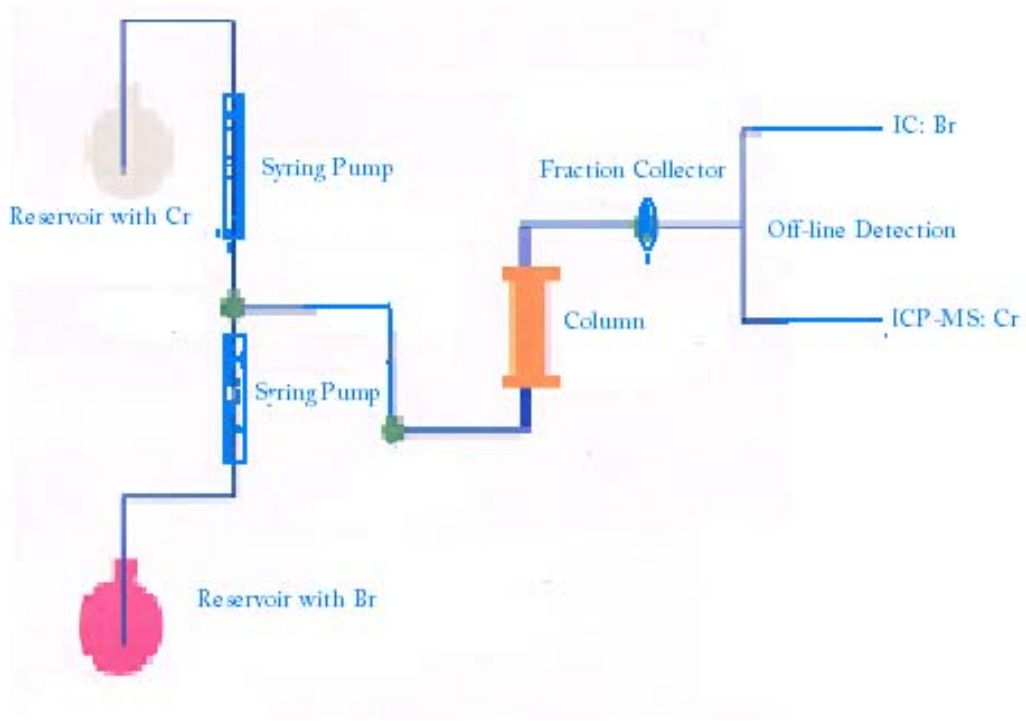
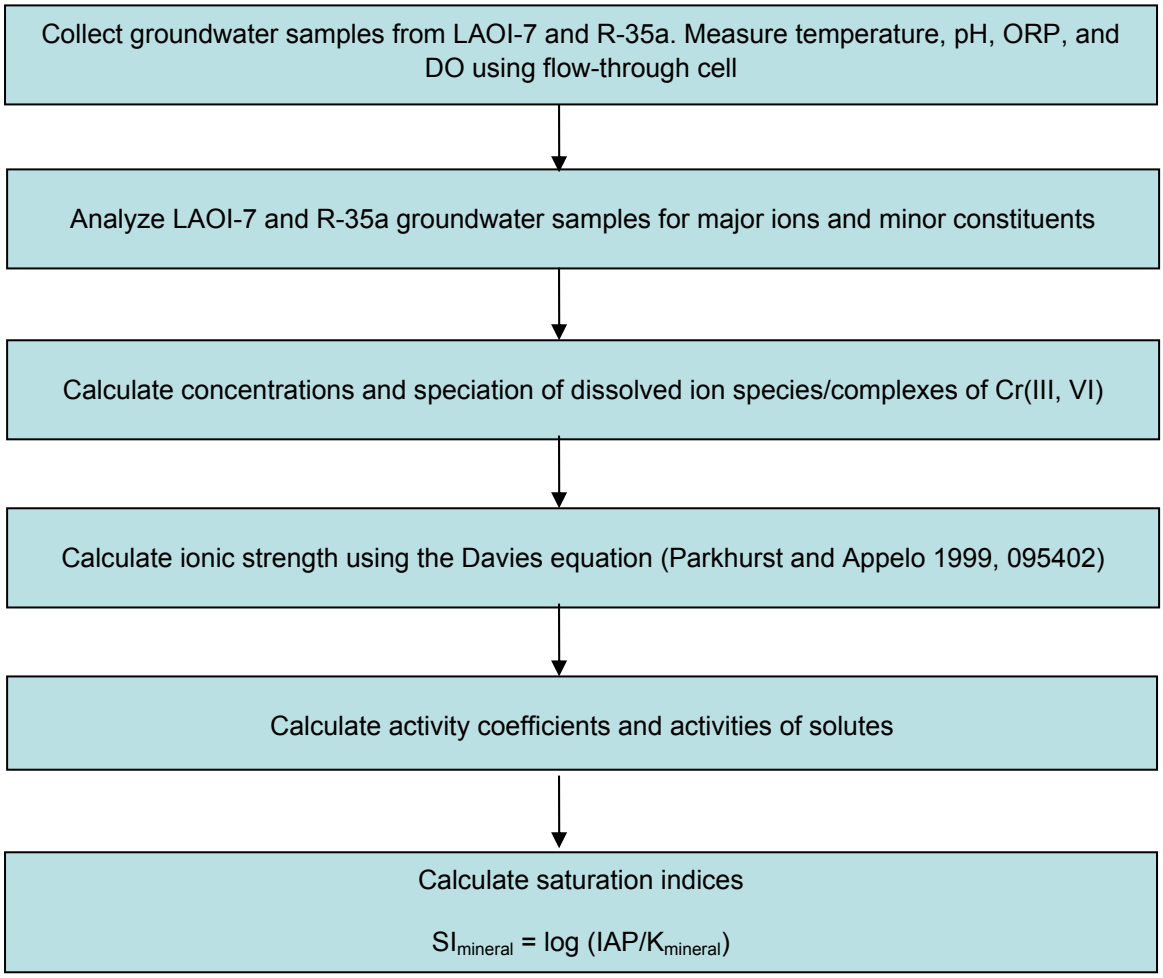


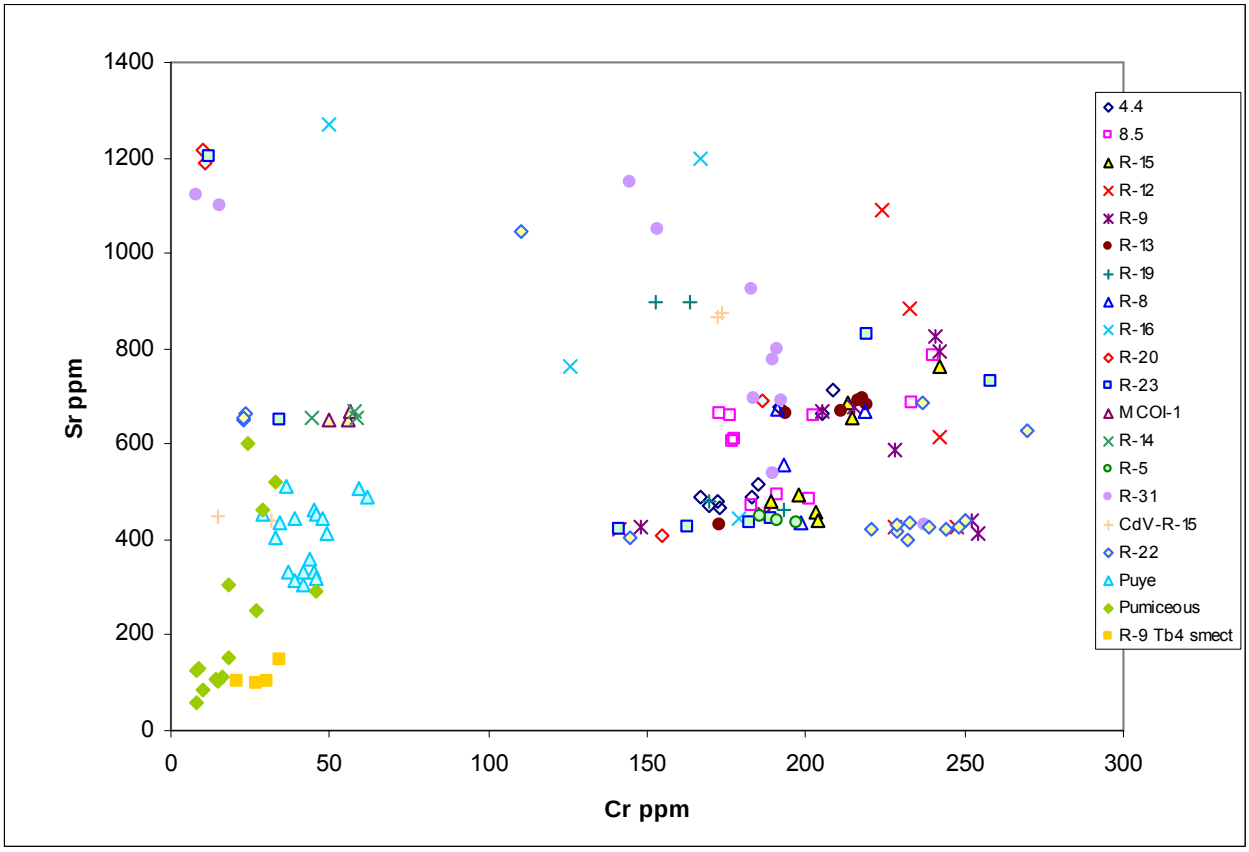
Not to scale

Figure I-2.6-1 Schematic of experimental column flow system



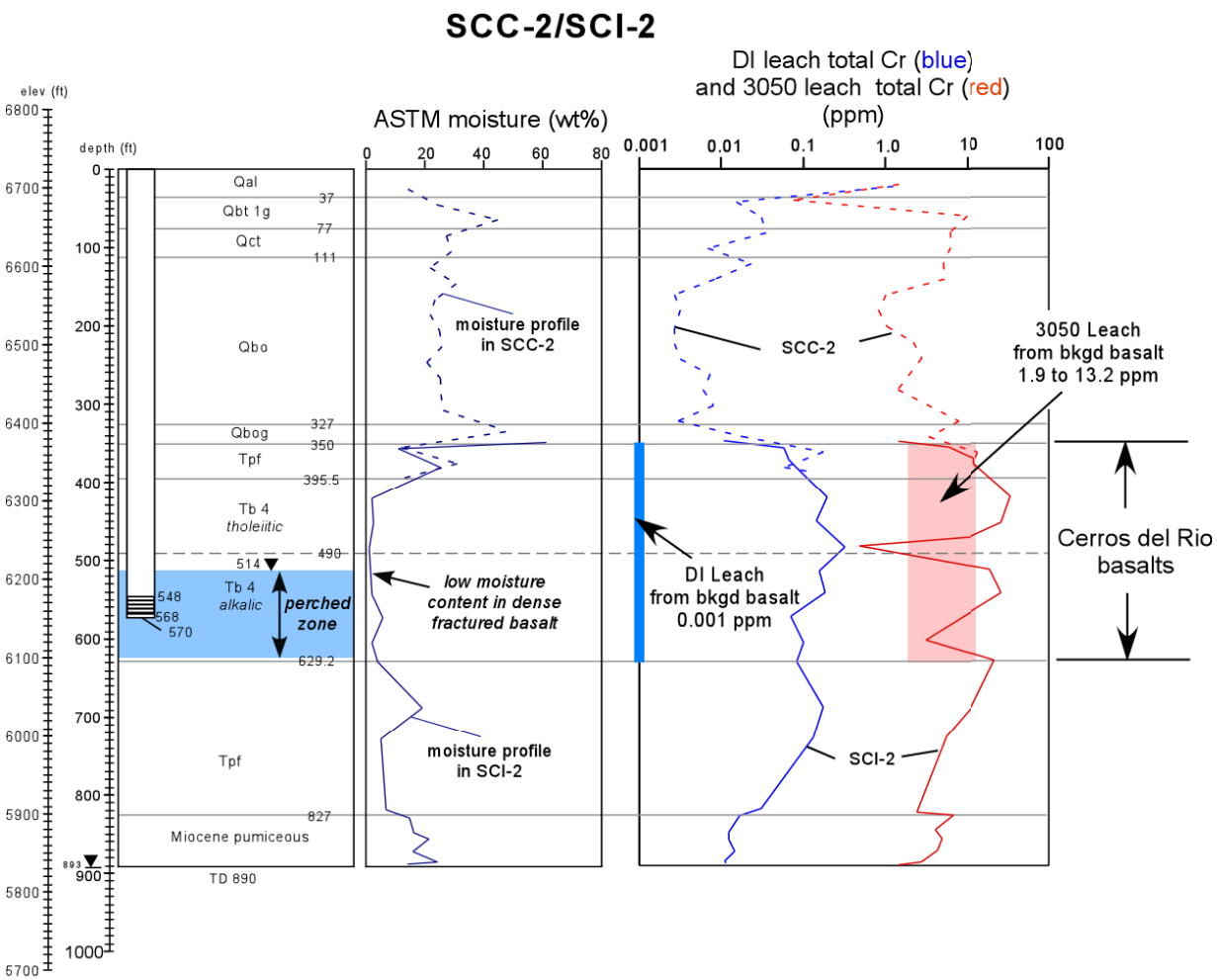
Notes: ORP = oxidation-reduction potential, IAP = ion activity product, K = equilibrium constant or solubility product.

Figure I-2.8-1 Speciation and mineral-SI calculation process for LAOI-7 and R-35a groundwater



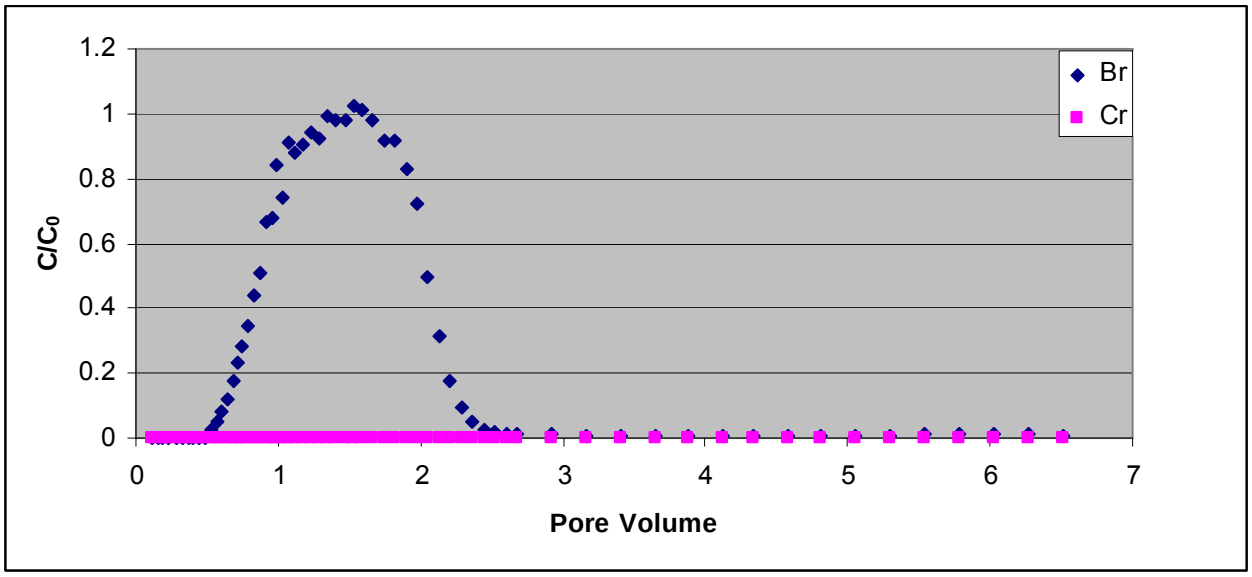
Notes: All samples with Cr greater than 100 ppm are basaltic; among the basalts, those with higher Sr (600 ppm Sr and more) include alkalic basalts and related magma types whereas those with less Sr are typically tholeiitic. Low-Cr (<100 ppm) and high-Sr compositions are typical of dacitic lavas. More evolved magma types such as rhyolitic pumiceous samples from the upper Santa Fe Group, which occur in the upper part of the regional aquifer, have much reduced concentrations of both Sr and Cr (green diamonds). Sediments of the Puye Formation (filled blue triangles) have Cr and Sr contents intermediate between the dacitic lavas and rhyolites. Smectite clay minerals found in fractures of the Cerros del Rio basalt (filled gold squares) contain little Cr or Sr, suggesting that these clay fractions are translocated from other sources.

Figure I-3.2-1 Strontium versus chromium in common rock types beneath the Pajarito Plateau, by borehole



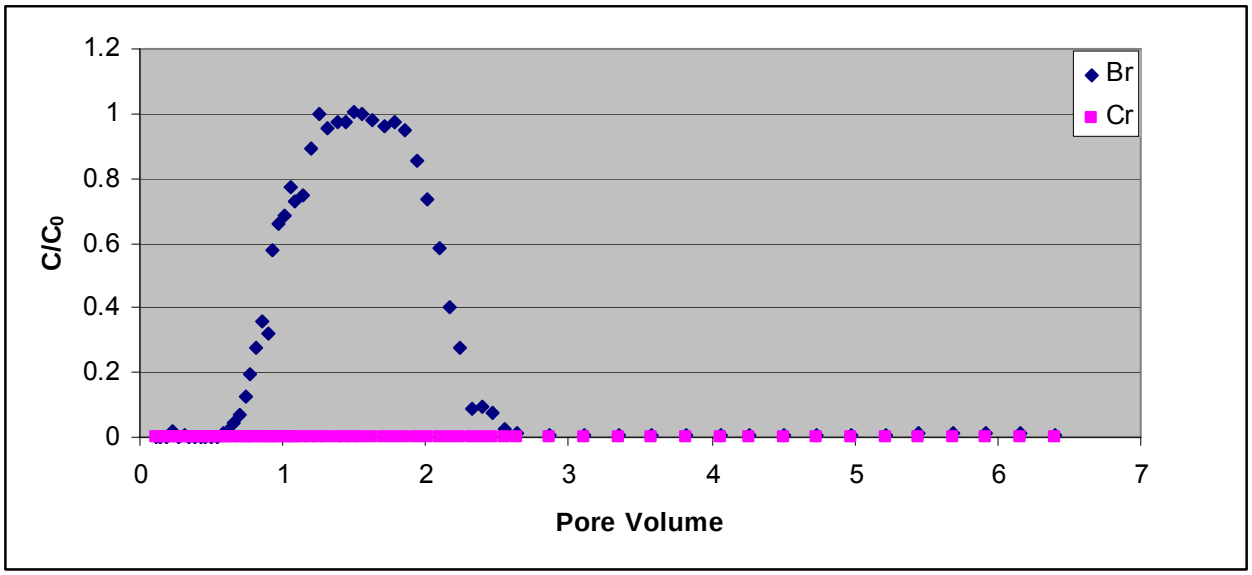
Note: Background DI water leach and EPA Method 3050 digestion values for Cerros del Rio basalt from Table I-3.1-3 are shown for comparison with the SCI-2 leachate profiles.

Figure I-3.2-2 Stratigraphy at SCC-2/SCI-2, moisture profile, and total chromium profiles for DI water leach and EPA Method 3050 digestion chromium from core at this locality



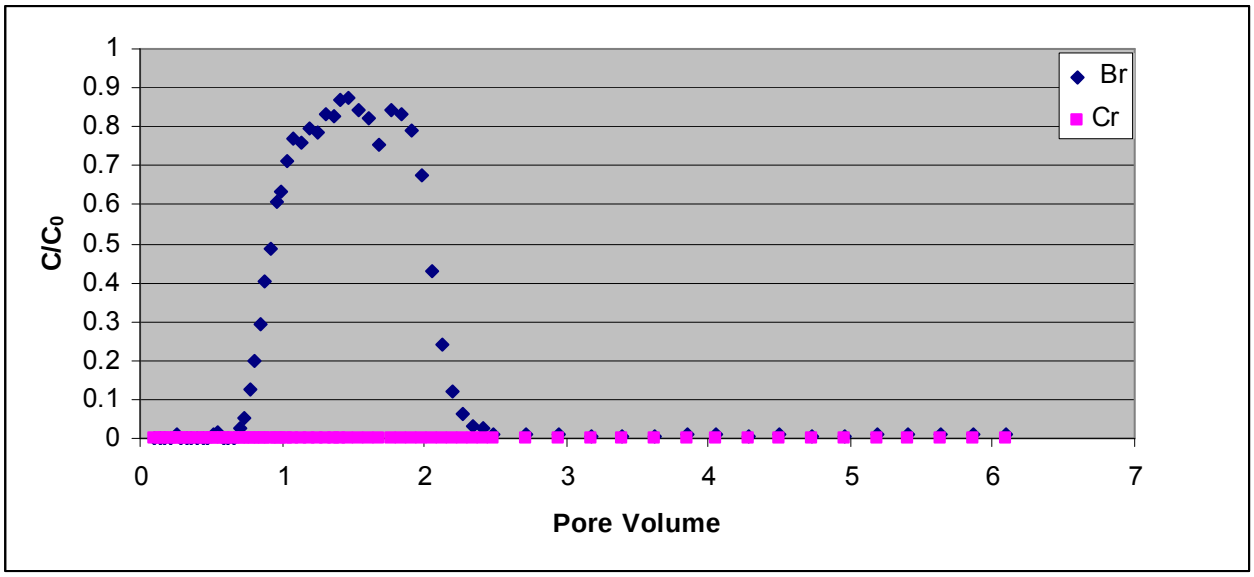
Note: Injection pulse was ~30 mL.

Figure I-3.3-1 Normalized breakthrough curves of bromide and chromium in column containing R-35a Santa Fe Group sediment at a flow rate of 0.5 mL/h



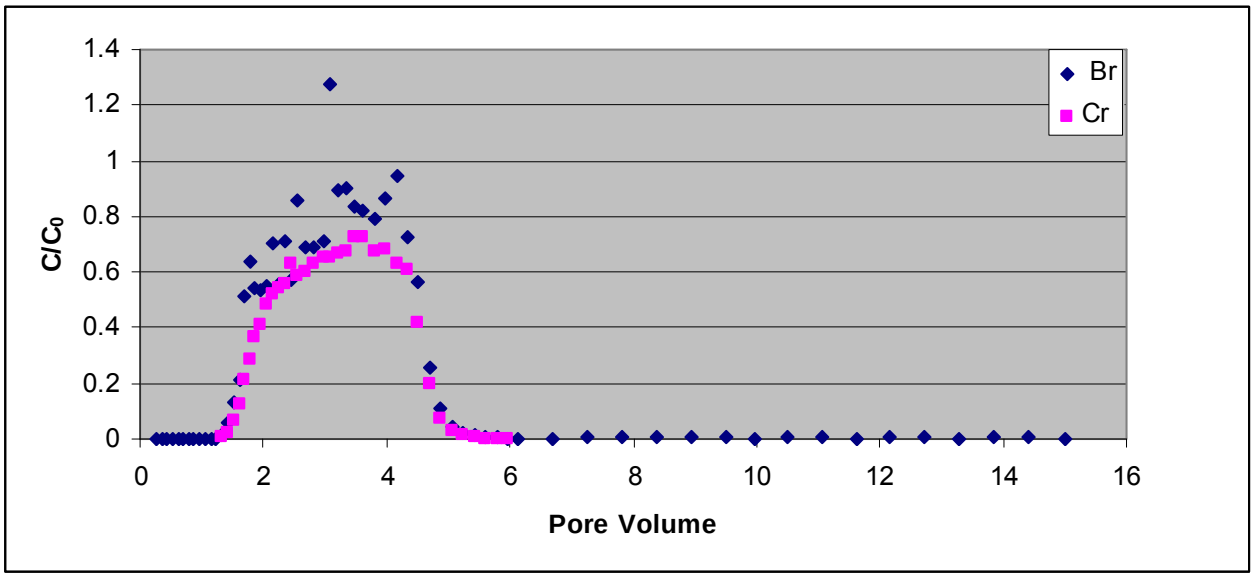
Note: Injection pulse was ~30 mL.

Figure I-3.3-2 Normalized breakthrough curves of bromide and chromium in column containing R-35b Puye Formation sediment at a flow rate of 0.5 mL/h



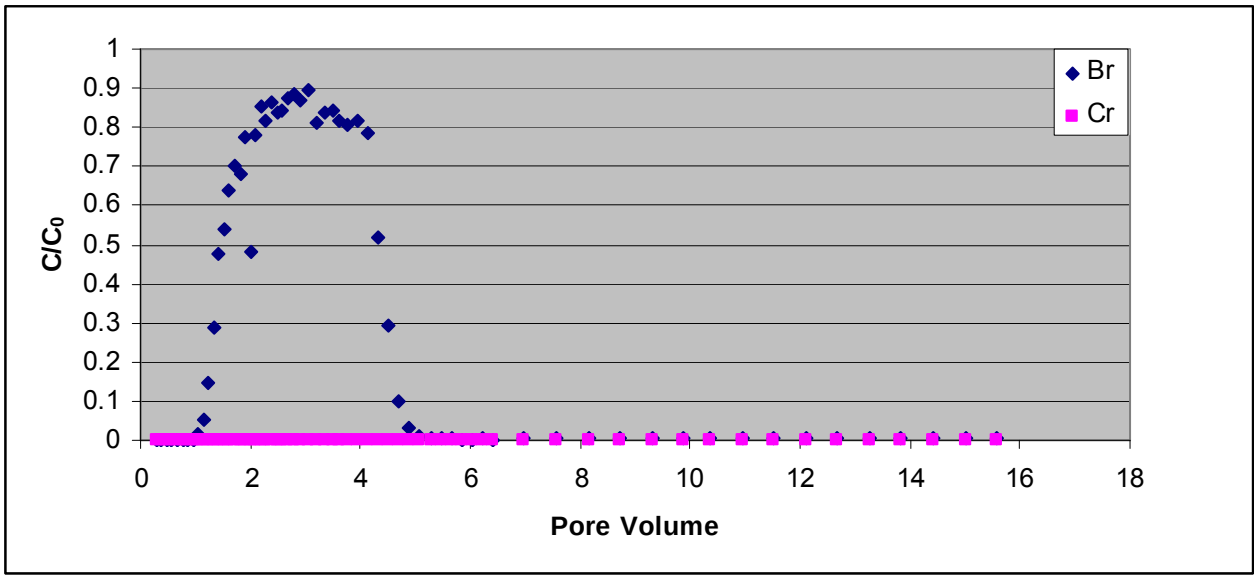
Note: Injection pulse was ~30 mL.

Figure I-3.3-3 Normalized breakthrough curves of bromide and chromium in column containing the LAOI-7 sample of clay-altered Cerros del Rio flow top at a flow rate of 0.5 mL/h



Note: Injection pulse was ~30 mL.

Figure I-3.3-4 Normalized breakthrough curves of bromide and chromium in column containing the Guaje Pumice Bed sample from MCOI-10 at the flow rate of 0.5 mL/h



Note: Injection pulse was ~30 mL.

Figure I-3.3-5 Normalized breakthrough curves of bromide and chromium in column containing samples of altered Cerros del Rio rubble from R-9c at the flow rate of 0.5 mL/h

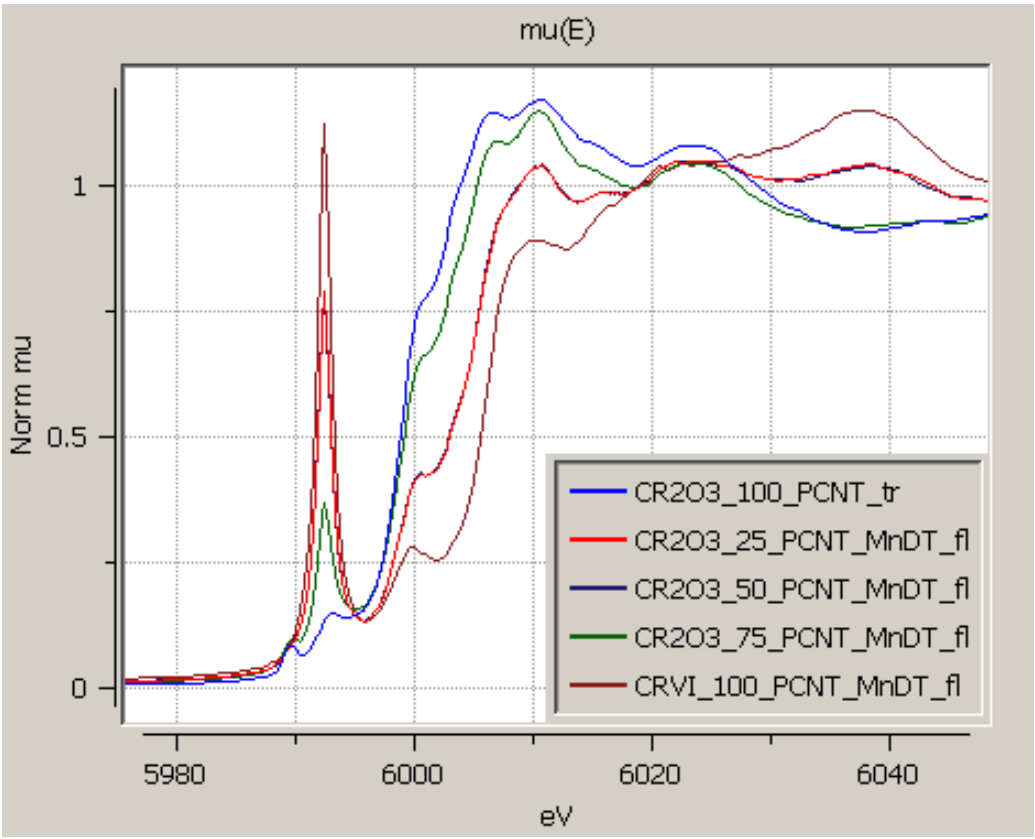


Figure I-3.4-1 Normalized pre-edge region of Cr_2O_3 and K_2CrO_4

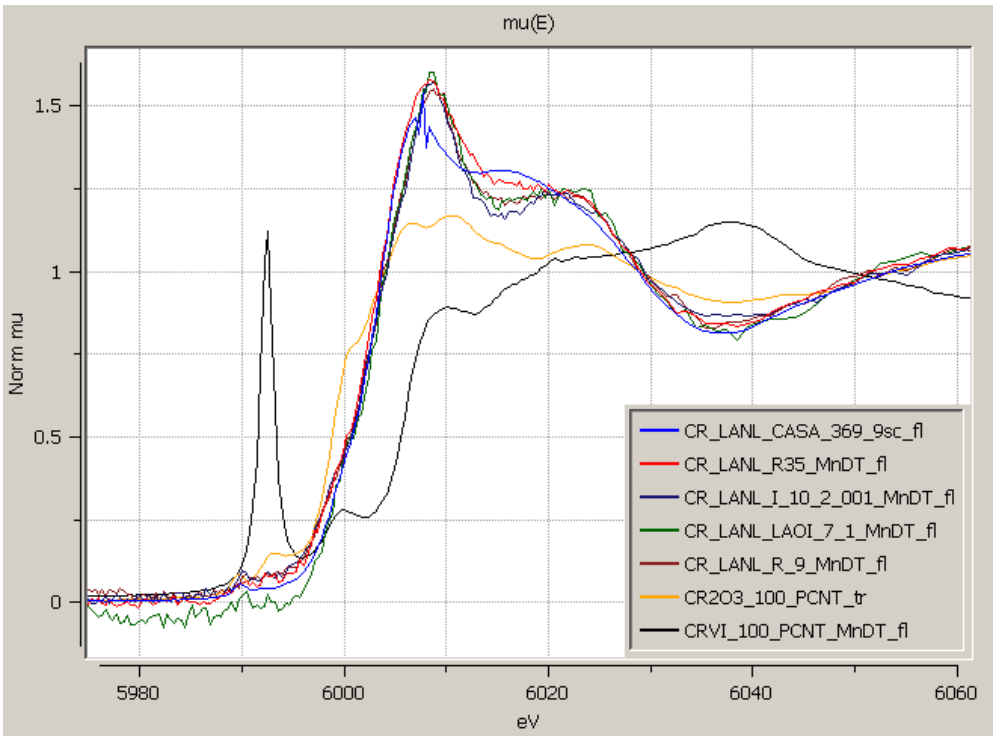
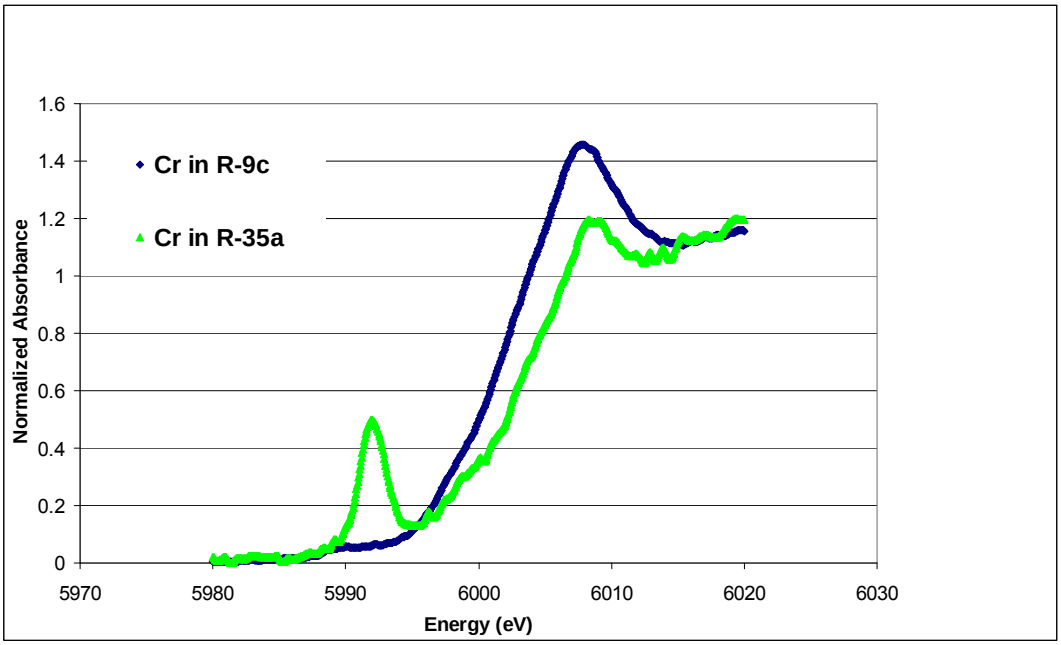


Figure I-3.4-2 XANES spectra of Cr(VI) reacted with the following samples: Sandia wetland CASA-369; R-35b (840–845 ft, PS <75 µm); MCOI-10 (714–715 ft, PS <75 µm); LAOI-7 (83.3–85.6 ft, PS <75 µm); R-9c (245.2–245.5 ft, PS <75 µm); and two chromium standards (100 wt% Cr_2O_3 and 100 wt% K_2CrO_4)



Note: Both samples sieved without crushing and grinding.

Figure I-3.4-3 XANES spectra of Cr(VI) reacted with samples from R-35a (1060–1065 ft, PS <75 µm) and R-9c (183–183.7 ft, PS <75 µm)

Table I-2.1-1
Semiquantitative XRD Analyses of Chromium Batch and Column Experiment Samples

Sample	Smectite	Kaolinite	Zeolite[a]	Quartz	Cristobalite	Alkali Feldspar	Plagioclase	Glass	Pyroxene	Olivine	Magnetite[a]	Hematite	Amphibole	Mica	Fe metal
Guaje Pumice Bed															
MCOI-10 675.9–676.4 ft	—[b]	—	—	m	—	m	—	M	—	—	—	—	—	tr	tr
MCOI-10 680.5–682.0 ft	—	—	—	m	—	m	—	M	—	—	—	—	—	tr	—
Cerros del Rio basalt															
MCOI-10 713.0–714.2 ft	m	tr	tr	M	m	—	M	—	tr	—	tr	tr	—	m	m
MCOI-10 714.6–715.0 ft	—	—	—	—	—	—	M	—	M	m	m	—	—	—	m
R-9 183.0–183.7 ft	tr	—	—	—	—	—	M	—	M	m	m	—	—	—	m
R-9 245.2–245.5 ft	—	—	—	—	—	—	M	—	M	m	m	—	—	—	m
LAOI-7 83.3–85.6 ft	M	—	—	M	—	—	M	—	—	—	m	—	—	m	tr
LAOI-7 234.3–236.2 ft	—	—	—	—	—	—	M	—	M	m	m	—	—	—	—
Puye Formation															
R-35b 820–845 ft	tr	—	—	M	—	—	M	—	—	—	tr	—	—	m	—[c]
Santa Fe Group															
R-35a 1060–1065 ft	M	—	—	—	—	—	M	—	—	—	tr	—	m	—	—
SCI-2 Fracture Samples															
SCI-2 540 ft	—	—	m	M	—	—	M	—	—	—	tr	—	—	m	—
SCI-2 548 ft	tr	—	m	M	—	—	M	—	—	—	—	—	—	m	—

Notes: M = major (>10%), m – minor (10-1%), tr = trace (<1%). All data from <75-µm sample splits.

[a] Zeolites likely include phillipsite and possible clinoptilolite; magnetite includes titanomagnetite and maghemite.

[b] - = Not detected.

[c] Iron metal was observed visually in a coarser split (75–500 µm) of the R-35b 840–845-ft interval sample.

Table I-2.2-1
Chemical Compositions of LAOI-7 and R-35a Groundwater

	Chemical Constituents	Unit	LAOI-7			R-35a		
			Average	Median	Stdev	Average	Median	Stdev
Field	Temperature (T)	(°C)	14.82	14.69	1.11	22.02	22.30	0.95
	pH	SU	7.25	7.37	0.40	7.83	7.83	0.10
	DO	mg/L	6.78	6.83	1.14	4.46	4.48	0.92
	TOC	mg/L	1.23	1.20	0.28	0.79	0.70	0.27
Major	Ca^{2+}	mg/L	15.10	14.70	1.36	22.02	21.80	0.85
	Mg^{2+}	mg/L	6.46	6.21	0.71	5.57	5.52	0.26
	Na^{+}	mg/L	10.54	10.40	0.64	19.25	19.30	1.06
	K^{+}	mg/L	4.86	4.81	0.26	4.74	4.75	0.34
	SiO_2	mg/L	54.51	56.00	6.75	81.48	80.40	3.4
	Cl^{-}	mg/L	20.70	19.00	4.75	6.20	6.14	0.22
	F^{-}	mg/L	0.22	0.22	0.02	0.34	0.34	0.03
	SO_4^{2-}	mg/L	9.32	8.99	0.73	5.57	5.42	0.43
	ALK-CO_3+HCO_3	mg/L	52.88	52.40	3.98	113.05	105.50	16.42
Trace	Br^{-}	mg/L	0.12	0.11	0.05	ND[a]	na[b]	na
	NO3+NO2-N	mg/L	0.25	0.28	0.08	0.45	0.50	0.24
	PO_4^{3-}	mg/L	0.05	0.03	0.03	0.05	0.05	0.01
	Al^{3+}	µg/L	ND	na	na	290.50	290.50	na
	Ba^{2+}	µg/L	23.99	23.45	2.36	323.33	322.00	13.86
	B	µg/L	15.39	15.00	4.32	35.88	39.00	8.06
	Cr	µg/L	1.38	1.40	0.29	7.82	4.90	5.79
	Fe	µg/L	42.49	34.90	23.34	163.94	99.60	201.80
	Mn	µg/L	4.21	3.95	1.35	7.88	3.56	9.64
	U	µg/L	0.61	0.60	0.05	0.69	0.67	0.10

[a] ND = Not detected.

[b] na = Not available.

Table I-2.6-1
Parameters for the Flow-Through Columns and Experimental Conditions

Geological Material	Column #1 R-35a Santa Fe Group	Column #2 R-35b Puye	Column #3 LAOI-7 Cerros del Rio Flow Top	Column #4 MCOI-10 Guaje Pumice Bed	Column #5 R-9c Cerros del Rio Rubble Zone
Interval (ft below ground surface)	1060–1065	840–845	83–86	680–682	183–184
Particle Size (µm)	75-500	75-500	75-500	75-500	75-500
Groundwater Used	R-35a	R-35a	LAOI-7	LAOI-7	LAOI-7
Diameter (cm)	1.5	1.5	1.5	1.0	1.0
Length of Column (cm)	20	20	20	20	20
Full Column Volume (cm^3)	35.34	35.34	35.34	15.71	15.71
Porosity (%)	68	70	73	66	64
Pore Volume (mL)	24.03	24.74	25.80	10.37	10.05
Hydraulic Conductivity (cm/min)	0.21	3.46	4.54	4.01	1.62
Dead Volume Inlet Tube (mL)	0.89	0.89	0.89	0.89	0.89
Dead Volume Outlet Tube (mL)	1.57	1.57	1.57	1.57	1.57
Flow Rate (mL/h)	0.5	0.5	0.5	0.5	0.5
Mass of Tracer Injected (mL)	29.83	29.91	29.85	29.64	30.13
Mass of Tracer Injected (pore volume)	1.24	1.21	1.16	2.86	3.00

Table I-3.1-1
Results of PHREEQC Simulations for LAOI-7 and R-35a Groundwater

Parameter/Species	Initial Solution	Spiked Solution	Initial Solution	Spiked Solution
Well	**LAOI-7**	**LAOI-7**	**R-35a**	**R-35a**
Chemical Compositions				
pH (standard units)	7.37	7.37	7.83	7.83
Temperature (°C)	25	25	25	25
DO (mg/L)	6.83	6.83	4.48	4.48
pe (O_2/H_2O)	13.21	13.21	12.71	12.71
Eh (mV)	781	781	752	752
Ionic strength (m)	0.00243	0.00243	0.00311	0.00311
Charge balance (%)	3.92	3.89	7.62	7.60
Total dissolved Cr (m)	2.693e-08	9.887e-07	9.426e-08	1.056e-06
CrO_4^{2-} (m)	2.405e-08	8.828e-07	9.032e-08	1.012e-06
$HCrO_4^-$ (m)	2.831e-09	1.039e-07	3.618e-09	4.054e-08
$NaCrO_4^-$ (m)	4.365e-11	1.602-09	2.965e-10	3.322e-09
$KCrO_4^-$ (m)	8.877e-12	3.259e-10	3.211e-11	3.597-10
$Cr(OH)_2^+$ (m)	6.831e-25	NC	1.440e-25	1.613e-24
$CrOH^{2+}$ (m)	2.829e-26	NC	2.115e-27	2.370e-26
$Cr(OH)_3^0$ (m)	5.717e-26	NC	3.449e-26	3.864e-25
CrO_2^- (m)	6.743e-28	NC	1.182e-27	1.325e-26
$Cr(OH)_4^-$ (m)	5.691e-28	NC	9.978e-28	1.118e-26
Saturation Index				
$Cr(OH)_3$am	-16.07	NC	-16.29	-15.24
$Cr(OH)_3$	-18.16	NC	-18.38	-17.33
$BaCrO_4$	-4.90	-3.33	-3.22	-2.17
$CaCrO_4$	-8.99	-7.42	-8.27	-7.22
$MgCrO_4$	-16.79	-15.22	-16.29	-15.24
K_2CrO_4	-15.07	-13.50	-14.52	-13.47
Na_2CrO_4	-17.38	-15.82	-16.29	-15.24

Notes: m = Molal or moles of solute/kg water. NC = not calculated by PHREEQC because predicted Cr(III) concentrations are less than 10e-30 molal and solution is strongly oxidizing. pe = $-\log_{10}$activity of e^-. pe is calculated from the O_2^0/H_2O redox couple.

Table I-3.2-1
Samples for Cerros del Rio Background Chromium Study

Sample	Type	XRF	DI Leach[a]	EPA Method 3050 Digestion	Composition[b]	Notes
MCOI-10 713.0–714.2 ft	Core	No	Yes	Yes	T	Altered flow top
MCOI-10 714.6–715.0 ft	Core	Yes	Yes	Yes	T	Unaltered flow
MCOI-10 755–760 ft	Cuttings	Yes	No	Yes	T	Unaltered flow
MCOI-10 845–850 ft	Cuttings	Yes	No	Yes	T	Unaltered flow
MCOI-10 895–900 ft	Cuttings	Yes	No	Yes	A	Unaltered flow
MCOI-10 940–945 ft	Cuttings	Yes	No	Yes	A	Unaltered flow
LAOI-7 204.8–207.2 ft	Core	Yes	Yes	Yes	T	Unaltered flow
LAOI-7 218.4–221.4 ft	Core	Yes	Yes	Yes	A	Unaltered flow
LAOI-7 240.1–245.9 ft	Core	Yes	No	Yes	A	Unaltered flow, perched zone
LAOI-7 242.9–245.9 ft	Core	No	No	Yes	Not available	Fracture material, perched zone

[a] DI leach data not from those samples collected from wells that were drilled with fluid or from saturated rock.

[b] T = Tholeiitic, A = alkalic.

Table I-3.2-2
XRF Data for Samples of Cerros del Rio Lavas Leached for the Chromium Background Study

Element	LAOI-7, 204.8–207.2 ft	LAOI-7, 218.4–221.4 ft	LAOI-7, 242.9–245.9 ft	MCOI-10, 714.6–715.0 ft	MCOI-10, 755–760 ft	MCOI-10, 845–850 ft	MCOI-10, 895–900 ft	MCOI-10, 940–945 ft
Major Elements (wt%)								
SiO_2	50.51	49.98	50.03	50.72	50.94	50.79	49.25	48.16
TiO_2	1.437	1.594	1.600	1.479	1.491	1.481	1.616	1.752
Al_2O_3	15.88	15.84	15.98	16.38	16.21	16.32	15.41	15.03
Fe_2O_3T[a]	11.28	10.87	10.81	11.30	11.55	11.43	10.85	11.1
MnO	0.163	0.167	0.161	0.165	0.168	0.158	0.193	0.165
MgO	6.41	6.70	6.66	5.99	6.51	6.28	7	7.89
CaO	8.84	8.92	8.96	9.09	9.02	9.05	8.74	8.76
Na_2O	3.21	3.53	3.49	3.33	3.45	3.43	3.41	3.4
K_2O	1.14	1.41	0.88	0.96	1.05	1.07	1.43	1.52
P_2O_5	0.383	0.542	0.547	0.371	0.35	0.37	0.538	0.644
Total	99.27	99.56	99.11	99.78	100.74	100.38	98.44	98.42
Trace Elements (ppm)								
V	171	207	191	203	202	202	202	197
Cr	185	192	200	163	190	184	224	235
Ni	77	101	105	71	88	86	125	164
Zn	128	125	113	117	131	131	133	105
Rb	20	23	22	15	21	22	20	30
Sr	486	662	661	525	480	511	661	758
Y	30	18	36	32	24	31	27	30
Zr	167	195	192	158	153	153	186	205
Nb	16	22	24	20	21	20	33	31
Ba	557	774	780	616	469	503	679	749
Total alkalis	4.36	4.94	4.37	4.29	4.50	4.50	4.84	4.92
Mg#[b]	0.53	0.55	0.55	0.51	0.53	0.52	0.56	0.58
Classification[c]	T	A	A	T	T	T	A	A

Note: Black text = Samples collocated with chromium attunation studies; Blue text = samples added specifically for chromium background analysis.

[a] Fe content is both ferrous and ferric but all is reported as ferric (Fe_2O_3T) in XRF results.

[b] Atomic ratio of (Mg) to (Mg+Fe).

[c] T = Tholeiitic, A = alkalic.

Table I-3.2-3
DI and EPA Method 3050 Leach Results for Cerros del Rio Background Chromium Study

Sample	Bulk Cr by XRF	DI Leach	3050 Leach	3050/Bulk (wt %)	Composition[a]	Notes
MCOI-10 713.0-714.2 ft	—[b]	1 ppb	7.76 ppm	—	T	Altered flow top
MCOI-10 714.6-715.0 ft	163 ppm	1 ppb	5.03 ppm	3.1%	T	Unaltered flow
MCOI-10 755-760 ft	190 ppm	—	5.34 ppm	2.8%	T	Unaltered flow
MCOI-10 845-850 ft	184 ppm	—	5.87 ppm	3.2%	T	Unaltered flow
MCOI-10 895-900 ft	224 ppm	—	4.58 ppm	2.0%	A	Unaltered flow
MCOI-10 940-945 ft	235 ppm	—	13.2 ppm	5.6%	A	Unaltered flow
LAOI-7 204.8-207.2 ft	185 ppm	<1 ppb	3.71 ppm	2.0%	T	Unaltered flow
LAOI-7 218.4-221.4 ft	192 ppm	<1 ppb	2.72 ppm	1.4%	A	Unaltered flow
LAOI-7 242.9-245.9 ft	200 ppm	—	10.4 ppm	5.2%	A	Unaltered flow, perched zone
LAOI-7 242.9-245.9 ft	—	—	1.88 ppm	—	Not available	Fracture material, perched zone

[a] T = tholeiitic, A = alkali.

[b] — = Not measured.

Table I-3.3-1
Borehole and Groundwater Samples Used for Batch Adsorption Experiments

Sample Location	Depth (ft bgs[a])	Sample Preparation Method[b]	Particle Size Fraction (µm)			Groundwater Used for Batch Experiments[c]
			500–2000	75–500	< 75	
R-35a	1060—1065	A	500—2000	75—500	< 75	R-35a
R-35b	820—825	B	500—2000	75—500	< 75	R-35a
R-35b	820—825	A	500—2000	75—500	< 75	R-35a
R-35b	840—845	B	500—2000	75—500	< 75	R-35a
R-35b	840—845	A	500—2000	75—500	< 75	R-35a
LAOI-7	83.3—85.6	B	500—2000	75—500	na[d]	LAOI-7
LAOI-7	83.3—85.6	A	500—2000	75—500	<75	LAOI-7
LAOI-7	234.3—236.2	B	500—2000	75—500	<75	LAOI-7
LAOI-7	234.3—236.2	A	500—2000	75—500	<75	LAOI-7
MCOI-10	675.9—676.4	B	500—2000	75—500	<75	LAOI-7
MCOI-10	675.9—676.4	A	500—2000	75—500	<75	LAOI-7
MCOI-10	680.5—682	B	500—2000	75—500	<75	LAOI-7
MCOI-10	680.5—682	A	500—2000	75—500	<75	LAOI-7
MCOI-10	713—714.2	B	500—2000	75—500	<75	LAOI-7
MCOI-10	713—714.2	A	500—2000	75—500	<75	LAOI-7
MCOI-10	714.6—715	A	500—2000	75—500	<75	LAOI-7
R-9c	183—183.7	B	500—2000	75—500	<75	LAOI-7
R-9c	183—183.7	A	500—2000	75—500	<75	LAOI-7
R-9c	245.2—245.5	A	500—2000	75—500	<75	LAOI-7
SCI-2	540.4—540.9	C	na	na	na	LAOI-7
SCI-2	548.7—549.3	C	na	na	na	LAOI-7
SCI-2	810.0—810.5	C	na	na	na	LAOI-7
SCI-2	874.6—874.8	C	na	na	na	LAOI-7

[a] bgs = Below ground surface.

[b] A = grind, crush, and dry sieve; B = without grinding and crushing, dry sieve; C = without grinding and crushing, no sieve process.

[c] The groundwater was filtered through 0.2-µm filters and stored in a cooler at ^{0}C.

[d] na = Not available.

Table I-3.3-2
Chromium Distribution Coefficients for Core Materials from Well MCOI-10

Solid Material (Well, Depth, PS µm)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concen. (ppb)	Liquid to Solid Ratio (mL/g)
Interval 675.9'–676.4': Otowi Formation (Guaje Pumice Bed); bag sample of Guaje Pumice Bed; clean core rubble zone from below-mesa locality away from contaminant sources					
MCOI-10 675.9'-676.4, <75 (B*)	27.4	27.8	0.5	50	35
MCOI-10 675.9'-676.4, <75 (B)	28.1			50	35
MCOI-10 675.9'-676.4, 75-500 (B)	3.5	4.2	1.0	50	35
MCOI-10 675.9-676.4, 75-500 (B)	5.0			50	35
MCOI-10 675.9'-676.4, 500-2000 (B)	6.0	6.2	0.2	50	35
MCOI-10 675.9'-676.4, 500-2000 (B)	6.3			50	35
MCOI-10 675.9'-676.4, <75	712	683	41	50	35
MCOI-10 675.9'-676.4, <75	654			50	35
MCOI-10 675.9'-676.4, 75-500	523	602	112	50	35
MCOI-10 675.9'-676.4, 75-500	681			50	35
MCOI-10 675.9'-676.4, 500-2000	8.8	8.2	0.9	50	35
MCOI-10 675.9'-676.4, 500-2000	7.5			50	35
Interval 680.5'–682': Otowi Formation; Lexan sample of Guaje Pumice Bed; clean, relatively intact core from below-mesa locality away from contaminant sources					
MCOI-10 680.5'-682', <75 (B)	9.9	9.5	0.6	50	35
MCOI-10 680.5'-682', <75 (B)	9.1			50	35
MCOI-10 680.5'-682', 75-500 (B)	8.9	9.1	0.3	50	35
MCOI-10 680.5'-682', 75-500 (B)	9.3			50	35
MCOI-10 680.5'-682', 500-2000 (B)	14.5	14.2	0.4	50	35
MCOI-10 680.5'-682', 500-2000 (B)	13.8			50	35
MCOI-10 680.5'-682', <75	395	487	130	50	35
MCOI-10 680.5'-682', <75	587			50	35
MCOI-10 680.5'-682', 75-500	126	99	38	50	35
MCOI-10 680.5'-682', 75-500	72.3			50	35
MCOI-10 680.5'-682', 500-2000	7.7	7.7	0.1	50	35
MCOI-10 680.5'-682', 500-2000	7.8			50	35
Interval 713'–714.2': Cerros del Rio lava; core of altered zone from the top of the Cerros del Rio lavas at a below-mesa locality away from contaminant sources					
MCOI-10 713'-714.2', <75 (B)	294	260	48	50	35
MCOI-10 713'-714.2', <75 (B)	226			50	35
MCOI-10 713'-714.2', 75-500 (B)	12.3	14.2	2.7	50	35
MCOI-10 713'-714.2', 75-500 (B)	16.1			50	35
MCOI-10 713'-714.2' , 500-2000 (B)	3.7	2.7	1.4	50	35
MCOI-10 713'-714.2', 500-2000 (B)	1.7			50	35
MCOI-10 713'-714.2', <75	564	490	104	50	35
MCOI-10 713'-714.2', <75	417			50	35

Table I-3.3-2 (continued)

Solid Material (Well, Depth, PS µm)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concen. (ppb)	Liquid to Solid Ratio (mL/g)
MCOI-10 713'-714.2' , 75-500	413	579	234	50	35
MCOI-10 713'-714.2' , 75-500	744			50	35
MCOI-10 713'-714.2', 500-2000	15.2	15.4	0.2	50	35
MCOI-10 713'-714.2', 500-2000	15.5			50	35
Interval 714.6'–715': Cerros del Rio lava; core of unaltered Cerros del Rio lava at a below-mesa locality away from contaminant sources					
MCOI-10 714.6'-715', <75	905	863	56	50	35
MCOI-10 714.6'-715', <75	821			50	35
MCOI-10 714.6'-715' , 75-500	1029	1389	510	50	35
MCOI-10 714.6'-715' , 75-500	1749			50	35
MCOI-10 714.6'-715', 500-2000	10.6	13.9	4.7	50	35
MCOI-10 714.6'-715', 500-2000	17.2			50	35

Note: Blank cells indicate sample is a duplicate run.

*B = Sample preparation method is B, as defined in Table I-3.3-1.

Table I-3.3-3
Chromium Distribution Coefficients for Core Materials from Well R-9c

Solid Material (Well, Depth, PS µm)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concen. (ppb)	Liquid to Solid Ratio (mL/g)
Interval 183'–183.7': Cerros del Rio lava, bag sample of altered rubble zone within upper perched zone.					
R-9c 183'-183.7' < 75 (B*)	37.8	39.7	2.8	50	35
R-9c 183'-183.7' < 75 (B)	41.7			50	35
R-9c 183'-183.7' 75-500 (B)	5.7	9.1	4.7	50	35
R-9c 183'-183.7' 75-500 (B)	12.4			50	35
R-9c 183'-183.7' 500-2000 (B)	2.3	2.8	0.7	50	35
R-9c 183'-183.7' 500-2000 (B)	3.3			50	35
R-9c 183'-183.7', < 75	514	523	73	50	35
R-9c 183'-183.7', < 75	532			50	35
R-9c 183'-183.7', 75-500	484	535	73	50	35
R-9c 183'-183.7', 75-500	587			50	35
R-9c 183'-183.7', 500-2000	38.0	38.5	0.8	50	35
R-9c 183'-183.7', 500-2000	39.1			50	35
Interval 245.2'–245.5': Cerros del Rio lava, intact massive, unaltered basalt beneath upper perched zone					
R-9c 245.2'-245.5' < 75	405	420	21	50	35
R-9c 245.2'-245.5' < 75	434			50	35
R-9c 245.2'-245.5', 75-500	362	420	82	50	35
R-9c 245.2'-245.5', 75-500	478			50	35
R-9c 245.2'-245.5', 500-2000	1.1	4.2	4.4	50	35
R-9c 245.2'-245.5', 500-2000	7.3			50	35

Note: Blank cells indicate sample is a duplicate run.
*B = Sample preparation method is B, as defined in Table I-3.3-1.

Table I-3.3-4
Chromium Distribution Coefficients for Core Materials from Well LAOI-7

Solid Material (Well, Depth, PS µm)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concen. (ppb)	Liquid to Solid Ratio (mL/g)
Interval 83.3'–85.6': Cerros del Rio lava, rubble zone with clay and possible pedogenic (carbonate?) coatings					
LAOI-7 83.3'-85.6' <75 (B*)	1.2	1.5	0.5	50	35
LAOI-7 83.3'-85.6' <75 (B)	1.9			50	35
LAOI-7 83.3'-85.6' 75-500 (B)	1.4	1.6	0.3	50	35
LAOI-7 83.3'-85.6' 75-500 (B)	1.8			50	35
LAOI-7 83.3'-85.6'500-2000 (B)	0.8	0.1	0.9	50	35
LAOI-7 83.3'-85.6'500-2000 (B)	0			50	35
LAOI-7 83.3'-85.6' <75	501	510	13	50	35
LAOI-7 83.3'-85.6' <75	519			50	35
LAOI-7 83.3'-85.6' 75-500	385	598	301	50	35
LAOI-7 83.3'-85.6' 75-500	811			50	35
LAOI-7 83.3'-85.6'500-2000	23.4	154.2	184.9	50	35
LAOI-7 83.3'-85.6'500-2000	285			50	35
Interval 234.3'–236.2': Cerros del Rio lava, rubble zone with abundant clay, within perched zone					
LAOI-7 234.3'-236.2' <75 (B^b)	5.1	3.7	1.9	50	35
LAOI-7 234.3'-236.2' <75 (B)	2.4			50	35
LAOI-7 234.3'-236.2' 75-500 (B)	2.0	0.7	1.9	50	35
LAOI-7 234.3'-236.2' 75-500 (B)	0			50	35
LAOI-7234.3'-236.2' 500-2000 (B)	0	0	0.4	50	35
LAOI-7234.3'-236.2' 500-2000 (B)	0			50	35
LAOI-7 234.3'-236.2' <75	301	340	54	50	35
LAOI-7 234.3'-236.2' <75	378			50	35
LAOI-7 234.3'-236.2' 75-500	428	433	6	50	35
LAOI-7 234.3'-236.2' 75-500	437			50	35
LAOI-7 234.3'-236.2'500-2000	35.5	29.3	8.7	50	35
LAOI-7 234.3'-236.2'500-2000	23.2			50	35

Note: Blank cells indicate sample is a duplicate run.
*B = Sample preparation method is B, as defined in Table I-3.3-1.

Table I-3.3-5
Cr Distribution Coefficients for Sediment Materials from Well R-35a and b

Solid Material (Well, Depth, PS µm)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concen. (ppb)	Liquid to Solid Ratio (mL/g)
Interval 1060'–1065' (R-35a): Santa Fe Group, large bulk sample with borehole groundwater; sample represents tuffaceous sands and gravels typical of lower part of screen					
R-35A, 1060'-1065', <75	409	362	67	50	35
R-35A, 1060'-1065', <75	315			50	35
R-35A, 1060'-1065', 75-500	20.6	26.2	7.8	50	35
R-35A, 1060'-1065', 75-500	31.7			50	35
R-35A, 1060'-1065', 500-2000	0	0	0	50	35
R-35A, 1060'-1065', 500-2000	0			50	35
Interval 820'–825' (R-35b): Puye Formation, bulk sample with borehole groundwater representing well-sorted pea gravel, abundant dark clay fraction, from upper part of screen					
R-35B, 820'-825', < 75 (B*)	12.4	13.0	0.9	50	35
R-35B, 820'-825', < 75 (B)	13.7			50	35
R-35B, 820'-825', 75-500 (B)	5.8	8.2	3.3	50	35
R-35B, 820'-825', 75-500 (B)	10.5			50	35
R-35B, 820'-825', 500-2000 (B)	0.3	1.2	1.2	50	35
R-35B, 820'-825', 500-2000 (B)	2.0			50	35
R-35B, 820'-825', < 75	350	494	203	50	35
R-35B, 820'-825', < 75	637			50	35
R-35B, 820'-825', 75-500	370	430	85	50	35
R-35B, 820'-825', 75-500	490			50	35
R-35B, 820'-825', 500-2000	4.5	6.1	2.3	50	35
R-35B, 820'-825', 500-2000	7.7			50	35
Interval 840'–845' (R-35b): Puye Formation; large bulk sample with borehole groundwater; sample represents coarser, angular gravels typical of lower part of screen					
R-35B, 840'-845', < 75 (B)	0	0.75	1.06	50	35
R-35B, 840'-845', < 75 (B)	1.5			50	35
R-35B, 840'-845', 75-500 (B)	0	2.10	2.97	50	35
R-35B, 840'-845', 75-500 (B)	4.2			50	35
R-35B, 840'-845', 500-2000 (B)	0.1	0.4	0.5	50	35
R-35B, 840'-845', 500-2000 (B)	0.8			50	35
R-35B, 840'-845', < 75	637	892	359	50	35
R-35B, 840'-845', < 75	1146			50	35
R-35B, 840'-845', 75-500	858	964	151	50	35
R-35B, 840'-845', 75-500	1071			50	35
R-35B, 840'-845', 500-2000	7.0	6.6	0.6	50	35
R-35B, 840'-845', 500-2000	6.2			50	35

Note: Blank cells indicate sample is a duplicate run.

*B = Sample preparation method is B, as defined in Table I-3.3-1.

Table I-3.3-6
Chromium Distribution Coefficients for Fracture Coatings of Core Materials from Well SCI-2

Solid Material (Well, Depth)	K_d (mL/g)	Average K_d (mL/g)	STDEV	Cr(VI) Initial Concentration (ppm)	Liquid to Solid Ratio (mL/g)
SCI-2 540.4'-540.9'	5.4	—*	—	50	35
SCI-2 548.7'-549.3'	0	—	—	50	35
SCI-2 810.0'-810.5'	5.9	—	—	50	35
SCI-2 874.6'-874.8'	4.6	—	—	50	35

*— = Not available.

Table I-3.4-1
Cr(III)/Cr(VI) Content Relative to Total Chromium Calculated by XANES Fitting

Chromium in Rock Sample (Well, Depth, PS µm)	Lithology	Cr(III)/Cr(VI) (%) by XANES Fitting
CASA-369 (from Sandia wetland)	Wetland sediment	100% Cr(III)
R-35a (1060'-1065', PS <75 µm)	Santa Fe Group sediment	50% Cr(III), 50% Cr(VI)
R-35b (840'-845', PS< 75 µm)	Puye Formation sediment	~100 % Cr(III)
R-9c (183'-183.7', PS < 75 µm, uncrushed)	Cerros del Rio basalt rubble zone	~100 % Cr(III)
R-9c (245.2'- 245.5', PS < 75 µm)	Cerros del Rio dense flow	~100 % Cr(III)
LAOI-7 (83.3'-85.6', PS < 75 µm)	Clay-altered Cerros del Rio flow top	~ 100% Cr(III)
MCOI-10 (714'-715', PS < 75 µm)	Cerros del Rio dense flow	~ 100% Cr(III)

Table I-4.0-1
Comparative Batch K_d Results for
Guaje Pumice Bed Samples with and without Iron Metal Contamination from Drilling

Sample	K_d for <75 µm Uncrushed	K_d for <75 µm Crushed
MCOI-10 675.9-676.4' (~0.6% iron metal)	27.8	683
MCOI-10 680.5-682' (no iron metal)	9.5	487

Appendix J

Sandia Wetland Dewatering
Experiments and Mass Balance Calculations

J-1.0 INTRODUCTION

The environmental aqueous geochemistry of chromium (Cr) is of considerable interest to physical scientists and toxicologists in quantifying the fate and transport of this metal in surface and subsurface environments. Chromium is stable as nontoxic Cr(III) and toxic Cr(VI) in aqueous solutions. Insoluble Cr(III) is particularly stable under reducing conditions typically encountered within organic-rich sediments including wetlands, and soluble Cr(VI) is stable under relatively oxidizing conditions typical of oxic surface water and groundwater (Rai et al. 1986, 091686).

Potassium dichromate ($K_2Cr_2O_7$) was used extensively at Los Alamos National Laboratory (the Laboratory) in the Technical Area 03 (TA-03) cooling towers from 1956 to 1972 (LANL 2007, 098938). The total mass of Cr(VI) released from the TA-03 cooling towers ranges between 31,000 and 72,000 kg during the 16-yr release history (LANL 2007, 098127). Cooling tower water averaging between 7 to 18 mg/L Cr(VI) was released from TA-03 to a stream channel within Sandia Canyon. Since 1951, releases of water into Sandia Canyon created a wetland that has expanded over the years. This wetland is estimated to contain between 5700 kg and 27,000 kg Cr(III), representing 21% to 49% of the total Cr released from cooling tower discharges (LANL 2007, 098127). Quantifying the mechanisms for reduction of Cr within the Sandia wetland is important for understanding long-term fate and transport of this metal within the Sandia watershed. Chemical analyses of sediments show that over 99.7% of the Cr is stable as Cr(III) in the wetland (LANL 2007, 098127). Chromium(III) concentrations up to 3740 mg/kg occur within organic-rich portions of the wetland. Other trace elements including arsenic (As), boron (B), molybdenum (Mo), and zinc (Zn) associated with releases of TA-03 industrial effluent also occur within the wetland. Major ions concentrated in the TA-03 sewage effluent released to Sandia Canyon include calcium (Ca), sodium (Na), total carbonate alkalinity, sulfate (SO_4), and chloride (Cl). Naturally occurring metals including aluminum (Al), iron (Fe), manganese (Mn), and barium (Ba) are also found in the Sandia wetland.

Surface water has a short residence time within the wetland with most of the flow occurring within the active stream channel. A fraction of surface water entering the wetland has a longer residence time in different areas containing abundant cattails, grasses, and other flora. Most of the surface water released from the TA-03 industrial outfalls provides recharge to alluvial groundwater within Sandia Canyon. Alluvial groundwater, in turn, provides recharge to perched intermediate-depth groundwater and the regional aquifer. Past releases of Cr from the TA-03 outfalls have resulted in groundwater contamination within perched intermediate-depth groundwater (wells SCI-1 and SCI-2) and the regional aquifer (R-11, R-28, R-42, R-44, and R-45). Up to 900 μg/L of total dissolved Cr have been measured at well R-42 in Mortandad Canyon.

The Laboratory is considering limiting the volume of treated-industrial discharge water released from TA-03 to Sandia Canyon, and as a consequence, portions of the Sandia wetland may become dewatered and dry out. This outcome raises concerns about the potential reoxidation of Cr(III) to Cr(VI) within the wetland during dewatering, drying, and decay of solid organic matter (SOM) as well as the possibility of physical destabilization of wetland sediments. Either possibility may result in additional releases of Cr to the stream-sediment channel, both as Cr(III) adsorbed or precipitated on sediments and as dissolved Cr(VI). Experiments were conducted on several Sandia wetland samples to quantify the potential release of Cr during dewatering and drying of the wetland material. A critical topic to address regarding Cr(III) stability in the Sandia wetland during dewatering and drying focuses on the presence and reactivity of chemical reductants including Fe(II) and SOM to prevent or limit oxidation of Cr(III) to Cr(VI). Mass balance calculations were performed to quantify the reducing capacity of the Sandia wetland by measuring concentrations of one of the reductants, Fe(II), and an important oxidant, Mn(IV), to determine

if there are excess concentrations of Fe(II) to keep Cr(III) stable within the wetland. Evaluation and verification of the extent of Cr(VI) reduction within portions of the Sandia Canyon wetland is based on measured concentrations of Cr(III) (up to 3740 mg/kg) in the sediments and SOM and average pore-water concentrations of total dissolved Cr less than 15 μg/L at wells SCA-1 and SCA-1dp.

This appendix describes the drying and leaching experiments conducted by the Laboratory's Earth and Environmental Sciences (EES) 14 group from April 2008 through August 2009, using sediment samples collected from eight locations within the Sandia wetland. The experiments are designed to represent dewatering and drying of the Sandia wetland under both ambient and elevated temperature (40°C). Leaching experiments were conducted to evaluate and quantify the potential for insoluble Cr(III) reoxidizing to soluble Cr(VI) by reacting the wetland material with deionized water and TA-03-treated effluent after various periods of drying. Drying times included 1, 2, 4, and 12 mo before leaching experiments were conducted. Deionized water is representative of rainwater and high-quality treated effluent process water. Reoxidation of Cr(III) may potentially occur if SOM concentrated in the Sandia wetland dries out and decomposes as overall oxidizing conditions become established, particularly if oxidizing conditions lead to reoxidation of Mn(II) to Mn(IV) that has the potential to oxidize Cr(III) to Cr(VI).

Manganese(IV) serves as an electron acceptor for oxidation of Cr(III) species, serving as an electron donor. One overall oxidation-reduction reaction involving Cr(III, VI) and Mn(II, IV) is

$$3MnO_2 + 2Cr(OH)_3 + 2H^+ = 4H_2O + 3Mn^{2+} + CrO_4^{2-}.$$

This reaction is important in describing oxidation of Cr(III) by Mn(VI) that potentially takes place to varying extents within the Sandia wetland samples, accounting for measurable Cr(VI).

J-2.0 SAMPLING LOCATION AND EXPERIMENTAL DESIGN

Details of sample preparation and experimental procedures using the Sandia wetland samples are provided at the end of this section. Sediment samples were collected from eight locations within the Sandia wetland shown on Plate 3 and include the following areas

- along the bank of the channel upstream of the currently active wetland (sample number SA-600108),
- within the dewatered, western portion of the wetland (sample numbers SA-600110 and SA-600112),
- within the central portion of the active wetland (sample numbers SA-600905 and SA-600906),
- at the headcut located at the eastern end of the wetland (sample numbers SA-600113A and SA-600113B), and
- within the dry bank east of the wetland containing relic cattails (sample number SA-600115).

Drying and leaching experiments were conducted on Sandia wetland samples to address the rate and extent of potential oxidation of Cr(III) to Cr(VI). Oxidation of Cr(III) to Cr(VI) would increase the mobility of Cr within the Sandia watershed. Aliquots of homogenized Sandia wetland samples were either dried in a vacuum oven at 25°C in the absence of atmospheric oxygen, in a fume hood at room temperature, or in an oven at 40°C to increase the rates of both drying and oxidation of Cr(III) to Cr(VI) in the presence of atmospheric oxygen for 48 h. The samples placed in the vacuum oven as a control with no potential for oxidation required different amounts of time to reach complete dryness, depending on initial moisture content. Samples collected from the eight wetland sites had their concentrations of Cr(VI) measured

within 24 h to determine the extent of initial oxidation of Cr(III). Aliquots of Sandia wetland samples collected from the eight locations were allowed to dry in a fume hood at room temperature for extended periods of time, including 1, 2, 4, and 12 mo, to simulate natural conditions. After drying, the aliquots were leached for 48 h with either deionized water or TA-03-treated effluent collected from the Sanitary Wastewater System Consolidation (SWSC) plant. The water to solid ratio was 3:2, typically using 300 mL of deionized water or SWSC effluent to 200 g wetland sediment. From February 2001 to June 2009, the concentrations of total Cr ranged from 1.4 to 5.0 μg/L in the SWSC effluent.

J-3.0 ANALYTICAL TECHNIQUES

Chemical analyses of the wetland leachate samples were performed by EES-14. The leachates were filtered through 0.22-μm membranes and analyzed for total dissolved Cr, dissolved Cr(VI), and other selected solutes. Samples were acidified at the EES-14 wet-chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

The wetland leachate samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (IC) (EPA Method 300, rev. 2.1) was the analytical method for chromium(VI), chloride (Cl), phosphate (PO_4), and sulfate (SO_4). Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) (EPA Method 200.7, rev. 4.4) was used for analyses of filtered samples including calcium (Ca), total Cr, Fe, magnesium (Mg), Mn, potassium (K), sodium (Na), and zinc (Zn). Arsenic (As), Cr, Fe, Mn, and/or Zn in filtered samples were also analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS) (EPA Method 200.8, rev. 5.4). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Speciation of Mn(II, IV) in the leachate samples was not determined from analytical instrumentation. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. Wetland leachate samples were analyzed for dissolved organic carbon (DOC) following EPA Method 415.1. Charge balance errors for total cations and anions were generally less than ±10% for complete analyses of the above inorganic chemicals. Generally negative cation-anion charge balance values indicate excess anions for the filtered samples.

J-4.0 RESULTS

This section provides a summary of drying and leaching experiments using eight sediment and organic-rich samples collected from the Sandia wetland to evaluate the potential of reoxidation of Cr(III) to Cr(VI) as wetland material becomes dewatered and dries out. The samples represent a wide variety of geochemical, biological, hydrological, and mineralogical conditions encountered in this extremely diverse setting. Detailed discussions on the leachability of Cr, As, Zn, and other anthropogenic chemicals released to Sandia Canyon upstream of the wetland are also presented for each of the eight sampling locations.

Analytical results for the Sandia wetland leachates including total dissolved Cr and Cr(VI) and other selected analytes are provided in Table J-4.0-1. Plate 3 shows the locations of the eight wetland samples used in the drying and leaching experiments. Figures J-4.0-1 through J-4.0-8 show sample drying time before leaching with deionized water or SWSC effluent versus dissolved concentrations of total Cr, Cr(VI), As and DOC in leachates for the eight wetland samples. The first set of leachates generated from vacuum-dried samples were selected as initial concentrations at time equal to 0 mo for plotting of Cr, As, and DOC in Figures J-4.0-1 through J-4.0-8. These four analytes are considered to be the most important regarding Cr stability and evaluating the mobility of As concentrated within the wetland. Phosphate, Fe, and Mn geochemistry and their concentrations in the leachate samples are also discussed but not plotted

in Figures J-4.0-1 through J-4.0-8. Chemical indicators of Cr(III) oxidation during drying of wetland samples include increased dissolved concentrations of Cr(VI) in leachates and lower dissolved concentrations of Mn in the form of soluble Mn(II). Lower dissolved concentrations of Mn(II) may indicate Mn(II) has oxidized to Mn(IV) and is available to oxidize Cr(III). Most of the dissolved Cr in the wetland leachates generally occurs as Cr(III), based on much smaller dissolved concentrations of Cr(VI) occurring in the leachates compared to total dissolved Cr (Table J-4.0-1 and Figures J-4.0-1 through J-4.0-8). As the deionized water and SWSC effluent are oxidizing, it is likely that a fraction of Cr(III) oxidized to Cr(VI) in the leachate samples. Detectable concentrations of total dissolved Cr and Cr(VI) in both types of leachates range from 0.005 to 2.09 ppm (5 to 2090 ppb) and from 0.00006 to 0.01449 ppm (0.06 to 14.49 ppb or μg/L), respectively. Total Cr concentrations in the SWSC effluent range from 1.4 to 5 μg/L (0.0014 to 0.005 ppm) in samples collected from February 2001 to June 2009. Higher concentrations of total dissolved Cr and/or Cr(VI) were leached from the wetland samples dried in the oven (40°C) and fume hood (25°C) in the presence of atmospheric oxygen, depending on sampling location. These include samples collected from the channel bank upstream of the active wetland (sample SA-600108), within the western portion of the dewatered wetland (samples SA-600110 and SA-600112), within the headcut at the eastern end of the wetland (sample SA-600113B), and within the active portion of the wetland (samples SA-600905 and SA-600906). It appears that atmospheric oxygen can be an important component enhancing the leaching of Cr from the wetland samples. In fact, low but detectable concentrations of Cr(VI), less than 20 μg/L, have been measured in surface water east of the Sandia wetland showing that a small fraction of Cr becomes oxidized and mobile.

J-4.1 pH and Redox Conditions in Leachate Samples

The solubility of amorphous $Cr(OH)_3$ is controlled by both pH and redox conditions in natural and contaminated settings and measurement of both these parameters is required to quantitatively evaluate the stability of this reactive solid. The solubility minimum for amorphous $Cr(OH)_3$ occurs between pH values from 6 to 9 under relatively reducing conditions. Most of the wetland leachate samples are characterized by circumneutral pH values ranging from 6.19 to 8.04 (Table J-4.0-1). Leachates produced from sample SA-600115, however, are characterized by more acidic pH values ranging from 3.70 to 5.04, resulting from deprotonation of reactive functional groups present in the highly abundant SOM. Most of the Sandia wetland samples contain a sufficient buffering capacity mainly in the form of carbonate alkalinity to prevent production of acidic pH leachates. Adsorption of Cr(III, VI) adsorbates onto hydrous ferric oxides (HFO) and SOM are controlled by pH with maximum adsorption of Cr(VI) onto HFO occurring under acidic pH conditions. Chromium(III) adsorbs onto HFO under circumneutral pH conditions with increasing number of negatively charged adsorption sites present on HFO. This adsorption process is considered to be important in certain portions of the Sandia wetland characterized by acidic and oxidizing conditions.

Most of the wetland leachate samples are characterized by overall oxidizing conditions with oxidation-reduction potential (ORP) values greater than zero (Table J-4.0-1). Uncorrected ORP values measured in leachate samples range from -97.9 to +319 millivolts (mV) and corrected ORP or Eh values range from 101 to 526 mV. A value of 198.5 mV was added to each uncorrected ORP value with the ORP electrode used in the measurements containing a saturated solution of Ag/AgCl. The ORP measurements were made at 25°C. Amorphous $Cr(OH)_3$ is stable below Eh values ranging from +500 to +400 mV between pH values ranging from 7 to 8, respectively (Rai et al. 1986, 091686). Most of the measured Eh values in the leachate samples are consistent with the stability of Cr(III) aqueous species and amorphous $Cr(OH)_3$. Corrected Eh values generally become more positive as drying times prior the leaching increased in several samples, including SA-600110, SA-600112, and SA-600115. This suggests that longer drying times result in increasing overall oxidizing conditions, which, however, did not result in complete oxidation of Cr(III), in the form of amorphous $Cr(OH)_3$, to Cr(VI) in the leachate samples. The solubility of

amorphous $Cr(OH)_3$ increases as Eh increases and therefore, increasing concentrations of total dissolved Cr also increase. Complete dissolution of amorphous $Cr(OH)_3$ occurs between 500 and 400 mV between pH values 7 and 8, respectively. This situation did not occur in the leachate samples.

J-4.2 Sample SA-600108

Sample SA-600108 was collected from the channel bank upstream of the active Sandia wetland (Plate 3). This sample consists primarily of stream gravels and sand with very small amounts of SOM. The sample was collected from 20- to 108-cm depth within the exposed bank and is characterized by overall oxidizing conditions. Chromium(III) comprises approximately 15% to 83% of total dissolved Cr leached from sample SA-600108. The percentages of dissolved Cr(III) in the leachate samples were determined by dividing dissolved concentrations of Cr(VI) into concentrations of total dissolved Cr. Each of these fractions were then subtracted from unity and multiplied by 100 to obtain percent of Cr(III). Similar concentrations of Cr(VI) were leached from sample SA-600108 using either deionized water or SWSC effluent after 0, 1, 2, 4, and 12 mo of drying time before leaching (Table J-4.0-1, Figure J-4.0-1). This suggests that Cr(VI) in the leachate samples contains both Cr(VI) in the SWSC effluent and the fraction leached or desorbed from each wetland sample. Dissolved concentrations of Cr(VI) varied from 0.00325 to 0.01449 ppm and from 0.00294 to 0.01146 ppm in the deionized water and SWSC effluent leachates, respectively. Sample SA-600115 produced leachates with the highest concentrations of Cr(VI). Maximum Cr(VI) concentrations leached from sample SA-600108 occurred at the first month of drying with sustained release of lower concentrations of Cr(VI) after 1 mo. Concentrations of total dissolved Cr varied from 0.006 to 0.019 ppm and from 0.015 to 0.025 ppm in the deionized water and SWSC leachates, respectively. Appreciable amounts of Cr(VI) were released from this sample as a result of oxidation associated with the drying experiments.

Iron(II) is an important reductant for Cr(VI) in natural settings including the Sandia wetland. Manganese(IV), however, is an electrochemically reactive oxidant for Cr(III) species (Rai et al. 1986, 091686). Complete oxidation of Cr(III) to Cr(VI) is likely to take place if the molar concentrations of Mn(IV) exceed those of Fe(II), Cr(III), and organic carbon. This situation, however, is rare within the active Sandia wetland because concentrations of total Fe, consisting mainly of Fe(II), and SOM are present at much higher weight percent concentrations than Mn(VI), which is usually present in the ppm range (see section J-6.0 for more details). During drying, however, Fe(II) can oxidize to Fe(III) and Mn(II) can oxidize to Mn(IV), making Mn(IV) available to oxidize Cr(III) to Cr(VI). Concentration and speciation of Fe, Mn, and Cr in leachate solutions can reveal how the redox chemistry affected these samples before sample collection and while they were dried laboratory experiments.

Dissolved concentrations of Fe varied from 0.026 to 0.161 ppm and from 0.020 to 0.049 ppm in deionized water and SWSC effluent leachates produced from sample SA-6000108, respectively. Total Fe and Mn concentrations measured in one sample of SWSC effluent were 141 and 17.8 μg/L (0.141 and 0.0178 ppm), respectively, collected on May 26, 2004. Higher concentrations of dissolved Fe suggest that this analyte became more soluble during the leaching process, suggesting that Fe(II) is present. Dissolved concentrations of Mn varied from 0.003 to 0.012 ppm and from 0.002 to 0.075 ppm in deionized water and SWSC effluent leachates, respectively. It is possible that Mn in this wetland sample becomes more soluble as a result of complexation with SO_4, PO_4, and total carbonate alkalinity in the SWSC effluent. These Mn concentrations are among the lowest measured (Table J-4.0-1), suggesting that oxidation of Mn(II) to Mn(IV) may have occurred, which in turn would tend to oxidize Cr(III) to Cr(VI). Dissolved concentrations of As varied from 0.0039 to 0.0058 ppm in the deionized water leachates, whereas higher dissolved concentrations of As, increasing from 0.0062 to 0.0095 ppm, were leached from sample SA-600108 using SWSC effluent (Table J-4.0-1 and Figure J-4.0-1). Reliable total As concentrations

range from 1.4 to 3.47 μg/L (0.0014 to 0.00347 ppm) in the SWSC effluent from February 2001 to June 2009.

Phosphate and SO_4 are concentrated within the SWSC effluent released to Sandia Canyon. Elevated above background concentrations of these two solutes are observed in the alluvium and the underlying vadose zone east of the Sandia wetland. Phosphate adsorbs the stronger than SO_4 onto HFO and clay minerals and its mobility is limited in the vadose zone compared to that of SO_4. These solutes, especially PO_4, have the potential to compete for Cr(VI)- and As(V)-adsorption sites present on reactive mineral surfaces (HFO and clay minerals). These competing anions enhance desorption of As(III, V) and Cr(VI) from adsorbents under circumneutral pH conditions characteristic of oxidized sections within the Sandia wetland. Increased desorption of As from the SA-600108 sample in the presence of SO_4 and PO_4, acting as competing anionic adsorbates, may account for this observation. Total As concentrations range from 23.6 to 1360 μg/L (0.0236 to 1.360 ppm) in the SWSC effluent from February 2001 to June 2009.

The mobility of Zn in organic-rich environments, including the Sandia wetland, is influenced by its ability to form strong complexes with DOC (Langmuir 1997, 056037) and total carbonate alkalinity that decrease its ability to adsorb onto HFO and clay minerals. This observation is based on elevated concentrations of dissolved Zn that occur within the Sandia wetland groundwater and within the underlying vadose zone down stream of the wetland. Dissolved concentrations of Zn in the deionized water and SWSC effluent leachates varied from 0.005 to 0.115 ppm and from 0.027 to 0.133 ppm, respectively, for sample SA-600108. Zinc sulfate compounds were added to the TA-03 cooling tower influent as an additional anticorrosion agent (LANL 2007, 098127).

Dissolved concentrations of PO_4 generally decreased from 3.74 to 2.01 ppm in deionized water leachates produced from sample SA-600108 with increasing sample drying times before leaching (Table J-4.0-1). Higher concentrations of this anion were observed in the SWSC effluent leachates (7.22 to 8.86 ppm). A fraction of the PO_4 previously released from the TA-03 cooling tower and SWSC effluent outfalls that had previously adsorbed onto the wetland sediment was desorbed. Total PO_4 concentration was 4.94 mg/L or ppm in a sample of the SWSC effluent collected on May 26, 2004. Dissolved concentrations of SO_4 in deionized water leachates increased from 7.11 to 31.1 ppm, whereas higher concentrations of this anion, 22.2 to 43.7 ppm, were found in the SWSC effluent leachates. A similar desorption process involving SO_4 took place during the 48-h oven-drying leach tests conducted on this and other wetland samples, resulting in increased concentrations of SO_4 in leachate samples. Total SO_4 concentrations ranged from 15.1 to 43.5 mg/L or ppm in the SWSC effluent from February 2001 to June 2009. Concentrations of DOC within the Sandia wetland exceed those occurring in background alluvial groundwater at the Laboratory and in downgradient alluvial wells including SCA-2, SCA-3, and SCA-4. Similar concentrations of DOC were leached from sample SA-600108 using either deionized water or SWSC effluent, with concentrations generally increasing from 8.89 to 28.2 ppm as drying times before leaching increased (Figure J-4.0-1). The main sources of DOC measured in leachates include the SWSC effluent and remnant SOM associated with Sandia wetland material that has undergone partial or incomplete oxidation resulting from dewatering and drying at this sampling location. The concentration of TOC was 4.44 mg/L or ppm in a sample of the SWSC effluent collected on May 26, 2004.

J-4.3 Sample SA-600110

Sample SA-600110 was collected from the dewatered western portion of the Sandia wetland (Plate 3). The sample contains aggregates of clay-sized material and SOM consisting of plant roots, including grasses. The sample was collected from 26- to 42-cm depth immediately north of the active stream channel. Chromium(III) comprises approximately 88% to 100% of total dissolved Cr leached from sample SA-600110. Significantly lower concentrations of Cr(VI) were leached from sample SA-600110 in

comparison to total dissolved Cr (Figure J-4.0-2). Variable concentrations of Cr(VI) were leached from sample SA-600110 using either deionized water or SWSC effluent with the maximum Cr(VI) concentrations occurring at 1 mo drying time before leaching (Table J-4.0-1, Figure J-4.0-2). Dissolved concentrations of detectable Cr(VI) varied from 0.00017 to 0.00032 ppm and from 0.00015 to 0.00171 ppm in deionized water and SWSC effluent leachates, respectively. Concentrations of total dissolved Cr varied from 0.009 to 0.026 ppm and from 0.014 to 0.031 ppm in the deionized water and SWSC leachates, respectively. During drying, Cr(III) in this sample appears to remain stable, suggesting that insufficient Mn(IV) is produced to oxidize appreciable amounts of Cr(VI).

Dissolved concentrations of total Fe in the deionized water leachates decreased from 0.210 to 0.051 ppm and increased from 0.010 to 0.044 ppm in the SWSC leachates produced from sample SA-600110 (Table J-4.0-1). The low concentrations of total dissolved Fe measured in several of the leachate samples suggest that Fe(II) has oxidized to Fe(III), likely in the form of $Fe(OH)_3$. Dissolved concentrations of Mn varied from 0.149 to 0.684 ppm and from 0.439 to 1.40 ppm in the deionized water and SWSC effluent leachates, respectively. It is very likely that soluble Mn(II) species are stable in both types of leachates produced from sample SA-600110, based on the relatively high dissolved concentrations of this redox-sensitive metal. Lack of oxidation of Mn(II) to Mn(IV) accounts for the low amounts of Cr(VI) leached from this sample. Dissolved concentrations of As varied from 0.0060 to 0.0079 ppm in the deionized water leachates with a larger range of dissolved As concentrations (from 0.0054 to 0.0094 ppm) leached from sample SA-600110 using SWSC effluent (Table J-4.0-1). Dissolved concentrations of Zn varied from 0.041 to 0.185 ppm and from 0.086 to 0.212 ppm in deionized water and SWSC effluent leachates, respectively, for sample SA-600110. Elevated concentrations of Zn in the two types of leachate produced from sample SA-600110 are possibly explained by complexing of Zn with DOC, mainly in the form of dissociated organic acids or anions. Elevated, above-background concentrations of As and Zn have been measured in sediment samples collected from the Sandia wetland (LANL 2007, 098127). Elevated above-background concentrations of Zn also occur within the alluvium and underlying unsaturated zone (SCC-designated core holes) east of the Sandia wetland (LANL 2007, 098983).

Phosphate and SO_4 are poorly bound to the SOM present in sample SA-600110, based on the relative high concentrations of these two anions measured in leachate samples. These two anions are not attracted to the negatively charged surfaces present on abundant SOM present in sample SA-600110. Dissolved concentrations of PO_4 varied from 2.74 to 4.32 ppm in deionized water leachates, and concentrations of this anion ranged from 3.44 to 5.78 ppm in the SWSC effluent leachates produced from sample SA-600110. Dissolved concentrations of SO_4 in the deionized water and SWSC leachates increased from 6.29 to 35.1 ppm and from 20.7 to 46.4 ppm, respectively. As drying time before leaching of sample SA-600110 increased, concentrations of DOC rose from 11.1 to 43.3 ppm in deionized water leachates. Similar concentrations of DOC, ranging from 11.4 to 47.6 ppm, were leached from sample SA-600110 using SWSC effluent. Drying of organic-rich samples collected from the Sandia wetland increases the solubility of humic and fulvic acids comprising an unknown fraction of SOM in the wetland. Physical abrasion of suspended organic matter during the 48-h leaching experiments may contribute to increasing concentrations of DOC. It is also possible that colloidal SOM is present in the leachate samples, even though they were filtered through 0.22-µm membranes before analyses. Maximum concentrations of DOC were leached from sample SA-600110 at 2 mo drying time using deionized water and at 4 mo drying time using SWSC effluent (Figure J-4-0-2). The main sources of DOC include abundant SOM within the Sandia wetland, as the primary source, that has been partly dewatered at this location, and the SWSC effluent as a secondary source.

J-4.4 Sample SA-600112

Sample SA-600112 was collected from the dewatered western portion of the Sandia wetland (Plate 3). The sample contains abundant SOM consisting of plant roots, including grasses. The sample was collected from 0- to 41-cm depth immediately north of the active stream channel. Chromium(III) comprises approximately 95% to 100% of total dissolved Cr leached from sample SA-600112. Significantly lower concentrations of Cr(VI) were leached from sample SA-600112 in comparison to total dissolved Cr (Figure J-4.0-3). Variable concentrations of Cr(VI), however, were leached from sample SA-600112 using either deionized water or SWSC effluent with maximum leaching occurring at 1 to 2 mo drying time before leaching (Table J-4.0-1, Figure J-4.0-3). Low dissolved concentrations of detectable Cr(VI) varied from 0.00017 to 0.00069 ppm and from 0.00006 to 0.001 ppm in deionized water and SWSC effluent leachates, respectively. Higher concentrations of total dissolved Cr varied from 0.005 to 0.022 ppm and from 0.011 to 0.028 ppm in deionized water and SWSC leachates, respectively. The large abundance of SOM in sample SA-600112 is sufficient to reduce most Cr(VI) to Cr(III) and helps to maintain the stability of amorphous $Cr(OH)_3$. During drying, Cr(III) in this sample appears to remain stable, suggesting that insufficient Mn(IV) is produced to oxidize appreciable amounts of Cr(VI).

Leachates produced from sample SA-600112 are oxidizing with respect to Fe, based on the relatively low concentrations of this metal measured in the solutions (Table J-4.0-1). Ferric iron possibly present as amorphous $Fe(OH)_3$ has the potential to adsorb Cr(III) species as well as coprecipitating with Cr(III). Dissolved concentrations of Fe in sample SA-600112 varied from 0.032 to 0.075 ppm in SWSC leachates. Dissolved concentrations of Mn in the deionized water and SWSC effluent leachates varied from 0.003 to 0.635 ppm and from 0.016 to 1.447 ppm, respectively (Table J-4.0-1). This variability in Mn concentrations suggests that soluble Mn(II) species occur in both types of leachates produced from sample SA-600112, based on the relatively high dissolved concentrations of this redox-sensitive metal. Stability of Cr(III) species is enhanced in the presence of Mn(II) species. Dissolved concentrations of As varied from 0.0072 to 0.0098 ppm in deionized water leachates with slightly higher concentrations of dissolved As, ranging from 0.0082 to 0.0128 ppm, leached from sample SA-600112 using SWSC effluent (Table J-4.0-1). Dissolved concentrations of Zn varied from 0.021 to 0.172 ppm and from 0.047 to 0.188 ppm in the deionized water and SWSC effluent leachates, respectively.

Phosphate and SO_4 are poorly bound to the SOM present in sample SA-600112, based on relative high concentrations of these two anions measured in leachate samples. Relative high concentrations of PO_4 were leached from sample SA-600112. Dissolved concentrations of PO_4 varied from 9.32 to 12.7 ppm in deionized water leachates produced from sample SA-600112. Slightly higher concentrations of this anion, 11.1 to 15.5 ppm, were found in the SWSC effluent leachates. Dissolved concentrations of SO_4 increased from 8.67 to 32.3 ppm and from 24.1 to 44.1 ppm in the deionized water and SWSC leachates, respectively. Concentrations of DOC ranged from 12.1 to 49.3 ppm in the deionized water leachates produced from sample SA-600112. Slightly higher concentrations of DOC, ranging from 12.4 to 63.0 ppm, were leached from this sample using SWSC effluent. Maximum concentrations of DOC were leached from sample SA-600112 at the 2 and 4 mo of drying times before leaching with deionized water and SWSC effluent, respectively (Figure J-4.0-3).

J-4.6 Sample SA-600905

Sample SA-600905 was collected within the active portion of the Sandia wetland (Plate 3). This water-saturated sample contains a high abundance of SOM consisting of cattails and other plant roots (50% of the sample). The sample was collected from the 0- to 15-cm depth within a well-developed section of thickly populated cattails. Chromium(III) comprises approximately 99% to 100% of total dissolved Cr leached from sample SA-600905. Concentrations of total dissolved Cr generally increased from 0.009 to

0.030 ppm and from 0.011 to 0.034 ppm in the deionized water and SWSC leachates, respectively, with increasing drying times before leaching (Figure J-4.0-4). Leachable total dissolved Cr, stable mainly as Cr(III), may occur as colloidal material consisting of amorphous $Cr(OH)_3$ and/or as Cr(III) complexed with soluble DOC. Concentrations of Cr(VI) leached from sample SA-600905 were generally less than analytical detection (0.05 μg/L or 0.00005 ppm) using ICPMS (Figure J-4.0-4). Low concentrations of Cr(VI), however, were measured at 0.00017 ppm in one of the deionized water leachates and at 0.00007 ppm in a SWSC effluent leachate. These detectable concentrations of Cr(VI) were observed at the 1 mo of drying time before leaching of sample SA-600905 (Table J-4.0-1, Figure J-4.0-4). The high abundance of SOM in sample SA-600905 allows for nearly complete reduction of Cr(VI) to Cr(III).

Aqueous leachates produced from samples SA-600905 and SA-600906 have similar concentrations of dissolved Fe, Mn, As, and Zn suggesting that geochemical reactions, including adsorption/desorption and mineral precipitation/dissolution, occur on the same scale in these two samples during the leaching experiments. Dissolved concentrations of Fe generally increased from 0.167 to 2.84 ppm and from 0.107 to 4.38 ppm in deionized water and SWSC leachates, respectively (Table J-4.0-1). Reductive dissolution of HFO in this sample, in the absence of Fe(III) colloids smaller than 0.22 μm, is hypothesized to account for some of the leachate samples having elevated concentrations of total dissolved Fe mainly as Fe(II). This hypothesis suggests that adsorption of Cr(III, VI) onto HFO is not likely and that precipitation of amorphous $Cr(OH)_3$ is favored under relatively reducing conditions.

Elevated concentrations of dissolved Mn suggest that wetland pore water, represented by leachates produced from sample SA-600905, is relatively reducing with Mn(II) species predominant. Chromium(III) species are stable in the presence of Mn(II) and in the absence of Mn(IV). Dissolved concentrations of Mn varied from 2.50 to 4.72 ppm and from 2.90 to 8.49 ppm in the deionized water and SWSC effluent leachates, respectively. The stability of Cr(III) species is significantly enhanced within the active wetland where samples SA-600905 and SA-600906 are located. Dissolved concentrations of As generally increased from 0.0074 to 0.0188 ppm in deionized water leachates with higher concentrations of dissolved As, ranging from 0.0069 to 0.0165 ppm, leached from sample SA-600905 using SWSC effluent (Table J-4.0-1). These high concentrations of dissolved As suggest that soluble As(III) is the stable form of this trace element in this and other water-saturated samples. Reductive dissolution of HFO enhances desorption of As, resulting in relatively high concentrations of this trace element within wetland pore water and leachates. This is an important geochemical aspect to consider and quantify if the Sandia wetland becomes completely dewatered, thereby increasing the mobility of As in the watershed downcanyon from the Sandia wetland. Dissolved concentrations of Zn varied from 0.064 to 0.290 ppm and from 0.119 to 0.723 ppm in the deionized water and SWSC effluent leachates, respectively. Elevated dissolved concentrations of Zn in the two types of leachate produced from this and other samples can be explained by complexing of Zn with DOC, mainly in the form of dissociated organic acids or anions.

Uptake of PO_4 within the root zones of the thriving cattails could account for the low dissolved concentrations of this anion leached from samples SA-600905 and SA-600906. Dissolved concentrations of PO_4 varied from 0.05 to 0.71 ppm in the deionized water leachates produced from sample SA-600905. Concentrations of this anion varied from 0.11 to 0.26 ppm in SWSC effluent leachates. Dissolved concentrations of SO_4 varied from 411 to 799 ppm and from 371 to 1165 ppm in deionized water and SWSC leachates, respectively. The two main sources of this anion include the SWSC effluent and TA-03 cooling towers. Sulfuric acid was used to adjust the pH of influent cooling tower water below 7, enhancing adsorption of chromate and molybdate onto metal surfaces in contact with cooling water, thereby inhibiting corrosion within the cooling towers. High concentrations of SO_4 in these and other leachate samples preclude reduction of this anion to sulfide, suggesting that the leachates are oxidizing with respect to sulfate. Chromium(III) species, however, are stable in the presence of dissolved sulfate.

Sulfate adsorbs poorly onto clay minerals under circumneutral pH conditions dominantly characteristic of the Sandia wetland.

As drying times before leaching increased, concentrations of DOC generally increased from 31.2 to 153 ppm in the deionized water leachates produced from sample SA-600905. Similar concentrations of DOC, ranging from 23.2 to 155 ppm, were leached from this sample using SWSC effluent. Maximum concentrations of DOC were leached from sample SA-600905 at 4 mo drying time before leaching using deionized water or SWSC effluent (Figure J-4.0-4). The main source of DOC leached from samples includes abundant SOM within the active Sandia wetland. It is likely that soluble forms of DOC consist of small-molecular weight deprotonated acids including aliphatic and aromatic carboxylates stable as anions. The anion contribution to major-ion charge balances for samples SA-600905 and SA-600906 are influenced by the elevated concentrations of DOC. In addition to this aspect of the reactivity of soluble DOC, complexation of Fe(II), Mn(II), Zn, Ca, and Mg with soluble organic anions is hypothesized to be an important geochemical process that could facilitate transport of metals by inhibiting adsorption and precipitation within sections of the active Sandia wetland.

Solid organic matter present in organic-rich portions of the Sandia wetland is considered to be the dominant reductant for immobilizing Cr. One reaction describing the reduction of Cr(VI) to Cr(III) in the presence of SOM, containing hydroquinone ($C_6H_6O_2$) that provides the reduction capacity (McBride 1994, 058947) is

$$1.5C_6H_6O_2 + CrO_4^{2-} + 2H^+ \rightarrow 1.5C_6H_4O_2 + H_2O + Cr(OH)_3.$$

According to this reaction, 1.5 moles of $C_6H_6O_2$ are required to reduce 1.0 mole of CrO_4^{2-}. This is easily accomplished with abundant solid organic matter present within the Sandia Canyon wetland. In the above reaction, 1.5 moles of $C_6H_6O_2$ oxidize to form 1.5 moles of quinone ($C_6H_4O_2$) with the release of two electrons. Characterization of SOM quantifying the amounts of various functional groups including hydroquinone, quinone, and carboxylic acids would help to reduce uncertainty related to the reductive and adsorptive capacities of the Sandia wetland.

The high abundance of SOM in sample SA-600905 and other wetland samples, in particular sample SA-600115, is sufficient in reducing, if not all, but of most of the Cr(VI) to Cr(III) species. These reducing conditions with respect to Cr help to maintain the stability of amorphous $Cr(OH)_3$. Two hypotheses are proposed for the geochemical attenuation of Cr in the SOM-rich samples;

1. Cr(III) in the forms of $CrOH_2^+$ and $Cr(OH)_2^+$ either adsorb onto negatively-charged surfaces present on HFO, or on negatively-charged sites present in SOM, mainly consisting of deprotonated carboxylates ($R\text{-}COO^-$) above pH 4.5 (Langmuir 1997, 056037), and
2. Cr(III) has precipitated from solution as $Fe_xCr_{1-x}(OH)_3$ and/or amorphous $Cr(OH)_3$. It is also likely that adsorption of Cr(III) onto SOM occurs before precipitation of $Fe_xCr_{1-x}(OH)_3$ and amorphous $Cr(OH)_3$.

J-4.7 Sample SA-600906

Sample SA-600906 also was collected within the active portion of the Sandia wetland (Plate 3). The sample contains a large abundance of SOM consisting of cattails and other plant roots. The sample was collected from 0- to 15-cm depth within a well-developed section of thickly populated cattails. Chromium(III) comprises approximately 96% to 100% of total dissolved Cr leached from sample SA-600906. Concentrations of total dissolved Cr generally increased from 0.009 to 0.030 ppm and from 0.011 to 0.034 ppm in deionized water and SWSC leachates, respectively (Figure J-4.0-5). Very small

concentrations of dissolved Cr(VI) leached from sample SA-600906 ranged from 0.00007 to 0.00042 ppm in deionized water leachates and from 0.00008 to 0.0004 in the SWSC leachates (Figure J-4.0-5). These detectable concentrations of Cr(VI) were observed at 1 mo drying time before leaching of sample SA-600906 (Table J-4.0-1, Figure J-4.0-5). The high abundance of SOM in sample SA-600906 enhances nearly complete reduction of Cr(VI) to Cr(III) species.

Elevated dissolved concentrations of Fe leached from sample SA-600906 suggest that a significant fraction of this metal is stable in its reduced form [Fe(II)] in this sample. This is consistent with high percentages of Cr(III) present in this sample. Dissolved concentrations of Fe generally varied from 0.020 to 3.48 ppm and from 0.049 to 3.04 ppm in the deionized water and SWSC leachates, respectively (Table J-4.0-1). Reductive dissolution of HFO accounts for the elevated concentrations of total dissolved Fe measured in both types of leachates produced from sample SA-600906. This suggests that adsorption of Cr(III, VI) onto HFO is not likely and that precipitation of amorphous $Cr(OH)_3$ is favored under relatively reducing conditions characteristic of this sample. Dissolved concentrations of Mn, in the form of soluble Mn(II), varied from 2.16 to 4.73 ppm and from 2.97 to 5.12 ppm in the deionized water and SWSC effluent leachates, respectively. Elevated concentrations of Mn(II) in this sample enhance the stability of Cr(III) species. As drying times before leaching increased, dissolved concentrations of As generally increased from 0.007 to 0.0188 ppm in the deionized water leachates. Similar concentrations of dissolved As, ranging from 0.0099 to 0.0177 ppm, were leached from sample SA-600906 using SWSC effluent (Table J-4.0-1) (Figure J-4.0-5). Dissolved concentrations of Zn varied from 0.110 to 0.191 ppm and from 0.110 to 0.256 ppm in deionized water and SWSC effluent leachates, respectively.

Variable concentrations of dissolved PO_4 were measured in the two types of leachates produced from sample SA-600906. Dissolved concentrations of PO_4 varied from 0.03 to 2.38 ppm in the deionized water leachates. Smaller concentrations of this anion varied from 0.10 to 0.15 ppm in the SWSC effluent leachates, suggesting that deionized water is more reactive than SWSC effluent in this sample. Similar concentrations of SO_4 were leached from sample SA-600906 using deionized water or SWSC effluent. Dissolved concentrations of SO_4 varied from 249 to 682 ppm in deionized leachates and from 237 to 747 ppm in the SWSC leachates produced from this sample. These leachate samples are oxidizing with respect to dissolved SO_4, which does not limit or prevent reduction of Cr(VI) to Cr(III) species in sample SA-600906. Concentrations of DOC generally increased from 27 to 91 ppm in the deionized water leachates, as the period of drying time before leaching increased for sample SA-600906. Similar concentrations of DOC, ranging from 37 to 90 ppm, were leached from sample SA-600906 with SWSC effluent. Maximum concentrations of DOC were leached from sample SA-600906 at 4 mo drying time before leaching using deionized water and SWSC effluent (Figure J-4.0-5). Elevated concentrations of DOC in the leachate samples are consistent with Cr dominantly stable as Cr(III) in sample SA-600906.

J-4.8 Samples SA-600113A and SA-600113B

Samples SA-600113A and SA-600113B were collected at a headcut at the eastern end of the Sandia wetland (Plate 3). These two water-saturated samples contain high abundances of SOM; decayed plant components make up a majority of the sample materials. Samples SA-600113A and SA-600113B were collected from 9- to 71-cm depth and from 71- to 101-cm depth, respectively. Sample SA-600113A contains higher dissolved concentrations of total Cr, Cr(VI), Fe, Mn, Zn, SO_4, PO_4, and DOC in the two types of leachates compared to sample SA-600113B. Higher concentrations of dissolved As, however, were leached from sample SA-600113B. One hypothesis explaining differences in the leachate chemistries between these two samples is that sample SA-600113A is more contaminated from TA-03 effluent containing higher concentrations of Cl, Ca, Mg, Na, and other solutes; is more reducing by having higher amounts of SOM with soluble DOC; and contains less colloid material possibly consisting amorphous $Cr(OH)_3$, $Fe_xCr_{1-x}(OH)_3$, and $Fe(OH)_3$.

Dissolved Cr(III) comprises approximately 97% to 100% of total dissolved Cr leached from sample SA-600113A. Concentrations of total dissolved Cr leached from sample SA-600113A varied from 0.049 to 0.130 ppm and from 0.058 to 0.133 ppm in deionized water and SWSC leachates, respectively. Detectable concentrations of Cr(VI) leached from sample SA-600113A ranged from 0.00033 to 0.001 ppm and from 0.00006 to 0.003 ppm using deionized water and SWSC effluent, respectively. Detectable Cr(VI) was observed at the 1, 2, and 4 mo drying time before leaching of sample SA-600113A (Table J-4.0-1, Figure J-4.0-6). These high concentrations of total dissolved Cr, mainly in the form of Cr(III), suggest that colloidal amorphous $Cr(OH)_3$ is likely to be present in the leachate samples. High abundances of SOM in samples SA-600113A and SA-600113B enhance the nearly complete reduction of Cr(VI) to Cr(III) species. This reduction maintains the stability of amorphous $Cr(OH)_3$.

Dissolved chromium(III) leached from sample SA-600113B comprises approximately 99% to 100% of total dissolved Cr. Detectable Cr(VI), however, was observed at 1, 2, and 4 mo drying time before leaching of sample SA-600113B (Table J-4.0-1, Figure J-4.0-7). Concentrations of total dissolved Cr leached from sample SA-600113B varied from 0.010 to 0.022 ppm and from 0.015 to 0.023 ppm in deionized water and SWSC leachates, respectively. Low detectable dissolved concentrations of Cr(VI) leached from sample SA-600113B ranged from 0.00006 to 0.00018 ppm and from 0.00009 to 0.00022 ppm using deionized water and SWSC effluent, respectively.

Variable concentrations of total dissolved Fe, Mn, and Zn were leached from samples SA-600113A and SA-600113B. The leachates produced from these two samples are reducing with respect to Fe and Mn, in which dissolved Fe(II) and Mn(II) species dominate. This is consistent with the very high percentages of dissolved Cr(III) in the leachate samples. The stability of Cr(III) species is significantly enhanced with the measured dissolved concentrations of both Fe and Mn. Dissolved concentrations of Fe in deionized water and SWSC leachates varied from 0.299 to 3.54 ppm and from 0.428 to 3.40 ppm, respectively, for sample SA-600113A (Table J-4.0-1). Reductive dissolution of HFO in this sample is hypothesized to account for the observed concentrations of total dissolved Fe measured in both types of leachates produced from samples SA-600113A and SA-600113B. This suggests that adsorption of Cr(III, VI) onto HFO is not likely and that precipitation of amorphous $Cr(OH)_3$ is favored under relatively reducing conditions. Dissolved concentrations of Mn leached from sample SA-600113A varied from 5.72 to 22.9 ppm and from 7.57 to 43.4 ppm in deionized water and SWSC effluent leachates, respectively, for sample SA-600113A. Reoxidation of Cr(III) to Cr(VI) in samples SA-600113A and SA-600113B is very unlikely, based on measured dissolved concentrations of Mn stable as Mn(II). Dissolved concentrations of As leached from sample SA-600113A varied from 0.0098 to 0.0292 ppm in the deionized water leachates, with higher concentrations of As, ranging from 0.0137 to 0.0306 ppm, leached with SWSC effluent (Table J-4.0-1, Figure J-4.0-6). Reductive dissolution of HFO accounts for the relatively high concentrations of dissolved As measured in the leachate samples. Dissolved concentrations of Zn varied from 0.71 to 10.2 ppm and from 0.86 to 33.8 ppm in the deionized water and SWSC effluent leachates, respectively, for sample SA-600113A. Elevated concentrations of Zn in the two types of leachate reacting with sample SA-600113A are explained by complexing of Zn with DOC, mainly in the form of dissociated organic acids stable as anions, and SO_4.

Dissolved concentrations of Fe leached from sample SA-600113B varied from 0.056 to 0.158 ppm and from 0.078 to 0.202 ppm in deionized water and SWSC leachates, respectively (Table J-4.0-1). Dissolved concentrations of Mn varied from 1.34 to 6.66 ppm and from 3.19 to 7.30 ppm in the deionized water and SWSC effluent leachates, respectively, produced from sample SA-600113B. Manganese(II) present in leachates produced from sample SA-600113B dominates over Fe(II) as the main reductant for Cr, based on higher dissolved concentrations of Mn compared to Fe. Similar dissolved concentrations of As were leached from sample SA-600113B using deionized water, ranging from 0.0149 to 0.0425 ppm, or SWSC effluent, ranging from 0.0134 to 0.0407 ppm, (Table J-4.0-1, Figure J-4.0-7). Leachates produced from

sample SA-600113B, however, contained the highest dissolved concentration of As. Reductive dissolution of HFO accounts for the relatively high concentrations of dissolved As measured in these leachate samples. These high concentrations of dissolved As suggest that soluble As(III) is the stable form of this trace element in this and other water-saturated samples. Arsenite species are more mobile in soil-pore water and groundwater under relatively reducing and circumneutral pH conditions compared to arsenate species, due to the stability of $H_3AsO_3^0$. This neutrally charged species does not significantly adsorb onto HFO, SOM, and clay minerals. Dissolved concentrations of Zn ranging from 0.04 to 0.30 ppm were leached from sample SA-600113B using deionized water. The SWSC effluents produced from sample SA-600113B contain similar dissolved concentrations of Zn ranging from 0.06 to 0.30 ppm (Table J-4.0-1).

Relatively low dissolved concentrations of PO_4 were leached from samples SA-600113A and SA-600113B using deionized water or SWSC effluent. Uptake of PO_4 within the root zones could account for the low dissolved concentrations of this anion leached from samples SA-600113A and SA-600113B. Dissolved concentrations of PO_4 varied from 0.01 to 0.71 ppm and from 0.01 to 0.31 ppm, respectively, in deionized water and SWSC effluent leachates produced from sample SA-600113A. Dissolved concentrations of SO_4 varied from 434 to 1403 ppm and from 474 to 2090 ppm in deionized water and SWSC leachates, respectively. Concentrations of DOC generally increased from 41.1 to 189 ppm in the deionized water leachates produced from sample SA-600113A. Higher concentrations of DOC, ranging from 34.6 to 201 ppm, were leached from the sample reacted with SWSC effluent. Maximum concentrations of DOC were leached from sample SA-600113A at 2 and 4 mo drying time before leaching using SWSC effluent and deionized water, respectively (Figure J-4.0-6).

During leaching of sample SA-600113B with deionized water, dissolved concentrations of PO_4 varied from 0.01 to 0.16 ppm. Dissolved concentrations of this anion varied from 0.01 to 0.44 ppm in SWSC effluent leachates produced from this sample. Dissolved concentrations of SO_4 varied from 203 to 634 ppm and from 204 to 645 ppm in deionized water and SWSC leachates, respectively. Maximum concentrations of DOC were leached from sample SA-600113B at two and 4 mo drying time before leaching with SWSC effluent and deionized water, respectively (Figure J-4.0-7). Similar concentrations of DOC were leached from this sample using deionized water, ranging from 20.2 to 87.8 ppm, or SWSC effluent, ranging from 22 to 83.5 ppm.

J-4.9 Sample SA-600115

Sample SA-600115 was collected from a dry bank east of the Sandia wetland; this is the eastern-most of all of the eight sediment samples collected (Plate 3). The sample contains a very high abundance of SOM consisting of decayed or partly humified cattails and other forms of SOM. The sample was collected from 0- to 30-cm depth, and relatively oxidizing conditions dominate at this sampling location, based on the absence of Cr(VI) species (LANL 2007, 098127). Deprotonation of aromatic and aliphatic carboxylic compounds in the humic and fulvic acids of SOM during leaching produced acidic pH conditions with pH values ranging from 3.70 to 5.04 (Table J-4.0-1). These are the most acidic pH values of all leachates generated in this investigation and similar conditions probably occur in the pore water at this sampling site. Dissolved concentrations of Cr(VI) leached from sample SA-6009115 were less than analytical detection (0.05 μg/L or 0.00005 ppm) using ICPMS (Figure J-4.0-8). Chromium(III) comprises 100% of total dissolved Cr leached from sample SA-600115 (Figure J-4.0-8). The ubiquitous abundance of SOM in sample SA-600115 helps to keep Cr(III) reduced. The solubility of amorphous $Cr(OH)_3$ is much higher under acidic conditions, and dissolution of this phase accounts for the elevated dissolved concentrations of Cr(III) in the leachate from this location. Results of PHREEQC calculations (Parkhurst and Appelo 1999, 095402) show that both types of leachate produced from sample SA-600115 are undersaturated with respect to both crystalline and amorphous $Cr(OH)_3$. Based on this calculation, the abundance of

Cr(III) is controlled by adsorption processes rather than precipitation of amorphous $Cr(OH)_3$. Concentrations of total dissolved Cr in the deionized water and SWSC leachates for sample SA-600115 increased from 1.50 to 2.03 ppm and from 1.50 to 2.09 ppm, respectively (Figure J-4.0-8). It is very likely that Cr(III) adsorbed onto SOM was released during the leaching process. This poorly bound Cr(III) and could be easily transported downcanyon under extreme flow conditions, if the Sandia wetland were completely dewatered and dried out.

An alternate and viable hypothesis is that Cr released during leaching of sample SA-600115 is colloidal, with particle sizes smaller than 0.22 µm. This concept is supported by analytical results for surface water (gaging stations E122 and E123) collected downstream of the Sandia wetland that were filtered through 0.45-, 0.2-, and 0.02-µm membranes before acidification and analyses for Cr. Concentrations of total Cr were not uniform in the different filtered samples, suggesting that colloidal Cr, possibly stable as amorphous $Cr(OH)_3$ and/or as Cr species adsorbed onto clay minerals and HFO, occurs at the eastern end and downstream the Sandia wetland. For example, one set of surface water samples collected from gaging station E122 contained 16.9, 20.2, and 12.4 µg/L of total Cr separately filtered through 0.45-, 0.22-, and 0.02-µm membranes. Other multiple-filtered aliquots of individual samples, however, contained similar concentrations of total Cr, including those collected at the terminus of base flow east of the Sandia wetland.

With regard to sample SA-6009115, dissolved concentrations of Fe, as Fe(II), generally varied from 6.24 to 12.50 ppm and from 7.78 to 14.89 ppm in deionized water and SWSC leachates, respectively (Table J-4.0-1). These very high Fe(II) concentrations emphasize the lack of oxidation occurring in this sample resulting from the high organic matter content. Elevated dissolved concentrations of Fe leached from sample SA-600115 suggest that a high percentage of this metal is stable in its reduced form within the dry bank east of the active Sandia wetland, in the absence of Fe(III) colloids. Reductive dissolution of HFO at this sampling location can account for the observed concentrations of total dissolved Fe measured in both types of leachates produced from sample SA-600115, in the absence of Fe(III) colloids. Reduction of Cr(VI) to Cr(III) by ubiquitous SOM under acidic pH conditions is most likely in sample SA-600115. An alternate hypothesis for reduction of Cr(VI) to Cr(III) includes oxidation of soluble Fe(II) to form insoluble amorphous $Fe(OH)_3$, based on spectroscopic results showing the association of Cr(III) with a form of Fe(III) (oxy)hydroxide or HFO (see Appendix I, Section I-3.5 for details). This association suggests that Cr(III) has precipitated as $Fe_xCr_{1-x}(OH)_3$.

Dissolved concentrations of Mn, in the form of Mn(II), varied from 13.07 to 13.98 ppm and from 13.56 to 14.50 ppm in the deionized water and SWSC effluent leachates, respectively. These very high Mn(II) concentrations also emphasize the reducing nature of this sample, even upon drying. The stability of Cr(III) in the form of $CrSO_4^+$, Cr^{3+} and $CrOH^+$ is significantly enhanced by the presence of Mn(II) in these sample leachates. Dissolved concentrations of As increased from 0.0036 to 0.0066 ppm in the deionized water leachates as drying times increased before leaching. Similar dissolved concentrations of As, ranging from 0.0041 to 0.0073 ppm, were leached from sample SA-600115 using SWSC effluent (Table J-4.0-1). For sample SA-600115, dissolved concentrations of Zn in the deionized water and SWSC effluent leachates varied from 14.1 to 15.1 ppm and from 14.1 to 15.9 ppm, respectively. Elevated concentrations of Zn measured in the two types of leachate can be explained by complexing of Zn with DOC, mainly in the form of dissociated organic acids during leaching, and SO_4. Zinc-humate complexes that are not significantly adsorbed by HFO and clay minerals could become transported downcanyon during storm events. Elevated concentrations of unspeciated zinc have been measured in alluvial groundwater and the underlying saturated zone east of the Sandia wetland (LANL 2007, 098938).

Previous uptake of PO_4 within thriving cattails before decay could account for the small dissolved concentrations of this anion leached from sample SA-600115. Dissolved concentrations of PO_4 varied

from 0.01 to 0.24 ppm in the deionized water leachates associated with sample SA-600115. Concentrations of this anion varied from 0.01 to 0.10 ppm in SWSC effluent leachates. Dissolved concentrations of SO_4 varied from 781 to 1294 ppm and from 781 to 1329 ppm in the deionized water and SWSC leachates, respectively. Concentrations of DOC generally increased from 30 to 111 ppm in the deionized water leachates produced from sample SA-600115. Higher concentrations of DOC, ranging from 32 to 167 ppm, were leached from this sample using SWSC effluent. Maximum concentrations of DOC were leached from sample SA-600115 a 4-mo drying time before leaching using deionized water and SWSC effluent (Figure J-4.0-8).

J-4.10 Wetland Drying Experiments at Elevated Temperatures

Aliquots of the eight Sandia wetland samples were placed in an oven at 40°C for 48 h before leaching experiments were conducted to evaluate the effects of elevated temperatures on Cr leachability (Table J-4.0-1). After drying, these samples were then reacted with deionized water or SWSC effluent for a period of 48 h before filtering and chemical analyses. Separate aliquots of the same wetland samples were placed in a vacuum chamber, without atmospheric oxygen present, at ambient temperature (25°C). The vacuum-dried samples required more time to dry out than the oven-dried samples. Slightly higher concentrations of total dissolved Cr and/or Cr(VI) were leached from seven of the eight wetland samples dried in the oven in the presence of atmospheric oxygen compared to the vacuum-dried samples. These include samples collected from the bank upstream of the active wetland (sample SA-600108), within the dewatered western portion of wetland (sample SA-600112), within the headcut at the eastern end of the wetland (samples SA-600113A and SA-600113B), within the active portion of the wetland (samples SA-600905 and SA-600906), and at the dry bank east of the wetland (sample SA-600115). Samples leached with SWSC effluent produced higher dissolved concentrations of Cr(VI) compared to those leached with deionized water (Table J-4.0-1). Presence of competing anions including PO_4 and SO_4 enhances desorption of Cr(VI) from the wetland samples. Atmospheric oxygen enhances the leaching of Cr from wetland samples, based on higher concentrations of Cr(VI) in the oven-dried samples in the presence of atmosphere.

J-5.0 SUMMARY OF DRYING AND LEACHING EXPERIMENTS

- Leaching of total dissolved Cr and dissolved Cr(VI) from the Sandia wetland samples occurred in seven of the eight samples. Sample SA-600115 did not contain detectable Cr(VI) (> 0.05 μg/L) in the leachates.
- Maximum leaching of dissolved Cr(VI), in concentrations ranging from 0.00006 to 0.0145 ppm, occurred at 0, 1, and 4 mo drying time before leaching. Sustained leaching of Cr(VI) was observed in some samples.
- Much higher concentrations of total dissolved Cr were leached from the wetland samples compared to Cr(VI), suggesting that most of the Cr occurs as Cr(III).
- Higher concentrations of total dissolved Cr typically were leached from samples using the SWSC treated effluent than from those leached with deionized water.
- Chromium(VI), stable as $HCrO_4^-$ and CrO_4^{2-}, does not adsorb onto SOM that has a net-negative surface charge created from deprotonation of abundant carboxylic acids. Chromium(III), stable as Cr^{3+}, $CrOH^{2+}$, and $Cr(OH)_2^+$, adsorb onto these negatively charged surfaces.
- Cations including Ca, Na, and Mg concentrated in the SWSC treated effluent may enhance desorption of Cr(III) through cation exchange reactions from the wetland samples.

- Sulfate, PO_4, and total carbonate alkalinity are competing anions for Cr(VI), which limits adsorption of Cr(VI) onto HFO under circumneutral pH conditions.
- Complexing of Cr(III) with DOC, in the forms of humate and fulvate ligands (anions), may also enhance desorption of Cr(III) from the organic-rich solids concentrated within the Sandia wetland.
- Colloids (smaller than 0.22 µm in size) consisting of $Fe_xCr_{1-x}(OH)_3$ and $Cr(OH)_3$ are mobilized through the leaching process.
- Leaching of As occurred in all of the eight wetland samples with a maximum of 0.0425 ppm (sample SA-600113B).

Monitoring of surface water upstream and downstream of the Sandia wetland shows that variable concentrations of total dissolved Cr (between 4 and 32 ppb or 4 and 32 µg/L) were released from the Sandia wetland between 2007 and 2009. Concentrations of total dissolved Cr in the leachates overlap but can be higher, than analytical results for field samples. The leachate concentrations, however, are dependent on the liquid to solid ratio during leaching and may be directly comparable to field values under saturated flow conditions within some portions of the Sandia wetland. Differences in Cr concentrations between leachates and field groundwater samples may also result from completely drying the wetland samples before leaching with SWSC treated effluent and deionized water. Analytical results obtained from the leaching experiments conducted from April to August 2009 show that up to 2.09 ppm of Cr, stable as Cr(III), are leached from the Sandia wetland samples. The maximum concentration of Cr(VI) was 14.5 µg/L in one of the deionized water leachates produced from sample SA-600108. Samples collected from the dry bank east of the active wetland (sample SA-600115) leached the highest concentrations of total dissolved Cr.

J-6.0 STABILITY OF CHROMIUM WITHIN THE SANDIA WETLAND, PRESENT-DAY CONDITIONS

This section summarizes the mass balance calculations performed to evaluate the stability of Cr(III) within the Sandia wetland under present-day conditions. Molar concentrations of total Cr, Cr(III), Cr(VI), Fe(II), and Mn(IV) in 14 Sandia wetland samples were used in the calculations. The three most important chemical reductants concentrated within the Sandia wetland include SOM, DOC, and Fe(II) for maintaining the stability of Cr(III). Oxidants, including Mn(IV), in the form of MnO_2, and atmospheric and dissolved oxygen, however, have the ability to reoxidize Cr(III) to Cr(VI). In addition, reoxidation of Cr(III) may potentially occur if SOM in the Sandia wetland completely dries out and decomposes and oxidizes to inorganic carbon.

Concentrations of Fe(II), total Fe, total Cr, and Cr(VI) associated with Sandia wetland sediments were previously reported by the Laboratory (LANL 2007, 098127). Concentrations of Cr(III) were determined by subtracting the amount of Cr(VI) from total Cr present in the sediment samples. Manganese(IV) extractions were conducted at the EES-14 analytical laboratory by reacting 0.5 g of dry soil with 25 mL of hydroxylamine hydrochloride solution for a period of 30 min on a mechanical shaker at ambient laboratory temperature (Chao 1972, 102495). Table J-6.0-1 provides analytical results for Cr(III), Cr(VI), Fe, Fe(II), and Mn(IV), determined from either acid digestion or selective extraction, along with results of mass balance calculations for evaluating potential oxidation of Cr(III) to Cr(VI). Analytical results for samples denoted by “J” values and those without qualifiers were only used for this evaluation of the stability of the Sandia wetland under present-day conditions with respect to Cr(III).

Concentrations of SOM were not included in these calculations because the composition and molecular weight of organic carbon, in the form of humic and fulvic acids, present in the Sandia wetland are not known. These data are required to determine mole concentrations of solid organic carbon. The

calculations only involving Fe(II) as a reductant are conservative, if the mass of this reductant alone is sufficient to maintain the stability of Cr(III) within the wetland.

Concentrations of extractable Cr(VI) and total Cr range from 0.04 to 2.01 mg/kg and from 11.8 to 3740 mg/kg, respectively, confirming that Cr(III) is the dominant form of Cr within the Sandia wetland (Table J-6.0-1). Concentrations of extractable Mn(IV) and Fe(II) range from 18.9 to 294 mg/kg and from 100 to 6540 mg/kg, respectively.

Manganese(IV) serves as an electron acceptor (oxidant) for Cr(III)) and Fe(II) serves as an electron donor (reductant for Cr(VI)). One overall oxidation-reduction reaction involving Cr(III, VI), Mn(II,IV), and Fe(II, III) is:

$$3MnO_2 + Cr(OH)_3 + 3Fe^{2+} + 4H_2O = 2H^+ + 3Mn^{2+} + CrO_4^{2-} + 3Fe(OH)_3.$$

According to this reaction, three moles of Fe^{2+} are required to prevent oxidation of one mole of $Cr(OH)_3$ to CrO_4^{2-}. Seven of the 11 wetland samples (64%) contain enough Fe(II) to potentially limit reoxidation of Cr(III) to Cr(VI). Four samples (CASA-07-634, CASA-07-637, CASA-07-638, and CASA-07-640) with molar ratios of Fe(II): Cr(III) less than 3 do not contain enough reductant (Fe^{2+}) to prevent partial oxidation of Cr(III), as amorphous $Cr(OH)_3$, to Cr(VI). Mole ratios of Fe(II) to Mn(IV) range from 2.31 to 67.63 for 11 wetland samples (Table J-6.0-1). Concentrations of Fe(II) exceed those of Mn(VI) and most of the Cr(III) should remain reduced. Mole ratios of Fe(II) to Cr(III) range from 0.49 to 167 for the samples (Table J-6.0-1), suggesting that most of the Cr(III) is stable in this oxidation state. Mole ratios of Fe(II) to Mn(IV) range from 2.31 to 67.63 for the samples (Table J-6.0-1), showing that there is not enough reactive Mn(IV) available to completely oxidize Cr(III) to Cr(VI). These calculations, however, are conservative because they do not consider the abundance of SOM, an excellent and ubiquitous reductant enhancing the long-term stability of Cr(III) within the active (water saturated) Sandia wetland. The high SOM content at a bank east of the Sandia wetland (sample SA-600115) is an excellent example of the robust reductive capacity for Cr(VI) at this location. Moreover, Fe(II) is so much more abundant than Mn(IV) (Table J-6.0-1) that the low concentrations of Mn(IV) are not sufficient to achieve a net amount of Cr(III) being oxidized to to Cr(VI). Another more localized Cr reductant possibly includes biogenic metal sulfides occurring in anaerobic and saturated portions of the Sandia wetland.

J-8.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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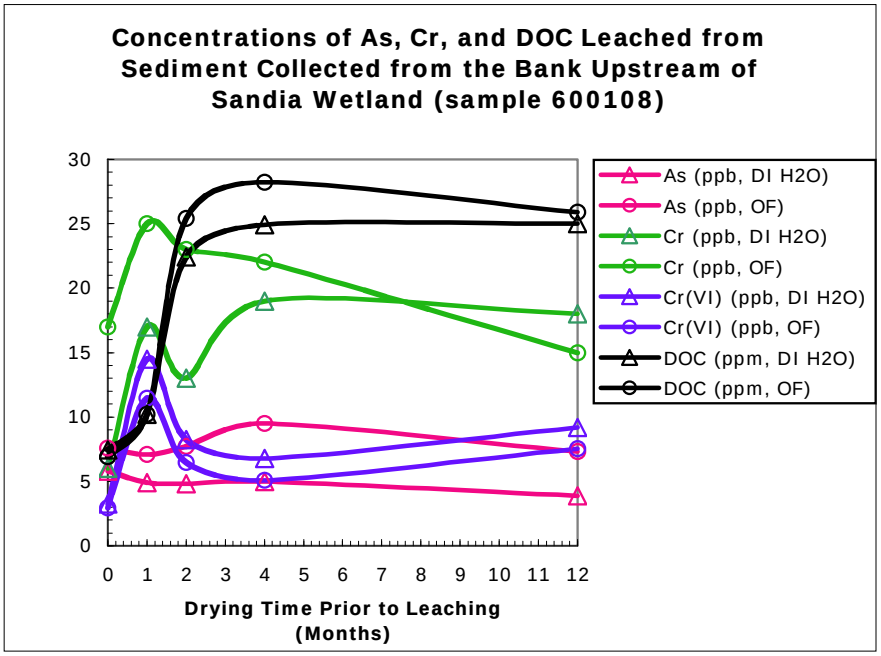
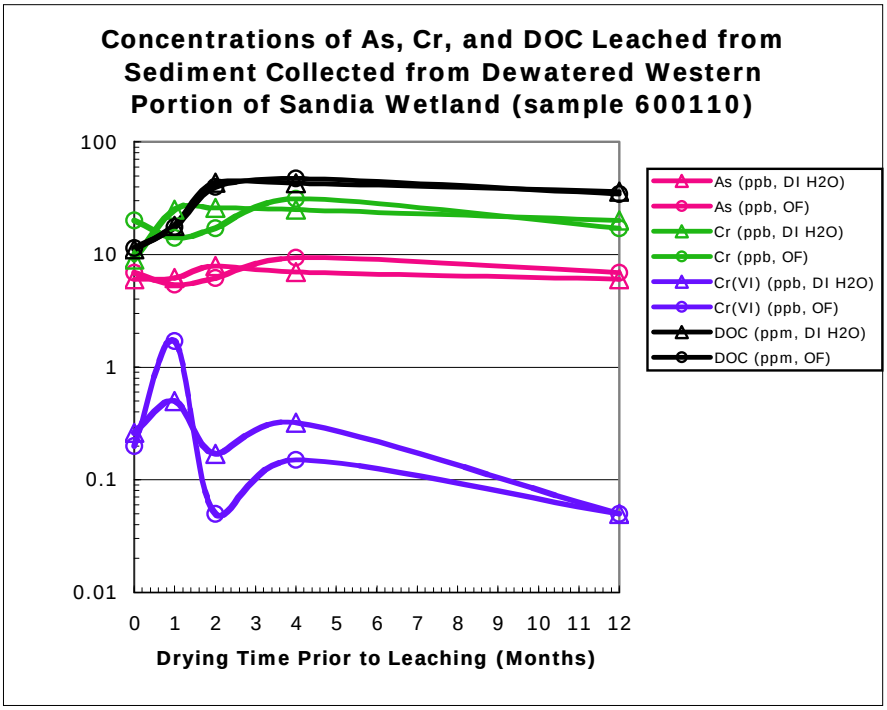


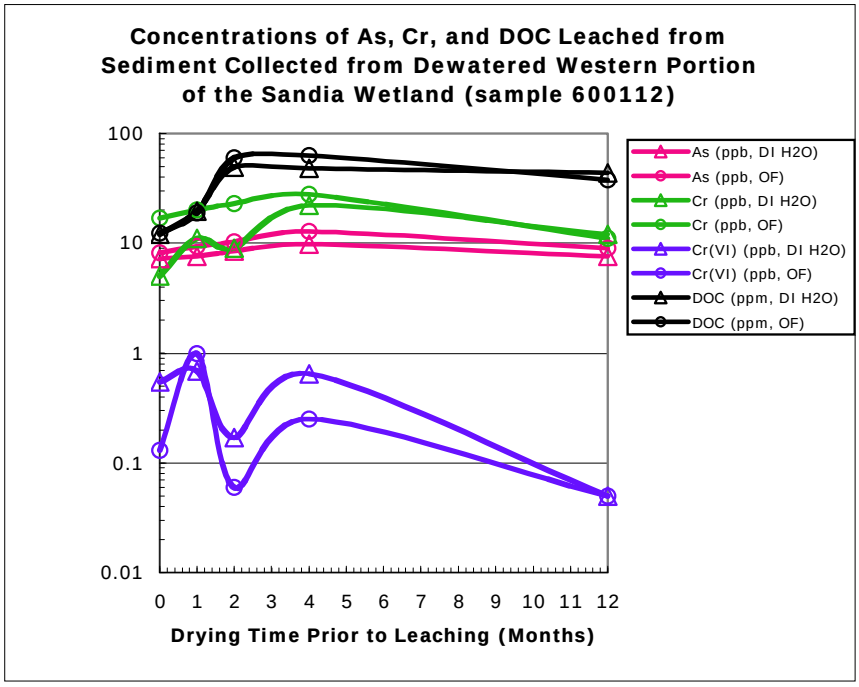
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-1 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600108



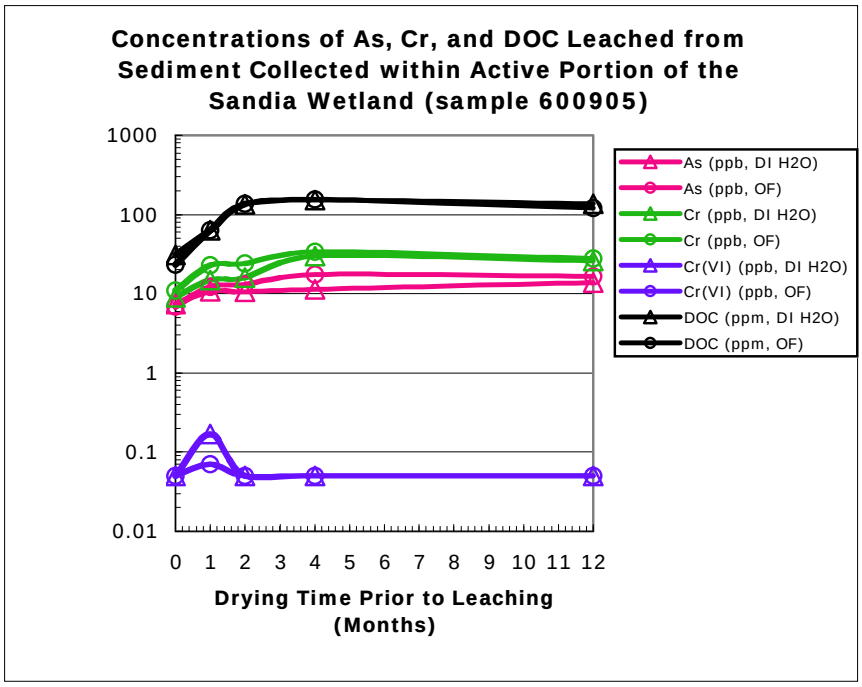
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-2 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600110



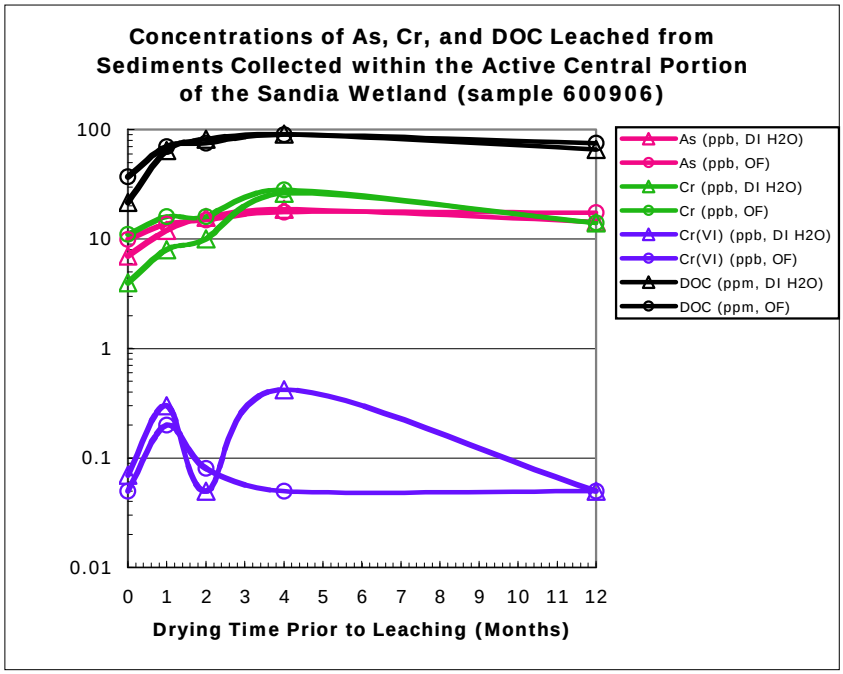
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-3 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600112



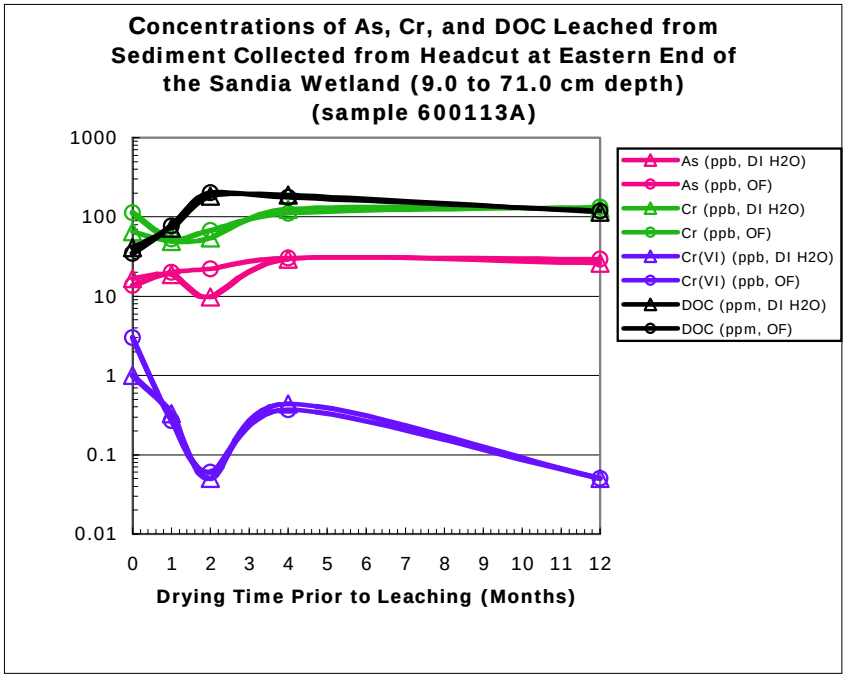
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-4 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600905



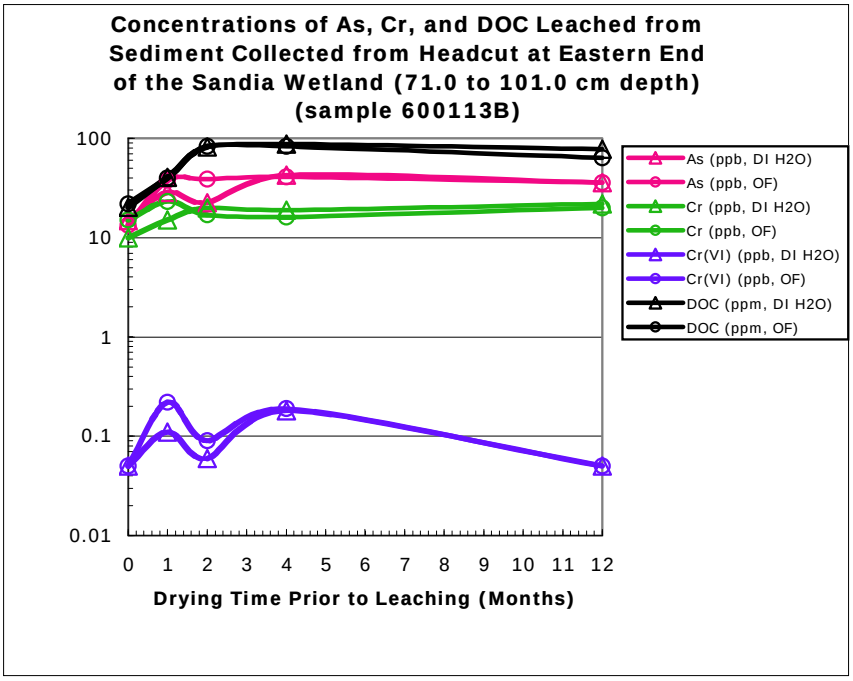
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-5 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600906



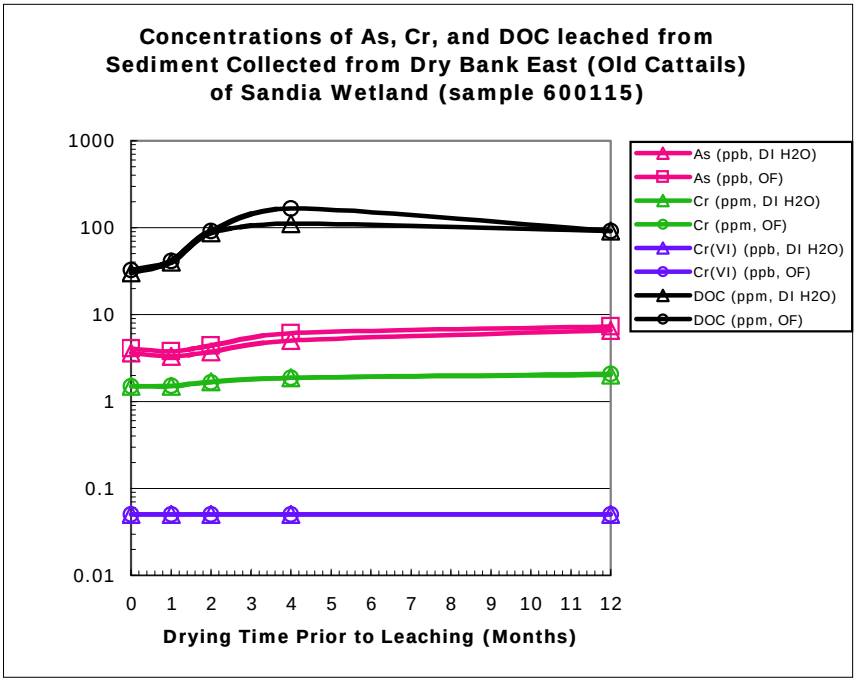
Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-6 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 60011A



Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J.4.0-7 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600113B



Note: Results for leaching by DI water and by SWSC plant outfall (OF) are shown.

Figure J-4.0-8 Sample drying time (in months) before leaching versus concentrations of dissolved concentrations of As (ppb), total Cr (ppb), Cr(VI), and DOC (ppm) for sample 600115

Table J-4.0-1
Analytical Results for Drying and Leaching Experiments Using Sandia Canyon Wetland Material

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600108 Init.		5/14/2008	**Bank, upstream of currently active wetland**	Initial sample. Measurements made in a 1:1 slurry	River sand/gravel, little to no organics	20.0–108.0	n/a[a]	NA[b]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		20.0–108.0	7.48	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0058	0.0001	NA	NA	NA	NA	7.46	9.36	0.02	NA	5.22	NA	NA	0.8	U	0.006	0.000
SA-600108-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		20.0–108.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0076	0.0001	NA	NA	NA	NA	6.89	47.2	0.0	NA	196	NA	NA	0.8	U	0.017	0.000
SA-600108-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0062	0.0000	NA	NA	NA	NA	NA	11.6	0.1	NA	4.61	NA	NA	0.8	U	0.009	0.000
SA-600108-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0079	0.0002	NA	NA	NA	NA	NA	48.2	0.1	NA	211	NA	NA	0.8	U	0.020	0.000
SA-600108-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0049	0.0000	NA	NA	NA	NA	10.2	14.0	0.0	NA	4.61	NA	NA	0.8	U	0.017	0.000
SA-600108-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0071	0.0000	NA	NA	NA	NA	10.2	48.7	0.4	NA	214	NA	NA	0.8	U	0.025	0.000
SA-600108-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0048	0.0001	NA	NA	NA	NA	22.4	18.2	0.1	NA	5.14	NA	NA	0.8	U	0.013	0.000
SA-600108-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0077	0.0000	NA	NA	NA	NA	25.4	51.4	0.2	NA	235	NA	NA	0.8	U	0.023	0.001
SA-600108-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0050	0.0001	NA	NA	NA	NA	24.9	21.5	0.1	NA	4.58	NA	NA	0.8	U	0.019	0.000
SA-600108-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0095	0.0002	NA	NA	NA	NA	28.2	48.9	0.4	NA	232	NA	NA	0.8	U	0.022	0.000
SA-600108-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		20.0–108.0	n/a	NA	NA	0.0039	0.0000	NA	NA	NA	NA	25.02	24.1	0.2	NA	24.5	NA	NA	0.8	U	0.018	0.000
SA-600108-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		20.0–108.0	n/a	NA	NA	0.0073	0.0003	NA	NA	NA	NA	25.88	52.5	0.2	NA	239	NA	NA	0.8	U	0.015	0.000
SA-600110 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Sample was frozen	26.0–42.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Clumps of clay and plant roots	26.0–42.0	22.73	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0060	0.0001	NA	NA	NA	NA	11.1	19.5	0.0	NA	11.4	NA	NA	0.8	U	0.009	0.000
SA-600110-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		26.0–42.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0069	0.0001	NA	NA	NA	NA	11.4	63.2	0.3	NA	200	NA	NA	0.8	U	0.020	0.001
SA-600110-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0072	0.0000	NA	NA	NA	NA	NA	18.0	0.0	NA	9.62	NA	NA	0.8	U	0.012	0.000
SA-600110-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0081	0.0001	NA	NA	NA	NA	NA	64.6	0.3	NA	213	NA	NA	0.8	U	0.020	0.001

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600110-1MON-DI	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0062	0.0001	NA	NA	NA	NA	17.9	27.5	0.1	NA	12.1	NA	NA	0.8	U	0.025	0.001
SA-600110-1MON-OF	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0054	0.0001	NA	NA	NA	NA	17.5	65.7	0.4	NA	236	NA	NA	0.8	U	0.014	0.000
SA-600110-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0079	0.0000	NA	NA	NA	NA	43.3	32.3	0.2	NA	9.84	NA	NA	0.8	U	0.026	0.000
SA-600110-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0062	0.0000	NA	NA	NA	NA	40.0	70.1	0.2	NA	238	NA	NA	0.8	U	0.017	0.000
SA-600110-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0070	0.0000	NA	NA	NA	NA	42.9	34.8	0.1	NA	8.63	NA	NA	0.8	U	0.025	0.001
SA-600110-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0094	0.0000	NA	NA	NA	NA	47.6	67.5	0.2	NA	239	NA	NA	0.8	U	0.031	0.001
SA-600110-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		26.0–42.0	n/a	NA	NA	0.0060	0.0003	NA	NA	NA	NA	36.0	34.0	0.1	NA	27.5	NA	NA	0.8	U	0.020	0.000
SA-600110-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		26.0–42.0	n/a	NA	NA	0.0069	0.0001	NA	NA	NA	NA	34.3	68.1	0.1	NA	244	NA	NA	0.8	U	0.017	0.000
SA-600112 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Many arthropods found alive	0.0–41.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Found some growing green grass	0.0–41.0	14.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0072	0.0001	NA	NA	NA	NA	12.1	20.0	0.1	NA	9.26	NA	NA	0.8	U	0.005	0.000
SA-600112-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–41.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0082	0.0002	NA	NA	NA	NA	12.4	64.2	0.5	NA	217	NA	NA	0.8	U	0.017	0.000
SA-600112-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0079	0.0000	NA	NA	NA	NA	NA	25.1	0.2	NA	7.21	NA	NA	0.8	U	0.005	0.000
SA-600112-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0097	0.0003	NA	NA	NA	NA	NA	70.2	0.2	NA	209	NA	NA	0.8	U	0.018	0.000
SA-600112-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0076	0.0001	NA	NA	NA	NA	19.7	30.6	0.1	NA	6.28	NA	NA	0.8	U	0.011	0.000
SA-600112-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0093	0.0002	NA	NA	NA	NA	18.8	71.1	0.2	NA	204	NA	NA	0.8	U	0.020	0.000
SA-600112-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0085	0.0002	NA	NA	NA	NA	49.3	42.5	0.1	NA	7.56	NA	NA	0.8	U	0.009	0.000
SA-600112-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0103	0.0002	NA	NA	NA	NA	60.3	79.9	0.1	NA	237	NA	NA	0.8	U	0.023	0.000
SA-600112-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0098	0.0002	NA	NA	NA	NA	47.9	40.1	0.3	NA	6.91	NA	NA	0.8	U	0.022	0.000
SA-600112-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0128	0.0001	NA	NA	NA	NA	63.0	76.9	0.5	NA	224	NA	NA	0.8	U	0.028	0.000
SA-600112-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–41.0	n/a	NA	NA	0.0076	0.0001	NA	NA	NA	NA	43.5	45.2	0.3	NA	26.2	NA	NA	0.8	U	0.012	0.000
SA-600112-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–41.0	n/a	NA	NA	0.0090	0.0000	NA	NA	NA	NA	37.8	76.9	0.2	NA	244	NA	NA	0.8	U	0.011	0.000

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600113A Init.		5/14/2008	**Heatcut at eastern end of wetland**	Initial interstitial water sample	Very wet. Mold growing on surface	9.0–71.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Moderate plant content (some growing)	9.0–71.0	52.92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0167	0.0003	NA	NA	NA	NA	41.1	367	3	NA	121	NA	NA	0.8	U	0.065	0.001
SA-600113A-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		9.0–71.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0137	0.0005	NA	NA	NA	NA	34.6	592	6	NA	356	NA	NA	0.8	U	0.113	0.003
SA-600113A-BL-IW	10	4/3/2008		Interstitial water collected before homogenization		9.0–71.0	n/a	NA	NA	0.0030	0.0001	NA	NA	NA	NA	NA	75.0	0.6	NA	106	NA	NA	0.8	U	0.018	0.000
SA-600113A-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0261	0.0004	NA	NA	NA	NA	NA	227	1	NA	110	NA	NA	0.8	U	0.039	0.001
SA-600113A-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0238	0.0001	NA	NA	NA	NA	NA	258	1	NA	364	NA	NA	0.8	U	0.045	0.000
SA-600113A-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0188	0.0003	NA	NA	NA	NA	72.7	110	1	NA	118	NA	NA	0.8	U	0.049	0.000
SA-600113A-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0199	0.0001	NA	NA	NA	NA	77.0	154	1	NA	317	NA	NA	0.8	U	0.053	0.001
SA-600113A-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0098	0.0003	NA	NA	NA	NA	182	132	0	NA	90.5	NA	NA	0.8	U	0.054	0.000
SA-600113A-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0221	0.0004	NA	NA	NA	NA	201	179	1	NA	319	NA	NA	0.8	U	0.068	0.001
SA-600113A-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0292	0.0001	NA	NA	NA	NA	189	167	1	NA	92.4	NA	NA	0.8	U	0.126	0.001
SA-600113A-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0306	0.0002	NA	NA	NA	NA	176	190	0	NA	303	NA	NA	0.8	U	0.111	0.001
SA-600113A-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		9.0–71.0	n/a	NA	NA	0.0263	0.0009	NA	NA	NA	NA	115	184	1	NA	96	NA	NA	0.8	U	0.130	0.000
SA-600113A-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		9.0–71.0	n/a	NA	NA	0.0292	0.0006	NA	NA	NA	NA	119	218	2	NA	330	NA	NA	0.8	U	0.133	0.000
SA-600113B Init.		5/14/2008	**Headcut at eastern end of wetland**	Initial interstitial water sample	Not many macros	71.0–101.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		71.0–101.0	34.55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0149	0.0000	NA	NA	NA	NA	20.2	131	0	NA	39.8	NA	NA	0.8	U	0.010	0.000
SA-600113B-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		71.0–101.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0134	0.0002	NA	NA	NA	NA	22.0	157	0	NA	326	NA	NA	0.8	U	0.015	0.000
SA-600113B-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		71.0–101.0	n/a	NA	NA	0.0015	0.0001	NA	NA	NA	NA	NA	118	0	NA	196	NA	NA	0.8	U	0.008	0.000
SA-600113B-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0218	0.0006	NA	NA	NA	NA	NA	53.0	0.3	NA	38.6	NA	NA	0.8	U	0.011	0.000

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600113B-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0279	0.0003	NA	NA	NA	NA	NA	89.0	0.3	NA	321	NA	NA	0.8	U	0.018	0.000
SA-600113B-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0284	0.0000	NA	NA	NA	NA	40.5	30.5	0.1	NA	36.6	NA	NA	0.8	U	0.015	0.000
SA-600113B-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0379	0.0002	NA	NA	NA	NA	40.0	75.3	0.6	NA	276	NA	NA	0.8	U	0.023	0.000
SA-600113B-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0224	0.0005	NA	NA	NA	NA	82.4	39.5	0.1	NA	38.3	NA	NA	0.8	U	0.020	0.001
SA-600113B-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0389	0.0008	NA	NA	NA	NA	83.5	74.4	0.3	NA	275	NA	NA	0.8	U	0.017	0.001
SA-600113B-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0425	0.0006	NA	NA	NA	NA	87.8	43.1	0.3	NA	36.8	NA	NA	0.8	U	0.019	0.000
SA-600113B-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0407	0.0001	NA	NA	NA	NA	82.7	76.8	0.6	NA	264	NA	NA	0.8	U	0.016	0.000
SA-600113B-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		71.0–101.0	n/a	NA	NA	0.0359	0.0013	NA	NA	NA	NA	78.1	55.9	0.4	NA	51	NA	NA	0.8	U	0.022	0.000
SA-600113B-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		71.0–101.0	n/a	NA	NA	0.0356	0.0005	NA	NA	NA	NA	63.9	87.7	0.3	NA	283	NA	NA	0.8	U	0.020	0.000
SA-600115 Init.		5/14/2008	**Dry bank east of wetland (old cattails)**	Initial sample. Measurements made in a 1:1 slurry	Sand grains in mud	0.0–30.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–30.0	33.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0036	0.0000	NA	NA	NA	NA	30.4	396	1	NA	22.8	NA	NA	0.8	U	1.50	0.01
SA-600115-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–30.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	0.0041	0.0001	NA	NA	NA	NA	32.4	431	2	NA	262	NA	NA	0.8	U	1.50	0.00
SA-600115-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0031	0.0000	NA	NA	NA	NA	NA	363	2	NA	23.8	NA	NA	0.8	U	1.36	0.02
SA-600115-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	414	3	NA	266	NA	NA	0.8	U	1.46	0.01
SA-600115-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0033	0.0000	NA	NA	NA	NA	40.0	387	2	NA	23.1	NA	NA	0.8	U	1.49	0.00
SA-600115-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	0.0038	0.0001	NA	NA	NA	NA	41.2	412	4	NA	264	NA	NA	0.8	U	1.51	0.01
SA-600115-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0037	0.0000	NA	NA	NA	NA	87.9	373	2	NA	19.5	NA	NA	0.8	U	1.69	0.05
SA-600115-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	0.0044	0.0001	NA	NA	NA	NA	91.7	409	3	NA	247	NA	NA	0.8	U	1.66	0.03
SA-600115-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0050	0.0001	NA	NA	NA	NA	111	351	2	NA	17.8	NA	NA	0.8	U	1.87	0.01
SA-600115-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	0.0061	0.0000	NA	NA	NA	NA	167	381	2	NA	244	NA	NA	0.8	U	1.87	0.01
SA-600115-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–30.0	n/a	NA	NA	0.0066	0.0002	NA	NA	NA	NA	91	380	1	NA	28	NA	NA	0.8	U	2.03	0.01

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600115-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–30.0	n/a	NA	NA	0.0073	0.0001	NA	NA	NA	NA	92	402	2	NA	139	NA	NA	0.8	U	2.09	0.02
SA-600905 Init.		5/14/2008	**Within active portion of wetland**	Initial interstitial water sample	Very wet. Aprox. half plant material	0.0–15.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	47.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0074	0.0000	NA	NA	NA	NA	31.2	223	2	NA	221	NA	NA	0.8	U	0.009	0.000
SA-600905-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0069	0.0002	NA	NA	NA	NA	23.2	362	5	NA	418	NA	NA	0.8	U	0.011	0.000
SA-600905-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		0.0–15.0	n/a	NA	NA	0.0017	0.0000	NA	NA	NA	NA	NA	79.0	0.7	NA	230	NA	NA	0.8	U	0.016	0.000
SA-600905-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0106	0.0003	NA	NA	NA	NA	NA	76.4	0.6	NA	183	NA	NA	0.8	U	0.014	0.000
SA-600905-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0108	0.0002	NA	NA	NA	NA	NA	100	1	NA	401	NA	NA	0.8	U	0.019	0.000
SA-600905-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0108	0.0001	NA	NA	NA	NA	63.3	97.2	0.5	NA	196	NA	NA	0.8	U	0.015	0.000
SA-600905-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0122	0.0002	NA	NA	NA	NA	63.7	117	0	NA	373	NA	NA	0.8	U	0.023	0.000
SA-600905-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0106	0.0000	NA	NA	NA	NA	135	123	1	NA	183	NA	NA	0.8	U	0.016	0.000
SA-600905-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0132	0.0000	NA	NA	NA	NA	137	139	1	NA	392	NA	NA	0.8	U	0.024	0.000
SA-600905-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0114	0.0000	NA	NA	NA	NA	153	127	0	NA	179	NA	NA	0.8	U	0.030	0.003
SA-600905-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0175	0.0000	NA	NA	NA	NA	155	141	1	NA	384	NA	NA	0.8	U	0.034	0.000
SA-600905-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0138	0.0005	NA	NA	NA	NA	136	180	2	NA	181	NA	NA	0.8	U	0.026	0.000
SA-600905-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0165	0.0005	NA	NA	NA	NA	120	196	1	NA	404	NA	NA	0.8	U	0.028	0.000
SA-600906 Init.		5/14/2008	**Central portion of active wetland**	Initial interstitial water sample	High plant material (mostly roots)	0.0–15.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	45.19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0070	0.0000	NA	NA	NA	NA	21.7	181	0	NA	98.1	NA	NA	0.8	U	0.004	0.000
SA-600906-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0099	0.0000	NA	NA	NA	NA	37.0	202	0	NA	387	NA	NA	0.8	U	0.011	0.000
SA-600906-BL-IW	10	4/9/2008		Interstitial water collected before homogenization		0.0–15.0	n/a	NA	NA	0.0021	0.0001	NA	NA	NA	NA	NA	111	1	NA	155	NA	NA	0.8	U	0.012	0.000

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Moisture Content (%)	Ag rslt (ppm)	Al rslt (ppm)	As rslt (ppm)	stdev (As)	B rslt (ppm)	Ba rslt (ppm)	Be rslt (ppm)	Br(-) ppm	DOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)
SA-600906-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0101	0.0002	NA	NA	NA	NA	NA	61.7	0	NA	86	NA	NA	0.8	U	0.008	0.000
SA-600906-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0117	0.0001	NA	NA	NA	NA	NA	92.6	0	NA	295	NA	NA	0.8	U	0.013	0.000
SA-600906-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0120	0.0000	NA	NA	NA	NA	64.4	72.0	0	NA	86.7	NA	NA	0.8	U	0.008	0.000
SA-600906-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0137	0.0002	NA	NA	NA	NA	69.9	100	0	NA	300	NA	NA	0.8	U	0.016	0.000
SA-600906-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0158	0.0000	NA	NA	NA	NA	81.9	91.5	0	NA	69.1	NA	NA	0.8	U	0.010	0.000
SA-600906-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0149	0.0000	NA	NA	NA	NA	75.0	114	0	NA	300	NA	NA	0.8	U	0.016	0.001
SA-600906-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0188	0.0002	NA	NA	NA	NA	91.0	98	1	NA	75.1	NA	NA	0.8	U	0.026	0.000
SA-600906-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0177	0.0004	NA	NA	NA	NA	89.9	113	1	NA	303	NA	NA	0.8	U	0.028	0.000
SA-600906-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	n/a	NA	NA	0.0143	0.0004	NA	NA	NA	NA	65.5	157	2	NA	86	NA	NA	0.8	U	0.014	0.000
SA-600906-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	n/a	NA	NA	0.0175	0.0004	NA	NA	NA	NA	75.0	164	2	NA	315	NA	NA	0.8	U	0.014	0.000
BLANK-1	B-1	4/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.02	NA	NA	0.8	U	0.001	U
BLANK-2	B-2	4/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.03	NA	NA	0.8	U	0.001	U
BLANK-3	B-3	4/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.02	NA	NA	0.8	U	0.001	U
BLANK-4	B-4	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.04	0.02	NA	0.04	NA	NA	0.8	U	0.001	U
BLANK-5	B-5	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.06	NA	NA	0.8	U	0.001	U
BLANK-6	B-6	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	0.01	NA	0.01	NA	NA	0.8	U	0.001	U
BLANK-7	B-7	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.03	NA	NA	0.8	U	0.001	U
BLANK-8	B-8	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.02	NA	NA	0.8	U	0.001	U
BLANK-9	B-9	6/17/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.01	U	NA	0.02	NA	NA	0.8	U	0.001	U
BLANK-10	B-10	8/20/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	2.90	0.08	0.01	NA	0.1, U	NA	NA	0.8	U	0.001	U
BLANK-11	B-11	8/20/2008				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	1.54	0.03	0.01	NA	0.1, U	NA	NA	0.8	U	0.001	U
BLANK-12	B-12	6/17/2009				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.03	0.00	NA	0.1, U	NA	NA	0.8	U	0.001	U
BLANK-13	B-13	6/17/2009				n/a	n/a	NA	NA	0.0002	U	NA	NA	NA	NA	NA	0.02	0.00	NA	0.1, U	NA	NA	0.8	U	0.001	U

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600108 Init.		5/14/2008	**Bank, upstream of currently active wetland**	Initial sample. Measurements made in a 1:1 slurry	River sand/gravel, little to no organics	20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		20.0–108.0	0.00325	NA	NA	NA	NA	0.16	0.00	61.3	NA	NA	3.45	0.02	NA	1.39	0.00	0.004	0.000	NA	10.0	0.0
SA-600108-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		20.0–108.0	0.00287	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		20.0–108.0	0.00294	NA	NA	NA	NA	0.02	0.00	194	NA	NA	14.7	0.1	NA	8.38	0.08	0.016	0.000	NA	117	1
SA-600108-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		20.0–108.0	0.00531	NA	NA	NA	NA	0.32	0.00	66.2	NA	NA	3.79	0.02	NA	1.68	0.00	0.002	0.000	NA	9.31	0.07
SA-600108-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		20.0–108.0	0.00586	NA	NA	NA	NA	0.01	NA	195	NA	NA	7.40	0.04	NA	4.44	0.04	0.010	0.000	NA	59.2	0.6
SA-600108-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		20.0–108.0	0.01449	NA	NA	NA	NA	0.05	0.00	105	NA	NA	2.13	0.02	NA	1.06	0.01	0.004	0.000	NA	4.90	0.04
SA-600108-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		20.0–108.0	0.01146	NA	NA	NA	NA	0.05	0.00	112	NA	NA	14.6	0.1	NA	8.88	0.08	0.040	0.000	NA	116	1
SA-600108-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		20.0–108.0	0.00823	NA	NA	NA	NA	0.11	0.00	90.9	NA	NA	4.46	0.02	NA	2.57	0.01	0.008	0.000	NA	11.0	0.1
SA-600108-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		20.0–108.0	0.00647	NA	NA	NA	NA	0.04	0.00	206	NA	NA	14.8	0.2	NA	9.11	0.01	0.075	0.001	NA	117	1
SA-600108-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		20.0–108.0	0.00678	NA	NA	NA	NA	0.05	0.00	99.2	NA	NA	5.4	0.0	NA	3.25	0.01	0.003	0.000	NA	12	0
SA-600108-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		20.0–108.0	0.00506	NA	NA	NA	NA	0.02	0.00	191	NA	NA	15.8	0.1	NA	9.32	0.00	0.002	0.000	NA	129	0
SA-600108-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		20.0–108.0	0.00918	NA	NA	NA	NA	0.03	0.00	102	NA	NA	6.6	0.1	NA	3.62	0.03	0.012	0.000	NA	11	0
SA-600108-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		20.0–108.0	0.00755	NA	NA	NA	NA	0.03	0.00	192	NA	NA	16.4	0.1	NA	10.2	0.2	0.024	0.000	NA	134	1
SA-600110 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Sample was frozen	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Clumps of clay and plant roots	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		26.0–42.0	0.00026	NA	NA	NA	NA	0.21	0.00	140	NA	NA	8.79	0.04	NA	3.33	0.02	0.149	0.001	NA	17.5	0.0
SA-600110-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		26.0–42.0	0.00020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		26.0–42.0	0.00015	NA	NA	NA	NA	0.02	0.00	263	NA	NA	20.0	0.1	NA	11.1	0.1	0.692	0.004	NA	114	1
SA-600110-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		26.0–42.0	0.00199	NA	NA	NA	NA	0.39	0.00	113	NA	NA	6.73	0.02	NA	2.89	0.01	0.014	0.000	NA	15.5	0.0
SA-600110-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		26.0–42.0	0.00084	NA	NA	NA	NA	0.02	0.00	256	NA	NA	17.9	0.1	NA	10.9	0.1	0.067	0.000	NA	112	0
SA-600110-1MON-DI	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		26.0–42.0	0.00171	NA	NA	NA	NA	0.11	0.00	199	NA	NA	8.56	0.03	NA	4.45	0.01	0.425	0.001	NA	16.9	0

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600110-1MON-OF	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		26.0–42.0	0.00050	NA	NA	NA	NA	0.01	NA	324	NA	NA	9.37	0.06	NA	5.89	0.03	0.439	0.004	NA	57.1	0
SA-600110-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		26.0–42.0	0.00017	NA	NA	NA	NA	0.07	0.00	184	NA	NA	9.38	0.04	NA	5.30	0.02	0.684	0.006	NA	17.8	0
SA-600110-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		26.0–42.0	0.00005, U	NA	NA	NA	NA	0.03	0.00	290	NA	NA	19.0	0.0	NA	12.5	0.1	1.405	0.007	NA	115	0
SA-600110-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		26.0–42.0	0.00032	NA	NA	NA	NA	0.07	0.00	191	NA	NA	10.8	0.0	NA	5.8	0.0	0.481	0.002	NA	18	0
SA-600110-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		26.0–42.0	0.00015	NA	NA	NA	NA	0.04	0.00	271	NA	NA	20.9	0.2	NA	12.7	0.1	0.903	0.011	NA	123	1
SA-600110-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		26.0–42.0	0.00005, U	NA	NA	NA	NA	0.05	0.00	166	NA	NA	11.7	0.1	NA	6.0	0.0	0.336	0.002	NA	18	0
SA-600110-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		26.0–42.0	0.00005, U	NA	NA	NA	NA	0.04	0.00	256	NA	NA	21.2	0.2	NA	13.4	0.1	0.665	0.006	NA	130	1
SA-600112 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Many arthropods found alive	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Found some growing green grass	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–41.0	0.00055	NA	NA	NA	NA	0.19	0.00	124	NA	NA	17.9	0.0	NA	3.39	0.02	0.003	0.000	NA	8.93	0.05
SA-600112-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–41.0	0.00013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–41.0	0.00024	NA	NA	NA	NA	0.03	0.00	266	NA	NA	35.5	0.4	NA	11.4	0.1	0.016	0.000	NA	108	0
SA-600112-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–41.0	0.00097	NA	NA	NA	NA	0.15	0.00	135	NA	NA	19.8	0.2	NA	4.14	0.04	0.003	0.000	NA	7.24	0.07
SA-600112-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–41.0	0.00057	NA	NA	NA	NA	0.15	0.00	287	NA	NA	37.7	0.3	NA	12.4	0.0	0.004	0.000	NA	107	1
SA-600112-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–41.0	0.00069	NA	NA	NA	NA	1.42	0.01	262	NA	NA	21.9	0.1	NA	5.55	0.04	0.158	0.001	NA	8.31	0.02
SA-600112-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–41.0	0.00100	NA	NA	NA	NA	0.07	0.00	254	NA	NA	36.7	0.5	NA	13.1	0.1	0.435	0.003	NA	111	1
SA-600112-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–41.0	0.00017	NA	NA	NA	NA	0.07	0.00	228	NA	NA	22.8	0.0	NA	6.92	0.03	0.635	0.002	NA	9.57	0.04
SA-600112-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–41.0	0.00006	NA	NA	NA	NA	0.08	0.00	354	NA	NA	37.0	0.5	NA	14.2	0.2	1.147	0.011	NA	106	0
SA-600112-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–41.0	0.00065	NA	NA	NA	NA	0.03	0.00	203	NA	NA	24.0	0.6	NA	6.8	0.0	0.048	0.003	NA	10	0
SA-600112-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–41.0	0.00025	NA	NA	NA	NA	0.04	0.00	318	NA	NA	39.8	0.3	NA	14.3	0.1	0.685	0.004	NA	117	1
SA-600112-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–41.0	0.00005, U	NA	NA	NA	NA	0.03	0.00	220	NA	NA	26.5	0.2	NA	8.0	0.1	0.184	0.003	NA	9	0
SA-600112-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–41.0	0.00005, U	NA	NA	NA	NA	0.03	0.00	316	NA	NA	39.3	0.5	NA	14.6	0.2	0.306	0.003	NA	123	1

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600113A Init.		5/14/2008	**Heatcut at eastern end of wetland**	Initial interstitial water sample	Very wet. Mold growing on surface	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Moderate plant content (some growing)	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		9.0–71.0	0.00005, U	NA	NA	NA	NA	0.75	0.00	0	U	NA	44.8	0.2	NA	72.2	0.4	22.890	0.198	NA	150	1
SA-600113A-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		9.0–71.0	0.00005, U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		9.0–71.0	0.00005, U	NA	NA	NA	NA	1.65	0.01	0	U	NA	60.5	0.5	NA	115	1	43.449	0.412	NA	268	2
SA-600113A-BL-IW	10	4/3/2008		Interstitial water collected before homogenization		9.0–71.0	0.00005, U	NA	NA	NA	NA	0.14	0.00	87.7	NA	NA	21.1	0.2	NA	17.1	0.0	3.988	0.052	NA	105	0
SA-600113A-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		9.0–71.0	0.00005, U	NA	NA	NA	NA	3.02	0.02	0	U	NA	36.6	0.2	NA	46.1	0.1	12.383	0.098	NA	128	0
SA-600113A-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		9.0–71.0	0.00021	NA	NA	NA	NA	4.08	0.01	50.7	NA	NA	43.9	0.2	NA	53.8	0.3	14.139	0.036	NA	216	1
SA-600113A-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		9.0–71.0	0.00033	NA	NA	NA	NA	0.30	0.00	18.4	NA	NA	29.3	0.3	NA	27.2	0.2	5.721	0.091	NA	123	2
SA-600113A-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		9.0–71.0	0.00027	NA	NA	NA	NA	0.43	0.00	112	NA	NA	38.5	0.3	NA	38.3	0.4	7.567	0.053	NA	219	1
SA-600113A-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		9.0–71.0	0.00005, U	NA	NA	NA	NA	0.46	0.01	61.2	NA	NA	36.8	1.1	NA	37.0	0.8	7.956	0.149	NA	153	2
SA-600113A-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		9.0–71.0	0.00006	NA	NA	NA	NA	0.55	0.00	88.5	NA	NA	36.8	0.4	NA	40.5	0.3	8.274	0.031	NA	210	0
SA-600113A-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		9.0–71.0	0.00044	NA	NA	NA	NA	2.29	0.02	54.1	NA	NA	33.3	0.2	NA	39.5	0.2	9.317	0.099	NA	133	1
SA-600113A-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		9.0–71.0	0.00037	NA	NA	NA	NA	2.50	0.01	96.4	NA	NA	39.3	0.1	NA	45.8	0.2	10.182	0.029	NA	214	1
SA-600113A-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		9.0–71.0	0.00005, U	NA	NA	NA	NA	3.54	0.04	82.2	NA	NA	34.5	0.2	NA	44.7	0.0	10.710	0.033	NA	137	1
SA-600113A-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		9.0–71.0	0.00005, U	NA	NA	NA	NA	3.40	0.03	88.5	NA	NA	40.2	0.4	NA	53.3	0.5	11.849	0.135	NA	228	2
SA-600113B Init.		5/14/2008	**Headcut at eastern end of wetland**	Initial interstitial water sample	Not many macros	71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		71.0–101.0	0.00005, U	NA	NA	NA	NA	0.16	0.00	22.1	NA	NA	36.5	0.3	NA	24.9	0.3	6.658	0.057	NA	86.0	0.9
SA-600113B-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		71.0–101.0	0.00012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		71.0–101.0	0.00005, U	NA	NA	NA	NA	0.08	0.00	85.0	NA	NA	43.0	0.2	NA	30.5	0.1	7.298	0.048	NA	173	1
SA-600113B-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		71.0–101.0	0.00005, U	NA	NA	NA	NA	0.04	0.00	0.0	U	NA	31.2	0.2	NA	20.6	0.1	4.916	0.036	NA	104	0
SA-600113B-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		71.0–101.0	0.00016	NA	NA	NA	NA	0.03	0.00	28.9	NA	NA	23.7	0.1	NA	10.5	0.0	2.470	0.021	NA	67.7	0.1

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600113B-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		71.0–101.0	0.00015	NA	NA	NA	NA	0.05	0.00	57.8	NA	NA	33.4	0.3	NA	17.6	0.1	3.761	0.016	NA	155	1
SA-600113B-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		71.0–101.0	0.00011	NA	NA	NA	NA	0.27	0.00	28.8	NA	NA	18.6	0.0	NA	6.22	0.04	1.336	0.011	NA	60.5	0.6
SA-600113B-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		71.0–101.0	0.00022	NA	NA	NA	NA	0.09	0.00	110	NA	NA	31.0	0.2	NA	15.6	0.1	3.265	0.037	NA	148	1
SA-600113B-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		71.0–101.0	0.00006	NA	NA	NA	NA	0.06	0.00	0.0	U	NA	20.3	0.1	NA	7.95	0.00	1.741	0.009	NA	64.9	0.4
SA-600113B-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		71.0–101.0	0.00009	NA	NA	NA	NA	0.08	0.00	36.1	NA	NA	29.8	0.2	NA	15.2	0.1	2.962	0.011	NA	147	1
SA-600113B-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		71.0–101.0	0.00018	NA	NA	NA	NA	0.06	0.00	0.0	U	NA	22.4	0.3	NA	8.9	0.0	1.877	0.022	NA	68	1
SA-600113B-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		71.0–101.0	0.00019	NA	NA	NA	NA	0.12	0.00	0.0	U	NA	32.7	0.3	NA	16.9	0.1	3.192	0.006	NA	156	1
SA-600113B-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		71.0–101.0	0.00005, U	NA	NA	NA	NA	0.14	0.00	45.5	NA	NA	25.9	0.2	NA	12.0	0.1	2.375	0.012	NA	74	0
SA-600113B-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		71.0–101.0	0.00005, U	NA	NA	NA	NA	0.20	0.00	72.9	NA	NA	34.1	0.3	NA	19.2	0.1	3.564	0.044	NA	162	2
SA-600115 Init.		5/14/2008	**Dry bank east of wetland (old cattails)**	Initial sample. Measurements made in a 1:1 slurry	Sand grains in mud	0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–30.0	0.00005, U	NA	NA	NA	NA	6.24	0.03	227	NA	NA	42.7	0.2	NA	29.7	0.1	13.720	0.103	NA	42.1	0.0
SA-600115-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–30.0	0.00005, U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–30.0	0.00005, U	NA	NA	NA	NA	7.89	0.01	390	NA	NA	50.8	0.2	NA	35.0	0.3	14.184	0.043	NA	147	1
SA-600115-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–30.0	0.00045	NA	NA	NA	NA	4.38	0.04	0	U	NA	41.3	0.3	NA	27.7	0.1	13.055	0.069	NA	41.5	0.2
SA-600115-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–30.0	0.00019	NA	NA	NA	NA	5.32	0.03	11.9	NA	NA	49.2	0.4	NA	32.8	0.2	13.466	0.089	NA	143	2
SA-600115-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–30.0	0.00005, U	NA	NA	NA	NA	6.82	0.02	20.7	NA	NA	41.2	0.2	NA	28.3	0.2	13.072	0.139	NA	41.5	0.1
SA-600115-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–30.0	0.00005, U	NA	NA	NA	NA	7.78	0.09	0	U	NA	52.2	0.7	NA	35.6	0.3	14.497	0.040	NA	153	1
SA-600115-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–30.0	0.00005, U	NA	NA	NA	NA	10.4	0.1	0	U	NA	41.2	0.0	NA	28.0	0.2	13.172	0.044	NA	41.6	0.2
SA-600115-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–30.0	0.00005, U	NA	NA	NA	NA	11.8	0.0	0	U	NA	48.8	0.1	NA	33.3	0.6	13.556	0.162	NA	143	1
SA-600115-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–30.0	0.00005, U	NA	NA	NA	NA	13.2	0.1	0	U	NA	43.6	0.4	NA	29.0	0.1	13.844	0.090	NA	43	0
SA-600115-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–30.0	0.00005, U	NA	NA	NA	NA	14.9	0.1	0	U	NA	50.2	0.5	NA	33.6	0.4	14.202	0.133	NA	148	2
SA-600115-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–30.0	0.00005, U	NA	NA	NA	NA	12.5	0.1	10	NA	NA	44.6	0.1	NA	32.1	0.2	13.977	0.078	NA	43	0

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600115-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–30.0	0.00005, U	NA	NA	NA	NA	12.1	0.1	0	U	NA	48.3	0.0	NA	34.9	0.3	13.558	0.017	NA	145	1
SA-600905 Init.		5/14/2008	**Within active portion of wetland**	Initial interstitial water sample	Very wet. Aprox. half plant material	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.65	0.00	374	NA	NA	48.2	0.2	NA	40.7	0.1	4.720	0.018	NA	160	1
SA-600905-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	0.00005, U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.11	0.00	285	NA	NA	67.9	0.5	NA	63.4	0.1	8.489	0.109	NA	282	3
SA-600905-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		0.0–15.0	0.00005, U	NA	NA	NA	NA	11.4	0.1	519	NA	NA	28.1	0.2	NA	20.5	0.2	2.889	0.045	NA	151	0
SA-600905-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	0.00010	NA	NA	NA	NA	0.11	0.00	354	NA	NA	39.2	0.2	NA	17.1	0.1	1.736	0.010	NA	140	1
SA-600905-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	0.00007	NA	NA	NA	NA	0.23	0.00	445	NA	NA	47.4	0.0	NA	22.7	0.1	2.178	0.007	NA	225	1
SA-600905-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	0.00017	NA	NA	NA	NA	0.17	0.00	208	NA	NA	49.9	1.0	NA	24.2	0.4	2.501	0.064	NA	166	3
SA-600905-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–15.0	0.00007	NA	NA	NA	NA	0.17	0.00	230	NA	NA	58.3	0.5	NA	29.9	0.2	2.900	0.011	NA	267	1
SA-600905-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.19	0.00	160	NA	NA	46.8	0.6	NA	25.6	0.1	2.982	0.010	NA	152	2
SA-600905-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.36	0.00	200	NA	NA	55.7	0.1	NA	30.8	0.0	3.411	0.035	NA	246	1
SA-600905-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.76	0.01	143	NA	NA	49.0	0.6	NA	28.1	0.2	3.446	0.028	NA	157	1
SA-600905-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	2.10	0.02	164	NA	NA	57.8	0.5	NA	33.6	0.1	3.905	0.028	NA	257	1
SA-600905-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	0.00005, U	NA	NA	NA	NA	2.84	0.01	228	NA	NA	53.5	0.7	NA	37.7	0.2	4.713	0.026	NA	162	1
SA-600905-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	4.38	0.06	253	NA	NA	68.7	0.6	NA	49.2	0.4	5.924	0.034	NA	265	3
SA-600906 Init.		5/14/2008	**Central portion of active wetland**	Initial interstitial water sample	High plant material (mostly roots)	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	0.00007	NA	NA	NA	NA	0.02	0.00	412	NA	NA	43.1	0.4	NA	34.1	0.2	4.658	0.032	NA	94.6	0.4
SA-600906-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	0.00040	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	0.05	0.00	343	NA	NA	52.0	0.4	NA	39.3	0.2	4.667	0.016	NA	208	2
SA-600906-BL-IW	10	4/9/2008		Interstitial water collected before homogenization		0.0–15.0	0.00005, U	NA	NA	NA	NA	21.6	0.3	817	NA	NA	30.6	0.1	NA	27.0	0.1	6.354	0.044	NA	127	2

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Cr 6+ rslt (mg/L)	Cs rslt (ppm)	Cu rslt (ppm)	F(-) ppm	F(-) (U)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	ALK-CO3+HCO3 (U)	Hg rslt (ppm)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	Na rslt (ppm)	stdev (Na)
SA-600906-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	0.00012	NA	NA	NA	NA	0.07	0.00	315	NA	NA	30.1	0.3	NA	13.5	0.2	1.547	0.026	NA	84.1	0.7
SA-600906-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	0.00007	NA	NA	NA	NA	0.14	0.00	435	NA	NA	42.6	0.2	NA	22.3	0.3	2.653	0.018	NA	190	3
SA-600906-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	0.00030	NA	NA	NA	NA	0.25	0.00	280	NA	NA	31.7	0.2	NA	15.7	0.1	2.157	0.013	NA	78.1	0.2
SA-600906-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/SWWS Outflow water		0.0–15.0	0.00020	NA	NA	NA	NA	0.59	0.00	315	NA	NA	44.7	0.1	NA	24.4	0.2	3.046	0.025	NA	193	1
SA-600906-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	0.00005, U	NA	NA	NA	NA	3.48	0.02	317	NA	NA	33.7	0.3	NA	19.8	0.1	2.967	0.055	NA	86.9	0.3
SA-600906-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	0.00008	NA	NA	NA	NA	3.04	0.01	319	NA	NA	44.6	0.1	NA	26.9	0.2	3.649	0.005	NA	195	2
SA-600906-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	0.00042	NA	NA	NA	NA	2.07	0.00	205	NA	NA	35.9	0.1	NA	20.8	0.2	3.111	0.026	NA	85	1
SA-600906-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	2.18	0.01	223	NA	NA	45.0	0.3	NA	27.4	0.1	3.938	0.021	NA	191	1
SA-600906-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	0.00005 U	NA	NA	NA	NA	0.87	0.00	208	NA	NA	42.6	0.4	NA	32.8	0.1	4.734	0.005	NA	98	1
SA-600906-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	0.00005, U	NA	NA	NA	NA	1.10	0.00	265	NA	NA	51.0	0.2	NA	37.8	0.1	5.124	0.023	NA	212	2
BLANK-1	B-1	4/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-2	B-2	4/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.02	0.00	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-3	B-3	4/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.02	0.00
BLANK-4	B-4	6/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.07	0.00
BLANK-5	B-5	6/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-6	B-6	6/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	0.000	NA	0.01	U
BLANK-7	B-7	6/17/2008				n/a	0.00005 U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-8	B-8	6/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-9	B-9	6/17/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-10	B-10	8/20/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.06	0.00	NA	0.01	0.00	0.001	U	NA	0.01	U
BLANK-11	B-11	8/20/2008				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.01	U	NA	0.01	U	0.001	U	NA	0.01	U
BLANK-12	B-12	6/17/2009				n/a	0.00005, U	NA	NA	NA	NA	0.02	0.00	0	U	NA	0.04	0.00	NA	0.01	U	0.001	U	NA	0.09	0.00
BLANK-13	B-13	6/17/2009				n/a	0.00005, U	NA	NA	NA	NA	0.01	U	0	U	NA	0.03	0.00	NA	0.01	U	0.001	U	NA	0.08	0.00

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600108 Init.		5/14/2008	**Bank, upstream of currently active wetland**	Initial sample. Measurements made in a 1:1 slurry	River sand/gravel, little to no organics	20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	179	NM[c]	8.42	NM	NM	NM	NA	NA	NA
SA-600108	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600108-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	190.3, 388.8[1]	NM	7.00	7.76	3.74	NA	NA	NA
SA-600108-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600108-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	182.3, 380.8	NM	7.68	7.88	7.22	NA	NA	NA
SA-600108-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	197, 395.5	NM	7.64	7.91	3.50	NA	NA	NA
SA-600108-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	167.8, 366.3	NM	7.65	7.32	7.69	NA	NA	NA
SA-600108-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	228.6, 427.1	NM	7.03	7.56	3.10	NA	NA	NA
SA-600108-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	203.5, 402.0	NM	7.83	7.37	8.11	NA	NA	NA
SA-600108-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.58	NM	2.30	NA	NA	NA
SA-600108-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.70	NM	7.60	NA	NA	NA
SA-600108-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.72	NM	2.01	NA	NA	NA
SA-600108-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.86	NM	7.39	NA	NA	NA
SA-600108-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.59	NM	2.92	NA	NA	NA
SA-600108-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.86	NM	8.86	NA	NA	NA
SA-600110 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Sample was frozen	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	145	NM	7.60	NM	NM	NM	NA	NA	NA
SA-600110	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Clumps of clay and plant roots	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600110-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	169.3, 367.8	NM	7.33	7.42	4.05	NA	NA	NA
SA-600110-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600110-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	160.3, 358.8	NM	7.54	7.41	4.92	NA	NA	NA
SA-600110-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	169.2, 367.7	NM	7.60	7.61	4.24	NA	NA	NA
SA-600110-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	175.5, 374.0	NM	7.75	7.40	4.75	NA	NA	NA
SA-600110-1MON-DI	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	194.8, 393.3	NM	7.69	7.35	3.08	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600110-1MON-OF	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	202.4, 400.9	NM	7.43	7.35	3.85	NA	NA	NA
SA-600110-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.59	NM	2.74	NA	NA	NA
SA-600110-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.79	NM	3.44	NA	NA	NA
SA-600110-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.57	NM	3.16	NA	NA	NA
SA-600110-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.78	NM	4.14	NA	NA	NA
SA-600110-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.55	NM	4.32	NA	NA	NA
SA-600110-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.78	NM	5.78	NA	NA	NA
SA-600112 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Many arthropods found alive	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	218	NM	7.74	NM	NM	NA	NA	NA	NA
SA-600112	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Found some growing green grass	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600112-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	161.7, 360.2	NM	7.56	7.67	9.32	NA	NA	NA
SA-600112-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	7.58	NA	NA	NA	NA
SA-600112-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	146.5, 345.0	NM	8.03	NM	13.2	NA	NA	NA
SA-600112-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	163.3, 361.8	NM	7.48	7.72	10.8	NA	NA	NA
SA-600112-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	171.1, 369.6	NM	7.69	7.35	13.9	NA	NA	NA
SA-600112-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	188.4, 386.9	NM	7.66	7.48	10.3	NA	NA	NA
SA-600112-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	183.4, 381.9	NM	7.77	7.41	11.2	NA	NA	NA
SA-600112-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.73	NM	9.39	NA	NA	NA
SA-600112-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.84	NM	11.8	NA	NA	NA
SA-600112-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.93	NM	9.33	NA	NA	NA
SA-600112-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	8.04	NM	11.1	NA	NA	NA
SA-600112-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.82	NM	12.7	NA	NA	NA
SA-600112-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.84	NM	15.5	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600113A Init.		5/14/2008	**Heatcut at eastern end of wetland**	Initial interstitial water sample	Very wet. Mold growing on surface	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	21.8	NM	6.94	NM	NM	NM	NA	NA	NA
SA-600113A	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Moderate plant content (some growing)	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600113A-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	64, 262.5	NM	3.86	5.88	0.01	NA	NA	NA
SA-600113A-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600113A-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	134.2, 332.7	NM	4.14	5.34	0.01	NA	NA	NA
SA-600113A-BL-IW	10	4/3/2008		Interstitial water collected before homogenization		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.41	NM	0.01	NA	NA	NA
SA-600113A-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	57.7, 256.2	NM	6.74	6.12	0.18	NA	NA	NA
SA-600113A-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	14.9, 213.4	NM	7.16	6.38	0.29	NA	NA	NA
SA-600113A-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	-55	NM	3.88	6.50	0.30	NA	NA	NA
SA-600113A-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	-73	NM	6.55	6.49	0.28	NA	NA	NA
SA-600113A-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.74	NM	0.05	NA	NA	NA
SA-600113A-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.87	NM	0.1	NA	NA	NA
SA-600113A-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.75	NM	0.43	NA	NA	NA
SA-600113A-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.08	NM	0.31	NA	NA	NA
SA-600113A-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.06	NM	0.01	NA	NA	NA
SA-600113A-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.80	NM	0.01	NA	NA	NA
SA-600113B Init.		5/14/2008	**Headcut at eastern end of wetland**	Initial interstitial water sample	Not many macros	71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	69.1	NM	6.36	NM	NM	NM	NA	NA	NA
SA-600113B	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600113B-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	142.7, 341.2	NM	4.59	5.82	0.07	NA	NA	NA
SA-600113B-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NA	NA	NA
SA-600113B-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	134.8, 333.3	NM	6.19	5.98	0.44	NA	NA	NA
SA-600113B-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	5.02	NM	0.1	NA	NA	NA
SA-600113B-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	155.5, 354.0	NM	6.77	6.36	0.12	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600113B-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	150.2, 348.7	NM	6.61	6.52	0.49	NA	NA	NA
SA-600113B-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	94, 292.5	NM	6.20	6.49	0.1	NA	NA	NA
SA-600113B-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	105.3, 303.8	NM	6.97	6.59	0.1	NA	NA	NA
SA-600113B-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	0.1	NA	NA	NA
SA-600113B-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.56	NM	0.1	NA	NA	NA
SA-600113B-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	5.24	NM	0.16	NA	NA	NA
SA-600113B-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.91	NM	0.12	NA	NA	NA
SA-600113B-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.89	NM	0.01	NA	NA	NA
SA-600113B-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.92	NM	0.01	NA	NA	NA
SA-600115 Init.		5/14/2008	**Dry bank east of wetland (old cattails)**	Initial sample. Measurements made in a 1:1 slurry	Sand grains in mud	0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	471	NM	3.85	NM	NM	NA	NA	NA	NA
SA-600115	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600115-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	314.4, 512.9	NM	3.70	3.85	0.24	NA	NA	NA
SA-600115-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600115-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	304.8, 503.3	NM	3.72	3.87	0.01	NA	NA	NA
SA-600115-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	327.8, 526.3	NM	4.04	3.84	0.01	NA	NA	NA
SA-600115-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	318.9, 517.4	NM	4.09	3.89	0.01	NA	NA	NA
SA-600115-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	317.9, 516.4	NM	3.98	3.86	0.01	NA	NA	NA
SA-600115-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	311.3, 509.8	NM	5.04	3.89	0.18	NA	NA	NA
SA-600115-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.83	NM	0.1	NA	NA	NA
SA-600115-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.88	NM	0.1	NA	NA	NA
SA-600115-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.77	NM	0.1	NA	NA	NA
SA-600115-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.75	NM	0.1	NA	NA	NA
SA-600115-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.74	NM	0.01	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600115-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	3.80	NM	0.01	NA	NA	NA
SA-600905 Init.		5/14/2008	**Within active portion of wetland**	Initial interstitial water sample	Very wet. Aprox. half plant material	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	-105	NM	6.76	NM	NM	NA	NA	NA	NA
SA-600905	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600905-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	108.6, 307.1	NM	6.83	6.77	0.05	NA	NA	NA
SA-600905-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600905-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	133.1, 331.6	NM	6.99	6.66	0.11	NA	NA	NA
SA-600905-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.89	NM	32.2	NA	NA	NA
SA-600905-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	103.5, 302.0	NM	7.40	7.08	0.74	NA	NA	NA
SA-600905-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	71.4, 269.9	NM	7.65	6.99	0.64	NA	NA	NA
SA-600905-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	82.5, 281.0	NM	6.99	6.94	0.71	NA	NA	NA
SA-600905-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	69.6, 268.1	NM	7.05	6.93	0.23	NA	NA	NA
SA-600905-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.81	NM	0.1	NA	NA	NA
SA-600905-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.97	NM	0.1	NA	NA	NA
SA-600905-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.92	NM	0.48	NA	NA	NA
SA-600905-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.86	NM	0.26	NA	NA	NA
SA-600905-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.43	NM	0.23	NA	NA	NA
SA-600905-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.36	NM	0.1	NA	NA	NA
SA-600906 Init.		5/14/2008	**Central portion of active wetland**	Initial interstitial water sample	High plant material (mostly roots)	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	-158	NM	6.64	NM	NM	NA	NA	NA	NA
SA-600906	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NA	NA	NA	NA
SA-600906-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	114.8, 313.3	NM	6.95	6.78	0.03	NA	NA	NA
SA-600906-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	113.3, 311.8	NM	NM	NM	NA	NA	NA	NA
SA-600906-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.31	6.86	0.15	NA	NA	NA
SA-600906-BL-IW	10	4/9/2008		Interstitial water collected before homogenization		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.97	NM	31.1	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Ni rslt (ppm)	NO2(ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	NO3-N (U)	C2O4 rslt (ppm)	Pb rslt (ppm)	Initial ORP (mV)	ORP after 2 day leach (mV)	Initial pH	pH	pH after 2 day leach	PO4(-3) rslt (ppm)	Rb rslt (ppm)	S2- rslt (ppm)	Sb rslt (ppm)
SA-600906-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	99.8, 298.3	NM	7.46	7.07	0.13	NA	NA	NA
SA-600906-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	82.4, 280.9	NM	7.54	7.55	0.26	NA	NA	NA
SA-600906-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	-98	NM	7.55	7.28	2.38	NA	NA	NA
SA-600906-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	-96	NM	7.66	7.08	0.1	NA	NA	NA
SA-600906-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.46	NM	2.22	NA	NA	NA
SA-600906-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.34	NM	0.1	NA	NA	NA
SA-600906-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.26	NM	0.11	NA	NA	NA
SA-600906-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.21	NM	0.13	NA	NA	NA
SA-600906-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.43	NM	0.1	NA	NA	NA
SA-600906-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	7.48	NM	0.1	NA	NA	NA
BLANK-1	B-1	4/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.95	NM	0.01, U	NA	NA	NA
BLANK-2	B-2	4/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.55	NM	0.01, U	NA	NA	NA
BLANK-3	B-3	4/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.56	NM	0.01, U	NA	NA	NA
BLANK-4	B-4	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.16	NM	0.01, U	NA	NA	NA
BLANK-5	B-5	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.59	NM	0.01, U	NA	NA	NA
BLANK-6	B-6	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.14	NM	0.01, U	NA	NA	NA
BLANK-7	B-7	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.22	NM	0.01, U	NA	NA	NA
BLANK-8	B-8	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.24	NM	0.01, U	NA	NA	NA
BLANK-9	B-9	6/17/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.44	NM	0.01, U	NA	NA	NA
BLANK-10	B-10	8/20/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	0.01, U	NA	NA	NA
BLANK-11	B-11	8/20/2008				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	0.01, U	NA	NA	NA
BLANK-12	B-12	6/17/2009				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	6.74	NM	0.01, U	NA	NA	NA
BLANK-13	B-13	6/17/2009				n/a	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	4.91	NM	0.01, U	NA	NA	NA

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600108 Init.		5/14/2008	**Bank, upstream of currently active wetland**	Initial sample. Measurements made in a 1:1 slurry	River sand/gravel, little to no organics	20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	7.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.053	0.001	103	1.11	1.36	-0.10
SA-600108-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		20.0–108.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600108-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	22.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.068	0.001	607	8.50	9.26	-0.04
SA-600108-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		20.0–108.0	NA	NA	NA	NA	7.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.052	0.001	109	1.22	1,42	-0.08
SA-600108-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	21.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.099	0.001	556	5.54	9.71	-0.27
SA-600108-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	8.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.046	0.000	144	1.06	2.08	-0.32
SA-600108-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	23.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.096	0.002	546	8.59	8.45	0.01
SA-600108-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	9.32	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.115	0.001	145	1.71	1.88	-0.05
SA-600108-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	23.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.133	0.000	666	8.73	10.60	-0.10
SA-600108-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	13.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.102	0.003	163	2.02	2.09	-0.02
SA-600108-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	25.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.133	0.001	660	9.20	10.31	-0.06
SA-600108-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		20.0–108.0	NA	NA	NA	NA	33.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.005	0.000	209	2.16	3.11	-0.18
SA-600108-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		20.0–108.0	NA	NA	NA	NA	43.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.027	0.001	697	9.68	10.91	-0.06
SA-600110 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Sample was frozen	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Clumps of clay and plant roots	26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	6.29	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.128	0.001	212	2.25	2.81	-0.11
SA-600110-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		26.0–42.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600110-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	20.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.115	0.001	698	9.56	10.44	-0.04
SA-600110-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		26.0–42.0	NA	NA	NA	NA	5.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.122	0.002	177	1.99	2.30	-0.07
SA-600110-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	20.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.127	0.002	701	9.46	10.70	-0.06
SA-600110-1MON-DI	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	9.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.132	0.003	283	2.71	3.87	-0.18

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600110-1MON-OF	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	23.6	NA	NA	NA	NA	NA	NA	NA	NA	0.086	0.002	727	6.50	12.52	-0.32
SA-600110-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	10.2	NA	NA	NA	NA	NA	NA	NA	NA	0.185	0.003	273	3.09	3.56	-0.07
SA-600110-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	24.7	NA	NA	NA	NA	NA	NA	NA	NA	0.212	0.002	776	10.08	12.04	-0.09
SA-600110-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	15.1	NA	NA	NA	NA	NA	NA	NA	NA	0.170	0.003	289	3.31	3.75	-0.06
SA-600110-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	30.1	NA	NA	NA	NA	NA	NA	NA	NA	0.208	0.003	771	10.34	11.87	-0.07
SA-600110-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		26.0–42.0	NA	NA	NA	NA	35.1	NA	NA	NA	NA	NA	NA	NA	NA	0.041	0.001	304	3.29	4.30	-0.13
SA-600110-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		26.0–42.0	NA	NA	NA	NA	46.4	NA	NA	NA	NA	NA	NA	NA	NA	0.086	0.000	786	10.71	12.12	-0.06
SA-600112 Init.		5/14/2008	**Dewatered western portion of wetland**	Initial sample. Measurements made in a 1:1 slurry	Many arthropods found alive	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Found some growing green grass	0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	9.68	NA	NA	NA	NA	NA	NA	NA	NA	0.114	0.001	203	2.13	2.61	-0.10
SA-600112-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–41.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600112-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	25.1	NA	NA	NA	NA	NA	NA	NA	NA	0.106	0.001	742	9.75	11.16	-0.07
SA-600112-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–41.0	NA	NA	NA	NA	8.2	NA	NA	NA	NA	NA	NA	NA	NA	0.086	0.001	218	2.41	2.72	-0.06
SA-600112-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	24.3	NA	NA	NA	NA	NA	NA	NA	NA	0.110	0.002	762	10.14	11.25	-0.05
SA-600112-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	8.67	NA	NA	NA	NA	NA	NA	NA	NA	0.169	0.001	357	2.91	4.79	-0.24
SA-600112-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	24.1	NA	NA	NA	NA	NA	NA	NA	NA	0.127	0.001	727	10.40	10.56	-0.01
SA-600112-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	9.85	NA	NA	NA	NA	NA	NA	NA	NA	0.172	0.002	338	3.72	4.28	-0.07
SA-600112-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	24.6	NA	NA	NA	NA	NA	NA	NA	NA	0.188	0.005	867	10.77	13.14	-0.10
SA-600112-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	12.1	NA	NA	NA	NA	NA	NA	NA	NA	0.130	0.002	314	3.63	3.90	-0.04
SA-600112-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	24.9	NA	NA	NA	NA	NA	NA	NA	NA	0.181	0.003	828	11.15	12.18	-0.04
SA-600112-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–41.0	NA	NA	NA	NA	32.3	NA	NA	NA	NA	NA	NA	NA	NA	0.021	0.000	381	3.99	5.18	-0.13
SA-600112-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–41.0	NA	NA	NA	NA	44.1	NA	NA	NA	NA	NA	NA	NA	NA	0.047	0.002	874	11.37	13.16	-0.07

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600113A Init.		5/14/2008	**Heatcut at eastern end of wetland**	Initial interstitial water sample	Very wet. Mold growing on surface	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A	1	5/14/2008		Moisture content jar. Oven dried @ 110°C	Moderate plant content (some growing)	9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	1403	NA	NA	NA	NA	NA	NA	NA	NA	NA	10.2	0.0	2192	32.98	32.54	0.01
SA-600113A-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		9.0–71.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113A-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	2090	NA	NA	NA	NA	NA	NA	NA	NA	NA	33.8	0.1	3561	54.64	53.35	0.01
SA-600113A-BL-IW	10	4/3/2008		Interstitial water collected before homogenization		9.0–71.0	NA	NA	NA	NA	363	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.46	0.01	782	10.45	12.01	-0.07
SA-600113A-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		9.0–71.0	NA	NA	NA	NA	845	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.25	0.00	1410	22.09	20.67	0.03
SA-600113A-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	885	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.28	0.00	1892	28.33	29.48	-0.02
SA-600113A-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	461	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.71	0.00	894	14.04	13.22	0.03
SA-600113A-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	491	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.86	0.01	1380	21.64	20.99	0.02
SA-600113A-2MON-DI	27	6/16/2008		Dried in fume hood for 2 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	434	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.26	0.03	955	17.52	12.60	0.16
SA-600113A-2MON-OF	28	6/16/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	474	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.20	0.01	1359	22.65	20.31	0.05
SA-600113A-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	598	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.55	0.02	1131	18.57	15.95	0.08
SA-600113A-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	566	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.39	0.01	1469	23.93	21.89	0.04
SA-600113A-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		9.0–71.0	NA	NA	NA	NA	744	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.54	0.01	1338	20.11	19.52	0.01
SA-600113A-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		9.0–71.0	NA	NA	NA	NA	727	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.48	0.01	1703	26.64	25.86	0.01
SA-600113B Init.		5/14/2008	**Headcut at eastern end of wetland**	Initial interstitial water sample	Not many macros	71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	634	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.29	0.01	982	13.48	14.69	-0.04
SA-600113B-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		71.0–101.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600113B-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	645	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.30	0.00	1469	19.24	24.00	-0.11
SA-600113B-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		71.0–101.0	NA	NA	NA	NA	655	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.28	0.00	1131	13.08	19.16	-0.19
SA-600113B-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		71.0–101.0	NA	NA	NA	NA	290	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.20	0.01	516	7.15	7.62	-0.03

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600113B-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	385	NA	NA	NA	NA	NA	NA	NA	NA	0.25	0.00	1064	13.60	18.02	-0.14
SA-600113B-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	226	NA	NA	NA	NA	NA	NA	NA	NA	0.26	0.00	410	5.20	6.23	-0.09
SA-600113B-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	251	NA	NA	NA	NA	NA	NA	NA	NA	0.19	0.00	911	12.38	14.82	-0.09
SA-600113B-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	203	NA	NA	NA	NA	NA	NA	NA	NA	0.26	0.00	377	6.03	5.33	0.06
SA-600113B-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	204	NA	NA	NA	NA	NA	NA	NA	NA	0.29	0.00	785	12.22	12.60	-0.02
SA-600113B-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	226	NA	NA	NA	NA	NA	NA	NA	NA	0.28	0.00	409	6.50	5.77	0.06
SA-600113B-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	227	NA	NA	NA	NA	NA	NA	NA	NA	0.28	0.01	778	12.97	12.17	0.03
SA-600113B-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		71.0–101.0	NA	NA	NA	NA	272	NA	NA	NA	NA	NA	NA	NA	NA	0.04	0.00	540	7.76	7.85	-0.01
SA-600113B-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		71.0–101.0	NA	NA	NA	NA	282	NA	NA	NA	NA	NA	NA	NA	NA	0.06	0.00	946	13.99	15.05	-0.04
SA-600115 Init.		5/14/2008	**Dry bank east of wetland (old cattails)**	Initial sample. Measurements made in a 1:1 slurry	Sand grains in mud	0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	1294	NA	NA	NA	NA	NA	NA	NA	NA	15.5	0.1	2092	26.02	31.25	-0.09
SA-600115-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–30.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600115-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	1304	NA	NA	NA	NA	NA	NA	NA	NA	15.9	0.1	2659	32.97	40.82	-0.11
SA-600115-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–30.0	NA	NA	NA	NA	1202	NA	NA	NA	NA	NA	NA	NA	NA	14.2	0.0	1733	24.11	25.65	-0.03
SA-600115-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	1292	NA	NA	NA	NA	NA	NA	NA	NA	14.9	0.1	2244	31.68	34.52	-0.04
SA-600115-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	1266	NA	NA	NA	NA	NA	NA	NA	NA	14.2	0.1	1844	25.36	27.30	-0.04
SA-600115-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	1279	NA	NA	NA	NA	NA	NA	NA	NA	15.6	0.0	2236	32.39	34.00	-0.02
SA-600115-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	1197	NA	NA	NA	NA	NA	NA	NA	NA	14.1	0.0	1740	24.64	25.43	-0.02
SA-600115-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	1236	NA	NA	NA	NA	NA	NA	NA	NA	14.8	0.1	2160	31.49	32.63	-0.02
SA-600115-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	1274	NA	NA	NA	NA	NA	NA	NA	NA	14.4	0.1	1802	23.78	26.97	-0.06
SA-600115-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	1329	NA	NA	NA	NA	NA	NA	NA	NA	14.8	0.1	2231	30.38	34.46	-0.06
SA-600115-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–30.0	NA	NA	NA	NA	781	NA	NA	NA	NA	NA	NA	NA	NA	14.8	0.0	1364	25.57	17.21	0.20

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600115-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–30.0	NA	NA	NA	NA	795	NA	NA	NA	NA	NA	NA	NA	NA	14.1	0.1	1607	31.37	20.45	0.21
SA-600905 Init.		5/14/2008	**Within active portion of wetland**	Initial interstitial water sample	Very wet. Aprox. half plant material	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	799	NA	NA	NA	NA	NA	NA	NA	NA	0.148	0.007	1872	22.80	28.95	-0.12
SA-600905-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600905-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	1165	NA	NA	NA	NA	NA	NA	NA	NA	0.723	0.008	2653	37.50	40.61	-0.04
SA-600905-BL-IW	10	4/8/2008		Interstitial water collected before homogenization		0.0–15.0	NA	NA	NA	NA	0.24	NA	NA	NA	NA	NA	NA	NA	NA	0.042	0.003	1075	12.99	15.34	-0.08
SA-600905-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	NA	NA	NA	NA	171	NA	NA	NA	NA	NA	NA	NA	NA	0.163	0.005	984	12.37	14.55	-0.08
SA-600905-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	181	NA	NA	NA	NA	NA	NA	NA	NA	0.148	0.004	1427	17.95	22.37	-0.11
SA-600905-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	411	NA	NA	NA	NA	NA	NA	NA	NA	0.203	0.006	1156	15.40	17.50	-0.06
SA-600905-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	389	NA	NA	NA	NA	NA	NA	NA	NA	0.187	0.008	1469	21.51	22.38	-0.02
SA-600905-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	416	NA	NA	NA	NA	NA	NA	NA	NA	0.290	0.005	1111	16.16	16.45	-0.01
SA-600905-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	405	NA	NA	NA	NA	NA	NA	NA	NA	0.291	0.003	1473	21.66	22.75	-0.02
SA-600905-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	417	NA	NA	NA	NA	NA	NA	NA	NA	0.275	0.005	1106	16.86	16.08	0.02
SA-600905-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	371	NA	NA	NA	NA	NA	NA	NA	NA	0.346	0.007	1415	22.55	21.23	0.03
SA-600905-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	606	NA	NA	NA	NA	NA	NA	NA	NA	0.064	0.001	1456	20.63	21.45	-0.02
SA-600905-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	636	NA	NA	NA	NA	NA	NA	NA	NA	0.119	0.002	1883	27.68	28.74	-0.02
SA-600906 Init.		5/14/2008	**Central portion of active wetland**	Initial interstitial water sample	High plant material (mostly roots)	0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906	1	5/14/2008		Moisture content jar. Oven dried @ 110°C		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-DI	7	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	682	NA	NA	NA	NA	NA	NA	NA	NA	0.160	0.004	1551	17.22	23.71	-0.16
SA-600906-BL-OF24	8a	5/13/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water, Cr 6+ check @ 24hrs		0.0–15.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SA-600906-BL-OF48	8b	5/14/2008		Vacuum dried @ 25°C until dry, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	747	NA	NA	NA	NA	NA	NA	NA	NA	0.196	0.005	1985	23.84	32.05	-0.15
SA-600906-BL-IW	10	4/9/2008		Interstitial water collected before homogenization		0.0–15.0	NA	NA	NA	NA	0.1, U	NA	NA	NA	NA	NA	NA	NA	NA	0.037	0.004	1327	14.28	18.09	-0.12

Table J-4.0-1 (continued)

Sample ID	ER ID #	Date Received	Location	Description	Sample Content	Depth Range (cm)	Se rslt (ppm)	Si rslt (ppm)	SiO2 rslt (ppm)	Sn rslt (ppm)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	Th rslt (ppm)	Ti rslt (ppm)	Tl rslt (ppm)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
SA-600906-DRY-DI	21	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ DI water		0.0–15.0	NA	NA	NA	NA	275	NA	NA	NA	NA	NA	NA	NA	NA	0.134	0.004	869	8.67	13.34	-0.21
SA-600906-DRY-OF	22	4/17/2008		Oven dried @ 40°C for 2 days, Leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	136	NA	NA	NA	NA	NA	NA	NA	NA	0.156	0.005	1217	15.88	18.29	-0.07
SA-600906-1MON-DI	24	5/15/2008		Dried in fume hood for 1 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	292	NA	NA	NA	NA	NA	NA	NA	NA	0.062	0.003	861	9.16	13.14	-0.18
SA-600906-1MON-OF	25	5/15/2008		Dried in fume hood for 1 month, leached w/SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	262	NA	NA	NA	NA	NA	NA	NA	NA	0.131	0.004	1245	16.65	19.09	-0.07
SA-600906-2MON-DI	27	6/17/2008		Dried in fume hood for 2 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	249	NA	NA	NA	NA	NA	NA	NA	NA	0.184	0.000	876	10.94	12.36	-0.06
SA-600906-2MON-OF	28	6/17/2008		Dried in fume hood for 2 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	268	NA	NA	NA	NA	NA	NA	NA	NA	0.199	0.004	1275	17.63	19.28	-0.04
SA-600906-4MON-DI	30	8/20/2008		Dried in fume hood for 4 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	215	NA	NA	NA	NA	NA	NA	NA	NA	0.191	0.004	741	11.35	9.97	0.06
SA-600906-4MON-OF	31	8/20/2008		Dried in fume hood for 4 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	237	NA	NA	NA	NA	NA	NA	NA	NA	0.256	0.003	1146	17.50	17.12	0.01
SA-600906-1YR-DI	36	6/18/2009		Dried in fume hood for 12 month, leached w/ DI water		0.0–15.0	NA	NA	NA	NA	519	NA	NA	NA	NA	NA	NA	NA	NA	0.11	0.00	1150	16.05	16.63	-0.02
SA-600906-1YR-OF	37	6/18/2009		Dried in fume hood for 12 month, leached w/ SWWS Outflow water		0.0–15.0	NA	NA	NA	NA	483	NA	NA	NA	NA	NA	NA	NA	NA	0.11	0.00	1535	21.98	23.27	-0.03
BLANK-1	B-1	4/17/2008				n/a	NA	NA	NA	NA	0.01	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-2	B-2	4/17/2008				n/a	NA	NA	NA	NA	0.02	NA	NA	NA	NA	NA	NA	NA	NA	0.002	0.000	1	0.00	0.03	-1.00
BLANK-3	B-3	4/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-4	B-4	6/17/2008				n/a	NA	NA	NA	NA	0.03	NA	NA	NA	NA	NA	NA	NA	NA	0.001	0.000	1	0.01	0.03	-0.50
BLANK-5	B-5	6/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-6	B-6	6/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-7	B-7	6/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-8	B-8	6/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-9	B-9	6/17/2008				n/a	NA	NA	NA	NA	0.01, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-10	B-10	8/20/2008				n/a	NA	NA	NA	NA	0.1, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.01	0.03	-0.50
BLANK-11	B-11	8/20/2008				n/a	NA	NA	NA	NA	0.1, U	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.00	0.03	-1.00
BLANK-12	B-12	6/17/2009				n/a	NA	NA	NA	NA	0.16	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.01	0.03	-0.50
BLANK-13	B-13	6/17/2009				n/a	NA	NA	NA	NA	0.07	NA	NA	NA	NA	NA	NA	NA	NA	0.001	U	1	0.01	0.03	-0.50

Note: Corrected Eh value is made by adding 198.5 mV to each uncorrected ORP value. Corrections to negative ORP valus were not made due to excel macros. These ORP values can be corrected by adding 198.5 mV to each measurement. Data qualifier definitions are presented in Appendix A.

[a] n/a= Not applicable.

[b] NA = Not analyzed.

[c] NM = Not measured.

Table J-6.0-1
Results of Mass Balance Calculations for Chromium Stability within the Sandia Canyon Wetland

Sample ID	Date Analyzed	Matrix	Qualifier	ER Request number with (sample location)	Solid Concentration Cr (mg/kg)	Solid Concentration Cr(VI) (mg/kg)	uMoles Cr(III)/g soil	uMoles Cr(VI)/g soil	uMoles Mn(IV)/g soil	uMolesMn(IV)/ uMolesCr(III)	Fe (mg/kg) 3050 dig.	Total Fe (mg/kg) (Huffman)	Fe(II) (mg/kg) (Huffman)	uMoles Fe(II)/g soil	uMolesFe(II)/g soil/ uMolesCr(III)/g soil	Potential for Cr(III) to remain reduced based on Fe(II)/Cr(III) ratio good, poor	uMolesFe(II)/g soil/ uMolesMn(VI)/g soil	Potential for Cr(III) to remain reduced based on Fe(II)/Mn(IV) ratio good, poor
casa-07-4012	8/14/2007	solid	J-	07-236 (wetland)	21.5	0.05	0.41	0.001	0.43	1.05	5870	1410	1400	25.07	61.15	good	58.3	good
casa-07-4014	8/14/2007	solid	J-	07-236 (wetland)	36.5	0.07	0.7	0.001	1.73	2.47	6040	6560	6540	117	167.14	good	67.63	good
casa-07-4016	8/14/2007	solid	UJ	07-236 (wetland)	19.0	0.29	0.36	0.006	3.62	10.06	3460	4270	4270	76.5				
casa-07-4018	8/14/2007	solid	J-	07-236 (wetland)	114.0	0.07	2.19	0.001	3.09	1.41	14400	6380	6360	114	52.05	good	36.89	good
casa-07-632	8/14/2007	solid	J+	07-92 (wetland)	11.8	0.16	0.22	0.003	0.48	2.19	11400	SA-600	100	1.79	8.14	good	3.73	good
casa-07-633	8/14/2007	solid	U	07-92 (wetland)	137.0	0.77	2.62	0.015	0.8	0.31	10200	5070	860	15.4				
casa-07-634	8/14/2007	solid	J+	07-92 (wetland)	112.0	0.14	2.15	0.003	1.57	0.73	12300	1380	320	5.73	2.67	poor	3.65	good
casa-07-635	8/14/2007	solid	J+	07-92 (wetland)	51.3	0.04	0.99	0.001	0.72	0.73	10SA-600	1200	210	3.76	3.8	good	4.73	good
casa-07-636	8/14/2007	solid	J+	07-92 (wetland)	16.9	0.12	0.32	0.002	0.97	3.03	9500	1110	210	3.76	11.75	good	3.88	good
casa-07-637	8/14/2007	solid	J+	07-92 (wetland)	3580.0	2.01	68.81	0.039	5.35	0.08	7980	5970	2660	47.6	0.69	poor	8.9	good
casa-07-638	8/14/2007	solid	J+	07-92 (wetland)	601.0	1.06	11.54	0.020	3	0.26	18200	3510	1250	22.4	1.94	poor	7.47	good
casa-07-639	8/14/2007	solid	U	07-92 (wetland)	3740.0	0.69	71.91	0.013	0.72	0.01	18000	10160	620	11.1				
casa-07-640	8/14/2007	solid	J+	07-92 (wetland)	592.0	0.31	11.38	0.006	2.4	0.21	12100	4140	310	5.55	0.49	poor	2.31	good
casa-07-641	8/14/2007	solid	J+	07-92 (wetland)	18.5	0.28	0.35	0.005	0.34	0.97	5070	970	230	4.12	11.77	good	12.12	good

Notes: 3MnO2 + Cr(OH)3 + 3Fe+2 + 4H2O = 2H+ + 3Mn+2 + CrO4-2 + 3Fe(OH)3. 3 : 1 Mole ratio of Fe(II) to Cr(III) required to maintainCr(III) stability. 1: 1 Mole ratio of Fe(II) to Mn(IV) required to maintainCr(III) stability.

Appendix K

Wetland Plant Uptake Investigations

K-1.0 INTRODUCTION

Metal and nutrient uptake by cattails was investigated as part of contaminant studies in the Sandia wetland in reach S-2. Metal concentrations, $\delta^{15}N$, $\delta^{13}C$ and carbon-nitrogen ratios (C/N) in roots/rhizomes and leaves of cattails at four sites were determined, along with metal concentrations in collocated sediment samples.

K-2.0 METHODS

Samples were collected on June 20, 2007, at four equally spaced locations along the length of the primary cattail wetland (c1ct unit; active channel with cattails) in reach S-2 of Sandia Canyon. Table K-2.0-1 shows sampling locations and identifications for plant and associated sediment samples. Sampling locations are shown on Plate 3. All cattails were collected from saturated sediments in the center of the c1ct unit. Samples of roots/rhizomes were carefully cleaned in the field using site water to minimize adhering sediment. The western location (SA-600904) had mostly coarse-grained sediment with a median particle size of medium sand, and the other three locations were finer grained, with a median particle size of coarse silt (particle-size data are presented in Table B-1.0-5).

Metals were analyzed at Huffman Laboratories, Inc. Samples for metals analysis were transferred to polypropylene drying trays and dried at room temperature (nominal 20°C). Dried samples were ground to a fine clippings size, and splits of approximately 50 g of the homogenized clippings were then fine ground to a nominal minus 200 mesh(<75 µm) size. This fine-ground material was stored in airtight glass jars and was used for all subsequent analyses. Samples were digested with nitric then refluxing perchloric acids to fully oxidize all organic matter. Hydrofluoric acid, which will solubilize silicate minerals within silt- and clay-sized fractions in or on the samples, was not used. Hexavalent chromium was measured using the U.S. Environmental Protection Agency (EPA) Method 3060A digestion protocol, which provides for leaching of the ground plant material with a phosphate buffered sodium carbonate/sodium hydroxide solution with agitation at 95 °C. An analysis for percent ash after stage ashing in air to 750°C and holding at temperature for 8 h was performed to give an indication of the inorganic content of the samples, including material incorporated into the plant tissue as well as material present as external residual mineral grains.

Aluminum, barium, calcium, iron, potassium, magnesium, manganese, sodium, vanadium, and zinc were analyzed by inductively coupled plasma–atomic emission spectroscopy (ICP-AES), using a Perkin-Elmer 5300 DV instrument. Other metals (see Table K-2.0-2), except for mercury and hexavalent Cr [Cr(VI)], are reported from measurement by inductively coupled plasma mass spectrometry (ICPMS) using a Perkin Elmer Elan 6100 DRC Plus instrument. Mercury was measured by cold vapor atomic absorption spectrophotometry, using a Milestone DMA-80 instrument. Hexavalent chromium was measured by digestion in base followed by chelation ion chromatography using a Dionex 4500i instrument with an NG-1 guard column and an AS-7 separator column. All metals analyses were performed on three separately weighed sample portions (sample, sample duplicate [laboratory duplicate], sample spiked before preparation). A separate digestion was used to analyze antimony, arsenic, and selenium to allow for a different final acid matrix after digestion and dilution. Measurement of Cr(VI) in aliquots of the leach solution was performed using EPA Method 7199, which provides for separation of Cr(VI) by ion chromatography, postcolumn derivatization with diphenylcarbazide, and ultraviolet detection of the resulting complex.

Samples for isotope analyses were placed in Ziplock bags, and then stored at 0°C. An aliquot of each sample was subsequently placed in paper bags and dried at 60°C for 48 h. Dried material was ground to

a fine powder using an Udy mill. These powders were then analyzed on a Micromass isotope ratio mass spectrometer for $\delta^{13}C$, $\delta^{15}N$, and C/N (i.e., the ratio of elemental carbon to nitrogen).

K-3.0 RESULTS AND DISCUSSION

Results of metals analyses are shown in Table K-2.0-2. Calculations of potential cattail sediment bioaccumulation factors are shown in Table K-3.0-1. Isotope and C/N results are shown in Table K-3.0-2.

As shown in Table K-2.0-2, no Cr(VI) was detected in any of the cattail samples at a detection limit of 0.01 mg/kg, and there was no recovery of Cr(VI) spikes added to the samples prior to digestion. Spiked method blanks carried through the procedure gave excellent recovery of added Cr(VI), and spiked standard reference materials (National Institute of Standards and Technology [NIST] vegetation and soils) also gave good recoveries. The lack of Cr(VI) and no recovery of Cr(VI) spikes in the cattail samples indicate a reducing sample matrix where Cr(VI), including Cr(VI) added in the lab as a spike, is not stable and becomes reduced to Cr(III). Significant levels of total Cr were found in the cattails. Given that no Cr(VI) was found in the samples, it would appear that either all the primary (nonspike) chromium present in the cattail samples was in reduced form [i.e., Cr(III)] or any Cr(VI) originally contained in the sample was reduced to Cr(III) during sample digestion. It is not known if the reducing nature of the cattail samples is because of the organic matter comprising the cattails proper or because of the possible presence of exogenous organic matter, sulfide, or ferrous iron contained within or on the tissues. Whatever the reductant, it would have to be present in significantly higher concentrations in the cattail samples than in spiked NIST vegetation and soils, as these yielded good spike recovery. It is possible, for example, that cattail tissue fluids contained ferrous iron that was oxidized upon digestion with oxidizing acids. Any Cr(VI) in the samples may have subsequently been reduced to trivalent Cr [Cr(III)] in a redox reaction coupled to ferrous iron oxidation. Cr(III) typically only oxidizes back to Cr(VI) during a coupled redox reaction in which Mn(IV) is reduced to Mn(II). Cattail iron concentrations range from approximately 100 to 1000 mg/kg (Table K-2.0-2) and chromium and iron concentrations in the cattails are highly correlated (Pearson correlation coefficient of 0.97, $p<0.001$). Iron speciation was not determined. Appendix J presents further discussion on reductants present in Sandia wetland sediments, and the capacity for Fe(II) to keep chromium in its reduced state in the wetland as a whole. Given the predominance of Cr(III) over Cr(VI) in wetland sediments (see section 7.1.1), it is likely that most of the total chromium measured in the cattails was in the form of Cr(III). It is possible that Cr(VI) reduction associated with oxidation of Fe(II) could occur within cattails growing in situ in the wetland sediments because cattails actively pump atmospheric oxygen to their roots and into surrounding sediments.

All metal concentrations, except for cadmium, magnesium, selenium and Cr(VI), correlate significantly ($p<0.1$) with ash content. Therefore, it is possible that a significant portion of the metals detected in cattail samples is from mineral material incorporated into the plant tissue as well as material present as external mineral grains. Total chromium is highly correlated to ash content with a Pearson correlation coefficient of 0.93 ($p<0.001$). Ash contents range from approximately 9% to 27 % by weight in the cattails, with leaves on the lower end of the range and roots/rhizomes having higher ash contents. With the caveat that metals concentrations in cattails may not reflect plant uptake of metals, potential plant bioaccumulation factors are presented in Table K-3.0-1. Most metals have potential plant bioaccumulation factors less than or close to unity, where bioaccumulation factors are defined as the ratio of metal concentration in cattails divided by metal concentration in the sediment (as determined from a weak acid leach of sediment plus associated pore water). These results suggest, for example, that cattail leaves do not represent a significant reservoir in terms of chromium mass balance calculations. Sodium, potassium, magnesium, manganese, and silver do exhibit potential bioaccumulation factors significantly greater than unity (herein, bioaccumulation factors greater than 2 are considered significant), with silver having higher

concentrations in rhizomes but not in leaves in three out of four samples. Sodium, potassium, and magnesium are important elements for metabolism. Potassium, for example, is an important ingredient in most plant fertilizers. Manganese may accumulate in cattails from accumulation of manganese oxides formed from oxidation of Mn(II) to Mn(IV) as oxygen is pumped through cattail leaves to rhizomes. Silver may be the only element that is truly bioaccumulated in cattail tissues in the Sandia wetland.

The $\delta^{13}C$ signature of cattail leaves and roots is typical of most plants. The $\delta^{15}N$ signature of the cattails is consistent with a predominantly sewage source of nitrogen (Heikoop et al. 2002, 107001; Fair and Heikoop 2006, 098045). The very heavy value of ~40‰ in the roots/rhizomes of sample CASA-07-4013 likely indicates the occurrence of denitrification in the sediments surrounding this cattail. Denitrification results in residual nitrate enriched in the heavy isotope of nitrogen (Heikoop et al., 2002, ER-ID). These results demonstrate that the cattails actively take up sewage nitrogen and that the wetland constitutes an actively denitrifying environment. Both factors can lead to partial attenuation of nitrate released to the Sandia wetland. With the exception of sample CASA-07 4013, roots/rhizomes typically have higher C/N than leaves. This finding probably reflects the fact that plant samples were collected during the active growing season when nitrogen taken up by roots will tend to be translocated to leaves to support new growth.

K-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Fair, J.M., and J.M. Heikoop, 2006. "Stable Isotope Dynamics of Nitrogen Sewage Effluent Uptake in a Semi-Arid Wetland," *Environmental Pollution,* Vol. 140, pp. 500-505. (Fair and Heikoop 2006, 098045)

Heikoop, J.M., D.D. Hickmott, D. Katzman, P. Longmire, and R.S. Beers, 2002. "N-15 Signals of Nitrogen Source and Fate in a Semiarid Wetland," Wetlands and Remediation II, Proceedings of the Second International Conference on Wetlands and Remediation, September 5–6, 2001, Burlington, Vermont, pp. 355–362. (Heikoop et al. 2002, 107001)

Table K-2.0-1
Sandia Wetland Cattail and
Collocated Sediment Samples

Sample ID	Location ID	Depth (cm)	Media
CASA-07-4024	SA-600904	n/a[a]	Leaves
CASA-07-4013	SA-600904	n/a	Roots
CASA-07-4012	SA-600904	0–15	Sediment
CASA-07-4025	SA-600905	n/a	Leaves
CASA-07-4015	SA-600905	n/a	Roots
CASA-07-4014	SA-600905	0–15	Sediment
CASA-07-4026	SA-600906	n/a	Leaves
CASA-07-4017	SA-600906	n/a	Roots
CASA-07-4016	SA-600906	0–15	Sediment
CASA-07-4027	SA-600907	n/a	Leaves
CASA-07-4019	SA-600907	n/a	Roots
CASA-07-4018	SA-600907	0–15	Sediment
CASA-07-4020[b]	SA-600907	n/a	Leaves

[a] n/a = Not applicable.

[b] CASA-07-4020 is a QA duplicate.

Table K-2.0-2
Metal Concentrations in Sandia Wetland Cattail Samples

Location	Sample Type	Sample ID	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cr+6	Cu	Fe	Hg
SA-600904	Leaves	CASA-07-4024	0.04	44	0.18	22	0.00	10267	0.05	0.12	5.0	0.00	3.1	84	0.013
SA-600904	Roots	CASA-07-4013	0.56	992	1.33	42	0.06	6311	0.14	1.02	24.6	0.00	10.3	2516	0.041
SA-600905	Leaves	CASA-07-4025	0.10	193	0.22	37	0.02	8779	0.04	0.28	7.1	0.00	3.9	222	0.017
SA-600905	Roots	CASA-07-4015	1.75	3761	3.34	80	0.20	7153	0.30	2.71	39.1	0.00	19.6	7262	0.092
SA-600906	Leaves	CASA-07-4026	0.05	96	0.20	26	0.01	8589	0.04	0.17	5.4	0.00	2.1	119	0.014
SA-600906	Roots	CASA-07-4017	0.71	1653	2.99	62	0.12	7989	0.26	1.56	22.5	0.00	11.5	4437	0.052
SA-600907	Leaves	CASA-07-4027	0.07	61	0.19	43	0.01	10444	0.05	0.23	5.0	0.00	3.0	85	0.013
SA-600907	Leaves	CASA-07-4020	0.04	49	0.15	33	0.01	8360	0.04	0.29	7.9	0.00	3.0	89	0.012
SA-600907	Roots	CASA-07-4019	3.48	2656	3.48	75	0.16	8226	0.61	1.95	26.2	0.00	21.1	5427	0.072

Table K-2.0-2 (continued)

Location	Sample Type	Sample ID	K	Mg	Mn	Na	Ni	Pb	Sb	Se	Tl	V	Zn	Ash
SA-600904	Leaves	CASA-07-4024	42248	2259	322	3963	0.6	0.2	-0.1	1.1	0.003	0.1	28	10.80
SA-600904	Roots	CASA-07-4013	18048	2014	158	8953	6.0	4.7	0.1	1.1	0.023	5.1	95	17.80
SA-600905	Leaves	CASA-07-4025	26031	1817	521	6079	1.5	0.8	-0.1	0.3	0.004	0.4	50	9.09
SA-600905	Roots	CASA-07-4015	9611	2450	288	8238	11.8	10.0	0.2	-0.1	0.059	15.4	444	26.95
SA-600906	Leaves	CASA-07-4026	31059	1688	583	4071	0.8	0.3	0.0	0.6	0.003	0.2	25	8.61
SA-600906	Roots	CASA-07-4017	10332	2275	389	7144	7.8	6.0	0.3	-0.1	0.036	12.8	294	11.94
SA-600907	Leaves	CASA-07-4027	32993	1791	723	3832	0.9	0.2	-0.1	1.4	0.003	0.1	35	8.91
SA-600907	Leaves	CASA-07-4020	31582	1812	601	3231	2.6	0.2	0.0	0.9	0.003	0.1	26	8.60
SA-600907	Roots	CASA-07-4019	14553	3068	433	8759	8.1	9.0	0.2	0.5	0.052	13.8	284	16.30

Notes: All concentrations in mg/kg except ash which is measured in units of weight %. Negative concentration values are treated as nondetects.

Table K-3.0-1
Sediment Metal Concentrations and Associated Potential Plant Accumulation Factors

Location ID	Sample ID	Sample Type	Ag	Al	As	Ba	Be	Cd	Co	Cr	Cr(VI)	Cu	Fe
SA-600904	CASA-07-4012	Sediment	0.182	1720	1.25	31.6	1.21	0.728	1.54	21.5	0.0501	9.48	5870
	CASA-07-4024	Leaves	0.04	44	0.18	22	0	0.05	0.12	5	0	3.1	84
	CASA-07-4013	Roots	0.56	992	1.33	42	0.06	0.14	1.02	24.6	0	10.3	2516
		Accumulation factor leaves	0.22	0.03	0.14	0.70	0.00	0.07	0.08	0.23	0.00	0.33	0.01
		Accumulation factor roots	**3.08**	0.58	1.06	1.33	0.05	0.19	0.66	1.14	0.00	1.09	0.43
SA-600905	CASA-07-4014	Sediment	1.36	2760	4.43	61.6	3.97	1.48	2.05	36.5	0.07	20.6	6040
	CASA-07-4025	Leaves	0.1	193	0.22	37	0.02	0.04	0.28	7.1	0	3.9	222
	CASA-07-4015	Roots	1.75	3761	3.34	80	0.2	0.3	2.71	39.1	0	19.6	7262
		Accumulation factor leaves	0.07	0.07	0.05	0.60	0.01	0.03	0.14	0.19	0.00	0.19	0.04
		Accumulation factor roots	1.29	1.36	0.75	1.30	0.05	0.20	1.32	1.07	0.00	0.95	1.20
SA-600906	CASA-07-4016	Sediment	0.348	1380	2.9	35.2	3.61	0.676	4.14	19	0.293	21.2	3460
	CASA-07-4026	Leaves	0.05	96	0.2	26	0.01	0.04	0.17	5.4	0	2.1	119
	CASA-07-4017	Roots	0.71	1653	2.99	62	0.12	0.26	1.56	22.5	0	11.5	4437
		Accumulation factor leaves	0.14	0.07	0.07	0.74	0.00	0.06	0.04	0.28	0.00	0.10	0.03
		Accumulation factor roots	**2.04**	1.20	1.03	1.76	0.03	0.38	0.38	1.18	0.00	0.54	1.28
SA-600907	CASA-07-4018	Sediment	0.195	8400	5.72	170	1.81	0.731	5.07	114	0.0707	49.1	14400
	CASA-07-4027	Leaves	0.07	61	0.19	43	0.01	0.05	0.23	5	0	3	85
	CASA-07-4019	Roots	3.48	2656	3.48	75	0.16	0.61	1.95	26.2	0	21.1	5427
		Accumulation factor leaves	0.36	0.01	0.03	0.25	0.01	0.07	0.05	0.04	0.00	0.06	0.01
		Accumulation factor roots	**17.85**	0.32	0.61	0.44	0.09	0.83	0.38	0.23	0.00	0.43	0.38

Table K-3.0-1 (continued)

Location ID	Sample ID	Sample Type	Hg	K	Mg	Mn	Na	Ni	Pb	Se	Tl	V	Zn
SA-600904	CASA-07-4012	Sediment	0.0864	496	690	89.4	153	12	14.4	1.04	0.41	12.4	87.5
	CASA-07-4024	Leaves	0.013	42248	2259	322	3963	0.6	0.2	1.1	0.003	0.1	28
	CASA-07-4013	Roots	0.041	18048	2014	158	8953	6	4.7	1.1	0.023	5.1	95
		Accumulation factor leaves	0.15	**85.18**	**3.27**	**3.60**	**25.90**	0.05	0.01	1.06	0.01	0.01	0.32
		Accumulation factor roots	0.47	**36.39**	**2.92**	1.77	**58.52**	0.50	0.33	1.06	0.06	0.41	1.09
SA-600905	CASA-07-4014	Sediment	0.154	687	871	101	476	61.1	15	4.43	0.886	10.5	293
	CASA-07-4025	Leaves	0.017	26031	1817	521	6079	1.5	0.8	0.3	0.004	0.4	50
	CASA-07-4015	Roots	0.092	9611	2450	288	8238	11.8	10	-0.1	0.059	15.4	444
		Accumulation factor leaves	0.11	**37.89**	**2.09**	**5.16**	**12.77**	0.02	0.05	0.07	0.00	0.04	0.17
		Accumulation factor roots	0.60	**13.99**	**2.81**	**2.85**	**17.31**	0.19	0.67	-0.02	0.07	1.47	1.52
SA-600906	CASA-07-4016	Sediment	0.122	408	484	118	423	38.2	13.6	4.38	1.06	11.9	618
	CASA-07-4026	Leaves	0.014	31059	1688	583	4071	0.8	0.3	0.6	0.003	0.2	25
	CASA-07-4017	Roots	0.052	10332	2275	389	7144	7.8	6	-0.1	0.036	12.8	294
		Accumulation factor leaves	0.11	**76.13**	**3.49**	**4.94**	**9.62**	0.02	0.02	0.14	0.00	0.02	0.04
		Accumulation factor roots	0.43	**25.32**	**4.70**	**3.30**	**16.89**	0.20	0.44	-0.02	0.03	1.08	0.48
SA-600907	CASA-07-4018	Sediment	0.282	1720	2350	354	472	15.2	36.9	3.18	0.337	31.6	378
	CASA-07-4027	Leaves	0.013	32993	1791	723	3832	0.9	0.2	1.4	0.003	0.1	35
	CASA-07-4019	Roots	0.072	14553	3068	433	8759	8.1	9	0.5	0.052	13.8	284
		Accumulation factor leaves	0.05	**19.18**	**0.76**	**2.04**	**8.12**	0.06	0.01	0.44	0.01	0.00	0.09
		Accumulation factor roots	0.26	**8.46**	**1.31**	**1.22**	**18.56**	0.53	0.24	0.16	0.15	0.44	0.75

Note: All concentrations are in mg/kg. Bolded red values have accumulation factors greater than 2.

Table K-3.0-2
Sandia Wetland Cattail $\delta^{13}C$, $\delta^{15}N$ and C/N

Sample ID	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C/N
CASA-07 4024	-26.84	20.83	18.54
CASA-07 4024 (D)	-26.98	21.06	17.74
CASA-07 4025	-27.29	24.57	25.69
CASA-07 4026	-27.67	24.28	18.69
CASA-07 4027	-27.58	21.55	22.48
CASA-07 4013	-27.07	40.04	18.18
CASA-07 4015	-27.17	19.67	44.62
CASA-07 4017	-27.14	19.19	52.06
CASA-07 4019	-26.38	20.20	27.00

Appendix L

Analytical Simulation of Chromium Contaminant Transport in the Regional Aquifer and Estimation of the Potential Locations of Contaminant Arrival at the Top of the Regional Aquifer

L-1.0 INTRODUCTION

Numerical flow and transport models of the unsaturated zone and the regional aquifer in the Sandia Canyon area are discussed in Appendix J of the chromium fate and transport update report (LANL 2008, 102996). In this report, an alternative approach for simulation is applied that uses an analytical solution of contaminant transport in the regional aquifer. The analytical model was developed to inform and enhance the understanding of the fate and transport of chromium in the environment. The goals of this study are to (1) calibrate the analytical model against available chromium concentration data observed in the regional aquifer, (2) estimate potential locations of contaminant arrival at the regional water table based on the available site data, and (3) estimate spatial and temporal (past and current) distributions of contaminant mass in the regional aquifer and their associated uncertainties. The simulations do not represent groundwater transport in the unsaturated zone; vadose zone modeling is addressed in Appendix J of the chromium fate and transport modeling report (LANL 2008, 102996). The effects of geochemical interactions of contaminants with rocks along the flow paths are also not considered. This appendix describes the current state of the development of this model and discusses the modeling results.

L-2.0 ANALYTICAL SOLUTIONS OF CONTAMINANT TRANSPORT

The analytical solution for concentration $c(x,y,z,t)$ of a contaminant released at a point source in the regional aquifer with coordinates (0, 0, z_0) has the following form (cf., Wexler 1992, 106994; Wang et al. 2004, 090535):

$$c(x,y,z,t) = \frac{1}{8\theta(v\pi)^{3/2}\sqrt{\alpha_L \alpha_{TH} \alpha_{TV}}} \int_0^t \frac{I(t-\tau)}{(\tau)^{3/2}} \exp\left(-\lambda - \frac{(x-v\tau)^2}{4\alpha_L v\tau} - \frac{y^2}{4\alpha_{TH} v\tau}\right) \times \left\{ exp\left[-\frac{(z-z_0)^2}{4\alpha_{TV} v\tau}\right] + exp\left[-\frac{(z+z_0)^2}{4\alpha_{TV} v\tau}\right] \right\} d\tau$$

Equation L-1

where α_L, α_{TH}, and α_{TV} are the longitudinal, transverse horizontal, and transverse vertical dispersivities [L], respectively; λ is the decay constant [T^{-1}]; θ is effective transport porosity [-], and $I(t)$ is the contaminant mass flux (mass per unit time) [MT^{-1}]. The contaminant flux in this case can be transient and vary in any functional or piecewise fashion. The groundwater flow occurs along the *x* solution axis with Darcy velocity *v*. The solution represents flow in a uniform aquifer bounded at the top (z = 0) and with infinitive thickness. If z_0 = 0, the source location will be at the top of the aquifer (at the regional water table). Since the size of the location where contaminants have reached the regional aquifer is expected to have some dimensions (larger than a point with zero size), an analytical solution is applied to simulate the transport for the concentration of chromium $c(x,y,z,t)$ released at a finite dimension source within the region aquifer (Figure L-2.0-1) (cf., Wexler 1992, 106994; Wang et al. 2004, 090535):

$$c(x,y,z,t) = \frac{1}{8\pi x_S y_S z_S}\int_0^t I(t-\tau)\exp(-\lambda\tau)\left[erfc\left(\frac{x-\frac{1}{2}x_S-v\tau}{2\sqrt{\alpha_L v\tau}}\right)-erfc\left(\frac{x+\frac{1}{2}x_S-v\tau}{2\sqrt{\alpha_L v\tau}}\right)\right]$$
$$\times\left[erfc\left(\frac{y-\frac{1}{2}y_S-v\tau}{2\sqrt{\alpha_{TH} v\tau}}\right)-erfc\left(\frac{y+\frac{1}{2}y_S-v\tau}{2\sqrt{\alpha_{TH} v\tau}}\right)\right]$$
$$\times\left[erfc\left(\frac{z-(z_0+z_S)}{2\sqrt{\alpha_{TV} v\tau}}\right)-erfc\left(\frac{z-z_0}{2\sqrt{\alpha_{TV} v\tau}}\right)+erfc\left(\frac{z+(z_0+z_S)}{2\sqrt{\alpha_{TV} v\tau}}\right)\right.$$
$$\left.-erfc\left(\frac{z+z_0}{2\sqrt{\alpha_{TV} v\tau}}\right)\right]d\tau$$

Equation L-2

The only difference between solutions in Equations L-1 and L-2 is the size of the region within which the contaminants are released into the regional aquifer. In Equation L-2, the region has a parallelepiped (box) shape with dimensions x_S, y_S, and z_S along each axes, respectively (Figure L-2.0-1), revealing the depth of the source below the water table; if $z_0 = 0$, the source location will be at the top of the aquifer. Equations L-1 and L-2 suggest that if contaminant mass flux is steady, after some time, the contaminant concentrations will reach steady values as well. As a result, the plume will reach steady shape, which will be manifested by steady contour lines of contaminant concentrations. Equations L-1 and L-2 do not include the background concentrations of chromium.

It is important to note that various U.S. Geological Survey codes for simulation of contaminant transport (such as ART3D, BIOSCREEN) currently use a solution proposed by Domenico (1987, 106996). However, this solution has been shown to be inaccurate, especially in situations where contaminant transport is dominated by plume dispersion, as demonstrated by other researchers (Srinivasan et al. 2007, 106993; West et al. 2007, 106995). The solution presented in Equation L-2 is used (cf., Wexler 1992, 106994; Wang et al. 2004, 090535) because it simulates three-dimensional contaminant transport.

The major limitations in applying the analytical solution rather than a numerical model for simulation of three-dimensional contaminant transport are that the analytical solution contains some assumptions: (1) the aquifer has uniform hydrogeological properties, (2) groundwater flow is steady state and uniform, (3) pumping effects from water-supply wells cannot be accounted for, and (4) the solution in Equation L-2 does not consider a potential vertical component of the groundwater flow. However, other analytical solutions account for this effect (cf., Wang et al. 2004, 090535). The major benefits in applying the analytical solution rather than a numerical model are (1) execution time is very fast (less than a second); (2) the analytical solution accurately represents aquifer dispersion (numerical models generally overestimate the dispersion as demonstrated in the chromium fate and transport update report (LANL 2008, 102996); (3) aquifer anisotropy can be efficiently captured; and (4) transients in the input contaminant flux and the observed concentrations at the monitoring wells can be easily incorporated in the model. It is important to note that the execution time is critical for the performance of the analyses presented below. The estimation of the potential locations of contaminant arrivals requires on the order of 10^5 to 10^6 analytical model executions. A single execution of a numerical model at the same scale and complexity requires 10 to 60 min.

In the applied method for simulating contaminant transport in the regional aquifer, the anisotropy of the aquifer can be represented using different analytical approaches. The aquifer anisotropy in the horizontal plane is captured by taking into account the uncertainty in the direction of advective transport (caused by groundwater flow). As discussed in Appendix G and shown in Figure G-1.2-1, the hydraulic gradient suggests that the flow direction near R-42 and R-28 is east-southeast. However, there is uncertainty in

this flow-direction estimate because of (1) the relatively small magnitude of the hydraulic gradient in this area, and (2) the lack of long-term water-level records at new wells R-42, R-43, R-44, and R-45. In addition, the aquifer permeability may exhibit horizontal anisotropy from the large-scale aquifer structures in the Puye Formation and Santa Fe Group such as tilted beds with contrasting hydraulic properties and channelized stream gravels. The anisotropy may divert the flow in a direction that is not aligned with the hydraulic gradient but instead is more aligned with the dominant principle direction in the permeability tensor (Freeze and Cherry 1979, 088742).

In Figure L-2.0-2, the thick blue arrow shows the (negative) hydraulic gradient direction, which aligns with the potential groundwater flow direction in the case of isotropic medium; the thick green arrow shows the potential advective-transport flow direction due to aquifer anisotropy. The aquifer anisotropy in the vertical direction is captured through selection of the dispersivity coefficients. The longitudinal dispersivity in Equation L-2 controls dispersion along the advective contaminant flowpath, while the transverse horizontal and vertical dispersivities control the dispersion transverse to the advective flowpath. The ratio between horizontal and vertical transverse dispersivities is representative of vertical anisotropy. Layering of aquifer material may cause lower vertical transverse dispersivity. By varying the ratio of the dispersivities, we can effectively capture the impact of aquifer anisotropy on the contaminant transport.

In the study area, the bedding within the Santa Fe Group strikes N72E and dips about 5.7° towards the south-southeast (Appendix N). The dip of aquifer strata supports the use of an anisotropic model that assumes contrast in horizontal and vertical properties.

L-3.0 MODEL PARAMETERS

The parameters applied in model simulations are listed in Table L-3.0-1. The initial estimates and calibration ranges are estimated based on the available site-specific data and literature data.

The x and y coordinates of the potential contaminant arrival location vary in a rectangular area that encompasses the region centered on R-42 (Figure L-3.0-1). The parallelepiped box represents the region in the regional aquifer where the contaminants arrive at the top of the regional aquifer (z = 0) in a zone with a fixed vertical dimension of 1 m (Table L-3.0-1). The assumed 1-m thick contaminant arrival region represents the zone of the initial mixing of vadose-zone contaminants with the regional aquifer groundwater. Seasonal fluctuations of the regional water table may also influence the vertical dimension of this region. The lateral dimensions of the contaminant-arrival region are allowed to vary and are estimated during model calibration.

Contaminant mass flux is assumed steady and equal to fixed value (in kg/yr) within a specified time window from a starting time t0 (in years) to an ending time t1 (also in years). The plausible mass flux values are defined to be within a wide range to account for the existing uncertainty (Table L-3.0-1); during the model calibration, the estimated contaminant flux never approached the lower and upper limits. The time of arrival of contaminants at the top of the aquifer, t0, is estimated to vary between 1956 (i.e., chromium was released in Sandia Canyon from 1956 to 1972) and 2004 (R-28 was drilled in 2004) to accommodate the existing uncertainty. The time at which contaminants cease to arrive in the regional aquifer, t1, is fixed (2020) and does not influence the simulations performed below. Contaminant half-life decay is set to zero. This assumption is based on analysis of chromium isotope data presented in Appendix H, which suggests that little to no reduction of Cr(VI) to Cr(III) occurs in the regional aquifer.

Setting initial estimates and uncertainty ranges of the pore velocity (Table L-3.0-1) require a detailed analysis of the available data. Based on the single-hole pumping tests, the aquifer permeability in monitoring wells near the chromium plume ranges between 2 and 135 ft/d (0.6 and 41 m/d) with a best

estimate of about 40 ft/d (12 m/d). Table L-3.0-2 lists, and Figure L-2.0-2 presents, spatial permeability data; the figure suggests no obvious spatial trend in the permeability distribution. In addition, the permeability estimates do not appear to be correlated with the hydrostratigraphic units (Table L-3.0-2); the limited amount of permeability data does not allow for more detailed statistical inference tests. There are no site-specific estimates of the effective transport porosity; based on literature data, porosity of the sandstones and gravels is expected to vary between 0.05 and 0.15 with a best estimate of 0.1 (Freeze and Cherry 1979, 088742). The hydraulic gradient in the vicinity of the chromium plume is on the order of 0.001, with an uncertainty range from 0.0005 to 0.002 (Appendix G). Based on all these data, the best estimate for the advective transport velocity (also called pore velocity) of a nonreactive contaminant is on the order of 50 m/yr with an uncertainty range between 1 and 600 m/yr (Table L-3.0-1).

The direction of the advective flow downgradient from the contaminant arrival region is represented by the angle between the easterly gradient axis and the flow vector. The angle can vary from 0 (flow due east) to –75 (flow almost due south), allowing for a wide range of uncertainty in the advective flow direction (Table L-3.0-1). There are no site-specific estimates of the dispersivity coefficients; initial estimates and uncertainty ranges are based on literature data that take into account the scale at which contaminant transport occurs (Freeze and Cherry 1979, 088742; Neuman 1990, 090184; Gelhar et al. 1992, 102465). Typically, the transverse horizontal and vertical dispersivities are assumed to be 1/10 and 1/100 of the longitudinal dispersivity, respectively.

L-4.0 CALIBRATION DATA FOR CHROMIUM CONCENTRATIONS AT THE MONITORING WELLS NEAR SANDIA CANYON

To perform the fate and transport modeling of chromium contamination in the subsurface, it is important to have a model that produces predictions consistent with the observed field data. This objective can be achieved through a formal process of model calibration (inversion) against existing data measurements. The data considered in the calibration process are called calibration targets. The chromium concentrations in the regional aquifer observed at the monitoring wells near Sandia Canyon are key calibration targets. The goal of the modeling is to predict chromium concentrations in the regional aquifer resulting from releases in Sandia Canyon (circa 1956 to 1972) that are consistent with the existing observations.

However, the chromium concentrations used to calibrate the model are uncertain. Uncertainties in the calibration data are caused by various factors discussed the chromium fate and transport update report (LANL 2008, 102996, Appendix G). The important sources of uncertainty are (1) background values of chromium concentrations in the regional aquifer and (2) transients in the observed chromium concentrations at the monitoring wells near Sandia Canyon (Figure L-4.0-1). The background concentration of chromium in the regional aquifer is estimated to be between 5 and 6 ppb (LANL 2008, 102996). For example, variations in concentrations of key geochemical constituents observed at R-28 appear to correlate with fluctuations in the R-28 water levels (Figure G-3.0-1). Similarly, variations in contaminant concentrations in well R-15 may be caused by transients in the concentrations at the contaminant arrival locations. The current simulations do not take into account the background concentrations of Cr(VI) and only simulate the anthropogenic concentrations in the regional aquifer. The current simulations also do not incorporate transients in the concentration data. At this time, the potential effects transients in groundwater flow have on contaminant transport are an uncertainty.

Appendix G of the chromium fate and transport update report (LANL 2008, 102996) presents a formal process for estimating calibration targets and their respective uncertainty ranges. The same approach is applied in this appendix; the calibration set presented in that report (LANL 2008, 102996) is expanded to include the new data collected at R-42, R-43 (screens 1 and 2), R-44 (screens 1 and 2), and R-45

(screens 1 and 2). The calibration data are presented in Table L-4.0-1. For all the wells except R-28, the calibration targets are equal to average concentrations representing current data (circa 2009; Table L-4.0-1); since R-28 has a longer observation record and is probably located relatively close to the contaminant entry point at the top of the regional aquifer, two calibration targets are applied (circa 2004 and 2009) to constrain model-predicted transients at this well (Table L-4.0-1). Model analyses (not discussed in this appendix) have demonstrated that transients in R-28 concentrations currently provide the most dominant constraint in the predicted transients in the contaminant arrival flux.

The calibration data are applied to calibrate the analytical model of contaminant transport in the regional aquifer. The calibration is performed using a standard Levenberg-Marquardt optimization technique (Moré 1978, 106991). The objective function applied during optimization is computed as a sum of the squared differences between observed and simulated concentrations at all the wells listed in Table L-4.0-1.

L-5.0 ESTIMATION OF POTENTIAL LOCATIONS OF CONTAMINANT ARRIVAL AT THE REGIONAL WATER TABLE

L-5.1 Methodology

To estimate potential locations of chromium arrival at the top of the regional aquifer, a set of 551 locations (entry points) are considered (Figure L-3.0-1). The locations span an area of 1400 × 900 m forming a two-dimensional grid (29 × 19) at the top of the regional aquifer. The evaluated potential locations are spaced at 50- × 50-m intervals. These intervals represent potential breakthrough locations at the top of the regional aquifer in the vicinity of Sandia and Mortandad Canyons for chromium that was released at the surface in Sandia Canyon (or possibly in Mortandad Canyon). Although chromium migrated by a combination of surface-water, alluvial-groundwater, and vadose-zone transport pathways to the regional aquifer, the exact pathways are not important for this analysis because the potential entry points at the regional aquifer are defined only by constraining the regional aquifer model such that it reproduces the currently observed chromium concentrations and their relative distributions in the regional aquifer.

For some of the entry locations, the inverse model estimates it is impossible to create a model that is consistent with all the existing data, and specifically with observed chromium concentrations. In these instances, the inverse models may be consistent with the chromium observations at some of the monitoring wells but not at all of them. Only those results that are consistent with all the chromium observations are considered plausible solutions because in this way the model will be calibrated and will adequately represent the current site conditions. This methodology allows not only the development of models that are calibrated and coherent with the existing data, but it also allows the estimation of the uncertainty in the model predictions. The chromium concentration predictions of all the models are within the predefined calibration ranges. Most importantly, this approach allows potential contaminant-arrival locations at the top of the regional aquifer to be identified.

The methodology for identification of contaminant-arrival locations is general, and it can consider wide ranges of uncertainties related to conceptual models (e.g., alternative water table maps), model parameters, single and multiple arrival locations (simultaneously affecting regional aquifer concentrations), and transients in the contaminant mass arriving at the top of the regional aquifer. However, the analysis below assumes that contaminant flux is uniform in time; currently the potential transients are accounted for by defining a time interval within which the uniform flux is applied. (As discussed above, the time interval is defined by a beginning and end time in years.) The assumption is that the contaminant mass flux arriving at the regional aquifer is steady; this is generally consistent with the current observations of chromium concentrations at the regional monitoring wells, which are also relatively steady (Figure L-4.0-1; see also section G-3.0 in Appendix G). Steady-state concentrations are

not expected to continue indefinitely because the original chromium source released to Sandia Canyon had a finite release period (from 1956 to1972). However, the assumption of a steady contaminant flux can be applied as an approximation to evaluate the current distribution of the chromium mass in the regional aquifer.

As discussed above, the groundwater transport velocity in the regional aquifer near R-28 may be on the order of 50 m/yr or even higher (up to 600 m/yr). If the contaminant arrival location is near R-42, it may take less than 8 yr for contaminants to reach R-28 (the distance between the two wells is ~400 m). Due to expected relatively short travel times to R-28, it is not surprising that chromium concentrations at R-28 have been relatively stable since 2004 when the chromium was initially detected at R-28. This also suggests that the contaminant plume has already reached a steady condition in the region between the potential contaminant arrival location and well R-28. In addition, because of the relatively short distance between R-28 and potentially downgradient wells (500 m to R-44 and 400 m to R-45), it may also be expected that the contaminant plume has already reached or is approaching a steady-shape condition at R-44 and R-45; future data collection at R-44, R-45, and the new well R-50 will be critical for better understanding the shape of the plume downgradient from R-28.

Because ambient groundwater flow velocities are relatively high, the recent concentrations at the contaminant entry point, rather than past transients, create the observed current concentrations at the monitoring wells. As a result, it is difficult to evaluate what the past chromium concentrations were upon arrival at the top of the regional aquifer because the data regarding past chromium concentrations in the regional aquifer are insufficient. Nevertheless, the analytical model of chromium transport in the regional aquifer is applied to evaluate the maximum contaminant mass that may have arrived at the regional aquifer between 1956 and 2004 and still yield concentrations consistent with the current observations.

The approaches for estimating the potential locations of contaminant arrival at the regional water table presented here are similar to those in the chromium fate and transport update report (LANL 2008, 102996). In both cases, the regional aquifer is assumed uniform, vadose-zone flow and transport are ignored, potential geochemical reactions are not represented in the simulations, and the analyses are based on uniformly-spaced locations of potential contaminant arrival at the top of the regional aquifer. A major difference between the two approaches is that the analytical model used here assumes uniform groundwater flow with uncertain direction, whereas the groundwater flow model was constrained by the shape of the regional water table (a single representation in that study). Furthermore, the approach presented here allows for (1) efficient evaluation of the uncertainty in model predictions (due to fast execution times); (2) efficient estimation of three-dimensional contaminant migration (the numerical model applied in 2008 was constrained to two dimensions to reduce execution times); (3) efficient estimation of plume dispersion (the 2008 analyses was performed for a set of discrete dispersivity values—here the dispersivity values are directly estimated in the calibration process); (4) efficient estimation of the dimensions of the area associated with contaminant arrival locations,; (5) estimation of uncertainty in advective transport direction; and (6) estimation of transients in contaminant transport (the 2008 analyses relied on the assumption that the contaminant plume is at steady-shape; the current analyses does not make this assumption).

L-5.2 Results

The analytical model was executed for each potential contaminant-arrival location presented in Figure L-3.0-1. If the model parameters (Table L-3.0-1) were successfully calibrated and the model predictions were within the calibration ranges (Table L-4.0-1), that potential contaminant-arrival location was defined to be plausible. The identified plausible locations of contaminant arrival at the top of regional aquifer are shown in Figure L-5.2-1 as solid purple squares. Out of 551 potential locations, the model has

identified 71 as plausible. The rejected contaminant-arrival locations are shows as open purple squares. These results are generally consistent with the results presented in Figures J-5.1-15 and J-5.1-16 in Appendix J of the chromium fate and transport update report (LANL 2008, 102996). In both reports, the contaminants are predicted to arrive at the top of the regional aquifer in an area near R-42. It is important to note that simulation results in the chromium fate and transport update report (LANL 2008, 102996) were obtained without using the concentration data collected at R-42, R-43, R-44 and R-45. This demonstrates consistency in the modeling analyses, and a general trend of diminishing reduction of uncertainty in the model predictions with the drilling of new wells and collection of new data.

Figure L-5.2-2 presents a representative subset from (11 out of 71) all the plausible model-predicted contaminant plumes at the top of the regional aquifer. Plumes are plotted showing chromium concentrations higher than 50 ppb. The plumes are consistent with all the available hydrogeological and geochemical data. They are produced using models that predict chromium transport from one of the contaminant-arrival locations presented in Figure L-5.2-1. Each model has parameters that are consistent with accepted uncertainty ranges of model parameters (Table L-3.0-1) and uncertainty ranges of chromium concentrations at the monitoring wells (calibration targets; Table L-4.0-1).

Figure L-5.2-3 shows the best estimate of the plausible chromium concentrations along the regional water table. The best estimate is computed by averaging the concentrations of all the plausible model-predicted contaminant plumes (a subset of these plumes is presented in Figure L-5.2-2). In this way, the figure also presents the model predictions of the nature and spatial extent of the chromium mass in the regional aquifer. This model prediction is consistent with all the available data for the regional aquifer. The results shown in Figure L-5.2-3 are consistent with those shown in Figures 4.2-1 and 4.2-2 of the chromium fate and transport update report (LANL 2008, 102996). A comparison of the figures presented in both reports demonstrates that the new data collected at R-42, R-43, R-44, and R-45 effectively constrains the spatial extent of the contaminant mass in the regional aquifer, demonstrating again general consistency in the modeling analyses. Figure L-5.2-3 shows that the new well R-50 will provide important information about the spatial extent of the plume in the regional aquifer to the south of Mortandad Canyon.

Table L-5.2-1 lists the best estimates and estimated uncertainty ranges associated with the successfully calibrated analytical models. Table L-5.2-2 lists the observed and model predicted concentrations (best estimates and uncertainty ranges) for existing monitoring wells and for the proposed R-50 monitoring well site. It is important to note the model results in Table L-5.2-2 list chromium concentrations expected in excess of background (approximately 5 to 6 ppb; LANL 2008, 102996) and match the observed chromium concentrations in existing wells relatively well. Based on the performed analyses, the chromium concentrations at the new well R-50 are expected to be at background levels (Table L-5.2-2). However, there is uncertainty in the model predictions. If the contaminant transport has a more southerly direction, the chromium concentration at R-50 may be as high 300 ppb (Table L-5.2-2). Data collected at R-50 will provide important constraints on the model predictions.

Table L-5.2-3 presents the sensitivity coefficients of the estimated model parameters related to applied calibration targets. The coefficients are local central derivatives representing the change in model predictions at calibration targets caused by the change of respective model parameters. The data in the table are also frequently referred as a Jacobian matrix. The sensitivity coefficients are not linear and vary in parameter space with the variation of the optimized parameters. Presented sensitivity values are associated with the best current estimate of the model parameters listed in Table L-5.2-1. According to the table, the chromium concentration observed at R-42 provides an important constraint for the (1) size of the area within which contaminants are estimated to arrive at the regional aquifer, (2) contaminant flux, (3) flow direction, (4) pore velocity, and (5) vertical transverse dispersivity. However, this calibration target does not provide information about the longitudinal/horizontal transverse dispersivity and contaminant

arrival time. The calibration targets downgradient from R-42 are important at R-28, R-44, R-45, and R-11. However, for this particular case, the calibration targets at R-13, R-15, R-34. R-35a/b, R-36, and R-43 appear to be unimportant. This can be misleading because these sensitivity results are conditioned on the particular set of model-parameter estimates that yield the best case simulation result. In general, the calibration targets provide important constraints on the properties of the contaminant transport in the regional aquifer as well as the location and the size of the area within which contaminants are estimated to arrive at the regional aquifer.

The estimates of the model parameters in Table L-5.2-1 appear to be highly correlated. As a result, the covariance matrix representing the correlations between the estimates of the model parameters cannot be properly estimated. Analyses of the solution properties demonstrate that the parameters controlling the location and the size of the area where contaminants are expected to arrive at the regional aquifer appear to be mutually correlated. These estimates are also correlated with the estimates of pore velocity and flow direction. As a separate group, estimates of pore velocity and dispersivity coefficients are also mutually correlated. As a result, there is a large range of plausible solutions. Thus, the analyses presented above have identified a series of plausible location where contaminants may arrive at the regional aquifer.

L-6.0 ESTIMATION OF CONTAMINANT MASS IN THE REGIONAL AQUIFER

Based on the model analyses, the chromium mass that currently resides in the regional aquifer can be estimated. Accounting for existing uncertainties in the model parameters and calibration targets, the chromium mass in the regional aquifer is estimated to be between 270 and 3300 kg, with a best estimate of about 550 kg (Table L-5.2-1). The chromium mass flux entering the regional aquifer is estimated to be between 10 and 78 kg/yr with a best estimate of about 18 kg/yr. This analysis is based on the assumption that the chromium flux arriving at the regional aquifer had steady concentrations. However, it is feasible that the concentrations of chromium that arrived at the regional aquifer were higher in the past. Under this scenario, the current observed concentrations in the regional aquifer might be from chromium that arrived in the past rather than a current-day flux of chromium arriving at the regional aquifer. Using the same analytical model, simulations were run to investigate how much higher past concentrations reaching the aquifer may have been before the existing monitoring network of regional-aquifer wells was created, and still calibrate to current observations. (The chromium was introduced in the surface environment in 1956 and the existing wells near Sandia Canyon were not drilled until 2000 or later.) The simulations demonstrate under this scenario, the mass of anthropogenic chromium that may have reached the regional aquifer is less than 3000 kg, a value that is within the uncertainty bounds described above. The low chromium concentrations observed in downgradient wells such as R-36, R-44, R-45, and R-10 provide an important constraint limiting the amount of chromium that may have been introduced into the regional aquifer in the past. Considering both scenarios, the total mass of anthropogenic chromium in the regional aquifer is expected to be less than 3300 kg. This mass is a small fraction of the total estimated mass of chromium released in the environment in Sandia Canyon (31,000 to 72,000 kg, section 2.1.1.1). This prediction is based on an assumption that geochemical reactions [e.g., reduction of Cr(VI) to Cr(III)] do not influence chromium transport in the regional aquifer. This assumption is based on analysis of chromium isotope data (Appendix H) that indicate little to no reduction of Cr(VI) to Cr(III) occurs in the regional aquifer.

L-7.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility

(RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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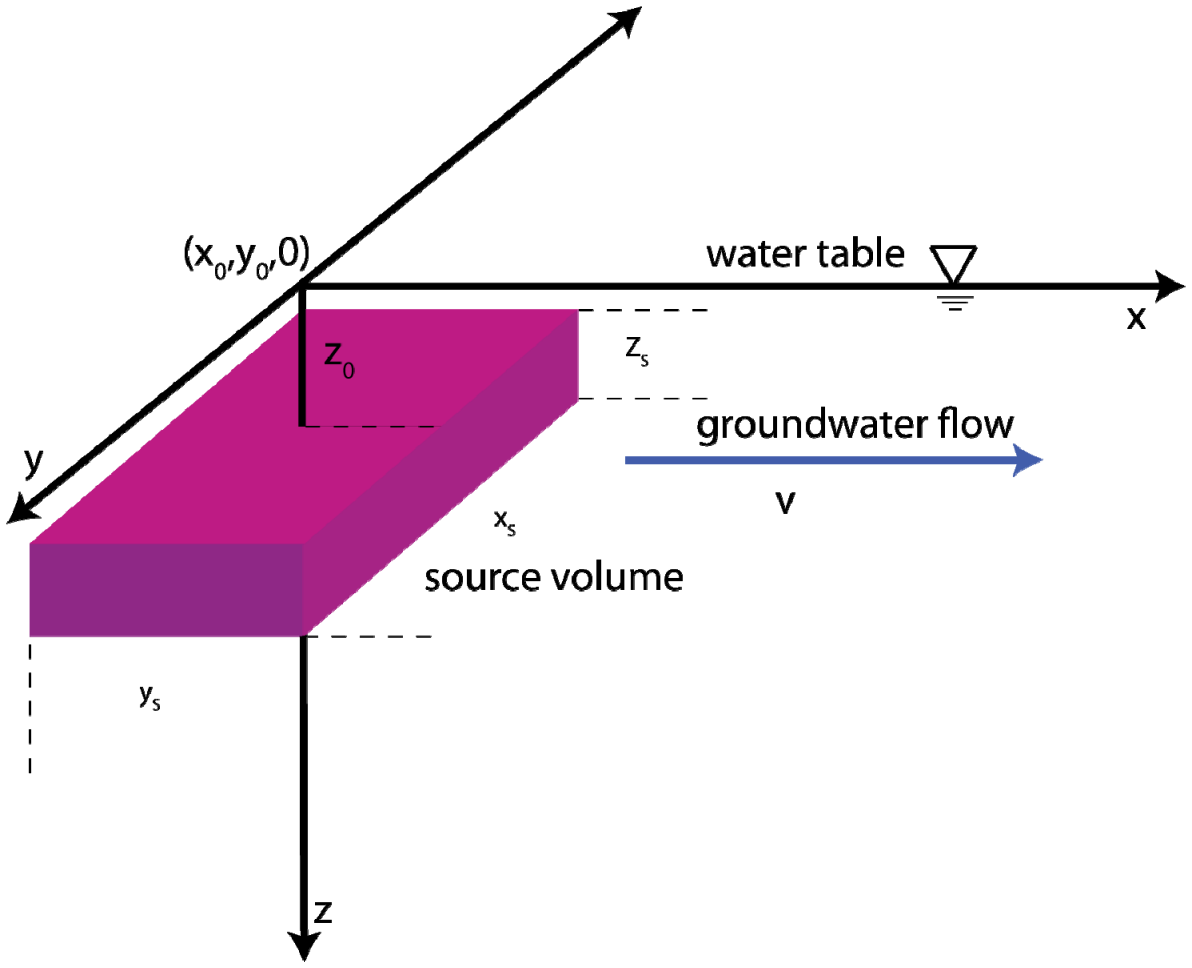
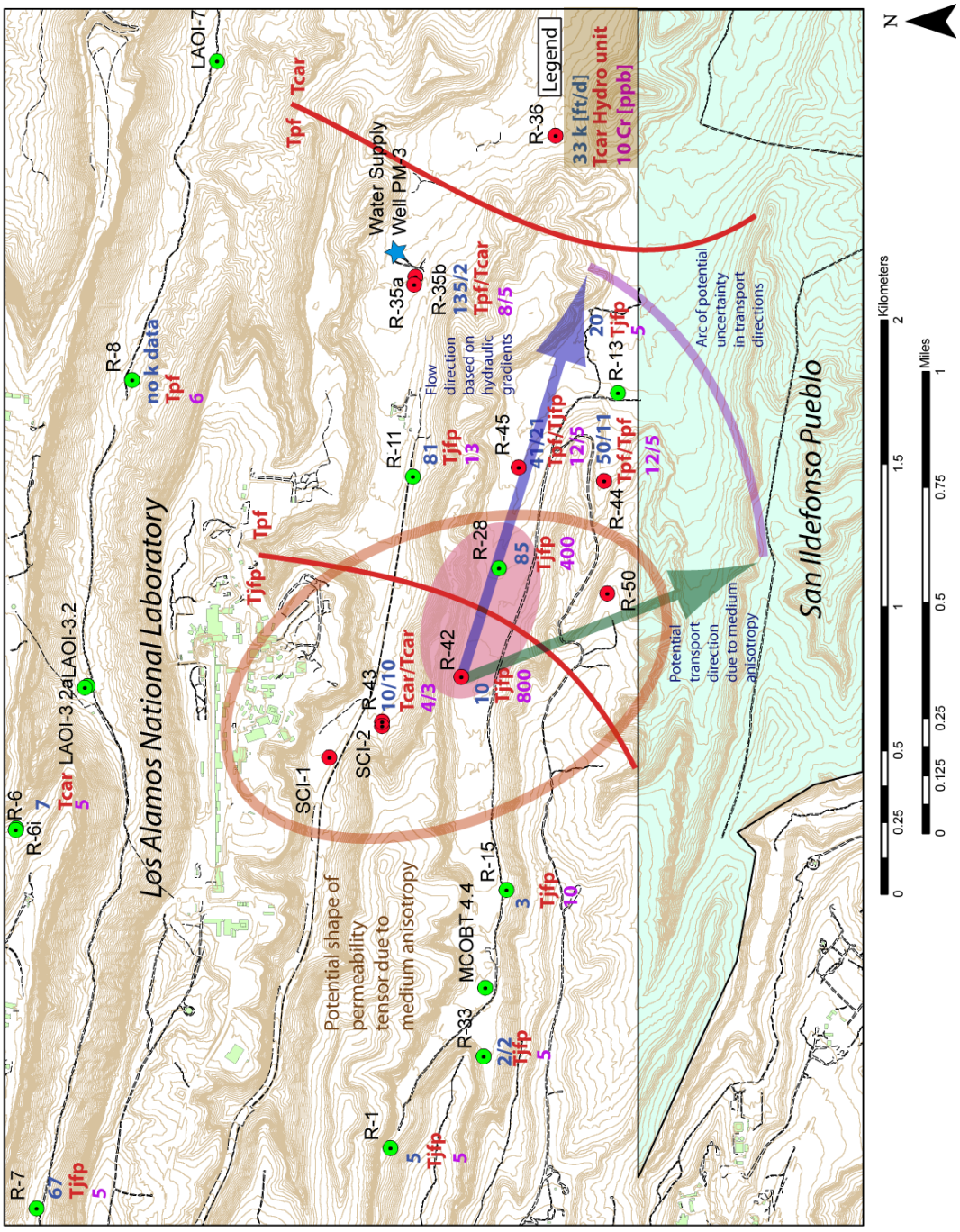


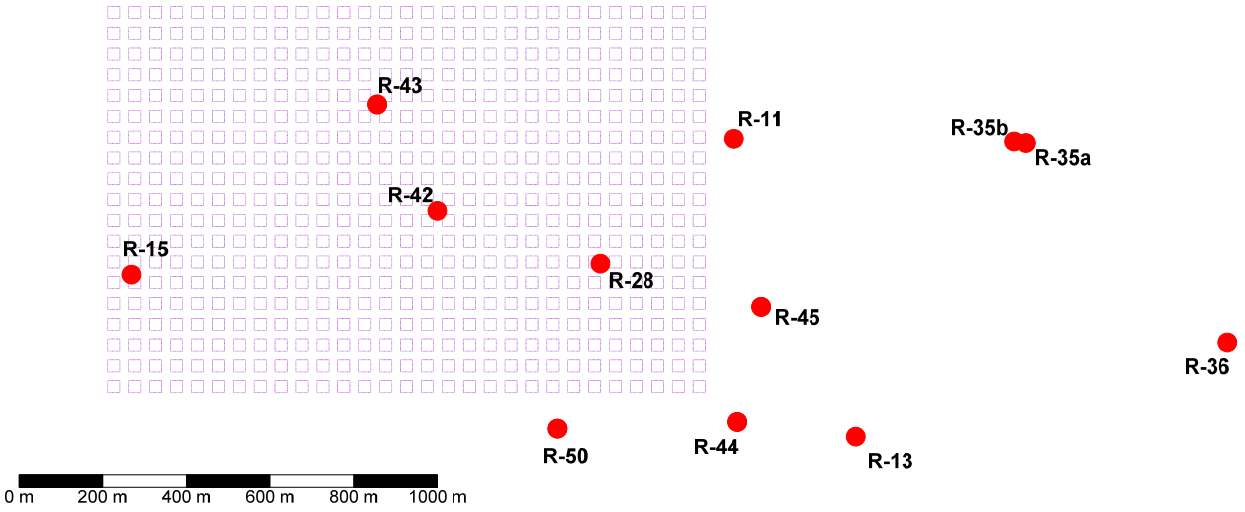
Note: The upper boundary is a no-flow boundary or a water table boundary.

Figure L-2.0-1 Schematic diagram of a three-dimensional source body within the regional aquifer



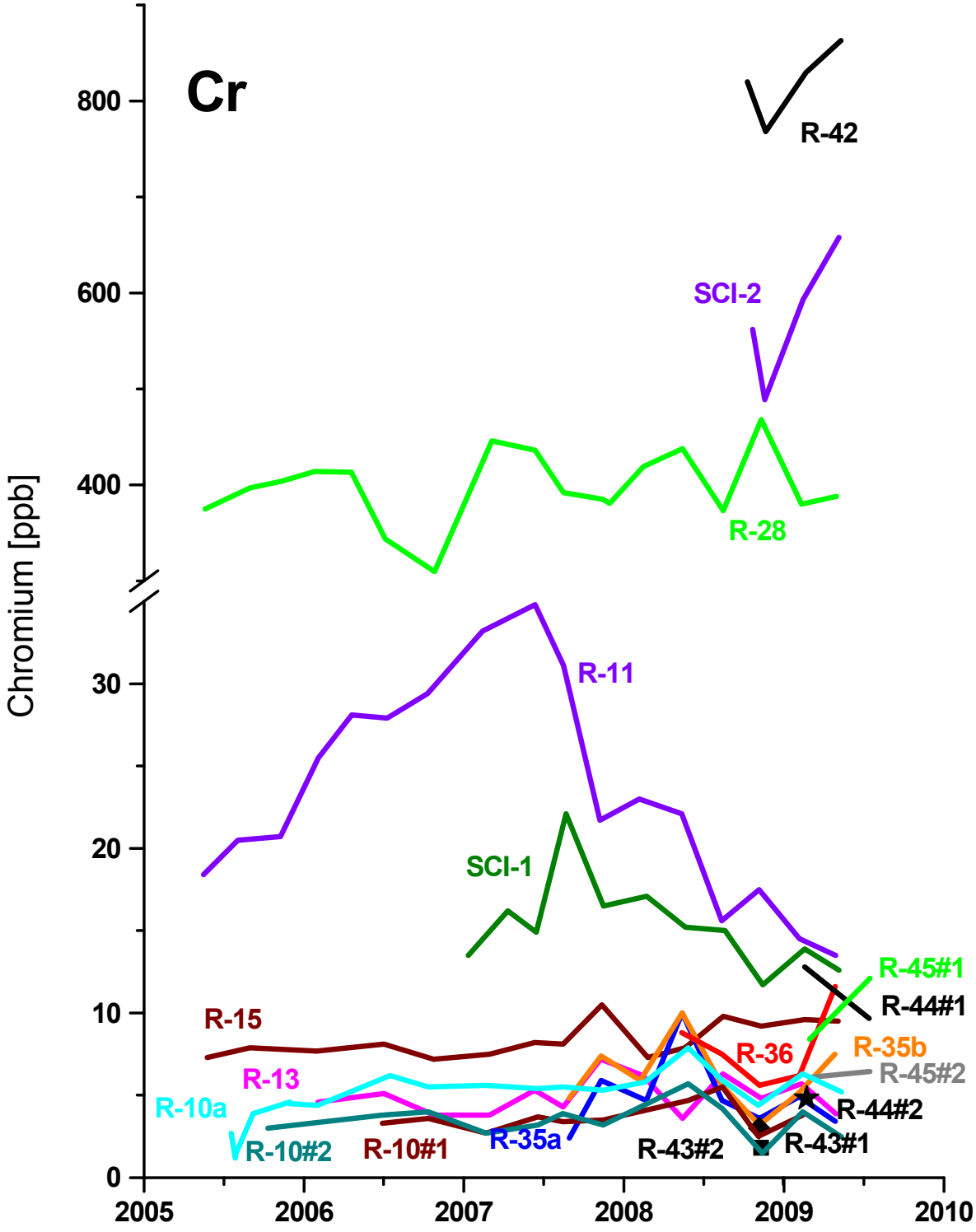
Notes: Representative average chromium concentrations [ppb], screened hydrostratigraphic unit and permeability estimates ([ft/d] based on single-hole pumping tests during well development) are listed for each well screen (upper/lower in the case of multiple screen wells). The red curved lines represent the estimated locations of the Tjfp/Tpf and Tpf/Tcar contacts along the regional water table. The thick blue arrow shows the potential groundwater flow direction based on hydraulic gradients (assuming isotropic medium). The brown ellipse graphically represents an example for the potential anisotropy of aquifer permeability. The thick green arrow shows the potential advective-transport flow direction due to medium anisotropy. The future monitoring well R-50 is placed based on its currently staked location.

Figure L-2.0-2 Monitoring wells near the chromium plume



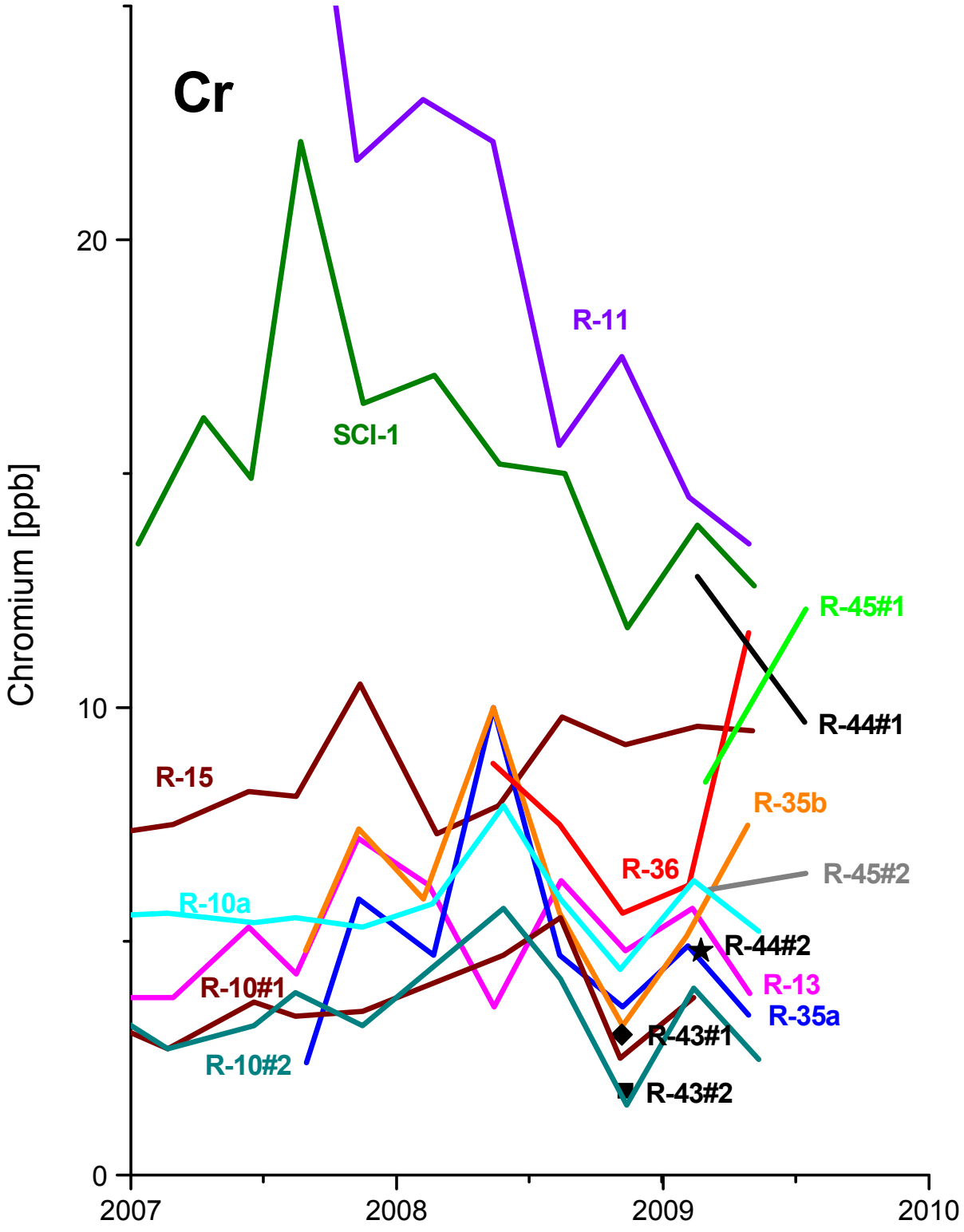
Notes: Locations are spaced by 50 × 50 m. (The squares identifying the entry locations do not represent the size of the entry location; they are intended for visualization purposes only.)

Figure L-3.0-1 Two-dimensional grid (29 × 19) of 551 potential contaminant-arrival locations at the top of the regional aquifer



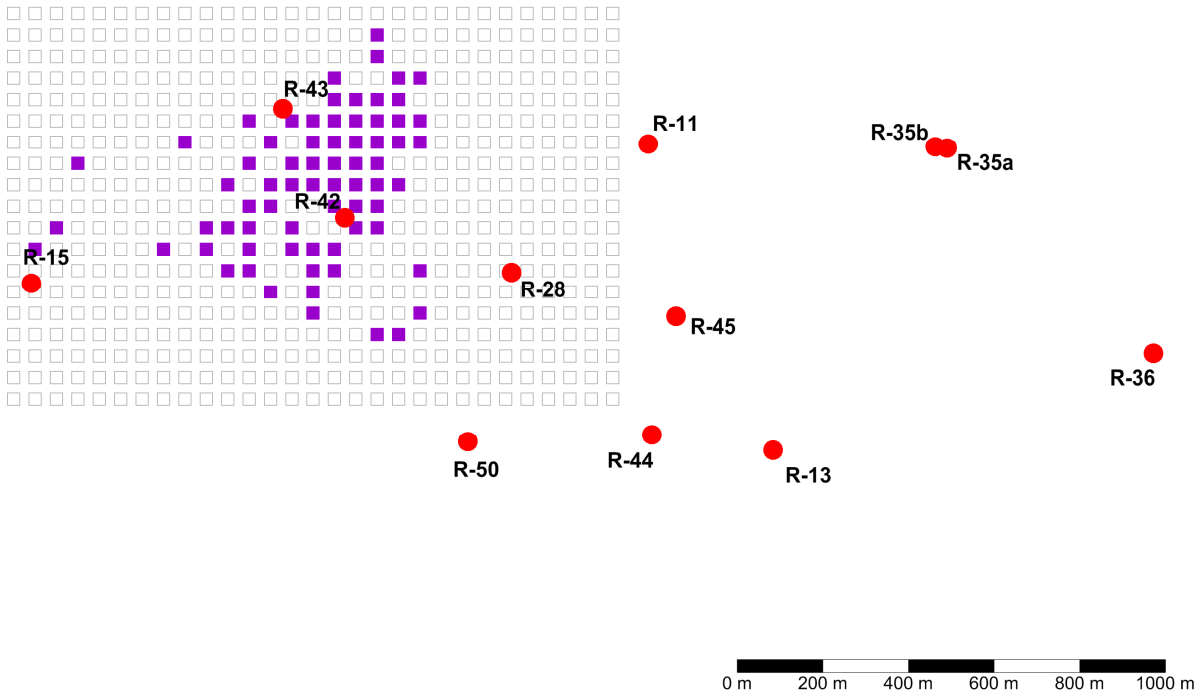
a.

Figure L-4.0-1 Observed transients in the chromium concentrations at the monitoring wells near Sandia Canyon: (a) all the wells; (b) zoom of the concentration data less than 25 ppb



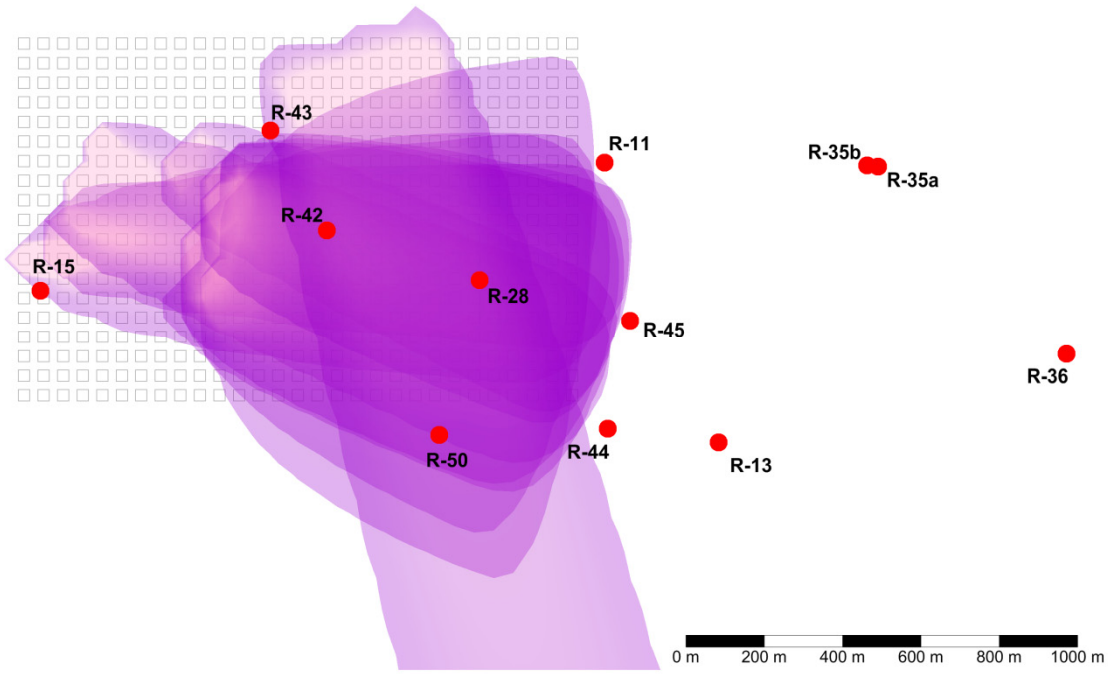
b.

Figure L-4.0-1 (continued) **Observed transients in the chromium concentrations at the monitoring wells near Sandia Canyon: (a) all the wells; (b) zoom of the concentration data less than 25 ppb**



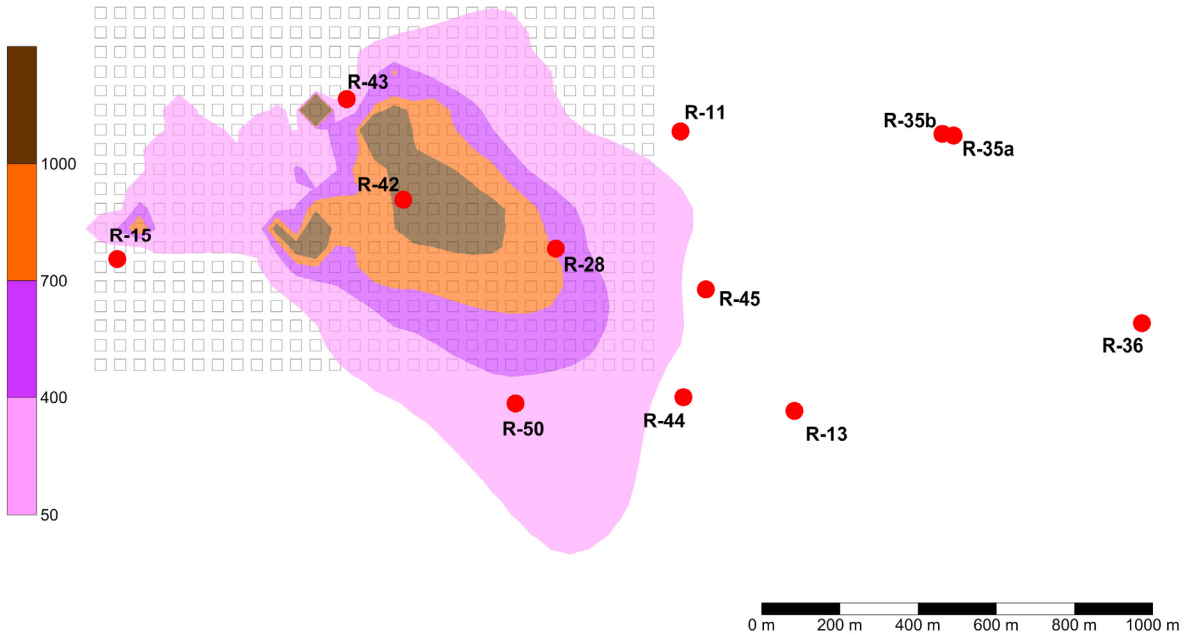
Note: The rejected contaminant-arrival locations are shows as open squares.

Figure L-5.2-1 Contaminant-arrival locations at the top of the regional aquifer (water table) that can reproduce observed chromium concentrations in the monitoring wells (purple squares)



Note: Plumes are plotted showing chromium concentrations higher than 50 ppb.

Figure L-5.2-2 Series of plausible contaminant plumes in the regional aquifer consistent with the available hydrogeological and geochemical data



Notes: The best estimate is computed by averaging the concentrations of all the of plausible model-predicted contaminant plumes (a subset of these plumes is presented in Figure L-5.2-2).

Figure L-5.2-3 Best estimate of the plausible chromium concentrations along the regional water table

Table L-3.0-1
Model Parameters for Analytical Simulation of Contaminant Transport

Model Parameter	Unit	Initial Estimate	Calibration Range	
			Minimum	Maximum
Source x coordinate	m	-	498400	499800
Source y coordinate	m	-	538700	539600
Source z coordinate	m	0	Fixed	
Source x dimension	m	100	10	500
Source y dimension	m	100	10	500
Source z dimension	m	1	Fixed	
Contaminant flux	kg/yr	10	1	1000
Contaminant arrival time	yr	1990	1956	2004
Contaminant cessation time	yr	2020	Fixed	
Half-life decay	1/yr	0	Fixed	
Flow Angle	Degrees	-35	-75	0
Horizontal pore velocity	m/yr	50	1	600
Longitudinal dispersivity	m	100	1	200
Horizontal transverse dispersivity	m	10	1	100
Vertical transverse dispersivity	m	1	0.1	10

Table L-3.0-2
Permeability Estimates (ft/d) Based on Single-Hole Pumping Test during Well Development at the Monitoring Wells Near Sandia Canyon

Unit					
Tjfp		Tpf		Tcar	
Well (screen)	K (ft/d)	Well (screen)	K (ft/d)	Well (screen)	K (ft/d)
R-7	67	R-45#1	41	R-35a	2
R-1	5	R-44#1	50	R-6	7
R-33#1	2	R-44#2	11	R-36	33
R-33#2	2	R-13	20		
R-42	10	R-35b	135		
R-28	85				
R-45#2	21				
R-11	81				
R-15	3				
Count	9	Count	5	Count	3
Mean	31	Mean	51	Mean	14
Variance	1299	Variance	2429	Variance	277

Note: Stratigraphic units are Tpf = Pliocene Puye Formation, Tjfp = Miocene pumiceous sediments, and Tcar = Miocene Chamita Formation.

Table L-4.0-1
Calibration Data for Chromium Concentrations
Observed at the Monitoring Wells near Sandia Canyon

Well (screen)	X (m)	Y (m)	Screen Depth Below the Water Table (m)		Chromium Calibration Targets (ppb)			
			Top	Bottom	Date	Best Estimate	Min	Max
R-01	497541.44	539374.57	8.50	16.52	2009	5	0	8
R-06	498655.54	540682.59	14.29	21.30	2009	5	0	15
R-07#3	497331.80	540609.43	0.00	10.68	2009	5	0	8
R-08#1	500157.29	540281.16	4.20	19.56	2009	5	0	8
R-10a	503959.86	537905.64	20.23	23.28	2009	5	0	15
R-11	499882.61	539296.05	5.57	12.55	2009	13	0	30
R-13	500174.36	538579.77	36.73	55.14	2009	5	0	15
R-15	498442.06	538969.46	0.00	15.04	2009	10	0	30
R-16r	505751.41	535451.51	10.80	16.16	2009	5	0	15
R-28	499563.69	538995.82	13.15	20.41	2004	400	300	700
					2009	400	300	700
R-33#1	497855.44	539040.32	4.04	11.05	2009	5	0	15
R-34	500972.02	537650.74	26.73	33.71	2009	5	0	15
R-35a	500581.13	539285.95	69.01	83.98	2009	5	0	15
R-35b	500553.15	539289.64	11.15	18.19	2009	8	0	15
R-36	501062.87	538806.13	4.86	11.87	2009	10	0	15
R-37#2	499209.91	537244.01	4.98	11.29	2009	5	0	5
R-42	499174.00	539122.84	3.66	10.09	2009	850	600	1000
R-43#1	499029.60	539378.56	3.32	9.63	2009	4	0	10
R-43#2	499029.60	539378.56	23.20	26.24	2009	3	0	10
R-44#1	499890.70	538615.08	4.94	7.99	2009	12	0	15
R-44#2	499890.70	538615.08	32.46	35.48	2009	5	0	10
R-45#1	499948.08	538891.80	3.59	6.64	2009	12	0	15
R-45#2	499948.08	538891.80	32.51	38.61	2009	5	0	10

Note: The calibration ranges include background and anthropogenic chromium concentrations.

Table L-5.2-1
Best-Estimates and Estimated Plausible Ranges for Various Model Parameters Calculated as a Result of the Model Calibration versus Chromium Concentration Data Observed at the Regional Monitoring Wells Near Sandia Canyon

Model Parameter	Unit	Best Estimate	Estimated Range of Uncertainty	
			Minimum	Maximum
Source x coordinate	m	499150	498450	499350
Source y coordinate	m	539000	538850	539550
Source x dimension	m	27	1	498
Source y dimension	m	468	1	500
Contaminant flux	kg/yr	18	10	78
Contaminant arrival time	yr	1977	1960	1994
Flow Angle	degrees	-7	-75	0
Horizontal pore velocity	m/yr	23	3	106
Longitudinal dispersivity	m	1	1	99
Horizontal transverse dispersivity	m	6	1	100
Vertical transverse dispersivity	m	1	0.10	5
Total contaminant mass	kg	550	270	3300

Table L-5.2-2
Observed and Model-Predicted Chromium
Concentrations at the Regional Monitoring Wells Near Sandia Canyon

Well	Date	Chromium Concentration above Background (ppb)			
		Observed	Best Prediction*	Uncertainty Range*	
				Minimum	Maximum
R-11	2009	13	13	0.0	27
R-13	2009	5	0	0.0	13
R-15	2009	10	0	0.0	22
R-28	2004	400	400	320	400
	2009	400	400	390	470
R-34	2009	5	0	0.0	0.0
R-35a	2009	5	0	0.0	0.0
R-35b	2009	8	0	0.0	0.0
R-36	2009	10	0	0.0	0.0
R-42	2009	850	850	790	880
R-43#1	2009	4	0	0.0	9
R-43#2	2009	3	0	0.0	5
R-44#1	2009	12	9.9	0.1	14
R-44#2	2009	5	6	0.1	10
R-45#1	2009	12	11	0.0	16
R-45#2	2009	5	7	0.0	11
R-50	2009	-	0.0	0.0	290.0

*Model predicted anthropogenic chromium concentrations above background.

Table L-5.2-3
Sensitivity of the Estimated Model Parameters to Applied Calibration Targets

Calibration Targets	Optimized Model Parameters								
	Source x Dimension (m)	Source y Dimension (m)	Contaminant Flux (kg/yr)	Contaminant Arrival Time (yr)	Flow Angle [degrees]	Pore Velocity (m/yr)	Longitudinal Dispersivity (m)	Horizontal Transverse Dispersivity (L)	Vertical Transverse Dispersivity (L)
R-11 (2009)	0.7	16.4	-47.7	43.9	76.3	-168	0.032	54.9	11.8
R-13 (2009)	0	0	0	0	0	0	0	0	0
R-15 (2009)	0	0	0	0	0	0	0	0	0
R-28 (2004)	-0.0847	-102	-1440	0	3.84	1280	0	-12.4	225
R-28 (2009)	-0.0847	-102	-1440	0	3.84	1280	0	-12.4	225
R-34 (2009)	0	0	0	0	0	0	0	0	0
R-35a (2009)	0	0	0	0	0	0	0	0	0
R-35b (2009)	0	0	0	0	0	0	0	0	0
R-36 (2009)	0	0	0	0	0	0	0	0	0
R-42 (2009)	1130	-224	-3060	0	2030	2720	-1	0	-212
R-43#1 (2009)	0	0	0	0	0	0	0	0	0
R-43#2 (2009)	0	0	0	0	0	0	0	0	0
R-44#1 (2009)	-3.8	5.6	-35.7	225.0	9.3	-1050	-0.2	8.1	9.3
R-44#2 (2009)	-2.3	3.5	-22.2	142.0	5.7	-660	-0.1	5.1	0.1
R-45#1 (2009)	-8.1	-2.9	-42.4	342.0	1.5	-1600	-0.3	-1.0	11.2
R-45#2 (2009)	-4.7	-1.7	-25.0	204.0	0.9	-958	-0.2	-0.6	-0.5

Appendix M

Sampling Test at Regional Aquifer Well R-28

M-1.0 INTRODUCTION

A continuous pumping and time-series sampling test was conducted at R-28 on November 28 and 29, 2007, to evaluate whether residual drilling fluid effects are present at R-28 that could impact the reliability and representativeness of groundwater-quality data. The study had particular focus on chromium because it is the most prevalent contaminant in the regional aquifer in the location of Sandia Canyon. Groundwater analyses conducted for R-28 for the period leading up to this test showed no indication of residual drilling fluid impacts.

M-2.0 CONCEPTUAL MODEL

Two organic polymer-based drilling fluids, EZ-MUD and QUIK-FOAM, were used during the drilling of R-28. These organic fluids that may have remained in aquifer materials outside the well screen after well development and could potentially stimulate local microbial growth in groundwater because they act as nutrient sources providing organic carbon and organic nitrogen for metabolism. Aerobic microbes utilize oxygen and perchlorate under oxic conditions and anaerobic bacteria utilize nitrogen, manganese, iron, and sulfur under reducing conditions. Once dissolved oxygen is completely consumed by aerobic bacteria, anaerobic bacteria become activated and start to reduce other electron acceptors, including manganese, iron, and sulfate, resulting in strongly reducing conditions that are not typical of the regional aquifer at Los Alamos. This reducing environment can influence the mobility of key indicators of background and contaminant chemistry in groundwater. Reactive aquifer solids, including ferric hydroxide and manganese dioxide, undergo reductive dissolution reactions as the organic-based drilling fluid biodegrades or oxidizes ultimately to carbon dioxide gas and water. Hypothetically, if such a reducing condition is present, dissolved chromium concentrations might also be expected to decrease because of precipitation of amorphous $Cr(OH)_3$.

The concept behind the continuous pumping and time-series sampling test is that prolonged pumping will draw groundwater into the well screen from a distance that is greater than the near-borehole environment that was potentially affected by organic additives during drilling. If residual drilling fluids are present, prolonged pumping should produce measurable changes in key chemical indicators as groundwater is drawn from progressively greater distances from the well. Examples of such changes would include a decrease in dissolved iron and manganese, increase in dissolved oxygen and an increase in dissolved chromium, sulfate, and nitrate to pre-drilling concentration at R-28.

Some degree of natural variations in these indicator parameters might be expected to occur because of local heterogeneities in the aquifer. Nonetheless, there should be an overall pattern of increasing concentrations of dissolved oxygen, sulfate, and nitrate in groundwater samples collected over the course of the test if the hypothesis is correct that aquifer material next to the well is more strongly affected by drilling fluids than aquifer materials farther away.

M-3.0 METHODOLOGY

Well R-28 was pumped at a rate that varied from approximately 2.50 to 4.25 gpm using the dedicated pump installed for sampling. An in-line flowmeter and stop-watch were used to monitor the pumping rates. Field parameters were measured using a flow-through chamber. Groundwater samples were collected for laboratory analyses as shown in Table M-3.0-1.

Automated water-level records were also collected throughout the test from a dedicated transducer located within R-28. Hydraulic analyses conducted before the test suggested that a capture zone would be created around R-28 in response to prolonged pumping. Based on these calculations, the zone or radius of influence around R-28 was calculated to be approximately 7 to 8 ft. Water levels in surrounding R-wells were also monitored to determine if the pumping at R-28 could be detected.

Approximately 105 gal. of QUIK-FOAM, 39 gal. of EZ_MUD, and 15,200 gal. of municipal water was used to drill the R-28 borehole. Following well installation, 25,309 gal. of water was removed from R-28 during well development and aquifer testing conducted from February 5 through March 8, 2004. During this time period, approximately 40 gal. of water was removed during bailing and swabbing of the well screen, 15,210 gal. of water was removed by pumping the well screen, and 10,059 gal. were removed during aquifer testing. While use of 15,344 gal. of water and additives to drill the R-28 borehole was distributed over the 1005-ft depth of the borehole, the 25,309 gal. of water removed from the well during development and aquifer testing was produced from the aquifer around the 23.8-ft well screen.

Table M-3.0-1 provides information about the continuous pumping and time-series sampling test conducted at R-28, including the duration of the sampling test, total gallons purged, discharge rates, groundwater levels, and radius of influence. A total of 6887 gal. of groundwater was pumped from R-28 during the 30-h test, resulting in the removal of 91.5 casing volumes. Pumping rates varied between 2.50 and 4.25 gpm. During the 30-h pumping of R-28, the radius of influence within the regional aquifer was calculated to be 10.2 ft, assuming an effective porosity of 0.1.

Groundwater samples were collected at the beginning of the test; at 13, 43, and 58 min after the test started; and at approximately every hour to the conclusion of the test at 30 h. A total of 33 groundwater samples were collected and analyzed for major ions, trace elements, tritium, and stable isotopes of nitrogen as shown in Table M-3.0-1.

M-4.0 RESULTS

Measurements of field parameters taken during the pumping test at R-28 are provided in Table M-4.0-1. Table M-4.0-2 provides analytical results for groundwater samples collected during the test. During the first part of the sampling test represented by sample numbers 1 through 7 (up to 4 h, Table M-3.0-1), concentrations of total dissolved chromium and total chromium are essentially equivalent (Figure M-4.0-1), indicating chromium is stable as chromium(VI) in the dominant form of chromate with some bichromate present. Chromate dominates in oxidizing aqueous solutions above pH 6.5 at 25°C. During the latter part of the sampling test, total dissolved concentrations of chromium are generally are less than total chromium in nonfiltered samples represented by samples 8 through 30 (5 to 28 h, Table M-3.0-1). In Figure M-4.0-1, the chromium concentrations are also plotted with dissolved oxygen (DO) and noncorrected oxidation-reduction potential (ORP) to evaluate if changes in these key field parameters relate to variations in chromium concentration. The concentrations and variations over time for these key indicator parameters indicate a steady state for groundwater flowing into the well had been established early in the test.

One explanation for the observed variability in chromium concentrations is that a fraction of chromium(VI) is adsorbed onto aquifer solids such as ferric hydroxide. This situation occurs when concentrations of total chromium in nonfiltered samples exceed those in associated filtered sample pairs. Reduction of dissolved chromium(VI) to chromium(III) hydroxide is not likely, based on measured DO concentrations and oxidizing, noncorrected ORP measurements (Table M-3.0-1). Dissolved concentrations of manganese are less than 3 ppb, suggesting that groundwater is oxidizing with respect to both manganese(IV) and chromium(VI) (Table M-4.0-2). Variation in chromium concentrations at R-28 is

attributed to plume heterogeneity in response to dilution, mixing, and adsorption processes occurring in the regional aquifer.

Figure M-4.0-2 shows concentrations of total dissolved chromium with ±1-sigma error associated with each analytical measurement, ranging from 0 to 32 ppb with a majority of the values less than 10 ppb. The analytical error for total chromium is ±5% using inductively coupled mass spectrometry (ICPMS). Most of the samples analyzed have a sampling error less than the analytical error, suggesting that the results are consistent, accurate, and precise. Several samples collected near the end of the pumping test, however, show greater than 5% error. Even though several samples have greater analytical uncertainty associated with them, the concentrations measured in samples collected at the end of the test are similar to those measured in samples collected at the beginning of the test.

Figure M-4.0-3 shows dissolved concentrations of nitrate(N), sulfate, and total dissolved chromium during the sampling test. Concentrations of dissolved nitrate(N) and sulfate varied from 3.96 to 4.13 ppm and from 45.0 to 47.5 ppm, respectively (Figure M-4.0-3). The concentrations of these key indicator constituents are consistent throughout the test, indicating uniformity of groundwater quality during the test.

Concentrations of total sulfide were less than analytical detection (0.010 ppm) (Table M-4.0-1). Concentrations of total organic carbon and dissolved iron varied from 0.63 to 1.0 ppm and from 0.01 to 0.02 ppm (10 to 20 ppb) (Table M-4.0-1), respectively, suggesting that reducing conditions with respect to carbon and iron do not occur at R-28. Total carbonate alkalinity was consistent throughout the test, ranging from 89.4 to 94.4 ppm (Table M-4.0-1); these results indicate no oxidation of residual organic carbon to inorganic carbon is occurring at R-28.

Ferric hydroxide is stable under oxidizing conditions characteristic of groundwater at R-28, based on measurable, but low concentrations of dissolved iron (Table M-4.0-1). This finding suggests that reductive dissolution of ferric hydroxide is not taking place at R-28 in response to residual drilling effects. Desorption of trace elements including arsenic and zinc from naturally occurring ferric hydroxide at R-28 is unlikely, based on dissolved concentrations of arsenic and zinc ranging from 0.8 to 1.2 ppb and from 2.0 to 12.0 ppb (Table M-4.0-1).

Multiple lines of evidence indicate that a geochemical reactive zone is not present in the aquifer materials surrounding the well screen at R-28. Most key parameters yielded consistent concentrations throughout the test. If a chemically reducing zone was present at R-28, then concentrations of total dissolved chromium and total chromium, sulfate, and nitrate(N) would have been expected to increase as more oxidizing groundwater entered the well screen. Some variation in measured chromium concentrations occurred during the test, but chromium concentrations in filtered and nonfiltered samples were independent of purge volumes and the corresponding radius of influence.

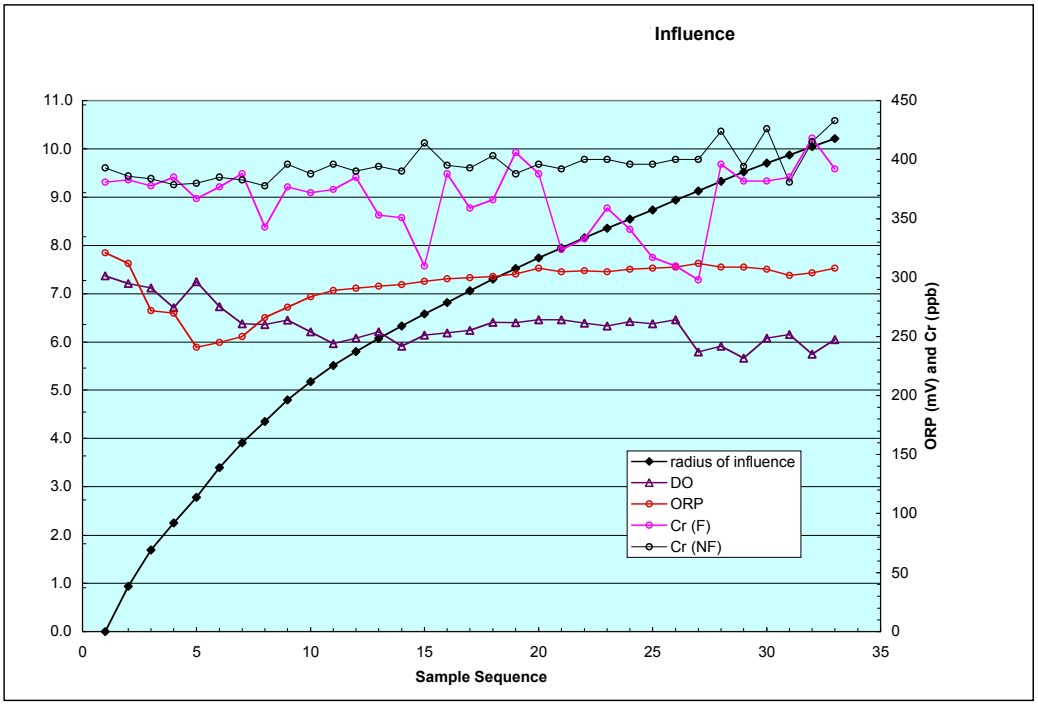


Figure M-4.0-1 Sample sequence versus radius of influence, DO, chromium in filtered samples (Cr, F), chromium in nonfiltered samples (Cr, NF), and noncorrected ORP

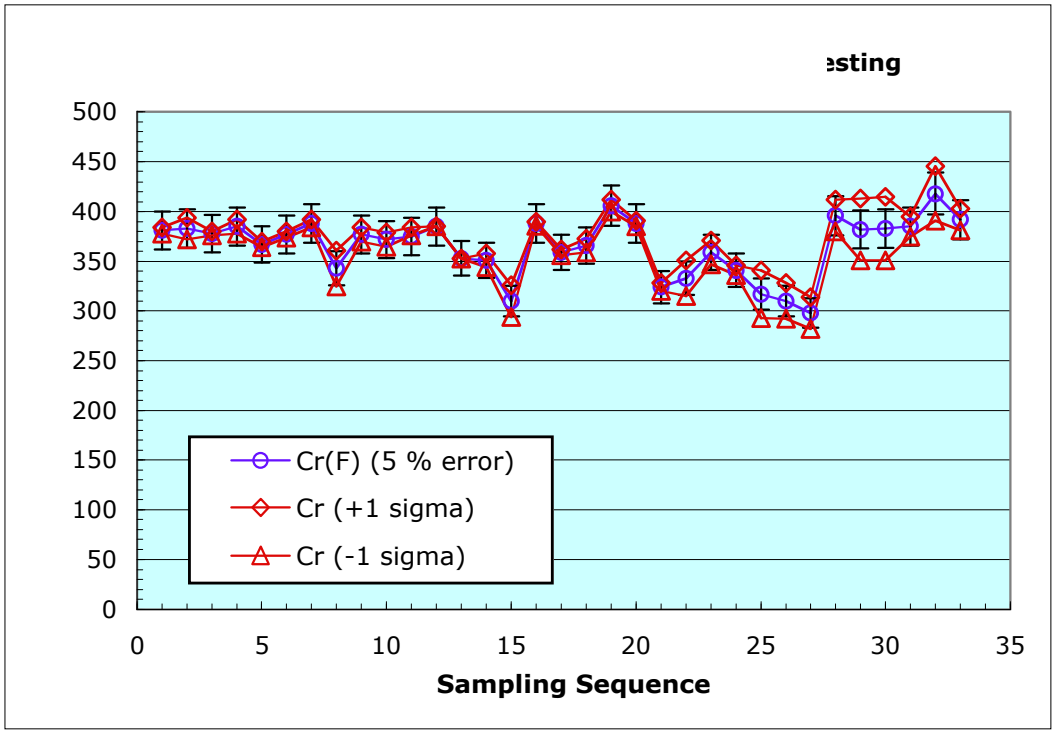


Figure M-4.0-2 Sample sequence versus dissolved concentrations of chromium (Cr, in ppb) showing 5 percent instrument error using argonICPMS and sample error

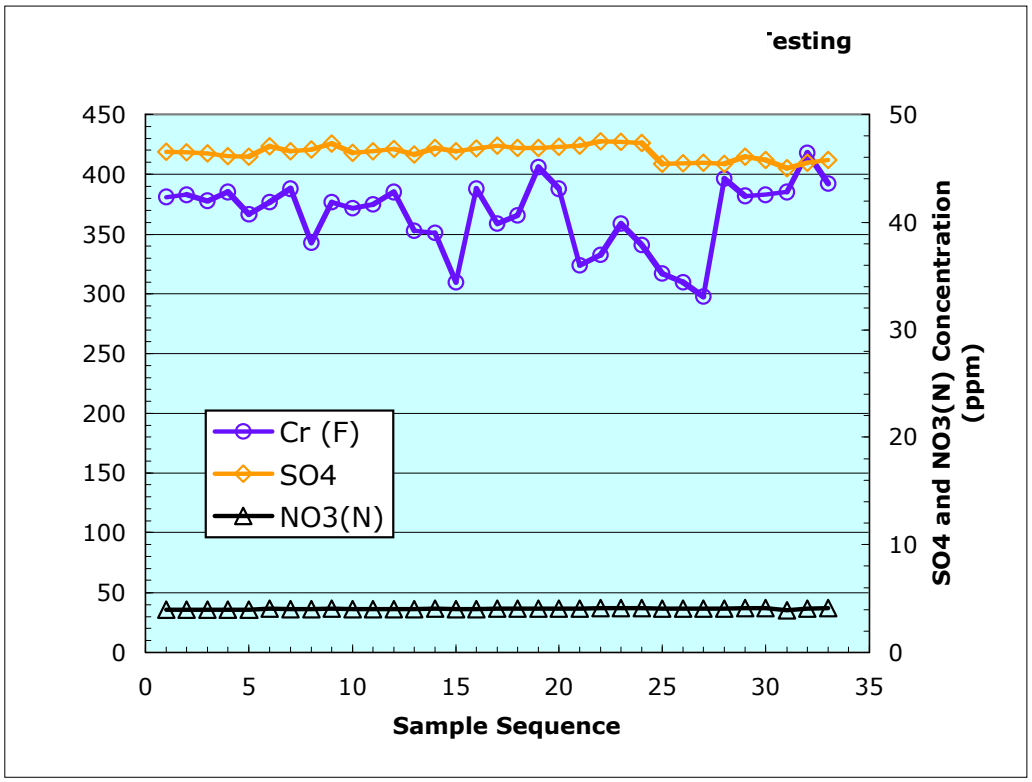


Figure M-4.0-3 Sample sequence versus dissolved concentrations of chromium (Cr, in ppb), sulfate (SO_4, in ppm), and nitrate-nitrogen (NO_3-N, in ppm)

Table M-3.0-1
Samples Taken

		Hour																															
		Initial	15 min	45 min	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		Sample Time																																
		0929	0945	1012	1027	1127	1227	1327	1427	1527	1627	1727	1827	1927	2027	2127	2227	2327	0027	0127	0227	0327	0427	0527	0627	0727	0827	0927	1027	1127	1227	1327	1427	1527
Field Prep	**Suite**																																	
	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	2				X	X	X	X											X															X
	3				X					X						X						X												X
	4				X														X															X
		Sample IDs: GW28-08-XXXX																																
Nonfiltered	Event 298	9130	9131	9132	9133	9134	9135	9136	9137	9138	9139	9140	9141	9142	9143	9144	9145	9146	9147	9148	9149	9150	9151	9152	9153	9154	9155	9156	9157	9158	9159	9160	9161	9162
Filtered (0.45 um)	Event 299	9166	9167	9168	9169	9170	9171	9172	9173	9174	9175	9176	9177	9178	9179	9180	9181	9182	9183	9184	9185	9186	9187	9188	9189	9190	9191	9192	9193	9194	9195	9196	9197	9198
Filtered (0.22 um)	Event 300				9202	9203	9204	9205											9207															9208

Note: Event 300, Sample ID 9206, no chain on record.

Suite	Number	Prep	Detail
1[a]	36	NF, F_1	Anions (F), Cations/Metals (F, NF), Sulfide (NF), Ammonium (NF), TOC (NF), acetone (NF), isopropyl alcohol (NF), Field parameters
2[a]	8	F_2 (0.2 um)	Anions, Cations/Metals, Sulfide, Ammonium
3	6	F_1	$d^{15}N$ (N^{14}/N^{15}) (F), low-level tritium[b] (NF)
4[c]	4	NF and F_1	TAL metals, general inorganics, low-level perchlorate

Note: NF = Nonfiltered; F1 = 0.45 µm filter; F2 = 0.20 µm filter.
[a] All analyses by LANL EES-6 laboratory unless noted; see Table 2 for analyte list.
[b] Tritium analysis at Univ. of Miami.
[c] Analyses by LANL contract laboratories.

Table M-4.0-1
Field Data

Date	Time	pH	Temp (°C)	Cond (µS/cm)	Dis. O2 (mg/L)	Turb (NTU)	ORP (mV)	Water Level (ft elev.)	Discharge Rate (gpm)*	Total Elapsed Time (Minutes)	Total Gallons Purged	Depth of Investigation (ft) Effective Porosity = 0.1	Depth of Investigation (ft) Effective Porosity = 0.2	Bore Volumes	Pumping Rate (gpm)
29-Nov	0929	7.77	16.3	352	7.37	2.10	321	5837.91	3.83	0	0	0.00	0.00	0.0	3.45
29-Nov	0942	7.92	19.0	351	7.21	1.07	312	5837.91	3.83	13	50	0.94	0.66	0.7	3.40
29-Nov	1012	7.91	18.5	351	7.12	0.38	272	5837.90	3.83	43	165	1.69	1.20	2.2	3.70
29-Nov	1027	7.80	19.0	351	6.71	0.28	270	5837.90	3.83	58	222	1.96	1.39	3.0	3.40
29-Nov	1127	7.74	19.6	350	7.25	0.22	241	5836.14	3.83	118	452	2.78	1.98	6.0	3.00
29-Nov	1227	7.78	19.9	350	6.73	0.21	245	5834.63	3.83	178	682	3.39	2.42	9.1	2.50
29-Nov	1327	7.79	20.2	349	6.38	0.18	250	5834.62	3.83	238	912	3.91	2.79	12.1	2.50
29-Nov	1427	7.81	20.3	349	6.36	0.76	266	5834.70	3.83	298	1142	4.35	3.11	15.2	2.50
29-Nov	1527	7.83	20.2	350	6.45	0.17	275	5834.65	4.25	358	1397	4.80	3.43	18.6	4.25
29-Nov	1627	7.84	20.2	344	6.21	0.15	284	5834.63	4.00	418	1637	5.18	3.71	21.8	4.00
29-Nov	1727	7.85	19.9	350	5.97	0.15	289	5834.72	3.75	478	1862	5.51	3.94	24.7	-
29-Nov	1827	7.86	19.6	351	6.08	0.23	291	5834.86	3.50	538	2072	5.80	4.15	27.5	3.50
29-Nov	1927	7.87	19.3	350	6.21	0.15	293	5834.85	3.50	598	2282	6.07	4.35	30.3	3.50
29-Nov	2027	7.88	19.1	351	5.91	0.13	294	5834.86	3.50	658	2492	6.33	4.54	33.1	3.50
29-Nov	2127	7.88	19.2	351	6.14	0.27	297	5834.85	3.50	718	2702	6.58	4.72	35.9	3.50
29-Nov	2227	7.88	19.4	351	6.19	0.13	299	5838.13	3.50	778	2912	6.82	4.89	38.7	3.50
29-Nov	2327	7.89	19.1	352	6.24	0.12	300	5837.97	3.75	838	3137	7.06	5.07	41.7	3.75
30-Nov	0027	7.88	19.0	352	6.41	0.13	301	5837.97	3.75	898	3362	7.30	5.24	44.7	3.75
30-Nov	0127	7.89	19.1	352	6.40	0.12	303	5837.97	3.75	958	3587	7.52	5.41	47.7	3.75
30-Nov	0227	7.89	18.9	353	6.46	0.13	308	5837.97	3.75	1018	3812	7.74	5.57	50.7	3.75
30-Nov	0327	7.89	19.1	353	6.46	0.11	305	5837.98	3.75	1078	4037	7.95	5.72	53.6	3.75
30-Nov	0427	7.89	19.7	353	6.39	0.15	306	5837.99	3.75	1138	4262	8.16	5.87	56.6	3.75
30-Nov	0527	7.89	19.4	354	6.33	0.11	305	5837.00	3.75	1198	4487	8.36	6.02	59.6	3.75
30-Nov	0627	7.89	19.8	354	6.42	0.11	307	5838.99	3.75	1258	4712	8.55	6.16	62.6	3.75
30-Nov	0727	7.89	20.1	354	6.38	0.16	308	5837.98	3.75	1318	4937	8.74	6.30	65.6	3.75
30-Nov	0827	7.89	20.1	354	6.46	0.13	309	5837.99	4.00	1378	5177	8.94	6.44	68.8	4.00
30-Nov	0927	7.88	19.3	354	5.79	0.12	312	5837.98	4.00	1438	5417	9.13	6.59	72.0	4.00
30-Nov	1027	7.93	15.6	353	5.91	0.12	309	5837.98	4.25	1498	5672	9.33	6.73	75.4	4.25
30-Nov	1127	7.90	18.9	355	5.66	0.12	309	5838.01	4.25	1558	5927	9.52	6.87	78.8	4.25
30-Nov	1227	7.89	18.5	354	6.08	0.13	307	5838.04	4.00	1618	6167	9.70	7.00	81.9	4.00
30-Nov	1327	7.89	18.9	355	6.16	0.16	302	5838.07	4.00	1678	6407	9.87	7.13	85.1	4.00
30-Nov	1427	7.89	19.0	355	5.75	0.13	304	5838.08	4.00	1738	6647	10.04	7.26	88.3	4.00
30-Nov	1527	7.90	19.5	355	6.05	0.13	308	5838.10	4.00	1798	6887	10.21	7.38	91.5	4.00

Note: 1 BV = 75.26 gal.
* Flow rates prior to 1610 are suspect and likely align with the values after 1627.

Appendix N

Hydrogeologic Cross-Sections Along and Across Sandia Canyon

N-1.0 INTRODUCTION

The hydrogeology of the subsurface near Sandia Canyon plays an important role in controlling groundwater flow in the vadose and saturated zones (including perched zones and the regional aquifer). Groundwater-flow properties of the subsurface are defined by the matrix and fracture properties of canyon-bottom alluvium, mesa-top soils, and underlying Pleistocene to Miocene bedrock. The bedrock unit that hosts stream canyons and alluvial fill is the Tshirege Member of the Bandelier Tuff, up to a point east of core hole SCC-5 where Sandia Canyon cuts into deeper units (Cerro Toledo interval, Otowi Member of the Bandelier Tuff, and east of well R-10, Cerros del Rio lavas [Figure 7.2-1 of the investigation report]). Hydrostratigraphic units of the vadose zone beneath the Bandelier Tuff include Puye Formation fanglomerates, Cerros del Rio lavas or (to the west) dacite lavas of the Tschicoma Formation, pumiceous sediments of the upper Santa Fe Group, and deeper sands and gravels of the Santa Fe Group.

The top of regional saturation beneath middle and lower Sandia Canyon occurs in pumiceous sediments of the upper Santa Fe Group in the vicinity of wells R-43 and R-11, in Puye Formation between well R-11 and municipal supply well PM-3, and in deeper sands and gravels and intercalated basalts of the Santa Fe Group between well PM-3 and the Rio Grande. There are no deep wells to characterize the regional aquifer beneath upper Sandia Canyon, but the top of regional saturation probably occurs primarily in the Puye Formation and pumiceous sediments of the upper Santa Fe Group.

In this appendix, a set of three cross-sections is used to illustrate the relationships between hydrostratigraphic units, the top of regional saturation, and known or suspected perched-intermediate zones. The cross-sections and their locations are shown in Figure N-1.0-1.

N-2.0 E-W SECTION LINE A-A'

This cross-section extends down the axis of Sandia Canyon from well SCI-1 to well PM-3 (Figure N-1.0-1). The western part of this section includes the hypothesized major zone of infiltration for surface water and alluvial groundwater into underlying bedrock units of the vadose zone beneath the canyon floor. The eastern part of the cross-section is located the area where surface water and alluvial groundwater become rare to absent in a down-canyon direction, thus delineating the eastern extent of infiltration into the vadose zone. There are two known perched-intermediate groundwater zones in this part of Sandia Canyon: an upper one in the Puye Formation (Tpf) above Cerros del Rio basalt at well SCI-1, and a lower one in the lower part of the Cerros del Rio basalt at SCI-2 (Figure N-1.0-1). The hydrogeology of the upper perched zone is described in this section, and the lower perched zone is described in section N-3.0 for Line B-B'.

Basalt stratigraphy beneath Sandia Canyon is partly defined borehole gamma logs that respond to changes in the chemistry of the basalts, specifically their uranium, thorium, and potassium contents. The basalt stratigraphy in Sandia Canyon is relatively simple with a thin package of low-gamma basalt overlying a thicker package of high-gamma basalt (Figure N-1.0-1). X-ray fluorescence analyses indicate the basalts with low gamma activities are chemically classified as tholeiites, and those with high-gamma activities are alkali basalts. The broad low-gamma and high-gamma basalt packages defined by the geophysical logs are themselves made up of stacked lavas that consist of multiple flow units separated by interflow breccias. Flow interiors are made up of dense, variably fractured impermeable rock. Under saturated conditions, groundwater flow in these lava interiors is controlled by fractures, with hydraulic conductivity determined by aperture dimensions, fracture density, interconnectivity, and the presence of fracture-filling minerals. Porous flow is expected to dominate groundwater flow in the interflow zones

made up of highly porous breccias, clinker, cinder deposits, and sedimentary deposits. Both nonfractured flow interiors and clay-filled fractured zones are expected to have very low saturated permeability. Zones with significant connected open fractures, lava tubes, and interflow zones are expected to have higher saturated permeability and low porosity, a combination of properties that can lead to very fast travel times. Flowpaths within these basalts are highly uncertain because the complex internal stratigraphy of these rocks.

The upper zone of intermediate saturation at SCI-1 is approximately 22 ft thick. The perching layer for this zone appears to be the top of the Cerros del Rio basalt. A local dip in the upper basalt surface in the vicinity of SCI-2 may focus infiltration from the perched zone into deeper bedrock units in this area. The top of the Cerros del Rio basalt also acts as a perching horizon at wells MCOI-4 and MCOBT-4.4 in Mortandad Canyon, suggesting this contact has favorable characteristics for perching groundwater over a wide area. A structure contour map presented in Appendix H of the "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon" (LANL 2007, 098938, Figure H-2) shows that the upper surface of the Cerros del Rio basalt near SCI-1 generally dips west towards well R-1 in Mortandad Canyon. Small variations in the surface of the Cerros del Rio basalt from erosion and the lateral abutment of basalt flows may result in southwesterly groundwater pathways, towards wells MCOI-4 and MCOBT-4.4 in Mortandad Canyon.

The top of regional saturation in cross section A-A' occurs mostly within pumiceous sediments of the upper Santa Fe Group in the area west of well R-11. To the east, between wells R-11 and PM-3, the top of regional saturation occurs within fanglomerate deposits of the Puye Formation.

N-3.0 NORTHWEST-SOUTHEAST SECTION B-B'

This cross-section extends from well SCI-1 in Sandia Canyon towards the south-southeast towards well R-42 in Mortandad Canyon, then turns towards southeastward to well R-28, and ends at well R-13 (Figure N-1.0-1). The western part of this section includes the hypothesized major zone of contaminant infiltration in Sandia Canyon and the portion of the regional aquifer containing the highest concentrations of chromium beneath Mortandad Canyon (wells R-28 and R-42). The line of section is parallel or subparallel to the dominant groundwater flow direction in the regional aquifer in this area.

The deep perched zone beneath Sandia Canyon at SCI-2 occurs in fractured lavas and interflow breccias of the Cerros del Rio basalt (Figure N-1.0-1). Compared to Sandia Canyon, the basalts beneath Mortandad Canyon are characterized more complex interfingering of high- and low-gamma basalt that probably reflects a more complex flow stratigraphy. The perched zone at SCI-2 is approximately 100 ft thick and occurs in the thick basal high-gamma basalt that has an apparent southerly dip towards Mortandad Canyon. Cuttings and borehole videos show this basalt is made up of multiple lava flows separated by blocky interflow breccias. The lava flows making up the basal high-gamma basalt were deposited over a south to south-southeast dipping surface that developed on top of the Puye Formation during the Pliocene (LANL 2007, 098938, Figure H-3). The nature of the perching horizon at the base of these basalts is poorly understood but may include relatively impermeable sedimentary rocks of the Puye Formation and clay-altered flow-base volcanic sediments at the base of the Cerros del Rio basalt. Beneath Sandia Canyon in the vicinity of SCI-2, groundwater contained the lower part of the Cerros del Rio basalt may follow the dip of basal high-gamma basalt towards the south and south-southeast. Lack of perched water in the Cerros del Rio basalt at R-28 and R-42 in Mortandad Canyon may indicate perched groundwater drained from the basalts and infiltrated the underlying Puye Formation, eventually reaching the regional aquifer in the area between SCI-2 and R-28 and R-42.

Figure N-3.0-1 contains rose diagrams showing the azimuths of bedding dips for regional aquifer rocks in wells R-11, R-13, and R-28. The data represent bedding measurements made from open borehole, oriented Formation Microimager logs conducted by Schlumberger, Inc. These well logs show the orientation of Miocene pumiceous beds in the upper part of the aquifer in the area near the chromium entry point from the vadose zone near well R-28 and along downgradient groundwater pathways. The Miocene pumiceous beds provide the best orientation data in the logs because of their well-stratified nature. Unfortunately, similar data for the underlying Miocene riverine deposits for this area are not available, and bedding data for the overlying Puye Formation are generally too noisy to produce consistent results. As Figure N-3.0-1 shows, bedding in the uppermost Miocene pumiceous sediments strike N72E and dip about 5.7° towards the south-southeast. Groundwater flowing easterly or east-southeasterly near the water table in the vicinity of wells R-42 and R-43 will flow through these highly stratified, dipping deposits. Although the predominant direction of groundwater flow is controlled by water-table gradients, contrasting hydrologic properties of dipping strata along the flow path will probably result in some lateral diversion of the advective groundwater flow and potentially enhanced dispersion of contaminant transport along bedding planes towards the east-northeast and west-southwest. Bedding of strata may also cause vertical diversion of the advective groundwater flow as groundwater may follow highly permeable beds dipping towards the south-southeast. On the other hand, the bedding stratification is also expected to impede vertical dispersion of contaminants. The vertical extent of the contaminant plumes probably does not go much deeper than 100 to 150 ft into the aquifer based water-level responses to municipal pumping and the distribution of chromium in monitoring wells. Modeling of contaminant transport in Appendix L incorporates the heterogeneity imposed dipping strata in the regional aquifer by the increasing the dispersivity in the flow model.

N-4.0 NORTH-SOUTH SECTION LINE C-C'

This north-south cross-section extends from the mesa north of Sandia Canyon south to mesa south of Mortandad Canyon. The cross-section includes the major zone of infiltration in Sandia Canyon near SCI-1 and shows the regional water table cutting up section from Miocene sands and gravels on the north to Miocene pumiceous sediments and the Puye Formation to the south.

The perched groundwater in Cerros del Rio basalt at SCI-2 beneath Sandia Canyon follows the dip of the basal high-gamma basalt to the south towards Mortandad Canyon (Figure N-1.0-1). Perched groundwater was absent when core hole MCOBT-8.5 was drilled, indicating this zone dies out before reaching Mortandad Canyon in a southerly direction. Similar zones of perched groundwater 20 to 40 ft thick occur near the base of the Cerros del Rio basalts at wells MCOI-5 and MCOI-6 in Mortandad Canyon, west of section C-C', indicating this setting is generally favorable for the formation of perched groundwater zones. The MCOI-5 and MCOI-6 perched groundwater probably receives local recharge from surface water and alluvial groundwater in middle Mortandad Canyon area.

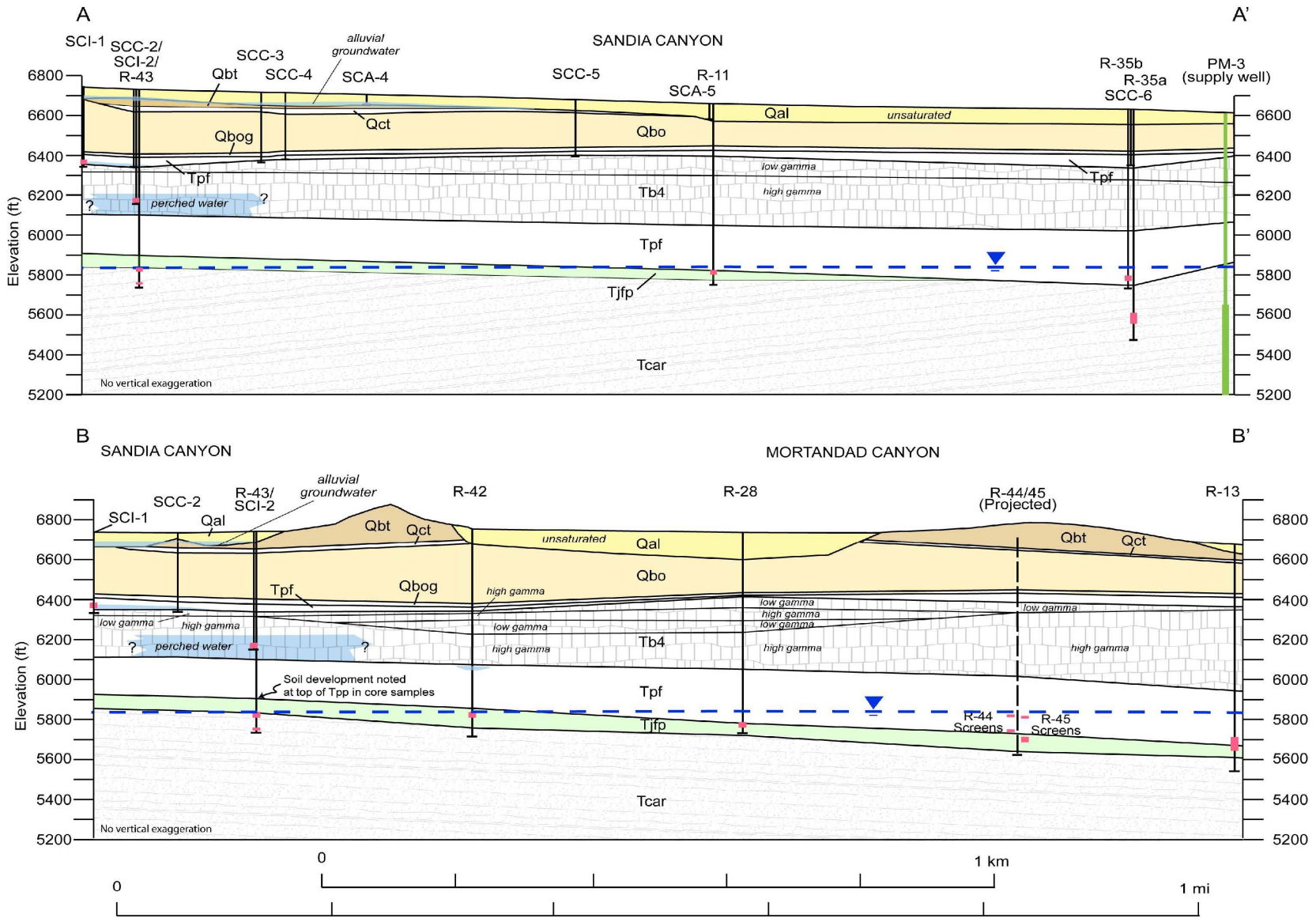
N-5.0 REFERENCE

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative

authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), September 2007. "Fate and Transport Modeling Report for Chromium Contamination from Sandia Canyon," Los Alamos National Laboratory document LA-UR-07-6018, Los Alamos, New Mexico. (LANL 2007, 098938)



Note: Locations of cross-sections and the legend of symbols are on the next page.

Figure N-1.0-1 Geologic cross-sections for Sandia and Mortandad Canyons

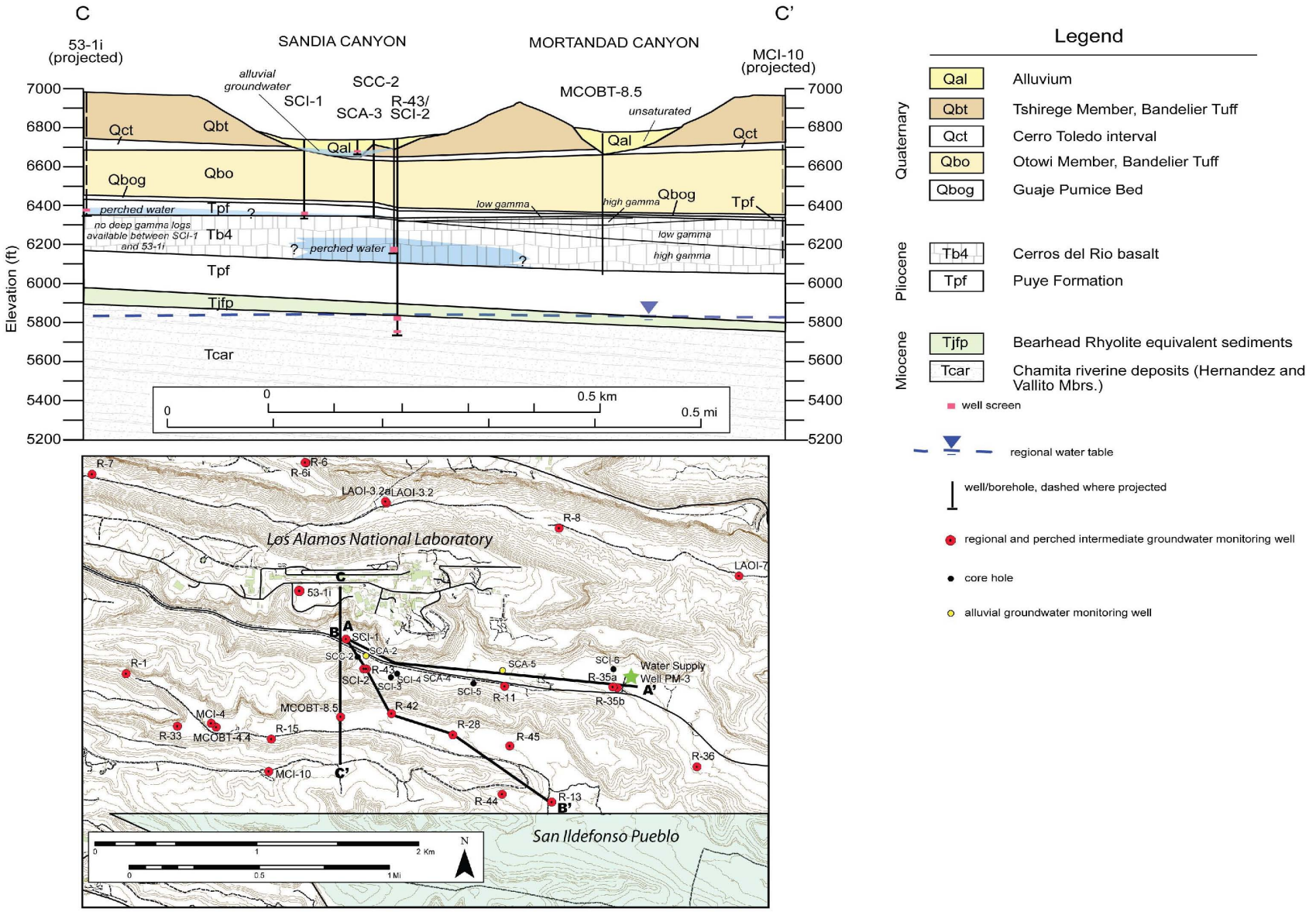


Figure N-1.0-1 (continued) Geologic cross-sections for Sandia and Mortandad Canyons

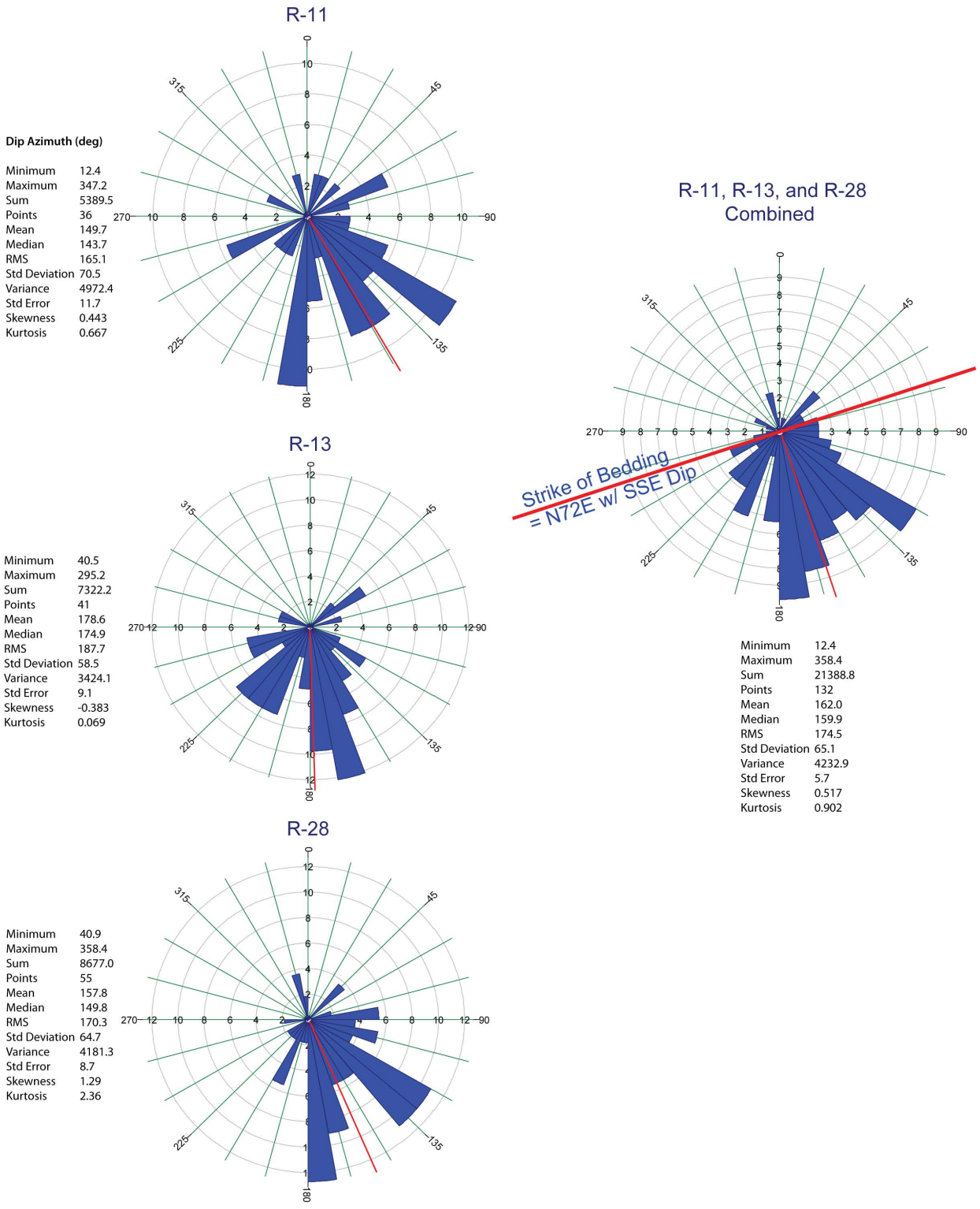


Figure N-3.0-1 Bedding azimuths determined from open borehole Formation Microimager logs for Miocene pumiceous sediments in wells R-11, R-13, and R-28

Attachment 1

Supplemental Tables for Appendixes B through M
(on CD included with this document)