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Cerro Grande Fire Impacts to Water Quality and Stream Flow near Los Alamos National Laboratory: Results of Four Years of Monitoring

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Edited by Hector Hinojosa, Group IM-1
Prepared by Teresa Hiteman, Group RRES-ECO

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Bruce M. Gallaher and Richard J. Koch

Abstract

In May 2000, the Cerro Grande fire burned about 7400 acres of mixed conifer forest on the Los Alamos National Laboratory (LANL), and much of the 10,000 acres of mountainside draining onto LANL was severely burned. The resulting burned landscapes raised concerns of increased storm runoff and transport of contaminants by runoff in the canyons traversing LANL. The first storms after the fire produced runoff peaks that were more than 200 times greater than prefire levels. Total runoff volume for the year 2000 increased 50% over prefire years, despite a decline in total precipitation of 13% below normal and a general decrease in the number of monsoonal thunderstorms. The majority of runoff in 2000 occurred in the canyons at LANL south of Pueblo Canyon (70%), where the highest runoff volume occurred in Water Canyon and the peak discharge occurred in Pajarito Canyon.

Increased runoff from the fire-impacted areas continued in 2001, 2002, and 2003, but due to the location of major precipitation events in these years, most runoff occurred in Pueblo Canyon, which drains Los Alamos town site areas and contains a significant amount of LANL legacy radioactive contamination in stream sediments. The estimated total downstream storm runoff at LANL in 2001 was 388 acre-ft (64% from Pueblo Canyon), 1.5 times higher than in 2000 and about 3.6 times higher than the prefire average annual runoff, although the seasonal precipitation recorded at TA-6 in 2001 (6.94 in.) was less than received in 2000 and less than the prefire average seasonal precipitation.

The estimated total downstream runoff in 2002 was 248 ac-ft (76% from Pueblo Canyon), about 2.3 times higher than the prefire average annual runoff, although the seasonal precipitation in 2002 was about 70% of the prefire average seasonal precipitation. The total downstream runoff in 2003 was 284 ac-ft (81% from Pueblo Canyon), which was 2.7 times higher than the prefire average although seasonal precipitation was 6.9 in., drought conditions. The higher than prefire average runoff at LANL in 2003 indicates effects from the Cerro Grande fire were still present. Lower runoff volumes in 2002 and 2003 were partially the result of lower precipitation amounts, but significantly lower peak flows and runoff yields in 2002 and 2003 reflect a partial recovery of the fire-impacted areas of watersheds since the Cerro Grande fire.

To evaluate the possible water quality impact downstream of LANL, runoff events were monitored and sampled throughout the summer runoff seasons of 2000 through 2003 by the Water Quality and Hydrology Group (WQH) at LANL and from 2000 through 2002 by the New Mexico Environment Department (NMED) Department of Energy Oversight Bureau. Additionally, the U.S. Geological Survey collected surface water and bed sediment samples from the Rio Grande upstream and downstream of LANL and from Cochiti Reservoir in 2000 and 2001. Environmental samples of runoff and baseflow were also collected by the LANL Environmental Restoration Project in 2000 and 2001; these results were compiled with the results of WQH and NMED sampling to provide a comprehensive evaluation of the effects of the Cerro Grande fire to the environment.

Runoff and baseflow samples were analyzed for radionuclide, major, minor, and organic constituents. The water quality data are evaluated by comparing with historical levels and relevant standards and, where possible, by examination of spatial and temporal trends. These comparisons indicate whether the results after the Cerro Grande fire vary significantly from previous years and provide some environmental health context to the individual results. Other studies use these runoff results to quantify potential health risks associated with the storm water.

Runoff quality was highly variable, a function of streamflow intensity and proximity to the burned areas and LANL legacy sources. Consistent with runoff associated with other forest fires around the world, the first pulses of runoff after the fire contained ash and newly eroded soil that were enriched in radionuclides from past atmospheric fallout and naturally occurring major and minor constituents and nutrients. Concentrations of 28 or more constituents were slightly to moderately elevated in storm runoff by the fire effects. These fire-related constituents were carried downstream in runoff and were partially deposited in stream beds and floodplains on LANL lands in 2000. LANL-derived constituents are evident in runoff collected near major contaminant sources. In 2000, the LANL impacts to runoff were often masked after mixing in stream channels with the fire-related constituents. High-volume runoff in 2001, 2002, and 2003 in Pueblo Canyon, however, eroded sediments and transported legacy LANL contaminants, primarily plutonium-239,240, downstream.

Concentrations of fire-related constituents declined progressively through the runoff seasons from 2000 through 2002, partly due to flushing of the ash from the upstream mountainsides and stream channels. The fire-related constituent concentrations continued to decline in 2002 and largely were not evident in 2003. Exceptions to this trend were observed in median annual concentrations of dissolved manganese and total sediment, which increased in storm runoff from 2000 through 2002, but showed a return to near normal conditions in 2003. The increase in dissolved manganese indicates a relatively persistent geochemical change in surface soils or a possible leaching of deposited ash, but is not known to represent a health hazard. Continued erosion of the burned area is evident through four runoff seasons after the fire, with increasing transport of suspended sediment in upstream LANL runoff in 2000 and 2001, but upstream transport of suspended sediment declined in 2002 and 2003. However, even by 2003, the fourth season after the fire, suspended sediment transport in downstream runoff remained about one order of magnitude higher than prefire conditions.

Sample results indicate that most (commonly 95% or more) of the radionuclides and minor constituents were bound to suspended sediment in the runoff rather than dissolved in the water. Dissolved concentrations of radionuclides and minor constituents near LANL generally met federal drinking water standards set for public health. Median concentrations of total radionuclides in runoff collected below the burned areas increased by 10 to 50 times from prefire levels, showing an accelerated movement of fallout radionuclides and minor constituents that had accumulated in forest vegetation and soils and was present in the ash from the burned hillslopes. Larger-magnitude stream flows resulted in an increase in the inventory of radionuclides and minor constituents that were carried downstream from LANL. Compared to the three years before the fire, the total activity of cesium-137 and strontium-90 transported across the downstream boundary increased by about 10 times, primarily the result of increased runoff and ash carried from burned areas. Transport of plutonium-239,240 beyond the downstream LANL boundary increased from prefire levels by approximately 50 times, reflecting large-magnitude flood events in Pueblo Canyon and accelerated movement of LANL-derived plutonium-239,240 into lower Los Alamos Canyon and the Rio Grande.

Within the Rio Grande, moderate increases were observed in concentrations of radionuclides (cesium-137 and plutonium-239,240) and minor constituents (barium, manganese, strontium, and zinc) in Cochiti Reservoir bed sediments, but no changes in dissolved minor constituent or radionuclide concentrations were apparent. Bed sediment concentrations were below applicable screening criteria for protection of aquatic life or residential activities. Dissolved concentrations of radionuclides and minor constituents in the Rio Grande were lower than U.S. Environment Protection Agency or U.S. Department of Energy drinking-water standards or guidelines, indicating no lasting impacts to the water column from the Cerro Grande fire.

1.0 Introduction

This report describes the observed effects of the Cerro Grande fire and related environmental impacts to watersheds at and near Los Alamos National Laboratory (LANL) for the first four runoff seasons after the fire, from 2000 through 2003.

Spatial and temporal trends in radiological and chemical constituents that were identified as being associated with the Cerro Grande fire and those that were identified as being associated with historic LANL discharges are evaluated with regard to impacts to the Rio Grande and area reservoirs downstream of LANL. The results of environmental sampling performed by LANL, the New Mexico Environment Department (NMED), and U.S. Geological Survey (USGS) after the Cerro Grande fire are included in the evaluation. Effects are described for storm runoff, baseflow, stream sediments, and area regional reservoir sediment.

1.1 The Cerro Grande Fire

In May 2000 the Cerro Grande fire burned approximately 43,000 acres that included portions of Bandelier National Monument, the Santa Fe National Forest, LANL, Los Alamos town site, and the Santa Clara and San Ildefonso Indian Reservations (BAER 2000). Figure 1.1-1 shows the location of the fire and the burn severity with respect to land ownership in the area. Many residences in the community of Los Alamos and thousands of acres of surrounding forestland were consumed by the most devastating wildfire ever recorded in the state of New Mexico (BAER 2000; Webb and Carpenter 2001).

Areas of the highest burn severity were located on the eastern flanks of the Sierra de los Valles, which comprise the headwaters of the main drainages that transect the Pajarito Plateau. The upper reaches of the main drainages that cross LANL and the Los Alamos town site were all impacted by the Cerro Grande fire. The Cerro Grande fire caused about $1 billion in property damage. Over 400 families were left homeless, and over 100 LANL structures burned. Additional information about the Cerro Grande fire was compiled by Webb and Carpenter (2001).

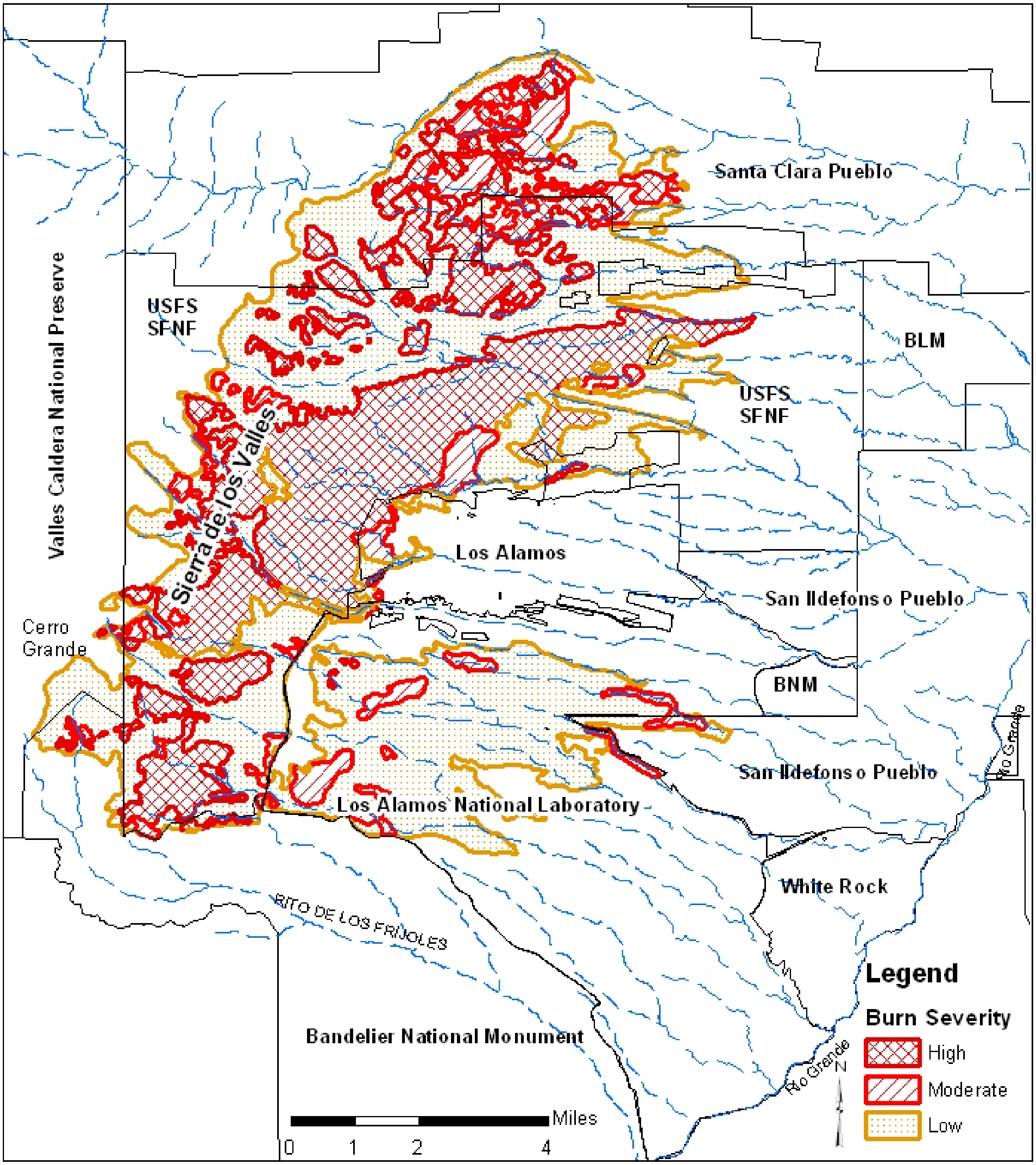
The Cerro Grande fire burned major portions of watersheds draining onto LANL from adjacent Santa Fe National Forest lands, where from 20% to 90% of the burned areas were considered high-severity burn. Table 1.1-1 lists the burn severity for the upper watersheds in the Los Alamos area. Most of the burned area at LANL was considered low-severity burn, but numerous small structures burned, and the cover vegetation at some inactive waste sites was at least partially burned.

Table 1.1-1. Upper Watershed Burn Severity

Watershed	Unburned (%)	Low (%)	Moderate (%)	High (%)
Guaje	29	22	26	22
Rendija	0	2	10	88
Pueblo	0	2	1	96
Los Alamos	25	43	0.5	32
Pajarito	0	44	3	53
Water	6	49	5	40

Source: BAER 2000

The area of greatest burn severity was generally in the Sierra del los Valles, in watersheds upstream (west) and north of the LANL boundary. Burning of trees and organic material on the forest floor removed material that previously absorbed rainfall and created hydrophobic (water repellant) conditions (BAER 2000), leading to increased runoff and erosion. Major and minor water quality constituents (for example, aluminum, iron, barium, manganese, and calcium) and fallout radionuclides (cesium-137; plutonium-239,



Source: BAER (2000)
(Note: USFS SFNF is U.S. Forest Service, Santa Fe National Forest; BLM is Bureau of Land Management; BNM is Bandelier National Monument.)

Figure 1.1-1. Location and burn severity of the Cerro Grande fire.

-240; and strontium-90) previously bound to forest materials were concentrated in resulting ash that was readily mobilized by runoff (e.g., Katzman et al. 2001, Johansen et al. 2003, LANL 2004). Storm runoff events after the fire carried these fire-related constituents onto LANL and several large runoff events extended across LANL to the Rio Grande (ESP 2001, Gallaher et al. 2002, Koch et al. 2001).

The Cerro Grande fire had significant impacts on the landscape around Los Alamos. The impacts include physical, chemical, and hydrologic changes in the major watersheds crossing LANL. These changes were initially reported by BAER (2000), Gallaher et al. (2002), and in the report titled *Environmental Surveillance at Los Alamos during 2000* (ESP 2001).

1.2 General Impacts of Wildfire on Watersheds

Many of the fire impacts observed immediately after the fire have also been reported for other local fires and elsewhere. Watersheds undergo significant responses to wildfire in southwest ecosystems. The responses include changes in the runoff characteristics, sediment yield, and water chemistry. The burning of the understory and forest litter triggers many of these changes. Under prefire conditions, grasses, brush, and the forest canopy serve to slow and capture runoff, nutrients, and sediments. In the absence of the vegetative cover, the runoff becomes flashier, with sharper, higher-magnitude flood peaks. Development of hydrophobic (water repellent) soils during fires also increases runoff.

For example, after the 1977 La Mesa fire and the 1996 Dome fire in the Jemez Mountains, peak flows in Frijoles and Capulin Canyons were estimated to be 164 and 123 times greater than the pre-burn peaks, respectively (Veenhuis 2001, 2002). With less infiltration, vegetative uptake and retention, the total water yields from burned watersheds are higher. Once the runoff begins, loose soils and ash are quickly removed from the steeper slopes. Fire-associated debris is swiftly delivered directly to streams in large quantities. Wildfires can also interrupt uptake of anions and cations by vegetation and speed mineral weathering. The concentrations of inorganic ions subsequently increase in streams after a fire (DeBano et al. 1979). The sudden addition of substantial quantities of chemically active carbon and minerals (like calcite) to the watershed initiates geochemical and pH (acidity) changes.

To understand the chemical water quality changes noted in runoff water after the Cerro Grande fire, Bitner et al. (2001a) compiled a summary of the reported effects of fire on runoff water chemistry and soils. For major water quality constituents, increases of dissolved calcium, magnesium, nitrogen, phosphorous, and potassium and pH in runoff water have been observed in watersheds after fire. Minor constituents and radionuclides have typically been much less studied, but manganese, copper, zinc, and cesium-137 have been observed to increase in runoff as a result of fire.

Purtymun and Adams (1980) and Veenhuis (2002) focused on water quality perturbations after the La Mesa fire and demonstrated a slight increase in calcium, bicarbonate, chloride, fluoride, and total dissolved solids (TDS) in the base flow of Frijoles Creek. Runoff samples contained elevated suspended sediment, barium, calcium, iron, bicarbonate, manganese, lead, phenol, and zinc concentrations. Base-flow water quality returned to normal three to five years after the fire.

Of note are studies that describe the concentration of fallout-associated radionuclides in ash and subsequently in runoff at other locations where forest fires have occurred (Amiro et al. 1996, Paliouris et al. 1995). The studies conclude that fire caused the mobilization of fallout radionuclides bound to the forest canopy, or in the forest litter, and concentrated radionuclides in the ashy layer of the burned surface soil, which was readily available for erosion. Studies indicate that changes in chemistry and flow conditions after forest fires are temporary, usually lasting less than five years, unless floods destroy the physical habitat of the streambed and hillsides. Early reestablishment of vegetative ground cover after a wildfire is a critical factor controlling the recovery.

1.3 Fire Effects to Soil

Barium, calcium, carbonate, iron, magnesium, manganese, potassium, sodium, silica, strontium, uranium, and other trace elements are concentrated in ash from the burning of ponderosa pine, producing an alkaline pH of 9.3 when leached with deionized water (Longmire et al. 2001). Calcite is formed within the ash from the oxidation of organic carbon according to the following overall reaction.

$$CaC_2O_4 + 0.5O_2(g) = CaCO_3 + CO_2(g)$$

Reduction of metal constituents occurs as a result of the high temperature of the fire (>680° C) and combustion of organic carbon. These reactions influence the solubility of manganese (II, IV) solids, for example $(Ca, Mn^{2+})Mn_4^{4+}O_9 3H_2O$ is observed in fracture fills within the Bandelier Tuff (Longmire et al. 2001). These reactions may provide the source of elevated concentrations of manganese and calcium in runoff from fire-impacted areas.

Surface soil samples were collected from areas within and around LANL after the Cerro Grande fire. The samples were analyzed for radionuclides, radioactivity, and minor constituents; the results were compared with soil samples collected in 1999 from the same sites. Also, many types of organic substances (volatile and semivolatile organic compounds, organochlorine pesticides, polychlorinated biphenyls, high explosives, and dioxin and dioxin-like compounds) were assessed in soils from LANL, perimeter, and regional sites after the fire. The mean radionuclide and radioactivity concentrations in soils collected from LANL and perimeter areas after the Cerro Grande fire were statistically similar to soils collected before the fire. Similarly, all mean trace elements in soils collected from LANL and perimeter areas after the fire were statistically similar to soils collected before the fire. The results showed that impacts to regional, perimeter, and on-site (mesa top) areas from smoke and fallout ash as a result of the Cerro Grande fire were minimal (Fresquez et al. 2000).

1.4 Characteristics of Ash and Muck from the Cerro Grande Fire

After the Cerro Grande fire, a large amount of residual ash remained in burned areas. The source of much of the material carried in storm water runoff during the 2000 runoff season was from ash and debris left by the Cerro Grande fire. Ash and muck (postfire sediments dominated by reworked ash) were sampled at locations representative of background conditions west (upstream) of LANL (LANL 2000a; Katzman et al. 2002; Johansen et al. 2003; LANL 2004). Ash samples were also collected in the Viveash Fire area (near Pecos, NM) for comparison with ash samples from the Cerro Grande fire (Hopkins 2001; Katzman et al. 2001). The results of the sampling document the presence of elevated cesium-137, plutonium-239,240, and strontium-90 concentrations in Cerro Grande fire ash samples compared to prefire sediment and soils concentrations. The ash also contained elevated concentrations of several naturally occurring major and minor constituents (for example, barium, manganese, and calcium), which are readily taken up into plant tissue.

Some radionuclide and minor constituent concentrations in ash were up to an order of magnitude greater than prefire sediment and soil. The mean concentration of cesium-137 in seven ash and muck samples collected after the fire in 2000 was 4.4 pCi/g, about five times the upper limit of the prefire background value (BV) for sediments and soils. The mean concentration of strontium-90 in the ash and muck samples was 2.08 pCi/g, about two times the prefire sediment BV; the mean concentration of plutonium-239,240 was 0.37 pCi/g, about five times the sediment BV (LANL 2000b; Katzman et al. 2001). These results are consistent with the scientific literature, which shows forest fires can condense and mobilize natural radionuclides, fallout radionuclides, and minor constituents (e.g., metals) (Bitner et al. 2001).

Based on a limited data set, ash from the Cerro Grande fire appears to have contained relatively higher concentrations of plutonium-239,240 than the ash from the Viveash Fire (Katzman et al. 2001). Based on previous evidence that LANL has contributed to the existing concentrations of plutonium-239,240 and other radionuclides in areas within a few miles of LANL (e.g., Fresquez et al. 1998), past stack emissions from LANL may have contributed to elevated plutonium-239,240 concentrations in the forest mass in the vicinity of LANL.

1.5 Flooding and Erosion after the Cerro Grande Fire

The increases in runoff and sediment yields after the fire were anticipated to be severe because the burned terrain was so steep and the high severity of the burn created water-shedding hydrophobic soils and removed virtually all ground cover (BAER 2000). The Burned Area Emergency Rehabilitation Team predicted peak flows from the upper watersheds after the fire hundreds of times larger than prefire conditions, even after considering aggressive postfire rehabilitation treatments.

The recorded hydrologic and water quality responses to the Cerro Grande fire largely mirror those described for fires elsewhere. Comparing post- and prefire conditions showed significant changes in the magnitude of flooding, sediment yield, and water quality.

Runoff in June and July 2000 from areas burned by the Cerro Grande fire was dramatic, although from historically insignificant rainfall amounts. The most destructive runoff event of 2000 occurred on June 28, when a short-duration (30-minute), relatively moderate-intensity thunderstorm occurred over the flanks of the Sierra de los Valles, just west of LANL. Rainfall recorded at TA-16 was 0.43 in., and the Water and Pajarito Canyons Remote Automated Weather Stations (RAWSs) received 0.79 and 0.69 in., respectively (Koch et al. 2001). The June 28, 2000, precipitation caused flooding in canyons west of and across LANL. The ensuing floodwaters destroyed the upstream gages in Pajarito Canyon, Cañon de Valle, and Water Canyon where record high discharges were observed. The maximum estimated peak flow in Pajarito Canyon upstream of State Road (SR) 501 was 1020 cfs, an all-time record for watersheds gaged by LANL on the Pajarito Plateau (previous maximum flow on the Pajarito Plateau for the period of record was 520 cfs in lower Ancho Canyon in 1993) (Shaull et al. 2001). The total downstream runoff in 2000 was about 248 ac-ft, about 2.3 times higher than the prefire average annual runoff.

Whereas runoff in 2000 was dominated by flood events in canyons from Los Alamos Canyon southward to Water Canyon (hereafter referred to as LANL canyons), runoff in 2001, 2002, and 2003 was dominated by flood events in Pueblo Canyon, which is mainly in Los Alamos town site (although part of the lower canyon is within the LANL boundary). The largest runoff event in 2001 occurred on July 2 when a short-duration, relatively high-intensity thunderstorm occurred over the western part of the Los Alamos town site. This event caused a flood in Pueblo Canyon that totaled about 90 ac-ft and caused extensive damage to a sewer line and access trail in the canyon. The total downstream storm runoff at LANL in 2001 was 388 ac-ft, 1.5 times higher than in 2000 and about 3.6 times higher than the prefire average annual runoff (106 ac-ft), even though the seasonal precipitation in 2001 (6.94 in.) was less than received in 2000 and less than the prefire average seasonal precipitation (12.4 in.) (Koch et al. 2002).

The largest storm runoff event in 2002 occurred on the night of June 21-22 when a high-intensity thunderstorm occurred over the western part of the Pajarito Plateau. This event created runoff in all major drainages at LANL that totaled 120 ac-ft (about 48% of all runoff in 2002) and caused a flood in Pueblo Canyon that totaled about 80 ac-ft (Shaull et al. 2003). The total downstream runoff at LANL in 2002 was 248 ac-ft, similar to the runoff in 2000, although the seasonal precipitation in 2002 (8.5 in.) was about 70% of the prefire average seasonal precipitation (12.4 in.) (Koch et al. 2003). For the postfire years of 2000 through 2003, the majority of runoff each year was derived from specific thunderstorms and resulting runoff events, which do not provide a correlation with seasonal precipitation amounts.

The largest runoff event in 2003 was on August 23 when the western Los Alamos town site received 1.8 in. of precipitation during a relatively short-duration thunderstorm. Runoff in Pueblo Canyon was about 73 ac-ft. The total seasonal storm runoff in 2003 was 284 ac-ft, about 2.5 times the prefire average (Shaull et al. 2004). The higher than prefire average runoff at LANL in 2002 and 2003 indicates that the effects of the Cerro Grande fire were still present with regard to runoff. Additional information about precipitation and storm runoff after the Cerro Grande fire is provided by Reneau et al. (2003a) and LANL (2004), and is further discussed in Section 2.1.

1.6 Flood Mitigation Projects after the Cerro Grande Fire

After the Cerro Grande fire in May 2000, the formerly densely forested slopes of the Sierra de los Valles upstream of LANL and the Los Alamos town site area were almost completely denuded of vegetation. Due to hydrophobic soils (non-permeable soil areas created as a result of very high temperatures often associated with wild fires) and the loss of vegetation from steep canyon sides caused by the fire, the risks of surface runoff and soil erosion on hillsides above LANL were greatly increased over prefire levels (BAER 2000). The danger to LANL facilities and structures located down-canyon from the burned area was magnified (NNSA 2002).

An Emergency Rehabilitation Project Plan was developed and implementation of the plan began during the summer of 2000 (BAER 2000; LANL 2000c). Based on modeling of potential floods from storm runoff, several projects were undertaken to reduce this risk. The Army Corps of Engineers recommended to the U.S. Department of Energy (DOE) that the following fire rehabilitation construction projects be completed to mitigate potential flooding and damage to infrastructure and facilities or to mitigate contaminant transport:

- Reinforcement of Los Alamos Reservoir in upper Los Alamos Canyon,
- Construction of low-head weir and sediment trap in Los Alamos Canyon,
- Construction of flood retention structure in middle Pajarito Canyon,
- Reinforcement of SR 501 crossing at Pajarito Canyon,
- Reinforcement of SR 501 crossing at Two Mile Canyon,
- Reinforcement of Anchor Ranch Road crossing at Twomile Canyon, and
- Reinforcement of SR 501 at Water Canyon.

A complete description of the flood mitigation projects that were conducted in the Los Alamos area after the Cerro Grande fire is in the *Special Environmental Analysis for the Department of Energy, National Nuclear Security Administration: Actions Taken in Response to the Cerro Grande Fire at Los Alamos National Laboratory, Los Alamos, New Mexico* (DOE 2000). A summary description of projects that pertain primarily to storm runoff follows.

After the large runoff event on June 28, 2000, in Pajarito Canyon (Figure 1.6-1), a flood retention structure was installed in the middle canyon upstream of Technical Area (TA) 18. This roller-compacted concrete flood and sediment retention structure was installed to control storm water flooding and runoff down the canyon into TA-18. A new road was constructed into Pajarito Canyon to accommodate the heavy concrete equipment needed for construction of the structure. The structure extends 390 ft (117 m) across the canyon and is about 70 ft (21 m) high (Figure 1.6-2). The bottom of the retention structure is equipped with one 42-in.- (105-cm-) diameter drainage conduit, which allows accumulated storm water to drain. Accumulated water is retained no longer than 96 hours behind the retention structure; water drains naturally into the existing streambed. Construction of the flood retention structure was conducted over about a six-week time period from July to late August 2000 (DOE 2000). In 2002, after two years of sediment accumulation upstream of the flood retention structure, an estimated 9,680 yd^3 of material had accumulated to a depth of 6 ft (NNSA 2002).

A trash rack and a 760-ft-long (228-m) steel diversion wall were constructed in Pajarito Canyon upstream of TA-18. The diversion wall was designed to divert storm water and debris to the south of critical assembly building 1 (Casa 1) at TA-18. Approximately 1000 ft (300 m) of steel panels attached to large metal beams were installed. The beams were driven vertically into the ground with a vibratory hammer. The sheets extended approximately 5 ft to 6 ft (1.5 m to 1.8 m) aboveground. Sheet piling was initiated in early July 2000 and completed in about three weeks. The structure was backfilled with earth to provide additional strength on the downstream side (DOE 2000).

In Los Alamos Canyon, structures at TA-2 and TA-41 were removed or reinforced to withstand potential flooding. The existing unpaved road in the lower portion of Los Alamos Canyon was regraded to accommodate heavy machinery transport. Rock gabions were installed as needed for erosion control along this roadway. At the upstream end of Los Alamos Canyon, the Los Alamos Reservoir was drained

Photograph by Billy Turney, RRES-WQH

Figure 1.6-1. Flooding in Pajarito Canyon at TA-18 on June 28, 2000.

Photograph Courtesy USACOE

Figure 1.6-2. Construction of the flood retention structure in middle Pajarito Canyon, September 2000 (downstream face shown).

to serve as a catchment for storm runoff and sediment and to facilitate strengthening the dam. The reservoir dam faces were strengthened to lessen the danger of dam failure so that the dam could trap water and debris from the heavily burned area of the watershed upstream from the reservoir. Shotcrete (blown concrete) was placed over all faces of the dam (DOE 2000).

A low-head weir and sediment trap were constructed in lower Los Alamos Canyon near the intersection of SR 4 and SR 502 to provide sediment control, mitigation of contaminant transport, and retention and deceleration of storm water flow. The weir includes a large, relatively shallow basin that serves as a sedimentation basin and sediment retention structure. The detention basin is 500 ft (150 m) long by 100 ft (30 m) wide by 10 ft (3 m) deep. The weir is located on the downstream side of the detention basin and is about 10 ft (3 m) high and is constructed of rock gabions about 10 ft high. The total area of the weir, detention basin, and excavated backfill area, is less than 3 ac (1.2 ha). Approximately 11,900 cubic yards (yd^3) (9,044 cubic meters [m^3]) of soil and rock were excavated and banked along the sides of the canyon (DOE 2000).

In addition to the projects performed by the Corps of Engineers, burned area rehabilitation for erosion control at LANL and surrounding areas included contour felling of burned trees, contour raking, seeding by hand and air, mulching, hydro-mulching, and construction of rock and log check dams (BAER 2000). Moderately and severely burned areas were contour raked to break up the soil surface and to redirect and reduce water flow. After raking, the areas were seeded by hand, by mechanical spreaders, or by small, low-flying aircraft. After seeding, straw mulch was spread by hand or by mechanical straw blowers (SWEIS 2001). The progress of the erosion control practices at LANL was reported by Buckley et al. (2002) and Buckley et al. (2003).

Culvert and drainage area clean-out activities were performed at all low-lying areas where storm runoff was expected and where any inadvertent ponding of storm water might be expected from debris damming. Various flood damage control measures were installed to provide protection to electric power pole structures and other utility structures (such as electric substation, gas lines, water lines, wells and chlorination stations, sewage lift stations, and telephone and communication structures) (SWEIS 2001).

In 2000 after the Cerro Grande fire, personnel from the LANL Environmental Restoration (ER) Project, New Mexico Environment Department (NMED), and the DOE evaluated potential release sites (PRSs) located within the burned area to assess which ones had been impacted by the fire. It was determined that 315 PRSs had been impacted to some degree by the fire. These 315 sites were field checked to determine the need for erosion control measures, called best management practices. Previous results of the Resource Conservation Recovery Act (RCRA) Facility Investigations of the 315 sites and the results of field checks were used to determine which sites had the highest prefire erosion potential to assure that all sites were appropriately evaluated. Of the 315 PRSs, 91 were recommended for best management practices, which included the placing of protective jute matting, rock check dams, log-silt barriers, and straw wattles, as well as other actions to control runoff and erosion at the PRSs. The description of activities and best management practices installed were reported by Veenis (2000) and Veenis and Johnson (2001).

Los Alamos County also performed rehabilitation projects, the most notable of which was the reinforcement and rehabilitation of the Pueblo Canyon landfill bridge at Diamond Drive in Los Alamos. The culverts beneath the land bridge were replaced with larger (86 in.) culverts and the structure was reinforced and stabilized to prevent flood waters from damaging or impacting this important transportation artery. The Los Alamos Reservoir partly filled with ash and muck during the first and second runoff seasons after the fire. To ensure the ability of the reservoir to provide flood control, and to ensure that the structure was not compromised by flooding, the reservoir was rehabilitated and armored against flooding in 2000 and the ash and muck were removed from the reservoir in 2001 (DOE 2000, Lavine et al. 2001).

During the first storm runoff events after the fire in June 2000, abnormally large runoff from the burned areas carried logs and rocks and debris downstream that plugged culverts beneath SR 501 and caused flooding over the highway, creating a safety hazard and a dangerous situation for travel. The U.S. Forest Service constructed debris catchers or ‘trash racks’ in the major canyons upstream of LANL and west of

SR 501 to prevent logs and debris from flowing downstream and plugging the culverts. The trash racks were constructed of steel tubing and were about 6 ft high and extended across the canyons about 0.25 mi upstream of roadways. Meteorological stations, called RAWS, were installed in each major drainage where fire occurred to alert local officials when rain rates were such that a flash flood might occur. Nine RAWS stations were installed in 2000 and as of spring 2004 were still operating; the real-time meteorological data are available on the internet at http://www.wrcc.dri.edu/losalamos/.

The LANL ER Project performed several remediation projects where known soil contamination present in canyons could have been eroded and transported by storm runoff flooding. In Los Alamos Canyon downstream of the confluence of Los Alamos Canyon and DP Canyon, approximately 915 yd^3 (700 m^3) of contaminated surface soil were removed from a 2.5-ac (1.0-ha) site during June 2000 (MK 2000). The soil was removed to minimize the overall potential for transport of contaminants in the event of a severe flood. The removed sediment contained low levels of radioactive contaminants from LANL operations at DP Site in the 1940s and 1950s. The sediments contained concentrations of radionuclides about 20 times greater than natural sediment deposits within Los Alamos Canyon. Heavy excavation and hauling equipment, such as a backhoe, excavator, and dump truck, was used to remove the soil. The contaminated soil was transported by truck for disposal at TA-54, Material Disposal Area (MDA) G (DOE 2000).

The LANL ER Project also removed contaminated sediment from the Mortandad Canyon sediment traps, where about 350 yd^3 (266 m^3) of sediment were removed from the three existing sediment traps during July 2000. The purpose of this maintenance action was to increase the capacity of the existing traps in case of flooding during an extreme rain event and to prevent the sediments from migrating downstream and potentially off site. The traps were constructed in 1986 and consist of large excavated basins surrounded by U-shaped berms that were built from the excavated alluvium; the traps had not been maintained since 1992. The traps are approximately 900 ft (270 m) long and a maximum of 200 ft (60 m) wide and are located along the Mortandad Canyon stream channel downstream from the confluence of Mortandad Canyon and Ten-Site Canyon. The total capacity of the sediment traps is about 1.2 million gal. (4.5 million L) (LANL 1997). The sediments were excavated using heavy equipment and placed onto trucks and removed to the LANL low-level waste disposal site at TA-54 (WGII 2000).

The long-term disposition of the flood control structures installed in Pajarito Canyon and Los Alamos Canyon was not considered as a part of the decision to undertake the construction actions. Watershed conditions are expected to return to a prefire status or approximate the prefire condition three to eight years after the fire. National Nuclear Security Administration personnel, through an Environmental Analysis (EA), evaluated alternative actions regarding the disposition of these structures when no longer needed to protect LANL facilities (NNSA 2002). The structures that were addressed in the EA included the following:

1) The flood retention structure constructed of roller compacted concrete located in Pajarito Canyon;
2) the low-head weir, constructed of rectangular rock-filled wire cages (gabions), and associated sediment detention basin in Los Alamos Canyon;
3) reinforcements of four road crossings, including a land bridge along Anchor Ranch Road in Twomile Canyon and SR 501 embankment reinforcements at Twomile Canyon, Pajarito Canyon, and Water Canyon; and
4) the steel diversion wall upstream of TA-18 in Pajarito Canyon (NNSA 2002).

The ‘Proposed Action’ recommended in the EA was to remove part of the aboveground portion of the flood control structure in Pajarito Canyon, including gabions that are along the downstream channel. Design studies performed at the time of removal would determine the channel width needed and the required slope. At the conclusion of the partial flood retention structure removal, the streambed would be graded, the remaining sides of the flood retention structure would be stabilized, and the banks would be reseeded. The Proposed Action would also include removal of the access road in order for that part of the canyon wall to be recontoured and stabilized if TA-18 facilities remain in place; if TA-18 facilities are relocated, this access road might remain in place. The site of the former flood retention structure would be monitored and maintained to prevent erosion of the slopes and damage to the floodplain and downstream wetlands. The Proposed Action also includes removal of the entire aboveground portions of the steel diversion wall at TA-18. The removal of these two structures would not occur until after the Pajarito watershed returns to prefire conditions, or the ecosystem has recovered adequately to approximate a prefire condition (NNSA 2002).

The low-head weir and detention basin in lower Los Alamos Canyon are planned to be left in place as part of the Proposed Action; routine maintenance activities would be performed. If a wetland were to develop in the detention basin, although this is uncertain, the wetland would remain in place. Current maintenance activities would be continued, including the replacement of wire mesh containers that rust or fail. Sampling of sediments would be performed to evaluate potential chemical, radiological, and heavy metal constituent concentrations in the detention basin, and sediments would be removed as required and disposed of appropriately through the LANL waste management program (NNSA 2002).

Road reinforcements at canyons along SR 501 are planned to be left in place as part of the Proposed Action. Routine inspection and maintenance activities would continue when required (NNSA 2002).

1.7 Health Related Assessments of Storm Runoff after the Cerro Grande Fire

In various sections of this report we compare measured runoff water quality results against a variety of regulatory standards developed to protect human health, wildlife, and livestock for a few generic common water uses. This allows us to quickly test if individual chemicals or radionuclides are present at excessive concentrations. However, this analysis does not account for the cumulative risk posed by the combination of multiple chemicals or radionuclides, nor does it account for site-specific land uses.

As a complement to this report, several in-depth risk analyses evaluated the cumulative short-term and long-term risks posed by these agents. A comprehensive risk analysis of the effects of the Cerro Grande fire was performed by the Interagency Flood Risk Assessment Team (IFRAT) (IFRAT 2001), a consortium of risk scientists from seven state and federal agencies. The IFRAT study included development of a long-term (30-year) risk assessment that compared ash, ash-containing sediment, and water samples in and around the Pajarito Plateau and LANL before and after the fire. Based on year 2000 results, the IFRAT results show that common activities, such as swimming or those that result in direct skin contact with ash-containing sediments or water, pose no substantial increased health risk over that posed by the same activities in non-ash containing sediment or water. To be protective, the IFRAT recommended that ash not be added to garden soils as an amendment because of the possibility that plant tissues could accumulate high levels of manganese that might be harmful to people if eaten.

A Laboratory risk assessment team evaluated the short-term (1-year) risks to humans from exposure to post-Cerro Grande fire runoff and sediments (Kraig et al. 2002). The objective was to estimate and assess potential radiological and nonradiological effects from the Cerro Grande fire that might have been experienced by the receptors most affected during calendar year (CY) 2000 and attempt to determine what component may have been caused by current or past LANL operations. The scenarios developed were intended to be as realistic as possible while incorporating enough conservatism so that we could conclude that larger exposures were very unlikely to have occurred. Where increased risks were observed, researchers were not able to identify LANL as the source for the increases, but could not preclude the possibility that legacy LANL wastes in canyons and the area surrounding LANL contributed to the increases, therefore, the effects of the fire were assessed independent of the source (Kraig et al. 2002).

Results of the risk assessment showed that the effects of the Cerro Grande fire resulted in increased concentrations of radiological constituents and chemicals in runoff and in sediments deposited during CY 2000. None of the radiological or chemical risk effects of the fire were believed to cause health effects for exposures received during 2000. The risk analyses indicated that the predominance of the effects was caused by the increased mobilization of locally deposited worldwide fallout radionuclides, or of naturally occurring substances that were concentrated by the fire (Kraig et al. 2002).

The NMED contracted Risk Assessment Corporation (RAC) to provide an independent assessment of the potential incremental health risks to the communities of northern New Mexico from these radionuclides and chemicals released by the Cerro Grande fire. The RAC report evaluates the risks to people exposed to radionuclides and chemicals in air from the Cerro Grande fire.

The RAC investigation concluded that:

> … exposure to LANL-derived contaminants during the Cerro Grande fire did not result in a significant increase in health risk over that incurred from the fire itself. The risk of cancer from exposure to radionuclides and metals in and on vegetation that burned was greater than that from radionuclides and chemicals released from contaminated sites at LANL. All cancer risks were below the U.S. Environmental Protection Agency range of acceptable risks of 10^{-6} to 10^{-4}. Hazard quotients from exposure to noncarcinogenic LANL-derived chemicals exceeded the 1.0 level at some locations on LANL property. However, the estimated hazard quotients are conservative and likely overestimate the actual risks that occurred. It is likely that the risks from exposure to PM10[1] far outweigh the risks from LANL-derived radionuclides and chemicals and those released from natural vegetation during the fire (RAC 2002).

The description of the assessments and the conclusions of the RAC investigation are available on the internet at http://www.nmenv.state.nm.us/DOE_Oversight/RAC.htm and http://www.racteam.com/Experience/Projects/CerroGrande.htm.

1.8 Runoff Monitoring at LANL after the Cerro Grande Fire

To determine the influence of fire-related effects to water quality from possible LANL sources, we distinguish results for samples collected upstream of LANL from samples collected within the LANL site and from samples downstream of LANL. On the Pajarito Plateau, the stations located upstream of LANL include those at the western boundary of LANL directly upstream or downstream of SR 501 in Los Alamos, Pajarito, and Water Canyons and Cañon de Valle, and those collected in Guaje Canyon upstream of Rendija Canyon to the north. Samples collected downstream of LANL on the Pajarito Plateau are those collected from stream gages located along the eastern boundary of LANL in Pueblo, Guaje, Los Alamos, Sandia, Pajarito, Potrillo, Water, and Ancho Canyons and Cañada del Buey. Along the Rio Grande, samples collected at Otowi Bridge and other locations upstream are considered upstream of LANL, and those samples collected downstream of Otowi Bridge are considered to be downstream of LANL. Table 1.8-1 lists the runoff collections sites at LANL and indicates which sites are upstream and downstream of LANL, and Figure 1.8-1 shows the locations of the runoff collections sites.

Storm runoff monitoring at Los Alamos after the Cerro Grande fire was primarily performed by the LANL Water Quality and Hydrology Group (WQH) as part of environmental surveillance monitoring and the Cerro Grande fire Recovery Project. Runoff samples collected by WQH were primarily located at existing or newly installed stream gaging stations on the Pajarito Plateau; immediately after the fire a few runoff samples were manually collected. The results of runoff sampling in 2000 after the Cerro Grande fire were reported by Johansen et al. (2001) and Gallaher et al. (2002).

After the Cerro Grande fire, the ER Project collected runoff samples in drainage areas where existing or planned canyon investigations were being implemented; most runoff samples collected by ER were located in Los Alamos and Pueblo Canyons (LANL 2003a).

The NMED DOE Oversight Bureau (OB) collected baseflow and storm runoff samples around Los Alamos after the fire as part of the independent evaluation of environmental media at LANL. The NMED storm runoff results for 2000 were provided via letter report on February 26, 2003 (NMED 2003a), and the results of sampling in 2002 were provided via letter report on April 23, 2003 (NMED 2003b).

[1] particulate matter less than or equal to 10 microns in diameter

Table 1.8-1. Storm Runoff Collection Sites in Watercourses at LANL.

Gage No.	Canyon	Location Name	Relative Location	Collection Method
E026	Los Alamos	Los Alamos Canyon below ice rink	Upstream	Automated
E030	Los Alamos	Los Alamos Canyon above DP Canyon	Onsite	Automated
E038	DP	DP Canyon above TA-21	Onsite	Automated
E039	DP	DP Canyon below meadow at TA-21	Onsite	Automated
E040	DP	DP Canyon above Los Alamos Canyon	Onsite	Automated
E042	Los Alamos	Los Alamos Canyon above SR 4	Downstream	Automated
E049	Los Alamos	Los Alamos Canyon Weir	Downstream	Manual
E050	Los Alamos	Los Alamos Canyon below LA Weir	Downstream	Automated
E055	Pueblo	Pueblo Canyon above Acid Canyon	Upstream	Automated
E056	Acid	Acid Canyon above Pueblo Canyon (Acid Weir)	Onsite	Automated
E060	Pueblo	Pueblo Canyon above SR 502	Downstream	Automated
E070	Bayo	Bayo Canyon below TA-10	Downstream	Automated
E089	Guaje	Guaje Canyon above Rendija Canyon	Upstream	Automated
E090	Rendija	Rendija Canyon above Guaje Canyon	Downstream	Automated
E099	Guaje	Guaje Canyon below SR 502	Downstream	Automated
E110	Los Alamos	Los Alamos Canyon above Rio Grande	Downstream	Automated
E121	Sandia	Sandia right fork at Power Plant	Onsite	Automated
E122	Sandia	Sandia left fork at Asphalt Plant	Onsite	Automated
E123	Sandia	Sandia Canyon below Wetlands	Onsite	Automated
E124	Sandia	Sandia Canyon above Firing Range	Onsite	Automated
E125	Sandia	Sandia Canyon above SR 4	Downstream	Automated
E200	Mortandad	Mortandad Canyon below Effluent Canyon	Onsite	Automated
E201.5	Ten Site	Ten Site Canyon above Mortandad Canyon	Onsite	Automated
E218	Cañada del Buey	Cañada del Buey at TA-46	Onsite	Automated
E225	Cañada del Buey	Cañada del Buey near MDA G	Onsite	Automated
E230	Cañada del Buey	Cañada del Buey above SR 4	Downstream	Automated
E240	Pajarito	Pajarito Canyon below SR 501	Upstream	Automated
E241	Pajarito	Pajarito Canyon above Starmers	Upstream	Automated
E242	Starmers/Pajarito	Starmers above Pajarito Canyon	Upstream	Automated
E242.5	La Delfe/Pajarito	La Delfe above Pajarito Canyon	Onsite	Automated
E243	Pajarito	Pajarito Canyon above Twomile Canyon	Onsite	Automated
E245	Pajarito	Pajarito Canyon above TA-18	Onsite	Automated
E245.5	Pajarito	Pajarito Canyon above Threemile Canyon	Onsite	Automated
E246	Threemile	Threemile Canyon at TA-18	Onsite	Automated
E250	Pajarito	Pajarito Canyon above SR 4	Downstream	Automated
E252	Water	Water Canyon above SR 501	Upstream	Automated
E253	Cañon de Valle	Cañon de Valle above SR 501	Upstream	Automated
E256	Cañon de Valle	Cañon de Valle below MDA P	Onsite	Automated
E257	Cañon de Valle	Cañon de Valle tributary at Burn Grounds	Onsite	Automated
E260	Water	Water Canyon above S Site Canyon	Onsite	Automated
E261	Water	S-Site Canyon above Water Canyon	Onsite	Automated
E262	Cañon de Valle	Cañon de Valle above Water Canyon	Onsite	Automated
E262.5	Water	Water Canyon below MDA AB	Onsite	Automated
E263	Water	Water Canyon above SR 4	Downstream	Automated
E264	Water	Indio Canyon at SR 4	Downstream	Automated
E265	Water	Water Canyon below SR 4	Downstream	Automated
E267	Potrillo	Potrillo Canyon above SR 4	Downstream	Automated
E273	Ancho	Ancho Canyon above SR 4	Downstream	Automated
E274	Ancho	Ancho north fork below SR 4	Downstream	Automated
E275	Ancho	Ancho Canyon below SR 4	Downstream	Automated
E338	Chaquehui	Chaquehui at TA-33	Downstream	Automated

1.8.1 Environmental Surveillance Monitoring

In 1991, LANL began regularly monitoring runoff from storm events on Laboratory property in Pueblo and Los Alamos Canyons. The number of monitoring locations (stream gages) was augmented from 1995 to 2002 and most of the stream gages were equipped with automated runoff samplers. By 2002, the sampling network comprised more than 70 sampling stations. Figure 1.8-1 shows the locations of the

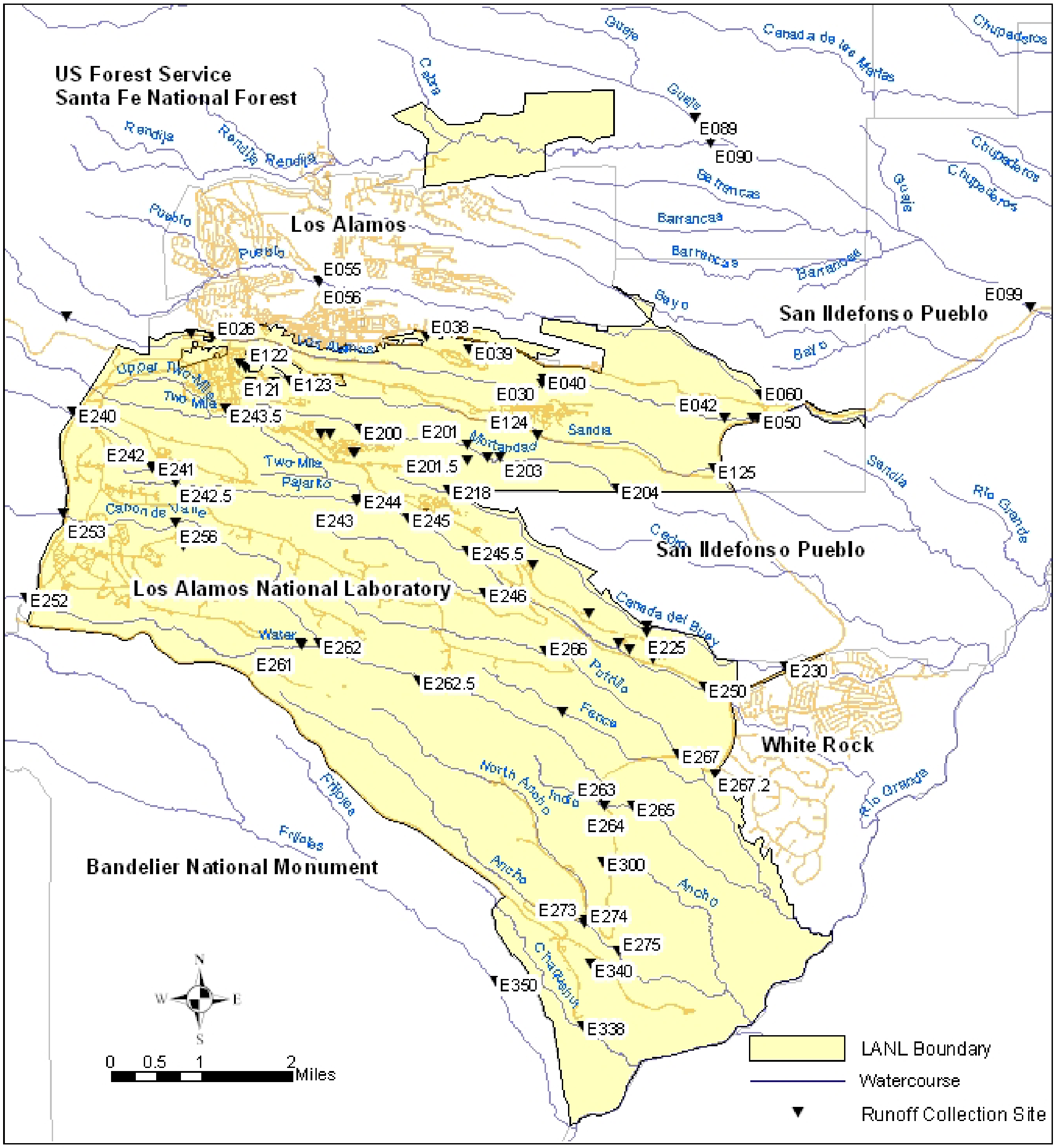


Figure 1.8-1. Storm runoff sampling stations in watercourses on the Pajarito Plateau.

runoff sampling stations in major drainages on the Pajarito Plateau. Runoff sampling at LANL is routinely performed to provide compliance with environmental permits and approvals (ESP 2000).

In 2000, WQH conducted an extensive environmental monitoring and sampling program to evaluate the effects of the Cerro Grande fire at LANL and especially to evaluate if LANL may have impacted public and worker health and the environment as a result of the fire (Gallaher et al. 2002). These monitoring and sampling activities continued through 2001 and 2002 to evaluate the extended impacts from the fire and to monitor impacts to storm water from LANL operations. Snowmelt and storm runoff sampling activities are conducted according to the Institutional Monitoring and Sampling Plan for Evaluating Impacts of the

Cerro Grande fire (LANL 2000a) and according to the procedure for Operation of Stream Gaging Stations and Collection of Storm Water Runoff Samples (LANL 2001).

Using the automated flow monitoring stations and visual inspections of runoff conditions, LANL personnel collect runoff samples at the following sites:

- In major watercourses upstream of LANL operational areas as storm runoff moves onto LANL property from the Sierra de los Valles,
- In major and minor watercourses on LANL property at
  - specific mesa-top sites where LANL operations occur, and
  - in watercourses as storm runoff originates and moves through LANL,
- In major watercourses near the downstream boundary of LANL, and
- In Rendija Canyon and Guaje Canyon north of LANL and downstream of historic LANL operations.

At times, runoff samples are also collected manually at specific locations where stream gages and automatic samplers are not located. These samples are designated as manual, or grab, runoff samples.

Table 1.8-1 lists the stream gage sampling stations that were active in main watercourses at LANL in 2002. This table shows the canyon where the sample collection sites are located, the common name of the collection site, and whether automated or manual runoff samples were collected at each site. A complete list of all stream gaging stations at LANL is provided by Shaull et al. (2003) and by Koch et al. (2003).

Stream gages in upper Pajarito Canyon, Cañon de Valle, and upper Water Canyon were destroyed by floodwaters on June 28, 2000. These gages were replaced and/or repaired and were in operating condition at the beginning of the 2001 storm water runoff season. Stream gages were also added north of Los Alamos in Rendija Canyon and Guaje Canyon in 2001. In 2001, storm water runoff was monitored at over 70 stream gage stations at LANL and runoff samples were collected from 34 automated samplers.

For the 2002 runoff season, stream gages were added in Guaje Canyon above SR 502 (E099) and in a tributary to Twomile Canyon near TA-3 (E243.5). Additionally, runoff gage height data became available for the stream gages in upper Pueblo Canyon above Acid Canyon (E055) and in Acid Canyon above Pueblo Canyon (E056) (Shaull, personal communication), but discharge data have not yet been published for these stream gages. In 2002 and 2003, storm runoff was monitored at over 70 stream gage stations at LANL and storm runoff samples were collected from 40 automated samplers. Figure 1.8-1 shows the locations of the stream gage stations and Table 1.8-1 lists the gage stations operable as of 2003. For the summary purposes and discussion in this report, the storm runoff season is considered to be from May through October of each year.

Storm runoff samples collected by WQH were usually collected automatically by ISCO samplers triggered by stream-height gaging equipment. The sampling equipment was programmed to collect 1 liter of sample every 5-minutes when triggered by rising water at the stream gage at the beginning of a runoff event. The ISCO samplers contain 12 1-liter containers, thus time-weighted samples were collected over the first 60-minutes of a runoff event (12 containers x 5 minutes = 60 minutes to fill all containers). All sample containers were homogenized for analyses except for the container that appeared to samplers to contain the largest amount of suspended material; this container was analyzed separately for maximum total suspended solids (TSSm). If the time of the runoff event was less than 60 minutes, not all bottles were filled, in this case analyses were prioritized based on contaminant history of each specific collection site.

The time-weighted runoff samples collected by LANL were intended to provide the closest approximation of contaminant concentrations in runoff. Concentrations of suspended particles and contaminants are greatest in runoff samples during the rising-limb of the hydrograph during a runoff event and lowest during the relatively longer hydrographic decay of runoff discharge. Therefore, for short-duration runoff events (e.g., total runoff time less than one hour), the time-weighted collection method may acquire contaminant concentrations lower than corresponding flow-weighted average (FWA) values. Conversely, for longer-duration runoff events (greater than one hour), the time-weighted sampling method employed may acquire contaminant concentrations of samples that over-approximate the corresponding FWA values for an event. The median duration of a runoff event in 2001 was about 7.1 hours and in 2002 was about 4.4 hours, with the average time from start of flow to peak flow 0.2 and 0.9 hrs, respectively (Koch et al. 2002; Koch et al. 2003). Thus, for most runoff events at LANL, the collection of time-weighted samples during the initial 1-hour of a flow event tends to conservatively approximate concentrations for the runoff event, when compared with concentrations derived from flow-weighted sampling during an entire flow event.

Appendix Table A summarizes the storm runoff samples collected in primary watercourses by WQH for environmental surveillance in 2000, 2001, 2002, and 2003. In 2000, runoff samples were collected on 26 days from 34 locations; in 2001 samples were collected on 21 days from 28 locations; in 2002 samples were collected on 26 days from 37 locations; and in 2003 samples were collected on 17 days from 23 locations. Tables in Appendix A show the number of analytical results available for filtered and unfiltered samples.

1.8.2 Environmental Restoration Monitoring

The ER Project collected storm runoff samples in limited reaches of some canyons at LANL after the Cerro Grande fire. Samples were collected in selected reaches of Pueblo, Los Alamos, and Pajarito Canyons. The results of the ER sampling were provided in data reports to NMED in 2003 (LANL 2003a) and to RAC in 2004 (RAC 2004); the pertinent runoff data are included in the summaries provided in this report. Appendix A tables list the locations of storm runoff samples that were collected in major watercourses by ER in 2000 and 2001. The available analytical results indicate that in 2000 ER collected 34 runoff samples from seven locations, and, in 2001, 18 samples were collected from four locations. The ER samples were analyzed for radionuclides, total organic carbon, and total suspended solid (TSS), and a few samples were analyzed for cyanide (LANL 2003).

1.8.3 NMED DOE Oversight Bureau Monitoring

The NMED DOE OB collected storm runoff samples in selected canyons at LANL as part of oversight of LANL environmental organizations. Appendix A tables summarize the storm runoff samples collected at Los Alamos in 2000, 2001, and 2002. A summary of the results of the NMED storm water sampling is summarized in following sections. Figure 1.8-2 shows the NMED sampling locations at LANL. In 2000 NMED collected 50 runoff samples from 31 locations on 16 days; in 2001, 12 samples from five locations on nine days; and in 2002, 25 samples from 13 locations on 12 days.

The NMED DOE OB sample location identification scheme is based on the canyon name (PU = Pueblo, LA = Los Alamos, SA = Sandia, MO = Mortandad, PA = Pajarito, WA = Water, etc.) and the distance in miles from the downstream confluence of the drainages. For example, PU-0.1 is located in Pueblo Canyon 0.1 miles upstream from the confluence with Los Alamos Canyon. This location is approximately located at the WQH E060 stream gage.

The sediment portion of unfiltered storm runoff samples collected by NMED was separated from the water portion of the samples before some laboratory analyses. Therefore, results for some unfiltered samples include two values, one value is per liter, and the other value is per kg.

NMED collects runoff samples manually and with automated samplers programmed to collect water samples at initiation of rising water at the beginning of a runoff event. NMED typically programs the automated samplers to fill all sample bottles at the beginning of a runoff event. These runoff samples are sometimes referred to as “first flush” samples, which are not weighted over time or flow volume. These samples are thought to provide higher concentrations of contaminants for a runoff event to provide a conservative “worst-case” scenario for contaminant transport.

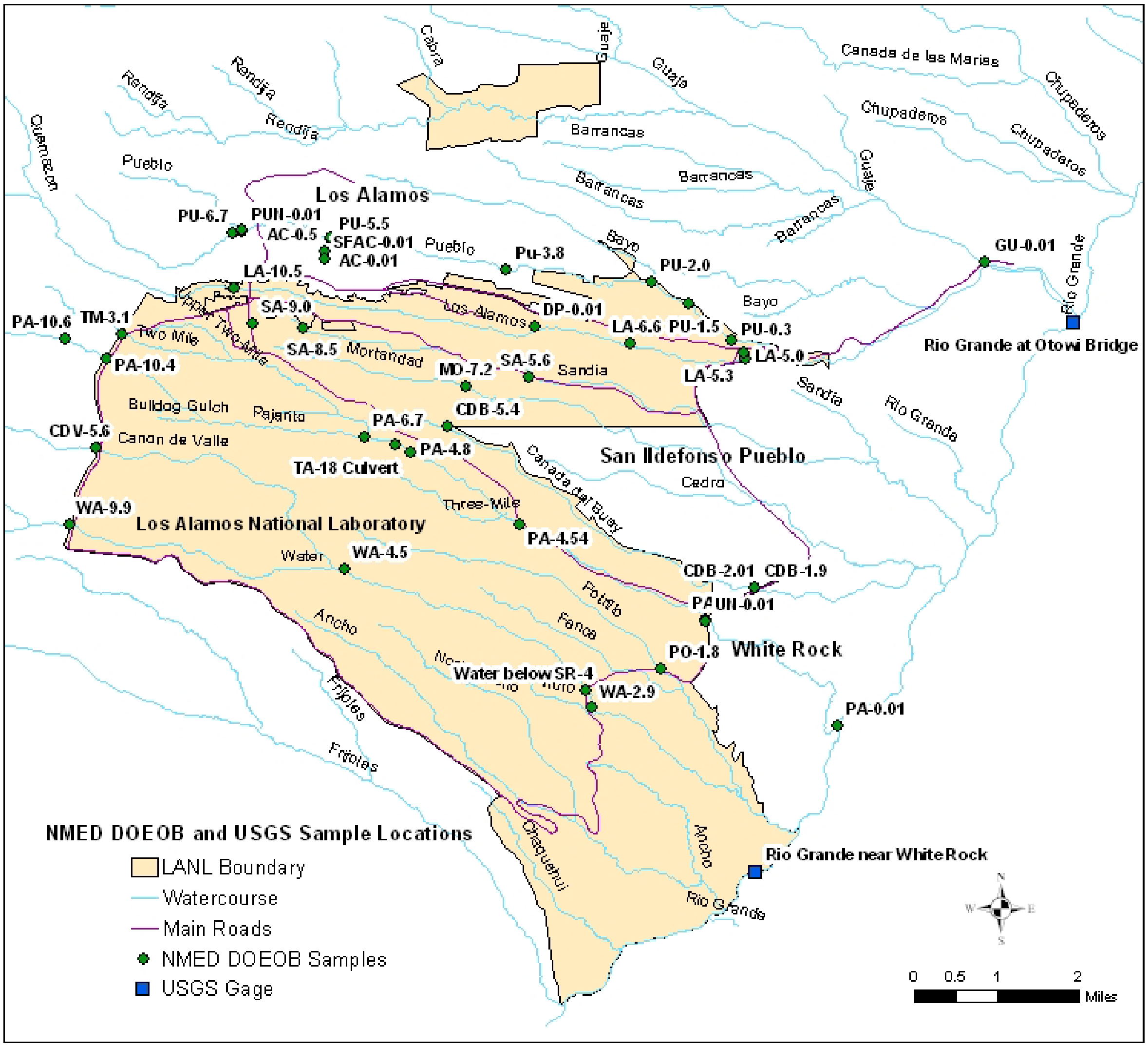


Figure 1.8-2. Location of NMED and USGS samples.

1.8.4 U.S. Geological Survey Rio Grande Sampling after the Cerro Grande Fire

In 2000 and 2001 after the Cerro Grande fire, the USGS collected surface water samples in the Rio Grande and from Cochiti Reservoir after significant storm runoff events from LANL and downstream of the watersheds that were affected by the fire. Because of logistical constraints, however, not all runoff events from the Pajarito Plateau were sampled in the Rio Grande and usually only one location could be sampled per day after a runoff event (Kraig et al. 2001, p. 5). Samples were collected from seven locations on five days in 2000 and from six locations on 11 days in 2001.

The USGS collected samples from the Rio Grande at Otowi Bridge and from a new stream gage that was located downstream of White Rock. USGS personnel established a temporary stream gaging station on the Rio Grande named “Rio Grande near White Rock, NM” (gage number 08313268). This stream gage was located downstream of the existing stream gage at Otowi Bridge (gage number 08313000) and between Water and Ancho Canyons. Figure 1.8-2 shows the locations of the USGS stream gages near Los Alamos and Appendix Table A-4 lists the water samples collected by the USGS. The USGS collected width-integrated water samples and bed sediment samples at the stream gaging locations in 2000 and 2001.

The USGS collected water and sediment samples from Cochiti Reservoir and from the Rio Grande downstream from Cochiti Reservoir in 2000 and 2001; the results of the USGS sampling are discussed in following sections. Information about the USGS stream gages is available on the USGS web site at http://waterdata.usgs.gov/nm/nwis/current/?type=flow. The information available for each stream gage includes both flow data and the results of water sampling at each location.

2.0 Impacts of the Cerro Grande Fire to Storm Runoff

One of the notable effects of the Cerro Grande fire was increased runoff from precipitation events during the summers of 2000, 2001, 2002, and 2003. When thunderstorms occurred over the Sierra de los Valles, runoff from burned slopes was significantly higher in canyons downstream than before the fire. Storm runoff in 2000 after the Cerro Grande fire was described by Shaull et al. (2001), Koch et al. (2001), Johansen et al. (2001), and Gallaher et al. (2002); storm runoff in 2001 was described by Shaull et al. (2002) and Koch et al. (2002); storm runoff in 2002 was described by Shaull et al. (2003) and by Koch et al. (2003); and storm runoff in 2003 was described by Shaull et al. (2004).

The increased volume of runoff from upstream mountain areas carried ash and sediment eroded from the mountains, but also, especially in 2001 and 2002 in Pueblo Canyon (e.g., Lyman et al. 2002, Wilson et al. 2002), caused erosion of stream banks and floodplains in canyons on the Pajarito Plateau. Stream banks and floodplains in some canyons contain contaminants, primarily radionuclides in the case of Pueblo Canyon, that were eroded and mobilized by the increased volume of runoff after the fire (e.g., LANL 2004). The following sections describe the flow characteristics of runoff after the fire and the contaminant concentrations that resulted from the high runoff volumes.

Because storm runoff and contaminant transport in Pueblo Canyon were significant in years 2001, 2002, and 2003, whereas flood events in 2000 after the fire were primarily located in canyons traversing the main part of LANL south of Pueblo Canyon (Los Alamos Canyon, Pajarito Canyon, Cañon de Valle, and Water Canyon), the following discussion of storm runoff often distinguishes the effects observed in "LANL canyons" from those observed in Pueblo Canyon. This is not intended to separate contaminants in Pueblo Canyon from LANL, but to provide a basis for better understanding the effects of the fire to storm runoff. Reference to "LANL downstream" and "LANL upstream" refer to canyons that traverse LANL, and include those canyons mentioned above. Although a small portion of Pueblo Canyon is within LANL, and contaminants in Pueblo Canyon are due to legacy LANL discharges (e.g., Reneau et al. 1998, LANL 2004), runoff and contaminant transport in this canyon are described separately from the other LANL canyons.

2.1 Storm Runoff Volumes after the Cerro Grande Fire

Figure 2.1-1 shows the annual upstream and downstream runoff at LANL and the downstream runoff in Pueblo Canyon for 2000 through 2003, the prefire average values, and the combined runoff from Rendija and Guaje Canyons for 2001 through 2003. Upstream runoff data are not available for Pueblo Canyon until 2003, thus only downstream estimated runoff for Pueblo Canyon is shown. Flow at gage E060 in lower Pueblo Canyon is primarily discharge from the Los Alamos County wastewater treatment plant; therefore, storm runoff at this gage was estimated using daily flow records that exceeded the usual wastewater discharges. In 2000 after the fire, the total upstream runoff at LANL was 331 ac-ft, 3.7 times higher than the prefire average; however, by 2002 and 2003, the upstream runoff was 66 and 21 ac-ft, respectively, significantly less than the prefire average upstream runoff. In 2000, the downstream runoff at LANL was 177 ac-ft, 2.8 times higher than the prefire average; however, in 2002 and 2003, the downstream runoff at LANL was similar to the prefire average.

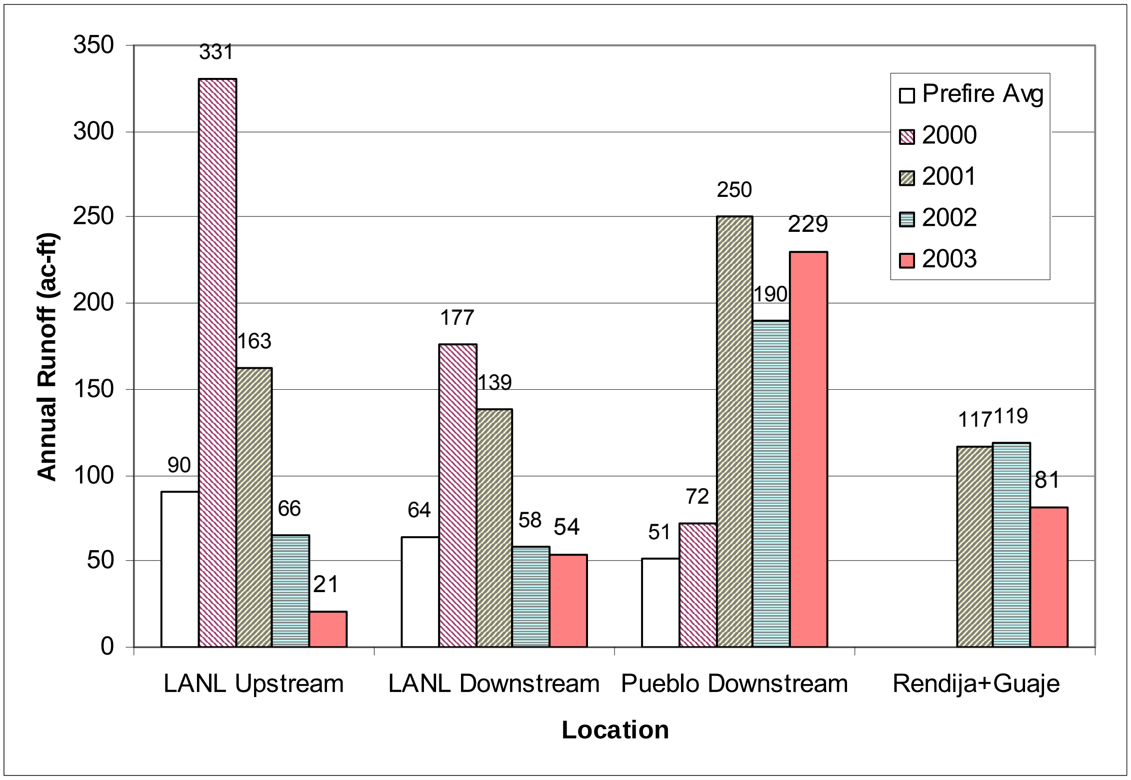
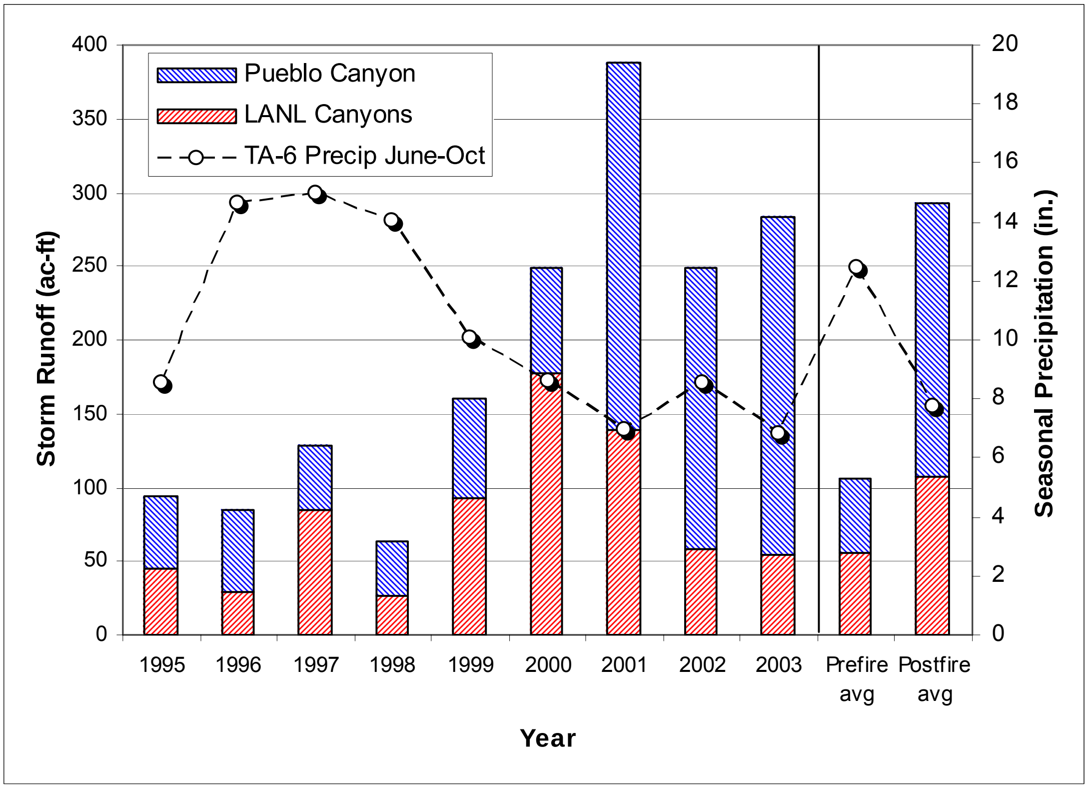


Figure 2.1-1. Annual storm runoff at locations upstream and downstream of LANL, prefire and postfire.

In 2000 storm runoff in lower Pueblo Canyon was 72 ac-ft, slightly higher than the prefire average, but in 2001 the runoff was 250 ac-ft, about 5 times higher than the prefire average; in 2002, runoff was 190 ac-ft, 3.7 times the prefire average, and in 2003, runoff was 229 ac-ft, about 4.5 times the prefire average. Whereas runoff in canyons at LANL appears to have returned to near prefire conditions by 2002, the runoff in Pueblo Canyon through 2003 continued to be 4 times higher than prefire runoff. Runoff data are not available for Rendija and Guaje Canyons for prefire years and for 2000, however, combined runoff in 2001 and 2002 was 117 and 119 ac-ft, respectively. Combined runoff from these canyons decreased in 2003 to about 81 ac-ft. Both Rendija and Guaje Canyons have larger drainage areas than Pueblo Canyon, and experienced similar fire intensity to the upper parts of the watershed as Pueblo Canyon (Figure 1.1-1), so the relatively higher runoff in Pueblo Canyon after the fire might be explained by the localized precipitation events that affected a higher percentage of Pueblo Canyon in 2001, 2002, and 2003.

Figure 2.1-2 shows the seasonal storm runoff measured at the LANL downstream gages and at the downstream Pueblo Canyon gage for the period 1995 through 2002 and the prefire and postfire average seasonal runoff. The seasonal storm runoff for each year is the sum of runoff at each downstream gage from June 1 through October 31 of each year. Also shown in Figure 2.1-2 is the seasonal precipitation received at the TA-6 meteorological station each year from June 1 through October 31.

The total downstream runoff in 2000 was 249 ac-ft, about 2.3 times higher than the prefire average of 106 ac-ft. The most runoff was in 2001, when the total downstream runoff was 389 ac-ft, about 3.7 times the prefire average. The total runoff in 2002 was 248 ac-ft, similar to the total runoff in 2000. About 120 ac-ft of the downstream runoff at LANL in 2002 (48%) occurred as a result of a single storm event that occurred on June 21-22. Runoff in 2003 was 284 ac-ft, about 2.7 times the prefire average. The average annual runoff after the fire was about 2.8 times higher than the prefire average. As shown in Figures 2.1-1 and 2.1-2, the higher-than-average runoff in 2001, 2002, and 2003 is primarily attributed to flood waters in



Note: Downstream gages include E060, E042, E125, E230, E250, E265, E267, and E275.

Figure 2.1-2. Annual seasonal precipitation and storm runoff at downstream gages.

Pueblo Canyon. Downstream runoff from LANL canyons declined each year after the fire and returned to the prefire average in 2002 and 2003. However, runoff in Pueblo Canyon continued to be about 4 times the prefire average in 2002 and 2003, possibly the result of a higher percentage of the upper Pueblo Canyon watershed that suffered higher burn severity (see Figure 1.1-1) in combination with relatively intense local rainfall.

The largest runoff event in 2000 after the Cerro Grande fire occurred after a thunderstorm on June 28, 2000, that primarily occurred in the upper reaches of Pajarito Canyon and Water Canyon. Due to the location of this storm event and the configuration of the affected canyons, downstream runoff from this storm (and other similar storms in 2000) was much smaller than for runoff events in Pueblo Canyon in subsequent years. Runoff from the June 28, 2000, event was only 2.75 ac-ft in lower Pajarito Canyon compared with an estimated 50 ac-ft at the upstream Pajarito Canyon gage; runoff in lower Water Canyon was 21.8 ac-ft, compared with an estimated 107 ac-ft at upstream Water Canyon-Cañon de Valle gages (Koch et al. 2001, Shaull et al. 2001). Since 2000, the major precipitation and runoff events occurred in the Pueblo Canyon drainage, where downstream runoff has been as high as 90 ac-ft from individual runoff events. Due to the presence of the reservoir in upper Los Alamos Canyon, runoff in this canyon was not significantly different after the fire.

Because precipitation drives runoff events and varies significantly each year, Figure 2.1-3 shows the result of normalizing upstream (LANL only) and downstream LANL and Pueblo Canyon runoff with seasonal precipitation. The normalization was performed by dividing the total annual downstream runoff (ac-ft) by the seasonal precipitation (in.) at TA-6. The most striking effect of the fire is seen in the 2000 normalized upstream runoff that was nearly 5 times higher than the prefire average. By 2002 the upstream normalized runoff was similar to the prefire average, and in 2003 the normalized upstream runoff was similar to prefire years 1996 and 1998, indicating the recovery of the upstream fire-impacted watersheds.

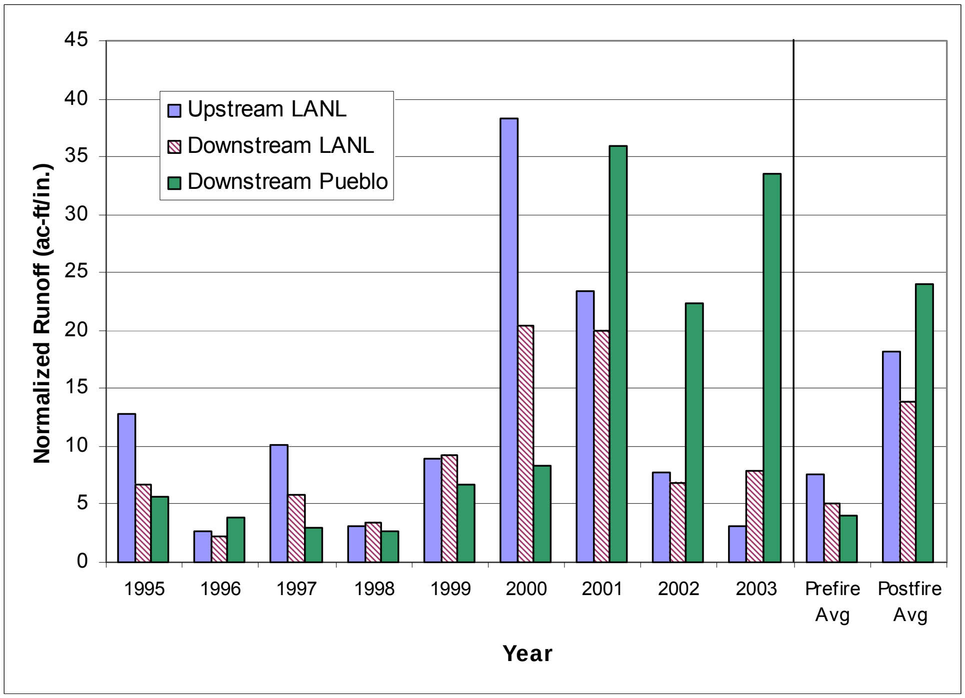


Figure 2.1-3. Upstream and downstream runoff normalized with TA-6 seasonal precipitation.

The normalized downstream LANL runoff was similar in 2000 and 2001, and about 4 times the prefire average; the 2002 and 2003 normalized LANL downstream runoff was similar to prefire conditions. In 2000 after the fire, the normalized downstream Pueblo Canyon runoff was only about 2 times the prefire average, but from 2001 to 2003, the normalized flow in Pueblo Canyon was 5 to 9 times the prefire average. Seasonal precipitation at TA-6 and the North Community gages were similar during the postfire years, thus normalizing the flow in Pueblo Canyon with the TA-6 seasonal precipitation was not significantly different than if the North Community precipitation had been used.

2.1.1 Peak Flows

Table 2.1-1 and Figure 2.1-4 show the instantaneous peak flow data for the prefire period of record and the postfire years 2000 to 2003. Peak annual runoff data are shown for 19 stream gages, of which peak flows at 15 gages were higher after the fire. Record peak flows were recorded at 10 gages in 2000, four gages in 2001, two gages in 2002, and one gage in 2003. However, the record peak flows recorded in 2002 and 2003 were not related to runoff from fire-impacted areas.

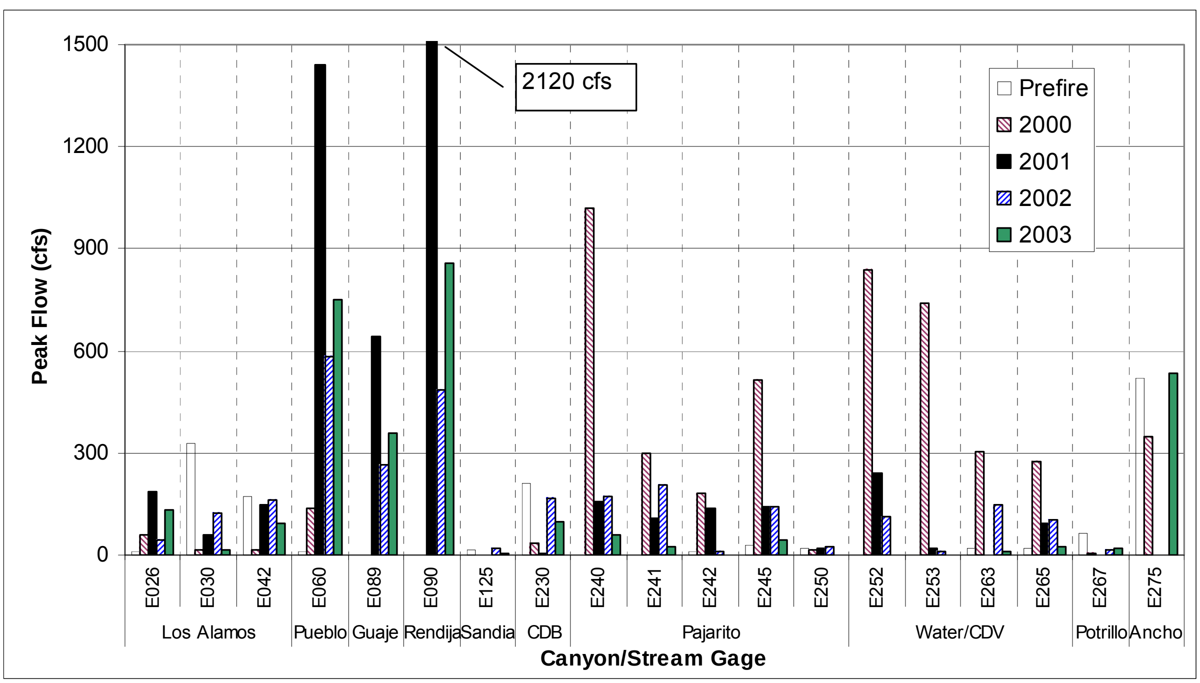
In 2000, the highest peak runoff after the Cerro Grande fire was 1020 cfs at gage E240 in upper Pajarito Canyon, while other record peak flows in 2000 ranged from 274 to 840 cfs. In 2001, peak flows at LANL gages were less than 250 cfs; whereas the peak flow in Pueblo Canyon was a record 1440 cfs. In 2001, newly installed gages E089 in Guaje Canyon and E090 in Rendija Canyon had peak flows of 644 cfs and 2120 cfs, respectively. In 2002, peak flows from fire-impacted areas at LANL gages were less than 200 cfs, and in 2003, peak flows were less than 135 cfs, indicating recovery of the burned areas upstream of LANL canyons.

Table 2.1-1 also shows the ratio of postfire peak flows to prefire peak flows. The postfire peak flows at upstream gages were 18.5 times higher in Los Alamos Canyon (buffered by the Los Alamos Reservoir), 425 times higher in Pajarito Canyon, and nearly 2900 times higher in Water Canyon. At downstream gages, peak flows after the fire were 1.3 times higher in Pajarito Canyon, 13 to 15 times higher in Water Canyon, and 131 times higher in Pueblo Canyon.

Table 2.1-1. Peak Flows at Los Alamos, Prefire and Postfire Years of 2000–2003.

			Pre-Fire		2000		2001		2002		2003		Ratio	
Canyon	Gage	Period of Record Start	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	Date of Peak Flow	Peak Flow (cfs)	Post-Fire peak/ Pre-fire peak	Comment
Los Alamos	E026	1993	05/04/95	10	7/18	**60**	8/9	**185**	6/21	43	8/11	134	18.5	E025 data before 2/26/01
	E030	1994	07/31/68	**329**	6/2	13	8/9	60	6/22	125	8/23	15	0.4	
	E042	1991	08/22/97	**171**	6/2	17	8/9	146	6/22	160	8/23	94	0.9	
Pueblo	E060	1992	07/09/99	11	10/24	**139**	7/2	**1440**	6/22	582	8/23	749	131	
Guaje	E089	2001					8/11	**644**	7/4	263	8/23	360		Gage installed in 2001
Rendija	E090	2001					8/11	**2120**	7/31	486	8/23	856		Gage installed in 2001
Sandia	E125	1994	09/08/95	13	N/A	0	N/A	0	8/28	**18**	8/22	3.0	1.4	2002 record peak flow
CDB*	E230	1991	06/17/99	**210**	8/9	33	8/4	5.8	8/28	168	5/26	100	0.8	
Pajarito	E240	1993	06/21/64	2.4	6/28	**1020**	8/9	155	6/21	173	8/23	61	425	
	E241	1999	09/16/99	0.21	6/28	**300**	8/9	109	6/21	207	8/11	25	1429	
	E242	1999	05/04/99	10	6/28	**180**	6/27	137	6/21	8	8/11	2.2	18.0	
	E245	1993	08/17/97	30	6/28	**517**	6/27	141	6/21	140	8/11	44	17.2	
	E250	1993	06/17/99	20	6/28	14	8/16	**22**	6/22	**26**	8/26	0.2	1.3	2002 record peak flow
Water/CDV*	E252	1994	03/23/97	0.29	6/28	**840**	7/22	242	6/21	114	8/28	2.1	2897	
	E253	1994		0	6/28	**740**	8/9	19	8/13	12	9/06	1.0		No flow before fire
	E263	1998		20	6/28	**306**			6/22	149	8/23	10.2	15.3	
	E265	1993	08/29/95	21	6/28	**274**	8/3	92	9/28	105	5/26	25	13.0	
Potrillo	E267	1993	08/29/95	**63**	8/9	7	N/A	0	8/28	15	5/25	19.7	0.3	
Ancho	E275	1993	06/29/95	520	8/6	348	8/12	0.05	N/A	0	5/26	**535**	1.0	2003 record peak flow

Source: Shaull et al. (2001, 2002, 2003, 2004). Bold numbers are record peak flows
* CDB = Cañada del Buey; CDV – Cañon de Valle



Note: See Table 1.8-1 for stream gage location names.

Figure 2.1-4. Peak runoff 2000 through 2003, compared with prefire peak flows.

The record peak flows in 2000 and 2001 (Table 2.1-1) were related to high-volume runoff from burned areas associated with the Cerro Grande fire; however, the record peak flows in 2002 and 2003 (Ancho, Sandia Canyons) were at downstream gages associated with local precipitation and runoff from the Pajarito Plateau rather than to any residual effects from the Cerro Grande fire. The peak flow data show that partial recovery of the fire-impacted areas in the upper parts of the watersheds near Los Alamos occurred within two years after the fire. Similar results were documented by the USGS in Rendija Canyon (Moody et al. 2002).

Prefire record peak flows are still in effect at three downstream gages after the fire, including E042 in lower Los Alamos Canyon, E230 in lower Cañada del Buey, and E267 in lower Potrillo Canyon. Potrillo Canyon and Ancho Canyon (where the postfire peak flow is similar to the prefire peak flow) were not significantly affected by the Cerro Grande fire. The upper reaches of Cañada del Buey were affected by low-burn severity fire, but due to the relatively small watershed area (and possibly due to a lack of local precipitation), an increase in the runoff to the lower part of the canyon was not evident after the fire. The Los Alamos Canyon reservoir in upper Los Alamos Canyon buffered the impact of runoff from burned areas in upper Los Alamos Canyon to the lower parts of Los Alamos Canyon and gage E042.

By 2002 and 2003, peak flows at most gages in fire-related drainages were significantly less than in 2000 and 2001, especially at upstream sites. Peak flows in upper Pajarito Canyon at gage E240 in 2002 were 17% of the 2000 peak. Similarly, 2002 peak flows in upper Water Canyon (gage E252) and upper Cañon de Valle (gage E253) were 14% and 2% of the 2000 peak flows, respectively. Peak flows reflect local storm intensity and are not necessarily comparable from year to year; however, the seasonal precipitation amounts in 2000 and 2002 were similar (see Figure 2.1-2). Thus, the significantly lower peak flows in 2002 indicate, to some degree, a partial recovery of the fire-impacted areas of watersheds since the Cerro Grande fire.

The peak flows in Guaje and Rendija Canyons in 2002 (263 cfs and 486 cfs, respectively) were 41% and 23% of the 2001 peak flows, respectively; however, peak flows in 2003 were slightly higher due to a single intense thunderstorm event on August 23.

2.1.2 Runoff Yield

The average annual storm runoff yield for each gaging station was calculated by dividing the annual runoff in ac-ft by the drainage area in mi^2. Table 2.1-2 summarizes the annual runoff yield for some gaging stations at LANL for prefire and postfire years, and Figure 2.1-5 shows the trends in annual runoff yield. Prefire runoff yields at most gages were 7 ac-ft/mi^2 or less, except at gage E240 in upper Pajarito Canyon, which had a prefire yield of 21 ac-ft/mi^2. The runoff yield at gage E240 in 2000 after the fire was 34.6 ac-ft/mi^2, about 1.6 times higher than the prefire average. Runoff yields for most gaging stations were higher in 2000 after the Cerro Grande fire.

High runoff events in Pueblo Canyon in 2001, 2002, and 2003 caused unusually high runoff yields for these years, resulting from the effects of the Cerro Grande fire in the upper part of the drainage. The higher yield in upper Pajarito Canyon in 2002 primarily resulted from one runoff event in June. Other upstream gaging stations in Los Alamos Canyon, Cañon de Valle, and Water Canyon have significantly lower runoff yields in 2002 and 2003 compared with 2000 and 2001, which suggests partial recovery of these drainages since the Cerro Grande fire.

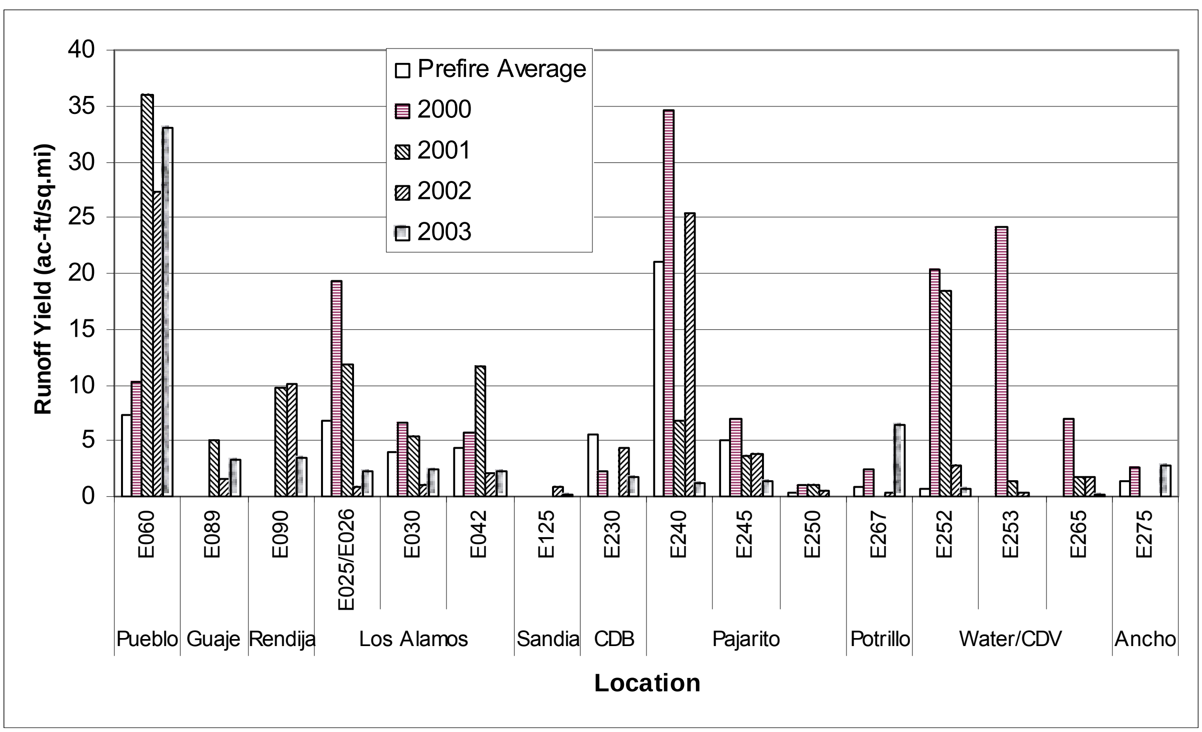
2.1.3 Runoff Impact to the Rio Grande after the Cerro Grande Fire

The largest runoff events from the Sierra de los Valles and the Pajarito Plateau extend in canyons across the Pajarito Plateau and runoff in some canyons occasionally extends to the Rio Grande. Figure 2.1-6 shows the sum of runoff at all downstream Los Alamos area gaging stations (eight canyons) for the years 2000 through 2003 and the prefire average annual downstream runoff. The only baseflow at downstream

Table 2.1-2. Summary of Annual Runoff Yield at LANL, Prefire and Postfire.

Canyon	Gage	Drainage Area (mi^2)	Prefire Average Runoff Yield (ac-ft/mi^2)	2000 Runoff Yield (ac-ft/mi^2)	2001 Runoff Yield (ac-ft/mi^2)	2002 Runoff Yield (ac-ft/mi^2)	2003 Runoff Yield (ac-ft/mi^2)
Pueblo	E060	6.9	7.3	10.3	36.0	27.4	33.1
Guaje	E089	14.6	ND*	ND	5.1	1.6	3.3
Rendija	E090	9.6	ND	ND	9.8	10.0	3.4
Los Alamos	E025/E026	7.1	6.7	19.2	11.7	1.0	2.3
	E030	8.6	4.1	6.5	5.5	1.1	2.4
	E042	9.1	4.4	5.7	11.6	2.1	2.3
Sandia	E125	2.5	0.0	0.0	0.0	0.8	0.1
CDB	E230	2.1	5.6	2.2	0.1	4.3	1.7
Pajarito	E240	1.9	21.1	34.6	6.7	25.4	1.3
	E245	7.8	5.0	7.0	3.6	3.8	1.3
	E250	10.9	0.3	1.1	1.0	0.5	0.0
Potrillo	E267	2.3	0.9	2.4	0.0	0.3	6.5
Water/CDV	E252	3.4	0.7	20.3	18.5	2.8	0.6
	E253	2.5	0.0	24.1	1.4	0.4	0.0
	E265	13.0	0.0	7.0	1.7	1.7	0.2
Ancho	E275	4.6	1.3	2.6	0.0	0.0	2.7

Note: See Table 1.8-1 for stream gage location names.
* NO = Nondetect; CDB = Cañada del Buey; CDV = Cañon de Valle



Note: See Table 1.8-1 for stream gage location names.

Figure 2.1-5. Summary of annual runoff yield at LANL, prefire and postfire.

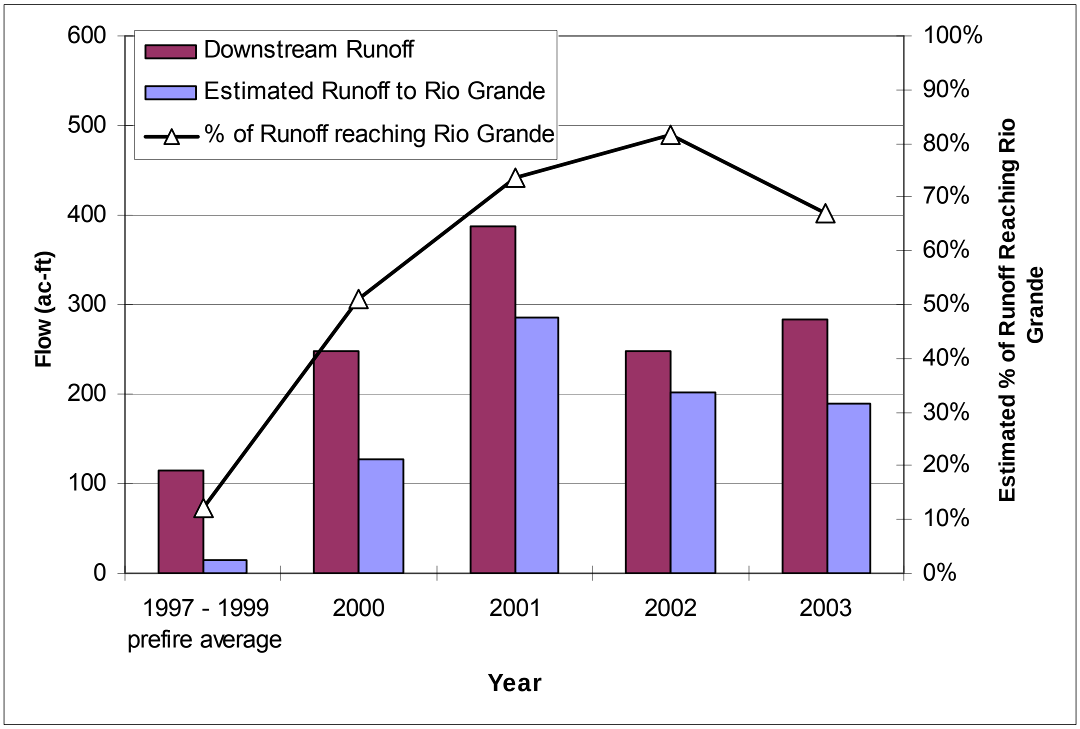


Figure 2.1-6. Annual runoff at downstream Los Alamos gages and estimated runoff to the Rio Grande.

Los Alamos area locations is in Pueblo Canyon where relatively constant baseflow occurs as a result of discharge from the Los Alamos County Bayo wastewater treatment plant. The mean daily (MD) baseflow in Pueblo Canyon is usually less than 10 cfs, whereas major runoff events typically generate MD flow greater than 10 cfs.

Assuming that all MD flow from Los Alamos area canyons (downstream gaging stations) greater than 10 cfs extends as runoff into the Rio Grande, Figure 2.1-6 also shows the estimated yearly runoff that has flowed to the Rio Grande from Los Alamos area canyons from 2000 through 2003 and the prefire annual average. The prefire average for years 1997 through 1999 was about 14 ac-ft per year. In 2000 after the fire an estimated 127 ac-ft of runoff flowed to the Rio Grande, an increase of about nine times the prefire average. The largest estimated yearly runoff to the Rio Grande was 286 ac-ft in 2001 (most of which was from Pueblo Canyon, see Figure 2.1-2), an increase of 20 times the prefire average. Runoff to the Rio Grande in 2002 and 2003 was about 200 ac-ft each year.

The yearly volume of runoff at downstream stations shown in Figure 2.1-6 comprises all storm runoff and includes smaller runoff events of less than 10 cfs MD flow, which don't typically extend to the Rio Grande; thus the difference between runoff downstream at Los Alamos and runoff that is estimated to flow to the Rio Grande (Figure 2.1-6).

Assuming that all MD flow greater than 10 cfs at all downstream canyons is runoff that flows into the Rio Grande, the stream gage data (Shaull et al. 2000, 2001, 2002, 2003, 2004) show that before the fire there was an average of one runoff event per year to the Rio Grande. In 2000 it is estimated that four events occurred, seven events in 2001, and four events in each 2002 and 2003 (Figure 2.1-7). Using the mentioned assumption, it is estimated that about 12% of the flow at downstream Los Alamos area gages extended to the Rio Grande before the fire (1997 through 1999). However, after the fire, 50% to 80% of the downstream runoff is estimated to have extended to the Rio Grande (Figure 2.1-6). The amount of annual runoff at downstream gages that extends to the Rio Grande is dependent on the number and magnitude of runoff events that occur in any given year, which is also a reflection of the number, location, and intensity of thunderstorms that occur.

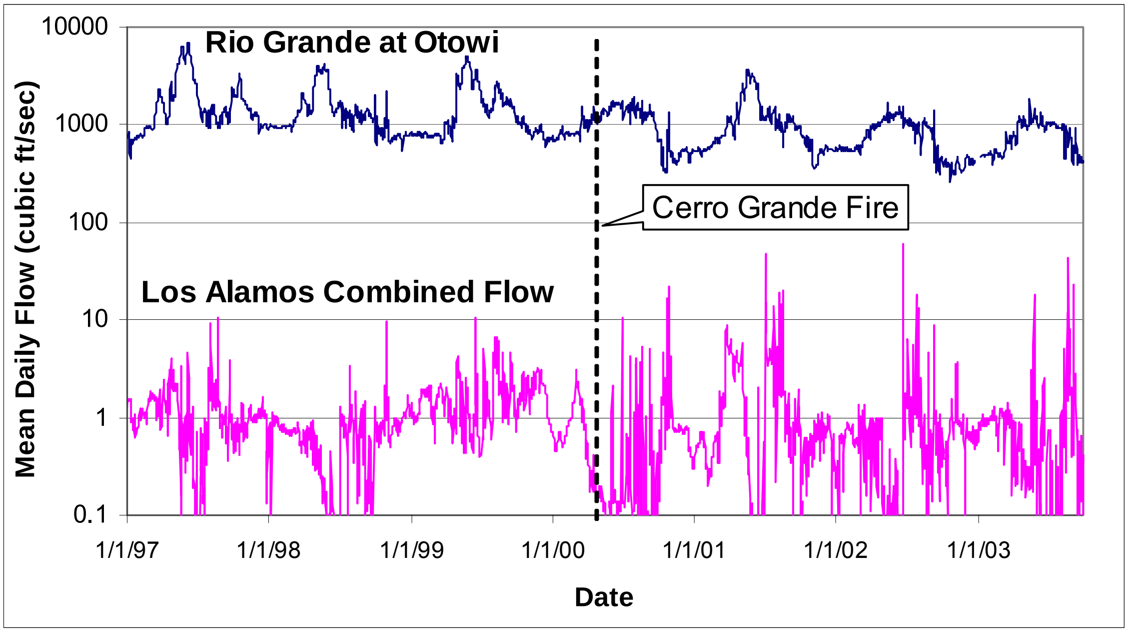


Figure 2.1-7. Mean daily flow from all Los Alamos canyons and in the Rio Grande at Otowi.

The amount of runoff contributed to the Rio Grande from Los Alamos area drainages after the fire, however, has been relatively insignificant to the amount of flow in the Rio Grande. Figure 2.1-7 shows the combined MD flow from all Los Alamos area canyons (downstream gaging stations) and MD flow for the Rio Grande at Otowi Bridge, for the period from 1997 through 2003. Before the fire, the average MD flow at all downstream Los Alamos area canyons was 1.14 cfs and rarely did runoff events occur greater than 10 cfs. However, after the fire, the average MD flow was 1.31 cfs, an increase of about 15%, and significantly more runoff events greater than 10 cfs MD flow occurred each year.

The average mean daily flow in the Rio Grande from 1997 to 1999 before the fire was about 1500 cfs, after the fire, the average mean daily flow was about 900 cfs, a decrease of about 40% due to regional climatic conditions. Mean daily flow in the Rio Grande is typically about one to two orders of magnitude higher than runoff from the Los Alamos area. It is apparent from the flow data that runoff impacts after the Cerro Grande fire, although significantly larger than before the fire, did not have an appreciable influence on flow in the Rio Grande.

Figure 2.1-8 shows the calculated MD flow gain or loss in the Rio Grande between the USGS Otowi Bridge gaging station (upstream of Los Alamos area canyons) and the gaging station near White Rock, which USGS operated from June 24, 2000, through September 30, 2002 (USGS 2003). The figure also shows the estimated error in flow measurement based on 5% of the measured flow (e.g., Veenhuis 2004). Gain in flow of the Rio Grande in the reach between these stations would be the result of runoff from most Los Alamos area canyons (with the exception of Ancho and Chaquehui Canyons), drainage from the east (Cañada Ancha), spring discharges to the Rio Grande, local runoff, groundwater discharge to the river, or perhaps from differences in the rating parameters for individual stream gages. Stream loss through the reach would be due to infiltration into the alluvium.

Also shown in Figure 2.1-8 is the estimated MD runoff from all Los Alamos canyons. The volume of runoff from Los Alamos canyons is typically less than the measurement error inherent in stream gaging on the Rio Grande. The maximum runoff from Los Alamos canyons from 2000 through 2002 was 60 cfs (MD) on June 22, 2002, which appears to have created a slight gain in the river. However, the large runoff event from Pueblo Canyon on July 2, 2001, does not appear to have had a significant impact on the flow in the river, and other runoff events from Los Alamos canyons after the Cerro Grande fire do not appear to have had a significant effect on the stream flow in the Rio Grande.

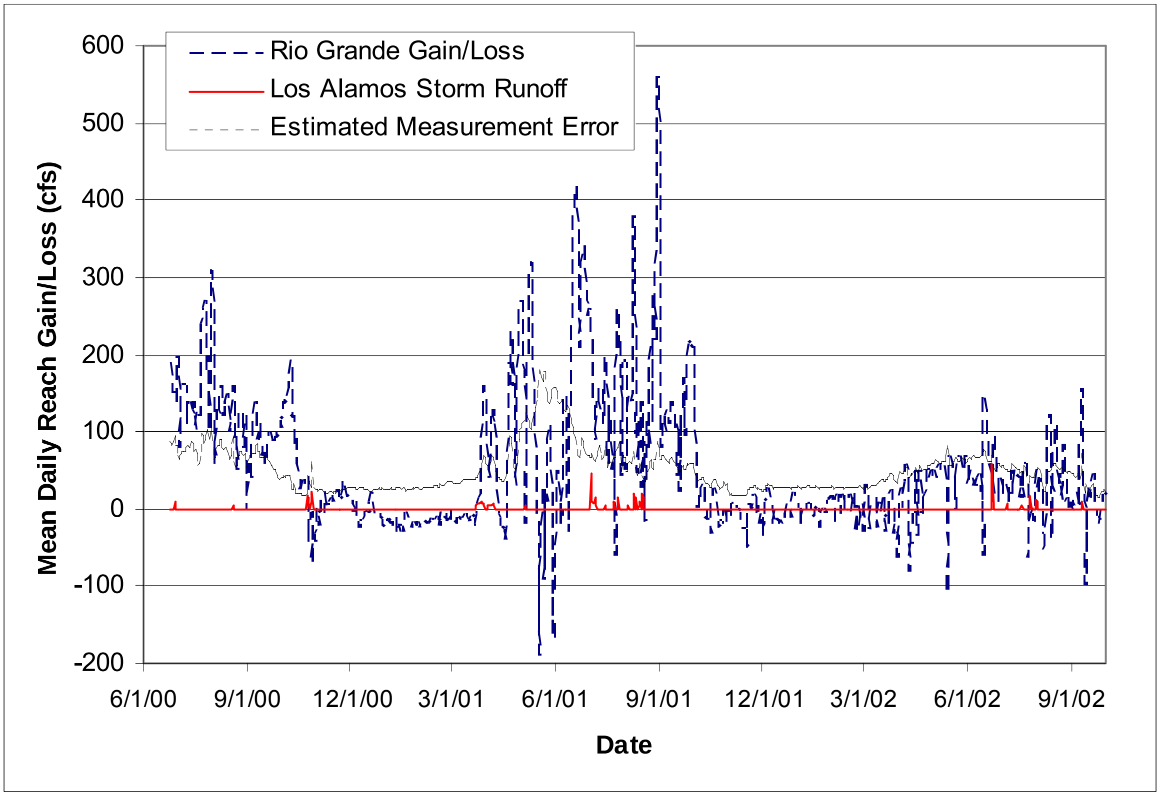


Figure 2.1-8. Stream flow gain/loss in the Rio Grande between USGS gaging stations at Otowi Bridge and near White Rock and runoff from Los Alamos canyons.

2.2 Constituent Characteristics in Storm Runoff

The following discussion of storm runoff constituent characteristics at LANL primarily focuses on the results of the collection of storm runoff samples in major drainages in the LANL area that were impacted by the Cerro Grande fire or that drain significant areas near Los Alamos. For this discussion, major drainages include Guaje, Rendija, Pueblo, Los Alamos, Sandia, Pajarito (including Twomile and Threemile Canyons and Starmers Gulch), Water, Ancho, and Potrillo Canyons and Cañada del Buey and Cañon de Valle. Storm runoff samples that were collected from mesa-top locations, such as at TA-54, TA-55, and other facility-specific runoff samples that were collected from areas not appreciably impacted by the Cerro Grande fire are not included in the following discussion. The results of the mesa-top and facility-specific storm water samples are discussed in the annual environmental surveillance reports (e.g., ESP 2001, 2002, and 2004).

2.2.1 Data Evaluation and Comparison Methods

2.2.1.1 Reference Standards and Guidelines Used to Evaluate Monitoring Data

We reviewed data on the concentrations of chemicals and radionuclides in water and sediments collected by LANL, NMED, and the USGS before and after the fire. Because of the large number of measured chemicals and radionuclides, we employed screening and graphical tools to focus on those chemicals and radionuclides most impacted by the Cerro Grande fire, or most likely to contribute to the health risk of those exposed directly or indirectly to surface water runoff from LANL and the burned areas.

The discussion includes interpretation of data collected for analysis of dissolved solids, radionuclides, volatile and semi-volatile organic compounds, and high explosives. Where applicable, these constituents are compared to New Mexico or U.S. Environmental Protection Agency (EPA) standards and guidelines. National recommended water quality criteria (EPA 2002) and proposed revisions to the New Mexico stream standards (NMED 2003c) are included in this interpretation. Although the proposed New Mexico stream standards are not promulgated or enforceable, we chose to screen against them because they are based on current EPA ambient water guidelines for most constituents and provide EPA's current perspective on environmental health risks posed by the chemicals.

The surface water screening levels are based on the following sources (in order of preference):

- State of New Mexico proposed stream standards,
- EPA Region 6 tap water residential screening levels (modified to reflect a target risk of 10^{-5} to be consistent with New Mexico standards), and
- Numeric standards for irrigation, livestock watering, wildlife habitat, aquatic life, and human health.

This list of standards includes approximately 25 inorganic and 90 organic chemicals. The screening levels are based on a one-in-one-hundred-thousand (10^{-5}) target risk for carcinogens, or a hazard quotient of 1 for noncarcinogens, which are consistent with New Mexico Water Quality Control Commission (NMWQCC) adopted standards. In instances where an individual contaminant has the capacity to elicit both types of responses, the screening levels preferentially report the screening value representative of the lowest (most stringent) contaminant concentration in environmental media. Radionuclide concentrations in surface water samples were compared against the Derived Concentrations Guidelines (DCGs) promulgated by the Department of Energy (DOE 1990) for protection of public health. We focused primarily on the fallout radionuclides americium-241, cesium-137, plutonium-238, plutonium-239,240, and strontium-90 because they have relatively long half lives and are commonly identified in both LANL operations and background soils.

Because surface water may percolate to groundwater, we also compared the dissolved analytical results (filtered samples only) against standards developed to protect groundwater quality. The groundwater screening levels are based on the following (in order of preference):

- NMWQCC standards,
- EPA Region 6 tap water residential screening levels (modified to reflect a target risk of 10^{-5}), and
- EPA maximum contaminant levels.

Dissolved radionuclide concentrations were compared (in order of preference) against

- EPA maximum contaminant levels and
- DOE DCGs promulgated for community drinking water systems.

Sediment quality data were evaluated by comparing against a suite of reference standards and values developed for assessment of potential risk to human health (residential soils) and aquatic organisms. Radiological data are compared to LANL Screening Action Levels for residential soil exposures (LANL 2001). Minor constituent and organic data are evaluated for human health concerns by comparing against EPA Region 6 residential soil screening levels (EPA 2003). We evaluated the risk to aquatic organisms along the Rio Grande by comparing sediment minor constituent and organic chemicals concentrations to threshold screening values developed by USGS's National Water Quality Assessment Program (Gilliom et al.1997) and by Environment Canada (2002).

In total, over 20 separate reference standards or guidelines were used in this evaluation, depending on location, environmental media, and regulatory guidance. Because of the myriad combinations of possible applicable standards, these screens should not be used to demonstrate with specificity regulatory compliance. Rather, the screens are used as a tool to synthesize large quantities of analytical results, establish general water quality patterns, and identify the chemicals most consistently exceeding the threshold screening values. Table 2.2.1-1 summarizes the different categories and references used in this

Table 2.2.1-1. Standards and References Used for Monitoring Data Evaluation.

			Potentially applicable to: Pajarito Plateau			Potentially applicable to: Rio Grande	
Type	**Source**	**Standard**	**Persistent Surface Water (snowmelt, spring supported, effluent supported)**	**Storm Runoff**	**Sediments**	**Surface Water**	**Sediments**
Standard	NMWQCC	Irrigation				x	
Standard	NMWQCC	Livestock Watering	x	x		x	
Standard	NMWQCC	Wildlife Habitat	x	x		x	
Standard	NMWQCC	Aquatic Life – acute				x	
Standard	NMWQCC	Aquatic Life – chronic				x	
Standard	NMWQCC	Human Health (persistent contaminants)	x	x		x	
Standard	NMWQCC	Human Health (cancer causing, or toxic)				x	
Standard	NMWQCC	GW for Human Health	x (filtered samples)	x (filtered)			
Standard	NMWQCC	GW other standards for domestic water	x (filtered)	x (filtered)			
Standard	EPA	Drinking Water Systems MCL				x (filtered)	
Standard	EPA	Fish consumption + Water				x	
Risk-human	EPA	EPA Region 6 Tap Water Screening Levels	x	x (filtered)			
Risk-human	DOE	DOE DCGs for public dose (radionuclides, 100 mrem dose per year)	x	x (filtered)		x	
Risk-human	DOE	DOE DCGs for drinking water systems (radionuclides, 4 mrem dose per year)	x (filtered)	x (filtered)		x (filtered)	
Risk-human	EPA	EPA Region 6 Residential and Industrial Outdoor Worker Soil Screening Levels (metals, organics, chemicals)			x		x
Risk-human	LANL	Residential Soil Screening Action Levels (radionuclides)			x		x
Reference	USGS / Environment Canada	Guideline for protection of aquatic life					x
Reference	LANL	Background radionuclides and metals			x		
Reference	LANL	Background radionuclides					x
Reference	USGS	Prefire metals and organic chemicals					x
Reference	LANL / NMED	Prefire metals and radionuclides	x	x	x	x	x

discussion. Concentrations above the screening levels do not automatically designate the location as “contaminated” or trigger the need for remediation; in some cases concentrations above screening levels could record background concentrations or baseline (non-LANL) concentrations. The comparisons are useful, however, for identifying the constituents with concentrations most commonly elevated above similar reference levels.

2.2.1.2 Box Plots and Statistical Analyses

Two types of data analyses were used to evaluate the concentrations of constituents in postfire samples as compared with prefire concentrations. In the first type, a graphical comparison using time series plots, or box plots, is made between sample data and background sample data. In the second type, the results of formal statistical testing are presented.

Many figures in the following discussion show summary “box plots” of environmental data. Box plots are useful for looking for differences between groups of data. The box plots summarize the distribution of the results of all samples analyzed for each data group, including samples reported as laboratory non-detects. Figure 2.2.1-1 illustrates the parameters displayed in box plots. The plots are a convenient way to compare groups of large numbers of data values. Box plots graphically show the minimum, median, and maximum values of the data set and the distribution pattern of the analytical results. Box plots provide a good representation of the variability of the data and the skewness or symmetry of the distribution. Box plots also indicate which data groups may be statistically different; if two boxes do not overlap vertically in the figure, there is a reasonable likelihood that the two groups are significantly different.

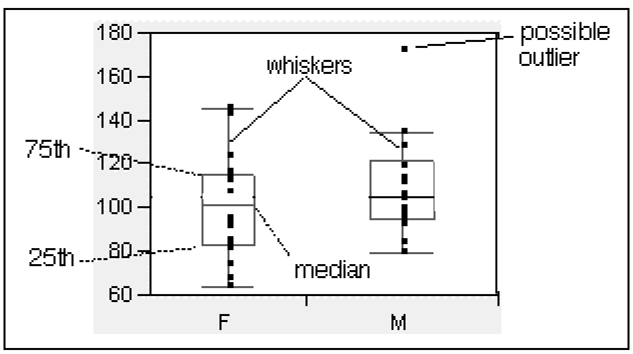


Figure 2.2.1-1. Example box plots.

The box contains the middle 50% of data values (25th to 75th percentile range, or 1st to 3rd quartiles). The bottom and top of the box is called the inner quartile (IQ) range. The median of the data set is represented by the middle bar in the box. The vertical lines, called whiskers, that extend above and below the box represent high and low data values that are within ±1.5 times the IQ range. Data values beyond the whiskers are shown by solid circles (1.5 to 3 times the IQ range) and open circles (>3 times IQ) (Tukey 1977). For sample results that are reported below analytical method detection limits by LANL, and for results that are reported less than zero, the detection limit values were used to provide a representative distribution pattern for concentration values.

Changes in sediment concentrations (suspended and deposited) were evaluated statistically. The tests pool prefire and postfire data into one set and determine whether the average rank of postfire data is greater than that of prefire data. The nonparametric Wilcoxon Rank Sum test or Kruskall Wallis test were used for statistical testing. The metrics used to determine if a statistically significant difference exists between postfire and baseline data are the calculated significance levels (p-values) for the tests. A low p-value (near 0) indicates that postfire results are greater than the baseline data; a p-value approaching 1 indicates no difference. If a p-value is less than some small probability (say, 0.05), there is some reason to suspect that the postfire concentrations are elevated above the comparison data set.

Some of the following figures summarize data collected after the Cerro Grande fire from 2000–2002 by showing results from the Pajarito Plateau (Los Alamos area) and from the Rio Grande compared to prefire range for each compound detected. When prefire data were not available, the results were compared against equivalent postfire results from environmental samples collected above LANL. The data were collected at a wide variety of locations and times. In order to represent the wide concentration ranges observed among the compounds, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1000), rather than the precise number. For organic compounds, we focus on those compounds that were detected in two or more samples.

2.2.1.3 Trend Comparisons Using Flow Adjusted (Weighted) Concentrations

Several chemical time series graphs in this report show how the concentrations of chemicals or radionuclides varied through the 2000 runoff season. The data values represent a wide spectrum of environmental and flow conditions present at the time of sampling. For completeness and to ensure that the data range is represented, all data values are treated alike and displayed similarly in the time series plots. From a chemical transport perspective, however, the larger flow events carry substantially larger quantities of material than the smaller events, and some adjustment is needed to emphasize (weight) the larger events. Thus, for selected analytes, we further evaluate the concentration trends by using an averaging technique to minimize (normalize) the impact of stream flow.

Changes caused by variation of stream flow are particularly troublesome in trend detection efforts (Gilbert 1987). As stream flow increases, many water quality properties and constituents (specific conductance, dissolved solids, major dissolved ions, and dissolved metals) decrease in value or concentration. Other constituent concentrations (suspended sediment and, occasionally, nutrients) increase with increasing stream flow.

Some analytical technique is required to control for, or to remove, the effects of discharge in order to reveal nonclimatological chronological trends (Harned et al. 1981). To estimate changes in TSS concentrations, we used an averaging technique (flow weighting) designed to account for the variation in sediment associated with a changing stream flow regime (Belillas and Roda 1993, Brown and Krygier 1971). We adjusted the measured runoff concentrations by stream flow to appropriately evaluate trends and changes from prior years.

For this effort, runoff volume and quality data were integrated for the individual drainages. The FWA concentration of selected analytes in storm water runoff in 2000 and recent years was calculated. First, the concentrations measured at each runoff event were multiplied by the total flow measured or estimated for each event (see Section 3.2), which determines the mass or activity value (in mg, µg, or Ci) of each analyte transported in each flow event. Next, the mass or activity values and total runoff volumes from each individual runoff event were summed for the year, and the total yearly mass or activity value was divided by the total yearly runoff volume to determine the FWA concentration for each radionuclide for each year:

$$Conc_w = \frac{\sum_{i=1}^{n} C_i \times V_i}{\sum_{i=1}^{n} V_i} = \frac{TotalMassOrActivity}{TotalVolume} ,$$

where $Conc_w$ = FWA concentration (mg/L, µg/L, or pCi/L) for period of interest,
C_i = Analyte concentration (mass or activity per L) measured in runoff event i,
V_i = Total volume (L) in runoff event i,
n = Total number of results (samples) in period of interest.

2.2.2 Major Water Quality Constituents

Major water quality constituents include major cations such as calcium and magnesium, anions such as chloride, nitrate, and sulfate, and other constituents such as total dissolved solids (TDS), TSS, and specific conductance. Most runoff samples collected before and after the Cerro Grande fire were analyzed for major water quality constituents.

Appendix Table B-1 summarizes the results of major water quality constituents that were collected by WQH in primary drainages after the fire. WQH collected storm runoff from 62 locations in primary drainages in 2000, 53 in 2001, 39 in 2002, and 44 in 2003. The LANL Environmental Restoration (ER) Project also collected storm runoff samples in Pueblo, Los Alamos, and Pajarito Canyons for a limited general inorganic analyses suite. Table B-2 summarizes the number of results obtained by ER for filtered and unfiltered major water quality constituents. The ER Project collected runoff samples from 23 major drainage locations in 2000, 14 locations in 2001, and 23 locations in 2003. Most general inorganic results obtained for ER samples are total suspended sediment and total organic carbon.

Table B-3 summarizes the results obtained by NMED for major water quality constituents in storm runoff. NMED collected 47 samples in 2000, 12 samples in 2001, 21 samples in 2002, and three samples in 2003. Most samples collected by NMED were in Pueblo Canyon; however, some samples were collected in other canyons at LANL.

Table B-4 summarizes the results available for surface water samples collected by the USGS from the Rio Grande and Cochiti Reservoir. These results are compared with the results of runoff from the Pajarito Plateau in the following sections to assess impacts to the Rio Grande from fire-related storm runoff.

Most runoff samples collected at LANL before the fire were collected by WQH. Table 2.2.2-1 summarizes the number of detects and non-detects for each general inorganic constituent for WQH samples collected before the fire (1990–1999) and for runoff samples collected by WQH, ER, and NMED after the fire (2000–2003). The average number of detections of general inorganic constituents in unfiltered samples collected before the fire was 89%, not significantly different than after the fire, when an average of 87% of constituents was detected. Before the fire the average detection of general inorganic constituents in filtered samples was 86%, however after the fire the detection rate was 93%.

Table 2.2.2-2 summarizes the minimum, average, and maximum concentration obtained for major water quality constituents for WQH samples. The minimum applicable water quality standard for major water quality constituents are also listed in Table 2.2.2-2.

2.2.2.1 Comparison of Major Water Quality Constituents with Historical Maximum Concentrations

Figure 2.2.2-1 shows the comparison of postfire (2000–2003) major water quality constituents in storm runoff from major drainages at Los Alamos with prefire maximum concentrations. Major water quality constituents that had significantly higher concentrations in storm runoff after the Cerro Grande fire than before the fire included calcium, total cyanide, potassium, and phosphate, similar to that reported by Gallaher et al. (2002, p. 24). Other constituents that were measured in concentrations higher than prefire levels include total alkalinity, cyanide (amenable), magnesium, sodium, ammonia, sulfate, total kjeldahl nitrogen (TKN), and TSS.

The maximum calcium concentration in unfiltered runoff was 1110 mg/L in 2000, significantly higher than the historical maximum of 140 mg/L; 15 of 25 samples (60%) collected in 2000 contained calcium concentrations greater than the historical maximum. Most samples containing calcium concentrations greater than 600 mg/L were collected from high-volume runoff from fire-impacted areas on June 28, 2000, in Pajarito Canyon and Water Canyon/Cañon de Valle; the other sample that contained greater than 600 mg/L calcium was collected from high-volume runoff in Guaje Canyon on July 9, 2000, which was also from fire-impacted areas. In 2002, runoff from Guaje Canyon contained calcium in concentrations as high as 470 mg/L.

Table 2.2.2-1. Summary of Detections of Major Water Quality Constituents in Storm Runoff, Prefire and Postfire.

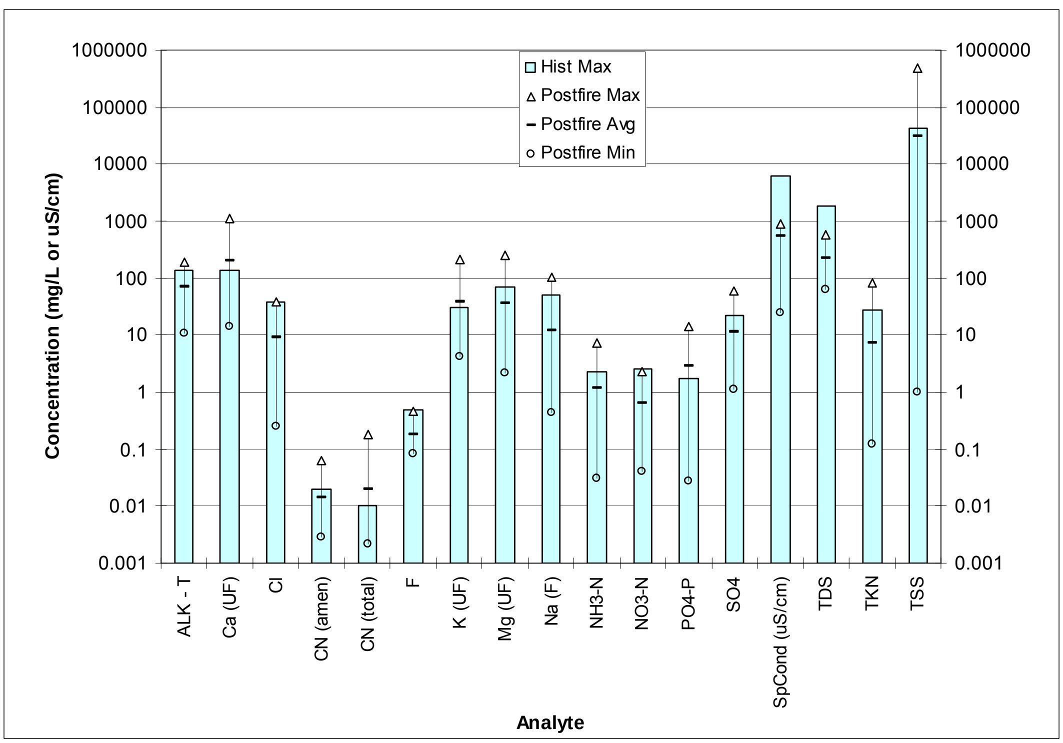
	Prefire								Postfire							
	Unfiltered Samples				Filtered Samples				Unfiltered Samples				Filtered Samples			
Analyte	No. Analyses	No. Detect	No. Non-Detects	% Detects	No. Analyses	No. Detect	No. Non-Detects	% Detects	No. Analyses	No. Detect	No. Non-Detects	% Detects	No. Analyses	No. Detect	No. Non-Detects	% Detects
ALK-CO_3	2	0	2	0	13	3	10	23	37	0	37	0	83	0	83	0
ALK-CO_3+HCO_3	2	2	0	100	13	12	1	92	35	35	0	100	83	83	0	100
ALK-HCO_3									37	37	0	100	83	83	0	100
Br					3	1	2	33	26				10	0		0
Ca	12	12	0	100	20	19	1	95	111	111	0	100	131	131	0	100
Cl^-	2	2	0	100	13	12	1	92	27	27	0	100	102	99	3	97
ClO_4									105	2	103	2				
CN (amen)									168	18	150	11				
CN(TOTAL)	24	1	23	4	9	1	8	11	219	134	85	61				
COD	19	19	0	100					129	128	1	99	21	21	0	100
F^-	2	2	0	100	13	12	1	92	25	18	7	0.72	33	33	0	100
HARDNESS	7	7	0	100	17	17	0	100	32	32	0	1	36	36	0	100
K	12	12	0	100	20	18	2	90	111	111	0	100	131	131	0	100
LOI									133	133	0	100	3	3	0	100
Mg	31	31	0	100	20	19	1	95	234	234	0	100	210	209	1	100
Na	12	12	0	100	20	19	1	95	112	104	8	93	131	131	0	100
NH_3-N	19	14	5	74					140	114	26	81	23	18	5	78
NO_3	21	13	8	62	12	10	2	83								
NO_3+NO_2-N									110	94	16	85	24	23	1	96
Oil & Grease									3	2	1	67				
P									64	64	0	100	23	17	6	74
PO_4	2	2	0	100	12	10	2	83	69	66	3	96	3	3	0	100
Si	2	2	0	100	13	12	1	92	46	46	0	100	49	49		
SiO_2									39	39	0	100	36	36	0	100
SO_4	2	2	0	100	13	13	0	100	27	26	1	96	102	99	3	97
Spec. Cond	6	6	0	100	7	7		100	121	131	-10	108	32	32	0	100
TDS					15	15	0	100					142	142	0	100
TKN	19	19	0	100					122	118	4	97	25	25	0	100
TOC									164	162	2	99				
TSS	119	118	1	99					836	834	2	100				
TSS(m)	25	25	0	100					240	240	0	100				
Total/Average	340	301	39	89	233	200	33	86	3522	3060	436	87	1516	1404	102	93

Note: prefire data from 1990 through 1999, postfire data from 2000 through 2003

Table 2.2.2-2. Summary of Major Water Quality Constituent Results in Storm Runoff, 2000–2003.

Analyte	Unfiltered (mg/L) Min	Unfiltered (mg/L) Avg	Unfiltered (mg/L) Max	Filtered (mg/L) Min	Filtered (mg/L) Avg	Filtered (mg/L) Max	Water Quality Stds. Min. Std. (mg/L)	Water Quality Stds. Std. Type*
Alkalinity-Total				10.5	68.7	186		
Ca	14	196.7	1110	4.21	31.9	112		
Cl				0.25	9.29	37.4	250	NM GW
ClO_4	ND	ND	ND				0.0037	Tap Water SL
CN (amen)	ND	0.00276	0.062				0.0052	NM Wildlife
CN (total)	ND	0.00626	0.176				0.20	NM GW
COD	20.6	279	3200					
F^-	0.11			0.09	0.18	0.46	1.6	NM GW
K	4.3	38.7	210	1.74	9.43	59.0		
LOI	66	1675	12800					
Mg	2.2	36.2	250	0.68	5.75	57.20		
Na	2.3	17.1	75.7	0.45	12.10	101.0		
NH_3-N	0.03	1.0	7.35					
NO_3+NO_2-N	0.01	0.6	2.31				10	NM GW
pH (SU)	7.15	7.29	7.29				6 - 9	NM GW
PO_4-P	0.03	2.7	14.5					
SO_4	12.0		76.0	0.41	13.12	61.20	600	NM GW
Spec. Cond. (uS/cm)	1.0	199.0	10600					
TDS				64.0	225.4	940.0	1000	NM GW
TKN	0.12	7.27	81.0					
TOC	2.6	35.31	110					
TSS	1.0	30893	497424					

ND = Not Detected
* NM GW = New Mexico Groundwater standards; SL = screening levels; NM Wildlife = New Mexico Wildlife Habitat Standard



Note: UF = Unfiltered, F = Filtered; SpCond = Specific Conductance

Figure 2.2.2-1. Postfire major water quality constituents compared with historical maximums.

The highest concentration of cyanide (total) measured before 2000 was 0.01 mg/L, and most historical cyanide analyses were below detection limits, however, in 2000 cyanide (total) was measured above the detection limit in 52 of 99 samples and the maximum concentration measured was 0.176 mg/L in a sample from Guaje Canyon on July 9. The highest concentration in samples from LANL was 0.146 mg/L in a sample from middle Pajarito Canyon on June 28, 2000. The higher cyanide (total) concentrations in 2000 were from runoff from fire-impacted areas. Cyanide concentrations in runoff in 2001 and 2002 were significantly lower than in 2000, the maximum concentration in 2001 was 0.0223 mg/L in a sample from upper Los Alamos Canyon and in 2002 the maximum was 0.0508 mg/L in a sample from Rendija Canyon, which suggests that the effects of the fire on cyanide concentrations was still present in 2002.

The maximum concentration of cyanide (amenable) in 2000 runoff was 0.062 mg/L in a sample collected from upper Water Canyon (gage E252) on June 28. The pre-2000 highest concentration was 0.02 mg/L, which was approximately the detection limit of historical sample analyses. In 2000, 10 of 83 samples (11%) analyzed for amenable cyanide contained detectable concentrations. In 2001, two samples from fire-impacted areas contained detectable amenable cyanide, one sample from Guaje Canyon contained 0.0056 mg/L, and a sample from upper Los Alamos Canyon contained 0.00292 mg/L. In 2002, no runoff samples from fire-impacted areas contained detectable amenable cyanide, although detections occurred in two samples, one from Sandia Canyon and another from Potrillo Canyon. Amenable cyanide is important because it is a measure of the potentially biologically harmful forms of cyanide. Amenable cyanide is that portion of cyanide that is amenable to chlorination and is comparable to “free acid dissociable” cyanide listed in the New Mexico stream standards.

The highest concentration of potassium in 2000 runoff was 111.3 mg/L in a sample from upper Pajarito Canyon collected on June 28. The previously highest potassium concentration was 30.67 mg/L. In 2000, 13 of 25 samples contained greater than 30 mg/L potassium. The nine highest concentrations of potassium were collected from the high-volume runoff event on June 28. Potassium concentrations correlate with TSS (see following section on TSS). In 2001, no runoff samples were analyzed for potassium, but in 2002, all potassium results were less than 30 mg/L, except one sample from Guaje Canyon collected September 10 that contained 41.5 mg/L potassium.

The highest concentration of phosphate (as phosphorous) in 2000 runoff was 14.5 mg/L in a sample from lower Water Canyon (gage E265) collected on July 29. The highest concentration measured before 2000 was 1.74 mg/L. In 2000, 27 of 76 samples (35%) contained higher concentrations of phosphate and nearly all of these samples were from runoff from fire-impacted areas and all samples containing greater than 2.3 mg/L were from fire-related runoff. No runoff samples collected in 2001 and 2002 from fire-related areas contained phosphate concentrations greater than prefire levels; however, one sample from Sandia Canyon collected on July 31, 2002, by NMED contained 2.3 mg/L phosphate (as phosphorous).

In 2000 after the fire, the highest TSS concentration in runoff was 76,000 mg/L in a TSS(m) sample (maximum TSS concentration obtained from sample bottle with the highest amount of suspended material) collected from Guaje Canyon on September 8. The highest concentration in a sample from LANL runoff was 71,400 mg/L in a sample collected from lower Water Canyon (gage E265) on October 23. The historical maximum concentration of TSS was 43,140 mg/L. In 2000 only 12 of 272 analyses (4%) for TSS were above the historical maximum and, except for the sample from Guaje Canyon, all other samples greater than the historical maximum concentration were from lower Water Canyon at gages E263 or E265.

In 2001, 17 of 81 samples (21%) contained TSS or TSS(m) concentrations greater than the prefire maximum. Samples with the highest concentrations in 2001 were from Guaje Canyon on August 8 (155,000 mg/L), from Water Canyon on July 6 (127,000 mg/L), and from Rendija Canyon on July 2, 2001 (126,000 mg/L). In 2001, runoff samples with TSS concentrations higher than prefire levels came from Guaje, Rendija, Pueblo, Los Alamos, Pajarito, and Water Canyons, which were all affected by the fire.

In 2002, 6 of 52 runoff samples (12%) contained TSS concentrations higher than the prefire maximum. Highest TSS concentrations were from Pajarito Canyon on June 21, 2002, where the maximum was

144,000 mg/L and from Guaje and Rendija Canyons where TSS concentrations were as high as 99,500 mg/L.

In 2003, 3 of 40 runoff samples (8%) contained TSS concentrations greater than the prefire maximum; two samples were from Pueblo Canyon and one sample was from Guaje Canyon, where the maximum TSS concentration was 132,000 mg/L.

2.2.2.2 Comparison of Major Water Quality Constituents with Current Reference Standards

The minimum standards that are applicable to storm water runoff are listed in Table 2.2.2-2 above. The summary of the major water quality constituents for which standards exist is shown in Figure 2.2.2-2 with the minimum standard values. The drinking water and groundwater standards are typically compared with results from filtered samples, and wildlife standards are typically compared with unfiltered results.

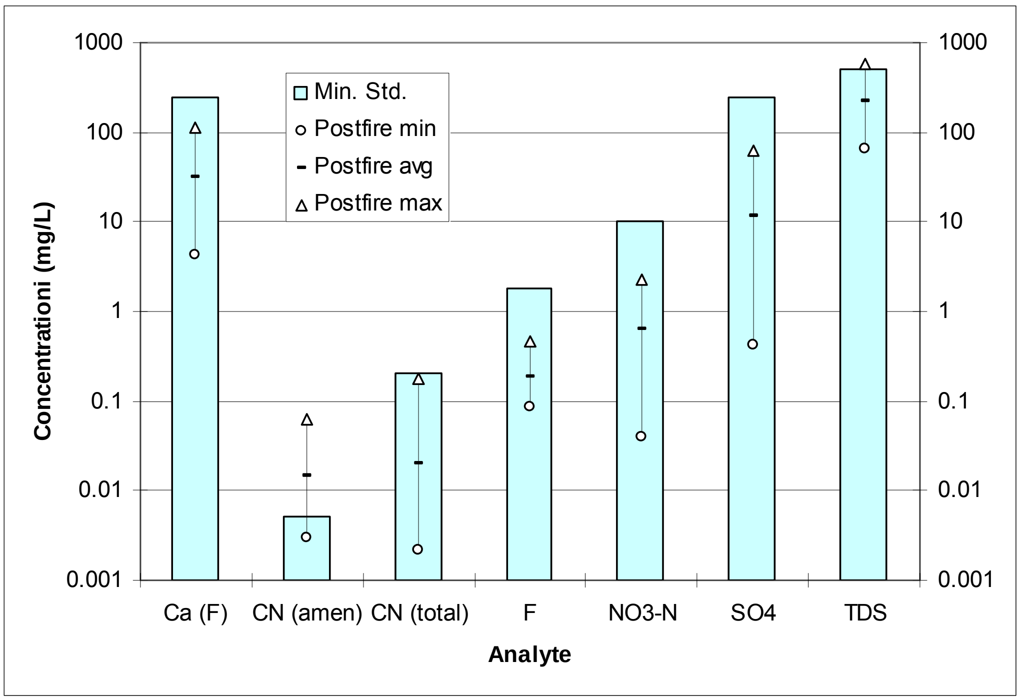


Figure 2.2.2-2. Summary of major water quality constituents compared with minimum reference standards.

The water quality constituents that were greater than minimum standards in postfire runoff include cyanide (amenable) and TDS. Cyanide (amenable) was found in concentrations greater than the wildlife habitat standard (0.0052 mg/L) (NMWQCC 2002) in three samples from Water Canyon in 2000 and one sample from Guaje Canyon in 2001. The highest concentration of cyanide (amenable) was 0.62 mg/L in a sample from upper Water Canyon (gage E252) collected on June 28, 2000. The other samples with cyanide (amenable) concentrations above the standard in 2000 were from Water Canyon below SR 4 collected on July 29 and August 18. NMED collected a runoff sample from Twomile Canyon at SR 501 on October 28, 2002, that contained 0.01 mg/L cyanide (amenable). A runoff sample from Guaje Canyon (above Rendija Canyon) collected on August 14, 2001, contained 0.00597 mg/L cyanide (amenable), slightly above the standard.

In 2000 a runoff sample from Guaje Canyon collected on September 8 contained 570 mg/L TDS, above the EPA secondary drinking water standard of 500 mg/L. In addition, NMED collected a runoff sample from Acid Canyon on October 28, 2000 (not fire related), that contained 546 mg/L TDS. In 2001, a runoff sample from Los Alamos Canyon above DP Canyon collected on July 26 contained 587 mg/L TDS, and NMED collected runoff samples from lower Pueblo Canyon on August 16 and from lower Water Canyon on August 3 that contained 590 mg/L and 840 mg/L, respectively.

In 2002, NMED collected runoff from three events that contained greater than 500 mg/L TDS. Samples were collected from lower Guaje Canyon at SR 502 on July 31, 2002, that contained up to 660 mg/L; samples from lower Pueblo Canyon collected on July 18 and 26 contained up to 940 mg/L and 580 mg/L, respectively.

2.2.2.3 Suspended Sediment and Sediment Transport

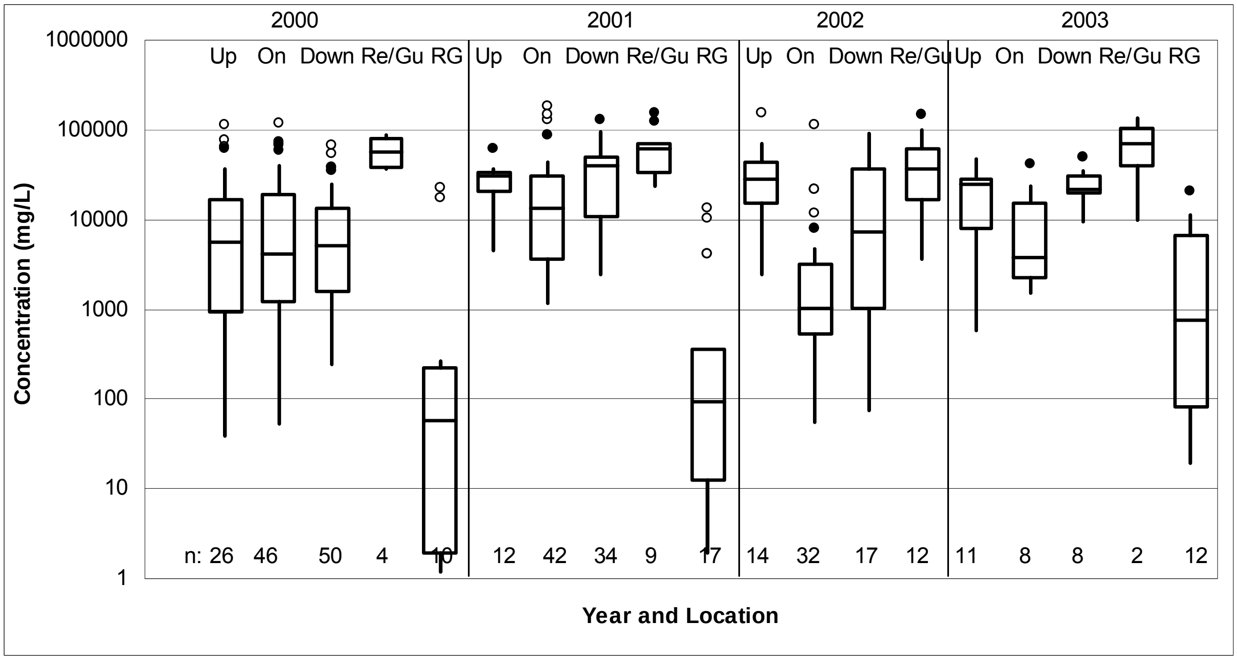
A major impact of the Cerro Grande fire was substantially increased transport of sediment onto and across LANL. A significant increase in TSS concentrations in storm water runoff from fire-affected areas was caused by a lack of vegetation and hydrophobic soils that created higher runoff rates and volumes, higher erosion of bare hill slopes, and higher scour of channels and banks. The initial runoff events in June and July 2000 carried abundant ash and sediment on a widespread basis across LANL, and in Pueblo Canyon, the major fire impacts with regard to TSS concentrations in storm runoff were observed in 2001 and 2002.

The prefire maximum TSS concentration in storm runoff at LANL was 43,140 mg/L, after the fire the maximum TSS concentration in runoff at LANL in 2000 was 76,000 mg/L, and 12 samples contained TSS greater than the prefire maximum. Runoff samples from automated samplers are collected in multiple sample containers that are typically composited before the samples are prepared for laboratory analyses, which routinely include TSS analyses. Beginning in 1999, a portion of the sampler container that had the highest apparent turbidity and suspended sediment was packaged separately for a unique TSS analyses that was labeled TSS(m), for maximum TSS concentration. The results of these analyses were reported separately by the analytical laboratory, but are included in the following discussion of TSS results. The routine TSS values are used with other analytical results to calculate mass or activity values of constituents.

The analytical method used for the analyses of suspended sediment for WQH samples changed in 2001 for some samples to suspended sediment concentration (SSC), although the analyses for SSC and TSS were both performed by the analytical laboratory using EPA method 160.2. These results are reported here as TSS. The analytic method for TSS concentration utilized a representative aliquot of a liter sample to determine the weight of solids per liter, while the SSC method utilizes the entire liter of sample to determine the weight of solids. No apparent systematic changes in TSS and SSC concentration results were noted in the storm runoff data using these two methods.

Figure 2.2.2-3 summarizes the results of analyses for TSS and total suspended load (some NMED samples) in storm runoff at upstream, onsite, and downstream locations from LANL, in Rendija and Guaje Canyons, and the Rio Grande in 2000, 2001, 2002, and 2003. All TSS results obtained by WQH, ER, and NMED, and in major drainages at LANL and in the Rio Grande by the USGS were included in the data set.

In 2000, the maximum TSS concentration in runoff was 120,000 mg/L in a sample collected in middle Pueblo Canyon (onsite) by ER. The maximum TSS concentration at upstream locations was 114,348 mg/L in a sample collected from the north tributary of Pueblo Canyon. The maximum at downstream locations was 65,800 mg/L in a sample from lower Water Canyon collected on October 28, 2000. TSS concentrations in runoff from Rendija and Guaje Canyons were typically higher than from LANL canyons, and ranged from 37,000 to 89,000 mg/L. The maximum TSS concentration in water samples collected from the Rio Grande in 2000 was 22,184 mg/L in a sample collected by NMED on October 24 from the White Rock stream gage. The median concentration of upstream LANL runoff was about 5500 mg/L, slightly higher than at downstream locations where the median concentration was 5175 mg/L. The median TSS concentration of runoff from Guaje and Rendija Canyons was 57,000 mg/L, about an order



Note: Re/Gu = Rendija/Guaje Canyons; RG = Rio Grande

Figure 2.2.2-3. Summary of TSS concentrations at upstream, onsite, and downstream locations, 2000–2003.

of magnitude higher than for runoff from LANL canyons. The median concentration of TSS in Rio Grande samples was 57 mg/L, indicating that, for the available data, the high sediment loads from the Pajarito Plateau did not significantly influence the concentrations in the Rio Grande. The high TSS concentration outliers shown in Figure 2.2.2-3 for 2000 are associated with high-volume runoff from fire-impacted areas. The high concentration outliers from the Rio Grande were from samples collected on October 24 and 28, 2000, when precipitation occurred over a wide area in northern New Mexico and the Rio Grande was carrying runoff from many areas, including the Pajarito Plateau.

In 2001, maximum TSS concentrations at onsite and downstream locations were higher than in 2000; the maximum onsite concentration was 179,000 mg/L in a sample collected in middle Pueblo Canyon by ER on August 9, 2001. The maximum concentration at downstream locations was 128,900 mg/L in a sample collected from lower Water Canyon by NMED on July 26, 2001. The median concentration at upstream locations in 2001 was about 30,000 mg/L, and at downstream locations about 40,000 mg/L, significantly higher than in 2000. The higher downstream TSS concentrations may represent remobilization and transport of fire debris that was deposited in canyons on the Pajarito Plateau in 2000. The median TSS concentration in runoff from Guaje and Rendija Canyons was 62,000 mg/L, slightly higher than in 2000.

The highest TSS concentrations in the Rio Grande in 2001 were 13,200 mg/L in a sample collected on July 27 from Otowi and 10,200 mg/L in a sample collected from the White Rock gage on July 26 by the USGS. Runoff from the Pajarito Plateau occurred on July 26, thus these elevated concentrations may be the result of runoff from Los Alamos, Pajarito, and Water Canyons. Samples collected from the Rio Grande near White Rock on August 9, 2001, contained 4140 mg/L TSS, which also may be associated with runoff from the Pajarito Plateau on that date. The median TSS concentration in Rio Grande samples in 2001 was 93 mg/L, slightly higher than in 2000.

The maximum TSS concentration in runoff from upstream locations in 2002 was 153,000 mg/L in a sample collected from Pueblo Canyon above Acid Canyon on July 25 by NMED. The maximum onsite concentration was 114,000 mg/L in a sample collected from middle Pajarito Canyon above Threemile

Canyon on June 21. The maximum concentration at downstream locations was 89,200 mg/L in a sample collected from lower Cañada del Buey on August 28. The maximum concentration from Guaje Canyon in 2002 was 145,000 mg/L in a sample collected at SR 502 on July 31 by NMED. The median concentration of samples collected at upstream locations in 2002 was about 28,000 mg/L, similar to 2001. The median concentration of samples collected onsite was about 1000 mg/L, significantly lower than in 2000 and 2001, but possibly due to dry conditions in 2002. The median concentration of samples collected from downstream locations was 7400 mg/L, significantly less than in 2001 but similar to 2000. The median concentration of samples from Guaje and Rendija Canyons was about 37,000 mg/L, about half of the median in 2000 and 2001.

The maximum TSS concentrations in runoff at upstream, onsite, and downstream LANL locations were significantly lower in 2003 than previous postfire years. The maximum TSS concentration from upstream locations in 2003 was 47,900 mg/L in a sample collected from Pueblo Canyon on August 11, 2003. The maximum TSS concentration from downstream locations was 50,100 mg/L in a sample collected from Pueblo Canyon on September 6, 2003. The TSS concentrations of two samples from Rendija and Guaje Canyons were similar to the previous postfire years. In 2003 more samples of storm runoff were collected from the Rio Grande, thus the median concentration in 2003 was about an order of magnitude higher than in previous years, although the maximum concentration was similar to previous years.

A comparison of annual FWA TSS concentrations in storm runoff for selected stream gages is shown in Figure 2.2.2-4. At the upstream gages through 2003, the TSS concentrations remained elevated above prefire levels by several orders of magnitude. The largest perturbation is seen in upper Pajarito Canyon, where postfire TSS concentrations were 10,000 times larger than prefire. The sustained elevated TSS concentrations may indicate that only partial recovery has occurred on the hillslopes and significant erosion and sediment transport continues three years after the fire. Canyons where runoff was not significantly impacted by the fire, such as Cañada del Buey and Potrillo and Ancho Canyons, do not show significantly different average TSS concentrations. The higher TSS concentrations in runoff from lower Pajarito Canyon in 2002 and 2003 are associated with local precipitation and sediment-laden runoff rather than to fire-related runoff.

Figure 2.2.2-5 shows the estimated annual transport of suspended sediment in storm runoff at “LANL” upstream and downstream sites, downstream Pueblo Canyon, and the total transport of suspended sediment downstream from 2000 through 2003, and the prefire average downstream transport. The mass of suspended sediment is estimated for each year for upstream, downstream, and Pueblo Canyon runoff by calculating the annual FWA TSS concentration at each of the locations and multiplying that concentration by the total seasonal runoff for the respective locations.

The estimated prefire average annual downstream transport of suspended sediment for years 1996 through 1999 was about 700 metric tons (MT); for this period insufficient upstream data were available, however, upstream runoff was minimal and upstream TSS concentrations were less than 300 mg/L, indicating very little transport of suspended sediment at upstream locations before the fire.

In 2000 after the Cerro Grande fire, an estimated 3100 MT of suspended sediment flowed onto LANL at upstream locations; the suspended sediment was largely composed of ash and muck in runoff from fire-impacted areas. About 1600 MT of suspended sediment flowed downstream of LANL (exclusive of Pueblo Canyon) in 2000, which indicates that about 1500 MT of suspended sediment material was deposited in floodplains in LANL canyons (excluding Pueblo Canyon) during the 2000 runoff season. About 700 MT of suspended sediment material flowed downstream from Pueblo Canyon in 2000 (note that there is no estimate of sediment transport into Pueblo Canyon from burned areas, so no estimate of net deposition in Pueblo Canyon is available). The total mass of suspended sediment that flowed downstream of LANL in all canyons in 2000 was about 2216 MT.

In 2001 the estimated total mass of suspended sediment in upstream runoff was about 4400 MT, about 1.4 times more than in 2000, and the estimated suspended material in downstream LANL runoff was about 2800 MT, about 1.8 times higher than in 2000. In Pueblo Canyon, the estimated suspended material in downstream runoff in 2001 was about 13,000 MT, about 18 times higher than in 2000,

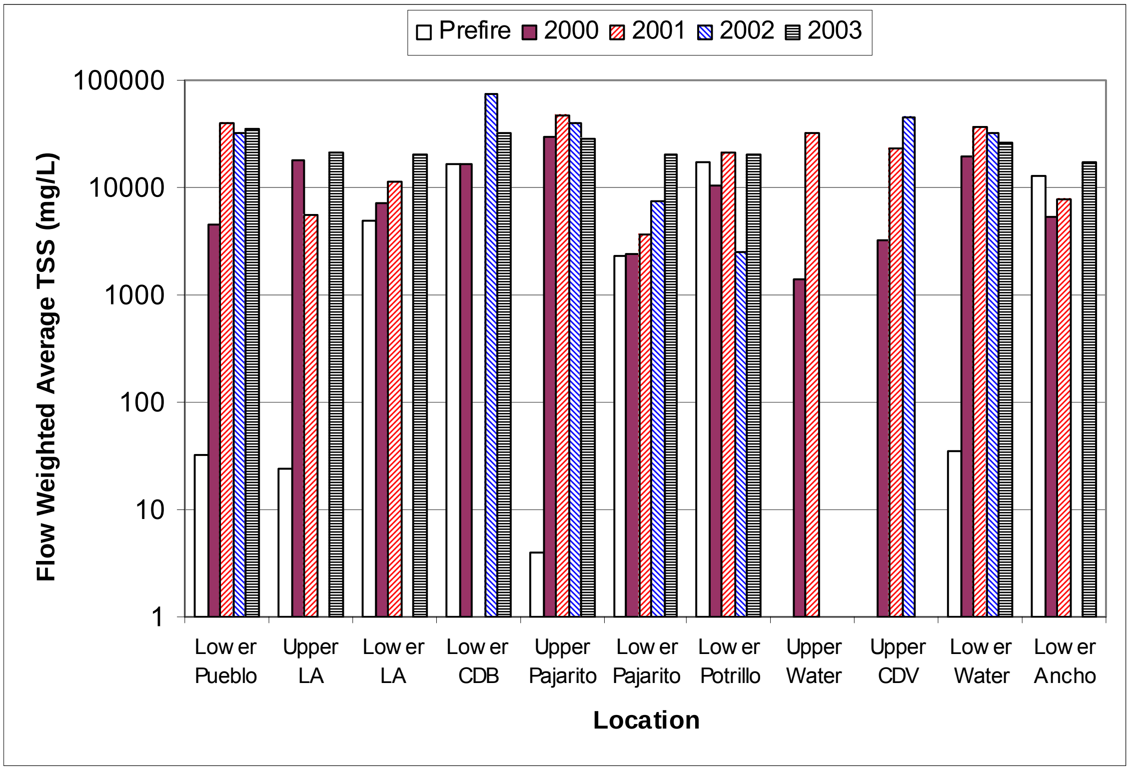


Figure 2.2.2-4. Comparison of postfire and prefire average annual TSS concentrations in storm runoff.

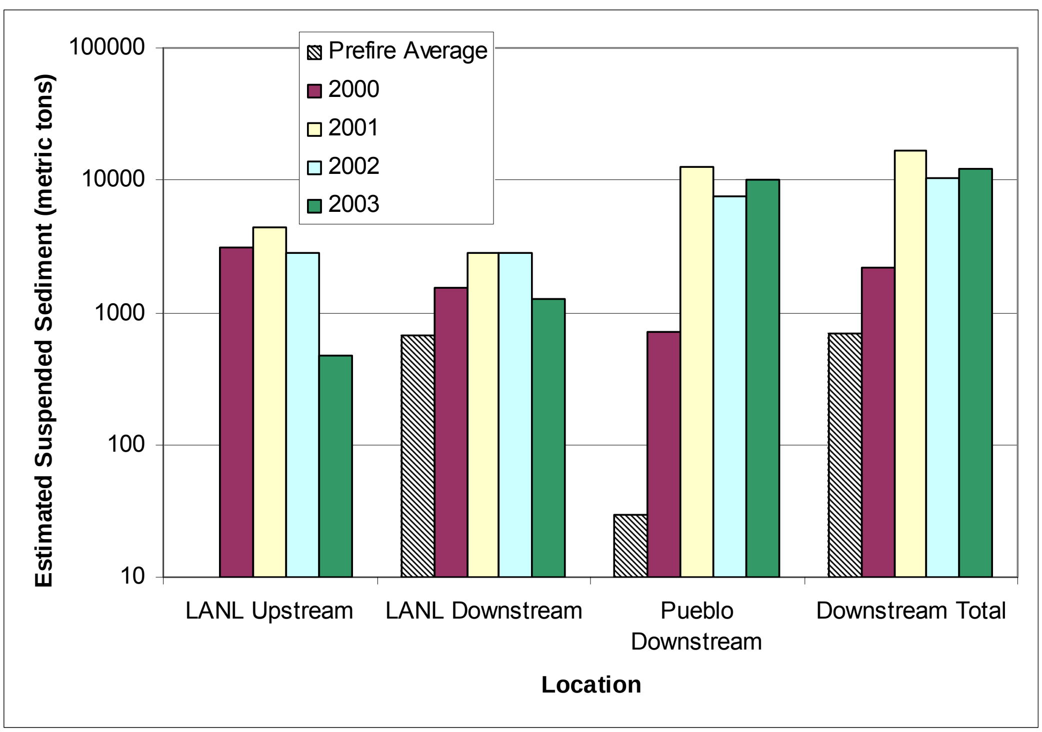


Figure 2.2.2-5. Summary of estimated transport of suspended sediment at upstream and downstream locations, 2000–2003.

primarily due to the large runoff event in Pueblo Canyon on July 2, 2001. The estimated total suspended sediment from all canyons in 2001 was over 16,600 MT, 7 times more than in 2000.

In 2002, the estimated suspended sediment material measured in upstream LANL runoff was about 2800 MT, slightly less than that in 2000, partly due to drought conditions, but possibly indicating some recovery of the fire-impacted areas. Estimated suspended sediment in downstream LANL runoff was about 2800 MT, similar to that in 2001, but about 1.8 times more than in 2000. The amount of estimated suspended sediment in downstream Pueblo Canyon runoff in 2002 was 7600 MT, about 60% of that in 2001. The total estimated amount of suspended sediment in 2002 runoff from all LANL canyons and Pueblo Canyon was about 10,000 MT, 60% of that in 2001 but about 5 times more than in 2000.

In 2003, the estimated suspended sediment in upstream LANL runoff was about 500 MT, significantly less than previous postfire years, partially due to drought conditions, but also partially due to recovery of the watersheds from the fire impacts. Estimated suspended sediment in downstream LANL runoff was about 1300 MT, less than half of that in 2001 and 2002. The estimated suspended sediment in upstream Pueblo Canyon runoff in 2003, the first year that flow volumes were available, was about 4800 MT. The estimated suspended sediment in runoff in downstream Pueblo Canyon runoff was about 10,000 MT, slightly higher than in 2002 but less than in 2001. The estimated total suspended sediment in all downstream runoff in 2003 was about 12,400 MT.

In 2000 and 2001 more suspended sediment was carried onto LANL (excluding Pueblo Canyon) in upstream runoff than flowed downstream of LANL; about 1500 MT of sediment were deposited in floodplains and stream banks at LANL during each year. In 2002, the amount of suspended sediment at upstream and downstream locations at LANL was approximately equal, and in 2003 there was about 800 MT more suspended sediment carried in downstream LANL runoff than flowed onto LANL. In Pueblo Canyon in 2003, it is estimated that downstream runoff carried about 5000 MT more suspended sediment than what was in upstream Pueblo Canyon runoff.

2.2.2.4 Impact of Los Alamos Canyon Weir on Sediment Transport

The Los Alamos Canyon weir was constructed in the summer of 2000 after the Cerro Grande fire to slow runoff and catch sediment and associated contaminants before runoff flowed downstream of LANL (Figure 2.2.2-6). In September and October 2000 and during the runoff season in 2001 storm runoff samples were collected upstream of the weir at stream gage E042 and downstream of the weir at stream gage E050. The results of analyses of these runoff samples enable an estimate of the quantity of suspended sediment that has been deposited behind the weir. Runoff samples were not collected in lower Los Alamos Canyon in 2002, partly due to the lack of rainfall and runoff events, but also due to failure of the automated sampling equipment to collect samples when runoff did occur. In total, there were 13 samples collected upstream of the weir and 12 downstream, equivalently split between 2000 and 2001.

Figure 2.2.2-7 shows the estimated mass of suspended sediment that flowed into and out of the Los Alamos Canyon weir and the estimated amount of suspended sediment deposited in the weir each year from 2000 through 2003 from storm runoff. The estimates are based on the FWA annual concentrations of TSS in runoff samples collected above and below the weir and the estimated volume of storm runoff that passed through the weir each year. Gaged flow volumes upstream and downstream of the weir are available for 2003, when about 63% of the flow at gage E042 above the weir flowed downstream of the weir at gage E050; this fraction was applied to gaged flows at E042 for 2000 through 2002 to approximate the amount of flow downstream of the weir in those years.

In 2000 after the weir was constructed, the FWA TSS at gage E042 upstream of the weir was about 3760 mg/L, while the FWA concentration at gage E050 downstream of the weir was about 1185 mg/L, indicating that suspended sediment was deposited in the weir. Approximately 200 MT of suspended sediment is calculated to have been deposited in the weir in 2000.

Figure 2.2.2-6. Low-head weir in Los Alamos Canyon retaining snowmelt runoff, April 5, 2001.

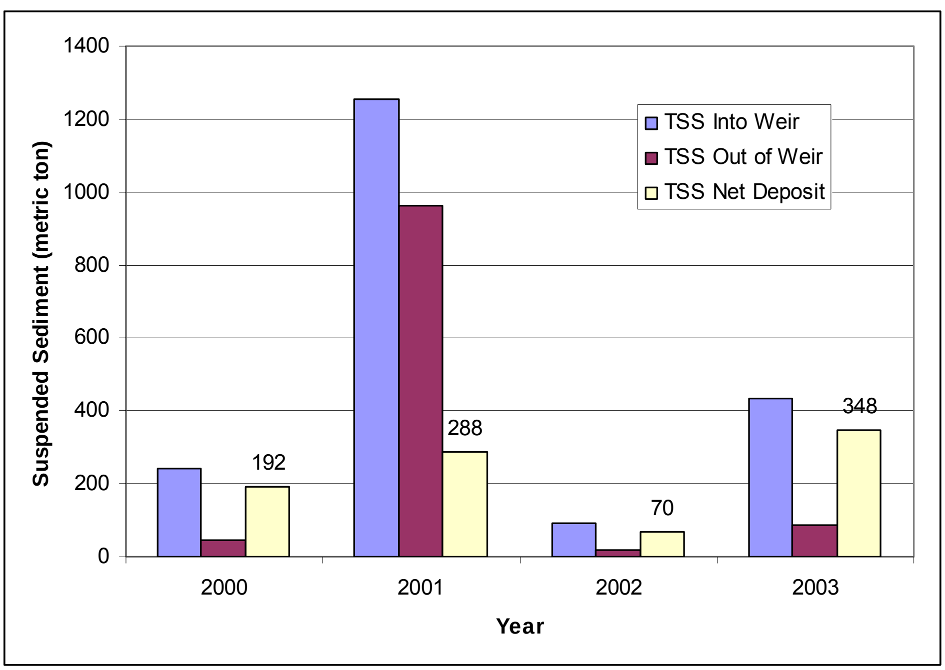


Figure 2.2.2-7. Estimated mass of suspended sediment deposited in the Los Alamos Canyon weir.

Unlike 2000, in 2001, TSS concentrations were higher downstream of the weir in two out of three flow events for which paired samples were collected upstream and downstream of the weir during a runoff event. In 2001, the FWA TSS concentration at gage E042 was 9660 mg/L, while the FWA concentration downstream of the weir was 11,790 mg/L, suggesting that some sediment formerly deposited in the weir in 2000 may have been remobilized in downstream runoff during large runoff events. However, because less volume of runoff is estimated to flow downstream of the weir, the net result in 2001 was the deposition of about 290 MT of suspended sediment. Due to significantly higher volumes of runoff in Los Alamos Canyon in 2001 than in 2000 (about twice the volume in 2001 [Shaull et al. 2001, 2002]), the amount of suspended sediment material that flowed into and out of the weir was much higher in 2001 (Figure 2.2.2-7).

Because runoff samples were not collected upstream or downstream of the weir in 2002 (due largely to the paucity of runoff during the drought), the amount of sediment deposited in 2002 was estimated using the 2000 average upstream and downstream FWA TSS concentrations and the flow volume measured at the upstream gage. The estimated amount of sediment deposited in 2002 is about 70 MT. In 2003 runoff samples were collected only from the upstream side of the weir; therefore, the amount of sediment deposited in 2003 was estimated using the FWA TSS concentration calculated for the upstream gage in 2003 and the 2000 downstream/upstream FWA TSS ratio from 2000 to estimate the FWA concentration at the downstream gage. As mentioned above, flow volumes at both upstream and downstream gages were available for 2003. The estimated amount of sediment deposited in the weir in 2003 is about 350 MT.

Table 2.2.2-3 summarizes the estimated runoff volumes and transport of suspended sediment into and out of the weir and the deposition of sediment in the weir. The estimated total amount of suspended sediment deposited in the weir from 2000 through 2003 is about 900 MT. Low-volume runoff events apparently have a much higher efficiency with respect to trapping sediment in the weir, as seen in 2000 (after the weir was constructed in September 2000) and 2002 when flows were less in volume and intensity and the efficiency of suspended sediment capture was about 80%. However, large runoff events overtop the weir and carry suspended sediment downstream and may even resuspend sediment previously deposited in the weir, as seen in 2001 when TSS concentrations were higher in runoff below the weir than above and the sediment capture efficiency was only about 23%. The estimated overall sediment capture efficiency for the four years from 2000 through 2003 was about 45%.

Table 2.2.2-3. Estimated Mass of Suspended Solids at the Los Alamos Canyon Weir.

Year	Upstream Flow (ac-ft)	Downstream Flow (ac-ft)	TSS Into Weir (MT)	TSS Out of Weir (MT)	TSS Net Deposit (MT)	Efficiency
2000	51.7	32.6	240	48	192	80%
2001	105.0	66.3	1252	964	288	23%
2002	19.2	12.1	89	19	70	79%
2003	20.7	13.1	435	86	348	80%
Total	197.7	124.1	2016	1117	899	45%

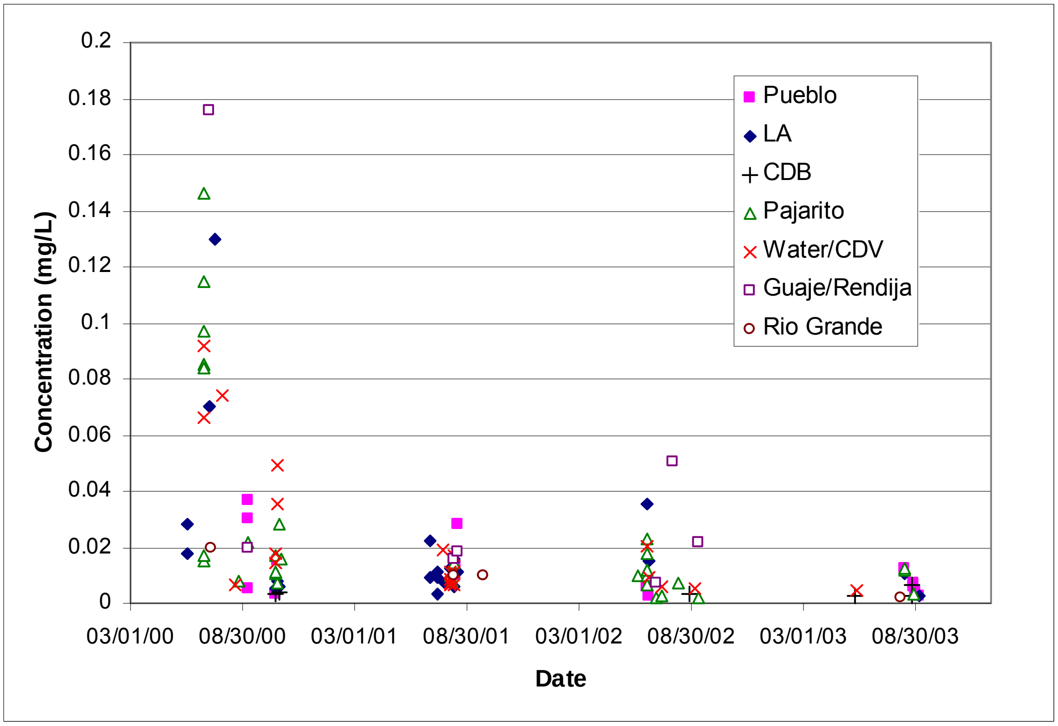
Note: 2003 flow volumes gaged, other downstream flow volumes based on upstream gaged flow and 2003 upstream/downstream ratio. TSS estimates for 2002 and 2003 based on ratio of upstream/downstream FWA TSS concentration from 2000.

2.2.2.5 Cyanide in Storm Runoff

Cyanide, if present in runoff in certain chemical forms (free or amenable cyanide), can be toxic to aquatic biota and wildlife. Cyanide was measured in both total and amenable concentrations in samples collected by WQH and in total, amenable, and weak acid disassociable concentrations in samples collected by NMED.

Most historical results for cyanide analyses were below detection limits. In 2000 after the Cerro Grande fire, total cyanide was measured above the detection limit in 52 of 99 runoff samples, and the maximum concentration measured was 0.176 mg/L in a sample from Guaje Canyon collected on July 9, 2000. The highest concentration in runoff from LANL was 0.146 mg/L in a sample from upper Pajarito Canyon collected on June 28, 2000. Results greater than 0.06 mg/L were from runoff collected from the large June 28, 2000, runoff event or from runoff in July 2000. The higher cyanide (total) concentrations in 2000 were associated with runoff from burned areas.

Figure 2.2.2-8 shows the time series of total cyanide detections in unfiltered runoff samples at LANL (WQH and NMED results) and the Rio Grande (USGS results) from 2000 through 2003. Since 2000, detectable total cyanide concentrations in runoff have usually been less than 0.04 mg/L. In 2002 the highest total cyanide concentration in runoff (0.0508 mg/L) was from Rendija Canyon in a sample collected on July 31, 2002. All detections of total cyanide in 2003 were less than 0.02 mg/L.



Note: LA = Los Alamos Canyon, CDB = Cañon del Buey, CDV = Cañon de Valle

Figure 2.2.2-8. Time series of total cyanide detections in unfiltered runoff by canyon, 2000–2003.

Figure 2.2.2-9 shows the distribution of cyanide concentrations in all runoff samples from the Pajarito Plateau from 2000 through 2003. The median concentrations and the distributions of concentrations in 2002 and 2003 are similar and indicate the cessation of runoff impacted by cyanide.

Cyanide (total) was detected in concentrations near the detection limit in 4 of 23 samples collected by USGS from the Rio Grande and Cochiti Reservoir in 2000 and 2001. Two detections (maximum concentration 0.02 mg/L on July 11, 2000) were from the Rio Grande below Cochiti Reservoir, one detection (0.01 mg/L on September 26, 2001) was from the Rio Grande at Otowi Bridge, and another detection (0.01 mg/L on August 9, 2001) was from the Rio Grande near White Rock stream gage.

Amenable cyanide (weak acid dissociable) was detected in 11 of 170 runoff samples (6%) collected after the fire from 2000 through 2002. The highest concentrations of amenable cyanide occurred in runoff from Water Canyon after the fire where the maximum concentration was 0.062 mg/L in a sample collected from

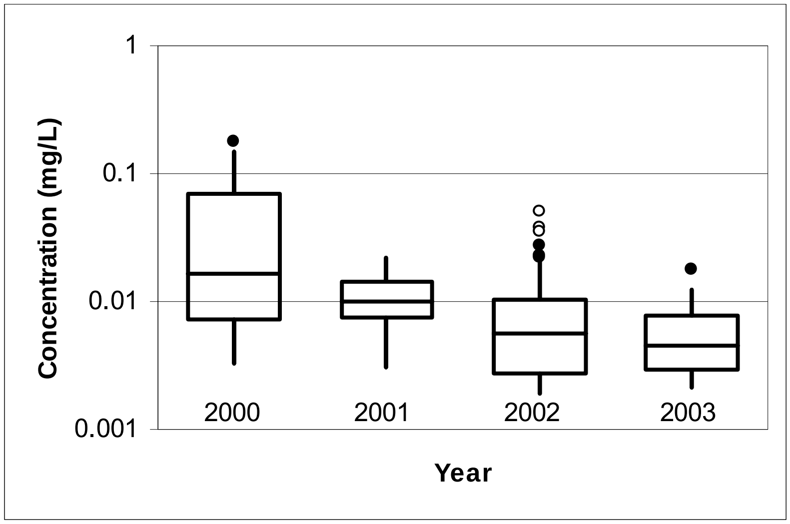


Figure 2.2.2-9. Distribution of cyanide (total) detections in unfiltered runoff from the Pajarito Plateau, 2000–2003.

upstream Water Canyon on June 28, 2000. In 2000 four runoff samples contained concentrations of amenable cyanide above the wildlife standard of 0.0052 mg/L (NMWQCC 2002); three samples were from Water Canyon, and one sample collected by NMED was from Twomile Canyon at SR 501. In 2001, one sample from Guaje Canyon contained 0.00597 mg/L amenable cyanide, slightly above the wildlife standard. In 2002 and 2003, runoff samples did not contain amenable cyanide in concentration above the standard.

Possible sources of the cyanide include fire retardant used in the Cerro Grande fire that contains a sodium hexaferrocyanide compound added as an anti-caking additive and as a corrosion inhibitor. According to U.S. Forest Service estimates, approximately 110,000 gallons of fire retardant were dropped during the fire suppression efforts, impacting the upland areas of many of the major canyons draining the Jemez Mountains (G. Kuyumjian, personal communication October 4, 2000). Figure 2.2.2-10 shows the outline of the Cerro Grande fire and locations of fire retardant drops; the figure was assembled from U.S. Forest Service base map and fire retardant application data. Another possibility to explain the presence of cyanide in runoff is that some cyanide may have been naturally created through slow burning or smoldering of biomass (e.g., Yolkeson et al. 1997) and then transported in the runoff with the ash.

The storm runoff analyses indicate that most cyanide detected in storm runoff was of the less toxic form. When postfire monitoring began, concerns were raised that biologically harmful forms of cyanide (free or amenable) could be generated through ultraviolet (UV) decomposition of the fire retardant (Little and Calfee 2000). These concerns were not borne out by the results of storm runoff analyses. Table 2.2.2-4 summarizes the results of cyanide analysis from 2000 through 2003 at Los Alamos. Total cyanide concentrations progressively declined over three years after the fire (see Figure 2.2.2-8) and amenable cyanide was detected above the New Mexico Acute Aquatic Life Standard (22 µg/L) in three storm runoff samples, and above the Wildlife Habitat standard (5.2 µg/L) in only one sample of baseflow (Table 2.2.2-4). The one baseflow sample that was above the Wildlife Habitat standard was collected in May 2003 and contained 5.22 µg/L, while a duplicate analysis of this sample was below the standard at 4.98 µg/L. The three storm runoff samples that were above the acute aquatic life standard were collected from Water Canyon in 2000 soon after the fire. No fish kills were reported in the Los Alamos area or in the Rio Grande after the Cerro Grande fire. Additionally, all detections of amenable cyanide were below the human health standard (220,000 µg/L).

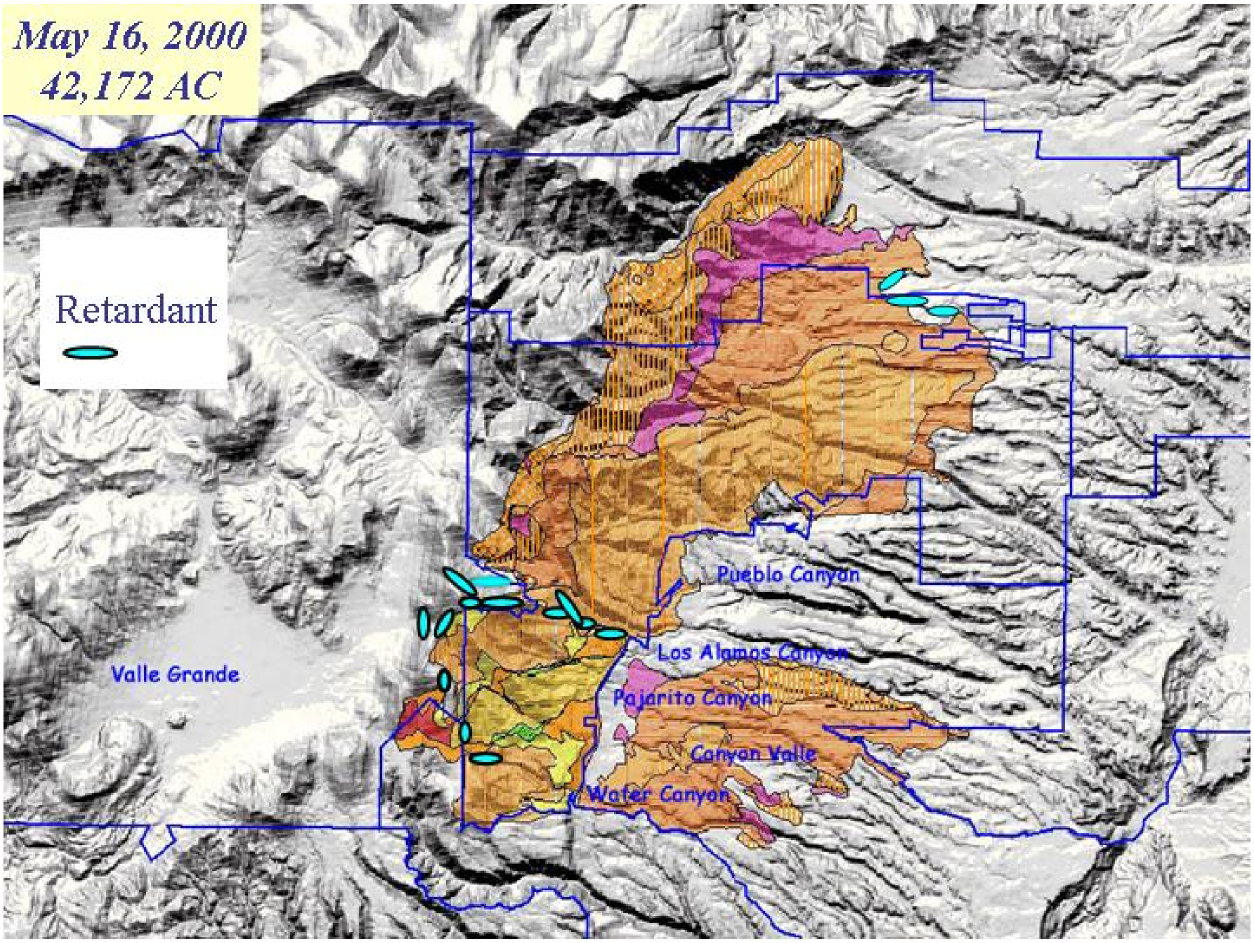


Figure 2.2.2-10. Cerro Grande fire area showing composite fire retardant drop pattern May 5–May 16, 2000.

2.2.2.6 Calcium in Storm Runoff

Figure 2.2.2-11 shows the distribution of calcium concentrations in upstream and onsite/downstream unfiltered storm runoff at LANL, Guaje Canyon, and in baseflow from the Rio Grande for prefire years and from 2000 through 2003. Calcium concentrations in unfiltered storm runoff were significantly higher in 2000 after the Cerro Grande fire. The maximum calcium concentration in unfiltered runoff in 2000 was 1110 mg/L in a sample collected from upstream Pajarito Canyon, significantly higher than the prefire maximum of 140 mg/L in all runoff at LANL. In 2000, 15 of 25 samples (60%) collected from all locations at LANL contained calcium concentrations greater than the historical maximum. The highest concentrations of calcium were collected from high-volume runoff in Pajarito Canyon, Water Canyon/Cañon de Valle, and Guaje Canyon on June 28 and July 9, 2000, from runoff that originated from fire-impacted areas. Analyses of ash from the Cerro Grande fire showed elevated concentrations of calcium (e.g., Katzman et al. 2002, Johansen et al. 2003, LANL 2004).

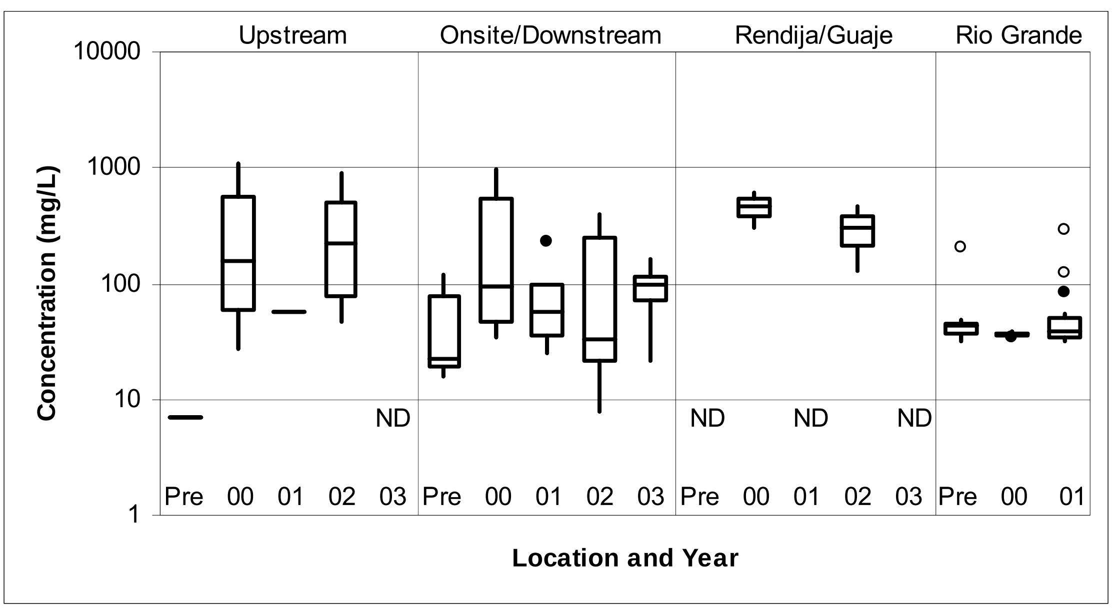
Median concentrations of calcium in the Rio Grande were similar before and after the fire; however, some component of runoff may be reflected by the higher outlier concentrations both prefire and in 2001. The highest calcium concentrations in samples collected from the Rio Grande were collected from Otowi (287 mg/L on July 27, 2001) and from near White Rock (124 mg/L on July 26, 2001). Most samples from the Rio Grande and Cochiti Reservoir contained less than 50 mg/L calcium.

Table 2.2.2-4. Cyanide Detections in Surface Water Samples.

	Baseflow/Snowmelt					Storm Runoff				
	Total	2000	2001	2002	2003	Total	2000	2001	2002	2003
Total Cyanide										
Number of Analyses	246	55	136	30	25	302	96	66	83	57
Number of Detections	49	23	13	7	6	169	50	40	44	35
Detection Frequency (%)	20	42	10	23	24	56	52	61	53	61
Results greater than NM domestic drinking water standards (%) [a]	00	0	0	0	0	0	0	0	0	0
Amenable Cyanide										
Number of Analyses	108	10	68	27	3	192	69	50	32	41
Number of Detections	8	0	2	4	2	17	8	3	2	4
Detection Frequency (%)	7	0	3	15	67	9	12	6	6	10
Number of detections greater than aquatic life or wildlife habitat standards [b]	1	0	0	0	1	3	3	0	0	0
Results greater than standards (%)	1	0	0	0	33	2	4	0	0	0
Number of detections greater than proposed doectic water supply standards (700 Fg/L) [b]	0	0	0	0	0	0	0	0	0	0
Results greater than proposed reference standard (%)	0	0	0	0	0	0	0	0	0	0

[a] Total cyanide results were compared with the New Mexico Domestic Water Supply Standard (200 µg/L). Comparison to the Domestic Water Supply standard is for general reference only as the standard applies to filtered water samples, while total cyanide analyses results reported in the table are from analyses of non-filtered samples.

[b] Amenable cyanide results were compared with three applicable standards: storm runoff (short-term flows) were compared with the New Mexico Acute Aquatic Life Standard (22 µg/L), and snowmelt runoff and baseflow surface waters (persistent flows) were compared with the New Mexico Wildlife Habitat Standard (5.2 ug/L) and the Chronic Aquatic Life Standards (5.2 µg/L). Reference to the aquatic life stream standard is for comparison; this standard applies to fisheries like the Rio Grande while streams within LANL do not contain fish. Baseflow and snowmelt were also compared with the proposed Domestic Water Supply standard, which is 700 µg/L (NMWQCC 2002)



Note: Pre = prefire, ND = no data.

Figure 2.2.2-11. Calcium in unfiltered LANL runoff and the Rio Grande, 2000–2003.

Figure 2.2.2-12 shows the time series of calcium concentrations in unfiltered runoff from each canyon and the Rio Grande from 2000 through 2003. The maximum calcium concentration in 2001 was in a sample collected from the Rio Grande at Otowi. In 2002, runoff from Pueblo Canyon contained up to 890 mg/L calcium. In 2003, calcium concentrations in runoff were less than 200 mg/L, which still indicate higher concentrations in runoff than before the fire.

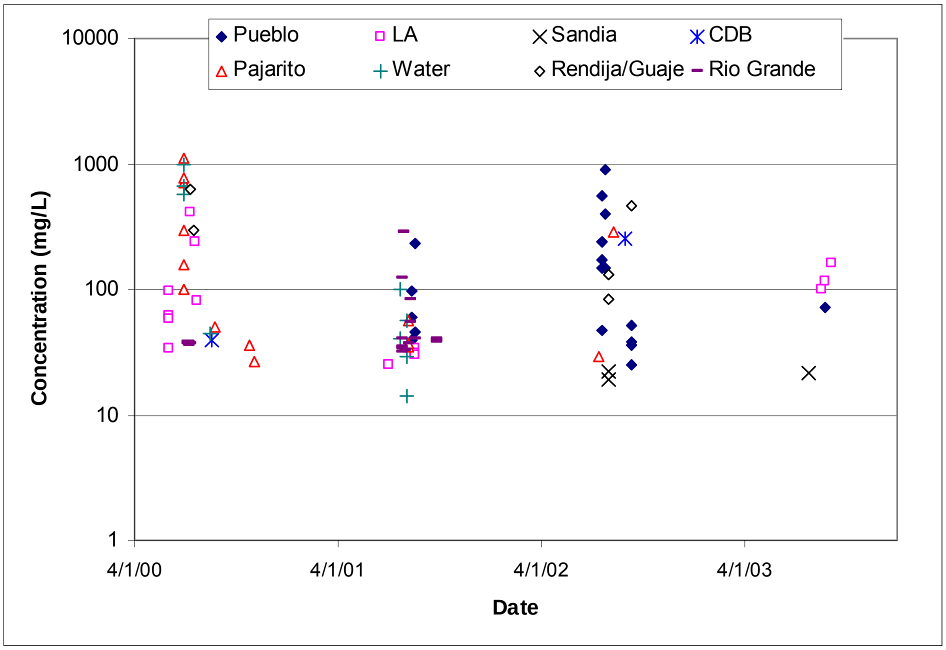


Figure 2.2.2-12. Time series of calcium concentrations in unfiltered runoff, 2000–2003.

2.2.2.7 Major Water Quality Constituents Dissolved in Storm Runoff

Figure 2.2.2-13 shows Stiff diagrams summarizing dissolved constituents (in meq/L) in upstream LANL runoff for the average prefire runoff and postfire years 2000 through 2003. Stiff diagrams graphically show the change in concentrations of major water quality constituents. The dissolved concentration data for all upstream storm runoff were averaged for each year to create the summary plots. Before the fire, upstream runoff was characterized as a calcium-magnesium-sodium-bicarbonate-chloride water type with concentrations less than 0.5 meq/L. After the fire, the upstream runoff was characterized primarily as calcium-magnesium-bicarbonate type water in 2000, 2001, and 2002. The highest dissolved calcium concentration was 2.3 meq/L in 2000 and 2001. By 2002, the concentrations of dissolved constituents in runoff were significantly less than in previous postfire years. In 2003 the upstream runoff was characterized as a calcium-sodium-bicarbonate-chloride, more similar to the prefire water type but with concentrations of calcium and bicarbonate about twice as high as the prefire runoff. Sodium and chloride were higher in upstream runoff in 2003 than previously observed, mainly from runoff in upper Pueblo Canyon, but probably not due to runoff from fire-impacted areas.

2.2.2.8 Summary of Major Water Quality Constituents in Storm Runoff

Major water quality constituents that had significantly higher concentrations in storm runoff after the Cerro Grande fire than before the fire include calcium, total cyanide, potassium, and phosphate. Other constituents that were measured in concentrations higher than prefire levels include total alkalinity, cyanide (amenable), magnesium, sodium, ammonia, sulfate, TKN, and TSS. The water quality constituents that were greater than minimum standards in postfire runoff include cyanide (amenable), and TDS.

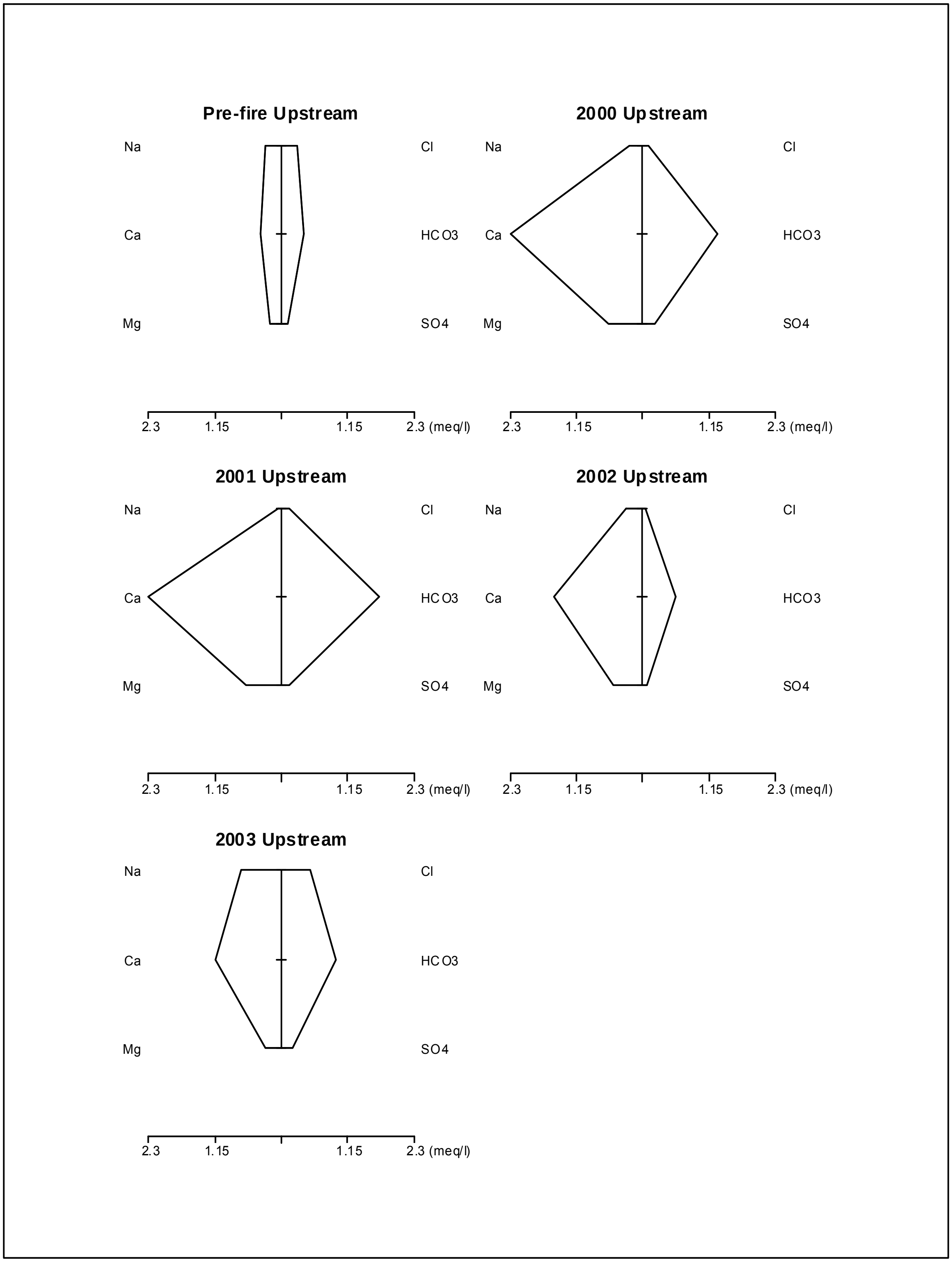


Figure 2.2.2-13. Stiff diagrams showing dissolved constituents in upstream runoff, prefire and postfire years.

After the Cerro Grande fire, TSSm concentrations in runoff were about one order of magnitude higher than before the fire. The higher TSS concentrations were associated with high-volume runoff from fire-impacted areas. The highest TSS concentrations were typically observed in runoff from Rendija and Guaje Canyons where the median concentrations were 57,000 mg/L, about an order of magnitude higher than for runoff from LANL canyons. The median concentration of TSS in Rio Grande samples was 57 mg/L, indicating that, for the available data, the high sediment loads from the Pajarito Plateau did not significantly influence the concentrations in the Rio Grande.

In 2000 and 2001, more suspended sediment was carried onto LANL in upstream runoff than flowed downstream of LANL; about 1500 MT of suspended sediment is estimated to have been deposited in floodplains in LANL canyons in 2000 and 2001. In 2002, the amount of estimated suspended sediment at upstream and downstream locations at LANL was approximately equal, and in 2003 an estimated 800 MT more suspended sediment was carried in downstream LANL runoff than flowed onto LANL. In Pueblo Canyon in 2003, downstream runoff carried an estimated 5000 MT more suspended sediment than what was in upstream Pueblo Canyon runoff. From September 2000 through 2003, the Los Alamos Canyon weir has trapped an estimated 900 MT of suspended sediment.

In 2000 after the Cerro Grande fire, high cyanide (total) concentrations were associated with runoff from fire-impacted areas. Cyanide (total) was measured above the detection limit in 52 of 99 runoff samples; the maximum concentration measured was 0.176 mg/L in a sample from Guaje Canyon. The highest concentration in runoff from LANL was 0.146 mg/L in a sample from upper Pajarito Canyon. Results greater than 0.06 mg/L were from runoff collected from the large June 28, 2000, runoff event or from fire-related runoff in July 2000. Since 2000, detectable total cyanide concentrations in runoff have usually been less than 0.04 mg/L. In 2002 the highest total cyanide concentration in runoff (0.0508 mg/L) was from Rendija Canyon in a sample collected on July 31, 2002. All detections of total cyanide in 2003 were less than 0.02 mg/L.

Amenable cyanide (weak acid dissociable) was detected in 11 of 170 (6%) runoff samples collected after the fire from 2000 through 2002. The highest concentrations of amenable cyanide occurred in runoff from Water Canyon after the fire where the maximum concentration was 0.062 mg/L. In 2000 four runoff samples contained concentrations of amenable cyanide above the wildlife standard of 0.0052 mg/L (NMWQCC 2002); three samples were from Water Canyon, and one sample was from Twomile Canyon upstream of LANL. In 2001, one sample from Guaje Canyon contained 0.00597 mg/L amenable cyanide, slightly above the wildlife standard. In 2002 and 2003 no runoff samples contained amenable cyanide above the standard.

Before the fire, upstream runoff at LANL was characterized by dissolved constituents as a calcium-magnesium-sodium-bicarbonate-chloride water type of concentrations less than 0.5 meq/L. After the fire, the upstream runoff was characterized primarily as calcium-magnesium-bicarbonate type water. The highest dissolved calcium concentration was 2.3 meq/L in 2000 and 2001. By 2002, the concentrations of dissolved constituents in runoff were significantly less than in previous postfire years. In 2003 the upstream runoff was characterized as a calcium-sodium-bicarbonate-chloride, more similar to the prefire water type but with concentrations of calcium and bicarbonate about twice as high as the prefire runoff.

2.2.3 Radionuclides in Storm Runoff

2.2.3.1 Summary of Sampling of Radionuclides in Runoff 2000–2003

After the Cerro Grande fire, from 2000 through 2003, a total of 582 storm runoff samples were collected in major drainages at Los Alamos and analyzed for radionuclide constituents; 370 samples were collected by WQH (166 filtered, 204 unfiltered); 68 samples were collected by LANL ER (20 filtered, 48 unfiltered); and 144 samples were collected by NMED (77 filtered and 67 unfiltered). The summary of the number of analyses performed for selected radionuclides and the number of detections and non-detections of radionuclides in unfiltered storm runoff samples is shown in Table 2.2.3-1. Table 2.2.3-2 shows the summary of detections for filtered samples. Summary data include all runoff samples collected (upstream, onsite, and downstream locations). Sample location names are listed in Appendix A.

Table 2.2.3-1. Summary of Analyses and Detections of Radionuclides in Unfiltered Storm Runoff Samples, prefire and 2000–2003.

Analyte	Prefire		2000		2001		2002		2003	
	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects
Am-241 [a]	32	78	47	81	79	86	38	50	46	30
Cs-137	43	63	85	34	96	42	35	37	25	32
GROSSA	34	35	63	71	55	100	41	98	19	95
GROSSB	34	59	63	79	55	100	41	100	19	89
H-3	22	0	52	2	45	24	23	9	23	4
Pb-210			33	73	57	98	10	100	21	100
Po-210			23	100	55	78	12	92	23	100
Pu-238	76	22	69	38	96	52	57	2	28	50
Pu-239,240	80	35	68	82	96	97	57	67	28	82
Ra-226			97	28	133	56	18	50	44	55
Ra-228			57	23	113	49	21	52	43	56
Sr-90	28	82	68	81	73	96	23	74	22	86
Th-228			49	92	57	68	14	93	19	100
Th-230			59	80	57	72	14	93	19	100
Th-232			49	94	57	68	14	93	19	100
U	40	98	55	98	74	100	35	100	37	100
U-234			49	94	76	87	46	100	10	100
U-235,236			134	23	172	31	80	46	25	100
U-238			82	44	135	50	54	81	47	53
Average %		52		64		71		70		75

a. Am-241 results by alpha spectrometry only.

Table 2.2.3-2. Summary of Analyses and Detections of Radionuclides in Filtered Storm Runoff Samples, prefire and 2000–2003.

Analyte	Prefire		2000		2001		2002		2003	
	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects	No. Analyses	% Detects
Am-241 [a]	33	33	75	12	60	15	12	17	30	0
Cs-137	79	14	124	0	58	0	13	0	14	7
GROSSA	63	2	64	50	40	48	11	64	17	59
GROSSB	63	71	64	100	40	98	11	100	17	100
H-3	55	5	3	33	0		0			
Pb-210			21	62	38	34	13	46	17	41
Po-210			18	67	38	58	12	75	15	13
Pu-238	145	1	78	8	55	5	12	0	16	0
Pu-239,240	149	5	79	14	55	16	12	0	16	25
Ra-226			74	16	78	9	27	26	30	27
Ra-228			41	10	77	19	25	16	31	13
Sr-90	33	42	78	65	56	80	34	59	14	64
Th-228			40	55	38	74	13	54	17	35
Th-230			43	74	38	76	13	77	17	100
Th-232			40	35	38	74	13	69	17	65
U	56	61	64	86	70	63	38	71	40	45
U-234			68	51	56	82	12	75	9	89
U-235,236			143	15	114	9	25	4	15	40
U-238			93	40	94	51	25	36	29	41
Average %		26		42		45		44		42

a. Am-241 and U-238 results by alpha spectrometry only.

Detections are defined as values exceeding both the analytical method detection limit and three times the individual one-standard-deviation measurement uncertainty (LANL 2001, Taylor 1987). On average, radionuclides were detected in 70% of the unfiltered samples and in 43% of the filtered samples. Radionuclides and related analytes that were detected most in unfiltered samples (>90%) include gross alpha, gross beta, lead-210, polonium-210, uranium (total), and uranium-234. Detections of these radionuclides were less frequent in filtered samples (see Table 2.2.3-2).

Table 2.2.3-3 shows the minimum, maximum, and average concentration values for the major radionuclides detected (>3 sigma) in runoff samples from 2000 through 2003. Concentrations of radionuclides measured in storm runoff samples are quite variable by location and through time, principally depending on whether Cerro Grande fire ash was present in the drainage at the time of sampling, whether legacy LANL contaminants are present in a canyon, and, for unfiltered samples, the suspended sediment concentration.

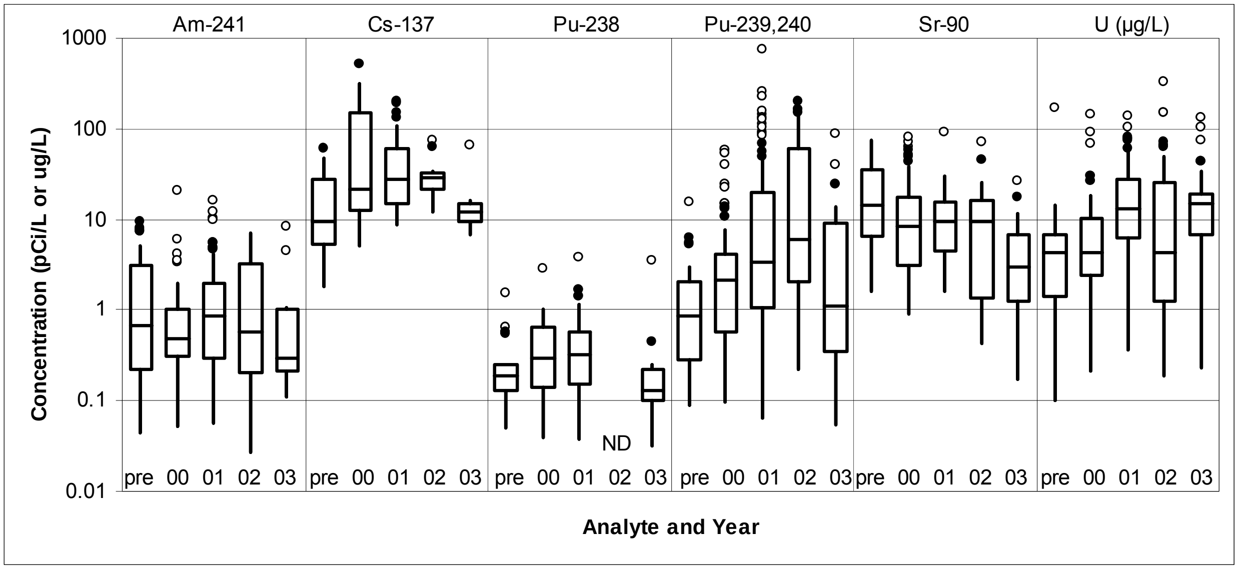
Table 2.2.3-3. Summary of Detections of Selected Radionuclides in Storm Runoff, 2000–2003.

	Unfiltered Samples (pCi/L)					Filtered Samples (pCi/L)				
Analyte	**Min**	**Max**	**Median**	**Min Std.**	**UF Std Type** [b]	**Min**	**Max**	**Median**	**Min F Std**	**F Std Type** [b]
Am-241 [a]	0.052	20.7	0.738	30	DOE DCG	0.029	0.069	0.040	15	EPA Prim. DW Std
Cs-137	5.0	511	22.9	3000	DOE DCG	ND	ND	ND	120	DOE DW DCG
GROSSA	5.5	**3350**	153.0	15	NM Livestock Water	1.12	9.62	3.00	15	EPA Prim. DW Std
GROSSB	6.7	**6210**	284.0	1000	DOE DCG	2.51	**47.30**	13.25	40	DOE DW DCG
H-3	161	546	254	20,000	NM Livestock Water	NA	NA	NA	20,000	EPA Prim. DW Std
Pu-238	0.032	3.86	0.298	40	DOE DCG	0.018	0.790	0.069	1.6	DOE DW DCG
Pu-239,240	0.055	**753**	2.920	15	DOE DCG	0.023	**16.40**	0.111	15	EPA Prim. DW Std
Sr-90	0.17	89.7	8.45	1000	DOE DCG	0.32	**8.77**	1.86	8	EPA Prim. DW Std
U (µg/L)	0.19	330	10.55	800	DOE DCG	0.03	**9.20**	0.83	1.6	DOE DW DCG
U-234	0.193	354	12.43	500	DOE DCG	0.059	3.80	0.418	20	DOE DW DCG
U-235,236	0.067	22.8	1.36	600	DOE DCG	0.027	**91.0**	0.113	24	DOE DW DCG
U-238	0.180	334	14.40	600	DOE DCG	0.041	4.97	0.421	24	DOE DW DCG

a. All data in pCi/L except where noted; b. standards shown for comparison only; c. Am-241 and U-238 data shown are by alpha spectrometry method only. d. ND = no data; e. DW = drinking water; f. DOE DW DCG = DOE Derived Concentration Guide for drinking water systems. Bold numbers show results above standard.

2.2.3.2 Comparison with Historical Concentrations

Figure 2.2.3-1 shows the distribution of concentrations of selected radionuclides detected in unfiltered runoff for the years 2000 through 2003 and, for comparison, the prefire distribution. The radionuclides and associated analytes that had significantly higher concentrations in runoff in 2000 after the Cerro Grande fire were cesium-137 and plutonium-239,240, and gross alpha and gross beta activities and plutonium-238. Radionuclide concentrations that were significantly higher in runoff in 2001 and 2002 in runoff primarily from Pueblo Canyon include gross alpha, gross beta, and plutonium-239,240. Radionuclides that show decreasing maximum concentrations after 2000 are cesium-137 and strontium-90. Maximum concentrations of cesium-137, plutonium-239,240, and strontium-90 have decreased each year since 2001.



Note: pre = prefire; ND = no detections

Figure 2.2.3-1. Distribution of concentrations of selected radionuclides detected in unfiltered runoff at all Pajarito Plateau stations, prefire and 2000–2003.

Most runoff in prefire years was typically from LANL drainages (south of Pueblo Canyon), as was the case in 2000 immediately after the Cerro Grande fire; thus, comparisons between runoff data in 2000 with prefire data from these canyons are most appropriate. The median concentrations of americium-241 and strontium-90 in 2000 were lower than previous years, suggesting that these radionuclides were not affected by fire-related runoff; however, the prefire data set included runoff samples from lower Los Alamos Canyon that contained elevated concentrations of americium-241 and strontium-90 from legacy LANL discharges in DP Canyon, which may bias the prefire data set. Ash from the fire has been shown to have contained elevated concentrations of americium-241 and strontium-90 (LANL 2004).

Median concentrations of cesium-137, plutonium-238, and plutonium-239,240 were higher in 2000 than previous years, apparently due to fire-related runoff. Most runoff in years 2001 through 2003 was from Pueblo Canyon (unlike prefire years and in 2000), and median concentrations of most radionuclides (except plutonium-238) show a significant increase in both 2001 and 2002. In 2001 and 2002, all samples containing greater than 14 pCi/L plutonium-239,240 were from Pueblo Canyon.

Median concentrations of cesium-137 and plutonium-239,240 increased each year from 2000 through 2002, initially due to higher concentrations in runoff from fire-impacted areas, but in 2001 and 2002, for plutonium isotopes, also due to high volume runoff in Pueblo Canyon and transport of sediment containing legacy LANL waste. Median concentrations of all radionuclides (except uranium) were significantly lower in 2003. The distribution of uranium concentrations in runoff in 2000 were not significantly different from prefire years, suggesting that uranium concentrations were not affected by the runoff from fire-impacted areas.

Figure 2.2.3-2 shows the minimum, maximum, and median concentrations of radionuclide detections (3 sigma) in unfiltered runoff from 2000 to 2003 and the maximum prefire concentrations of radionuclides in unfiltered runoff. The 1997 through 1999 portion of the historical data set was chosen because it is the period when radionuclide data in storm water runoff were systematically collected at LANL. Maximum concentrations of all the target radionuclides in storm runoff in 2000 after the fire were greater than historical maximums except for uranium, which was greater than the historical maximum in 2002 (runoff from upper Pueblo Canyon). The peak concentrations of cesium-137 and strontium-90 were directly attributable to fire effects, while the peak concentrations of plutonium-238 and plutonium-239,240 were

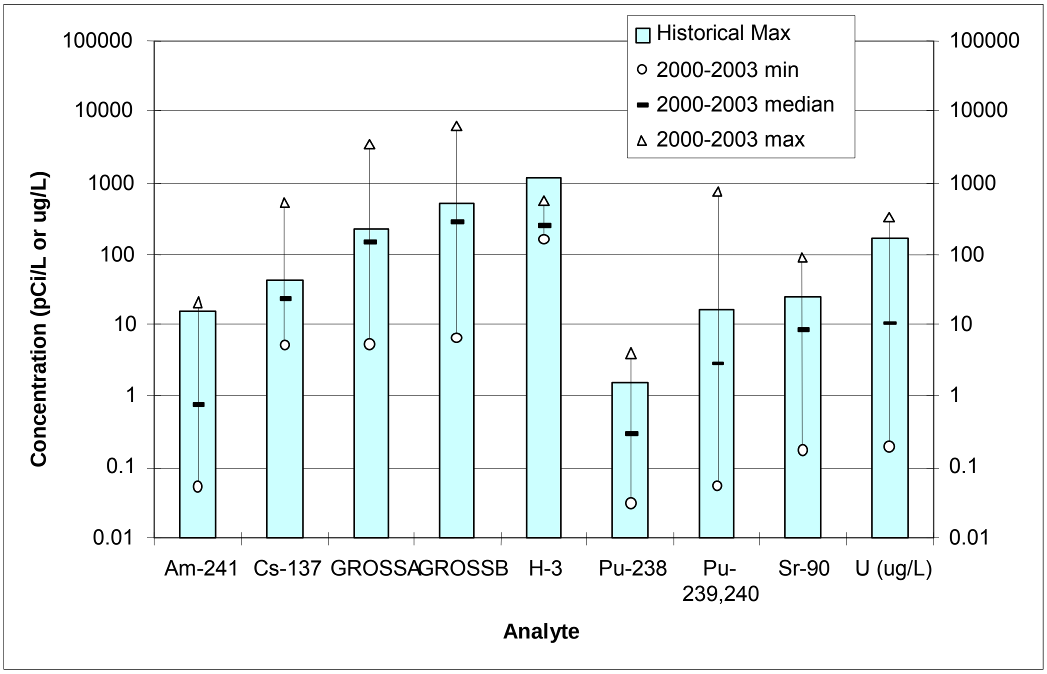


Figure 2.2.3-2. Radionuclide detections in unfiltered runoff 2000–2003 compared with prefire maximum concentrations.

attributable to runoff associated with areas containing legacy LANL discharges, although concentrations of plutonium-239,240 were also found to be elevated in runoff from fire-impacted areas.

Cesium-137, gross alpha, gross beta, plutonium-239,240, and strontium-90 have the largest increases in concentrations in unfiltered runoff in postfire runoff compared with prefire years. The maximum concentration of cesium-137 observed postfire was 511 pCi/L in 2000, compared to an historical maximum of 42.3 pCi/L, about an order of magnitude higher in 2000. This peak cesium-137 value was recorded upstream of LANL in Twomile Canyon and was in runoff from fire-impacted areas. The maximum concentration of plutonium-238 in runoff in major drainages after the fire was 3.86 pCi/L in a sample from middle Pueblo Canyon collected in 2001, compared with a prefire maximum of 1.53 pCi/L; the maximum Pu-238 concentrations are related to legacy LANL contaminants in Pueblo Canyon. The highest concentrations of strontium-90 after the fire were 89.7 pCi/L in runoff from Rendija Canyon in 2001 and 80.8 pCi/L in runoff from Guaje Canyon in 2000, compared with a prefire maximum of 25 pCi/L. A total of 19 runoff samples collected after the fire had concentrations of strontium-90 higher than the prefire maximum; the elevated concentrations were found in high-volume runoff from fire-impacted areas.

In 2000 after the fire, plutonium-239,240 concentrations in unfiltered runoff were only slightly higher than the prefire maximum concentration. However, high-volume runoff from Pueblo Canyon in 2001 and 2002 was significantly higher in plutonium 239,240 (see Figure 2.2.3-1) due to erosion and remobilization of sediments containing legacy LANL contaminants. The prefire (1995–1999) maximum concentration of plutonium-239,240 was 15.78 pCi/L in a runoff sample from lower Pueblo Canyon. In 2001 and 2002 the maximum concentration of plutonium-239,240 in Pueblo Canyon was 753 pCi/L in a sample collected by LANL ER on August 16, 2001. Runoff in Pueblo Canyon contained plutonium-239,240 concentrations greater than 60 pCi/L during at least four runoff events in 2001, three runoff events in 2002, and one runoff event in 2003.

Figure 2.2.3-3 shows the ratio of the annual median concentrations of selected radionuclides in unfiltered runoff (all locations, major Pajarito Plateau drainages) to the prefire median concentration for years 2000

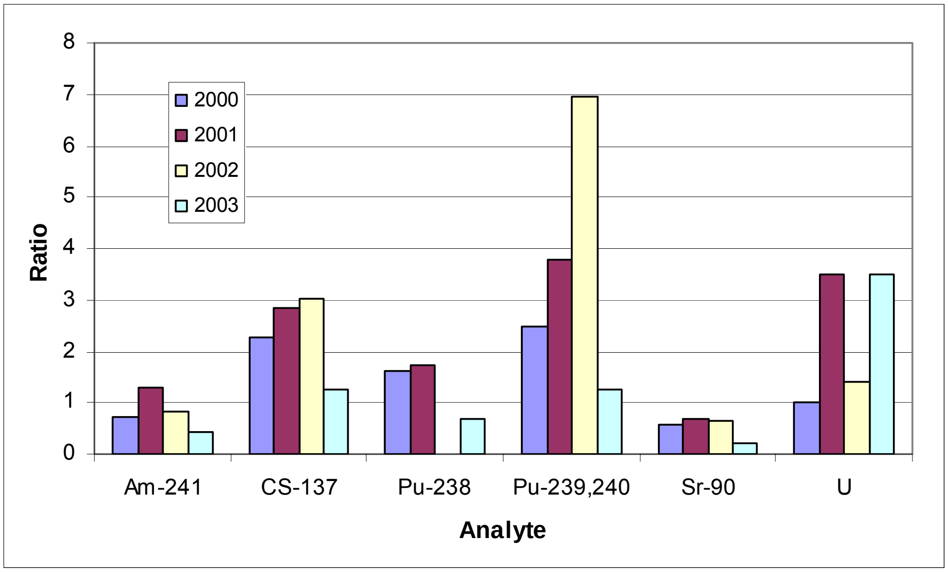


Figure 2.2.3-3. Ratio of median concentrations of radionuclides in unfiltered runoff to prefire median concentrations.

through 2003. The cesium-137 and plutonium-239,240 ratios increased each year from 2000 to 2002, but in 2003 the median concentration were similar to prefire concentrations. Significant trends with respect to fire-related runoff are not apparent for americium-241, plutonium-238, strontium-90, or uranium. The high plutonium-239,240 ratio in 2002 is mainly due to the paucity of samples collected in canyons other than Pueblo Canyon; see Section 2.2.3.7 for additional information on sample distribution.

Figure 2.2.3-4 shows the minimum, maximum, and median dissolved concentrations of radionuclides detected in filtered runoff from 2000 to 2003 and the maximum prefire concentrations for filtered runoff. After the fire, there were no detections of cesium-137 in the major drainages. Maximum concentrations measured after the fire were greater than LANL-wide historical maximums for gross beta, plutonium-238, plutonium-239,240, and uranium. The maximum concentrations of other radionuclides were below historical maximum concentrations.

The highest concentration of dissolved plutonium-238 in fire-related runoff was 0.79 pCi/L in a sample collected from the upstream Los Alamos Canyon site on August 9, 2001. Two other samples collected from middle Los Alamos Canyon and Guaje Canyon above Rendija Canyon on this date also contained plutonium-238 higher than the historical maximum of 0.105 pCi/L. A sample collected from lower Pueblo Canyon on October 27, 2000, contained 0.111 pCi/L dissolved plutonium-238.

The highest concentration of dissolved plutonium-239,240 in runoff was 16.4 pCi/L in a sample collected from Acid Canyon by NMED on October 13, 2000; other runoff samples from Acid Canyon collected in 2000 ranged in concentrations from 1.3 to 2.6 pCi/L. Acid Canyon was not impacted by fire; plutonium in Acid Canyon is from legacy LANL discharges. A cleanup of contaminated sediment and soil from Acid Canyon was performed by the LANL ER Project in the fall of 2001 to reduce the average concentrations of plutonium (Reneau et al. 2002). Most samples containing dissolved plutonium-239,240 greater than 0.1 pCi/L after the fire were collected from Pueblo Canyon or Acid Canyon. A filtered runoff sample from lower Potrillo Canyon collected by NMED on October 23, 2000, contained 4.2 pCi/L plutonium-239,240. The high dissolved concentrations of plutonium-239,240 appear to be generally associated with legacy LANL discharges rather than to the effects of the fire.

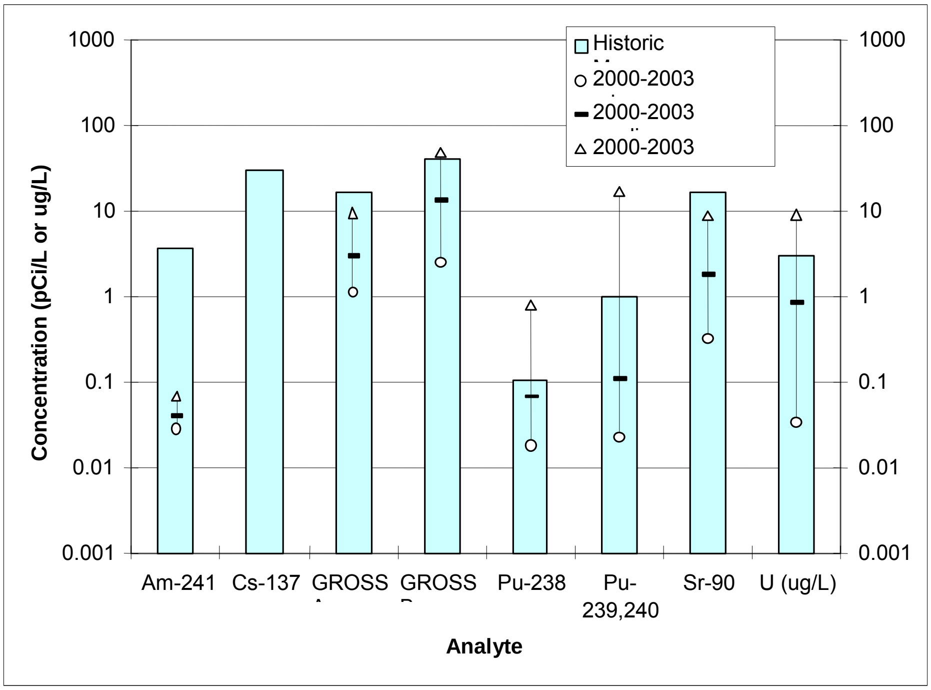


Figure 2.2.3-4. Radionuclides in filtered runoff 2000–2002 compared with prefire maximum concentrations.

The highest concentration of dissolved uranium in runoff from the Pajarito Plateau was 9.2 µg/L in a sample collected on July 25, 2002, from Pueblo Canyon above Acid Canyon. The higher concentrations of dissolved uranium in runoff on the Pajarito Plateau in 2000 were observed in fire-related runoff at onsite and downstream locations where uranium in suspended sediment materials may have had more of an opportunity to dissolve, possibly as the result of chemical changes of the water created by the presence of fire-related compounds.

The highest concentrations of dissolved uranium in surface water after the fire were found in baseflow/runoff samples collected from the Rio Grande near White Rock stream gage in October 2000 by NMED, which contained up to 11.1 µg/L. The data suggest that the higher dissolved uranium concentrations in the Rio Grande in October 2000 are likely from other sources upstream in the Rio Grande and not from runoff from the Pajarito Plateau.

2.2.3.3 Comparison of Radionuclides in Storm Runoff with Current Reference Standards

Water quality standards have not been established specific to most radionuclides in storm runoff; however, activities of radionuclide concentrations in unfiltered storm runoff can be compared to either the DOE DCGs for public exposure or the NMWQCC stream standards. The NMWQCC stream standards reference the New Mexico Environmental Improvement Board's New Mexico Radiation Protection Regulations (Part 4, Appendix A), however, New Mexico radiation protection activity levels are, in general, two orders of magnitude greater than the DOE DCGs for public dose, so only the DCGs are usually addressed. In addition, the results for unfiltered runoff samples are compared to NMWQCC standards for livestock watering (NMWQCC 2002).

Figure 2.2.3-5 shows the summary of the results for radionuclides in unfiltered runoff from 2000 to 2003 and the minimum standards for unfiltered runoff for comparison. Concentrations of cesium-137, tritium, plutonium-238, strontium-90, and uranium in unfiltered storm runoff in main drainages from 2000 through 2003 were below minimum standard levels.

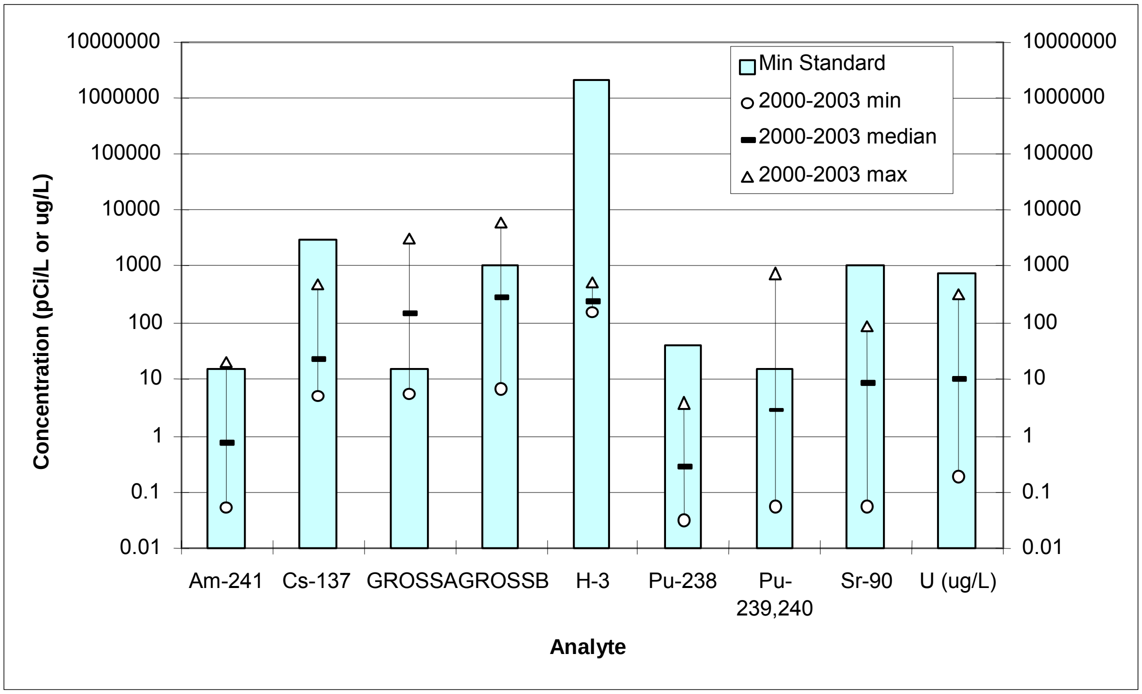


Figure 2.2.3-5. Summary of detections of radionuclides in unfiltered runoff compared with minimum reference standards.

Total gross alpha concentrations were greater than public dose DCG levels (30 pCi/L) and State of New Mexico livestock watering standards (15 pCi/L) at many locations upstream and on LANL. The gross alpha DCG is based on the most restrictive anthropogenic alpha emitters (plutonium-239,240 and americium-241) and is commonly exceeded by runoff laden with naturally derived alpha emitters (such as the uranium-decay series). The New Mexico livestock standard excludes radon and uranium from the gross alpha limit. The gross beta DCG for public dose (1000 pCi/L) was exceeded in samples from a total of 27 runoff events in the three years after the fire, one event in 2000 (Rendija Canyon), 10 events in 2001 (from five canyons), and 16 events in 2002 (from five canyons). The highest gross beta activity in 2002 was 6210 pCi/L in a sample collected by NMED on July 25, 2002, from Pueblo Canyon upstream of Acid Canyon. Seven of 27 (26%) runoff samples that contained gross beta activity greater than 1000 pCi/L were from locations upstream of LANL. The median detected value of gross alpha activity in all runoff after the fire was 284 pCi/L, over 18 times the standard value of 15 pCi/L.

The highest concentrations of americium-241 (up to 20.7 pCi/L) were in runoff samples collected from DP Canyon in 2000 and 2001. This canyon was not impacted by the Cerro Grande fire; the high americium-241 concentrations are from legacy LANL discharges to DP Canyon. The five runoff samples that contained greater than 10 pCi/L americium-241 were from DP Canyon or downstream in Los Alamos Canyon. Americium-241 does not appear to have been significantly elevated in runoff from fire-impacted areas. Other studies have found that americium-241 was somewhat elevated in ash and postfire sediments (e.g., LANL 2004).

Table 2.2.3-4 lists runoff events in major drainages on the Pajarito Plateau that contained plutonium-239,240 concentrations greater than the NM Livestock Watering standard of 15 pCi/L for gross alpha. In 2000 after the fire, the maximum concentration of plutonium-239,240 in unfiltered runoff was 57.4 pCi/L in a sample collected from middle Pueblo Canyon by LANL ER on August 2. Five relatively small runoff events occurred in Pueblo Canyon in 2000 that contained plutonium-239,240 in concentrations greater than 15 pCi/L. Runoff in Los Alamos Canyon at SR 4 and in Guaje Canyon at SR 502 on July 9, 2000, also contained plutonium-239,240 above the standard. These elevated concentrations of plutonium-

Table 2.2.3-4. Runoff events containing Pu-239,240 greater than 15 pCi/L.

Date	Canyon	Maximum Measured Pu-239,240 (pCi/L)
7/9/2000	Guaje	17.7
7/9/2000	Los Alamos	24.8
8/2/2000	Pueblo	57.4
8/12/2000	Pueblo	52.4
9/8/2000	Pueblo	40.6
10/23/2000	Pueblo	22.8
10/27/2000	Pueblo	15.1
7/2/2001	Pueblo	30.3
8/4/2001	Pueblo	222.0
8/9/2001	Pueblo	145.0
8/11/2001	Pueblo	55.8
8/14/2001	Pueblo	112.0
8/16/2001	Pueblo	753.0
6/22/2002	Pueblo	197.0
7/18/2002	Pueblo	147.0
7/26/2002	Pueblo	85.0
9/10/2002	Pueblo	27.2
5/25/2003	Cañada del Buey	39.4
8/26/2003	Pueblo	24.1
9/6/2003	Pueblo	88.7

239,240 in runoff were likely associated with legacy LANL waste discharges or proximity to LANL rather than to direct effects of the Cerro Grande fire, although fire-related runoff upstream of LANL appears to have contained elevated plutonium-239,240 concentrations that were related to concentration of biomass in the ash (see Section 1.4).

High-volume storm runoff events in Pueblo Canyon in 2001, 2002, and 2003 contained significantly higher concentrations of plutonium-239,240. The highest concentration of plutonium-239,240 in storm runoff at LANL was 753 pCi/L in a sample collected from middle Pueblo Canyon by the LANL ER Project on August 16, 2001. In 2001, six runoff events contained plutonium-239,240 above the reference value and, in 2002, four runoff events were above the reference value for gross alpha. Plutonium-239,240 was not detected in concentrations above 15 pCi/L in other canyons at LANL in 2001 and 2002. However, in 2003, runoff in Cañada del Buey on May 25 contained 39.4 pCi/L plutonium-239,240 (likely not fire-related), and two runoff events in Pueblo Canyon on August 26 and September 9 contained 24.1 and 88.7 pCi/L, respectively.

Figure 2.2.3-6 shows the summary of dissolved radionuclides compared with minimum standards appropriate to filtered runoff. The results of radionuclides in filtered water samples are compared with EPA drinking water standards or DOE DCGs for drinking water systems only for perspective, as the standards are applicable only to community drinking water systems and not to runoff.

All filtered storm water runoff samples collected from major drainages associated with fire-impacted areas met EPA standards and DOE drinking water guidelines for specific radionuclides. One filtered runoff sample from Mortandad Canyon collected by NMED in October 2000 contained 51.3 pCi/L gross beta activity, slightly greater than the 50 pCi/L EPA screening level. Mortandad Canyon was impacted by fire; however, the elevated gross beta activity is likely related to historic discharges of treated liquid radioactive waste from TA-50. One runoff sample collected in the south fork of Acid Canyon in 2000 contained 16.4 pCi/L plutonium-239,240, slightly above the EPA primary drinking water standard and the livestock watering standard for gross alpha (NMWQCC 2002). A cleanup was performed in Acid Canyon by the LANL ER Project in 2001; filtered runoff samples have not been collected for plutonium-239,240 analyses in Acid Canyon or Pueblo Canyon since the cleanup.

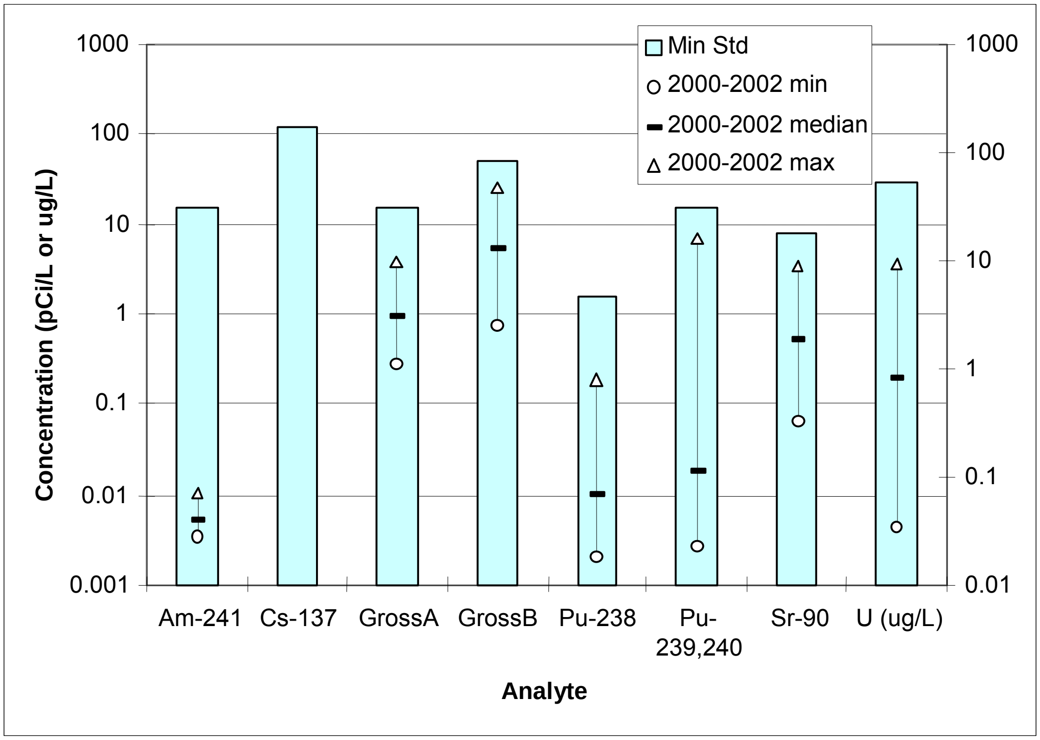


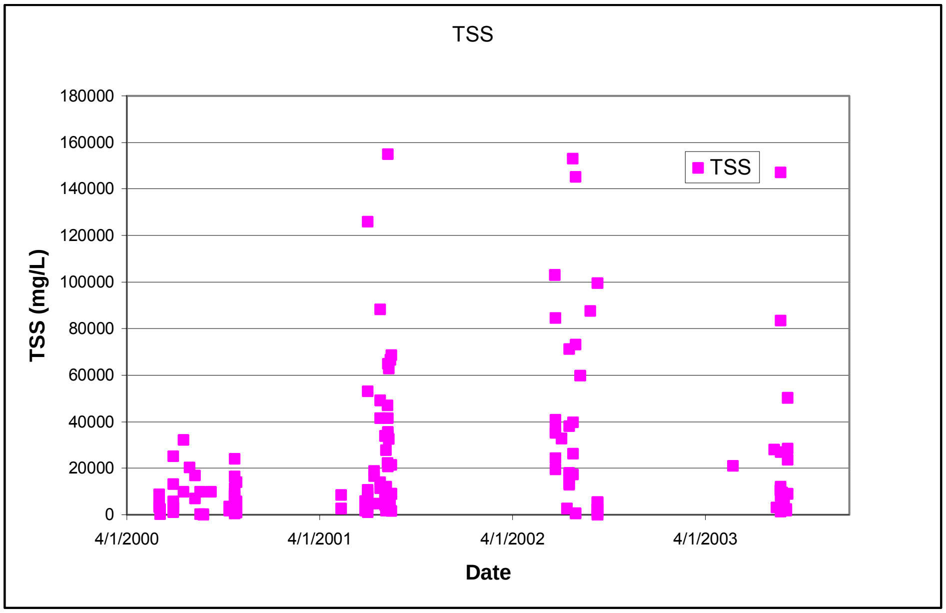
Figure 2.2.3-6. Summary of detections of radionuclides in filtered runoff compared with minimum standards and guidelines.

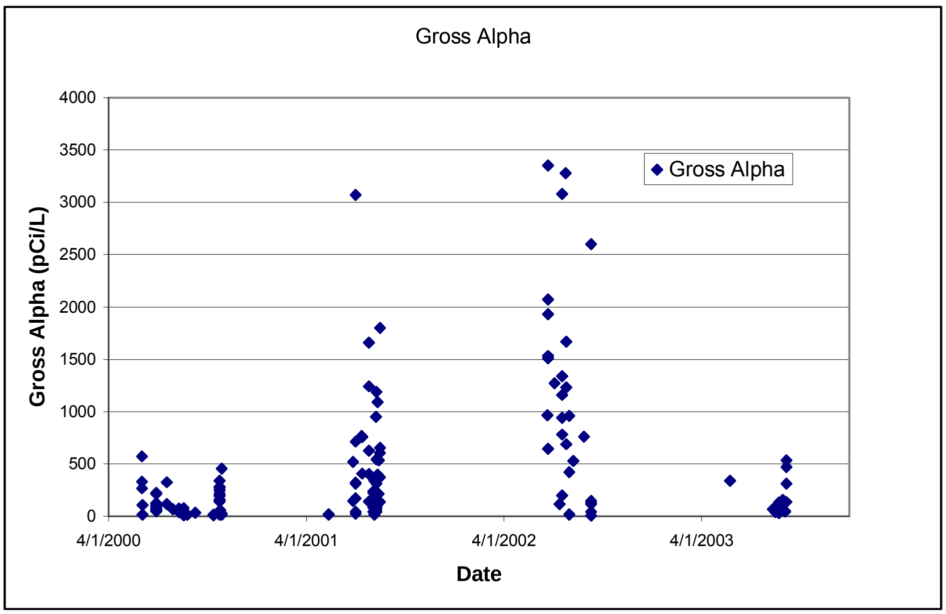
Several filtered runoff samples collected downstream of disposal sites at LANL have contained strontium-90 concentrations greater than the EPA primary drinking water standard of 8 pCi/L. The highest dissolved concentration of strontium-90 in storm runoff was 9.8 pCi/L in a sample collected from Acid Canyon by NMED in September 2000. As mentioned previously, Acid Canyon was the site of a cleanup action by LANL ER in 2001. A dissolved concentration of 9.7 pCi/L strontium-90 was measured in a runoff sample collected in Mortandad Canyon by NMED in October 2000, and a runoff sample from DP Canyon in June 2001 contained 8.77 pCi/L strontium-90. Acid, DP, and Mortandad Canyons were not affected by runoff from burned areas. Additionally, a surface water sample from Los Alamos Canyon collected on July 21, 2000, from the Los Alamos Canyon weir construction site contained 26.6 pCi/L dissolved strontium-90. The weir was installed in 2000 after the fire in Los Alamos Canyon as a sediment catchment structure. The sample was collected from water pumped from the weir several days after a runoff event (see Koch et al. 2001). The source of the dissolved strontium-90 in this sample could be fire-related or from historical Laboratory releases.

2.2.3.4 Gross Alpha Particle Activity in Runoff

Monitoring of storm runoff following the Cerro Grande wildfire has shown widespread gross alpha activities greater than the New Mexico surface water Livestock Watering stream standard of 15 pCi/L (NMWQCC 2002). Gross alpha activity is the only radiological measurement having a median value greater than the reference standard. In response to these findings, the NMED designated several Los Alamos area drainages as water quality impaired and added them to the federal Clean Water Act §303(d) List (NMED 2003c). The affected drainages are Guaje Canyon, Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon, Pajarito Canyon, and Water Canyon.

Figure 2.2.3-7 shows the trends in gross alpha activities and TSS concentrations in storm runoff samples collected in the four years since the Cerro Grande fire. In 2001 and 2002, gross alpha activities were





Note: Data include results from background sites and stations downstream of LANL operations.

Figure 2.2.3-7. Time trends in TSS and total gross alpha activity in storm runoff on the Pajarito Plateau, 2000–2003.

approximately the same, remaining several orders of magnitude greater than the stream standard. The largest gross alpha activities were in runoff from Guaje, Rendija, and Pueblo Canyons during large runoff events. The gross alpha activities generally correspond to the TSS concentrations. The data indicate that the elevated alpha activities are predominantly due to enhanced natural sediment loads from increased sediment transport after the fire, rather than a LANL source; there are no known LANL sources for gross alpha in Guaje and Rendija Canyons (LANL 2001b). By 2003 the gross alpha activities in storm runoff were similar to those in 2000 and prefire years.

Figure 2.2.3-8 shows the distribution of gross alpha activity in unfiltered storm runoff from major drainages on the Pajarito Plateau for prefire years and for each year since the Cerro Grande fire. The distribution of

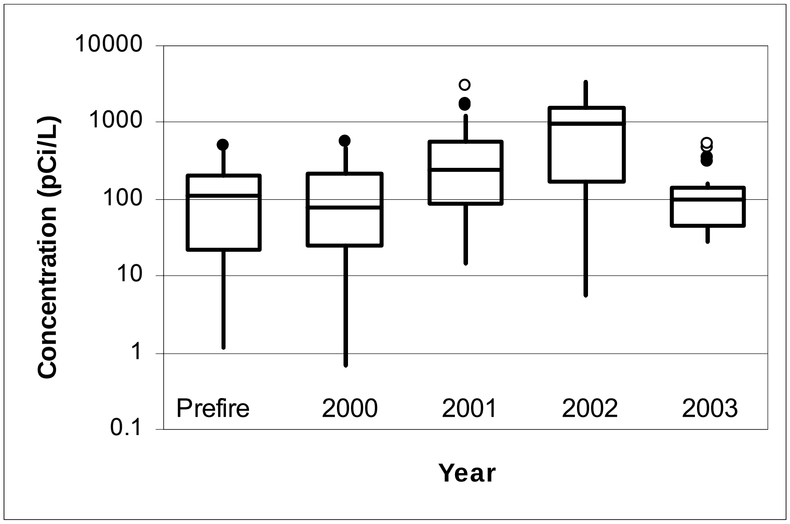


Figure 2.2.3-8. Distribution of gross alpha activity in unfiltered storm runoff, prefire and postfire years.

gross alpha activities in runoff in 2000 is not significantly different from for prefire years. However, the activities in 2001 and 2002 are significantly higher, with median activities in 2002 about one order of magnitude higher than prefire years and in 2000. The distribution of activities in 2003 was again similar to prefire years. The data indicate that runoff in 2000 from fire-impacted areas did not have a significantly higher gross alpha activity than before the fire; however, large runoff events in Pueblo Canyon in 2001 and 2002 contained higher gross alpha activity as a result of higher sediment transport, a secondary effect of the Cerro Grande fire.

To examine further if elevated concentrations might be due to LANL operations or from natural sources, we assessed how gross alpha activity varies with location. In Figure 2.2.3-9 we compare gross alpha

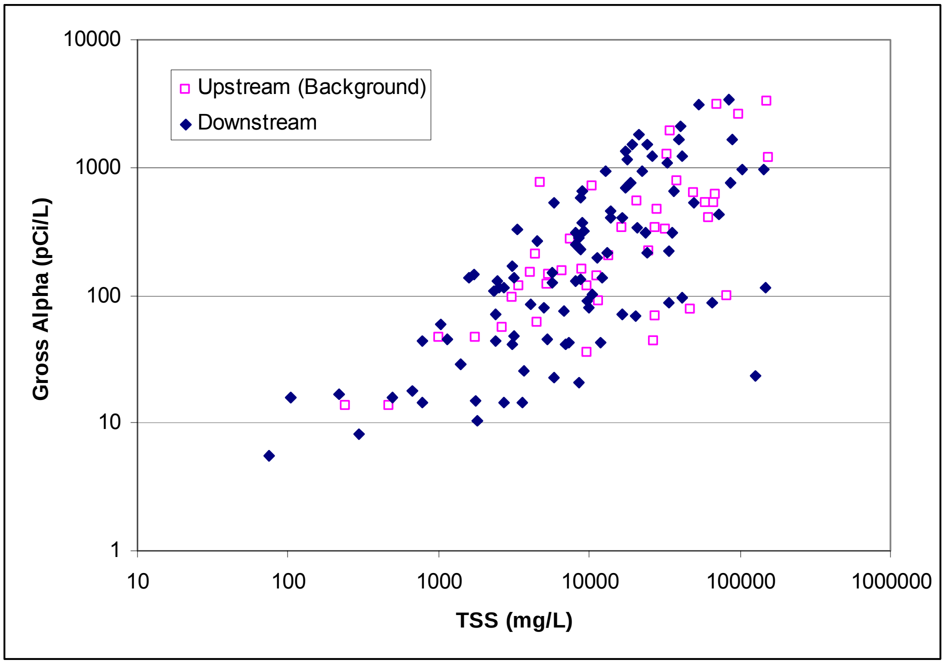


Figure 2.2.3-9. Comparison of total gross alpha activity with TSS in storm runoff at sites located upstream (background) and onsite and downstream of LANL operations.

activities in LANL upstream and offsite (background) storm runoff samples against those collected onsite or downstream of LANL. Gross alpha activities are compared with an independent measure (TSS) to account for the sediment load. Figure 2.2.3-9 shows no appreciable differences in gross alpha activities upstream or downstream of LANL, indicating that the elevated concentrations are largely due to other factors than LANL operations and apparently are the result of higher sediment transport in storm runoff that occurred as a secondary result of the Cerro Grande fire. While LANL has historically released alpha emitters into some canyons, particularly Acid, Pueblo, DP, and Mortandad Canyons, the net effect apparently has been slight compared to the total gross alpha activities measured at upstream stations.

2.2.3.5 Gross Beta Particle Activity in Runoff

Figure 2.2.3-10 shows the time series of gross beta particle activity in storm runoff for each major canyon from 1997 through 2003. Before the fire the highest gross beta activities were in runoff in Cañada del Buey, and all activities were less than 700 pCi/L. In 2000 after the fire, somewhat higher concentrations were observed in runoff from Los Alamos, Pajarito, Water, and Guaje Canyons. However, significantly higher concentrations were observed in runoff in 2001 and 2002 from Pueblo and Guaje Canyons where gross beta activities greater than 4000 pCi/L occurred. The DOE DCG for gross beta is 1000 pCi/L (see Table 2.2.3-3).

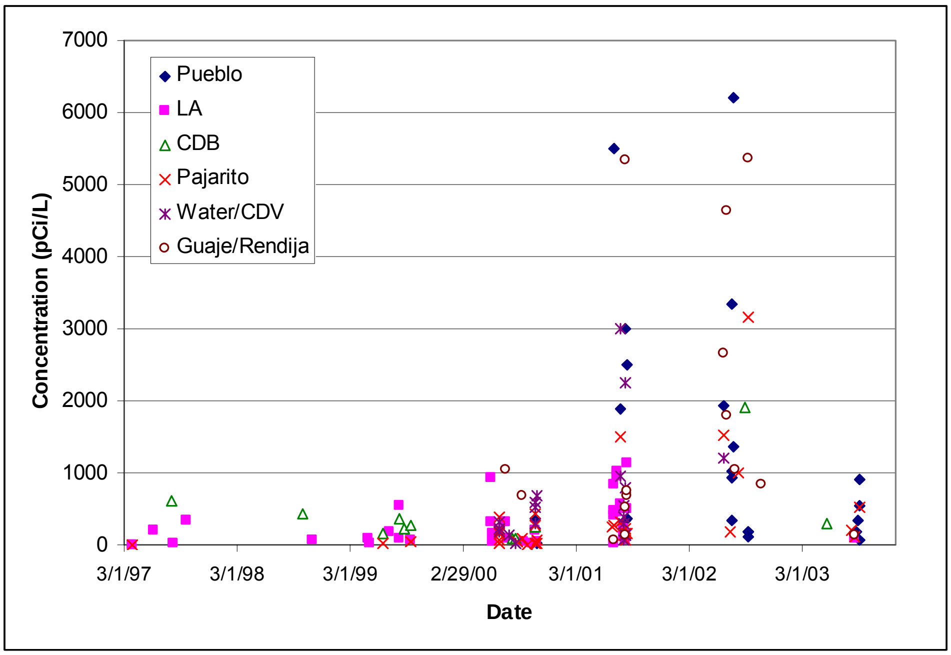


Figure 2.2.3-10. Time series of gross beta activity in unfiltered runoff in major canyons, 1997–2003.

Figure 2.2.3-11 shows the distribution of gross beta activity in storm runoff from upstream, onsite, downstream, and Guaje/Rendija Canyons for prefire years (1997–1999) and each postfire year 2000 through 2002. The highest gross beta activity in runoff was 6210 pCi/L in an upstream sample collected from Pueblo Canyon above Acid Canyon by NMED on July 25, 2002. Runoff events in 2001 and 2002 collected from Guaje Canyon above Rendija Canyon contained greater than 5000 pCi/L gross beta. The highest gross beta activity in runoff in Pajarito Canyon was 3160 pCi/L in an upstream sample collected on September 9, 2002. The gross beta activity in runoff from upstream fire-impacted areas increased each year from 2000 through 2002. The data suggest that the higher gross beta activities in runoff were not associated with ash immediately after the fire, but were likely the result of higher sediment loads containing eroded soil and sediment materials one to two years after the fire. All runoff sampled in 2003, three years after the fire, contained less than 1000 pCi/L gross beta activity, similar to prefire years.

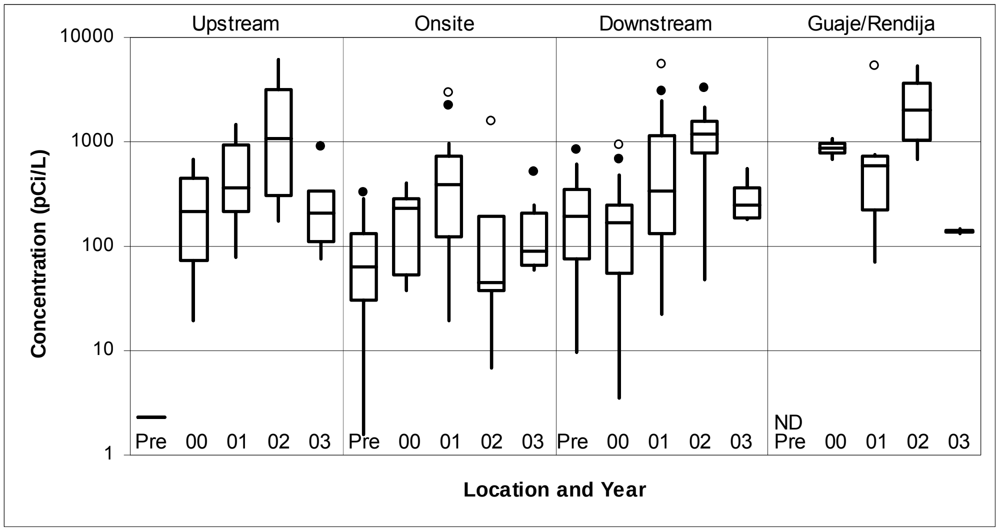


Figure 2.2.3-11. Distribution of gross beta activity in runoff, prefire and postfire years.

2.2.3.6 Cesium-137 in Runoff

Figure 2.2.3-12 shows the time series of total cesium-137 detections (>3 sigma) in runoff from the major canyons for 2000 through 2003. The highest concentrations in runoff were in 2000 with ash and muck-laden runoff from fire-impacted areas. Guaje, Pueblo, and Pajarito Canyons had concentrations greater than 200 pCi/L. The highest concentrations were from upstream locations relative to LANL or from Rendija and Guaje Canyons. Cesium-137 concentrations in runoff from Los Alamos Canyon were lower compared with other canyons, probably because the Los Alamos Canyon reservoir in the upper part of the canyon trapped much of the ash from the burned areas. There were no detections in unfiltered samples collected from the Rio Grande during this period, indicating that runoff from fire-impacted areas did not significantly impact the Rio Grande. Samples from the Rio Grande in 2000 were collected in early July, about one week after the large runoff event on June 28, 2000.

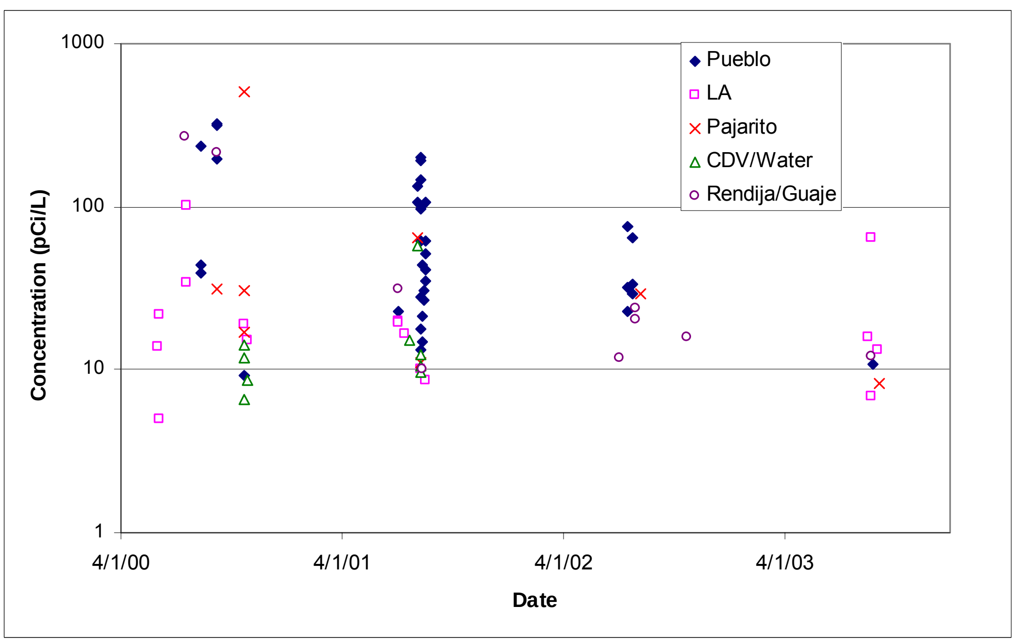
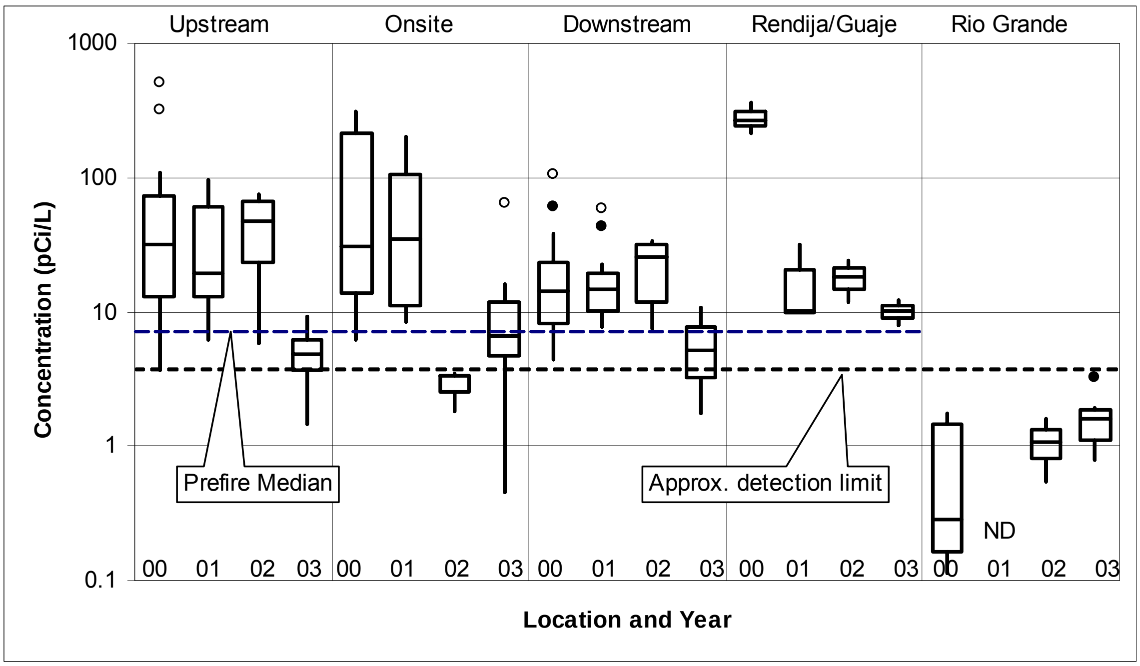


Figure 2.2.3-12. Time series of total cesium-137 detections in runoff from each canyon, 2000–2003.

In 2001, concentrations of cesium-137 in runoff were less than 200 pCi/L; the highest concentrations were from Pueblo Canyon, where most runoff occurred in 2001. The highest concentration in 2002 was 75 pCi/L in runoff from Pueblo Canyon, again, where most runoff occurred in 2002. The highest concentration in runoff in 2003 was 64.7 pCi/L in a sample collected from Los Alamos Canyon above DP Canyon by NMED; other detections in 2003 were less than 20 pCi/L. The decreases in the maximum yearly concentrations of cesium-137 appear to be related to diminished sources of fire-related ash to runoff.

Figure 2.2.3-13 shows the distribution of cesium-137 concentrations (all data) in unfiltered runoff from upstream, onsite, downstream, and Guaje Canyon and the Rio Grande in 2000 through 2002. The prefire median concentration of runoff on the Pajarito Plateau (8.4 pCi/L) and the approximate detection limit for the analyses are also shown on the figure.



Note: ND = no data

Figure 2.2.3-13. Distribution of cesium-137 concentrations in unfiltered runoff from upstream, onsite, downstream, and Guaje Canyon and in unfiltered baseflow in the Rio Grande, 2000–2002.

In 2000 after the fire, the highest cesium-137 concentrations in runoff were from upstream and Guaje/Rendija Canyon locations. The maximum concentrations at upstream, onsite, downstream, and Guaje locations decreased each year since the fire. Concentrations of cesium-137 in the Rio Grande (baseflow samples) have been about one order of magnitude less than runoff from the Pajarito Plateau and do not appear to have been impacted by fire-related runoff. By 2003, the concentrations of cesium-137 in runoff on the Pajarito Plateau were similar to prefire conditions, apparently indicating the end of fire-related impacts with regard to cesium-137 concentrations in ash.

2.2.3.7 Plutonium-239,240 in Runoff

Figure 2.2.3-14 shows the time series of plutonium-239,240 detections (3 sigma) in unfiltered runoff from each major canyon and for samples from the Rio Grande from 2000 through 2003. Each year the highest concentrations of plutonium-239,240 in runoff have been from Pueblo Canyon where the high concentrations are the result of erosion and suspension of sediment deposits that contain legacy contaminants from historic LANL discharges (e.g., LANL 2004). Other canyons where runoff contained

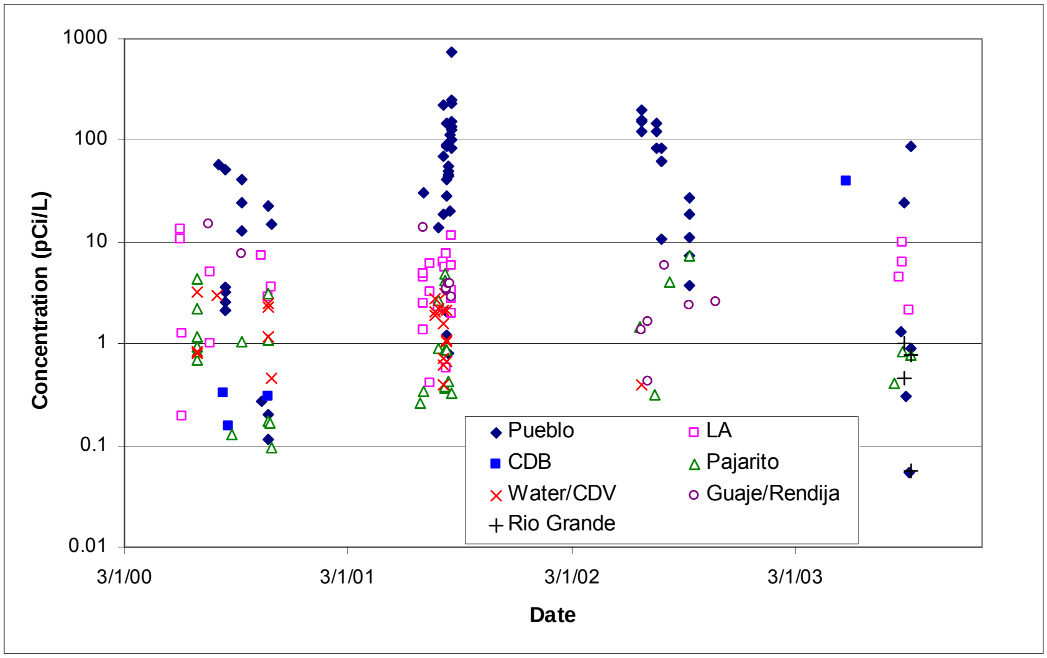


Figure 2.2.3-14. Time series of plutonium-239,240 detections in unfiltered runoff from each canyon and the Rio Grande, 2000–2003.

>10 pCi/L plutonium-239,240 include Rendija (2000, 2001), Guaje (2000), Los Alamos (2000, 2001), and Cañada del Buey (2003). The maximum concentrations of plutonium-239,240 in Pueblo Canyon storm runoff were in 2001 (753 pCi/L), since then, maximum concentrations have been less, and in 2003 the maximum concentration was less than 100 pCi/L, possibly the result of lower peak flows during runoff events.

Figure 2.2.3-15 shows the distribution of plutonium-239,240 concentrations (all data) in unfiltered runoff from upstream locations and from Rendija and Guaje Canyons from 2000 through 2003. There were no detections of plutonium-239,240 in upstream runoff before the Cerro Grande fire, but after the fire most runoff samples from upstream (background) locations and from Guaje and Rendija Canyons contained detectable plutonium-239,240. The highest upstream concentrations were in runoff from Guaje and Rendija Canyons north of LANL, where fire intensity was generally highest. The maximum concentrations in runoff from upstream LANL and from Rendija and Guaje Canyons were similar, indicating a similar provenance.

The distribution of concentrations in upstream LANL runoff were not significantly different for years 2000, 2001, and 2002, but in 2003 the upstream runoff shows a decrease in the maximum concentration of about one order of magnitude compared with prior years. The concentrations of plutonium-239,240 in runoff from Guaje and Rendija Canyons have decreased from circa 10 to 20 pCi/L in 2000 to circa 2 to 5 pCi/L in 2002, and to less than detection limits in 2003 (see Figure 2.2.3-15), which likely reflects the decrease in the amounts of ash in the runoff. As discussed in Section 1.3, ash from the Cerro Grande fire appears to have contained relatively higher concentrations of plutonium-239,240 than the ash from the Viveash Fire (Katzman et al. 2001). Based on previous evidence that plutonium-239,240 and other radionuclide concentrations are higher in soils in areas within a few miles of LANL (e.g., Fresquez et al. 1998), available data suggest that historic emissions (e.g., stack emissions) from LANL contributed to elevated plutonium-239,240 concentrations in the forest mass near LANL and to elevated concentrations in the ash after the Cerro Grande fire. The resulting fire-related runoff data from upstream of LANL and the runoff data from Rendija and Guaje Canyons indicate that the effects of plutonium-239,240 to runoff from fire-impacted areas near LANL have declined in the years since the fire, and by 2003, plutonium-239,240 concentrations in runoff from fire-impacted areas were similar to prefire conditions.

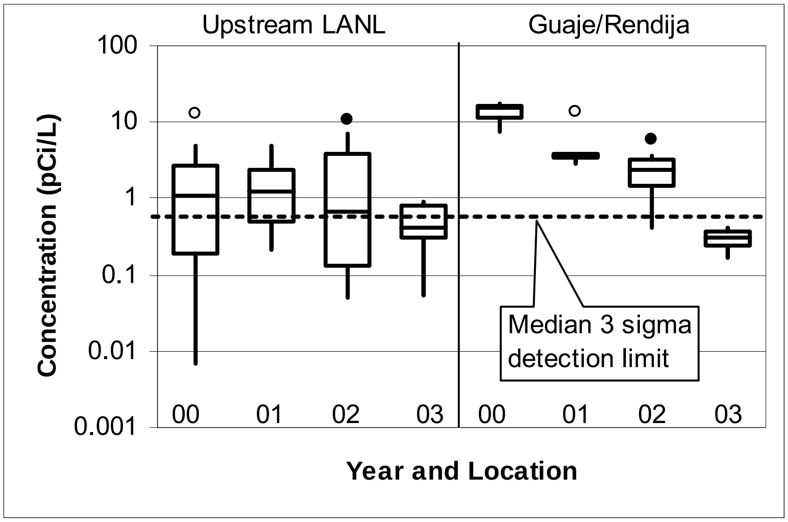


Figure 2.2.3-15. Distribution of plutonium-239,240 concentrations in upstream and offsite runoff, 2000–2003.

Figure 2.2.3-16 shows the distribution of plutonium-239,240 concentrations (all data) in runoff from onsite and downstream LANL locations from 2000 through 2003 and in samples collected from the Rio Grande in 2000, 2001, 2002, and 2003. The concentrations in LANL downstream runoff increased each year from 2000 to 2002, due mainly to the high-volume runoff events in Pueblo Canyon in these years. The distributions of concentrations of plutonium-239,240 in runoff at downstream locations were similar in 2002 and 2003, about one order of magnitude higher than in 2000 and 2001. These downstream data indicate that one of the secondary effects of flooding after the Cerro Grande fire in Pueblo Canyon was the erosion of historically derived contaminant-laden sediments by flooding in ensuing years.

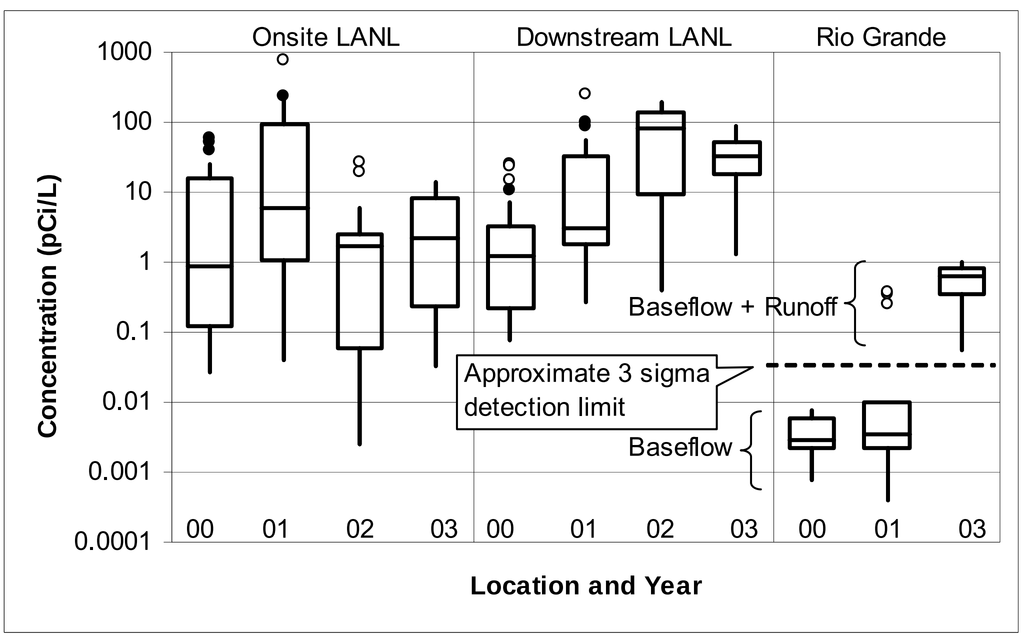


Figure 2.2.3-16. Distribution of plutonium-239,240 concentrations in unfiltered runoff from upstream, onsite, downstream, and Guaje Canyon and Rio Grande locations, 2000–2003.

Figure 2.2.3-16 indicates samples from the Rio Grande that were primarily baseflow in 2000 and 2001, and those that contained a component of runoff in 2001 and 2003. The baseflow samples contained concentrations less than the 3 sigma detection limit, and reported concentrations were less than 0.01 pCi/L. However, in 2001, samples collected from the Rio Grande on July 26 and August 9, after runoff events from Pueblo Canyon, contained up to 0.38 pCi/L plutonium-239,240, about two orders of magnitude higher than the baseflow samples.

In 2003, runoff samples were collected from the Rio Grande both upstream (Otowi Bridge) and downstream of most LANL drainages (near White Rock). These runoff samples all contained greater than 3 sigma detections of plutonium-239,240. Figure 2.2.3-17 shows the results of the 2003 Rio Grande sampling on two days when river levels increased due to runoff events. Samples collected downstream of LANL contained up to 1 pCi/L, about one order of magnitude higher than samples collected at Otowi Bridge upstream of LANL runoff. The higher concentrations downstream of LANL appear to be related to higher flows and higher transport of plutonium-239,240 from Pueblo Canyon.

A regression analysis was performed for plutonium-239,240 concentrations in Pueblo Canyon storm runoff and the instantaneous peak flow of the runoff event. Using all data, no correlation was apparent, possibly because many samples collected by the LANL ER Project in the middle reaches of Pueblo Canyon were from known contaminated sediment reaches and the samples may not have been collected at the time of peak runoff. Excluding the ER samples and excluding the record peak flow of 1440 cfs in 2001, the resulting regression analysis indicates an R-squared value of 0.27 and a p-value of 0.048, showing that there is a statistically significant relationship between Pu-239,240 and instantaneous peak flow at the 95% confidence level. Figure 2.2.3-18 shows the results of the regression analysis for plutonium-239,240 and peak flow volumes in Pueblo Canyon.

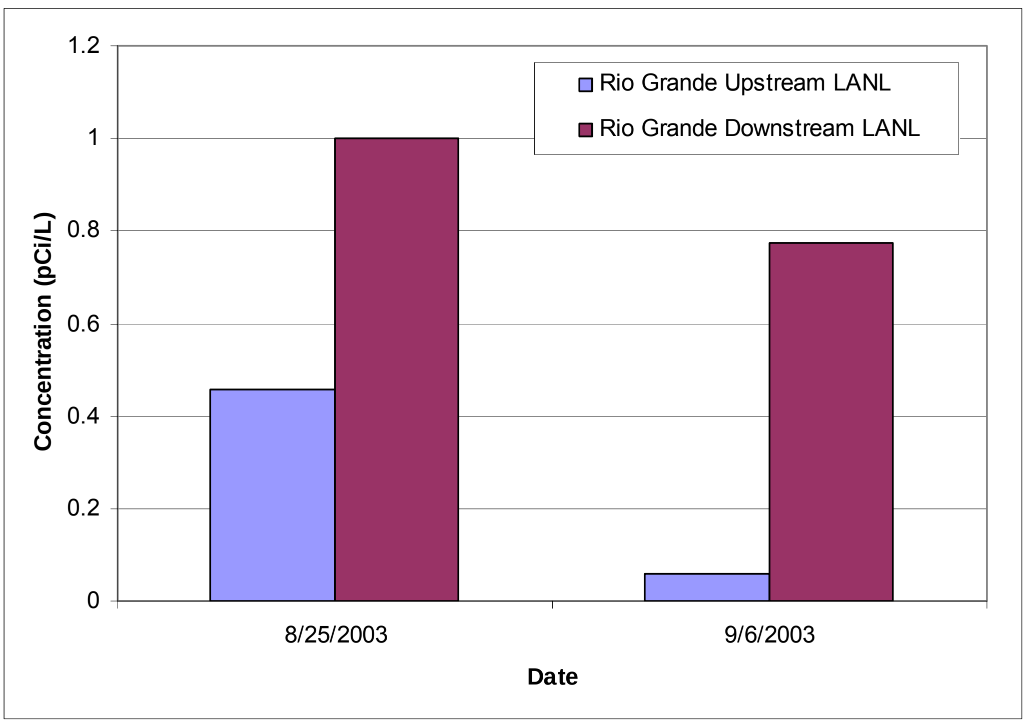


Figure 2.2.3-17. Plutonium-239,240 in unfiltered runoff from the Rio Grande in 2003.

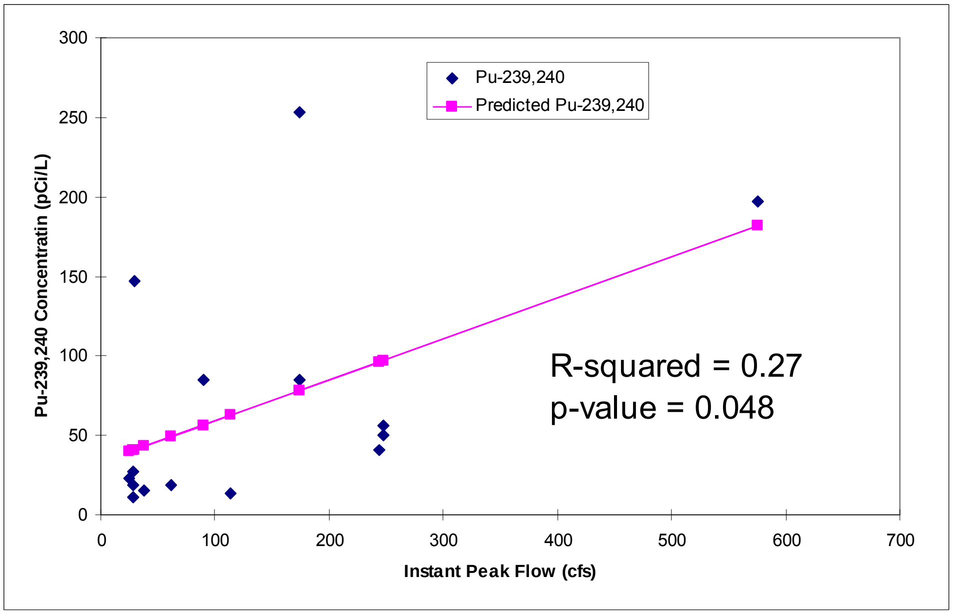


Figure 2.2.3-18. Regression analysis of plutonium-239,240 concentrations and peak flow in Pueblo Canyon.

2.2.3.8 Strontium-90 in Runoff

Figure 2.2.3-19 shows the time series of strontium-90 concentrations (3 sigma detections) in unfiltered runoff from each canyon at LANL, from Guaje and Rendija Canyons, and in samples collected from the Rio Grande from 2000 through 2003. The figure also shows the maximum concentration of strontium-90 (25 pCi/L) in runoff for prefire years 1995 through 1998. Since the fire, the highest concentrations of

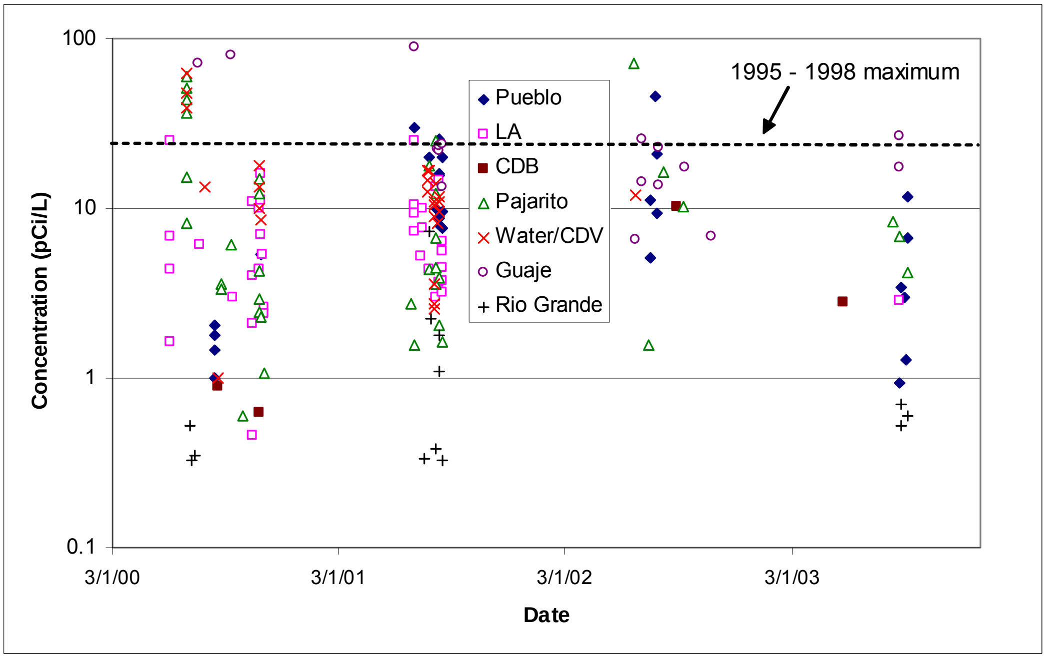


Figure 2.2.3-19. Time series of total strontium-90 in unfiltered runoff from each canyon and the Rio Grande, 2000–2003.

strontium-90 were in runoff from Guaje and Rendija Canyons (up to 90 pCi/L) and in Pajarito and Water Canyons at LANL (up to 59.1 pCi/L). The highest concentrations in LANL runoff were in ash-laden runoff from upstream Pajarito and Water Canyons on June 28, 2000, and from upper Pueblo Canyon on July 25, 2002, supporting that ash from the fire may have contained elevated concentrations of strontium-90, as demonstrated by ash data (Katzman et al. 2001, 2002; LANL 2004).

Since 2000, the maximum concentrations of strontium-90 in runoff have declined each year, and in 2003 all runoff samples contained less than 30 pCi/L strontium-90, similar to prefire conditions. The higher concentrations of strontium-90 in runoff from Guaje Canyon are evidently associated with ash in the runoff.

Figure 2.2.3-20 shows the distribution of strontium-90 concentrations in unfiltered runoff from upstream, onsite, downstream, and Guaje and Rendija Canyons and in samples collected from the Rio Grande from 2000 through 2003. In 2000 and 2001, the higher concentrations of strontium-90 were from upstream LANL and Guaje and Rendija Canyon sites, reflecting the impact of the ash from fire-related areas. The higher concentrations (>30 pCi/L) observed at onsite and downstream locations in 2001 and 2002 were also in runoff from burned areas. Runoff from DP Canyon typically contains 15 to 28 pCi/L strontium-90, but after the fire, these concentrations were overshadowed by runoff from fire-impacted areas.

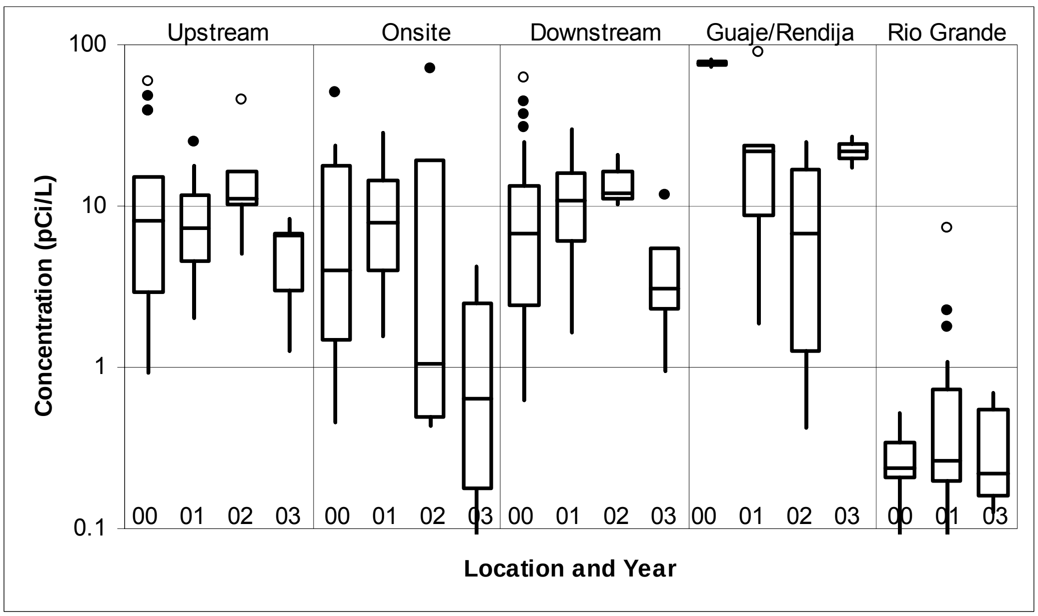


Figure 2.2.3-20. Distribution of total strontium-90 concentrations in unfiltered runoff from upstream, onsite, downstream, and Rendija and Guaje Canyons and in unfiltered baseflow in the Rio Grande, 2000–2003.

In 2003, the highest concentrations of strontium-90 were in a runoff event from Guaje Canyon on August 23, 2003, when samples collected above Rendija Canyon and downstream at SR 502 contained 17.4 and 26.8 pCi/L, respectively. Runoff samples from upstream, onsite, and downstream at LANL were generally less than 10 pCi/L, except for one sample collected from lower Pueblo Canyon that contained 11.6 pCi/L.

Rio Grande water samples that contained concentrations of strontium-90 greater than 1 pCi/L were collected on July 26, 2001 (7.4 pCi/L), and August 9, 2001 (1.8 pCi/L). On July 26, runoff from the Pajarito Plateau contained up to 19.8 pCi/L strontium-90 (Pueblo Canyon), and on August 9 runoff from the plateau contained up to 22 pCi/L strontium-90 (Guaje Canyon), which may have caused the higher concentrations in the Rio Grande.

2.2.3.9 Uranium in Runoff

Figure 2.2.3-21 shows the time series of uranium concentrations in unfiltered runoff in each canyon from 1997 through 2003. Before the fire the most uranium concentrations in runoff were less than 14 µg/L, except for one sample from Ancho Canyon in 1999 that contained 170 µg/L (possibly due to runoff from firing sites in Ancho Canyon at TA-39). In the years since the fire, many more runoff samples have contained higher concentrations of uranium (over 20 µg/L) than before the fire. The higher concentrations of uranium in runoff in 2000, 2001, and 2003 were from Water Canyon and/or Guaje Canyon, but in 2002, the higher concentrations were in runoff from Pueblo Canyon.

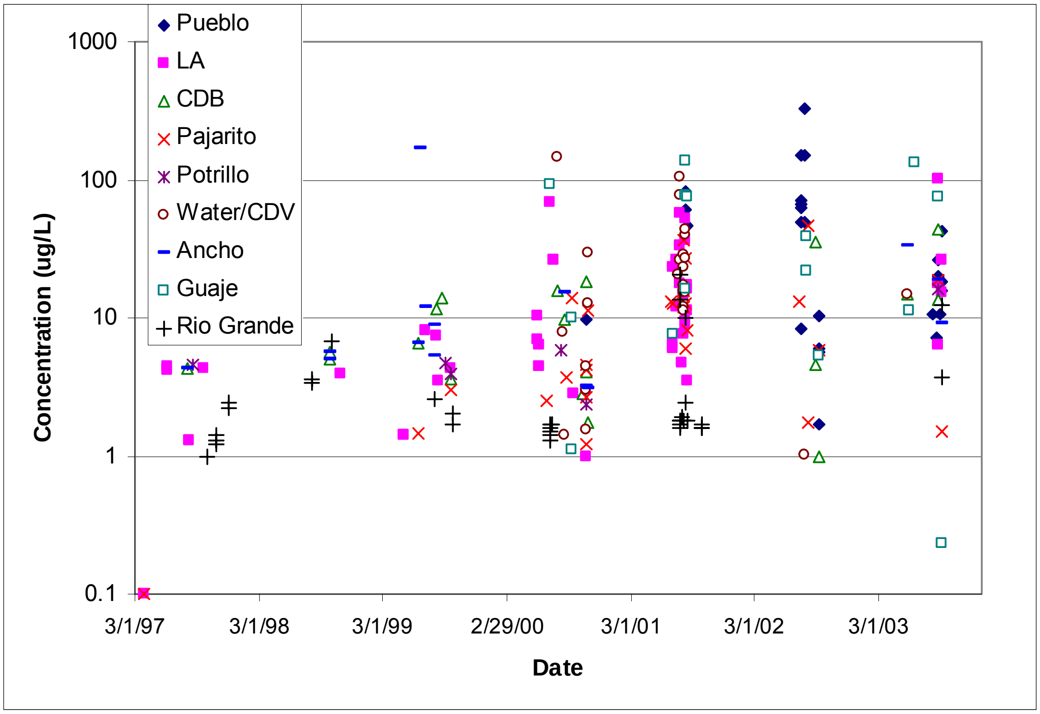


Figure 2.2.3-21. Time series of total uranium in unfiltered runoff, 1997–2003.

Figure 2.2.3-22 shows the distribution of uranium concentrations in unfiltered runoff at upstream, onsite, downstream, and Guaje Canyon locations and in samples from the Rio Grande for 2000 through 2003. The maximum concentration of uranium in upstream runoff in 2000 after the fire was 26 µg/L from upper Los Alamos Canyon. The median uranium concentration in upstream runoff in 2000 was 2.9 µg/L, however, the median concentrations in 2001 through 2003 ranged from 15.8 to 28.2 µg/L. This increase in concentration would not appear to be a direct impact of the Cerro Grande fire, but may be associated with geochemical weathering of soil or bedrock volcanic rocks as an indirect result of the effects of the fire. The higher concentrations of uranium in runoff at upstream locations in 2002 (>50 µg/L) were all from Pueblo Canyon (NMED samples); these runoff samples may have been impacted by construction activities that were occurring at the Pueblo Canyon landfill bridge in 2002. The highest concentrations of uranium in upstream runoff, exclusive of Pueblo Canyon, were from upstream in Pajarito Canyon, where concentrations were 46 µg/L on August 8, 2002, and 27.2 µg/L on August 9, 2001.

In 2000 after the fire, the maximum concentration of uranium in downstream LANL runoff was 146 µg/L from Water Canyon. In 2001 and 2002 the maximum concentrations in downstream LANL runoff were 81.8 ug/L and 150 ug/L, respectively, from Pueblo Canyon. In 2003 the maximum uranium concentration in runoff was from lower Los Alamos Canyon near Otowi Bridge that contained 102 µg/L uranium on August 23, 2003. Runoff from Los Alamos Canyon and Pueblo Canyon on August 22 and 23 contained

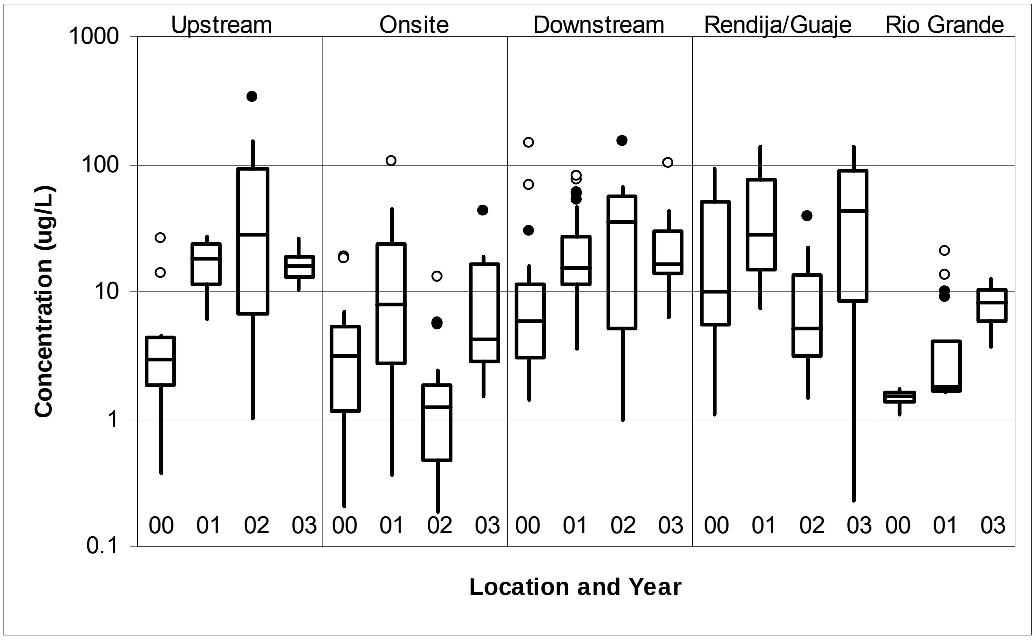


Figure 2.2.3-22. Distribution of uranium concentrations in unfiltered runoff from upstream, onsite, downstream, and Guaje Canyon and unfiltered baseflow from the Rio Grande, 2000–2003.

less than 8 µg/L uranium, thus the source of the uranium in the lower Los Alamos Canyon runoff does not appear to be from LANL. The distribution of uranium concentrations in downstream LANL runoff was similar from 2001 through 2003 due to the large volumes of runoff from Pueblo Canyon.

In 2000, baseflow samples from the Rio Grande contained less than 2 µg/L uranium; however, in 2001, samples collected from the Rio Grande on July 26, 2001, downstream of LANL contained 20.4 µg/L, and samples collected on August 9, 2001, contained up to 10 µg/L. These samples contained a component of runoff from the Cerro Grande fire burn area, but because samples collected at Otowi upstream of Los Alamos Canyon contained 13.4 µg/L on July 27, 2001, and 2.4 µg/L on August 8, 2001, the uranium concentrations were not entirely due to runoff from LANL.

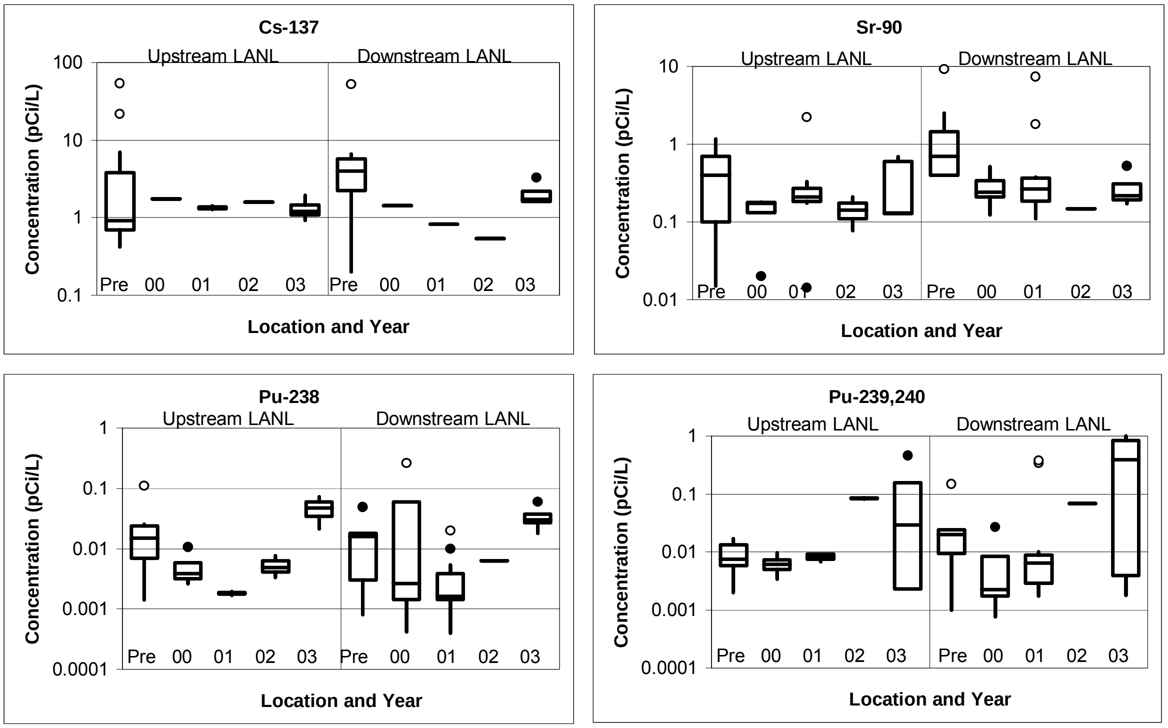
2.2.3.10 Radionuclides in the Rio Grande

Earlier discussion of radionuclides in runoff from the Pajarito Plateau have included summary data for the samples collected from the Rio Grande that provided a reference for understanding the potential impacts to the Rio Grande. Figure 2.2.3-23 summarizes the distribution of concentrations of cesium-137, plutonium-238, plutonoium-239,240, and strontium-90 in unfiltered baseflow and runoff samples (some 2001 and 2003 data) collected from the Rio Grande before and after the fire.

For the samples collected from the Rio Grande after the fire, no increases in concentrations were observed for these radionuclides; distributions of concentrations after the fire are generally similar to prefire distributions. However, samples of runoff collected in the Rio Grande in 2001 and 2003 show higher concentrations of some radionuclides both upstream and downstream of LANL. The median concentration of plutonium-239,240 downstream of LANL in 2003 was about one order of magnitude higher than upstream of LANL, likely indicating a contribution from runoff from Pueblo Canyon.

2.2.3.11 Radionuclides in Suspended Sediment

Because the suspended solids in storm runoff contain a large portion of the total radionuclide load, the suspended sediment in runoff was investigated for significant concentrations of the individual



Note: For results reported as non-detect, the reported detection limit was substituted for the result for representation of the data.

Figure 2.2.3-23. Summary of radionuclide concentrations in unfiltered samples from the Rio Grande, prefire and postfire.

radionuclides. For samples collected by NMED, the suspended sediment fraction of runoff samples was analyzed separately from the liquid fraction of the samples by the analytical laboratory; per-gram results were therefore provided for the suspended sediment fraction. For runoff samples collected by LANL WQH and the ER Project, the concentrations of radionuclides in the suspended sediment fraction of the runoff samples were calculated using the concentrations of radionuclides in the unfiltered runoff and the TSS concentrations.

The calculations were performed for storm runoff samples that had TSS concentrations greater than 300 mg/L and did not consider dissolved concentrations in the filtered runoff; therefore, the calculated results are relatively conservative and are considered maximum concentrations of radionuclides in suspended sediment. The USGS collected bed sediment samples from the Rio Grande that were analyzed separately from the filtered and unfiltered water samples.

Table 2.2.3-5 shows the summary of the results of calculating radionuclide concentrations in suspended sediment at downstream locations and the historic maximum concentrations (1995 through 1999) and the sediment BVs (upper limit background values) developed for stream sediments at LANL (Ryti et al. 1998, McDonald et al. 2003) and for Rio Grande and other area stream sediments and reservoir sediments (McLin and Lyons 2002, McLin 2004). The sediment BVs are shown for comparison purposes only because the concentration of radionuclides in deposited streambed sediments would be expected to be lower than what is calculated for the suspended sediment, which is selectively comprised of finer grained materials with higher radionuclide concentrations by weight (Johansen et al. 2001). Specific screening levels for radionuclides in suspended sediment in storm water runoff are not available so historical maximum concentrations measured and calculated for radionuclides in suspended sediment in runoff at downstream locations are shown in Figure 2.2.3-24 for comparison with downstream runoff from 2000 through 2003.

Table 2.2.3-5. Summary of Calculated Concentrations of Radionuclides in Suspended Sediment in Downstream Runoff, 2000–2003.

Analyte	No. of Calcu-lations	Min-imum (pCi/g)	Max-imum (pCi/g)	Median (pCi/g)	ER Sediment BV[a] (pCi/g)	Rio Grande River BV[b] (pCi/g)	Rio Grande Reservoir BV[b] (pCi/g)	Suspended Sediment Historic Maximum (pCi/g)
Am-241	60	0.004	1.53	0.10	0.04	0.076	0.010	2.43
Cs-137	41	0.075	9.48	0.91	0.90	0.56	0.98	37.96
GROSSA	56	1.355	87.34	17.18	58.80	15.70	15.90	92.10
GROSSB	56	1.931	145.93	21.84	46.10	17.60	9.70	88.56
Pu-238	53	0.001	0.45	0.02	0.006	0.0087	0.0012	0.291
Pu-239,240	67	0.009	8.21	0.53	0.068	0.0130	0.0201	3.588
Sr-90	64	0.054	18.29	0.55	1.30	1.02	1.19	20.28
U (mg/kg)	64	0.035	14.77	1.03	2.22	4.49	4.58	6.44

a Background values from Ryti et al. 1998, McDonald et al. 2003
b Rio Grande background values from McLin and Lyons 2002; McLin 2004.

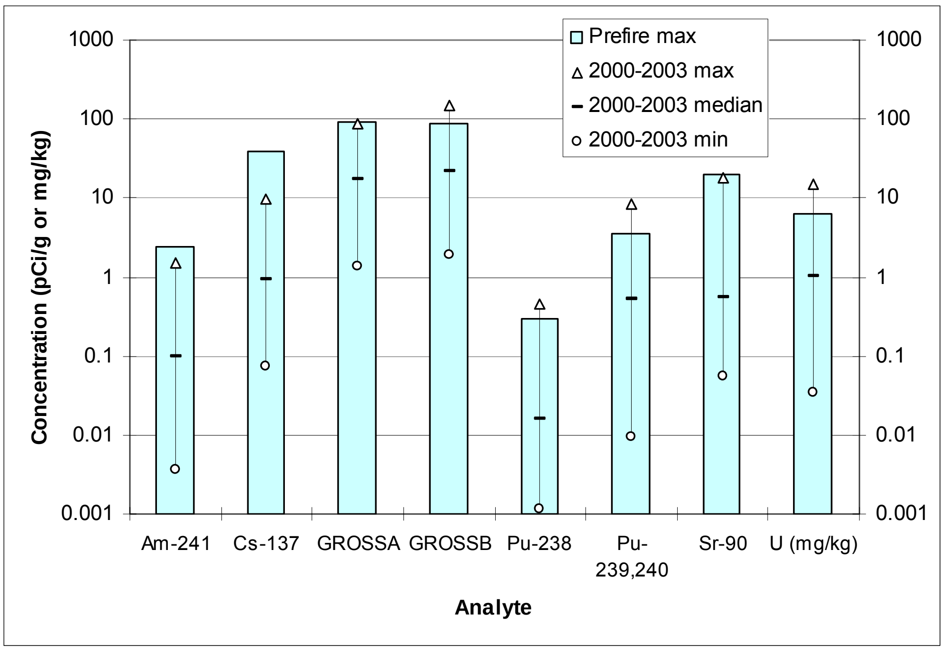


Figure 2.2.3-24. Calculated radionuclide concentrations in suspended sediment at downstream locations compared with historic maximum values.

The radionuclides and analytes present in higher concentrations in downstream suspended sediments than in previous years include plutonium-238, plutonium-239,240, uranium, and gross beta activity. The highest concentration of plutonium-238 in suspended sediments was 0.447 pCi/g from a sample collected from lower Los Alamos Canyon on October 12, 2000. The maximum concentration of plutonium-239,240 was 8.21 pCi/g in a sample collected from lower Pueblo Canyon on July 18, 2002. The maximum concentration of uranium in downstream suspended sediment was 14.77 mg/kg in a sample collected in lower Pajarito Canyon on October 27, 2000. The maximum gross beta activity in downstream suspended sediment was 149.9 pCi/g in a sample from lower Pajarito Canyon collected on June 27, 2001.

Figure 2.2.2-25 shows the summary of calculated radionuclides and uranium concentrations in suspended sediment at downstream locations compared with sediment BVs. Maximum concentrations of all analytes in suspended sediment are greater than the sediment BV, and median concentrations of all analytes except strontium-90 and uranium are above the sediment BV. Because suspended sediment in runoff is typically composed of finer-grained materials than stream sediments, concentrations greater than stream sediment BVs would be expected in the suspended sediment material.

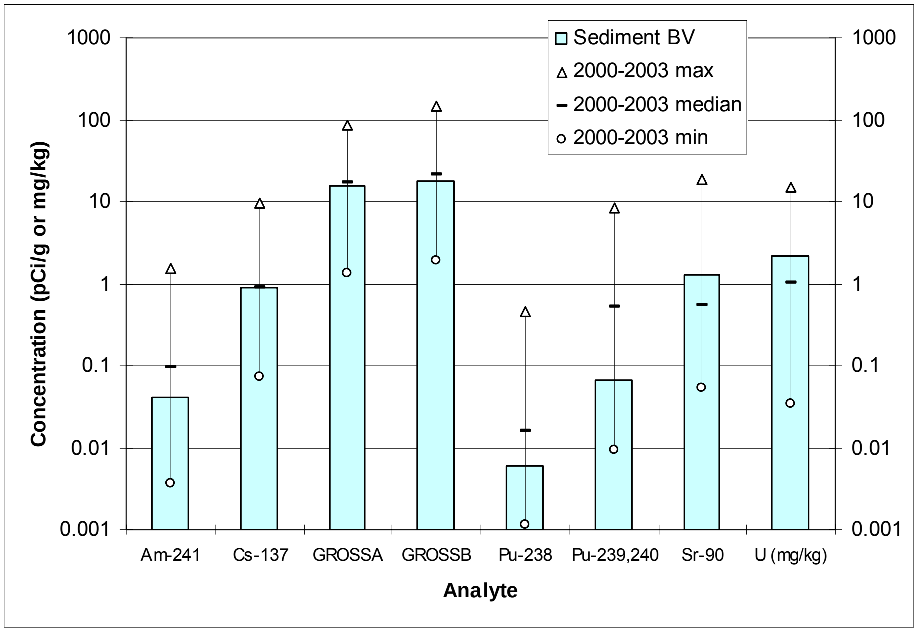
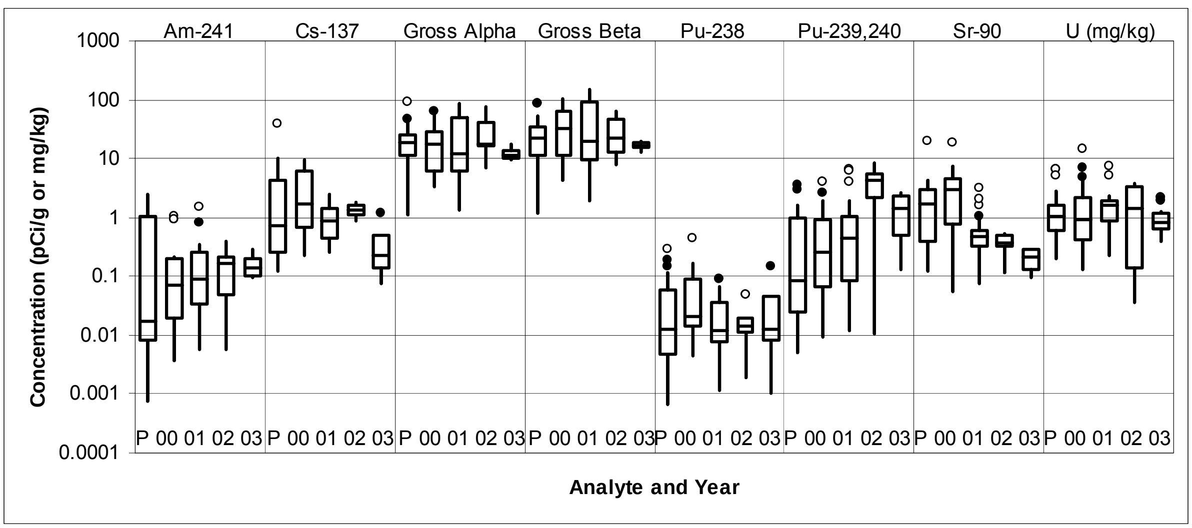


Figure 2.2.3-25. Calculated radionuclide concentrations in suspended sediment from downstream locations compared with sediment BVs (prefire BVs).

Figure 2.2.3-26 shows the box plot distributions of calculated radionuclide concentrations in suspended sediment at downstream locations for the prefire years (1995–1999) and the postfire years of 2000



Note: P = prefire data

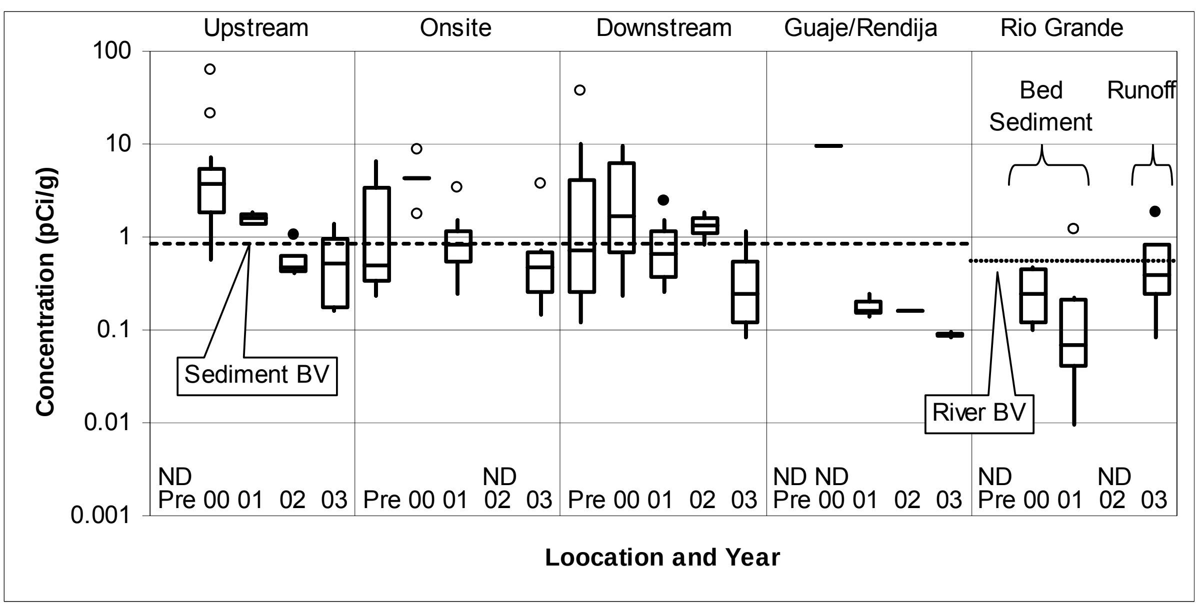
Figure 2.2.3-26. Calculated radionuclide concentrations in suspended sediment at downstream locations, prefire and 2000–2003.

through 2003. The median concentrations of all radionuclides except uranium were higher in 2000 than in prefire years; however, the overall distribution of concentrations of most radionuclides in suspended sediment was not statistically different from year to year. Median concentrations of cesium-137, gross beta activity, plutonium-238, and strontium-90 show a declining trend from 2000 to 2003, but median concentrations of americium-241 and plutonium-239,240 suggest an increasing trend. The median concentration of plutonium-239,240 was about an order of magnitude higher in 2002 than previous years, largely due to the high-volume runoff from Pueblo Canyon. Concentrations of cesium-137 and strontium-90 were about one order of magnitude lower in 2003 compared with 2000, primarily due to lower concentrations in runoff from fire-impacted areas.

2.2.3.11.1 Cesium-137 in Suspended Sediment

From a public exposure perspective, cesium-137 is the radionuclide likely to be of most concern in postfire sediment deposits (RAC 2002). Figure 2.2.3-27 shows the calculated concentrations of cesium-137 in suspended sediment in samples from upstream, onsite, and downstream locations, Guaje Canyon, and bed sediment (for years 2000 and 2001) and suspended sediment (2003) concentrations in samples from the Rio Grande. In 2000 after the fire, the highest concentrations of cesium-137 in suspended sediment were in upstream runoff from fire-impacted areas. The median concentration of cesium-37 in upstream runoff in 2000 was 3.8 pCi/g, in 2001, 1.6 pCi/g, and in 2002, 0.46 pCi/g, a notable decrease each year since the fire. Similar trends are observed at onsite, downstream, and Guaje and Rendija locations. The prefire downstream median concentration was 0.73 pCi/g, similar to downstream median concentration in 2001, suggesting that cesium-137 concentrations in suspended sediment approached prefire conditions by 2001. Downstream runoff in 2002 was primarily from Pueblo Canyon where the median calculated concentration of cesium-137 was 1.8 pCi/g, but the median in 2003 was 0.24, significantly lower.

The median concentrations of cesium-137 in Rio Grande bed sediments were 0.25 pCi/g and 0.07 pCi/g in 2000 and 2001, respectively, about an order of magnitude less than upstream and downstream runoff from fire-impacted areas. The median concentration of suspended sediment in Rio Grande runoff in 2003 was 0.39 pCi/g.



Note: ND = no data; Sediment BV from Ryti et al. (1998); River BV from McLin and Lyons (2002)

Figure 2.2.3-27. Calculated concentrations of suspended cesium-137 activities in storm runoff from upstream, onsite, downstream, and Guaje Canyon and in Rio Grande bed sediment and runoff.

Figure 2.2.3-28 shows the time series of calculated and measured (NMED data) concentrations of cesium-137 in suspended sediment samples from each major canyon system that was associated with flooding after the fire. Concentrations in all canyons were highest in runoff in June 2000 immediately after the fire, and decreased during the 2000 runoff season. The highest concentration in 2000 was 67.4 pCi/g in runoff from upper Twomile Canyon, a tributary to Pajarito Canyon. The highest concentration in 2001 was 2.6 pCi/g in a sample collected from lower Los Alamos Canyon. In 2002, the highest concentration of cesium-137 in suspended sediment was 1.25 pCi/g in a sample collected from lower Pueblo Canyon by NMED, and in 2003 the maximum concentration was 3.98 pCi/g in a sample from middle Los Alamos Canyon above DP Canyon.

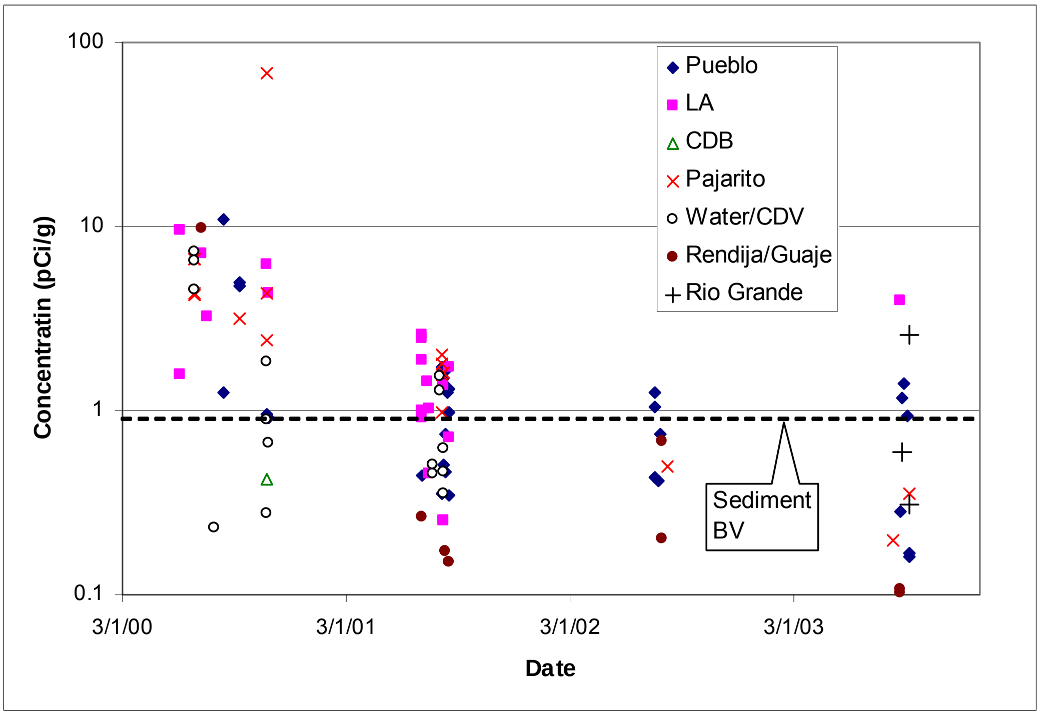
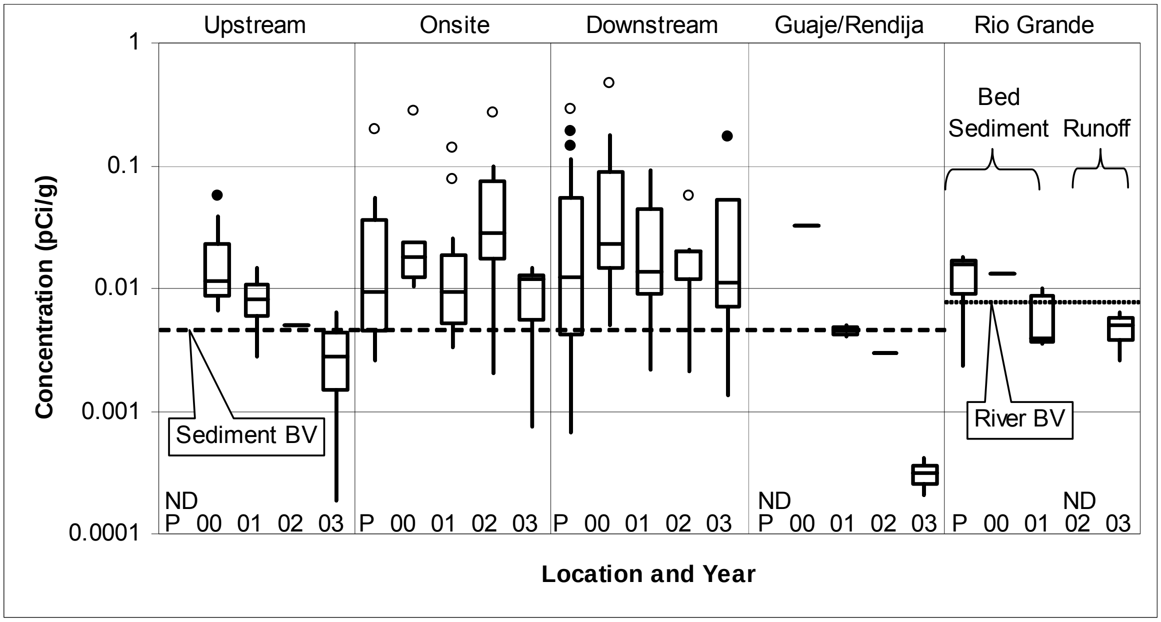


Figure 2.2.3-28. Time series of cesium-137 concentrations in suspended sediment.

In 2000 after the fire, the higher concentrations of cesium-137 in suspended sediment commonly occurred in samples collected upstream of LANL, where the radionuclides should be primarily derived from worldwide fallout. Because ash and associated radionuclides concentrate in finer-grained materials that tend to be held in suspension in runoff, the concentrations in stream bed sediment found in deposits after the runoff events will likely be substantially lower than in suspended sediment in the runoff samples. The data indicate that fire-related impacts with regard to higher concentrations of cesium in suspended sediment did not occur significantly after 2000 (see Figure 2.2.3-27). In 2002 one runoff event in Pueblo Canyon contained greater than 1 pCi/g cesium-137, and in 2003 runoff events in Pueblo and Los Alamos Canyons contained greater than 1 pCi/g cesium-137. A runoff sample collected from the Rio Grande on September 6, 2003 contained 2.58 pCi/g cesium-137; this sample contained a component of runoff Los Alamos and Pueblo Canyons.

2.2.3.11.2 Plutonium-238 in Suspended Sediment

Figure 2.2.3-29 shows the calculated concentrations of plutonium-238 in suspended sediment at upstream, onsite, and downstream locations and Guaje Canyon for 2000 through 2002 and the bed sediment concentrations from the Rio Grande in 2000 and 2001 and suspended sediment in Rio Grande runoff in 2003. The upstream and Guaje Canyon concentrations show a significant decrease in



Note: ND = no data; Sediment BV from Ryti et al. (1998); River BV from McLin and Lyons (2002)

Figure 2.2.3-29. Calculated concentrations of plutonium-238 in suspended sediment, prefire and 2000–2003, and in Rio Grande bed sediment.

plutonium-238 concentrations from 2000 to 2003, possibly indicating a decline in the contribution of fire-related ash to storm runoff (see Section 2.2.2.3).

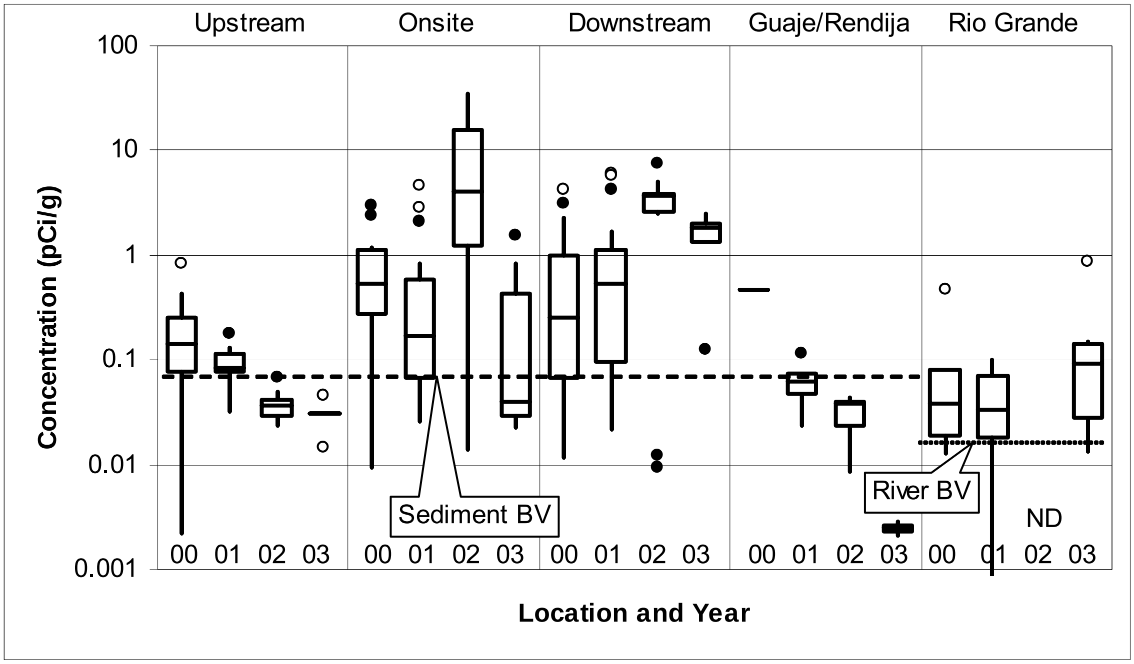
The maximum concentrations of plutonium-238 in suspended sediment from onsite and downstream runoff are about an order of magnitude higher than upstream and Guaje/Rendija concentrations, largely due to erosion of sediment deposits in Los Alamos Canyon and Pueblo Canyon. The distribution of Rio Grande bed sediment concentrations in 2000 and 2001 are similar to the upstream distributions, which likely represents background concentrations. Plutonium-238 was not detected in runoff from upstream, Guaje/Rendija, and the Rio Grande in 2003.

2.2.3.11.3 Plutonium-239,240 in Suspended Sediment

Figure 2.2.3-30 shows the calculated concentrations of plutonium-239,240 in suspended sediment at upstream, onsite, and downstream locations and in Guaje Canyon and the Rio Grande for 2000 through 2003. The distribution of suspended sediment concentrations in upstream and Guaje/Rendija Canyons runoff show a significant decrease each year since 2000, indicating a decline in the contribution of fire-related ash to storm runoff.

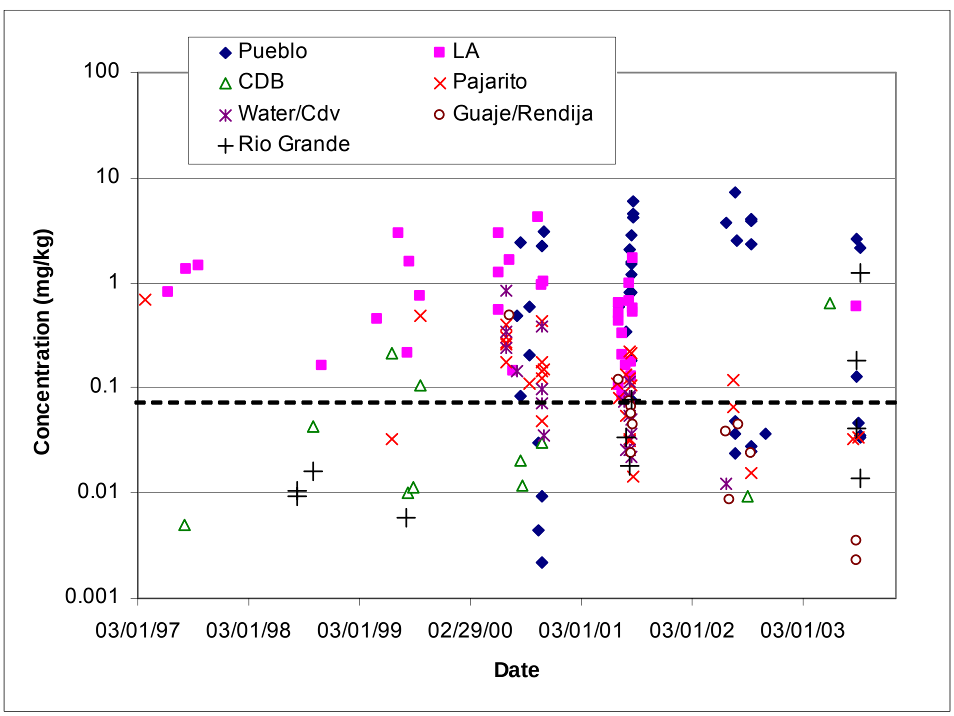
The maximum concentrations of plutonium-239,240 from onsite and downstream runoff are one to two orders of magnitude higher than upstream concentrations, largely due to runoff from Los Alamos Canyon and Pueblo Canyon. Median concentrations of plutonium-239,240 in suspended sediment in the Rio Grande are about one order of magnitude less than downstream LANL runoff.

The time series of plutonium-239,240 concentrations in suspended sediment in storm runoff is shown in Figure 2.2.3-31. Before the fire only runoff from Los Alamos Canyon contained suspended sediment in concentrations greater than 1 pCi/g. However, after the fire, concentrations greater than 1 pCi/g have been observed in runoff from Los Alamos and Pueblo Canyons, and the number of samples containing greater than 1 pCi/g was larger in the years after the fire, probably due to indirect effects of the fire. In 2003 one runoff sample collected from the Rio Grande on September 6 contained a calculated concentration of 1.24 pCi/g plutonium-239,240; this sample contained a component of runoff from Pueblo and Los Alamos Canyons.



Note: ND = no data; Sediment BV from Ryti et al. (1998); River BV from McLin and Lyons (2002)

Figure 2.2.3-30. Calculated concentrations of plutonium-239,240 in suspended sediment, 2000–2003.

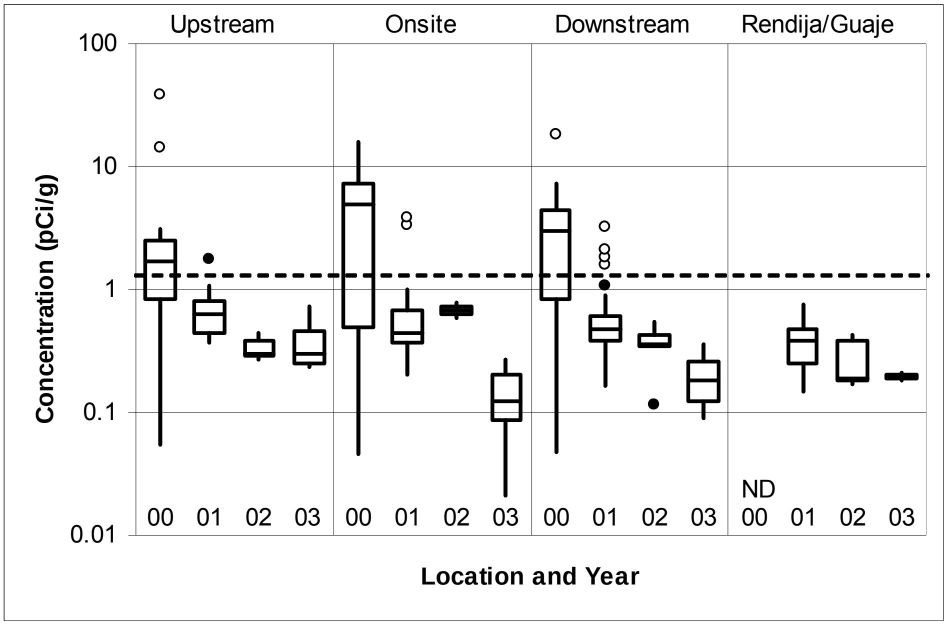


Note: Dashed line is LANL Sediment BV

Figure 2.2.3-31. Time series of calculated plutonium-239,240 concentrations in suspended sediment.

2.2.3.11.4 Stronitium-90 in Suspended Sediment

Figure 2.2.3-32 shows the calculated concentrations of strontium-90 in suspended sediment in runoff at upstream, onsite, downstream, and Guaje Canyon locations. All locations show a significant decrease in strontium-90 concentrations in 2001 and later years, indicating a decline in the contribution of fire-related ash and muck to storm runoff. The highest concentrations were observed in runoff upstream of LANL in Water Canyon and Cañon de Valle during the June 28, 2000, runoff event. Similarly, the highest downstream concentration was in Pajarito Canyon during the same runoff event. The data show that the higher concentrations of strontium-90 in suspended sediment in runoff was from fire-impacted areas.



ND = no data; dashed line is LANL Sediment BV

Figure 2.2.3-32. Calculated concentrations of strontium-90 in suspended sediment, 2000–2003.

Figure 2.2.3-33 shows the time series of calculated strontium-90 concentrations in suspended sediment in the major canyon systems from 1997 through 2003 and the sediment BV (Ryti et al. 1998). Before the fire, concentrations higher than the BV (1.3 pCi/g) were usually in runoff from Los Alamos Canyon, where strontium-90 was present from DP Canyon sources. In 2000 after the fire, concentrations higher than the BV were observed in Los Alamos Canyon, Water Canyon, Cañon de Valle, and Pajarito Canyon; the highest concentrations were from upstream locations and runoff from fire-affected areas. In 2001, concentrations above the BV were in runoff from downstream locations in Los Alamos and Pajarito Canyons and upstream in Pueblo Canyon.

Concentrations of strontium-90 in suspended sediment decreased significantly in 2001 and 2002; in 2001 concentrations above the BV were observed in runoff from Los Alamos, Pueblo, and Pajarito Canyons. No concentrations above the BV were observed in 2002 and 2003, partly because significant runoff events did not occur in Los Alamos Canyon these years. The higher concentrations of strontium-90 in ash and muck-laden runoff in 2000 appear to have overshadowed LANL contaminant concentrations from Los Alamos Canyon. It is not clear if the concentrations seen in Los Alamos Canyon in 2001 were from contaminant sources or fire-related sources. The one runoff sample from Pajarito Canyon that contained strontium-90 in suspended sediment in a concentration above the BV in 2001 was from a downstream location during a Pajarito Plateau-only precipitation event on June 27, 2001. This runoff event may have caused erosion and transport of ash and muck material that was deposited in Pajarito Canyon during the floods in 2000 after the fire (Gallaher et al. 2002). The 2001 Pueblo Canyon sample that contained strontium-90 above the BV was from an upstream location, which indicates a fire-related source.

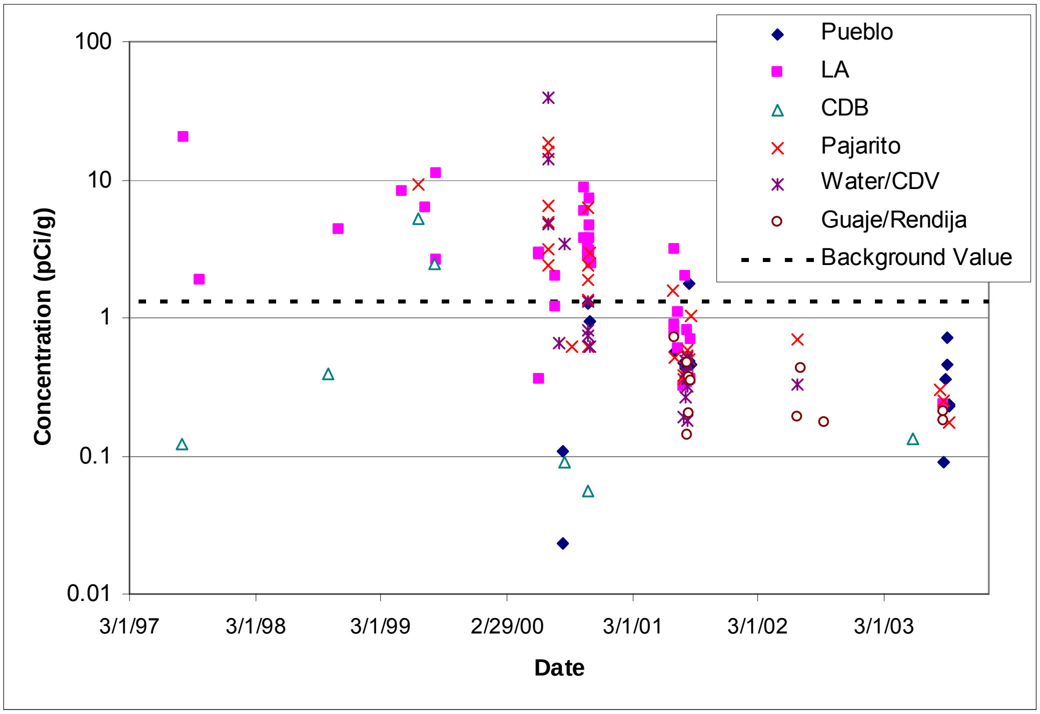
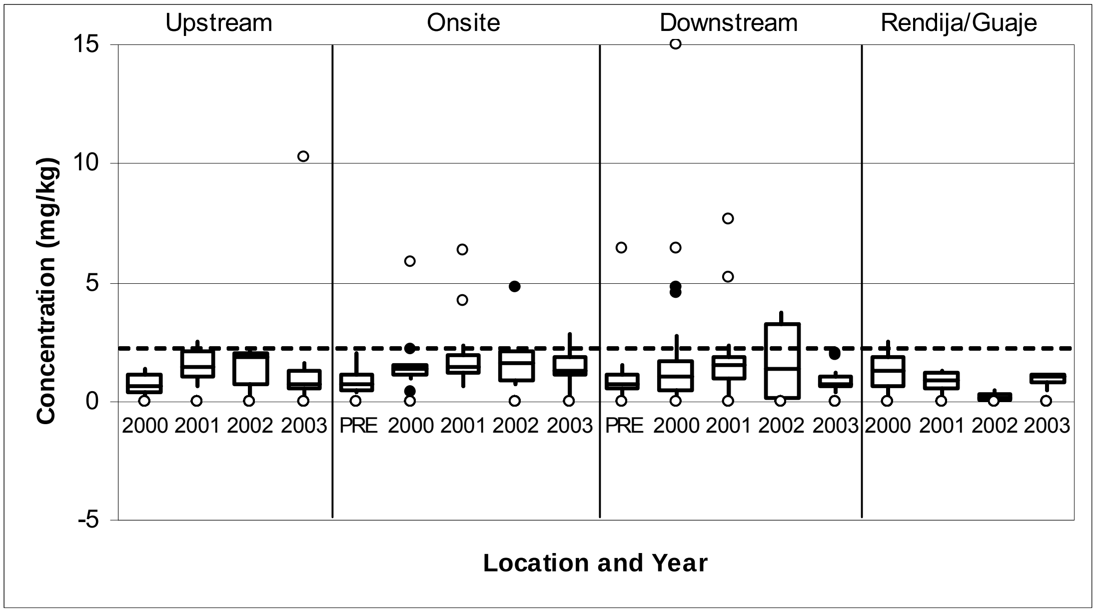


Figure 2.2.3-33. Time series of calculated concentrations of strontium-90 in suspended sediment in storm runoff.

2.2.3.11.5 Uranium in Suspended Sediment

Figure 2.2.3-34 shows the calculated uranium concentrations in suspended sediment for upstream, onsite, and downstream LANL locations and for Guaje Canyon for prefire years and 2000 through 2003. The highest concentration of uranium in suspended sediment in storm water runoff was 14.8 mg/kg in a sample collected from lower Pajarito Canyon. Data for prefire years are available for onsite and downstream locations only, where the median prefire concentrations were 0.71 and 0.75 mg/kg, respectively. In 2000 after the fire, median concentrations of uranium at onsite and downstream locations increased to 1.4 mg/kg and 1.03 mg/kg, respectively, although the upstream median concentration in 2000 was 0.6 mg/kg. The maximum concentrations of uranium in suspended sediment in 2000 runoff were apparently not from fire-related sources. In 2001, the median concentrations of uranium in suspended sediment at upstream, onsite, and downstream locations were 1.44 mg/kg, 1.48 mg/kg, and 1.56 mg/kg, respectively, possibly showing a slight increase as runoff flows downstream. The maximum concentrations of uranium in suspended sediment in runoff at onsite and downstream locations are about an order of magnitude higher than the maximum concentrations at upstream locations (except for an anomalous sample from upper Pueblo Canyon in 2003). Uranium concentrations in suspended sediment from Guaje Canyon are less than 2.5 mg/kg, similar to upstream LANL runoff, which indicates no direct impacts from fire-related areas.

Figure 2.2.3-35 shows the time series of uranium concentrations in suspended sediment from 1997 through 2003. Postfire runoff containing concentrations of uranium in suspended sediment greater than 5 mg/kg are from Pajarito and Water Canyons in 2001 and 2002; these canyons drain firing sites at LANL, which may be a source of uranium to runoff. Ancho Canyon also drains firing sites at LANL but was not significantly impacted by the fire and was not subject to high runoff flow volumes the first two years after the fire; a runoff sample collected in 1999 contained greater than 6 mg/kg uranium in suspended sediment.



Dashed line is LANL Sediment BV

Figure 2.2.3-34. Calculated concentrations of uranium in suspended sediment at upstream, onsite, and downstream locations and Guaje Canyon, prefire and 2000–2002.

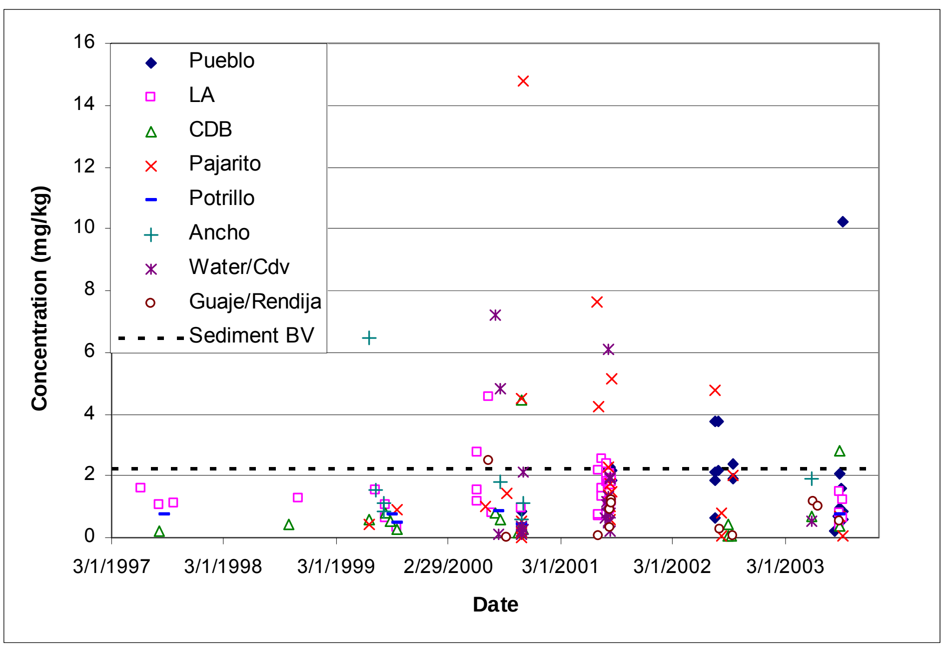


Figure 2.2.3-35. Time series of calculated uranium concentrations in suspended sediment.

The uranium runoff data indicate that the highest concentrations of uranium in suspended sediment originate in runoff within the LANL site; the maximum concentrations may be indirectly related to the effects of the Cerro Grande fire that pertain to higher flow volumes in major canyons that drain firing sites. The higher flow volumes may have caused erosion and re-suspension of legacy LANL contaminants in stream sediments.

2.2.3.12 Radionuclide Concentrations in Runoff Upstream and Downstream of Los Alamos Canyon Weir

Figure 2.2.3-36 shows the average concentrations of selected radionuclides in unfiltered storm runoff samples collected above and below the Los Alamos Canyon weir in 2000 and 2001. In 2000, the average strontium-90 concentration above the weir was about 10.4 pCi/L, compared with about 4.4 pCi/L below the weir, about 2.4 times higher above the weir. In 2001, the average concentrations of all radionuclides (except uranium) were higher above the weir than below the weir, an average of 3.6 times higher above the weir. The average concentration of uranium was slightly higher in runoff below the weir, indicating that uranium may be present in the finer-sized particles in runoff and present in the dissolved fraction of runoff.

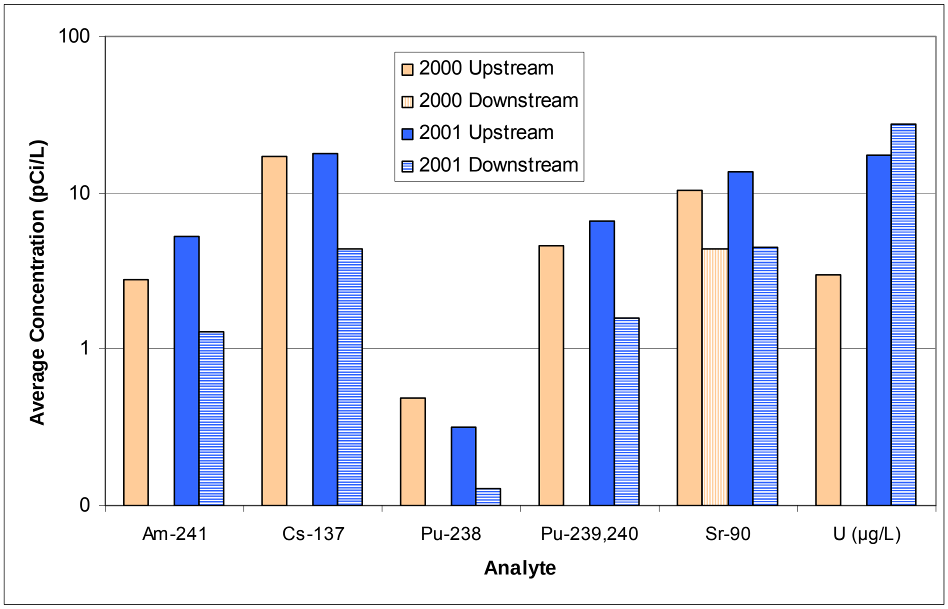


Figure 2.2.3-36. Average concentrations of radionuclides above and below the Los Alamos Canyon weir.

Figure 2.2.3-37 shows the average concentrations of calculated radionuclide concentrations in suspended sediment in storm runoff above and below the weir. In 2001 the calculated concentrations of radionuclides in suspended sediment were appreciably higher above the weir than below the weir, on average, about 2.5 times higher above the weir. The concentrations of uranium in suspended sediment were similar above and below the weir in 2001.

In summary, runoff data upstream and downstream of the Los Alamos Canyon weir indicate that the weir effectively lowered by 50% to 75% the radionuclide (except uranium) concentrations in Los Alamos Canyon storm runoff. This was accomplished by trapping a significant portion of the suspended sediment load (see Section 2.2.2.4). Calculated concentrations of radionuclides in suspended sediment below the weir were comparable to, or lower than, above the weir. This suggests that the weir trapped both fine (silts and clays) and coarser-grained (sand) sediment, because if the fine-grained sediments, which contain the highest radionuclide concentrations, were not appreciably trapped, radionuclide concentrations in suspended sediment would be expected to be higher below the weir.

2.2.3.13 Transport of Radionuclides in Storm Runoff

The detection of trends in stream water quality is difficult when concentrations in water vary with stream flow volumes and suspended sediment concentrations, which is the usual situation. This difficulty was

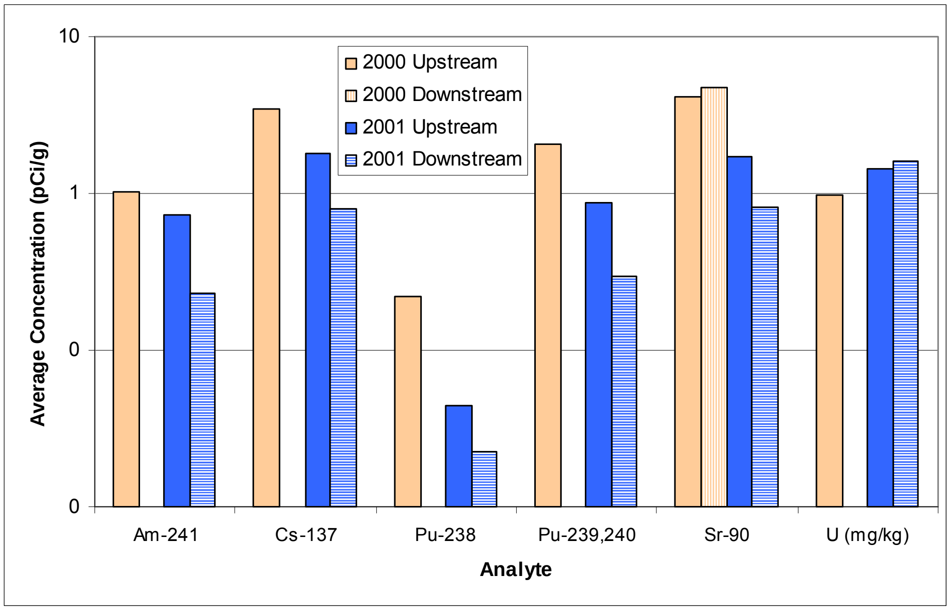


Figure 2.2.3-37. Average concentrations of radionuclides in suspended sediment, above and below weir.

amplified after the fire with a more responsive hydrologic environment and increased flows. To obtain an understanding of the trends in transport of radionuclides in runoff at Los Alamos and to evaluate the effects of runoff from fire-impacted areas during the runoff seasons after the fire, we calculated annual FWA concentrations of radionuclides in storm runoff. Sufficient historical runoff data from upstream LANL stations are not available to provide an adequate prefire/postfire comparison, thus FWA concentrations were calculated for downstream LANL stations where prefire data are available.

Figure 2.2.3-38 shows the calculated annual FWA concentrations of selected radionuclides in downstream LANL runoff (including Pueblo Canyon) from 2000 through 2003. These FWA concentrations for downstream stations may represent the typical "load" of radionuclides in a unit volume of runoff potentially entering the Rio Grande from storm runoff at LANL. The average of the prefire (1997 through 1999) yearly FWA concentrations are also shown on Figure 2.2.3-38 for comparison. Radionuclides that are observed in higher FWA concentrations after the Cerro Grande fire include cesium-137, plutonium-239,240, strontium-90, and uranium.

The radionuclide showing the largest FWA concentration increase in 2000 after the fire was cesium-137, which had a FWA concentration about one order of magnitude higher than before the fire. The measured concentrations of cesium-137 in runoff at downstream stations was similar in years 2000 through 2003 after the fire (see Figure 2.2.3-13), but the FWA concentrations decreased each year after the fire, indicating a reduced influence of runoff from fire-impacted areas.

The FWA plutonium-238 concentrations in 2000 were similar to prefire concentrations, but due to high-volume runoff events in Pueblo Canyon in 2001 and 2002, the FWA concentrations for these years are slightly higher than the prefire and 2000 average flow-weighted concentration; the FWA concentration in 2003 was similar to prefire runoff.

The annual FWA concentration of plutonium-239,240 was about two times higher in 2000 than in previous years, a result of higher concentrations in ash-laden runoff (Gallaher et al. 2002). However, the large runoff events in Pueblo Canyon in 2001, 2002, and 2003 caused the FWA concentrations of plutonium-239,240 to increase by over one order of magnitude. In 2001 the FWA concentration of plutonium-239,240 was 42 pCi/L, in 2002, the FWA was 105 pCi/L, which resulted from high-volume runoff in

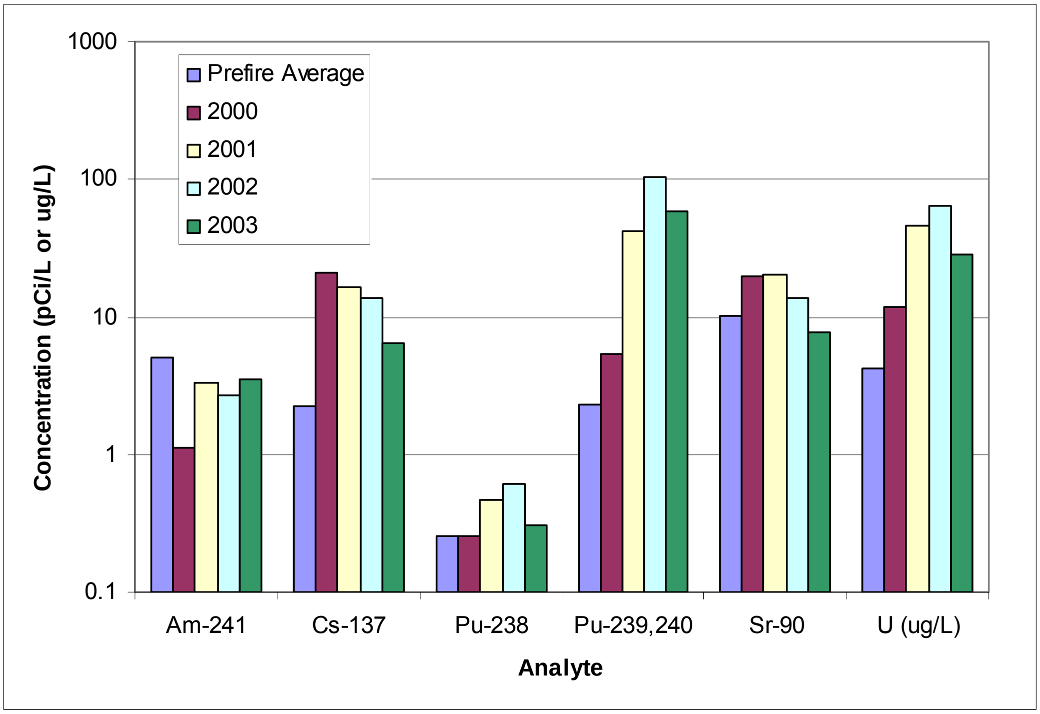


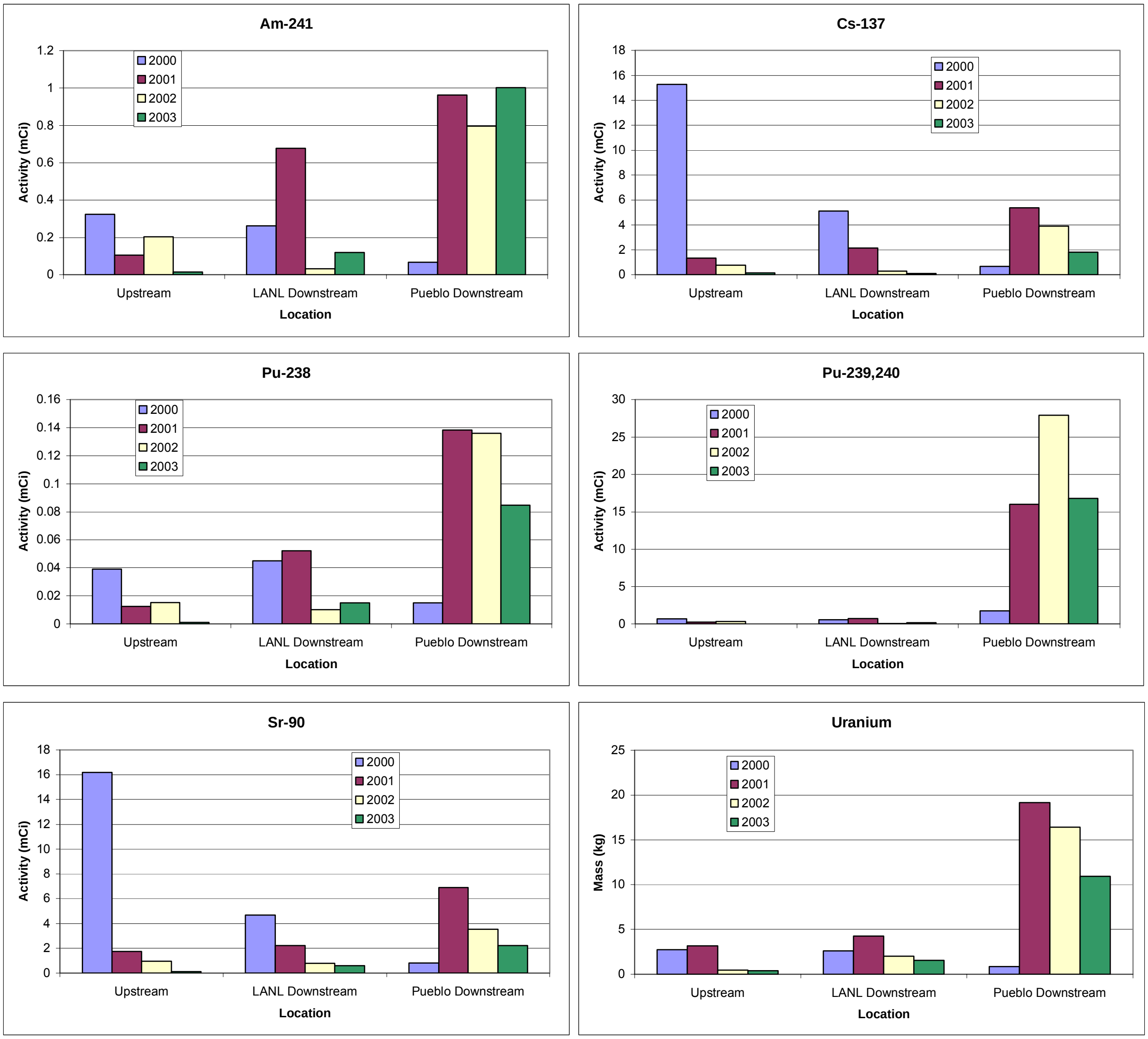
Figure 2.2.3-38. Annual FWA concentrations of radionuclides in downstream runoff, prefire and 2000–2003.

Pueblo Canyon that eroded and transported sediments containing legacy LANL contaminants. In 2003 the FWA concentration was 59.1 pCi/L, still an order of magnitude higher than in prefire years and in 2000.

The FWA concentration of strontium-90 increased by about a factor of two in 2000 and 2001, compared with the prefire concentration, but in 2002 and 2003 the concentration was comparable to the prefire average. The prefire annual average flow-weighted concentration of uranium was 4.2 µg/L. In 2000 after the fire, the FWA uranium concentration was 11.7 µg/L, an increase of about threefold. However, in 2001 and 2002, largely due to higher concentrations of uranium and higher volumes of runoff in Pueblo Canyon, the FWA concentrations increased to 45 µg/L and 65 µg/L, respectively, which is 10 to 15 times higher than observed in prefire years. In 2003 the FWA concentration of uranium was 29.3 µg/L, still higher than 2000 and prefire years.

The FWA concentrations of radionuclides are useful to compare the yearly concentrations of radionuclides in fire-impacted storm runoff; however, FWA concentrations were also used as the basis for estimating the total annual activity of radionuclides in runoff. The total activity was estimated by multiplying the annual FWA radionuclide concentration from specific locations, such as from all upstream and downstream locations, by the total volume of runoff measured at upstream and downstream gaging stations each year. As previously discussed in Section 2.1, fire-related runoff in 2000 primarily occurred in LANL streams south of Pueblo Canyon (Los Alamos Canyon southward to Water Canyon), but in 2001, 2002, and 2003 most fire-related runoff occurred in Pueblo Canyon when much less fire-related runoff occurred in other LANL streams. Therefore annual FWA concentrations and total annual activities were calculated independently for runoff from Pueblo Canyon and for combined runoff from other LANL streams.

Figure 2.2.3-39 shows the activity (in mCi) of radionuclides and the mass of uranium (in kg) that were calculated passing upstream and downstream gages at LANL south of Pueblo Canyon and past the



Note scale change on each graph.

Figure 2.2.3-39. Calculated activity of radionuclides in runoff at upstream and downstream locations, 2000–2003.

Pueblo Canyon downstream gage. Significantly higher activities of cesium-137 (15.3 mCi) and strontium-90 (16.2 mCi) in upstream LANL runoff in 2000 reflect the increased load of ash in runoff from fire-impacted areas that contained these radionuclides. Lower activities of these radionuclides at downstream locations in 2000 indicate that most of the activity (and ash) was deposited in LANL watersheds south of Pueblo Canyon. The activities of cesium-137 and strontium-90 declined each year since 2000 at both upstream and downstream LANL locations, reflecting the decreased impact of fire-related runoff after the fire.

The high-volume runoff events in Pueblo Canyon in 2001, 2002, and 2003 resulted in significant transport of radionuclides present in canyon sediments from historic LANL discharges, most notably, plutonium-239,240. In 2001, about 16.0 mCi, in 2002, about 27.9 mCi, and in 2003, about 16.8 mCi plutonium-239,240 is estimated to have been transported in suspended sediment downstream from Pueblo Canyon storm runoff. These estimates correspond well with numerical modeling results of postfire plutonium bed load and suspended load transport in Pueblo Canyon (Wilson et al. 2003) and with NMED estimates of transport in suspended sediment (Ford-Schmid and Englert 2004). For the four years since the Cerro Grande fire (2000 through 2003), an estimated total of 62.4 mCi of plutonium-239,240 was transported downstream in suspended sediment from Pueblo Canyon. Given the estimated inventory of 1.1 Ci of plutonium-239,240 reported by Reneau et al. (2003b) in Acid and Pueblo Canyons in 2000, the estimated amount suspended sediment transported represents about 5.7% of the inventory.

With the exception of cesium-137 and strontium-90, which were concentrated in the ash in 2000 runoff, transport of radionuclides from Pueblo Canyon in 2001, 2002, and 2003 surpassed the downstream transport of radionuclides from all LANL drainages in 2000. The activities of cesium-137 and strontium-90 declined each year since 2001 in Pueblo Canyon runoff, reflecting the decreased impact of fire-related runoff since the large runoff event in 2001 in that canyon.

The masses of uranium in runoff at upstream (2.7 kg) and downstream stations (2.6 kg) at LANL in 2000 were approximately similar, indicating that the uranium was carried in the high-volume runoff from fire-impacted areas rather than from LANL sources. The mass of uranium in Pueblo Canyon runoff in 2001 was about four times higher than in all other LANL canyons combined, although storm runoff in Pueblo Canyon in 2001 was only about 1.4 times the combined storm runoff of the other LANL canyons. The mass of uranium in runoff declined each year since 2001 in both Pueblo Canyon and the LANL canyons. As shown later in this section, the uranium in runoff can primarily be attributed to natural sources rather than to LANL sources.

Table 2.2.3-6 and Figure 2.2.3-40 show the estimated annual difference in the activity of radionuclides between upstream and downstream locations in LANL streams. A positive value indicates that more activity flowed onto LANL than flowed downstream of LANL, and a negative value indicates that more activity flowed downstream of LANL than flowed onto LANL. In 2000 after the fire more activity of each radionuclide flowed onto LANL than flowed downstream. An estimated total of about 10.2 mCi cesium-137 and 11.5 mCi strontium-90 was deposited in LANL streams and floodplains in 2000. However, in 2001, the activity of radionuclides in downstream runoff was higher than in upstream runoff, suggesting that some of the ash and muck deposited in LANL streams and floodplains in 2000 may have been remobilized and transported in subsequent years.

Table 2.2.3-6. Calculated Difference in Activity of Radionuclides in Runoff at Upstream and Downstream LANL Locations (upstream minus downstream; excludes Pueblo Canyon).

Year	Am-241 (mCi)	Cs-137 (mCi)	Pu-238 (mCi)	Pu-239,240 (mCi)	Sr-90 (mCi)	U (kg)
2000	0.061	10.16	-0.006	0.124	11.50	0.12
2001	-0.572	-0.81	-0.040	-0.516	-0.47	-1.08
2002	0.170	0.48	0.005	0.282	0.17	-1.54
2003	-0.104	0.06	-0.014	-0.154	-0.47	-1.16
4-yr Total	-0.444	9.88	-0.055	-0.264	10.74	-3.65

Because upstream flow data are not available for Pueblo Canyon, only the main drainages at LANL are represented on Figure 2.2.3-40 (note that downstream activity in Pueblo Canyon represents the bulk of activity of radionuclides in 2001, 2002, and 2003 see Figure 2.2.3-39).

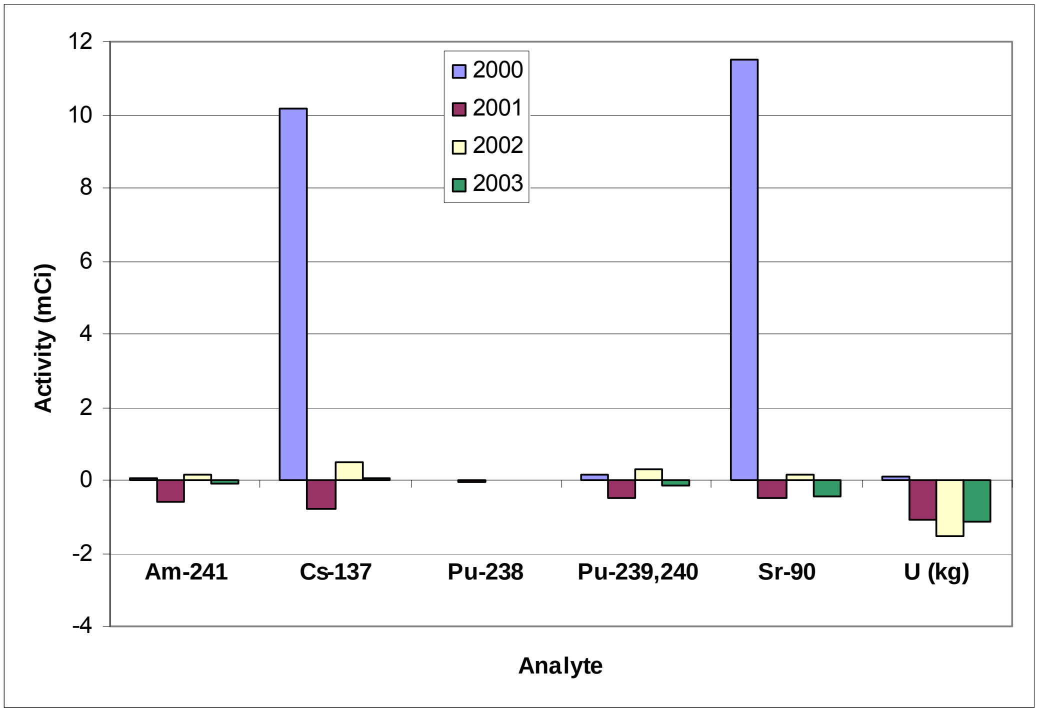


Figure 2.2.3-40. Calculated difference in activity of radionuclides in runoff at upstream and downstream LANL locations (upstream minus downstream; excludes Pueblo Canyon).

Table 2.2.3-6 and Figure 2.2.3-40 show that in 2000 after the fire, it is estimated that over 10 mCi of both cesium-137 and strontium-90 were deposited in stream channels and floodplains at LANL. Slightly more activity of americium-241 and plutonium-239,240, and about 0.12 kg of uranium were deposited on LANL in 2000 after the fire. It was previously demonstrated by Gallaher et al. (2002) that in 2000 most of the ash eroded from the burned areas was deposited in Pajarito Canyon and Water Canyon at LANL. The Los Alamos Reservoir in upper Los Alamos Canyon provided a catchment for runoff from burned areas in the upper part of that watershed and effectively trapped sediment and associated radionuclides, thereby reducing the amount of material downstream in Los Alamos Canyon.

In 2001, more activity of each radionuclide flowed downstream in LANL streams south of Pueblo Canyon than came onto LANL in upstream runoff. In 2001, approximately 0.8 mCi more cesium-137, 0.5 mCi more of plutonium-239,240, and strontium-90, and 1 kg more uranium flowed downstream from LANL south of Pueblo Canyon than came onto LANL. This may reflect the erosion and transport of some ash and muck material from LANL that was deposited in 2000, and/or may be the result of precipitation and runoff events that occurred more often over the Pajarito Plateau in 2001 than over the Sierra de los Valles (e.g., Koch et al. 2002).

In LANL streams south of Pueblo Canyon in 2002, slightly more activity of americium-241 (0.17 mCi), cesium-137 (0.48 mCi), plutonium-239,240 (0.28 mCi), and strontium-90 (0.17 mCi) occurred in upstream runoff than occurred in downstream runoff; however, the high activities of cesium-137 and strontium-90 observed in 2000 were not evident. More uranium was contained in downstream runoff in 2001 (1 kg) and 2002 (1.5 kg) than was in upstream runoff, suggesting source of uranium in runoff originated at LANL, or reflecting a difference in natural bedrock uranium content between upstream and downstream locations (e.g., Ryti et al. 1998).

Figure 2.2.3-41 shows the total estimated activity of radionuclides and uranium in unfiltered downstream runoff (including Pueblo Canyon) from 2000 through 2003 and the prefire average annual activity for the years 1997 through 1999. The radionuclides that show significant increased total activity in storm runoff at

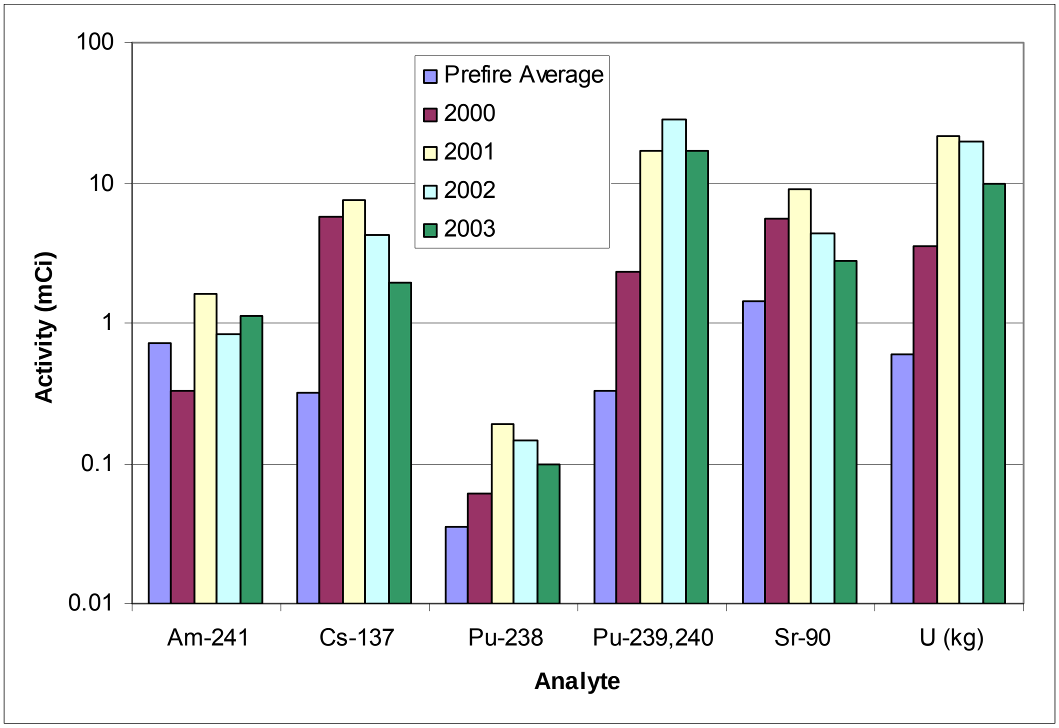


Figure 2.2.3-41. Estimated total annual activity of radionuclides in all downstream runoff (including Pueblo Canyon), 2000–2003.

downstream locations in 2000 after the fire include cesium-137, plutonium-238, plutonium-239,240, strontium-90, and uranium. The highest yearly activity for each radionuclide in downstream runoff was 7.6 mCi of cesium-137 in 2001, 0.2 mCi of plutonium-238 in 2001, 28.0 mCi of plutonium-239,240 in 2002, and 9.1 mCi of strontium-90 in 2001. The maximum annual mass of uranium in downstream runoff was 21.7 kg in 2001.

The increase in activity in 2000 over prefire averages is mainly due to ash-laden runoff that occurred in canyons at LANL. However, in 2001, 2002, and 2003, the transport of radionuclides was associated with high-volume runoff from Pueblo Canyon that included fire-related impacts (mainly cesium-137 and strontium-90), but also included significant amounts of contaminant-laden sediment that primarily contained plutonium-239,240 and lesser amounts of americium-241 and plutonium-238.

Storm runoff also contains radionuclides and uranium that can be attributed to background levels from atmospheric fallout and natural concentrations in bedrock units and stream sediment. The background levels of radionuclide activity and uranium mass were approximated in downstream runoff using the annual mass of suspended sediment in runoff (see Section 2.2.2.3) and the stream sediment Bvs (upper limit) determined by Ryti et al. (1998). This approximation method may overestimate activity attributable to background concentrations because the BV is the estimated upper limit of background concentrations. On the other hand, this approximation method may somewhat underestimate the total mass attributable to background because the relatively finer-grained suspended material transported in storm runoff likely contains higher concentrations of radionuclides relative to streambed sediments.

The annual total activities of radionuclides in runoff at downstream locations were divided by the calculated annual background levels resulting from the transport of suspended sediment to obtain the annual ratio of radionuclide activity in runoff to that attributable to background levels; the resulting ratio is shown in Figure 2.2.3-42. A ratio greater than one indicates that activities are greater than can be attributed to the natural stream sediment load, while a ratio less than one indicates that activities observed in runoff could be within background levels.

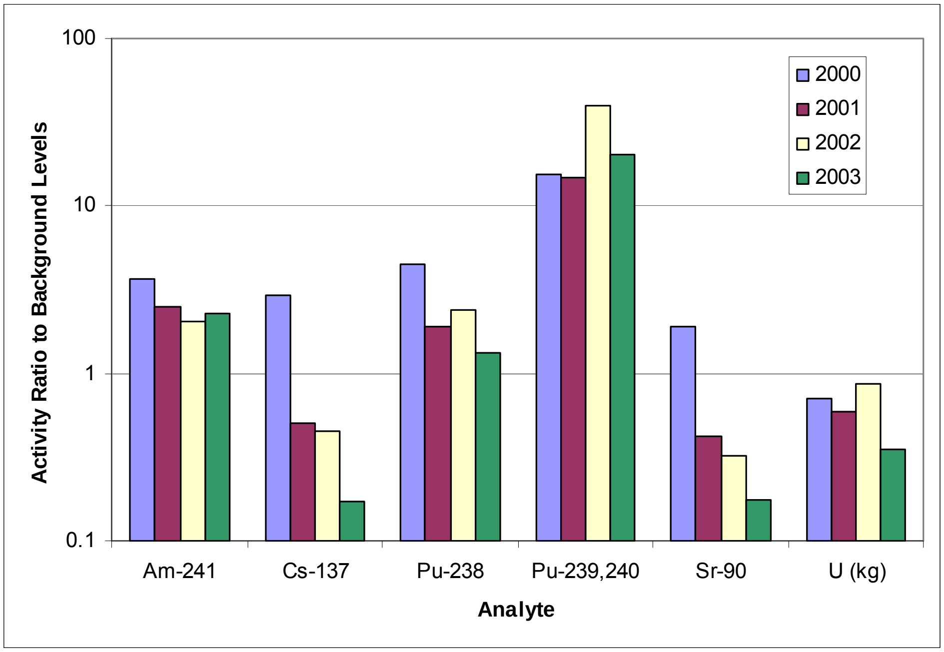


Figure 2.2.3-42. Ratio of estimated radionuclide activity to upper bound on background levels in downstream runoff (including Pueblo Canyon).

The downstream runoff data indicate that in 2000 after the fire, runoff contained above-background levels of americium-241, cesium-137, plutonium-238, plutonium-239,240, and strontium-90. In 2001 and subsequent years, the ratio of cesium-137 and strontium-90 to background levels is <1, indicating that the activity of these radionuclides may possibly be attributable to background concentrations and showing that the elevated concentrations of these radionuclides in runoff from fire-impacted areas occurred in the first months following the fire and not in subsequent years. The mass of uranium in runoff after the fire may be attributed to natural background concentrations. The ratios of americium-241, plutonium-238, and plutonium-239,240 all remained >1 in the years after the fire, indicating that these radionuclides are present in Los Alamos area drainages as the result of legacy discharges from LANL.

Although some of the radionuclides continued to be above background levels in Los Alamos area storm runoff, a portion of the activity can be attributed to background sediment values. Table 2.2.3-7 shows the percentage of the activity in downstream runoff that may be attributable to background levels in suspended sediment. In 2000, up to 34% of the cesium-137 and up to 53% of the strontium-90 in downstream runoff may be attributable to background levels; the portion of the activity not attributable to background concentrations in suspended sediment in 2000 was largely attributable to the effects of the Cerro Grande fire for cesium-137 and strontium-90. This is mainly due to contribution of the large ash-laden June 28, 2000, runoff event in Pajarito and Water Canyons. However, because such a small portion of plutonium-239,240 (2% to 7%) is attributable to background values in sediment, in comparison with the

Table 2.2.3-7. Percentage of Activity in Downstream Runoff Possibly Attributable to Natural Sediment Background Levels.

Year	Am-241	Cs-137	Pu-238	Pu-239,240	Sr-90	U (kg)
2000	27%	34%	22%	7%	53%	100%
2001	41%	100%	52%	7%	100%	100%
2002	50%	100%	42%	2%	100%	100%
2003	44%	100%	74%	5%	100%	100%

other fallout radionuclides, available data indicate that much of the plutonium-239,240 in the Cerro Grande fire runoff is LANL-derived (see Section 2.2.3.7). The mass of uranium contained in downstream runoff is probably attributable to background levels.

In 2001, 2002, and 2003, the total activities of cesium-137, strontium-90, and uranium in downstream runoff were possibly attributable to background levels in steam sediments, but americium-241, plutonium-238, and plutonium-239,240 were above background levels, largely due to runoff from Pueblo Canyon. The radionuclide in runoff that was highest above background levels was plutonium-239,240, which ranged from 15 to 40 times higher than background levels. In 2002, however, up to 50% of the americium-241 and 42% of the plutonium-238 was attributable to background levels.

2.2.3.14 Summary of Radionuclides in Storm Runoff and Related Fire Impacts

After the Cerro Grande fire, storm runoff from areas impacted by the fire contained cesium-137 and plutonium-239,240 in significantly higher concentrations than before the fire; other radionuclides and analytes that showed increased concentrations included gross alpha and gross beta activity and plutonium-238. Radionuclide concentrations significantly higher in 2001 and 2002 when runoff was primarily from Pueblo Canyon include gross alpha, gross beta, and plutonium-239,240.

Higher concentrations of cesium-137, plutonium-238, plutonium-239,240, and strontium-90 occurred in 2000 after the fire than previously; these concentrations were primarily related to runoff from areas impacted by the Cerro Grande fire. The most pronounced increases of radionuclide concentrations in runoff were observed for cesium-137, with samples exceeding the LANL-wide historical maximums by as much as 10 times. The increases in most of the radionuclide concentrations directly after the fire are attributable to two main factors: 1) increased ash and sediment load in runoff and 2) the enhanced constituent concentrations in the ash (see LANL 2000b;Johansen et al. 2003; Katzman et al. 2001, 2002; LANL 2004). High-volume runoff in Pueblo Canyon in 2001 and 2002 contained significantly higher concentrations of plutonium-239,240 that resulted from suspension and transport of contaminant-laden sediment in Pueblo Canyon. From 2000 through 2003, 20 runoff events contained greater than 15 pCi/L plutonium-239,240, of which 17 events were in Pueblo Canyon.

There is a suggestion of possible fire-related impacts associated with uranium in runoff at upstream sites; however, higher concentrations of uranium in runoff at onsite and downstream locations in some canyons at LANL suggest a LANL contribution. The gross beta activity data suggest that the higher activities in runoff were not associated with ash and muck immediately after the fire, but were probably the result of higher sediment loads containing eroded soil and sediment materials 1 to 2 years after the fire. By 2003, storm runoff in the Los Alamos area contained significantly lower concentrations of radionuclides (except uranium), indicating reduced impacts of the fire and that most of the primary and secondary effects of the Cerro Grande fire had been ameliorated.

Radionuclide concentrations were significantly lower in filtered samples than in unfiltered samples. About 75% to 95% of the radioactivity in a runoff sample was typically associated with the suspended sediments (ash, silt, clay, etc.) and carried by the runoff rather than dissolved in the water.

Radionuclides present in higher concentrations in suspended sediment in downstream runoff after the fire included cesium-137, plutonium-238, plutonium-239,240, strontium-90, and gross beta activity. The concentration of plutonium-239,240 in suspended sediment was about an order of magnitude higher in 2001 and 2002 than in prefire years, largely due to the high-volume runoff from Pueblo Canyon and the absence of sampled runoff and floods in years preceding the fire. Concentrations of cesium-137, plutonium-238, and strontium-90 in suspended sediment declined each year after the fire, probably due to reduced amounts of ash in runoff from fire-impacted areas. The higher concentrations of uranium in suspended sediment originate within LANL, possibly related to secondary effects of the Cerro Grande fire related to higher flow volumes in major canyons that drain firing sites; the higher flow volumes may have caused erosion and re-suspension of legacy LANL uranium that was present in stream sediments, although median concentrations of uranium in upstream and downstream runoff are similar.

Suspended sediment in downstream runoff after the fire contained above background concentrations of americium-241, cesium-137, plutonium-238, plutonium-239,240, and strontium-90. However, in 2000, up to 27% of the americium-241, 34% of the cesium-137, and 53% of the strontium-90 in downstream runoff was possibly attributable to background levels, whereas only 7% of the plutonium-239,240 was possibly attributable to background levels. The mass of uranium contained in downstream runoff from 2000 through 2003 was within background levels, and from 2001 through 2003, the total activities of cesium-137 and strontium-90 in downstream runoff were within background levels, but americium-241, plutonium-238, and plutonium-239,240 were above background levels, largely due to runoff from Pueblo Canyon.

Evidence for substantial fire impacts on concentration of radionuclides in runoff includes the following:

- The highest concentrations of some radionuclides, such as cesium-137 and strontium-90, were collected from locations located upstream of LANL or from Rendija and Guaje Canyons north of LANL.
- Gross alpha activities in unfiltered runoff upstream of LANL show that the storm runoff flowing onto LANL after the fire contained about one order of magnitude higher levels than before the fire.
- Gross beta activities in unfiltered runoff upstream of LANL show that the storm runoff flowing onto LANL after the fire contained about two orders of magnitude higher levels than before the fire.
- Cesium-137 and strontium-90 concentrations show a decline through the 2000 runoff season and in the years 2001 through 2003, presumably as the source of ash on the burned areas upstream of LANL was depleted and the ash and muck in flood deposits was stabilized in floodplain and bank deposits and/or flushed downstream.

The introduction of fire-derived radionuclides, especially cesium-137 and strontium-90, into most of the LANL watercourses in 2000 apparently masked the impact of similar Laboratory-derived constituents. Essentially, the “background” levels for many constituents significantly changed as result of the addition of the ash in the runoff. For most of the canyon runoff samples collected in 2000, LANL impacts are not clearly discernible because of the higher radionuclide concentrations in the ash.

Consistent with prefire conditions, LANL impacts to storm runoff were first indicated in Pueblo Canyon and Los Alamos Canyon in early 2000 runoff events. LANL impacts are identifiable in the first significant runoff events in 2000 in Los Alamos Canyon and throughout 2001 and 2002 for americium-241 and plutonium-239,240, and, to a lesser extent, plutonium-238. Higher onsite and downstream concentrations of uranium in Los Alamos, Pajarito, and Water Canyons indicate a possible contribution from historic LANL activities in these watersheds at LANL.

Unfiltered runoff samples did not contain concentrations of cesium-137, tritium, strontium-90, or uranium greater than the EPA primary drinking water standards. Total gross alpha concentrations were greater than public dose DCG levels (30 pCi/L) and State of New Mexico livestock watering standards (15 pCi/L) at many locations upstream and on LANL. The gross alpha DCG is based on the most restrictive anthropogenic alpha emitters (plutonium-239,240 and americium-241) and is commonly exceeded by runoff laden with naturally derived alpha emitters (such as the uranium-decay series). The median detected value of gross alpha activity in all runoff after the fire was 201 pCi/L, over 13 times the 15 pCi/L standard value.

The gross beta activity DCG for public dose (1000 pCi/L) was exceeded in samples from a total of 24 runoff events in the three years after the fire, one event in 2000 (Rendija Canyon), 10 events in 2001 (from five canyons), and 13 events in 2002 (from five canyons). The highest gross beta activity was 6210 pCi/L in 2002 in a sample collected by NMED on July 25, 2002, from Pueblo Canyon upstream of Acid Canyon. Seven of 27 (26%) runoff samples that contained gross beta activity greater than 1000 pCi/L were from locations upstream of LANL. The gross beta activity data suggest that the higher gross beta activities in runoff were not associated with ash immediately after the fire, but were likely the result of higher sediment loads containing eroded soil and sediment materials one to two years after the fire. All runoff sampled in 2003, three years after the fire, contained less than 1000 pCi/L gross beta activity, similar to prefire years.

In filtered samples, concentrations of americium-241, cesium-137, gross alpha, plutonium-238, and uranium were not more than the minimum standard and guideline values. All filtered storm water runoff samples collected from major drainages associated with fire-impacted areas met EPA and DOE drinking water standards and guidelines for specific radionuclides. One filtered runoff sample from Mortandad Canyon in October 2000 contained 51.3 pCi/L gross beta activity, slightly greater than the 50 pCi/L EPA screening level. One runoff sample collected from the south fork of Acid Canyon in 2000 (not fire related) contained 16.4 pCi/L plutonium-239,240, slightly above the EPA primary drinking water standard and the NMWQCC livestock watering standard for gross alpha (NMWQCC 2002). A cleanup was performed in Acid Canyon by the LANL ER Project in 2001 (Reneau et al. 2002). Filtered runoff samples collected in lower Pueblo Canyon in 2003 contained up to 0.222 pCi/L plutonium-239,240.

Several filtered runoff samples collected downstream of disposal sites at LANL contained strontium-90 concentrations greater than the EPA primary drinking water standard of 8 pCi/L. The highest dissolved concentration of strontium-90 in storm runoff was 9.8 pCi/L in a sample collected from Acid Canyon (not fire affected) in September 2000. Acid Canyon was the site of a cleanup action by the LANL ER Project in 2001. In canyons not affected by the fire, a dissolved concentration of 9.7 pCi/L strontium-90 was measured in a runoff sample collected in Mortandad Canyon in October 2000, and a runoff sample from DP Canyon in June 2001 contained 8.77 pCi/L strontium-90. Additionally, a surface water sample from Los Alamos Canyon collected on July 21, 2000, from the Los Alamos Canyon weir construction site contained 26.6 pCi/L dissolved strontium-90. The weir was installed in 2000 after the fire in Los Alamos Canyon as a sediment catchment structure. The sample was collected from water pumped from the weir several days after a runoff event (see Koch et al. 2001). The source of the dissolved strontium-90 in this sample could be fire-related or from historical Laboratory releases.

Radionuclides that were observed in higher FWA concentrations in runoff in 2000 after the Cerro Grande fire than before the fire include cesium-137, plutonium-239,240, strontium-90, and uranium. Of these, the FWA concentrations of cesium-137 and strontium-90 declined significantly in subsequent years, reflecting the relationship with fire-related ash in runoff. The annual FWA concentration of plutonium-239,240 was slightly higher in 2000 than in previous years, a result of higher concentrations in ash-laden runoff (Gallaher et al. 2002). However, the large runoff events in Pueblo Canyon in 2001, 2002, and 2003 caused the FWA concentrations of plutonium-239,240 to increase by over one order of magnitude. In 2001 the FWA concentration of plutonium-239,240 was 42 pCi/L, in 2002, 105 pCi/L, and in 2003, 59 pCi/L; these elevated concentrations resulted from high-volume runoff in Pueblo Canyon that eroded and transported sediments containing legacy LANL contaminants.

The FWA concentration of strontium-90 increased by about a factor of two in 2000 and 2001, compared with the prefire concentration, but in 2002 and 2003, the concentration was comparable to the prefire average. In 2000 after the fire, the FWA uranium concentration was 11.7 µg/L, an increase of about threefold when compared with the prefire average concentration. However, in 2001, 2002, and 2003, largely due to higher concentrations of uranium and higher volumes of runoff in Pueblo Canyon, the FWA concentrations increased to 45 µg/L, 65 µg/L, and 28 µg/L, respectively, which was 10 to 15 times higher than observed in prefire years. Because higher concentrations of uranium were not observed at upstream locations and in runoff from Guaje and Rendija Canyons, the higher FWA uranium concentrations appear to have originated from resuspension and transport of uranium in sediments in canyons at LANL that contained legacy LANL uranium.

The radionuclides that show significant increased total activity in storm runoff at downstream locations in 2000 after the fire include cesium-137, plutonium-238, plutonium-239,240, strontium-90, and uranium. Higher activities of cesium-137 and strontium-90 in upstream runoff in 2000 reflect the load of ash in runoff from fire-impacted areas. In 2000 after the fire an estimated 10.2 mCi of cesium-137 and 11.5 mCi of strontium-90 were deposited in stream channels and floodplains at LANL south of Pueblo Canyon.

The high-volume runoff from Pueblo Canyon in 2001 and 2002 resulted in the transport of radionuclides, especially plutonium-239,240; in 2001 about 16 mCi, in 2002, about 28 mCi, and in 2003, about 17 mCi of plutonium-239,240 were estimated to have been transported downstream from Pueblo Canyon in suspended sediment. With the exception of cesium-137 and strontium-90, which were concentrated in the ash in 2000 runoff, transport of radionuclides from Pueblo Canyon in 2001, 2002, and 2003 surpassed the fire-related downstream transport of radionuclides from LANL in 2000.

The highest estimated annual activity of each radionuclide in suspended sediment in downstream runoff was 7.6 mCi of cesium-137 in 2001, 0.2 mCi of plutonium-238 in 2001, 28.0 mCi of plutonium-239,240 in 2002, and 9.1 mCi of strontium-90 in 2001. The estimated maximum annual mass of uranium in downstream runoff was 21.7 kg in 2001. In 2001, 2002, and 2003, the estimated total activities of cesium-137, strontium-90, and uranium in downstream runoff were possibly attributable to background levels in stream sediments. The radionuclide in runoff that was highest above background levels was plutonium-239,240, which ranged from 15 to 40 times higher than background levels after the fire. By 2003, however, over 40% of the americium-241 and over 70% of the plutonium-238 was possibly attributable to background levels.

2.2.4 Minor Constituents in Storm Runoff

2.2.4.1 Summary of Sampling and Analysis for Minor Constituents in Storm Runoff

Minor constituents include trace elements and metals as described by Hem (1985). Minor constituent analyses were performed on a total of 296 unfiltered runoff samples and 235 filtered runoff samples in major drainages from 2000–2003. Table 2.2.4-1 summarizes the number of filtered and unfiltered samples that were analyzed for minor constituents by LANL WQH and NMED for the years 2000 through 2003.

Table 2.2.4-1. Summary of Samples Collected for Minor Constituents Analyses in Storm Runoff, 2000–2003.

	LANL WQH		NMED		Totals	
Year	Unfiltered Samples	Filtered Samples	Unfiltered Samples	Filtered Samples	Unfiltered Samples	Filtered Samples
2000	65	43	19	41	84	84
2001	71	68	17	17	88	85
2002	65	32	21	21	86	53
2003	35	13	3	0	38	13
Total	236	156	60	79	296	235

Table 2.2.4-2 summarizes the number of analyses performed for each metal constituent from 2000 through 2003 and the numbers of detections and non-detections. Because duplicates of some samples were analyzed, results are available for more than the number of samples collected; the data in Table 2.2.4-2 represent the total number of results obtained for each metal constituent. On average, minor constituents were detected in 69% of unfiltered samples and in 32% of filtered samples.

The summary of minor constituent concentrations in storm runoff from 2000 through 2003, including the minimum, maximum, and median concentrations of each metal detected in runoff samples are shown in Table 2.2.4-3.

As with radionuclide constituents, the concentrations of minor constituents in unfiltered runoff samples are typically higher than in the dissolved state. The minor constituents that were measured at much higher (about 100 times) concentrations in unfiltered samples compared with filtered samples include aluminum, beryllium, cobalt, lead, and iron. Most other minor constituent concentrations were between about two times and 50 times higher in unfiltered samples compared with filtered samples. The concentrations of most minor constituents in unfiltered runoff generally correspond with TSS concentrations. Minor constituents in unfiltered samples that do not have an apparent correlation with TSS concentrations include boron, molybdenum, antimony, selenium, tin, titanium, thallium, and zinc; these constituents are usually measured at or near their respective detection limits in runoff.

Table 2.2.4-2. Summary of Minor Constituent Analyses in Storm Runoff, 2000–2003.

	Unfiltered Samples				Filtered Samples			
Analyte	No. Analyses	No. Detects	No. Non-Detects	% Detects	No. Analyses	No. Detects	No. Non-Detects	% Detects
Ag	324	42	282	13	275	9	266	3
Al	285	281	4	99	274	215	59	78
As	324	254	70	78	275	57	218	21
B	265	120	145	45	244	30	214	12
Ba	278	275	3	99	274	243	31	89
Be	335	241	94	72	313	8	305	3
Cd	345	236	109	68	269	12	257	4
Co	278	232	46	83	274	44	230	16
Cr	278	237	41	85	274	39	235	14
Cu	281	267	14	95	274	85	189	31
Fe	294	290	4	99	278	230	48	83
Hg	302	75	227	25	233	1	232	0
Li	45	36	9	80	50	6	44	12
Mn	278	278	0	100	274	230	44	84
Mo	248	36	212	15	223	20	203	9
Ni	278	237	41	85	274	53	221	19
Pb	333	324	9	97	286	93	193	33
Sb	287	24	263	8	286	48	238	17
Se	323	95	228	29	249	34	215	14
Sn	225	28	197	12	203	5	198	2
Sr	270	270	0	100	240	240	0	100
Ti	117	108	9	92	99	33	66	33
Tl	244	117	127	48	243	27	216	11
V	278	260	18	94	274	96	178	35
Zn	287	283	4	99	273	186	87	68
Total/Avg	6802	4646	2156	69	6231	2044	4187	32

2.2.4.2 Comparison with Historic Data

The minor constituent concentrations measured in runoff from 2000 through 2003 are compared with maximum historic concentrations to provide an assessment of metals in fire-related runoff with prefire maximum concentrations. Figure 2.2.4-1 shows the range of minor constituent concentrations observed in unfiltered runoff from 2000 through 2003 and the historic maximum minor constituent concentrations observed from 1997 through 1999. The maximum concentrations of most minor constituents in unfiltered runoff after 2000 were higher than historically observed. Minor constituent concentrations significantly higher (greater than one order of magnitude) in postfire runoff include silver, arsenic, boron, cobalt, chromium, manganese, nickel, tin, strontium, thallium, vanadium, and zinc. Minor constituents in unfiltered runoff that were not significantly higher than historic maximums were cadmium, mercury, molybdenum, antimony, and selenium. Laboratory method detection limits for minor constituent analyses in 2000 were lower than previous years, which likely influenced the results of minor constituents that occur at or near detection limits such as mercury, antimony, and selenium.

Figure 2.2.4-2 shows the range of dissolved minor constituent concentrations observed in runoff from 2000 through 2003 and the historic maximum dissolved minor constituent concentrations observed in filtered runoff from 1997 through 1999. The maximum concentrations of dissolved minor constituents in runoff after the fire that were higher than historically observed include arsenic, barium, cadmium, copper, manganese, molybdenum, antimony, selenium, strontium, and zinc. The minor constituent that was in concentrations one order of magnitude greater than historically observed was antimony; however, all concentrations of antimony greater than 11 µg/L were from a Twomile Canyon tributary at TA-3 sampler, which was installed in 2002, and where runoff is not related to the Cerro Grande fire.

Table 2.2.4-3. Summary of Detects of Minor Constituents in Storm Runoff, 2000–2003.

	Unfiltered Samples			Filtered Samples		
	Minimun (µg/L)	Median (µg/L)	Maximum (µg/L)	Minimun (µg/L)	Median (µg/L)	Maximum (µg/L)
Ag	1.06	13.7	307	0.09	0.49	15
Al	73.4	84000	1500000	3.5	620	19900
As	3.58	25.2	330	0.4	2.45	22.2
B	50.7	119	2700	50.5	101.2	210
Ba	17.7	2000	29800	8.83	67.3	5210
Be	0.22	15.25	190	0.039	0.1	7.24
Cd	0.05	3.92	57.3	0.06	0.262	22.9
Co	5.43	57.6	1100	0.05	0.18	28.3
Cr	5.18	79.4	1230	0.15	1.24	8.08
Cu	5.55	93.0	1300	0.55	5.39	70.7
Fe	110.0	61848	1300000	29	398	9240
Hg	0.051	0.465	6.3	0.08	0.08	0.08
Li	16.0	109.5	1400	0.3	6.42	10
Mn	50.0	6650	102000	1.26	132	12200
Mo	6.40	20.0	82.793	2.32	16.05	82.6
Ni	5.17	78.4	1300	0.46	2.55	21.7
Pb	2.49	135.7	3000	0.055	0.79	77.1
Sb	0.43	11.43	109	0.08	0.52	97.5
Se	5.10	10.45	145	0.1	0.3	5.2
Sn	10.4	22.65	561.977	0.12	0.68	29.4
Sr	14.7	473	410000	8.92	106.5	1770
Ti	0.51	171	2980	0.026	9.69	157
Tl	0.13	2.37	47.6	0.02	0.06	0.935
V	6.28	114.5	1800	0.9	5.38	17.4
Zn	2.94	642	47000	0.635	14.6	2600

The concentrations of most minor constituents in filtered runoff after the fire were lower than historically observed maximums, largely due to implementing laboratory methods utilizing lower detection limits in 2000 and later years. Dissolved mercury, selenium, and titanium had not previously been detected in filtered historic runoff samples, but due to the lower detection methods used in 2000, dissolved mercury was detected in one sample, selenium was detected in 31 samples, and titanium was detected in 29 samples.

2.2.4.3 Comparison with Current Reference Standards

The concentrations of minor constituents in unfiltered storm water runoff were compared with the livestock watering standards and the wildlife habitat standards (NMWQCC 2002). The quality of filtered storm runoff was compared with the NMWQCC groundwater standards because of the possibility of seepage of dissolved constituents from the streambed into underlying shallow groundwater.

Figure 2.2.4-3 shows the comparison of total concentrations of mercury and selenium in unfiltered storm runoff to standards for mercury (0.77 µg/L) and selenium (5 µg/L). Of 302 analyses of mercury in runoff by LANL and NMED, 27 samples (9%) contained total concentrations greater than the standard value. These samples were obtained from 18 runoff events, five events containing concentrations greater than the standard value were from Pueblo Canyon (2002 and 2003 only), four events were in Sandia Canyon (2003 only), three events were in Los Alamos Canyon, two were from Guaje Canyon, and one each from Ancho, Cañada del Buey, and Water Canyons. The highest concentration of total mercury (6.3 µg/L) was in a runoff sample collected from Pueblo Canyon above Acid Canyon in July 2002; all concentrations greater than 1.5 µg/L were from Pueblo Canyon or Los Alamos Canyon. Mercury has been shown to be

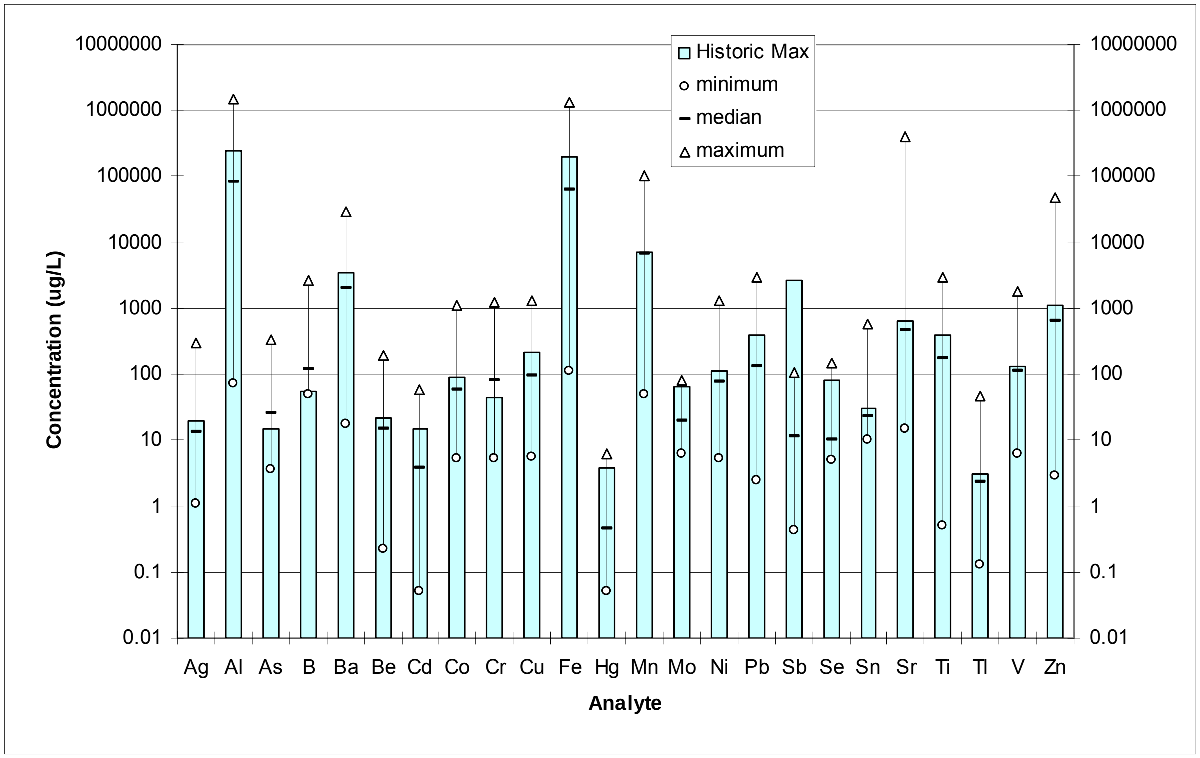


Figure 2.2.4-1. Minor constituent concentrations in unfiltered postfire storm runoff compared with historic maximum concentrations.

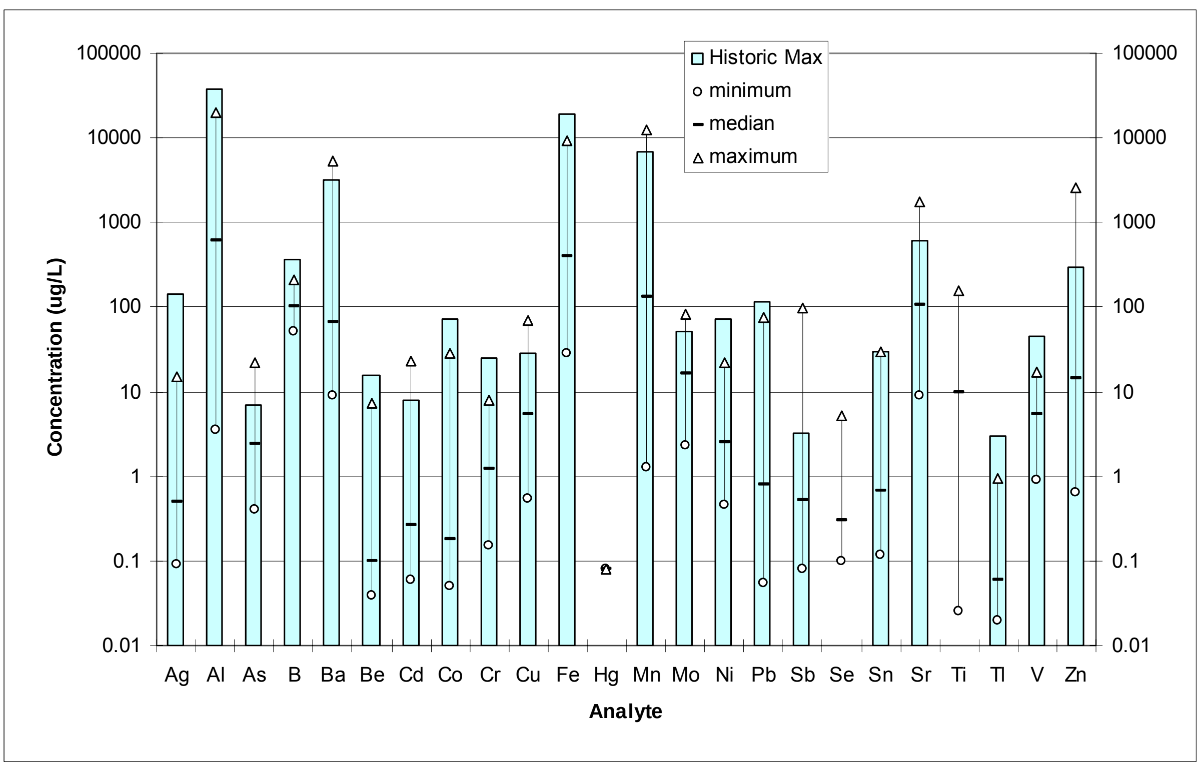


Figure 2.2.4-2. Minor constituent concentrations in filtered storm runoff compared with historic maximum concentrations.

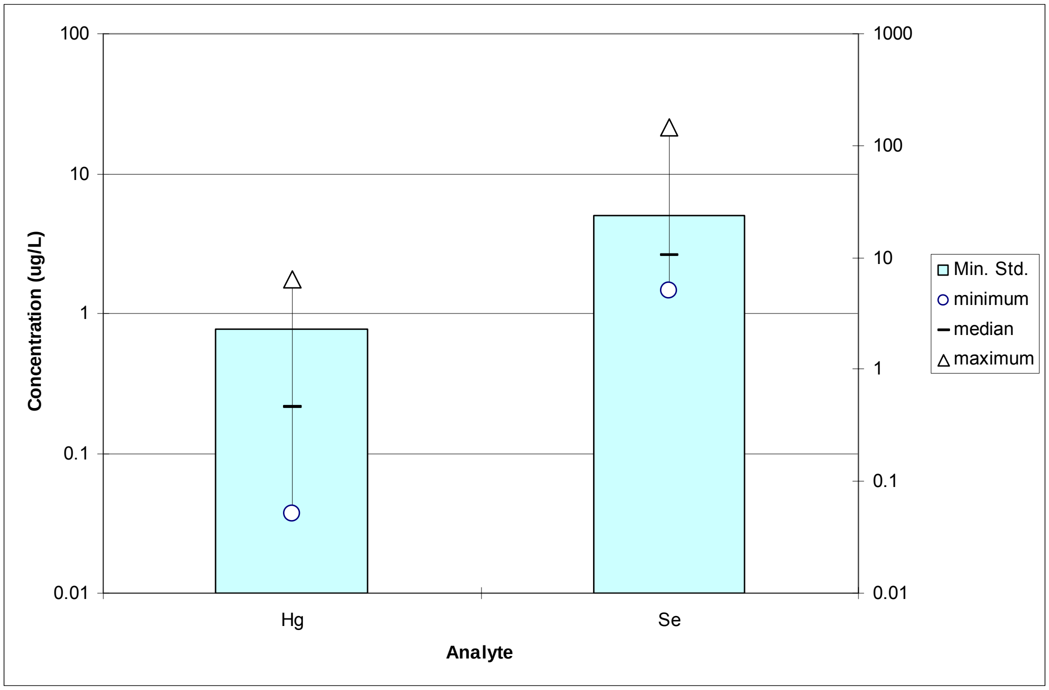


Figure 2.2.4-3. Summary of total detectable mercury and selenium concentrations in unfiltered runoff, 2000–2003, compared with minimum standard values.

present in sediments in Pueblo Canyon above Acid Canyon and below the former Pueblo Wastewater Treatment Plant (LANL 2004, p. 7-14). Runoff from Guaje Canyon contained up to 1.5 µg/L total mercury and runoff from Pajarito Canyon contained up to 1.33 µg/L. The source(s) of the elevated mercury is not clear (except for Pueblo Canyon) because mercury was found in runoff both onsite and upstream of LANL. There are recognized sources at LANL, natural soil mercury, as well as widespread atmospheric deposition from other sources distant from Los Alamos. The highest concentration of total mercury in samples collected from the Rio Grande after the Cerro Grande fire was 0.4 µg/L in a sample collected on October 24, 2000, from Cochiti Reservoir by NMED.

The EPA recommended water quality criteria for mercury in freshwater continuous concentration (chronic) and the proposed NMWQCC mercury standard for aquatic life (chronic) is 0.77 µg/L (dissolved). Of 232 samples analyzed for dissolved mercury in runoff from 2000 through 2003, only one sample contained detectable dissolved mercury; one sample from Sandia Canyon collected on October 23, 2000, by NMED contained 0.08 µg/L dissolved mercury, about one order of magnitude less than the recommended dissolved standards.

Total recoverable selenium was measured above the wildlife habitat standard of 5.0 µg/L in 94 of 323 (29%) unfiltered runoff samples, of which 19 were from upstream locations (all canyons), 24 were from onsite locations, 36 were from downstream locations, and 15 were from Guaje and Rendija Canyons. The source(s) of the elevated selenium is not yet definitive, although selenium was found in elevated concentrations in postfire sediment deposits in Los Alamos and Pueblo Canyons (LANL 2004). The distribution of these occurrences shows the presence of some natural selenium in the runoff. Selenium is commonly found in volcanic rich soils and rocks. LANL sources also may be present in unknown quantities. Selenium was found in one sample from the Rio Grande in a concentration greater than the standard; a sample collected near White Rock on August 9, 2001, contained 8.6 µg/L selenium. Additional information about selenium in runoff is in Section 2.2.4.5.

Figure 2.2.4-4 shows the summary of dissolved minor constituent concentrations in storm runoff and the comparison standards for filtered runoff. Dissolved minor constituents that were measured in concentrations above minimum standard values were aluminum, barium, beryllium, cadmium, iron, manganese, lead, and antimony. Minor constituents measured in concentrations one order of magnitude greater than the standard were manganese and antimony. All of the concentrations of minor constituents above standards are attributable to natural sources. Aluminum was measured above the New Mexico groundwater limit (5000 µg/L) in one sample collected in 2000, four samples in 2001, two samples in 2002, and two samples in 2003 (Guaje Canyon); of these, three samples were from locations upstream of LANL.

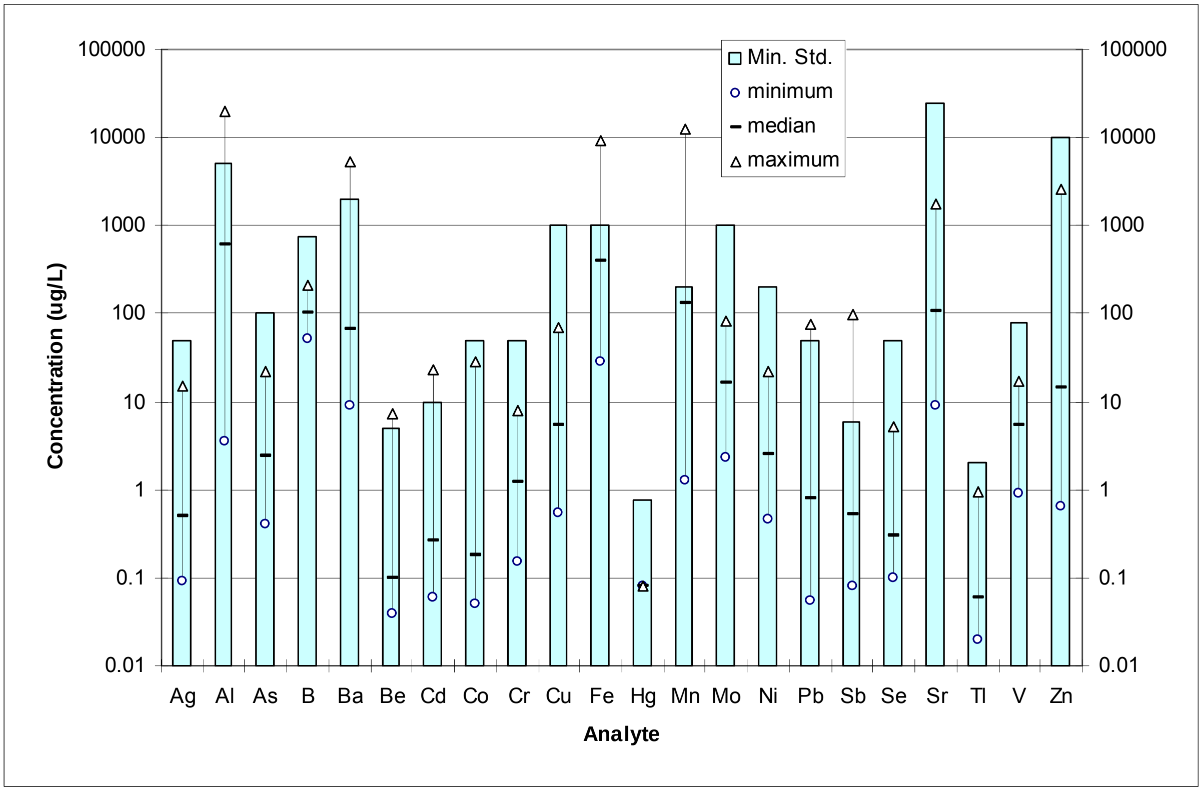


Figure 2.2.4-4. Dissolved minor constituent concentrations in filtered runoff, 2000–2003, compared with minimum reference values.

Dissolved barium and beryllium were measured above their groundwater limits (2000 µg/L and 5 µg/L, respectively) in one sample collected from upper Cañon de Valle collected on July 26, 2001. The barium concentration in this sample was 5210 µg/L; the next highest barium concentration in runoff was 989 µg/L, also from upper Cañon de Valle in a sample collected on August 5, 2001. The beryllium concentration in this sample was 7.24 µg/L, much higher than the next highest detection of beryllium, which was 0.1 µg/L. The dissolved concentrations of aluminum, iron, and several other minor constituents were unusually high in this particular sample, which suggests that the filtration of this runoff sample may have been compromised.

Dissolved cadmium was measured above the groundwater limit of 10 µg/L in one runoff sample collected from Guaje Canyon above Rendija Canyon on August 14, 2001, when the concentration was 22.9 µg/L. The next highest detection of cadmium was 5 µg/L in a sample collected from upper Cañon de Valle on July 26, 2001. The source of the high cadmium value to Guaje Canyon is not known.

Dissolved iron was measured above the groundwater limit (1000 µg/L) in 39 runoff samples that included samples from seven upstream locations (multiple canyons), seven onsite locations, 15 downstream locations, and 10 samples from Guaje and Rendija Canyons. Of these 39 samples, seven were collected in 2000, 18 in 2001, eight in 2002, and six in 2003. The highest concentration was 9240 µg/L in a sample collected from Guaje Canyon above Rendija Canyon on June 1, 2003, three years after the fire. The dissolved iron data suggest that the higher concentrations were not necessarily caused by the high ash and muck content in runoff immediately after the fire, but probably by elevated TSS concentrations in subsequent high-volume runoff events that contained eroded soil and rock materials.

Dissolved manganese exceeded the New Mexico groundwater standard (200 µg/L) in 39 of 83 (47%) filtered samples in 2000, 42 of 94 (45%) of samples in 2001, 16 of 56 (29%) samples in 2002, and 4 of 28 (14%) in 2003. The highest dissolved concentration was 12,200 µg/L in the sample from upper Cañon de Valle collected on July 26, 2001 (see comment above); the next highest concentration was 8590 µg/L in a sample collected from Guaje Canyon on September 8, 2000. Manganese has been shown to be present in runoff from fire-impacted areas in increased concentrations (e.g., Bitner et al. 2001, p. 7) because it is a natural component in plant tissue and surface soils. The substantial increase in dissolved levels after fires has been attributed to heat-induced physio-chemical breakdown of manganese complexed with organic matter (Chambers and Attiwill 1994). An increase of 279% in the concentrations of water-soluble manganese has been recorded after heating soil to 400˚C (Chambers and Attiwill 1994). After the fire at Los Alamos, several samples containing significantly higher dissolved manganese concentrations were collected from standing water or residual baseflow several hours or days after a runoff event. The highest concentration observed in 2002 was 4500 µg/L in a sample collected from Guaje Canyon and the highest in 2003 was 1090 µg/L, also from Guaje Canyon; the lower concentrations in later years indicates some recovery of the fire-impacted areas with respect to manganese.

Dissolved lead was measured above the domestic water supply standard (50 µg/L) in one runoff sample collected from Guaje Canyon above Rendija Canyon on September 3, 2003. This sample result was probably not directly related to the affects of the fire.

Dissolved antimony was found in concentrations above the EPA primary drinking water standard (6 µg/L) in numerous samples collected at the Twomile Canyon tributary at TA-3 in 2002 and 2003. Runoff from this tributary contained up to 97.5 µg/L antimony. Dissolved antimony in runoff from major drainages was found in concentrations greater than the standard in one sample collected from Rendija Canyon on July 17, 2000, when the runoff contained 10.7 µg/L antimony. The highest concentration of dissolved antimony in the Rio Grande was 2 µg/L in a sample collected from Cochiti Reservoir on July 6, 2000.

2.2.4.4 Naturally Occurring Minor Constituents in Storm Runoff

Figure 2.2.4-5 shows the percentage of results in which a minor constituent concentration was greater than a New Mexico surface water standard in both unfiltered and filtered samples collected upstream, downstream, and from the Rio Grande. The minor constituent analyses show that, on the Pajarito Plateau, concentrations in storm runoff from upstream stations are comparable to those downstream of LANL operations. The minor constituent most often found at high concentrations relative to the comparison screening values is aluminum, followed by arsenic, lead, and selenium; from one-third to one-half of these minor constituent results are greater than the screening values. Each of these constituents is a natural component of soils. While several of the minor constituent concentrations are frequently greater than the comparison values in short-term storm runoff events, they are generally less than the comparison values in more long-term persistent waters, i.e., spring-supported, effluent-supported, or snow melt flows. Thus, livestock or wildlife regularly watering on the Pajarito Plateau typically will be exposed to surface water with concentrations below the screening values.

On the Rio Grande, minor constituent concentrations in storm runoff are below the screening values in 90% of samples, except for aluminum. Aluminum concentrations were greater than the screening values in over 50% of the samples collected. As on the Pajarito Plateau, natural minor constituent concentrations comprise a large fraction of the total minor constituent load in the Rio Grande.

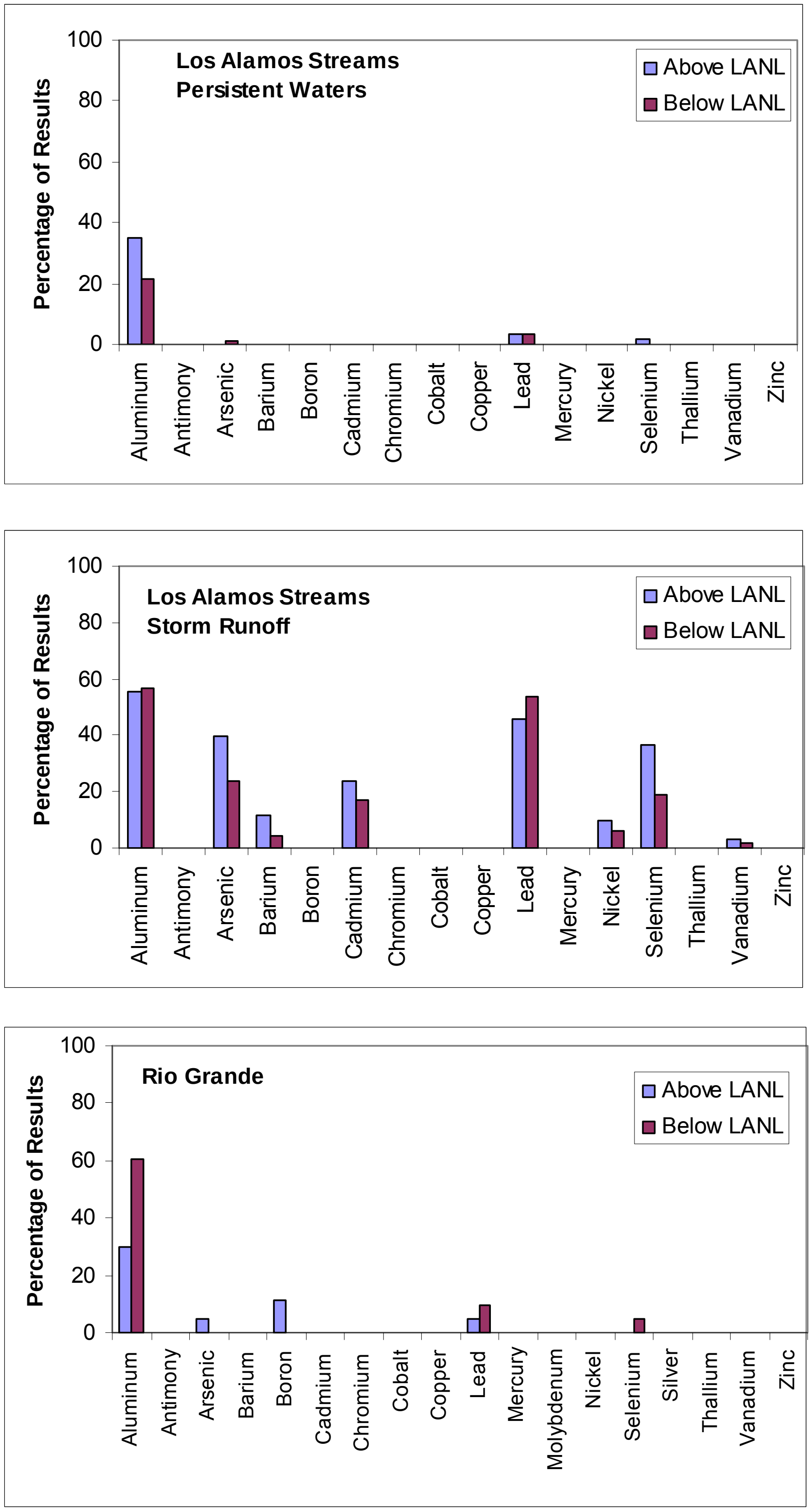
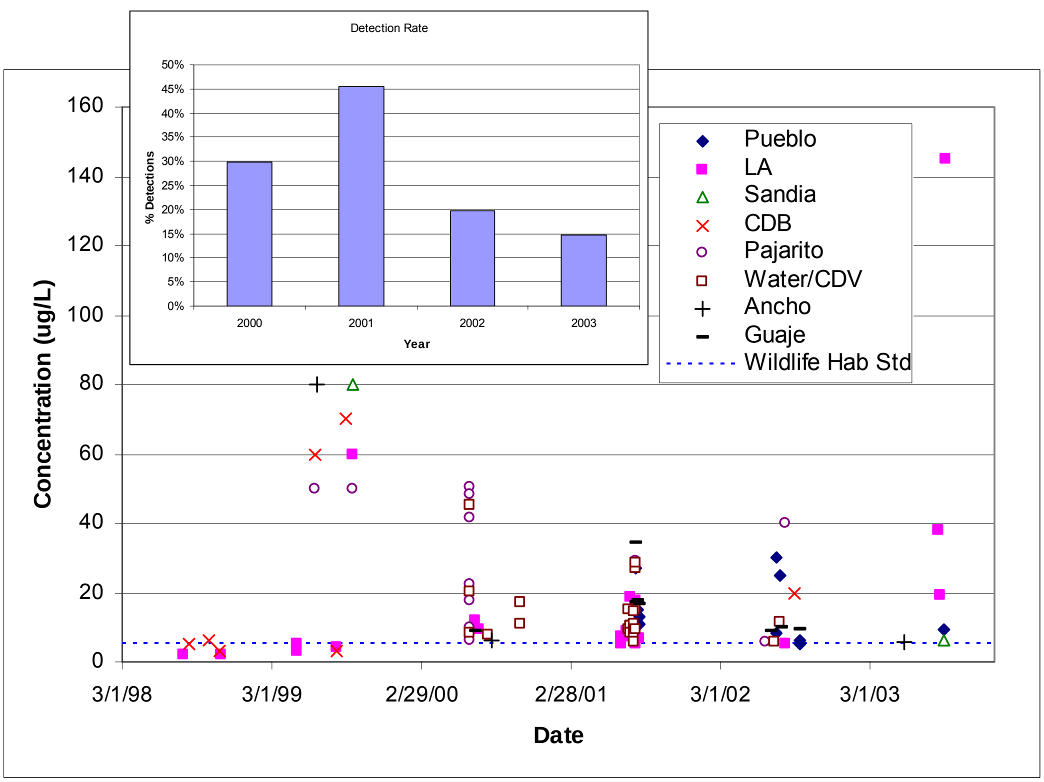


Figure 2.2.4-5. Percentage of results in which a minor constituent concentration was greater than a New Mexico surface water standard in unfiltered and filtered samples.

2.2.4.5 Total Recoverable Selenium in Storm Runoff

Monitoring of storm runoff following the Cerro Grande wildfire has shown total recoverable selenium concentrations greater than the New Mexico Wildlife Habitat surface water stream standard of 5 µg/L (NMWQCC 2002). In response to these findings, the NMED designated several Los Alamos area drainages as water quality impaired and added these drainages to the Federal Clean Water Act §303(d) List (NMED 2003c). The designated canyons are Guaje, Rendija, Los Alamos, Pajarito, Water, and Ancho.

Figure 2.2.4-6 shows the time series of detected selenium concentrations in storm runoff samples collected from major drainages from 1998 through 2003. The selenium concentrations were generally highest in 1999 when runoff in five canyons was greater than 50 µg/L. In 2000 after the fire, 30% of the runoff samples contained detections and runoff in Water and Pajarito Canyons contained selenium in concentrations greater than 20 µg/L. In 2001, 46% of runoff samples contained detectable selenium and Guaje, Pajarito, and Water Canyons contained runoff with greater than 20 µg/L. In 2002, 20% of samples contained detections and Pajarito Canyon, Pueblo Canyon, and Cañada del Buey contained runoff with greater than 20 µg/L. In 2003, only 15% of samples contained detectable selenium and only runoff events in Los Alamos Canyon contained greater than 20 µg/L total selenium. The data indicate that runoff concentrations after the fire appear to progressively decline over the four-year period and selenium is not detected in most samples. The downward trend in the selenium detection rate and concentrations in subsequent years after the fire for runoff from fire-impacted areas are possibly related to a general flushing of Cerro Grande fire ash from the landscape, a concept supported by data from LANL ER Project investigations (LANL 2004). The elevated concentration of selenium in Los Alamos Canyon in 2003 (145 ug/L) suggests a possible unknown source of selenium in that canyon (although none have been identified [LANL 2004]), or a delayed scour of ash material relocated from the reservoir in upper Los Alamos Canyon.



Note: Data include results from background sites and stations downstream of LANL operations.

Figure 2.2.4-6. Time trends in total recoverable selenium (detections only) in storm runoff, 1998–2003, and percentage of samples with detections from 2000–2003 (inset).

To examine further if elevated selenium concentrations in runoff were due to LANL operations or from natural sources, we assessed how concentrations varied with location. In Figure 2.2.4-7 we compare selenium concentrations in "background" storm runoff samples collected upstream or north of LANL against those collected onsite or downstream of LANL for the period 2000 through 2003. Selenium concentrations were normalized against an independent measure (iron) to account for the sediment load. The regression analysis line-fit plots show a good correlation (upstream: $r^2 = 0.22$, $p = 0.02$; downstream: $r^2 = 0.19$, $p = 0.002$) between iron and selenium concentrations and slightly higher selenium concentrations at upstream locations; the data indicate that the elevated concentrations of selenium in runoff are largely due to natural factors, probably a combination of suspended sediment load and ash content in runoff. Because only detectable concentrations of selenium were used in the analyses (median detection limit 2.36 µg/L), the regression plots likely show higher than expected concentrations of selenium in nature near the y-intercept value.

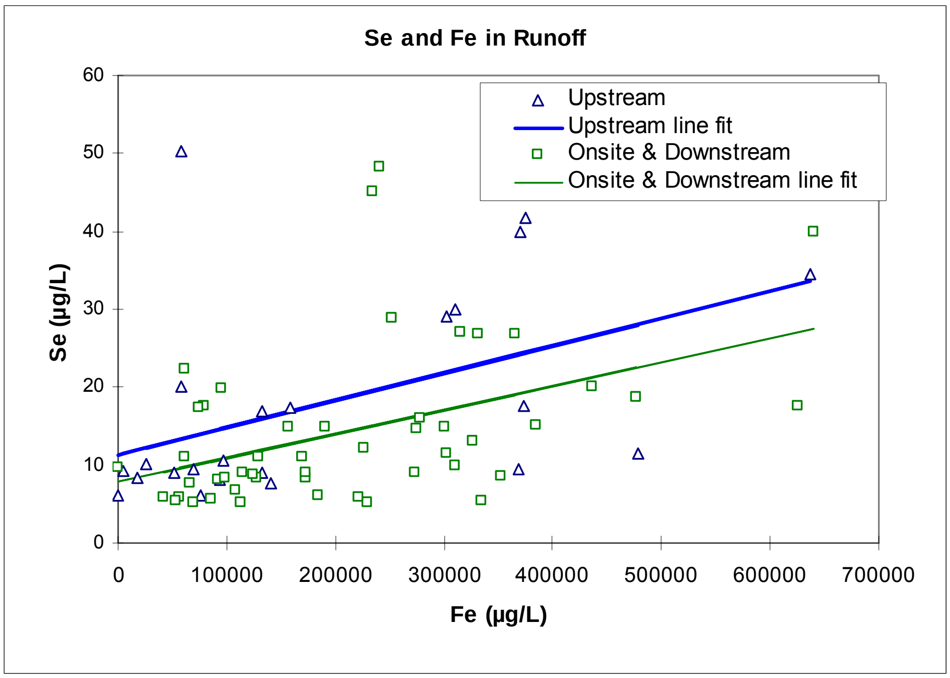


Figure 2.2.4-7. Comparison of selenium and iron concentrations in runoff at upstream sites with onsite and downstream LANL runoff.

2.2.4.6 Dissolved Barium in Runoff

Barium has been identified as being significantly elevated in ash and postfire sediment deposits (e.g., Kraig et al. 2002; Katzman et al. 2001; Katzman et al. 2002; LANL 2004). Barium from LANL sources has also been identified in surface water and groundwater in the southwestern portion of LANL (e.g., LANL 2003b, ESP 2004). Figure 2.2.4-8 shows the dissolved barium concentrations in runoff from upstream, onsite, downstream, and Guaje Canyon and in samples collected from the Rio Grande for prefire years 1997 to 1999 and postfire years 2000 through 2003. Figure 2.2.4-9 shows the time series of dissolved barium concentrations in runoff from each canyon from 1996 through 2003. The anomalously high upstream dissolved barium concentration in 2001 was from upper Cañon de Valle upstream of LANL discharges; several other minor constituents were also anomalously high in this sample, suggesting possible compromise of the filtration process.

Prefire dissolved barium concentrations greater than 800 µg/L were observed in Cañada del Buey and Ancho Canyon. After the fire, concentrations greater than 800 µg/L were observed in Cañon de Valle at the upstream gage and above the confluence with Water Canyon. From 2000 through 2002 the highest dissolved barium concentrations were in runoff from Cañon de Valle or Water Canyon. In 2003 the

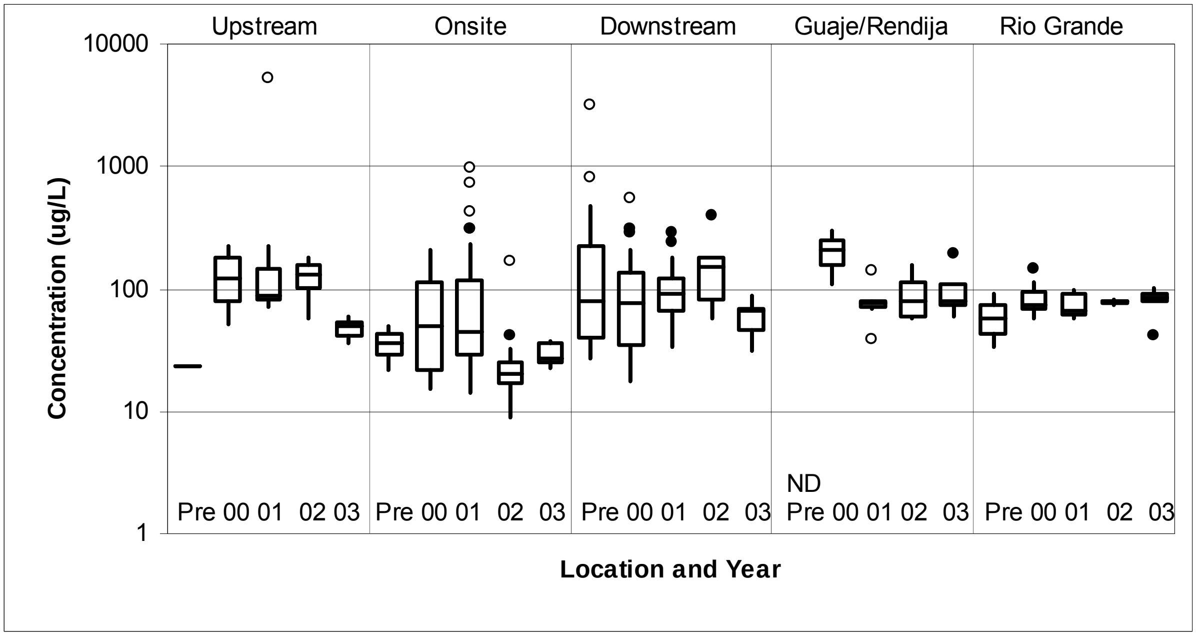


Figure 2.2.4-8. Dissolved barium in runoff at upstream, onsite, downstream, and Guaje Canyon and in baseflow from the Rio Grande, prefire and 2000–2002.

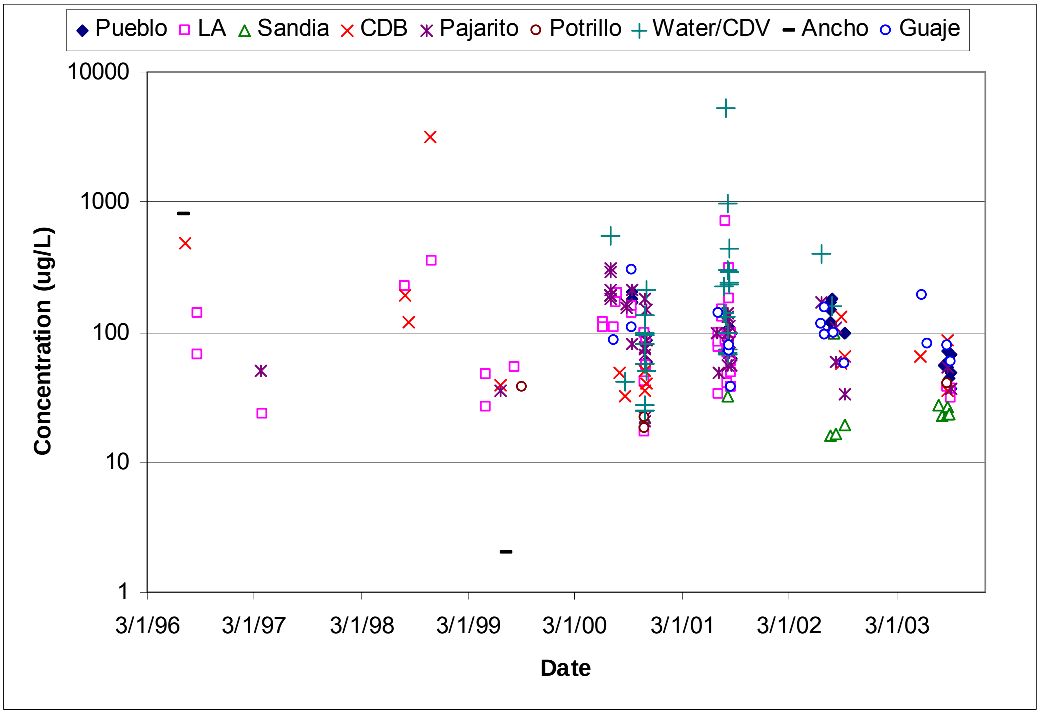


Figure 2.2.4-9. Time series of dissolved barium in runoff from major canyons, 1996–2003.

highest concentration was 192 µg/L in a runoff sample from Guaje Canyon above Rendija Canyon. The runoff data show a LANL contribution of barium to runoff in some canyons, and suggest a possible source of barium in upper Cañon de Valle, upstream of LANL.

In Guaje Canyon, the median dissolved barium concentration in 2000 after the fire was 205 µg/L, which decreased in 2001 to 75.3 µg/L (see Figure 2.2.4-8), suggesting a contribution from fire-related runoff that diminished within about one year. However, the distribution of concentrations at upstream LANL locations did not change appreciably from 2000 through 2002; however, in 2003 the upstream LANL distribution declined significantly.

2.2.4.7 Dissolved Manganese in Runoff

Manganese has been identified as a constituent found in increased concentrations in runoff from forest fires (e.g., Bitner et al. 2000; Katzman et al. 2001, Kraig et al. 2002, LANL 2004). Figure 2.2.4-10 shows the distribution of dissolved concentrations of manganese in runoff at upstream, onsite, and downstream locations and Guaje Canyon and in samples from the Rio Grande. The median concentrations of dissolved manganese in runoff at upstream LANL locations and in runoff from Guaje Canyon increased each year after the fire from 2000 through 2002, but concentrations in 2003 were significantly lower, about one order of magnitude lower in 2003 than in 2000 in upstream runoff. The median concentrations of manganese in upstream runoff was up to one order of magnitude greater than median concentrations at downstream locations from 2000 through 2002, indicating a major contribution from runoff from fire-related areas.

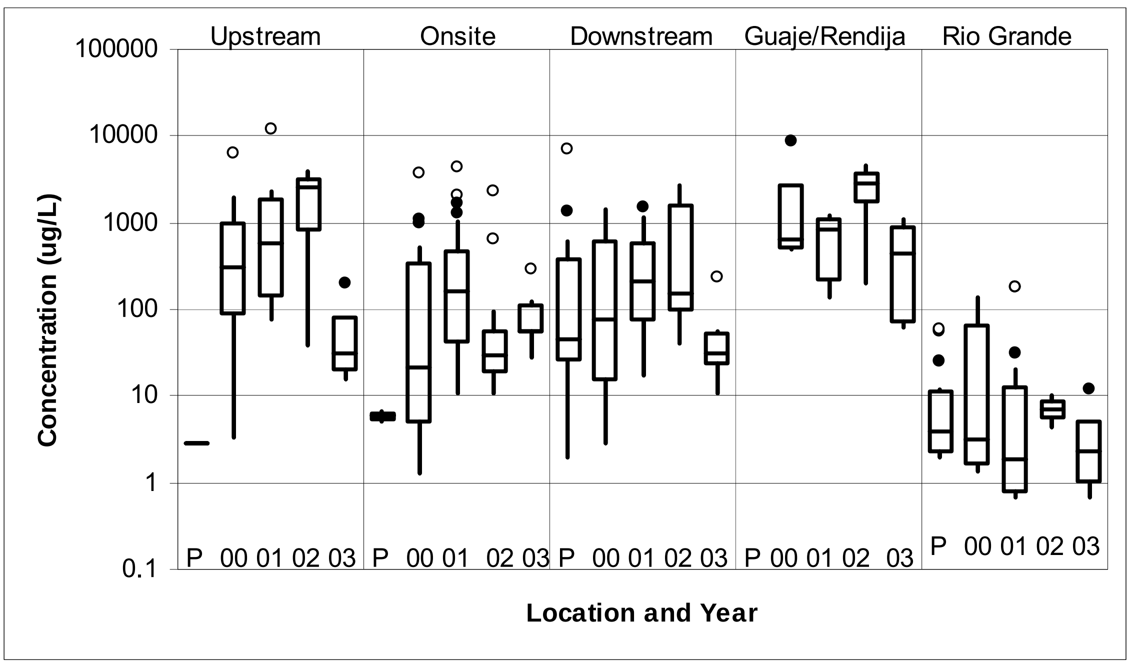


Figure 2.2.4-10. Dissolved manganese in runoff at upstream, onsite, downstream locations and Guaje Canyon and in baseflow from the Rio Grande, prefire and 2000–2003.

The highest dissolved concentration of manganese in the Rio Grande after the fire was 179 µg/L in a sample collected on July 25, 2001. This sample was collected one day prior to a relatively large runoff event from the Pajarito Plateau, so the result does not appear to be directly attributable to fire-related runoff from LANL, but may be from other fire-related runoff from upstream in the Rio Grande basin. The distribution of dissolved manganese concentrations in the Rio Grande did not change significantly after the fire, suggesting minimal impact of runoff from the Cerro Grande fire to the Rio Grande.

Figure 2.2.4-11 shows the time series of dissolved manganese concentrations in runoff from major canyons on the Pajarito Plateau. Before the fire, most concentrations were less than 1000 µg/L, but after the fire many runoff samples contained 1000 to 4000 µg/L dissolved manganese. The highest concentrations in runoff in 2000, 2002, and 2003 were from Guaje Canyon, and in 2001 the highest concentration was from Los Alamos Canyon. Maximum concentrations were lower each year after the fire, and, in 2003, the highest concentration was 1090 µg/L, similar to prefire conditions.

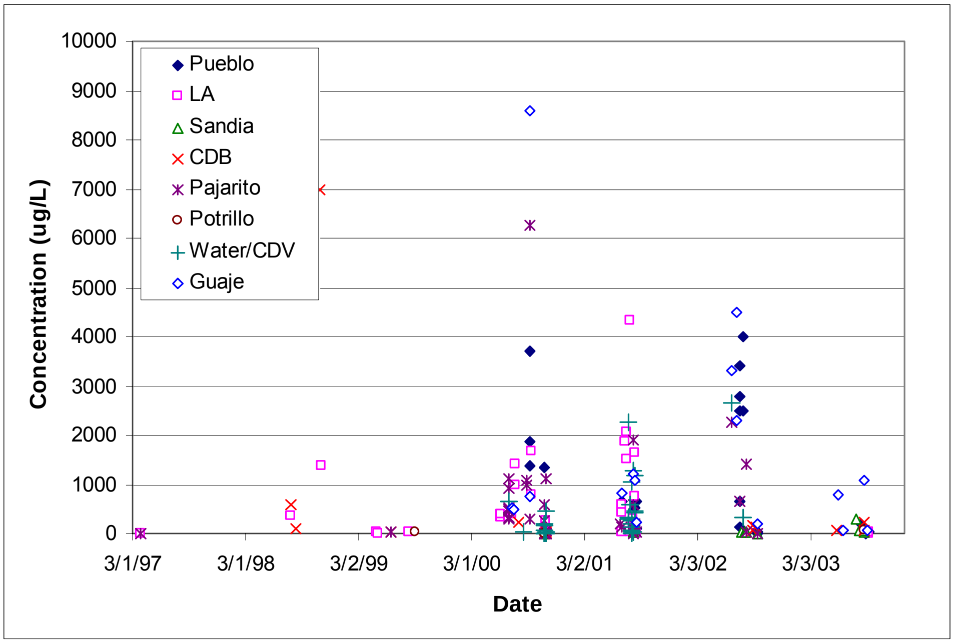


Figure 2.2.4-11. Time series of dissolved manganese in runoff from major canyons, 1997–2003.

2.2.4.8 Dissolved Strontium in Runoff

Figure 2.2.4-12 shows the distribution of dissolved strontium in runoff at locations on the Pajarito Plateau and in baseflow (1997–2002) and runoff (2003) in the Rio Grande. Upstream runoff after the fire contained significantly higher dissolved strontium than the limited data available for prefire upstream runoff. The median concentration in 2000 at upstream locations was 230 µg/L, higher than all other runoff at onsite and downstream locations. The upstream concentrations decreased each year after the fire and in 2003 the median upstream concentration was 111 µg/L. Median concentrations of dissolved strontium at onsite LANL locations were less than 100 µg/L each year, and were less than 60 µg/L in 2002 and 2003; the median concentration in downstream LANL runoff was less than 200 µg/L in 2000 and 2001, and less than 100 µg/L in 2002 and 2003. Guaje and Rendija Canyons runoff contained about 200 µg/L dissolved strontium in 2000 after the fire, but median concentrations in 2001 and later were about 100 µg/L. The higher concentrations of dissolved strontium in upstream LANL runoff from 2000 through 2002 suggest a contribution of strontium from the biomass upstream of LANL.

Median concentrations of dissolved strontium in the Rio Grande range from 243 to 352 µg/L, about 200 to 300 µg/L higher than runoff at LANL, and indicate a source of dissolved strontium to the Rio Grande other than the Pajarito Plateau.

Figure 2.2.4-13 shows the time series of dissolved strontium concentrations in runoff from major canyons on the Pajarito Plateau. Before the fire most dissolved strontium in runoff was less than 120 µg/L, but after the fire maximum concentrations were nearly 600 µg/L. The maximum concentrations declined each year after the fire and, in 2003, the maximum concentration was 156 µg/L and most concentrations were less than 120 µg/L, similar to prefire conditions.

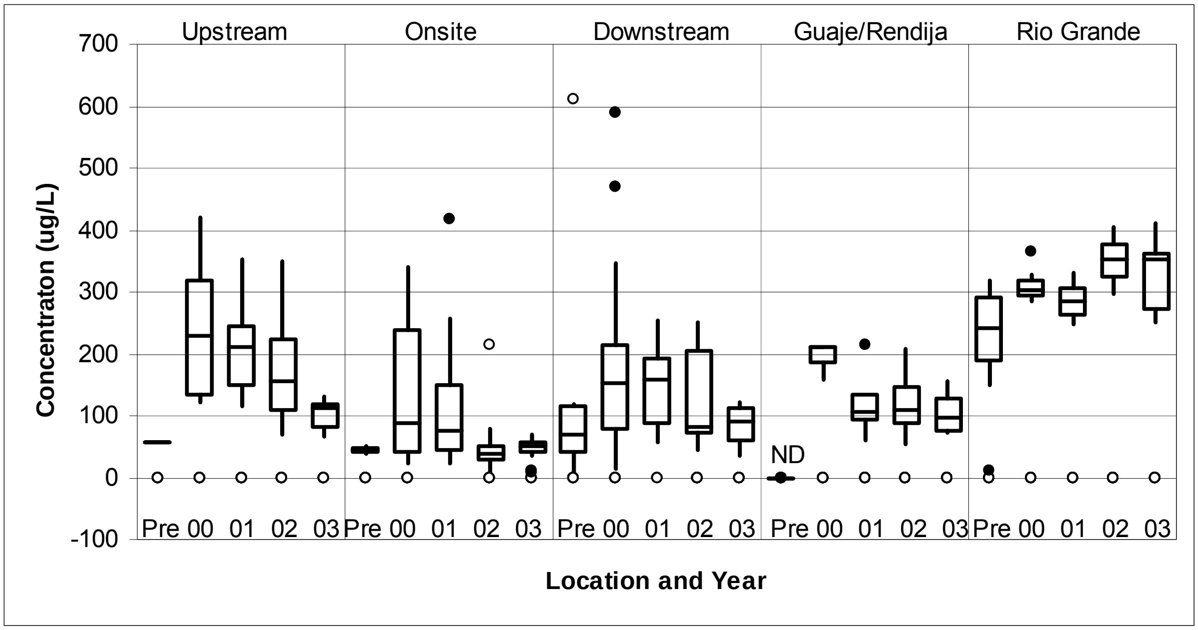


Figure 2.2.4-12. Dissolved strontium in runoff upstream, onsite, downstream, and Guaje Canyon and in baseflow from the Rio Grande, prefire and 2000–2003.

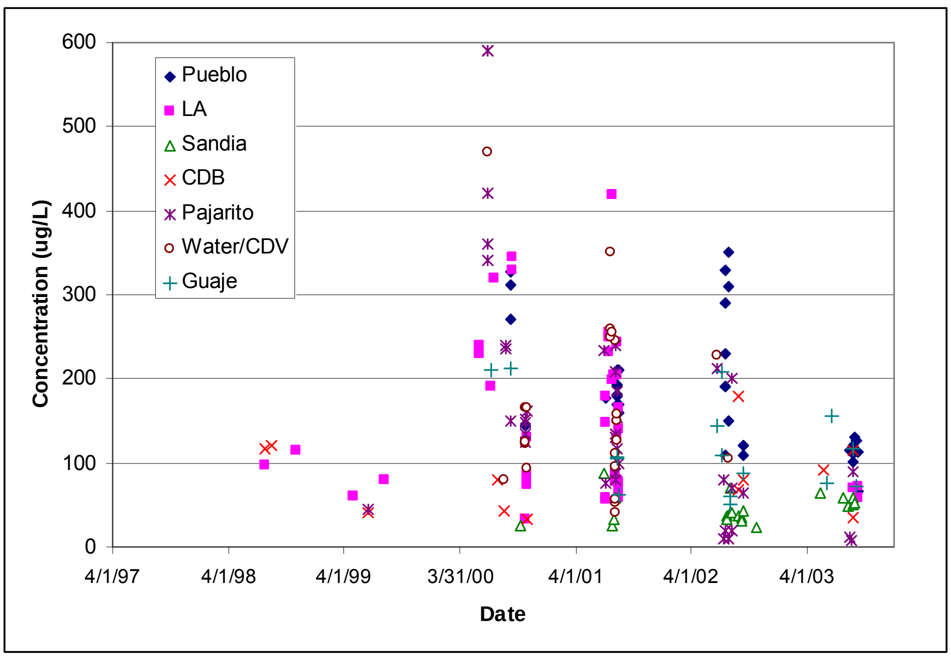


Figure 2.2.4-13. Time series of dissolved strontium concentrations in runoff from major canyons.

2.2.4.9 Minor Constituents in Suspended Sediment

Suspended solids comprise the major portion of the total minor constituent load in the runoff samples and were therefore examined to determine if minor constituent concentrations present in the suspended sediment were above screening levels. The concentrations of minor constituents in the suspended sediment fraction of the runoff samples were calculated using the concentrations of minor constituents in the unfiltered runoff and the TSS concentrations. Samples with TSS concentrations greater than 300 mg/L were used to calculate the suspended sediment concentrations, which comprised the majority of runoff events. These calculations did not consider dissolved concentrations in the filtered runoff; therefore, the results are considered maximum concentrations of minor constituents in suspended sediment. Specific screening levels for storm runoff are not available so relatively conservative screening levels for residential soil (EPA 2003) and sediment BVs (Ryti et al. 1998; McDonald et al. 2003) were used to evaluate the minor constituent concentrations in the suspended sediment fraction of the storm water runoff. The concentration of minor constituents in streambed sediments resulting from deposition from the runoff would be expected to be significantly lower than what was calculated for the suspended sediment; but concentrations in floodplain deposits could be similar.

Table 2.2.4-4 shows the summary of the results of the calculated minor constituent concentrations in suspended sediment from 2000 through 2003 and shows the EPA screening levels and sediment BVs. Figure 2.2.4-14 shows the summary of the results and the comparison with the screening levels. Minor constituents with concentrations in the suspended sediment fraction of the runoff greater than screening levels include chromium, iron, manganese, and thallium. Of these, manganese and iron were most often observed in concentrations above the screening levels.

Table 2.2.4-4. Summary of Calculated Minor Constituent Concentrations in Suspended Sediment in Runoff, 2000–2003.

Analyte	2000		2001		2002		2003		EPA Residential Soil SL [a]	Number of Analyses >SL				Sediment BV [b]
	Median	Max	Median	Max	Median	Max	Median	Max		2000	2001	2002	2003	
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Count	Count	Count	Count	mg/kg
Ag	2.6	13.2	9.0	12.9	11.7	14.9	8.7	12.8	390	0	0	0	0	1
Al	10621.3	61787.6	16030.8	44418.6	15265.7	39710.1	17051.4	36923.1	76000	0	0	0	0	15400
As	3.1	18.5	3.5	11.3	2.6	9.3	3.7	7.9	22	0	0	0	0	3.98
B	11.1	321.8	4.7	15.6	2.0	15.0	6.4	45.8	5500	0	0	0	0	
Ba	249.3	2019.3	222.6	1173.9	220.1	787.4	184.6	300.7	5400	0	0	0	0	127
Be	1.3	5.1	1.3	3.7	1.1	4.1	1.5	2.7	150	0	0	0	0	1.31
Cd	0.5	2.3	0.5	1.9	0.2	3.3	0.5	5.8	39	0	0	0	0	0.4
Co	6.5	25.2	5.2	8.8	5.5	16.0	5.7	10.0	3400	0	0	0	0	4.73
Cr	8.6	32.9	9.6	165.0	11.1	258.9	11.1	261.7	210	0	0	2	2	10.5
Cu	14.2	85.8	15.1	72.2	15.7	114.8	14.5	84.0	2900	0	0	0	0	11.2
Fe	8507.9	42227.4	11809.8	26210.5	13668.3	26503.1	13076.0	27115.4	23000	4	4	1	0	13800
Hg	0.1	0.5	0.0	0.1	0.1	0.5	0.0	0.7	23	0	0	0	0	0.1
Mn	803.0	16991.7	802.4	1867.9	748.5	2232.1	720.2	1400.5	3200	8	0	0	0	543
Mo	5.3	31.6	23.1	45.6	0.7	42.0	6.2	17.1	390	0	0	0	0	
Ni	8.9	43.1	10.4	22.4	9.7	25.8	11.7	22.1	1600	0	0	0	0	9.38
Pb	30.3	110.5	26.3	92.1	27.4	84.2	22.3	143.6	400	0	0	0	0	19.7
Sb	1.6	18.2	0.6	0.6	3.7	3.7	1.0	1.0	31	0	0	0	0	0.83
Se	1.7	19.2	0.6	2.0	0.6	2.2	1.1	4.2	390	0	0	0	0	0.3
Sn	16.7	214.5	0.6	10.3	ND	ND	1.5	2.0	47000	0	0	0	0	
Sr	72.1	2908.4	55.9	254.7	58.8	217.6	45.5	130.1	47000	0	0	0	0	
Tl	0.3	18.2	0.2	0.8	0.0	0.7	0.2	2.1	6.3	2	0	0	0	0.73
V	15.5	67.5	17.1	50.3	21.2	46.9	19.6	43.6	550	0	0	0	0	19.7
Zn	83.2	877.2	73.2	1376.3	67.5	1084.8	80.5	877.1	23000	0	0	0	0	60.2

a. SL = screening level EPA 2001; b. Ryti et al. 1998; ND = no data

The majority of the runoff samples contained minor constituent concentrations in suspended sediment that were less than the screening levels. Minor constituents in suspended sediment above the screening levels included chromium, iron, manganese, and thallium. Chromium was above the screening level in two runoff events in Sandia Canyon in both 2002 and 2003 (probably related to historic cooling tower discharges rather than fire-related). Iron was above the screening level in four samples in 2000 and 2001, and one sample in 2002; manganese was calculated in concentrations higher than the screening level in eight samples in 2000 but no samples in 2001, 2002, or 2003; and thallium was calculated in concentrations above the screening level in two samples in 2000. Manganese was significantly higher than the screening level in 2000 (see Figure 2.2.4-14).

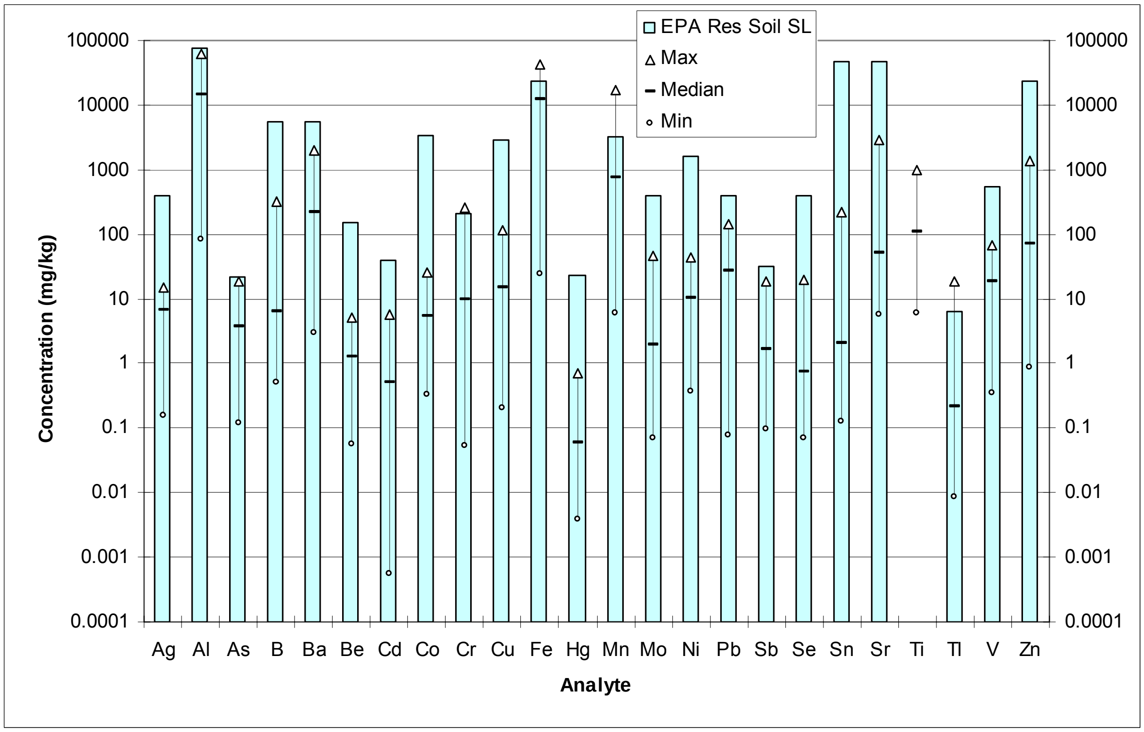


Figure 2.2.4-14. Summary of calculated minor constituent concentrations in suspended sediment, 2000–2003, compared with EPA residential soil screening level.

In 2000, the highest iron concentration in suspended sediment was 42,227 mg/kg (1.8 times the EPA residential soil screening level) in runoff collected from lower Pajarito Canyon on June 28, 2000, during the high runoff event. In 2001, 2002, and 2003, the highest iron concentrations in runoff were similar each year and the maximum was 27,115 mg/kg (1.2 times the screening level) in a sample collected from upper Pueblo Canyon.

Thallium was calculated in suspended sediment to be present in a concentration of 18.2 mg/kg (2.9 times the screening level) in a sample collected from upper Pajarito Canyon and in a concentration of 7.4 mg/L (1.2 times the screening level) in a sample collected from upper Water Canyon, both on June 28, 2000.

2.2.4.9.1 Barium in Suspended Sediment

Barium has been identified as being significantly elevated in ash and postfire sediment deposits (e.g., Kraig et al. 2002; Katzman et al. 2001; Katzman et al. 2002; LANL 2004). Barium from LANL sources has also been identified in surface water and groundwater in the southwestern portion of LANL (e.g., LANL 2003a; ESP 2004). Figure 2.2.4-15 shows the calculated and measured distribution of barium in suspended sediment from upstream, onsite, downstream, and Guaje Canyon runoff and in bed sediment collected by the USGS in 2000 and 2001 from the Rio Grande, Rio Grande bank sediment in 2002, and Rio Grande suspended sediment in 2003.

The highest concentration of barium in suspended sediment in 2000 was 2019 mg/kg in a sample from upper Water Canyon collected on June 28. Similarly, the higher concentrations at onsite and downstream runoff in 2000 were in runoff from fire-impacted areas on June 28. In 2001 the highest concentration of barium in suspended sediment was 1174 mg/kg in a sample collected from lower Cañon de Valle above the confluence with Water Canyon on August 9. In 2002 the highest concentration was 787 mg/kg in a sample collected from lower Potrillo Canyon and in 2003 the highest concentration was 289 mg/kg in a sample collected from Sandia Canyon below the wetlands.

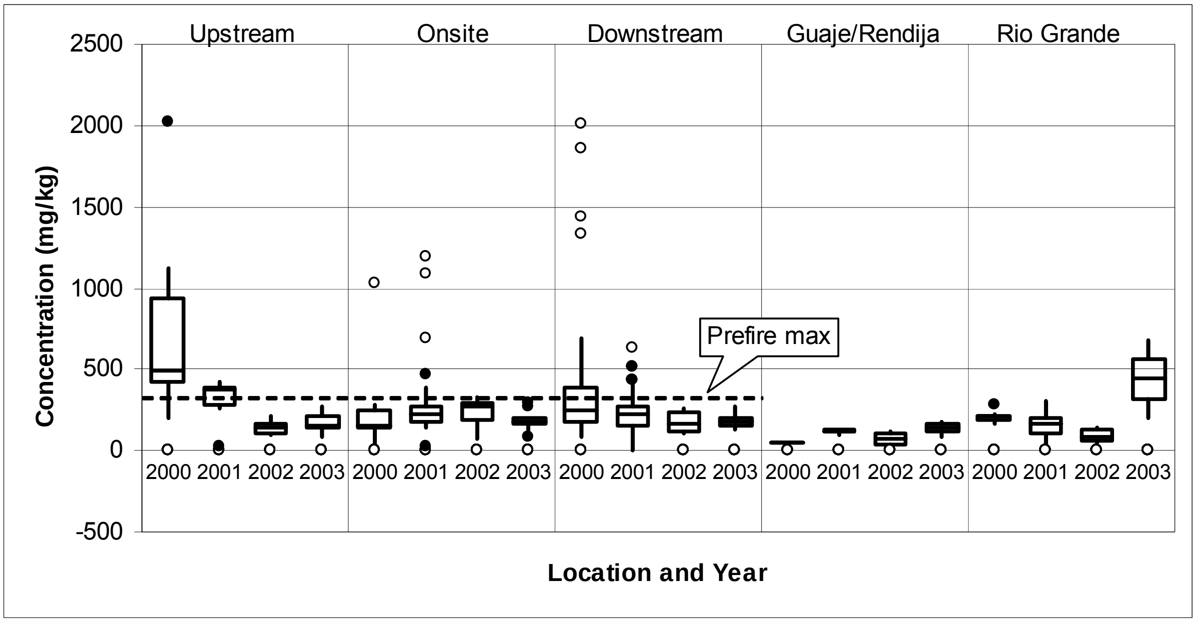


Figure 2.2.4-15. Distribution of barium in suspended sediment in runoff from upstream, onsite, downstream, and Guaje Canyon and in the Rio Grande, 2000–2003.

The higher barium concentrations in suspended sediment were observed in upstream and through-canyon runoff from fire-impacted areas immediately after the fire. By 2002 the concentrations of barium in suspended sediment in upstream, onsite, and downstream runoff was less than the prefire maximum of 300 mg/kg. The elevated concentrations of barium in suspended sediment were not observed in runoff from Guaje Canyon, so the source of the barium in the ash in runoff upstream of LANL may have been from legacy air dispersion of barium in the vicinity of LANL that was incorporated into the forest mass.

The highest concentration of barium in bed sediment in the Rio Grande was 304 mg/kg in a sample from Cochiti Reservoir collected in 2001. Suspended sediment in runoff in the Rio Grande on September 6, 2003, contained 203 mg/kg barium at Otowi Bridge and 682 mg/kg near White Rock.

2.2.4.9.2 Manganese in Suspended Sediment

The highest manganese concentration in suspended sediment was 16,992 mg/kg (5.3 times the standard, see Figure 2.2.4-14) in a sample collected from upper Water Canyon on June 28, 2000. Other runoff samples that contained manganese concentrations above the screening level were collected on June 28, 2000, in Pajarito Canyon, Cañon de Valle, Starmers Gulch, and Indio Canyon. Manganese was identified as occurring in elevated concentrations in ash and muck after the fire (LANL 2000a; Katzman et al. 2001; Kraig et al. 2002; LANL 2004), which is likely the source of elevated concentrations in the runoff suspended sediment.

Figure 2.2.4-16 shows the distribution of calculated and measured manganese concentrations in suspended sediment in runoff from upstream, onsite, downstream, and Guaje locations and in bed sediment from the Rio Grande collected in 2000 and 2001, Rio Grande bank sediment in 2002, and Rio Grande runoff suspended sediment in 2003. Manganese concentrations in suspended sediment from upstream locations were highest in 2000 after the fire; maximum and median concentrations decreased in 2001 and 2002. Similarly, maximum concentrations of manganese in suspended sediment from downstream locations decreased each year. However, median concentrations of samples collected at onsite, downstream, and Guaje locations increased slightly each year from 2000 through 2002, which may be the result of erosion and transport of ash from the burned areas and muck that was deposited in floodplains in 2000.

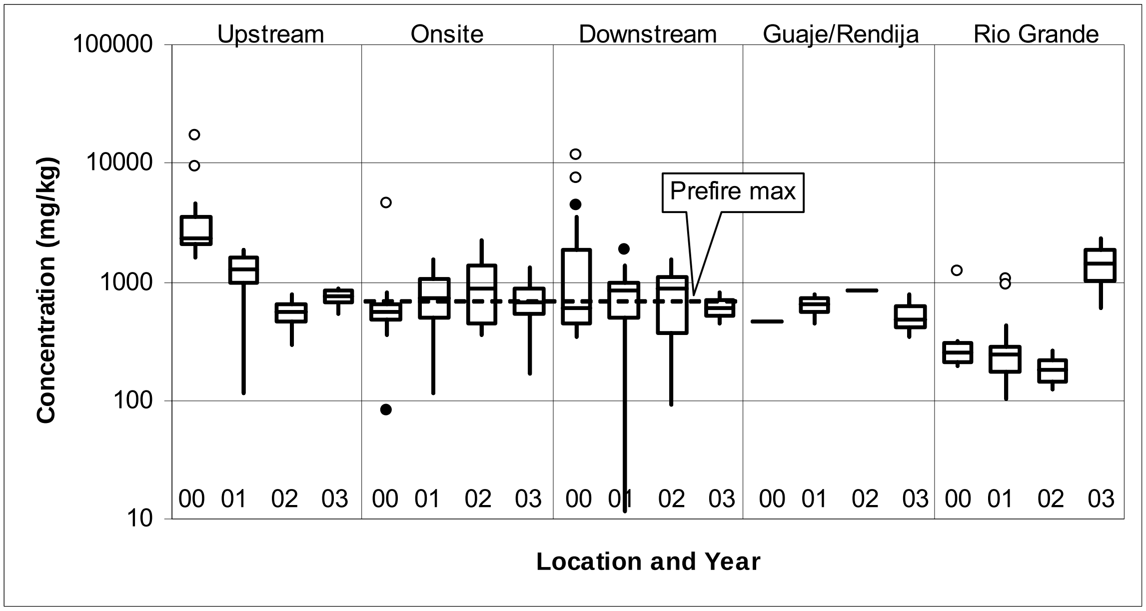


Figure 2.2.4-16. Distribution of manganese in suspended sediment in runoff from upstream, onsite, downstream, and Guaje Canyon and in the Rio Grande, 2000–2003.

The highest concentration of manganese in bed sediment collected from the Rio Grande by the USGS in 2000 was 1210 mg/kg and in 2001 was 1070 mg/kg in samples collected from Cochiti Reservoir. The median concentration of manganese in bed sediments from the Rio Grande and Cochiti Reservoir was 254 mg/kg in 2000 and 21 mg/kg in 2001. The higher concentrations in the bed sediment may be associated with fire-related runoff from the Pajarito Plateau. Sediment collected from the Rio Grande downstream of LANL in 2002 contained a maximum concentration of 265 mg/kg manganese. Runoff in the Rio Grande in 2003 contained up to 2290 mg/kg manganese in a sample collected near White Rock.

The evaluation of minor constituents in suspended sediment in runoff identified manganese as the minor constituent most likely to be of concern from a public exposure perspective (RAC 2002). The elevated concentrations commonly occurred in samples collected from Pajarito Canyon and Water Canyon both onsite, downstream, and upstream of LANL, where the concentrations should be primarily derived from natural sources. Median manganese concentrations calculated for suspended sediment in fire-related runoff were about 25% of the screening level. Due to further downstream mixing, the concentrations in bed sediment in Rio Grande samples in 2000 and 2001 after runoff events were about one order of magnitude lower than concentrations calculated for the runoff samples in 2000.

2.2.4.10 Minor Constituent Flow-Weighted Average Concentrations and Transport in Storm Runoff

Figure 2.2.4-17 shows the estimated FWA annual concentrations of minor constituents in storm water runoff at downstream LANL sites for 2000 through 2003 and the prefire average for years 1997 through 1999. Minor constituents that have higher FWA concentrations in 2000 than previous years include silver, aluminum, arsenic, boron, barium, beryllium, cobalt, chromium, copper, iron, mercury, manganese, nickel, lead, antimony, tin, strontium, vanadium, and zinc. Minor constituents that had higher FWA concentrations in prefire years include molybdenum and selenium. The higher FWA concentrations after the fire are partially due to the higher flow volumes and associated TSS in runoff from burned areas and the higher concentrations of some minor constituents observed in fire-related runoff.

In 2000 after the fire, substantial increases occurred in estimated FWA minor constituent concentrations of silver, arsenic, boron, barium, manganese, tin, and strontium. Increases of 5 to 10 times above prefire

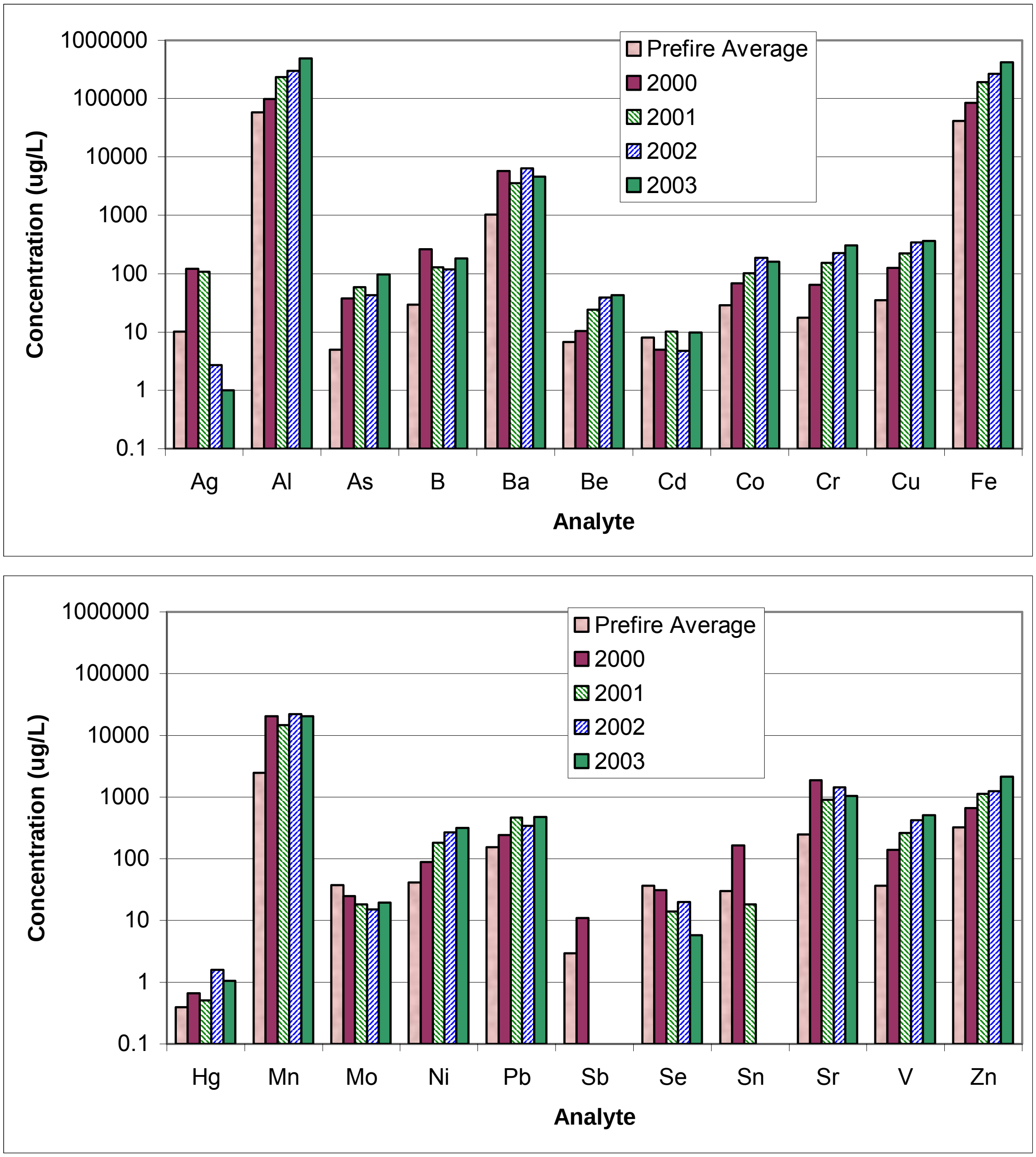
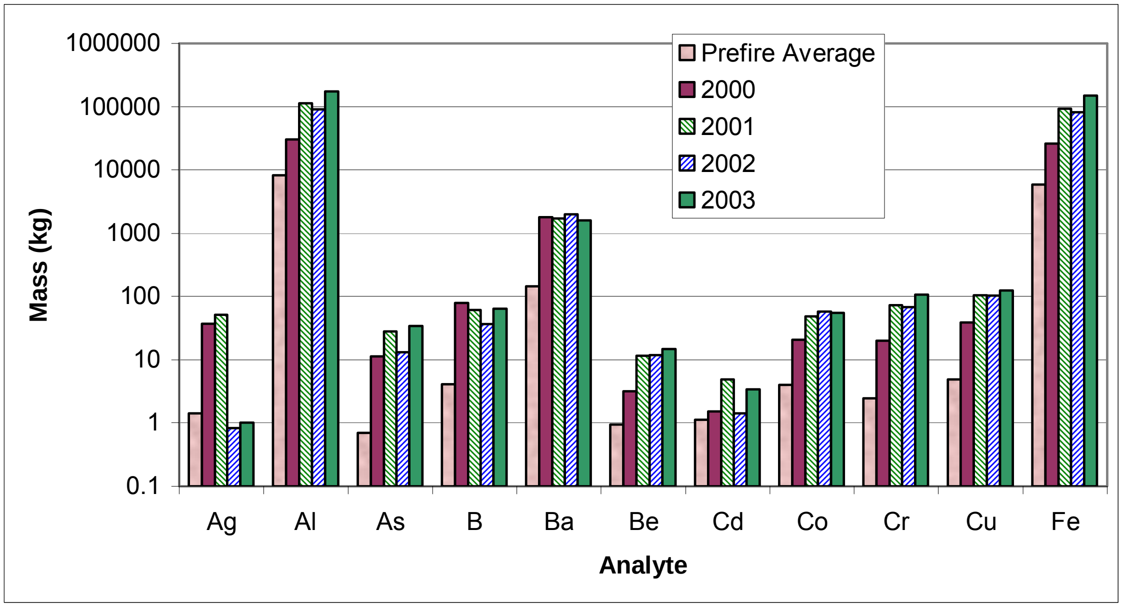


Figure 2.2.4-17. Estimated FWA annual concentrations of minor constituents in unfiltered runoff at downstream sites.

levels were observed for most of these constituents. In addition, concentrations of cobalt, chromium, copper, iron, nickel, antimony, vanadium, and zinc were at least twice the prefire concentrations in 2000.

Average concentrations of minor constituents that increased progressively each year after the fire include aluminum, beryllium, cobalt, chromium, copper, iron, nickel, vanadium, and zinc. Molybdenum showed a decrease in FWA concentrations from 2000 through 2002. Minor constituents that do not appear to have been appreciably affected by fire-related runoff include cadmium, mercury, molybdenum, selenium, and tin.

Figure 2.2.4-18 shows the estimated mass of minor constituents that was transported in runoff downstream of LANL from 2000 through 2003 and the prefire average annual mass in downstream runoff. The annual mass of most minor constituents increased by an order of magnitude, mostly resulting from the high volume of runoff after the fire. Minor constituents that did not change significantly in downstream runoff transport include molybdenum and selenium. Minor constituents that show a general increasing trend in annual transport from 2000 through 2003 include aluminum, beryllium, cobalt, chromium, copper, iron, vanadium, and zinc. Minor constituents that increased after the fire and have had similar annual transport since the fire include barium, manganese, and strontium, which, as mentioned previously, have been identified in runoff from fire-impacted areas.



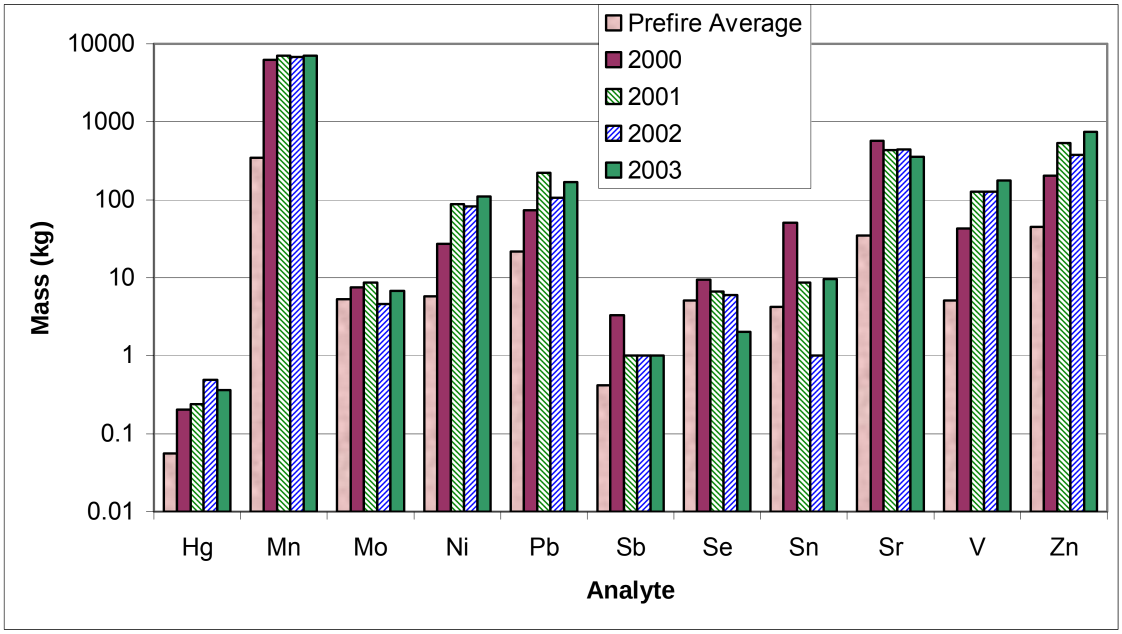


Figure 2.2.4-18. Estimated annual mass of minor constituents in runoff at downstream sites.

2.2.4.11 Summary of Minor Constituents in Storm Runoff after the Cerro Grande Fire

The maximum concentrations of most minor constituents in unfiltered runoff after 2000 were higher than historically observed. Minor constituent concentrations significantly higher (greater than one order of magnitude) in postfire runoff included silver, arsenic, boron, cobalt, chromium, manganese, nickel, tin, strontium, thallium, vanadium, and zinc. Minor constituents in unfiltered runoff that were not significantly higher than prefire historic maximums were cadmium, mercury, molybdenum, antimony, and selenium.

The concentrations of minor constituents in unfiltered storm water runoff were compared with the livestock watering standards and the wildlife habitat standards (NMWQCC 2002). The quality of filtered storm runoff was compared with the NMWQCC groundwater standards because of the possibility of seepage of dissolved constituents from the streambed into underlying shallow groundwater. Twenty seven runoff samples (9%) analyzed for total mercury contained concentrations greater than the NMWQCC Wildlife Habitat standard. The highest concentration of total mercury (6.3 µg/L) was in a runoff sample collected from upper Pueblo Canyon above Acid Canyon in July 2002; all mercury concentrations greater than 1.5 µg/L were from Pueblo Canyon or Los Alamos Canyon. The source(s) of the elevated mercury in runoff is not clear because mercury was found in runoff both downstream and upstream of LANL. There are recognized sources at LANL, natural soil mercury, as well as widespread atmospheric deposition from other sources distant from Los Alamos. The highest concentration of mercury in samples collected from the Rio Grande after the Cerro Grande fire was 0.4 µg/L in a sample collected on October 24, 2000, from Cochiti Reservoir.

Total recoverable selenium was measured above the NMWQCC wildlife habitat standard of 5 µg/L in 94 (29%) unfiltered runoff samples, of which 19 were from upstream locations, 24 were from onsite locations, 36 were from downstream locations, and 15 were from Guaje and Rendija Canyons. The source(s) of the elevated selenium is not yet determined. The distribution of these occurrences shows the presence of some natural selenium in the runoff. Selenium is commonly found in volcanic rich soils and rocks. LANL sources also may be present in unknown quantities. Selenium was found in one sample from the Rio Grande in a concentration greater than the standard; a sample collected near White Rock on August 9, 2001, contained 8.6 µg/L selenium.

Dissolved minor constituents in runoff that were measured in concentrations above minimum standard values were aluminum, barium, beryllium, cadmium, iron, manganese, lead, and antimony. Minor constituents measured in concentrations one order of magnitude greater than the standard were manganese and antimony. The concentrations of minor constituents above standards are attributable to natural sources.

Dissolved manganese exceeded the New Mexico groundwater standard (200 µg/L) in 39 of 83 (47%) filtered samples in 2000, 42 of 94 (45%) samples in 2001, 16 of 56 (29%) samples in 2002, and 4 of 28 (14%) in 2003. Manganese has been shown to be present in runoff from fire-impacted areas in increased concentrations (e.g., Bitner et al. 2001, p. 7; LANL 2000a; Katzman et al. 2001; Kraig et al. 2002; LANL 2004) because manganese is a natural component in plant tissue and surface soils. After the Cerro Grande fire, several surface water samples containing significantly higher dissolved manganese concentrations were collected from standing water or residual baseflow several hours or days after a runoff event where the water was in contact with ash-rich sediment. The highest concentration observed in 2002 was 4500 µg/L in a sample collected from Guaje Canyon, while the highest in 2003 was 1090 µg/L, also from Guaje Canyon. The higher concentrations of manganese in runoff after the fire indicate that manganese was a significant constituent in fire-related runoff; declining concentrations in years following the fire reflect the reduction of ash in runoff and provides an indication of the recovery of the fire-impacted areas following the fire.

The annual mass of most minor constituents transported in runoff after the fire increased by an order of magnitude, mostly resulting from the high volumes of runoff after the fire. Minor constituents that show a general increasing trend in annual transport from 2000 through 2003 include aluminum, beryllium, cobalt, chromium, copper, iron, vanadium, and zinc. Minor constituent concentrations that increased after the fire include barium, manganese, and strontium, which were constituents in runoff from fire-impacted areas. Minor constituents that did not increase significantly in transport in downstream runoff include molybdenum and selenium.

2.2.5 Organic Compounds in Storm Runoff

Table 2.2.5-1 lists the number of detections of organic compounds that were found in storm runoff in major drainages from 2000 through 2002. During this period, 13 runoff samples contained detections of high explosive compounds; of these, three samples were from upstream locations in Pajarito Canyon and Cañon de Valle. Nine runoff samples contained detections of polychlorinated biphenyl (PCB) compounds; these samples were from Pueblo, Los Alamos, Sandia, Pajarito, and Water Canyons. A total of 32 runoff samples contained detections of semivolatile organic compounds and 10 samples contained detections of volatile organic compounds.

Table 2.2.5-1. Number of Organic Compounds Detected in Storm Runoff on the Pajarito Plateau, 2000–2002.

Sample Date	Location Name	Relative Location	Number of Detections			
			HEXP	PCB	SVOA	VOA
6/3/2000	Los Alamos above Ice Rink	Upstream			4	
6/3/2000	Los Alamos above SR 4	Downstream			4	
6/28/2000	Canon de Valle above SR 501	Upstream	5		1	
6/28/2000	Indio at SR 4	Downstream	6		1	
6/28/2000	Pajarito above SR 4	Downstream	1		1	
6/28/2000	Pajarito below SR 501	Upstream	4		1	
6/28/2000	Pajarito SR 4 Culvert	Downstream	4		1	
6/28/2000	Starmers above Pajarito	Onsite			2	
6/28/2000	Water below SR 4	Downstream	4		1	
7/9/2000	Guaje Canyon at SR 502	Offsite	1		6	
7/9/2000	Los Alamos above SR 4	Downstream			3	
7/18/2000	Los Alamos above Ice Rink	Upstream			2	
8/18/2000	Water below SR 4	Downstream				1
9/8/2000	Guaje Canyon at SR 502	Offsite			1	3
9/8/2000	Pajarito below SR 501	Upstream				2
9/8/2000	PU-2.0	Onsite		1		
9/8/2000	PUN-0.01	Upstream		1		
10/23/2000	Canon de Valle above SR 501	Upstream			1	3
10/23/2000	Pajarito below SR 501	Upstream			2	2
10/23/2000	Starmer's Gulch above SR 501	Upstream			2	3
10/23/2000	Twomile above SR 501	Upstream			2	3
10/23/2000	Water above SR 501	Upstream			3	3
10/23/2000	Water below SR 4	Downstream				1
10/24/2000	Pajarito above SR 4	Downstream				1
10/27/2000	Water at SR 4	Downstream	2			
10/28/2000	LA-5.0	Downstream		1		
10/28/2000	SA-5.6	Onsite		1		
8/5/2001	PA-4.54	Onsite		1	2	
6/21/2002	Los Alamos below Ice Rink	Upstream			1	
6/22/2002	Canon de Valle above SR 501	Upstream	3			
6/22/2002	Pajarito above SR 4	Downstream	8		3	
7/4/2002	Sandia below Wetlands	Onsite		2		
7/14/2002	La Delfe above Pajarito	Onsite	5			
7/14/2002	Sandia below Wetlands	Onsite		1		
7/14/2002	Water below SR 4	Downstream	5			
8/7/2002	Sandia below Wetlands	Onsite			1	
8/28/2002	Canada del Buey above SR 4	Downstream	3			
9/10/2002	Pueblo above SR 502	Downstream		1		
9/10/2002	Water below SR 4	Downstream		1		

Note: HEXP = high explosive compounds; PCB = polychlorinated biphenyl compounds; SVOA = semivolatile organic analysis; VOA = volatile organic analysis

A detailed summary of organic compounds detected by LANL and the USGS in surface water samples collected from the Pajarito Plateau and the Rio Grande from 2000 through 2002 is provided in Appendix E. The table provides summary statistics of concentrations measured, comparative surface water and ground water screening values, and rates of detections upstream and downstream of LANL operations. Overall, the vast majority of results are below screening values and 90% of samples were within limits in the proposed New Mexico Stream Standards (NMED 2003).

2.2.5.1 High Explosive Compounds in Storm Runoff and Snow Melt

High explosive compounds were detected at sub- or low-part-per-billion concentrations in runoff and snow melt samples collected within the southern canyons (Cañon de Valle and Water and Ancho Canyons) at LANL; high explosive compounds were detected in runoff from both upstream and downstream locations. No high explosives compounds were detected in water samples collected from the Rio Grande or Cochiti Reservoir. One runoff sample collected on July 9, 2000, from Guaje Canyon was analyzed for high explosive compounds; this sample contained a detectable concentration of 1,3,5-trinitrobenzene (1.5 ug/L).

Table 2.2.5-2 shows the concentrations of high explosive compounds detected in storm runoff and snow melt in LANL canyons from 2000 through 2002. Seven different high explosive compounds were detected: HMX, RDX, and four members of the DNT/TNT family. Water quality criteria have been established or proposed for six of the seven compounds. Measured concentrations for all of the compounds were below the water screening values.

Table 2.2.5-2. High Explosive Compounds Detected in Storm Runoff in Major LANL Drainages, 2000–2003.

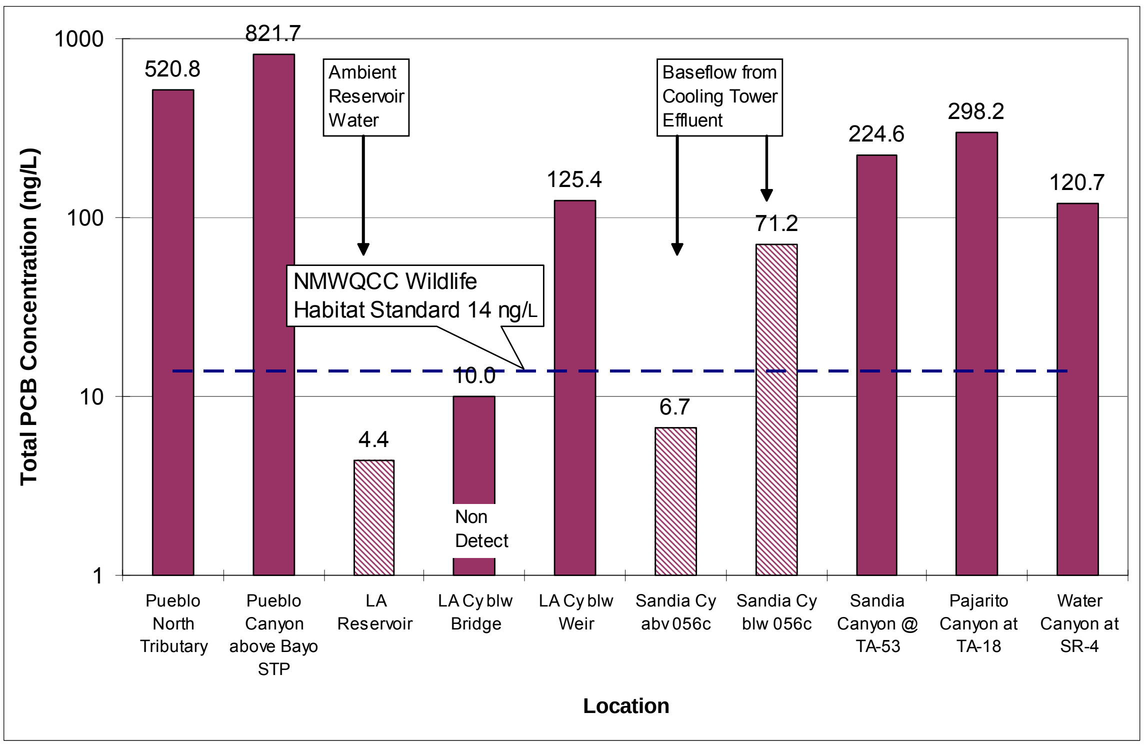
Date	Location	Rel Loc	1,3-Dinitrobenzene µg/L	2,4,6-Trinitrotoluene µg/L	2,4-Dinitrotoluene µg/L	2,6-Dinitrotoluene µg/L	2-Amino-4,6-dinitrotoluene µg/L	2-nitrotoluene µg/L	3-Nitrotoluene µg/L	4-Amino-2,6-dinitrotoluene µg/L	4-Methylnitrobenzene µg/L	HMX µg/L	RDX µg/L	Tetryl µg/L
06/28/00	Indio at SR 4	Down										2.2		
10/27/00	Water at SR 4	Down										0.52	0.76	
06/22/02	Canon de Valle above SR 501	Up				0.33	0.31			0.33				
06/22/02	Pajarito above SR 4	Down	0.048		1.4	2.1		0.82	0.28		0.27	0.29	2.7	
07/14/02	La Delfe above Pajarito	Down			0.19							1.2	1.1	
07/14/02	Water below SR 4	Down		0.35	0.95					0.05		2	1.5	
08/28/02	Canada del Buey above SR 4	Down			0.56									0.27
Max. Conc. Upstream LANL		Up				0.33	0.31			0.33				
Max. Conc. Downstream LANL		Down	0.048	0.35	1.4	2.1		0.82	0.28	0.05	0.27	2.2	2.7	0.27
Screening Value*			3.7	2.2	34	37		61	61	0.99		1800	6.1	
Max. Conc. Above LANL as % of Screening Value		Up				1%				33%				
Max. Conc. Below LANL as % of Screening Value		Down	1%	16%	4%	6%		1%	0%	5%		0.1%	44%	

*Screening Level default is proposed NM Stream Standards (NMED 2003), or NM Groundwater Standards (NMWQCC 2002), or EPA Region 6 Tap Water Screening Levels (HQ =1; modified cancer risk = 10^{-5}). Screening levels are not available for all constituents.

The main impact of the Cerro Grande fire on high explosive constituents was increased stream flow in the Water Canyon and Pajarito Canyon watersheds, where most of the LANL high explosive operations are located; the increased flows likely eroded and transported historically contaminated sediments. The RAC health risk assessment identified RDX as a key constituent of concern for the surface water environment (RAC 2002). With increased runoff, larger amounts of RDX may enter the Rio Grande, be incorporated in fish, which then are eaten by people. The monitoring results from this study, however, have not identified high explosive impacts on the Rio Grande. As stated earlier, none of the water or sediment samples from the Rio Grande contained detectable levels of RDX or other high explosive compounds.

2.2.5.2 PCBs in Storm Runoff

One of the impacts of the Cerro Grande fire was increased erosion and transport of PCBs attached to sediment in some canyons at LANL. A portion of the PCB inventory is from LANL, although upstream sources near the Los Alamos town site are also indicated. Figure 2.2.5-1 shows the detections of PCBs in storm runoff in the Los Alamos area and in samples from the Rio Grande from 2000 through 2002 using the EPA Method 1668 for the analysis of PCB congeners. Figure 2.2.5-1 also shows the NMWQCC wildlife standard for PCBs in water, which is 14 ng/L.



*Congener data from NMED (2003); Mullen and Koch (2004).

Figure 2.2.5-1. PCBs detected in storm runoff, 2000–2002.

The north tributary of Pueblo Canyon sampled by NMED on September 8, 2000, west of the Diamond Drive land bridge contained abundant ash from the Cerro Grande fire, and a concentration of 521 ng/L total PCB. This runoff was downstream of urban areas in Los Alamos, which may have contributed to elevated PCB content of the runoff. Runoff collected in lower Pueblo Canyon on this date contained 822 ng/L total PCBs, which suggests an additional source of PCBs in Pueblo Canyon downstream of legacy LANL discharge sites (NMED 2003a).

A depth-integrated surface water sample collected from the Los Alamos reservoir on August 31, 2000, contained 4.4 ng/L total PCBs, which may represent approximate background concentrations from atmospheric sources, and indicates that runoff from fire-impacted slopes did not contain concentrations of PCBs above the wildlife standard. Runoff in Los Alamos Canyon above SR 4 on October 28, 2000, contained 125 ng/L total PCBs, indicating a LANL source of PCBs in Los Alamos Canyon. On August 5, 2000, runoff in Pajarito Canyon at TA-18 contained 298 ng/L total PCBs (NMED 2003a; Mullen and Koch 2004).

NMED collected surface water samples from Sandia Canyon in 2000 (not fire-related); using standard analytical procedures, Aroclors 1254 and 1260 were detected at concentrations up to 100 ng/L. However, using EPA Method 1668, the congener method, analyses of runoff and baseflow in Sandia Canyon contain total PCB concentrations as high as 253 ng/L, and indicated that PCBs in Sandia Canyon and other LANL locations appear to be an environmentally weathered Aroclor 1260 (Mullen and Koch 2004).

The measured PCB concentrations in runoff in Los Alamos area drainages are considerably greater than the EPA surface water screening value of 0.64 ng/L. The screening value was developed to protect humans who eat fish contaminated with PCBs. While there are no fish in the affected Pajarito Plateau drainages, ultimately, PCBs become of concern if transported into the Rio Grande.

In 2002, storm runoff samples were collected in Pueblo, Sandia, Pajarito, and Water Canyons at LANL and baseflow samples (possibly with a component of runoff) were collected from the Rio Grande for the analysis of PCB congeners. The results of the analyses are shown in Figure 2.2.5-2. The highest total PCB concentration in LANL runoff was 252.6 ng/L in Sandia Canyon, where runoff does not typically extend to the Rio Grande. Runoff from Pueblo Canyon contained up to 92.9 ng/L total PCB concentration and runoff in Water Canyon contained up to 36.9 ng/L. Local runoff from lower Pajarito Canyon contained 5.4 ng/L, the only storm runoff sample at LANL to be less than the NMWQCC wildlife standard. The highest concentration of PCBs in the Rio Grande was 1.37 ng/L in a sample collected below Ancho Canyon on August 6, 2002 (Mullen and Koch 2004).

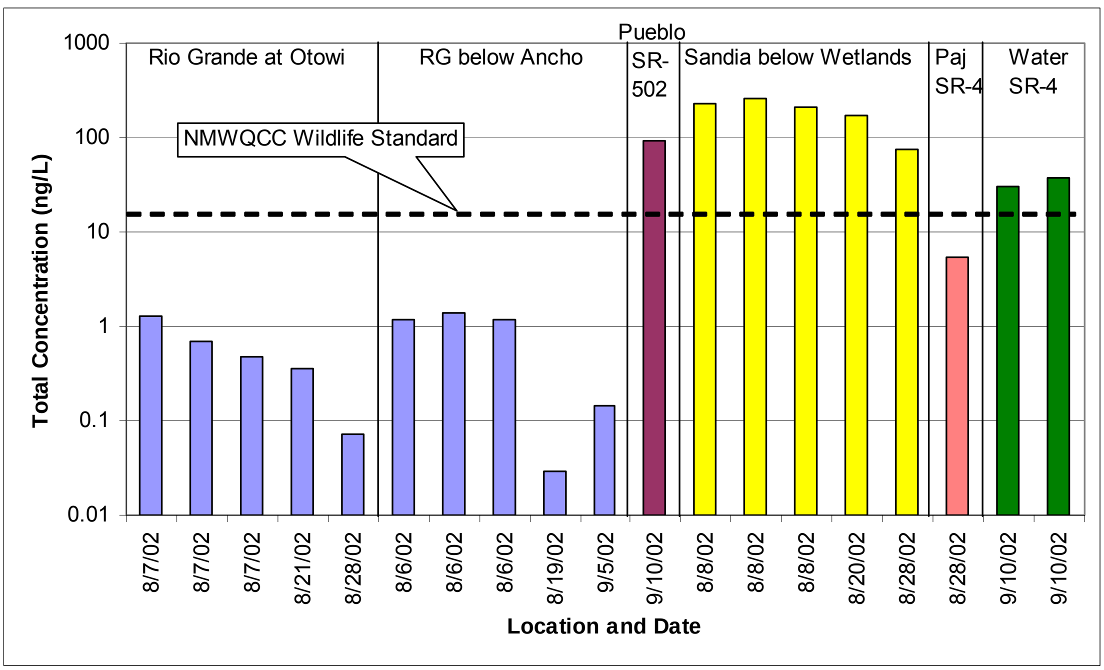


Figure 2.2.5-2. Total PCB concentration in LANL runoff and the Rio Grande in 2002.

In 2003, runoff samples were collected from the Rio Grande upstream and downstream of LANL. Figure 2.2.5-3 summarized the results of the total PCB congener concentrations of the samples. The concentration of PCBs in the Rio Grande varies about one order of magnitude, from about 1 ng/L on September 6, 2003, to about 10 ng/L on August 25, 2003, apparently depending on the source of the storm runoff to the Rio Grande. The maximum concentration of total PCBs in Rio Grande runoff was 12.8 ng/L in a sample collected from the Rio Grande below Ancho Canyon on August 25, 2003. The sample collected from Otowi Bridge upstream of LANL on September 25, 2003, contained 10.5 ng/L total PCBs. All samples of surface water and runoff in the Rio Grande collected in 2002 and 2003 contained total PCB concentrations less than the NMWQCC wildlife standard.

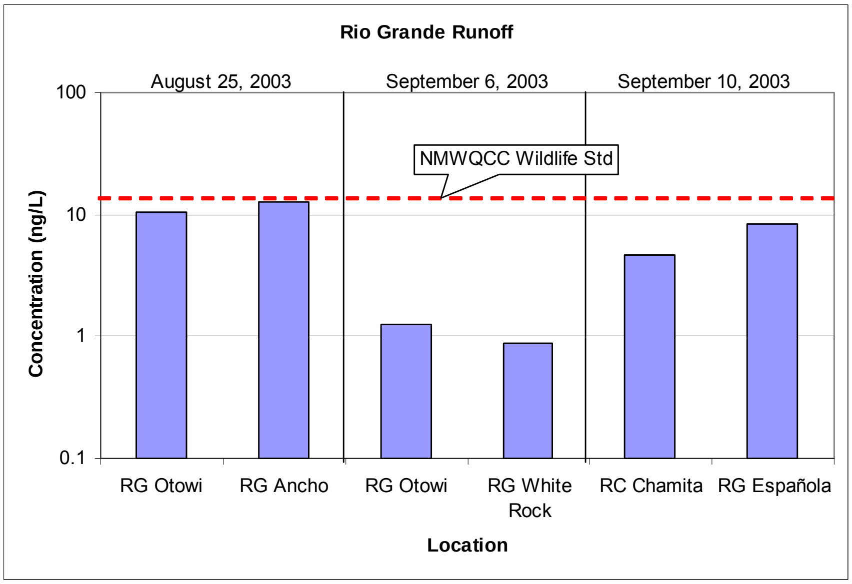


Figure 2.2.5-3. Total PCB concentration in runoff in the Rio Grande, 2003.

PCB data collected after the Cerro Grande fire show that runoff from fire-impacted areas contained detectable PCB concentrations, but these concentrations were not above the NMWQCC wildlife standard of 14 ng/L. Runoff samples collected in Pueblo Canyon and canyons at LANL downstream of municipal and industrial sites contained significantly elevated concentrations of PCBs, with Sandia Canyon runoff containing the highest total PCB concentrations; however runoff from Sandia Canyon industrial sites (not fire-affected) does not typically reach the Rio Grande. Surface water and runoff samples collected from the Rio Grande contain detectable concentrations of PCBs up to 12.8 ng/L in runoff, but samples from the Rio Grande did not contain concentrations exceeding the NMWQCC wildlife standard.

2.2.5.3 Semivolatile Organic Compounds in Storm Runoff and Snowmelt

Table 2.2.5-3 shows the detections of semivolatile organic compounds in storm runoff at LANL from 2000 through 2002. A total of 22 runoff samples contained detectable semivolatile compounds, of which 10 samples were from upstream locations, which was primarily runoff from fire-impacted areas. Nine of 10 upstream samples contained detections of benzoic acid and five samples contained detections of benzyl alcohol. Other semivolatile compounds detected in upstream runoff samples in 2000 after the fire include 4-Methylphenol, phenol, and pyridine.

Figure 2.2.5-4 shows the detections of semivolatile organic compounds in surface water from the Pajarito Plateau for the period 2000 through 2002 and the prefire range of detections. Where prefire data were not available, postfire data from background locations were used in the figure for reference. The screening levels for surface water and groundwater are also shown on the figure for comparison. Several polycyclic aromatic hydrocarbons (PAHs) were detected in snowmelt samples collected April 2001 about one year after the fire. The largest concentrations were from upstream locations, indicating a fire-associated impact.

In total, the PAHs were detected infrequently (2% of samples), yet are noteworthy because of their low health thresholds. All of the detections of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, and ideno(1,2,3-cd)pyrene were greater than the surface water screening values. Samples of deposited stream sediments collected in 2001 and 2002 show PAH concentrations approaching or greater than EPA Residential Soil Screening levels for benzo(a)pyrene, benzo(a)anthracene, and benzo(k)fluoranthene (Gallaher et al. 2003). A portion of the PAHs in the deposited stream sediments appears to be fire-associated.

Table 2.2.5-3. Semivolatile Organic Compounds Detected in Storm Runoff, 2000–2002.

Sample Date	Location Name	Relative Location	2-Methylphenol	4-Methylphenol	Benzoic Acid	Benzyl Alcohol	Bis(2-ethylhexyl)phthalate	Di-n-butylphthalate	Naphthalene	Phenol	Pyridine
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
6/3/2000	Los Alamos above Ice Rink	Upstream		15	690					50	49
6/3/2000	Los Alamos above SR 4	Downstream		11	250					19	37
6/28/2000	Canon de Valle above SR 501	Upstream			670						
6/28/2000	Indio at SR 4	Downstream			940						
6/28/2000	Pajarito above SR 4	Downstream			1300						
6/28/2000	Pajarito below SR 501	Upstream			1800						
6/28/2000	Pajarito SR 4 Culvert	Downstream			1900						
6/28/2000	Starmers above Pajarito	Onsite			1300	22					
6/28/2000	Water below SR 4	Downstream			1100						
7/9/2000	Guaje Canyon at SR 502	Offsite	2.7	4.4	67	2.9				7.4	16
7/9/2000	Los Alamos above SR 4	Downstream			16		1.9				3.4
7/18/2000	Los Alamos above Ice Rink	Upstream			21	7					
9/8/2000	Guaje Canyon at SR 502	Offsite				5.3					
10/23/2000	Canon de Valle above SR 501	Upstream			46.4						
10/23/2000	Pajarito below SR 501	Upstream			32.8	17.5					
10/23/2000	Starmer's Gulch above SR 501	Upstream			111	31.6					
10/23/2000	Twomile above SR 501	Upstream			457	129					
10/23/2000	Water above SR 501	Upstream			43.8	16.3					
8/5/2001	PA-4.54	Onsite			8.7	3.1					
6/21/2002	Los Alamos below Ice Rink	Upstream						3.2			
6/22/2002	Pajarito above SR 4	Downstream	13.4	2.4						0.64	
8/7/2002	Sandia below Wetlands	Onsite							0.2		

Four semivolatile organic compounds were detected more than once in Rio Grande and Cochiti Reservoir samples: bis(2-ethylhexyl)phthalate, diethylphthalate, fluoranthene, and pyrene. Concentrations in the Rio Grande downstream of LANL were comparable or lower than those measured in the Rio Grande upstream of LANL (Otowi Bridge and upstream). Few of the semivolatile compounds detected in Pajarito Plateau surface waters were detected in Rio Grande or Cochiti Reservoir water samples. Overall, there appears to be minimal effect from fire-associated semivolatile organic compounds on the Rio Grande waters.

2.2.5.4 Volatile Organic Compounds in Storm Runoff

Table 2.2.5-4 shows the detections of volatile organic compounds in storm runoff in 2000 and 2001 (runoff samples from major canyons were not analyzed for volatile organic compounds in 2002 and 2003). All of the 21 reported detections of volatile organic compounds were in estimated concentrations close to the detection limits of the analytical procedure. Benzene was detected in six upstream runoff samples and in runoff from Guaje Canyon in September and October 2000. Toluene was detected in five upstream runoff samples, and methylene chloride was detected in four upstream and two downstream samples; these compounds are often introduced by analytical laboratory procedures. Ethylbenzene was detected in two runoff samples from lower Guaje and Pajarito Canyons and 1,4-dichlorobenzene was detected in one sample from lower Water Canyon. Runoff samples collected from Pueblo, Los Alamos, and Pajarito Canyons in 2001 by NMED did not contain detections of volatile organic compounds. Detections of all of organic chemicals were at concentrations below the EPA Region 6 screening values for tap water (EPA 2001).

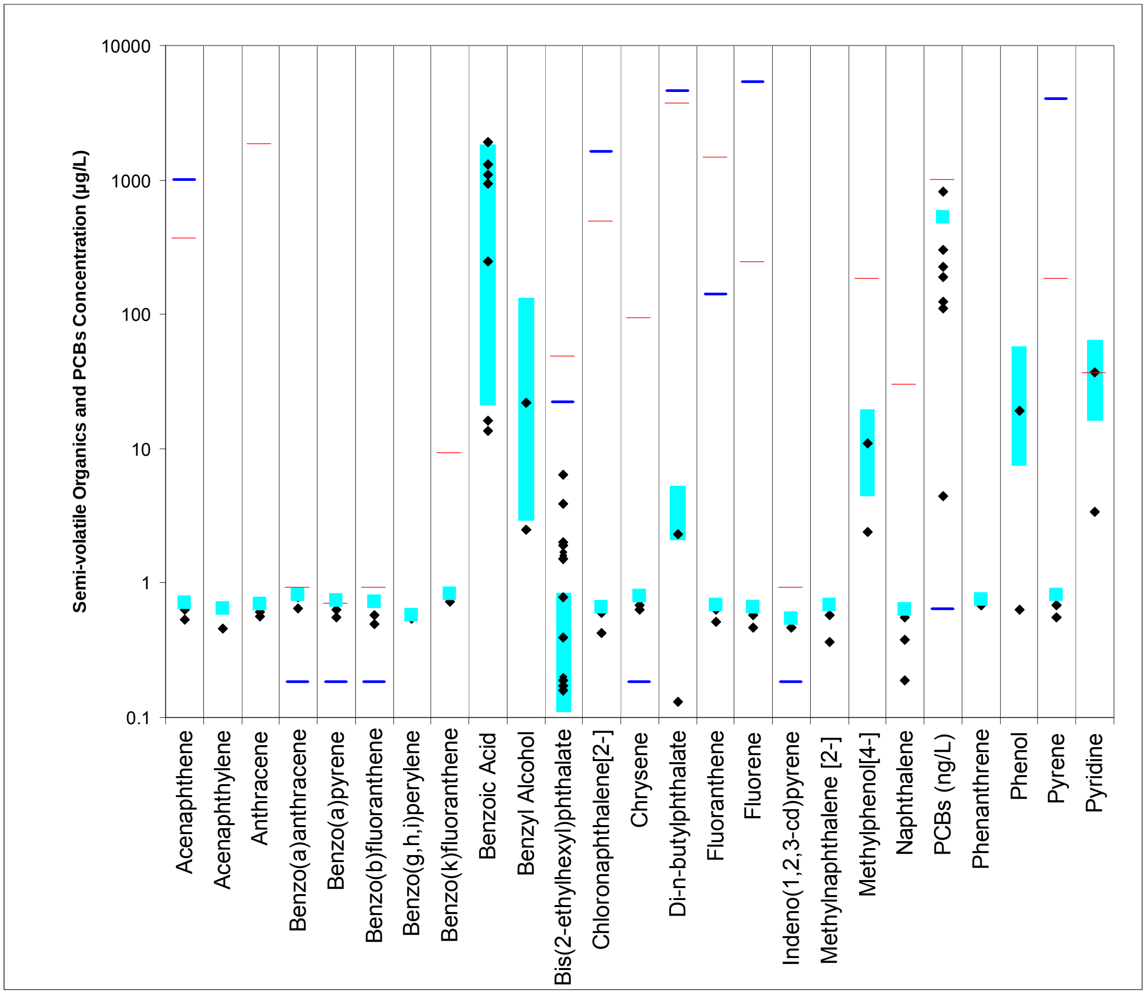


Figure 2.2.5-4. Summary of semivolatile organic compounds in Pajarito Plateau surface water, 2000–2002, showing range of prefire detections (shading) and screening levels for surface water (wide blue bar) and groundwater (narrow red bar).

Table 2.2.5-4. Volatile Organic Compounds Detected in Storm Runoff, 2000–2002.

Sample Date	Location Name	Relative Location	1,4-Dichloro benzene µg/L	Benzene µg/L	Ethylbenzene µg/L	Methylene chloride µg/L	Toluene µg/L
8/18/2000	Water below SR 4	downstream	0.12				
9/8/2000	Guaje Canyon at SR 502	offsite		0.39	0.073		
9/8/2000	Pajarito below SR 501	upstream		0.27	0.068		
10/23/2000	Canon de Valle above SR 501	upstream		0.31		1.4	0.37
10/23/2000	Pajarito below SR 501	upstream		0.35			0.39
10/23/2000	Starmer's Gulch above SR 501	upstream		0.27		1.2	0.42
10/23/2000	Twomile above SR 501	upstream		0.38		1.3	0.45
10/23/2000	Water above SR 501	upstream		0.3		1	0.36
10/23/2000	Water below SR 4	downstream				1.1	
10/24/2000	Pajarito above SR 4	downstream				1.1	

Figure 2.2.5-5 summarizes the detections of organic compounds in two or more Rio Grande surface water samples. Most organic compounds in samples collected from the Rio Grande were detected in estimated concentrations; acetone was the most detected compound (18 samples), which was also detected in several blank samples. Other volatile organic compounds detected in low concentrations included benzyl alcohol, bromomethane, chloromethane, dibromofluoromethane, ethylbenzene, OCDD, and styrene; detections occurred in samples from both upstream and downstream of LANL, except butanone, ethylbenzene, and styrene were only detected at Otowi bridge upstream of LANL and chloromethane was only detected in one sample from the Rio Grande near White Rock.

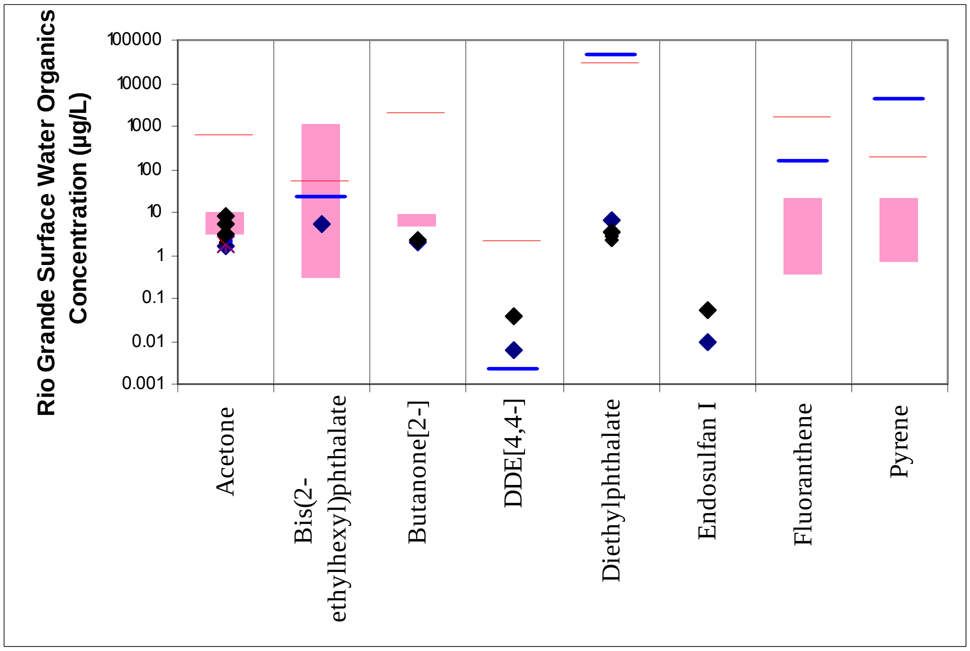


Figure 2.2.5-5. Summary of organic compounds detected in two or more Rio Grande surface water samples, showing range of prefire detections (shading) and screening levels for surface water (wide blue bar) and groundwater (red bar).

2.2.5.5 Pesticides

Pesticides detected in low concentrations in samples from the Rio Grande included BHC[alpha-], BHC[beta-], BHC[delta-], BHC[gamma-], DDD[4,4'-], Dieldrin, Endosulfan I, Endosulfan II, Endosulfan Sulfate, Endrin, Heptachlor Epoxide, Hexachlorodibenzofurans (Total), Methoxychlor[4,4'-], Tetrachlorodibenzodioxins (Total), and Toxaphene (Technical Grade). Most detections of pesticides were reported in estimated concentrations by the analytical laboratory.

2.2.5.6 Dioxins and Furans

Dioxins and furans are released to the environment in emissions from wood burning in the presence of chlorine, in exhaust from automobiles powered by leaded gasoline, in accidental fires involving transformers containing PCBs, and in stack emissions from the incineration of municipal refuse (EPA 2004). These compounds are some of the most toxic and environmentally stable tricyclic aromatic compounds. Testing was performed on the Pajarito Plateau (waters) and in the Rio Grande (waters and sediments) out of concern that these compounds could be formed by the Cerro Grande fire. There are minimal prefire data available for these compounds. Table 2.2.5-5 summarizes the sampling effort and the rates of detection for the dioxins and furans.

Table 2.2.5-5. Dioxins and Furans Detection Frequency.

Location	Media	Polychlorinated dibenzodioxins			Polychlorinated dibenzofurans		
		No. of Samples	No. of Samples with Detects	Rate of Detection	No. of Samples	No. of Samples with Detects	Rate of Detection
PP Above LANL	SW	35	0	0%	35	0	0%
PP Below LANL	SW	35	0	0%	35	0	0%
PP Above LANL	Sediment	0	NA	NA	0	NA	NA
PP Below LANL	Sediment	0	NA	NA	0	NA	NA
RG Above LANL	SW	4	1	25%	4	0	0%
RG Below LANL	SW	20	3	15%	20	1	5%
RG Above LANL	Sediment	4	2	50%	7	0	0%
RG Below LANL	Sediment	17	5	29%	17	0	0%

PP = Pajarito Plateau, RG = Rio Grande, SW = Surface water, NA = Not Applicable

To evaluate the significance of detected dioxins or furans, we considered the relative degree of toxicity of each compound and estimated the risks associated with exposures to mixtures of polychlorinated dibenzodioxins and polychlorinated dibenzofurans. Relative toxicity factors have been developed for 17 compounds (EPA 1989). The most toxic compound is 2,3,7,8-tetrachlorinated dibenzodioxins (2,3,7,8-TCDD) and mixtures of dioxins and furans are expressed as a summed concentration equivalent to 2,3,7,8-TCDD. The measured concentration of each detected compound is adjusted by the relative toxicity factor and the adjusted concentrations are summed to quantify the combined risk posed by the mixture.

On the Pajarito Plateau, dioxins and furans were not detected in 35 snowmelt and storm runoff samples. Due to very low water solubility, most dioxins occurring in water are expected to be associated with sediments or suspended material. While no Pajarito Plateau sediment samples were evaluated for dioxin content by WQH after the fire, some postfire data were provided in Kraig et al. (2002) and the LANL ER Project (LANL 2004). Kraig et al. report a maximum concentration of 0.0035 µg/kg for summed 2,3,7,8-TCDD equivalent in postfire sediment deposits in middle Los Alamos Canyon, and a maximum dioxin concentration of 0.00047 µg/kg in ash-rich sediments collected downstream of burned areas and upstream of LANL. Each of the maximum concentrations was lower than sediment screening levels for protection of aquatic life and for residential exposures (Kraig et al. 2002). Table 2.2.5-6 compares the total dioxin concentrations to screening levels.

In the Rio Grande, dioxins were detected in seven sediment and three water samples in 2000 and 2001, and a furan was detected in a 2000 water sample. As a class, dioxins were detected in one of three sediment samples and one in seven water samples. A single dioxin compound, (Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]), was detected in water and sediment upstream of LANL influences and indicate a dioxin source(s) upstream of Otowi Bridge, but the upstream data set is small and not definitive.

The summed 2,3,7,8-TCDD equivalent concentrations measured in Rio Grande sediment are low and less than 1% of the aquatic life and residential soil screening levels. Three of 24 water samples contained summed 2,3,7,8-TCDD equivalent concentrations that were 126, 1.4, and 2.8 times greater than EPA human health criteria, modified to 10^{-5} excess cancer risk (EPA 2002). We are unable to completely evaluate the risks from dioxins and furans in water samples, however, because the analytical detection limits typically are one to three orders of magnitude greater than the screening levels. Although there are no prefire results to compare against, the detection of dioxin in the ash-rich sediment deposits upstream of LANL (Kraig et al. 2002) supports the possibility that dioxins were formed by the Cerro Grande fire.

Table 2.2.5-6. Comparison of Total Dioxin Concentrations to Screening Levels.

Bottom Sediments

Location Name	Sample Date	Summed 2,3,7,8-TCDD Conc.[a] (ug/kg)	PEL[b] Aquatic Life Criterion (ug/kg)	Ratio: Total Dioxin Conc. / PEL	Residential Soil Screening Level (RSD 10^{-5})	Ratio: Total Dioxin Conc. / RSSL
Los Alamos Canyon Weir (max conc.)[d]	2000	0.0035	0.0215	0.16	0.0390	0.090
Ashy Sediment below burned areas (max. conc.)[d]	2000	0.00047	0.0215	0.02	0.0390	0.012
Rio Grande near White Rock	7/7/2000	0	0.0215	0	0.0390	0
Rio Grande below Cochiti	7/11/2000	0.000045	0.0215	0.002	0.0390	0.001
Cochiti Middle	7/24/2001	0.000245	0.0215	0.011	0.0390	0.006
Cochiti Upper	7/24/2001	0.000011	0.0215	0.001	0.0390	0.0003
Rio Grande at Otowi Bridge	7/27/2001	0.000008	0.0215	0.0004	0.0390	0.0002
Rio Grande near White Rock	7/28/2001	0.000116	0.0215	0.005	0.0390	0.003
Rio Grande at Otowi Bridge	8/8/2001	0.000014	0.0215	0.0007	0.0390	0.0004

Surface Water

Location Name	Sample Date	Total Dioxin Equivalent Conc. (ug/L)	Screening Level for Human Health[c] (ug/L)	Ratio: Total Dioxin Conc. / Screening Level
Rio Grande below Cochiti	7/11/2000	0.0000063	0.00000005	126
Rio Grande near White Rock	7/26/2001	0.00000007	0.00000005	1.4
Rio Grande at Otowi Bridge	7/27/2001	0.00000014	0.00000005	2.8

[a]Summed 2,3,7,8-TCDD Equivalent Conc. = Sum [Result x 2,3,7,8-TCDD Toxicity Equivalency Factor] (EPA 1989) for each detected dioxin or furan compound.
[b]PEL = Probable Effects Level (Environment Canada 2002)
[c]Ambient Water Quality Criteria (EPA 2002) (modified RSD 10^{-5} risk-specific dose at a cancer risk of 1 in 100,000)
[d]Data from Kraig et al. (2002).

2.2.5.7 Organic Compounds not Detected in Surface Water

Dioxins, furans, herbicides, high explosives, insecticides, PCBs, semivolatile organic compounds, and volatile organic compounds **not** detected in surface waters of the Pajarito Plateau and of the Rio Grande study area are listed in Table 2.2.5-7.

2.2.6 Biotoxicity of Surface Water

LANL WQH and NMED personnel collected a total of 15 baseflow, storm runoff, and snowmelt water samples in 2000 and 2001 for the analysis of acute and chronic biological toxicity. Sample locations and test results are shown in Table 2.2.6-1. The EPA Region 6, Houston Branch, conducted all the toxicity monitoring following standard test protocols (EPA 1993). In the acute test, a population of daphnia (an aquatic insect, *Ceriodaphnia dubia)* was exposed for 48 hours to various dilutions of water decanted off centrifigued storm water samples. Storm water dilutions of 0% (lab control), 6.25%, 12.5%, 25%, 50%, and 100% (undiluted storm water) were used to establish a dose-response relationship, if any, for survival of the insect. An acceptable survival rate is 20% lower than the control sample. None of these samples showed significant acute effects.

Table 2.2.5-7. Organic Compounds Not Detected in Surface Water of the Pajarito Plateau and the Rio Grande.

Dioxins and Furans	**Insecticides**	**SVOC (continued)**	**VOC (continued)**
Heptachlorodibenzodioxin	Aldrin	Nitroaniline[2-]	Dichloropropane[1,3-]
[1,2,3,4,6,7,8-]	Chlordane[alpha-]	Nitroaniline[3-]	Dichloropropane[2,2-]
Heptachlorodibenzodioxins	Chlordane[gamma-]	Nitroaniline[4-]	Dichloropropene[1,1-]
(Total)	DDD[4,4'-]	Nitrobenzene	Dichloropropene
Heptachlorodibenzofuran	Endrin Aldehyde	Nitrophenol[2-]	[cis-1,3-]
[1,2,3,4,6,7,8-]	Endrin Ketone	Nitrophenol[4-]	Dichloropropene
Heptachlorodibenzofuran	Heptachlor	Nitrosodimethylamine[N-]	[trans-1,3-]
[1,2,3,4,7,8,9-]		Nitroso-di-n-propylamine[N-]	Hexachlorobutadiene
Heptachlorodibenzofurans	**PCBs**	Nitrosodiphenylamine[N-]	Hexanone[2-]
(Total)	Aroclor-1016	Oxybis(1-chloropropane)	Iodomethane
Hexachlorodibenzodioxin	Aroclor-1221	[2,2'-]	Isopropylbenzene
[1,2,3,4,7,8-]	Aroclor-1232	Pentachlorophenol	Isopropyltoluene[4-]
Hexachlorodibenzodioxin	Aroclor-1242	Tetrachlorophenol[2,3,4,6-]	Methyl-2-pentanone[4-]
[1,2,3,6,7,8-]	Aroclor-1248	Trichlorobenzene[1,2,4-]	Propylbenzene[1-]
Hexachlorodibenzodioxin	Aroclor-1262	Trichlorophenol[2,4,5-]	Tetrachloroethane
[1,2,3,7,8,9-]		Trichlorophenol[2,4,6-]	[1,1,1,2-]
Hexachlorodibenzodioxins	**Semi-volatile Organic**		Tetrachloroethane
(Total)	**Compounds (SVOC)**	**Volatile Organic**	[1,1,2,2-]
Hexachlorodibenzofuran	Acetophenone	**Compounds (VOC)**	Tetrachloroethene
[1,2,3,4,7,8-]	Aniline	Acrolein	Trichloroethane
Hexachlorodibenzofuran	Anthracene	Acrylonitrile	[1,1,1-]
[1,2,3,6,7,8-]	Azobenzene	Bromobenzene	Trichloroethane
Hexachlorodibenzofuran	Benzidine	Bromochloromethane	[1,1,2-]
[1,2,3,7,8,9-]	Bis(2-chloroethoxy)methane	Bromoform	Trichloroethene
Hexachlorodibenzofuran	Bis(2-chloroethyl)ether	Butylbenzene[n-]	Trichlorofluoromethane
[2,3,4,6,7,8-]	Bromophenyl-phenylether[4-]	Butylbenzene[sec-]	Trichloropropane
Octachlorodibenzofuran	Butylbenzylphthalate	Butylbenzene[tert-]	[1,2,3-]
[1,2,3,4,6,7,8,9-]	Carbazole	Carbon Disulfide	Trichlorotrifluoroethane
Pentachlorodibenzodioxin	Chloro-3-methylphenol[4-]	Carbon Tetrachloride	Trimethylbenzene
[1,2,3,7,8-]	Chloroaniline[4-]	Chlorobenzene	[1,2,4-]
Pentachlorodibenzodioxins	Chlorophenol[2-]	Chloroethane	Trimethylbenzene
(Total)	Chlorophenyl-phenyl	Chloroethyl vinyl ether[2-]	[1,3,5-]
Pentachlorodibenzofuran	[4-] Ether	Chlorotoluene[2-]	Vinyl Chloride
[1,2,3,7,8-]	Dibenzofuran	Chlorotoluene[4-]	Xylene (Total)
Pentachlorodibenzofuran	Dichlorobenzene[1,2-]	Dibromo-3-	Xylene[1,2-]
[2,3,4,7,8-]	Dichlorobenzene[1,3-]	Chloropropane[1,2-]	Xylene[1,3-+Xylene[1,4-]
Tetrachlorodibenzodioxin	Dichlorobenzidine[3,3'-]	Dibromoethane[1,2-]	
[2,3,7,8-]	Dichlorophenol[2,4-]	Dibromomethane	
Tetrachlorodibenzofuran	Dimethyl Phthalate	Dichlorobenzene[1,2-]	
[2,3,7,8-]	Dimethylphenol[2,4-]	Dichlorobenzene[1,3-]	
	Dinitro-2-methylphenol[4,6-]	Dichlorodifluoromethane	
Herbicides	Dinitrophenol[2,4-]	Dichloroethane[1,1-]	
Chloro-o-tolyloxyacetic[4-] Acid	Di-n-octylphthalate	Dichloroethane[1,2-]	
D[2,4-]	Diphenylamine	Dichloroethene[1,1-]	
TP[2,4,5-]	Diphenylhydrazine[1,2-]	Dichloroethene	
	Hexachlorobenzene	[cis/trans-1,2-]	
High Explosives	Hexachlorobutadiene	Dichloroethene	
Nitrobenzene	Hexachlorocyclopentadiene	[cis-1,2-]	
PETN	Hexachloroethane	Dichloroethene	
Tetryl	Isophorone	[trans-1,2-]	
Trinitrobenzene[1,3,5-]	Methylpyridine[2-]	Dichloropropane[1,2-]	

In the chronic tests, two different test organisms were used. A population of daphnia was exposed for four to seven days to a control sample and to undiluted water decanted off centrifuged storm water sample to look for survival and reproduction effects, while the embryo and larvae of fat head minnows (*Pimephales promelas*) were studied for survival and teratogenicity effects. Thirteen samples showed no significant chronic effects. However, two storm water samples collected by NMED from upper Pueblo Canyon

Table 2.2.6-1. Acute and Chronic Biological Toxicity Test Results, Los Alamos Area.

Station ID	Organization	Date	Canyon	Sample Type	Acute Test Results	Chronic Tests Results*
LA 12.5	NMED	08/13/00	Los Alamos	Baseflow	No Effect	No Effect
LA reservoir	NMED	08/31/00	Los Alamos	Baseflow	No Effect	No Effect
E240	LANL	09/08/00	Pajarito	Runoff	No Effect	No Effect
EGS4	LANL	09/08/00	Guaje	Runoff	No Effect	No Effect
PUN 0.01	NMED	09/08/00	Pueblo	Runoff	No Effect	70% mortality
PU 6.7	NMED	09/08/00	Pueblo	Runoff	No Effect	100% mortality
PU 2.0	NMED	09/08/00	Pueblo	Runoff	No Effect	No Effect
E025	LANL	04/04/01	Los Alamos	Snowmelt	Not performed	No Effect
E042	LANL	04/04/01	Los Alamos	Snowmelt	Not performed	No Effect
E050	LANL	04/04/01	Los Alamos	Snowmelt	Not performed	No Effect
E240	LANL	04/18/01	Pajarito	Snowmelt	Not performed	No Effect
E240	LANL	04/18/01	Pajarito	Snowmelt	Not performed	No Effect
E025	LANL	05/02/01	Los Alamos	Snowmelt	Not performed	No Effect
E042	LANL	05/02/01	Los Alamos	Snowmelt	Not performed	No Effect
E050	LANL	05/02/01	Los Alamos	Snowmelt	Not performed	No Effect

*Chronic tests--7-day exposure for 2000 samples; 4-day exposure for 2001 samples.

Locations:

EGS4	Guaje Canyon above SR 502
LA 12.5	approximately 1/4 to 1/2 mile upstream from LA Reservoir
LA reservoir	Depth composite sample from center of reservoir, near the concrete standpipe
E025	Los Alamos Canyon above skating rink
E050	Los Alamos Canyon below low-head weir
PUN 0.01	Pueblo Canyon, North Tributary (north tributary above land bridge)
PU 6.7	Pueblo Canyon above land bridge
PU 2.0	Pueblo Canyon near Bayo Treatment Plant
E240	Pajarito Canyon above SR 501

showed 70% and 100% mortality, and significantly reduced reproduction in the 7-day Survival and Reproduction daphnia test (NMED 2003a). These samples were collected upstream of LANL discharges and above most urbanized areas of Los Alamos. The specific source(s) of the toxicity have not been identified.

3.0 Impacts of the Cerro Grande Fire to Natural Baseflow

3.1 Occurrence of Natural Baseflow

Figure 3-1 shows the locations of springs and major drainages in the western part of LANL where natural baseflow samples were collected on the flanks of the Sierra de los Valles. Upper Los Alamos, Pajarito, and Water Canyons contain spring-fed perennial streams that flow through highly fire-impacted areas upstream of LANL. Stream flow extends eastward on the flanks of the Sierra de los Valles for variable distances. The spring-fed stream in upper Los Alamos Canyon is temporarily contained in the reservoir in upper Los Alamos Canyon and then flows downstream to near the western LANL boundary before seeping into the subsurface.

In upper Pajarito Canyon, perennial flow extends to about 0.25 miles upstream of the LANL western boundary and abruptly terminates at the surface expression of the Pajarito fault, where upper Bandelier Tuff units outcrop at about 8,100 ft elevation (Dale et al. 2001). Similarly, in upper Water Canyon, flow downstream of the Water Canyon Gallery spring extends to near the Pajarito fault zone, where the water apparently seeps into subsurface units. Approximately 1 to 1.5 miles east of the fault, several permanent springs emanate from the Bandelier Tuff on LANL land in the Pajarito Canyon, Cañon de Valle, and Water Canyon watersheds at about 7,640 ft elevation. The Pajarito fault system approximately parallels the western LANL boundary and SR 501. The rate of stream loss across the fault in Pajarito Canyon and Water Canyon is usually sufficient such that the streams are dry downstream of the fault at SR 501. The infiltration of perennial stream flow into the fault zone and the presence of springs on LANL down gradient to the east, suggest a hydrologic connection between the fault and the springs (Dale et al. 2001).

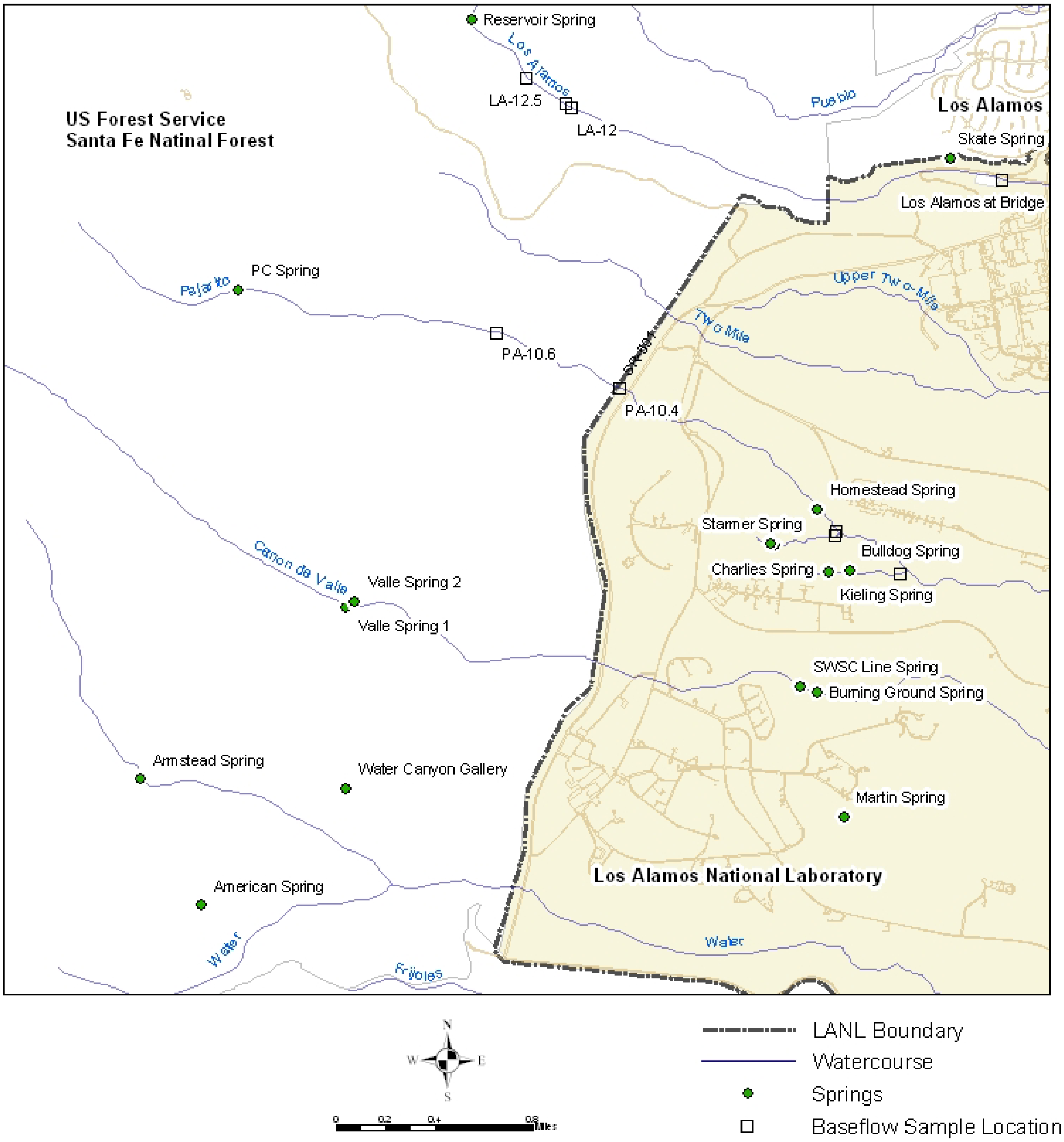


Figure 3-1. Locations of springs and baseflow sample locations on the flanks of the Sierra de los Valles and on the western Pajarito Plateau.

Limited-extent reaches of baseflow from industrial and sanitary outfalls occur at LANL in Sandia Canyon and Mortandad Canyon and in lower Pueblo Canyon downstream of the Los Alamos County Wastewater Treatment Plant; however, only naturally occurring baseflow from springs in the Sierra de los Valles was included in the evaluation of fire-impacts to baseflow.

3.2 Fire Impacts to Quality of Baseflow

After the Cerro Grande fire, baseflow was sampled by NMED personnel two weeks after the fire and prior to major storm runoff in upper Los Alamos and Pajarito Canyons to determine the presence of changes to the hydrochemistry of the water. Baseflow was also sampled before and after the fire by WQH as part of environmental surveillance at LANL (ESP 2001) and by the LANL ER Project (LANL 2000d, LANL 2000e). Additionally, springs along the western boundary of LANL were sampled by NMED to determine if chemical changes in baseflow upstream of LANL could be detected in the springs. Table 3.2-1 summarizes the results of sampling baseflow after the Cerro Grande fire. Only three naturally occurring baseflow samples were collected in 2003, so the following discussion of baseflow after the Cerro Grande fire primarily focuses on results for 2000 through 2002.

Table 3.2-1. Summary of Postfire Dissolved Major Water Quality Constituents in Baseflow.

Analyte	Units	Min	Max	Median	Min STD	Standard Type
HCO_3	mg/L	29.6	230	63.8		
Ca	mg/L	6	63	13.2		
Cl	mg/L	0.748	15	4.95	250	EPA Secondary DW Std and NMWQCC GW Limit
CN (amenable)	mg/L	ND	ND	ND	0.0052	NMWQCC Wildlife Habitat Std
CN (total)	mg/L	ND	ND	ND	0.2	EPA Primary DW Std and NMWQCC GW Limit
F^{-1}	mg/L	0.07	0.19	0.103	1.6	NMWQCC GW Limit
HARDNESS	mg/L	27	58	34		
K	mg/L	1.059	14	2.955		
Mg	mg/L	2	15	3.9		
NA	mg/L	3.795	11	6.75	20	EPA Health Advisory
NO_3+NO_2-N	mg/L	0.08	0.71	0.25	10	EPA Primary DW Std and NMWQCC GW Limit
PO_4^{-3}	mg/L	0.02	0.12	0.062		
SO_4	mg/L	1.14	25	3.8	250	EPA Secondary DW Std
TDS	mg/L	59	369	110	500	EPA Secondary DW Std

Note: ND = not detected; reference standards from NMWQCC (2002) and EPA (2002)

Figure 3-2 shows the distribution of concentrations of major water quality constituents in filtered upstream baseflow compared with minimum applicable standards for the postfire years 2000 through 2002. There were no constituents detected in upstream baseflow in concentrations above minimum applicable standards.

Figure 3-3 shows the median concentrations of selected major and minor water quality constituents in filtered baseflow samples, prefire and for 2000 through 2003. In 2000, the median concentrations of each constituent increased notably over prefire median concentrations. The highest increase is observed in manganese concentrations, which increased over one order of magnitude in 2000 after the fire. Concentrations decreased each year after the fire for most constituents, and by 2002, most concentrations were close to prefire levels. Only two filtered baseflow samples were collected in 2003, both in Los Alamos Canyon, where median barium, calcium, magnesium, manganese, sodium, and sulfate concentrations were higher than in 2002.

Detections of radionuclides in baseflow prefire and postfire were scattered and few, and existing detections were usually near the method detection limits. The existing results of radionuclide analyses for upstream baseflow do not provide sufficient data for adequate analyses.

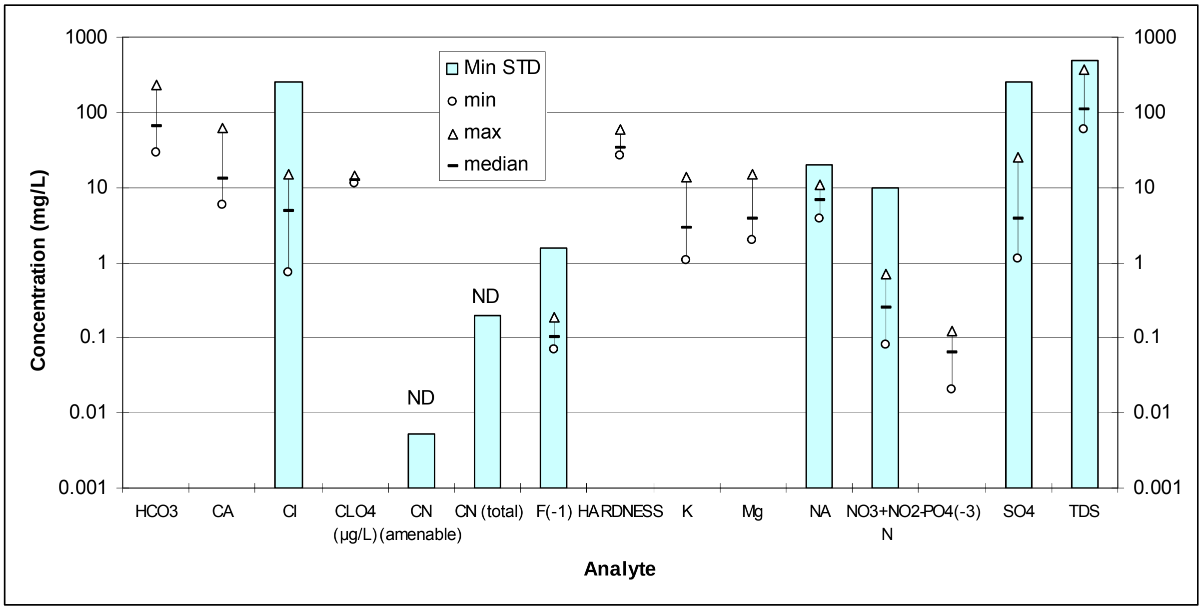


Figure 3-2. Major water quality constituents in filtered upstream baseflow compared with reference standards, 2000–2002.

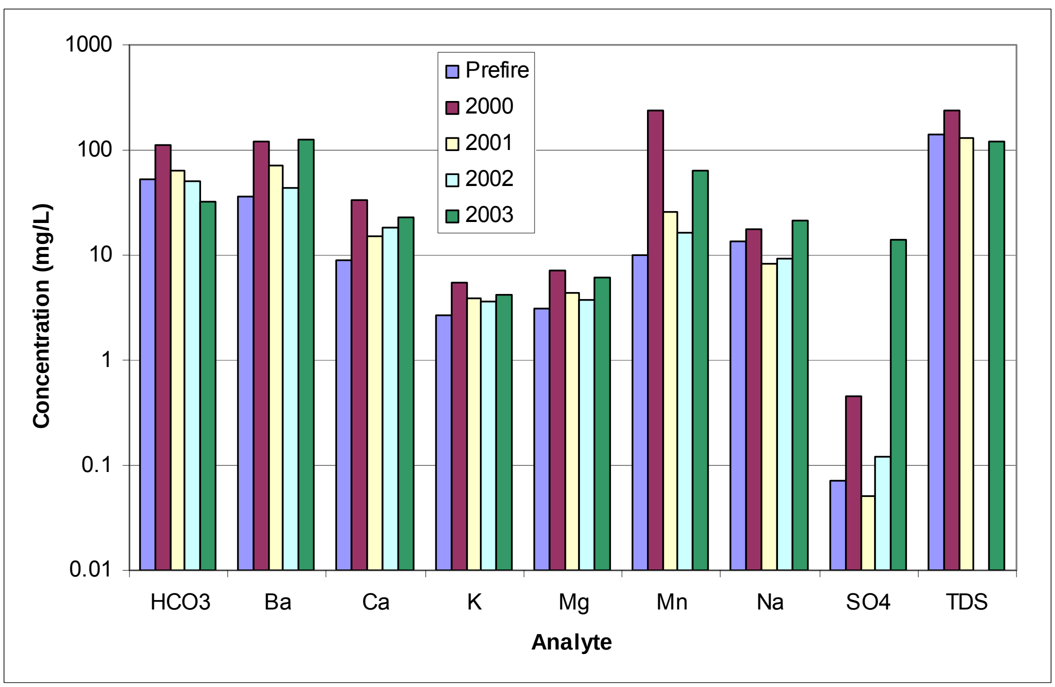


Figure 3-3. Median concentrations of selected major and minor water quality constituents in filtered baseflow, prefire and 2000–2003.

After the Cerro Grande fire, chemical changes to the baseflow in the upper part of the canyons were observed in the major water quality constituents as described above. NMED personnel sampled springs on LANL land east of the Pajarito fault about one month after the fire to determine the possibility of connectivity and the possible rate of water travel between the fault and the springs. Analytical results show that the springs contained elevated concentrations of bicarbonate and calcium, suggesting that fire-impacted baseflow from the upper canyons had apparently passed through the fault and spring system. Hence, the travel time from the point of recharge to discharge appears to be less than 30 days, assuming the referenced ions moved at the same velocity as groundwater (Dale et al. 2001).

Figure 3-4 shows the time series of dissolved calcium concentrations in baseflow upstream of LANL and in springs near the Pajarito fault. Springs sampled on June 15, 2000, about five weeks after the fire contained elevated calcium concentrations compared with the springs sampled a few days before the fire. Dissolved calcium concentrations greater than 50 mg/L were observed in samples collected from Los Alamos Reservoir and from baseflow in upper Pajarito Canyon in July and August 2000 after the fire. In 2001 the highest dissolved calcium concentration in the Los Alamos Reservoir was 39 mg/L, similar to prefire concentrations.

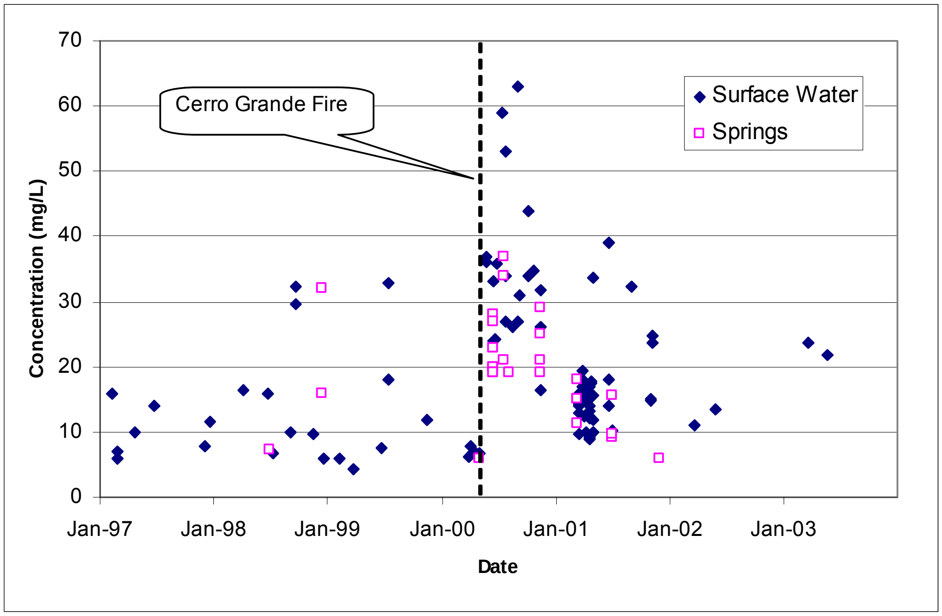


Figure 3-4. Time series of dissolved calcium concentrations in baseflow and springs near the Pajarito fault.

Figure 3-5 shows the distribution of dissolved calcium concentrations in upstream baseflow and springs near the Pajarito fault for prefire years and 2000 through 2002. Concentrations of dissolved calcium in springs compare with the baseflow concentrations for each period, although the maximum concentrations observed in springs are less than those observed in baseflow. The distribution of concentrations of dissolved calcium in both baseflow and springs in 2002 approximate prefire distributions.

Figure 3-6 shows the time series of dissolved manganese in baseflow and springs from 1997 to 2003. Before the Cerro Grande fire most results for dissolved manganese were non-detect (about 10 µg/L) but occasionally higher concentrations were observed in samples from Martin Spring Canyon (2420 mg/L) in 1999 and the TA-16 90 Pond (520 mg/L) in 1998. After the Cerro Grande fire surface water samples collected from the Los Alamos Reservoir in 2000 and 2001 and samples from upper Pajarito Canyon in 2000 contained over 1000 µg/L dissolved manganese. Generally, surface water samples that were in contact with reworked ash from the fire contained elevated concentrations of dissolved manganese. By 2002, concentrations of dissolved manganese in surface water were similar to prefire conditions.

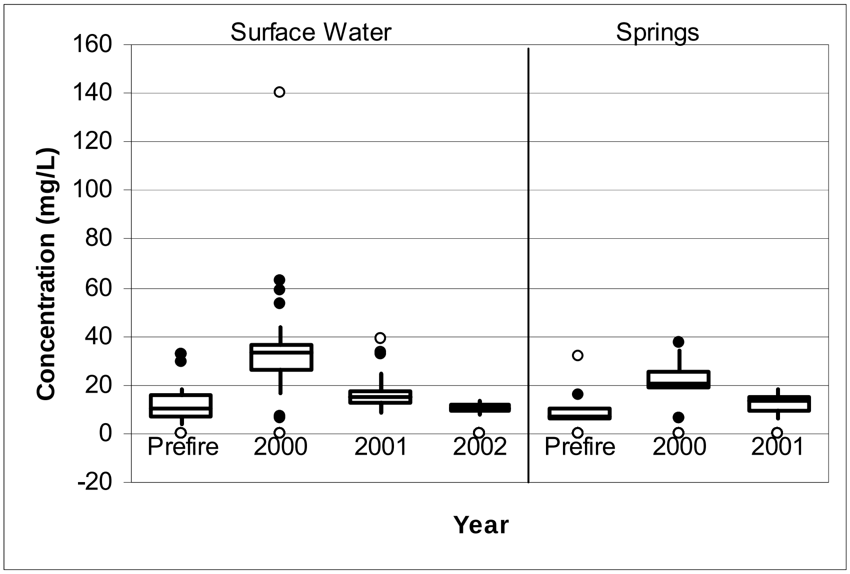


Figure 3-5. Distribution of dissolved calcium concentrations in baseflow and springs, prefire and postfire.

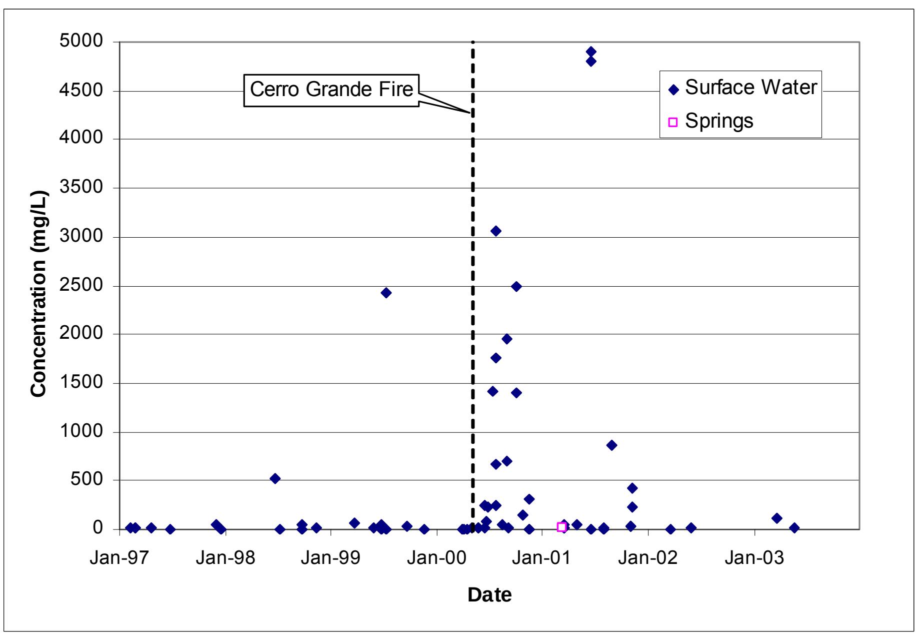


Figure 3-6. Time series of dissolved manganese concentrations in baseflow and springs, 1997–2003.

4.0 Impacts of the Cerro Grande Fire to Alluvial Groundwater

WQH collects alluvial groundwater annually in canyons at LANL, which include Pueblo, Los Alamos, Mortandad, and Pajarito Canyons. In addition, the LANL ER Project collected alluvial groundwater samples in these canyons for characterization of potential release sites and to evaluate potential impacts from the Cerro Grande fire (LANL 2000f, g, h; Katzman 2001). Figure 4-1 shows the locations of alluvial wells that were sampled before and after the fire. Alluvial groundwater wells used to evaluate fire impacts were those upstream of LANL operations and included LAO-B and LAO-C in Los Alamos Canyon, PAO-1 in Pueblo Canyon, and for some constituents (excluding barium and organics), CDV-MW-2 in Cañon de Valle.

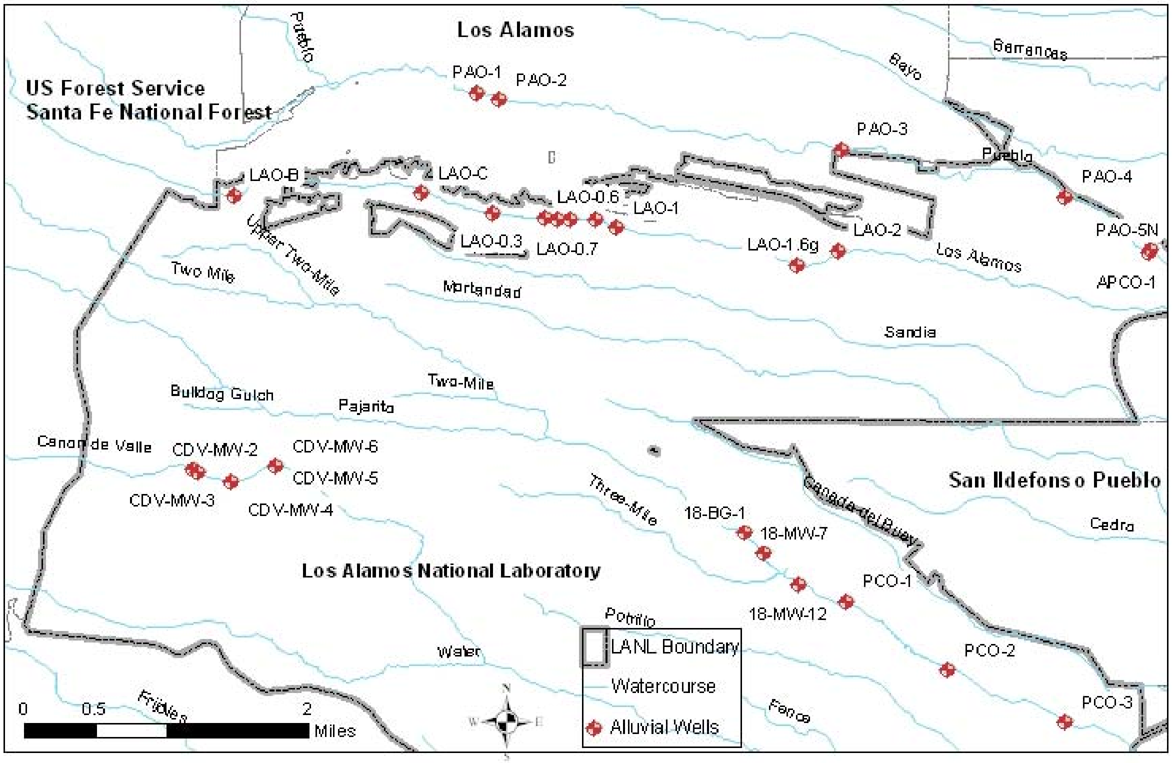


Figure 4-1. Alluvial groundwater wells at LANL sampled before and after the fire.

Figure 4-2 shows the annual median dissolved concentrations of selected constituents in alluvial groundwater from upper Los Alamos Canyon (LAO-B and LAO-C) and from upper Cañon de Valle (CDV-MW-2). Barium from CDV-MW-2 in Cañon de Valle was not included with this analysis because barium is a contaminant in Cañon de Valle and concentrations are about two orders of magnitude higher in Cañon de Valle than in other canyons. The data indicate that dissolved barium and calcium concentrations appear to have increased in alluvial groundwater since the fire, which is consistent with the observations of baseflow after the fire (see Section 3.2).

Figure 4-3 shows the time series of dissolved calcium concentrations in alluvial groundwater from Pueblo, Los Alamos, and Pajarito Canyons and Cañon de Valle. Most data are available for Los Alamos Canyon and Cañon de Valle where quarterly alluvial groundwater samples were collected from some wells. Before the fire, dissolved calcium concentrations in alluvial groundwater were generally less than 20 mg/L. The data indicate that a pulse of higher calcium concentrations occurred in 2000 after the Cerro Grande fire when concentrations in some wells nearly doubled to 30 to 55 mg/L for a short time. There is also an indication that dissolved calcium concentrations in alluvial groundwater continued to increase in 2002 and 2003 over prefire conditions.

Figure 4-4 shows the time series of dissolved barium concentrations in alluvial groundwater in upper Los Alamos and Pueblo Canyons. The data indicate that dissolved barium concentrations in wells apparently increased after the fire during the storm runoff season, but concentrations declined to approximately prefire levels in 2001 during the snowmelt runoff period, and again increased after the 2001 storm runoff season. The concentrations in Pueblo Canyon and Los Alamos Canyon at PAO-1 and LAO-B were quite similar in 2000 and 2001 after the fire. The alluvial groundwater data indicate that dissolved concentrations fluctuate with the seasons and react to the type of flow present in the stream channel.

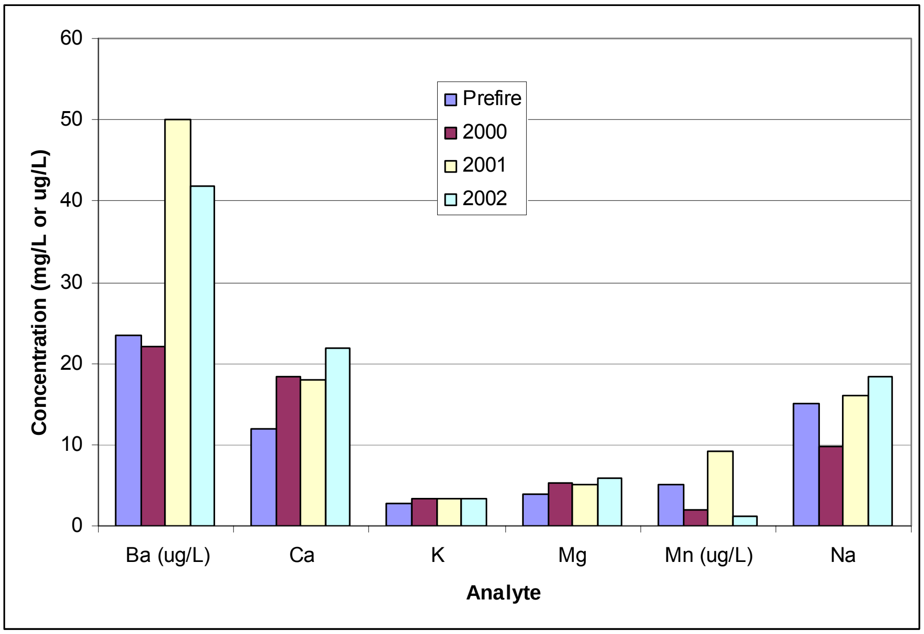


Figure 4-2. Median annual dissolved concentrations of constituents in alluvial groundwater.

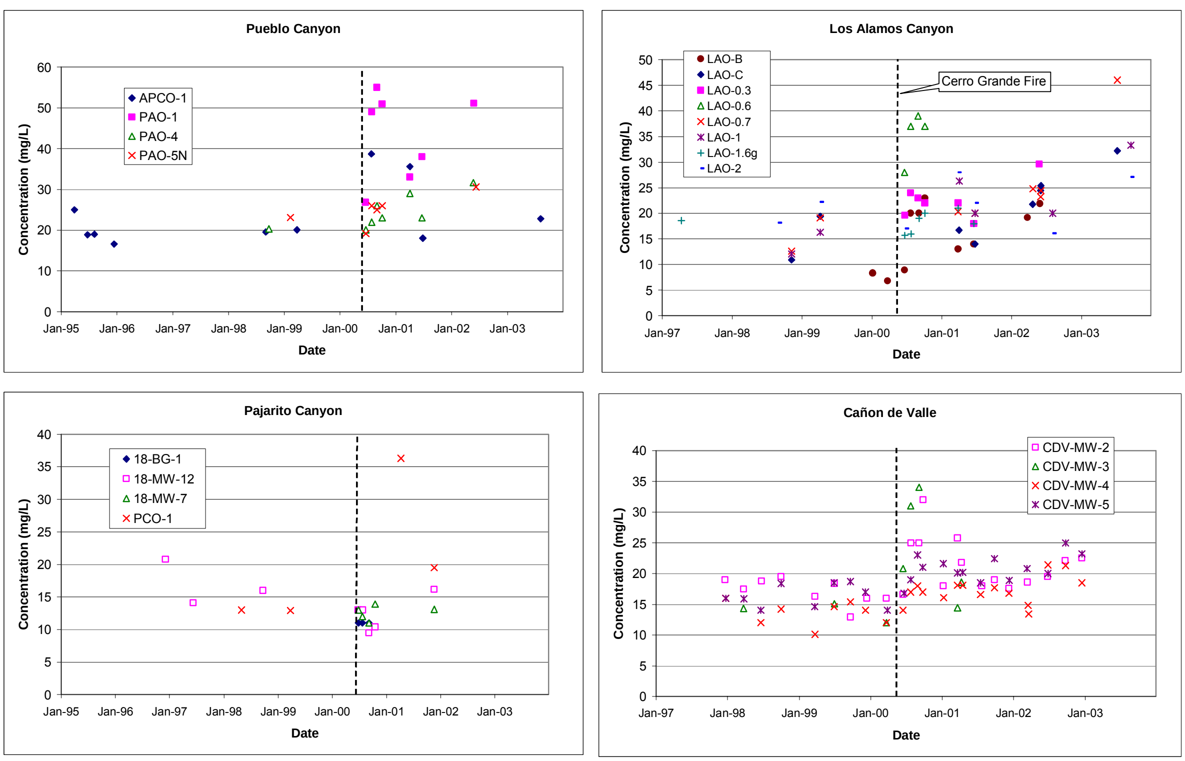


Figure 4-3. Time series of dissolved calcium concentrations in alluvial groundwater.

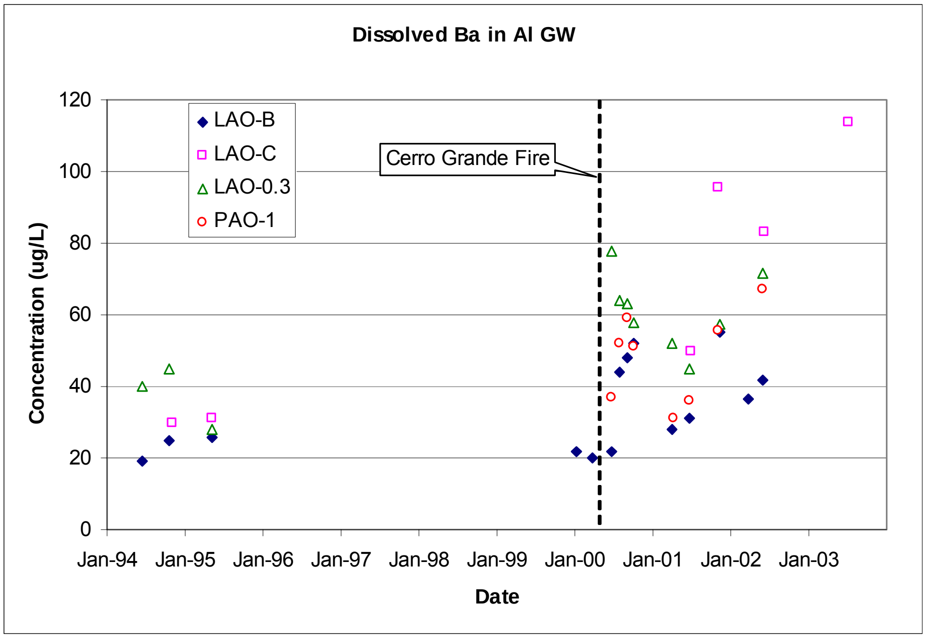


Figure 4-4. Time series of dissolved barium concentrations in alluvial groundwater in upper Los Alamos and Pueblo Canyons.

The available radionuclide detection data for upstream alluvial groundwater are not sufficient to provide an appropriate analysis of impacts from the fire; however, available radionuclide data do not indicate that alluvial groundwater was significantly impacted by runoff from the Cerro Grande fire.

Figure 4-5 shows the percentage of detections of organic compounds in samples collected from alluvial groundwater wells LAO-B, LAO-C, and PAO-1 for prefire and postfire years. The percentage of detections was determined by dividing the total number of organic detections in samples by the total number of organic analyses performed each year. The percentage of detections of organic compounds increased in 2000 after the fire and has declined each year after the fire for which data are available. Table 4-1 summarizes the detections of semivolatile and volatile organic compounds in upstream alluvial groundwater prefire and postfire.

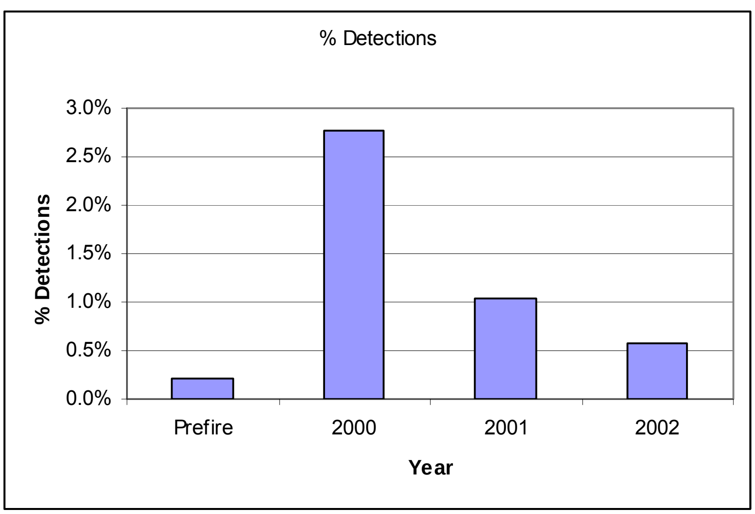


Figure 4-5. Percentage of detections of semivolatile and volatile organic compounds in upstream alluvial groundwater.

Table 4-1. Summary of Detections of Semivolatile and Volatile Organic Compounds in Upstream Alluvial Groundwater.

Organic Compound	Prefire No. Detections	Postfire No. Detections
1,2,3,4,6,7,8-HpCDD	0	1
Acetone	0	1
Benzene	0	1
Benzo(k)fluoranthene	0	1
Bis(2-ethylhexyl)phthalate	0	2
DDT_4,4'-_	0	4
Dibenz(a,h)anthracene	0	1
Dieldrin	0	1
Diethylphthalate	1	0
Ethylbenzene	0	1
Heptachlorodibenzodioxins (Total)	0	1
Methylene chloride	0	3
OCDD	0	1
OCDF	0	1
Toluene	1	1
Trimethylbenzene_1,2,4-_	0	1
Xylene (Total)	0	1
Xylene_1,2-_	0	1
Xylene_1,3-_+Xylene_1,4-_	0	1

5.0 Impacts of the Cerro Grande Fire to Stream Sediment

5.1 Stream Sediment Sampling Program

WQH collects active-channel sediment samples annually from each canyon in the vicinity of LANL and from the Rio Grande as well as bottom sediment samples from area reservoirs. Sediment stations on the Pajarito Plateau (Figure 5.1-1) are located within approximately 4 km of LANL boundaries, with the majority located within LANL boundaries. Many of the sediment sampling locations on the Pajarito Plateau are located in tributary canyons to monitor sediment contamination related to past and/or present effluent release sites. Sediment samples are also collected in major canyons upstream of LANL operations (along SR 501 and in Pueblo Canyon upstream of Acid Canyon) and downstream of LANL operations, and at watercourse confluences with the Rio Grande (e.g., ESP 2004).

The LANL ER Project collected stream sediment samples from channel and overbank locations after the fire in lower Los Alamos Canyon and selected other locations at LANL. A summary of the results of the ER sampling is in Section 5.1.5.

5.1.1 Cyanide in Stream Sediment

Figure 5.1-2 shows the distribution of detectable total cyanide concentrations in active-channel and bank (Rio Grande samples) stream sediment collected from locations around LANL from 2000 through 2003, although most samples were collected in 2001 and 2002. Cyanide was not routinely analyzed in sediment samples before the fire, thus comparison with prefire concentrations is not possible. The distribution of concentrations is similar at upstream and downstream LANL locations and in the Rio Grande. Amenable cyanide was detected in 9 of 188 (<5%) of the sediment analyses from the Pajarito Plateau; the detections of amenable cyanide were from Los Alamos, Sandia, Fence, and Water Canyons; Fence Canyon was not impacted by the Cerro Grande fire, and Sandia Canyon was not significantly affected by the fire. All detections of amenable cyanide were significantly less than the EPA soil screening value of 1200 mg/kg.

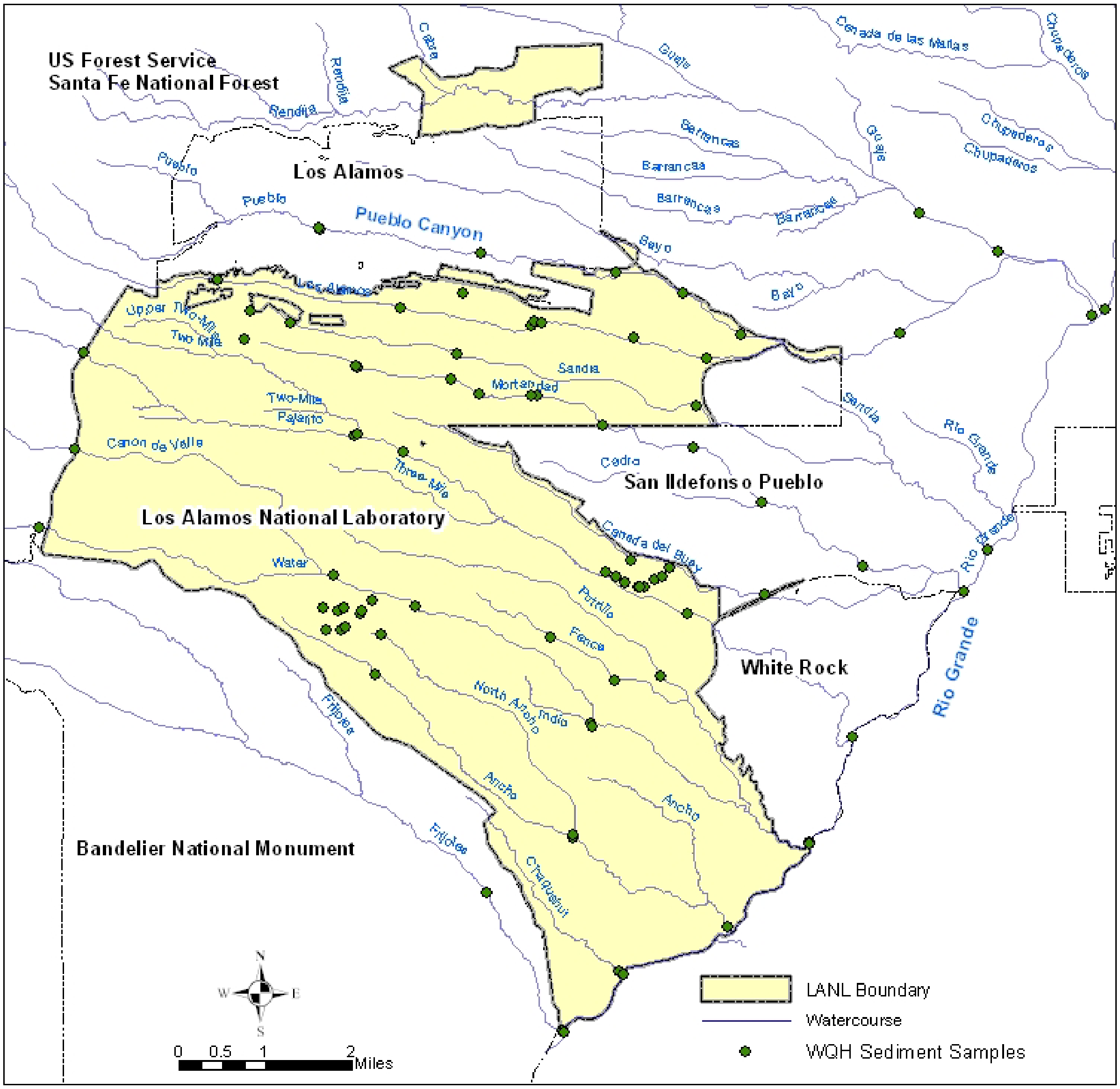


Figure 5.1-1. Sediment sample locations in the Los Alamos area.

In 2000 only two active-channel sediment samples were analyzed for total cyanide; one of the samples contained detectable cyanide. In 2001, 25 of 60 (42%) of samples contained detections, in 2002, 23 of 64 (36%), and in 2003, 23 of 61 (38%) of samples contained detections.

Figure 5.1-3 shows the time series of total cyanide concentrations in active-channel sediment from each canyon from 2000 through 2003. The highest concentrations have been in samples collected from lower Pajarito Canyon, where in 2003 the total cyanide concentration was 2.74 mg/kg. In 2003, sediment samples from the Los Alamos Canyon weir and the Pajarito Canyon retention structure were analyzed for cyanide; total concentration results were 1.17 mg/kg and 1.42 mg/kg, respectively. The available total cyanide data in active-channel stream sediment samples do not indicate a pattern that would suggest significant impact from the Cerro Grande fire.

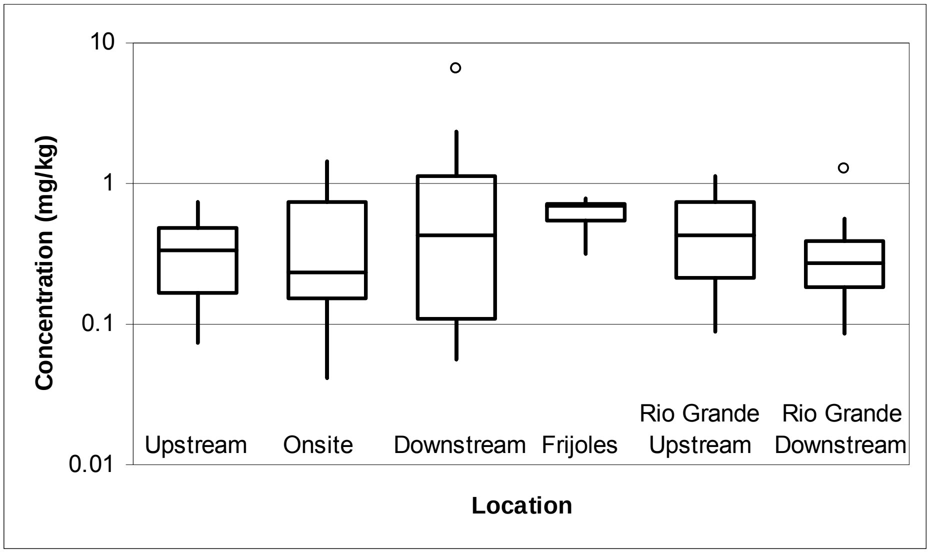


Figure 5.1-2. Distribution of total cyanide concentrations in active-channel stream sediment.

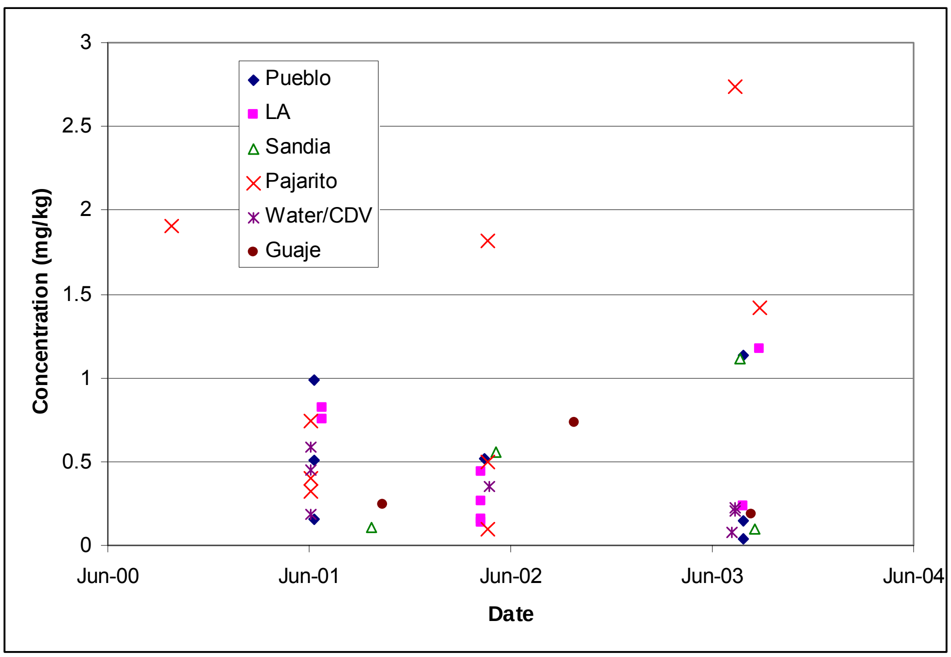
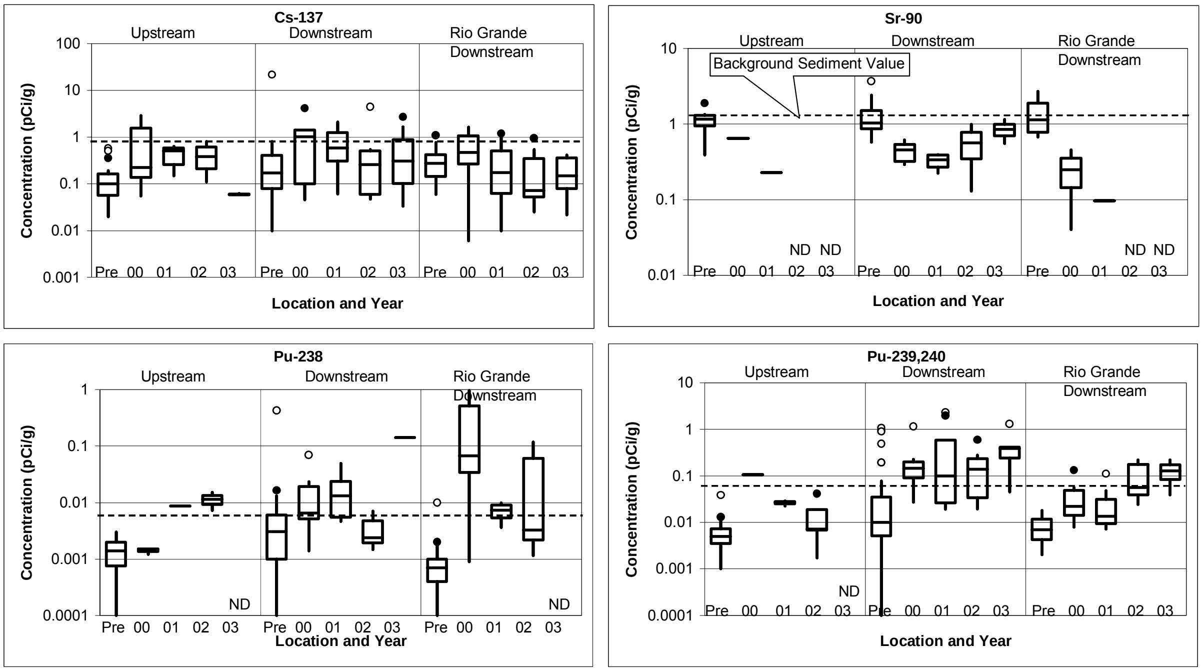


Figure 5.1-3. Time series of total cyanide concentrations in active-channel sediment from major canyons at LANL.

5.1.2 Radionuclides in Stream Sediment

Figure 5.1-4 shows the distribution in concentrations of cesium-137, strontium-90, plutonium-238, and plutonium-239,240 in sediment samples collected at LANL upstream and downstream locations and in the Rio Grande downstream of LANL for prefire years and each postfire year 2000 through 2003. Sediment samples collected in 2000 before May are included with the prefire data set. The data are for active-channel sediment samples collected by WQH only (see description of flood-deposited sediment



Note: Data shown for values reported as analytical laboratory detections, Sr-90 data for 1999 omitted from prefire data set; ND = not detected; dashed line is sediment background value from Ryti et al. (1998). LANL downstream data for major canyons that were impacted by fire-related flows.

Figure 5.1-4. Distribution of radionuclides in active-channel sediment samples from upstream and downstream LANL locations and downstream Rio Grande locations.

samples collected by LANL ER Project below). In 2000 after the Cerro Grande fire, concentration distributions of cesium-137 and plutonium-239,240 were higher than prefire at LANL upstream and downstream locations and in Rio Grande sediment downstream of LANL. Median concentrations of cesium-137 at upstream and downstream locations were less than the sediment background value (Ryti et al. 1998). Cesium-137 concentrations at downstream locations and in the Rio Grande decline each year after the fire, reflecting the decreasing impact of runoff from areas impacted by the Cerro Grande fire.

In 2000 after the fire, one upstream sediment sample from the Los Alamos reservoir contained 0.106 pCi/g plutonium-239,240, above the background sediment value of 0.068 pCi/g and obviously affected by ash from the Cerro Grande fire. Upstream sediment samples collected in 2001 and 2003 contained concentrations of plutonium-239,240 less than the BV, and in 2003 there were no upstream detections of plutonium-239,240. However, plutonium-239,240 concentrations in active-channel sediment from downstream LANL locations after the fire were consistently above the BV, and the median concentration increased in 2002 and 2003. A similar increase in the median concentrations are observed in sediment from the Rio Grande in 2002 and 2003, reflecting the LANL-derived plutonium-239,240 that was transported downstream from Pueblo Canyon in runoff. Plutonium-239,240 concentrations in the Rio Grande were usually below the background value in 2000 and 2001, but many samples were above the background value in 2002 and 2003.

Although higher concentrations of strontium-90 were observed in suspended sediment in runoff from fire-impacted areas, concentrations of strontium-90 in active-channel sediment samples do not show an increase after the fire.

5.1.3 Minor Constituents in Stream Sediment

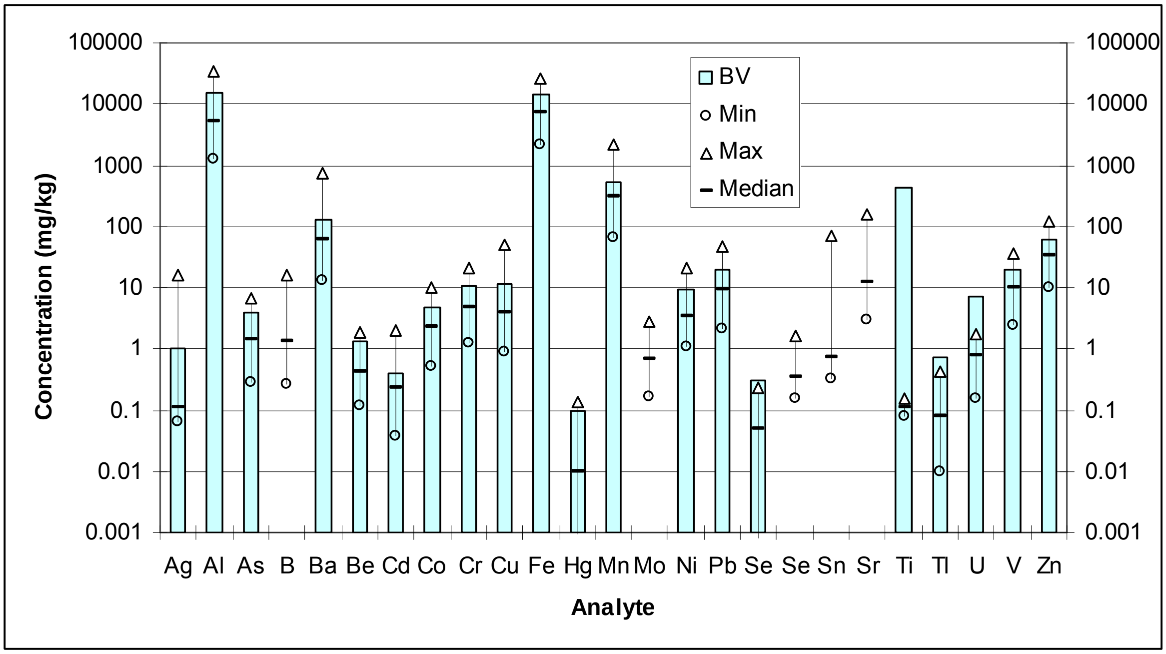
Table 5-1 and Figure 5.1-5 summarize the minor constituent concentrations in active channel stream sediment samples collected from the primary fire-impacted canyons on the Pajarito Plateau from 2000 (postfire) through 2003. Table 5-1 also lists the LANL ER Project sediment BVs (Ryti et al. 1998, McDonald et al. 2003) and the EPA residential soil screening levels (EPA 2003) for comparison. Median concentrations for all minor constituents were below sediment BVs; however, maximum concentrations of most minor constituents in sediment after the fire were greater than respective BVs. Minor constituents with maximum concentrations below the BV include selenium, titanium, and thallium.

Table 5-1. Summary of Minor Constituent Concentrations in Major Canyon Active-Channel Stream Sediment, 2000–2003.

Analyte	Number Analyses	Min (mg/kg)	Max (mg/kg)	Median (mg/kg)	Sediment BV (mg/kg)	EPA Residential Soil Screening Level (mg/kg)
Ag	136	0.066	15.849	0.1125	1.0	390
Al	138	1240	35020	5105	15400	76000
As	138	0.281	6.49	1.445	3.98	22
B	138	0.263	16.4	1.345		5500
Ba	138	12.8	749	59.4	127	5500
Be	138	0.115	1.87	0.4305	1.31	150
Cd	140	0.038	2.04	0.227	0.4	39
Co	138	0.529	9.71	2.275	4.73	900
Cr	138	1.21	20.8	4.838	10.5	210
Cu	138	0.892	51.6	3.97	11.2	2900
Fe	138	2150	26180	7460	13800	23000
Hg	138	0.00091	0.135	0.00997	0.1	23
Mn	138	67.6	2100	299	543	3200
Mo	138	0.162	2.77	0.664		390
Ni	138	1.07	20.9	3.445	9.38	1600
Pb	140	2.18	48.3	9.59	19.7	400
Sb	140	1E-04	0.226	0.0499	0.3	31
Se	138	0.157	1.66	0.349		390
Sn	138	0.332	71.9	0.736		47000
Sr	138	2.94	161	11.95		47000
Ti	10	0.08	0.16	0.11	439	
Tl	144	0.00979	0.437	0.0799	0.73	6.3
V	138	2.52	35.8	10.15	19.7	78
Zn	138	9.76	123	32.95	60.2	23000

Note: BV from Ryti et al. (1998) and McDonald et al. (2003); Screening Values from EPA (2003).

The highest silver concentration in sediment was 15.3 mg/kg in a sample from Guaje Canyon collected in June 2000; all other silver detections were less than 3 mg/kg in samples from Pueblo and Pajarito Canyons. The highest concentrations of barium in sediment were from lower Pajarito Canyon in 2002 and 2003 where sediment contained up to 749 mg/kg barium, about six times the BV. In 2001, sediment from the Rio Grande at Pajarito Canyon contained 353 mg/kg barium, 2.8 times the BV. Barium concentrations in Guaje Reservoir approximately doubled after the fire, from around 80 mg/kg prefire to 222 mg/kg in 2002, likely a result of fire-related deposits in the reservoir.



Note: BV from Ryti et al. (1998) and McDonald et al. (2003)

Figure 5.1-5. Summary of minor constituent concentrations in major canyon stream sediment, 2000–2003.

Beryllium, cadmium, chromium, cobalt, copper, lead, manganese, and nickel concentrations in sediment from lower Pajarito Canyon were also greater than 1.5 times BVs. Chromium, mercury, and silver were above background levels in Sandia Canyon, but not likely associated with fire effects. Manganese was above BVs in Guaje, Pueblo, Los Alamos, Pajarito, and Frijoles Canyons, likely the result of fire-associated deposits in canyons downstream of fire-impacted areas. Selenium concentrations were two to six times BVs in samples from all canyons including Guaje and Frijoles.

Figure 5.1-6 shows the median concentrations of minor constituents detected in sediment samples from upstream and downstream LANL locations prefire and each year since the fire. Sediment samples were not collected at upstream locations in 2000 after the fire, so postfire data for 2000 are not available.

Figure 5.1-7 shows the ratio of postfire median concentrations to the median prefire concentration for minor constituents in active-channel sediment from upstream and downstream locations. Minor constituents that showed higher concentrations in upstream sediment after the fire (postfire/prefire ratio >1.1) are those that most significantly resulted from fire-related impacts, and include aluminum, arsenic, barium, beryllium, cobalt, chromium, copper, iron, manganese, nickel, strontium, and vanadium. Similar results for fire impacts were reported by the LANL ER Project for samples collected in Pueblo and Los Alamos Canyons (LANL 2004).

Minor constituents that showed significantly higher concentrations in downstream LANL sediment after the fire (ratio >1.25) are those that may have been impacted by the Cerro Grande fire and/or by a LANL contribution; these include silver, aluminum, arsenic, barium, beryllium, cobalt, chromium, copper, iron, manganese, nickel, lead, selenium, strontium, vanadium, and zinc.

Minor constituent concentrations in downstream runoff that increased in 2000 but declined each year after the fire include chromium, manganese, and strontium; these constituents were apparently concentrated in sediment impacted by deposits from fire-affected areas. For most minor constituents in sediment, increased concentrations in constituents observed at upstream locations were also observed at downstream locations. Any impacts due to LANL were apparently minor and overshadowed by the impacts observed from the fire, with the possible exception of silver.

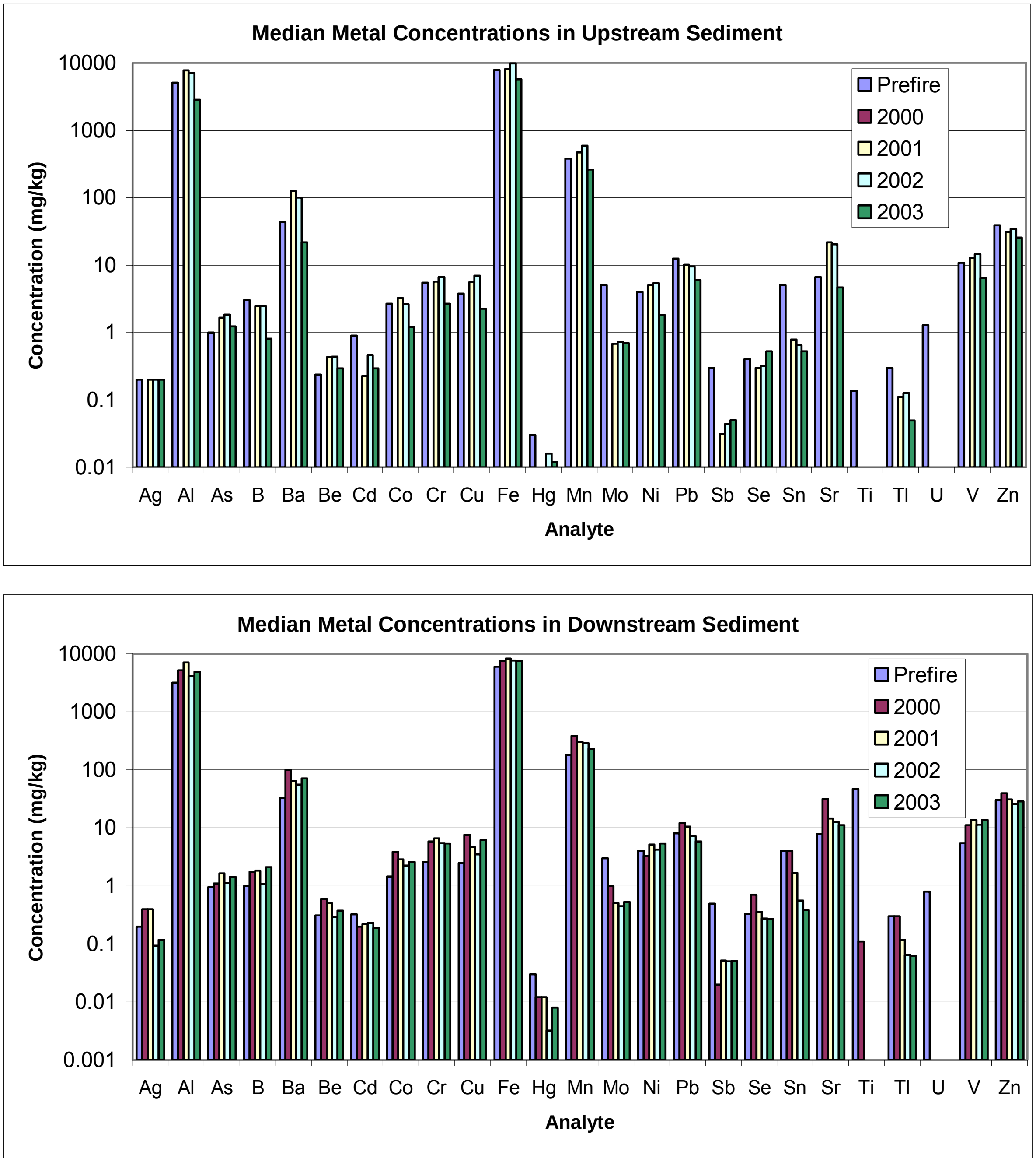


Figure 5.1-6. Median concentrations of minor constituents in sediment samples at upstream and downstream locations, prefire and postfire years 2000–2003.

5.1.4 Organic Compounds in Stream Sediment

Organic compounds detected in upstream LANL active-channel sediment after the fire include the semivolatile organic compounds 4-Methylphenol, aniline, bis(2-ethylhexyl)phthalate, dibenzofuran, fluoranthene, fluorine, naphthalene, phenanthrene, and pyrene. Of these, 4-Methylphenol, bis(2-ethylhexyl)phthalate, and naphthalene were detected in Guaje Reservoir sediment, suggesting that these compounds, and perhaps the others mentioned, may have resulted from the Cerro Grande fire. Additionally, the high explosive compounds 2,4,6-trinitrotoluene, 2-nitrotoluene, HMX, and RDX were detected in sediment samples collected upstream of LANL operations.

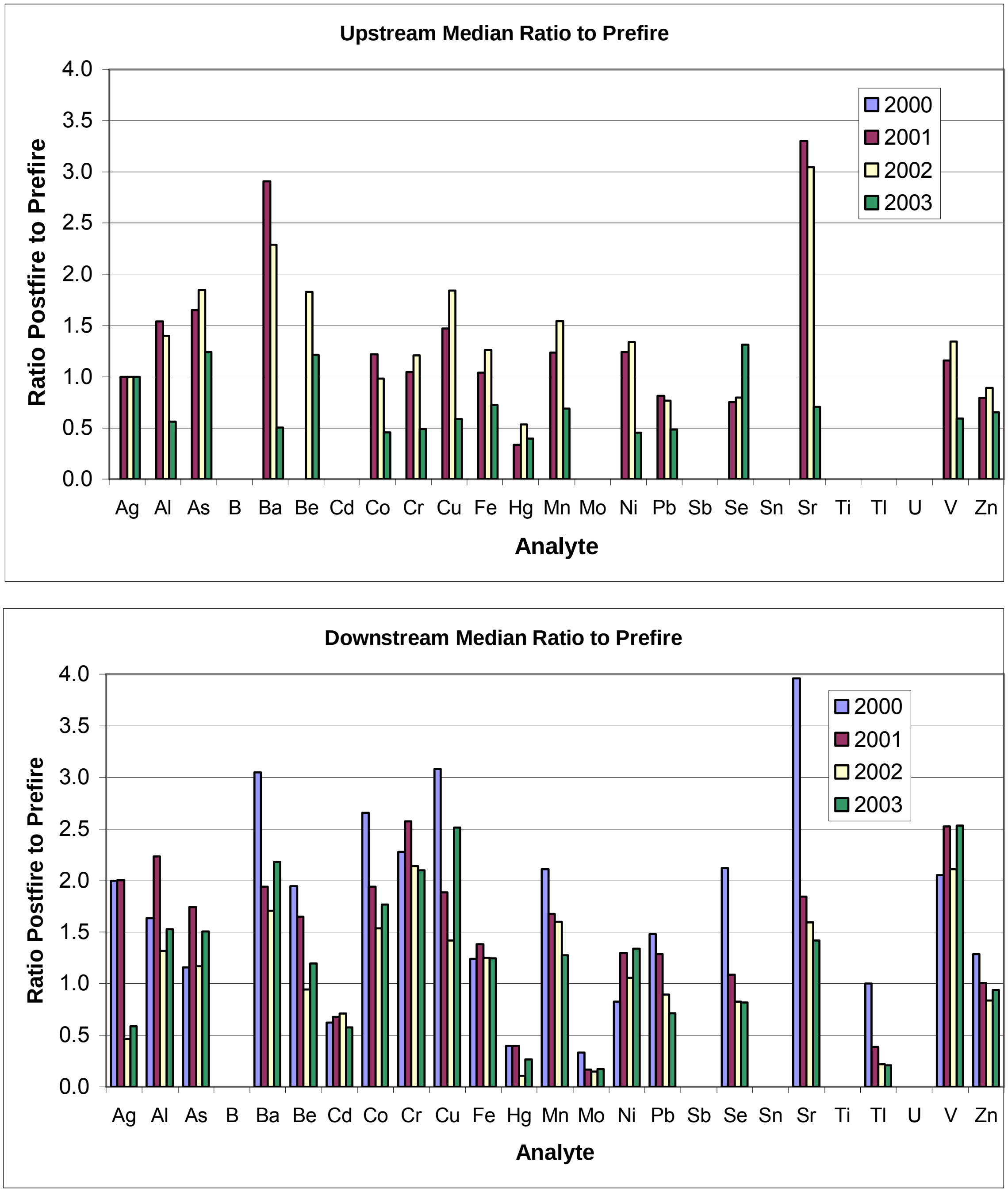


Figure 5.1-7. Ratio of median postfire concentration to median prefire concentration for minor constituents.

5.1.5 Flood Sediment Deposits after the Cerro Grande Fire in Lower Los Alamos Canyon

In 2000 after the Cerro Grande fire, runoff in the Los Alamos Canyon watershed, which includes Pueblo, Rendija, and Guaje Canyons, deposited layers of ash and ash-rich sediment (muck) in the lower part of Los Alamos Canyon. Sediment samples were collected in March 2001 to assess the radionuclide and nonradiological content of the flood-deposited sediments in lower Los Alamos Canyon at Totavi, where sediment samples were collected over a channel distance of approximately 1000 ft. Observations during sampling indicated that the recent flood deposits covered approximately 25% of the floodplain area along the reach sampled. Thickness of the deposits varied, but was generally less than about 20 cm. Some of the flood sediment that contained ash was preserved in local areas within the channel, but the majority was preserved at relatively shallow depths on the floodplain. The deposits were highly stratified and included a wide range of sediment textures ranging from silts to very coarse sand. The floods were not of sufficient magnitude at this location to transport significantly larger sediment sizes (Kraig et al. 2002).

Sediment samples were collected from representative locations in the reach near Totavi from layers representing a variety of sediment sizes within the deposits. All samples included one or more layers of ash-rich sediment typical of postfire Cerro Grande flood deposits. Samples were analyzed for strontium-90, cesium-137, americium-241, isotopic plutonium and uranium, and inorganic constituents.

The statistical analyses of the results suggested that postfire concentrations of one radionuclide (cesium-137) at Totavi and 16 minor constituent concentrations were greater than respective prefire concentrations at that location. The minor constituents included aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, vanadium, and zinc. Eleven organic chemicals [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, 4-methylphenol, naphthalene, phenanthrene, pyrene, and summed 2,3,7,8-TCDD equivalent] were detected in the sediment samples (Kraig et al. 2001, Kraig et al. 2002).

The results of the analyses indicated that the predominance of the increases in concentrations in flood deposits was caused by the increased mobilization of locally deposited worldwide fallout, or naturally occurring substances that were concentrated by the fire. Where increased concentrations were observed, LANL-related sources were not identified as the source for the increases. However, for many constituents, legacy LANL wastes in canyons could not be precluded as a partial source of the increased concentrations. Therefore, the health effects of the increased concentrations were calculated independent of the source where the source could not be determined. None of the radiological or nonradiological effects calculated for residents of Totavi or for direct or indirect users of Rio Grande water were believed to cause health effects for exposures received during 2000 (Kraig et al. 2001, Kraig et al. 2002). Additional data and analysis of fire effects to sediments in Los Alamos and Pueblo Canyons have been reported by the LANL ER Project (LANL 2004).

5.2 Stream Sediment and Reservoir Sediment in the Rio Grande and Rio Chama

Sediment samples have been collected along the Rio Grande and Rio Chama and from reservoirs in northern New Mexico as part of the environmental surveillance program at LANL. Reservoir sediment samples have been collected annually since 1982 and stream sediment samples have been collected at selected locations along the Rio Grande since 1956 and annually since 1973. Table 5-2 summarizes the sediment and surface water samples that have been collected from the Rio Grande and Rio Chama and Table 5-3 summarizes reservoir sediment sampling.

5.2.1 Cyanide in Rio Grande Sediment

After the Cerro Grande fire, sediment samples collected from reservoirs and stream sediment in the Rio Grande and Rio Chama were analyzed for total and amenable cyanide concentrations. Three samples contained detectable amenable cyanide, two samples were from locations upstream of LANL (Heron and Abiquiu reservoirs), and one sample was downstream of LANL (Rio Grande at Frijoles). The maximum concentration of amenable cyanide was 0.394 mg/kg in a sample from Heron Reservoir.

Figure 5.2-1 shows the distribution of total cyanide concentrations in Rio Grande and Rio Chama sediment collected from 2000 through 2003 at locations upstream and downstream of LANL. The distribution of concentrations are similar for upstream and downstream locations; however, the maximum concentrations observed in Rio Grande sediment were from Cochiti Reservoir, where sediment contained 1.29 mg/kg total cyanide in 2001 and 0.641 mg/kg in 2002. These elevated concentrations my be the result of runoff from the Cerro Grande fire.

Table 5-2. Stream and Reservoir Sediment Sample Summary.

Location	Dates Sampled
Rio Chama at Chamita	1976–2002
Rio Grande at Embudo	1973, 1976–2002
Rio Grande at Otowi	1973, 1976–2002
Rio Grande at Sandia	1979–1994, 2001–2002
Rio Grande at Mortandad	1992, 2001–2002
Rio Grande at Pajarito	1977–1994, 2001–2002
Rio Grande near White Rock	2000, 2001
Rio Grande at Water	1991–1994, 2001
Rio Grande at Ancho	1977–1994, 2001–2002
Rio Grande at Chaquehui	1991–1994, 2001
Rio Grande at Frijoles	1976–2002
Rio Grande below Cochiti	1973, 1976–1979, 1983, 1995, 1998–1999, 2002
Rio Grande at Bernalillo	1973, 1976–2002

Table 5-3. Summary of Reservoir Sediment Samples.

Location	Dates Sampled
Rio Chama	
Heron Reservoir	
Heron Lower	1982–1985, 1994–2001
Heron Middle	1982–1985, 1994–2001
Heron Upper	1982–1985, 1994–2001
El Vado Reservoir	
El Vado Lower	1982–1985, 1995–2001
El Vado Middle	1982–1985, 1995–2001
El Vado Upper	1982–1985, 1995–2001
Abiquiu Reservoir	
Abiquiu Lower	1982–2002
Abiquiu Middle	1973, 1984–2002
Abiquiu Upper	1982–2002
Rio Grande	
Cochiti Reservoir	
Cochiti Lower	1982–2003
Cochiti Middle	1982–2003
Cochiti Upper	1982–2003

5.2.2 Radionuclides in Rio Grande and Rio Chama Sediment

Figure 5.2-2 summarizes the prefire and postfire results of sampling bed sediments in the Rio Grande downstream of Otowi (downstream of LANL and Cerro Grande fire runoff) and Cochiti Reservoir for selected radionuclides. The figure also shows the range of detections observed before the Cerro Grande fire and the EPA soil screening level for residential soils. After the fire, higher concentrations of americium-241, gross alpha, gross beta, plutonium-238, and plutonium-239,240 were measured in sediments; however, all concentrations were below respective screening levels for residential soil.

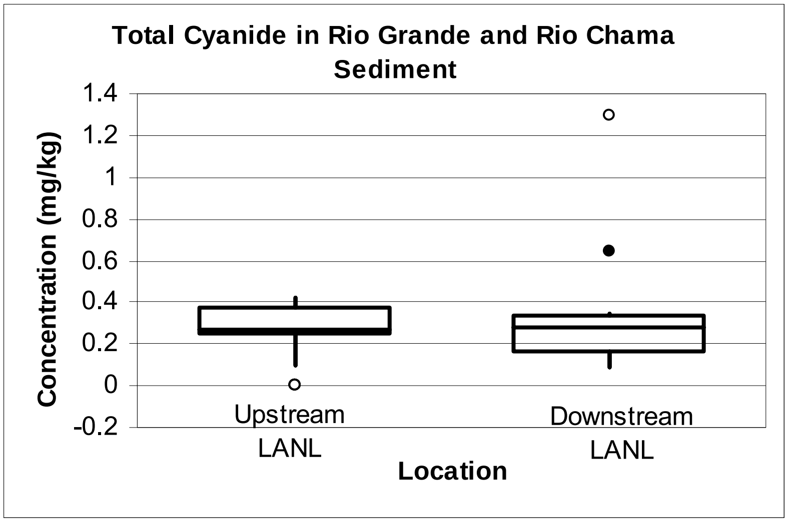


Figure 5.2-1. Distribution of total cyanide concentrations in Rio Grande and Rio Chama sediment, 2000–2003.

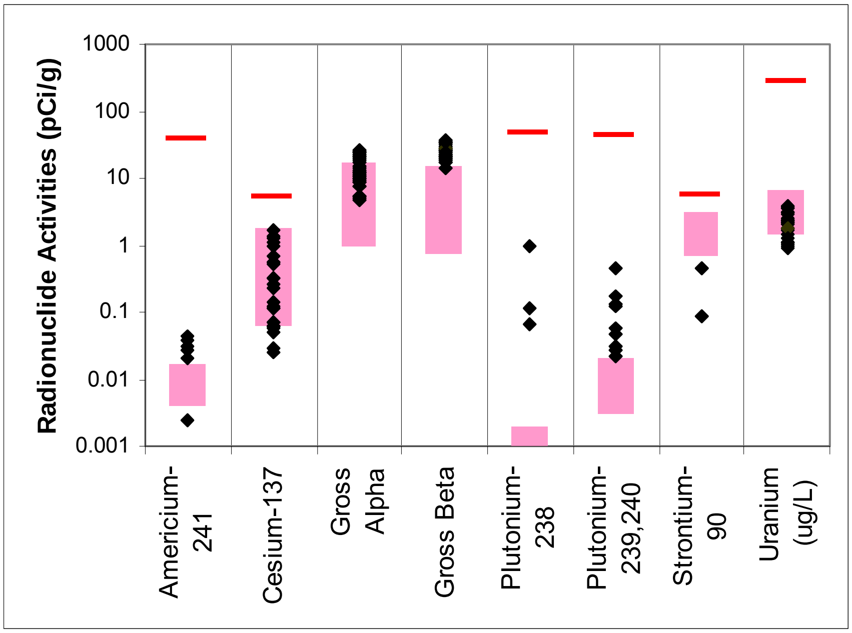


Figure 5.2-2. Summary of radionuclide concentrations in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire range (shaded) and screening level for residential soil.

5.2.3 Minor Constituents in Rio Grande Sediment

Figure 5.2-3 summarizes the results of selected minor constituent concentrations in Rio Grande bed sediments downstream of Otowi and Cochiti Reservoir bottom sediments, with comparison to historical concentrations and reference criteria. Minor constituents that were detected in higher concentrations after the fire include barium, boron (limited prefire detection set), chromium, and cobalt; however, concentrations of these metals were less than the guidelines for protection of aquatic life and the EPA screening level for residential soil.

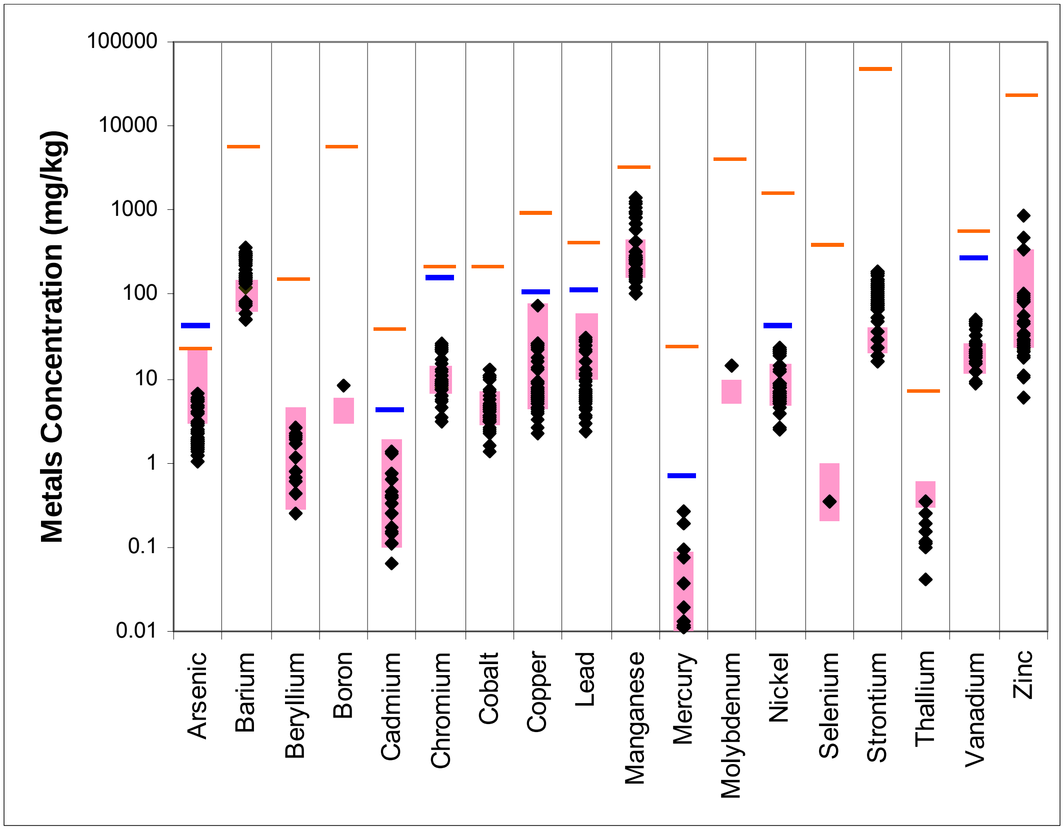
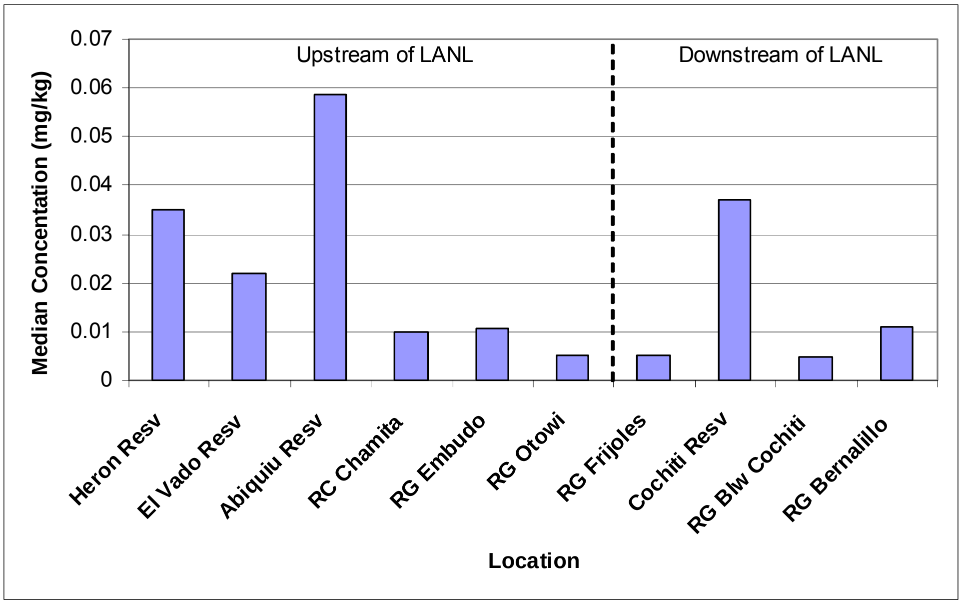


Figure 5.2-3. Summary of minor constituent concentrations in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire range (shaded), guideline for protection of aquatic life (blue thick bar), and screening level for residential soil (red bar).

5.2.3.1 Mercury in Rio Grande and Rio Chama Sediment

Figure 5.2-4 shows the comparison of the median mercury concentrations measured in stream sediment samples collected along the Rio Chama and Rio Grande for years 2000 through 2003. Impacts to the Rio Grande would be expected to be greatest during this time period because post-Cerro Grande wildfire impacts from above normal storm runoff to the Rio Grande would tend to be emphasized. The results shown in Figure 5.2-4 are presented in an upstream to downstream order, and include data from both river and reservoir monitoring stations. Mercury concentrations in finer-grained reservoir sediments are typically higher than in coarser-grained riverbed sediments. Since the Cerro Grande fire, LANL and the USGS measured mercury concentrations in more than 60 sediment samples from the Rio Grande and Rio Chama. About half of these samples were collected downstream of LANL runoff influences to the Rio Grande.

Figure 5.2-4 shows that median mercury concentrations in Rio Grande sediments collected downstream of LANL are comparable to those collected upstream of LANL. Statistically, mercury concentrations in Cochiti Reservoir bottom sediments are indistinguishable from samples collected from Heron, El Vado, and Abiquiu reservoirs (Kruskall Wallis Median Test and Mann Whitney U Test, α = 0.05). Similarly, Rio Grande bed sediments collected downstream of LANL contain mercury levels that are statistically indistinguishable from those in samples collected upstream of LANL.



The stations are ordered in a north to south direction. The "RG Frijoles" station includes all data from the Rio Grande collected between Otowi and Cochiti Reservoir.

Figure 5.2-4. Median mercury concentrations in sediments collected along the Rio Chama (RC) and Rio Grande (RG), 2000–2003.

All water bodies contain some mercury from natural sources (such as volcanoes and the weathering of rock in mountains) and human activities (like burning fossil fuels and discharging industrial waste). Near Los Alamos, for example, mercury is detected in about one-half of the sediment samples collected at background sites upstream and north of LANL. Noteworthy is the detection of mercury in 5 of 5 samples collected from Guaje Reservoir, located on the flanks of the Jemez Mountains in the Santa Fe National Forest and distant from LANL operations (ESP 2004). Mercury is of concern due to toxicity, persistence in the environment, and the ability to accumulate in the tissue of people and fish (ATSDR 2003). Mercury also threatens the health of fish-eating wildlife such as raccoons. The New Mexico Departments of Health and Environment have issued a mercury health advisory regarding consumption of fish caught in Cochiti Reservoir (NMED 2001).

Storm runoff in the Los Alamos area occasionally contains total mercury at concentrations approaching or exceeding the New Mexico Wildlife Habitat stream standard (see Section 2.2.4.3). These higher concentrations have been observed downstream of LANL operations as well as in watercourses draining undeveloped National Forest lands. Extensive sampling of sediments in the Rio Grande drainage system since the Cerro Grande fire shows that mercury levels downstream of LANL runoff impacts to the Rio Grande are statistically the same as upstream of LANL impacts. While storm runoff from the Los Alamos area and from the Cerro Grande fire has entered the Rio Grande, there are no identifiable impacts to mercury concentrations in river or reservoir sediments.

5.2.4 Organic Compounds in Rio Grande Sediment

Figure 5.2-5 summarizes the organic compounds detected in sediment samples collected from the Rio Grande downstream of Otowi and Cochiti Reservoir before and after the fire. The figure also shows the guidelines for protections of aquatic life and the screening level for residential soil. Organic compounds detected in higher concentrations after the fire than before the fire include diethylphthalate, di-n-butylphthalate, and phenol. All detections of organic compounds in Rio Grande and Cochiti Reservoir sediment samples were below screening levels.

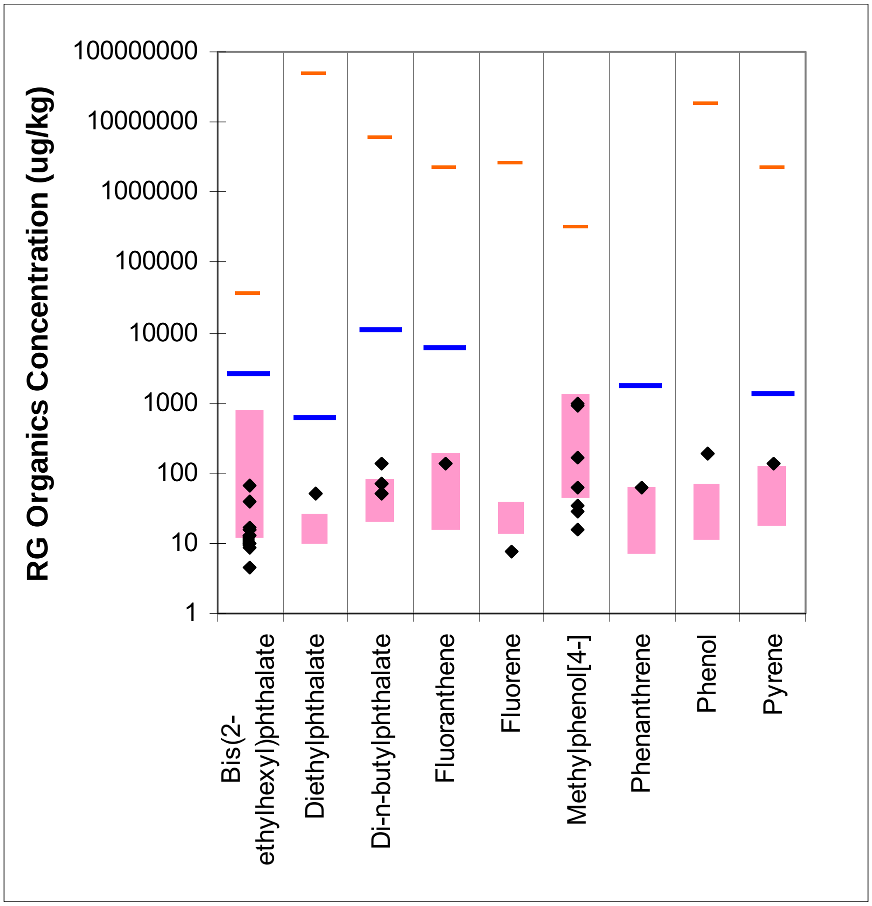


Figure 5.2-5. Summary of detections of organic compounds in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire range (shaded), guidelines for protection of aquatic life (blue thick bar), and screening level for residential soil (red bar).

6.0 Summary and Conclusions

6.1 Fire-Related Impacts to Runoff

6.1.1 Flow Volumes

In 2000 after the Cerro Grande fire, storm runoff upstream of LANL (in canyons south of Pueblo Canyon) increased an estimated 3.7 times over the prefire average (four previous years), but in 2001, upstream runoff was only 1.8 times more than the prefire average. In 2002 and 2003, the upstream runoff was significantly less than the prefire average, mostly due to drought conditions, but also due to partial recovery of the burned hill slopes.

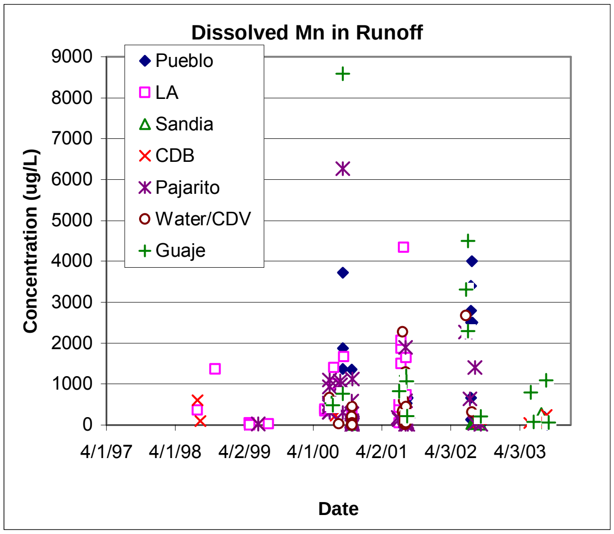
Downstream runoff at LANL (south of Pueblo Canyon) in 2000 after the fire was an estimated 2.8 times higher than the prefire average, while in lower Pueblo Canyon runoff was only slightly higher than the prefire average. In 2001, downstream runoff at LANL was about 2.2 times more than the prefire average, but runoff in Pueblo Canyon was 250 ac-ft, about five times higher than the prefire average, in 2002, 3.7 times the prefire average, and in 2003, about 4.5 times the prefire average. Downstream runoff at LANL south of Pueblo Canyon in 2002 and 2003 was similar to prefire conditions.

Notable flooding occurred in canyons west of LANL in 2000, whereas relatively slight flooding occurred in Los Alamos, Pajarito, and Water Canyons in 2000. Due to the paucity of precipitation events in these watersheds in 2001, 2002, and 2003, significant flooding did not occur at LANL south of Pueblo Canyon after the Cerro Grande fire. However, in 2001, 2002, and 2003, relatively larger precipitation events occurred in the Pueblo Canyon watershed where significant flooding occurred in 2001, 2002, and 2003.

6.1.2 Flushing of Fire Constituents from Burned Areas

The initial storm runoff events sampled below the Cerro Grande burned areas contained elevated concentrations of suspended solids, minor constituents, and fallout radionuclides. This is consistent with results of other studies around the world that show forest fires can condense and mobilize natural radionuclides, fallout radionuclides, and minor constituents (Bitner et al. 2001). Time trend analyses shows that most of the ash and fire-affected surface soils were flushed downstream within two to three runoff seasons following the fire (Johansen et al. 2003). Lower concentrations were noted by 2003 for constituents dissolved in the runoff as well as for constituents carried by the runoff (particulates, soils, sediments), and near prefire conditions were observed in 2003 for constituent concentrations (see transport of suspended sediment in Section 2.2.2.3).

Dissolved concentrations of many minerals and minor constituents recovered from 3 to 10 times prefire levels immediately after the fire to near prefire levels over the three-year period from 2000 to 2003. Figures 6.1-1 and 6.1-2 show these water quality changes in a series of graphs for minor constituents (dissolved strontium and manganese), dissolved calcium, and total cyanide. For reference, prefire time trends are also shown with postfire trends. Concentrations of these four constituents were elevated above prefire averages due to fire effects. Following the first major runoff event on June 28, 2000, concentrations in runoff began a recovery lasting for about three years. Dissolved concentrations of minor constituents and radionuclides approached prefire conditions in 2003. Unlike other constituents, the median dissolved manganese concentrations increased in 2001 and again in 2002 (see Section 2.2.4.7), but were significantly lower in 2003, similar to prefire conditions. The increases in 2001 and 2002 indicate that an abundant supply of manganese remained on the burned land surface that did not chemically stabilize until 2003.



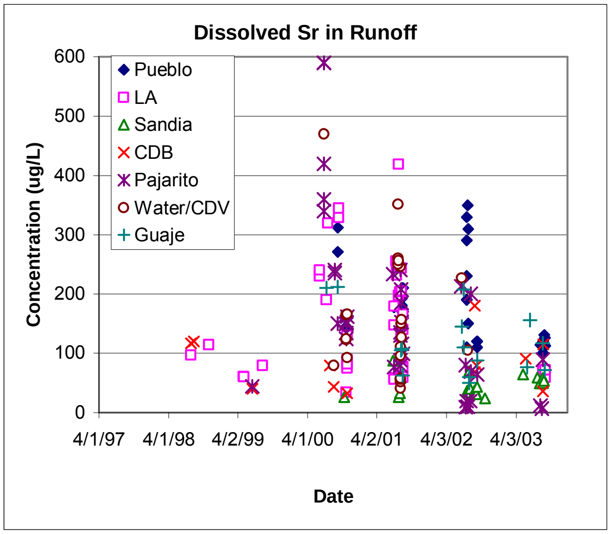
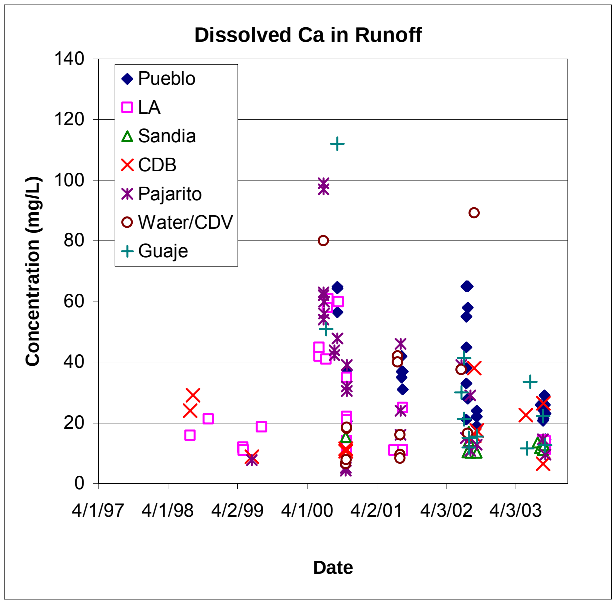


Figure 6.1-1. Time series of dissolved manganese and strontium concentrations in runoff, 1997–2003.



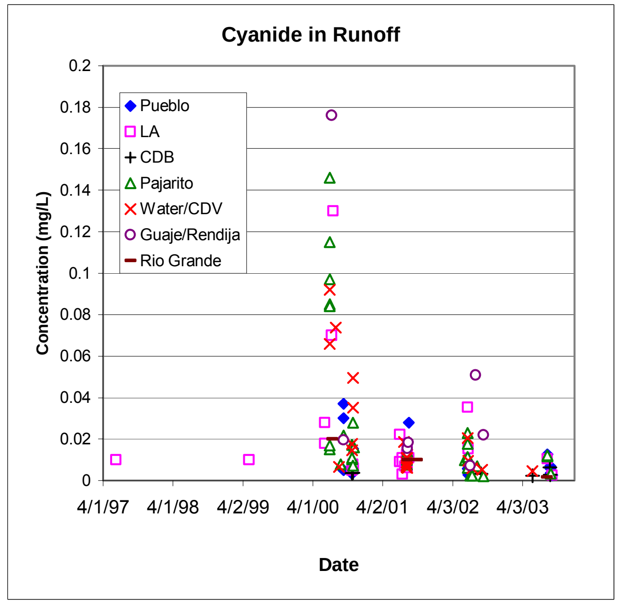


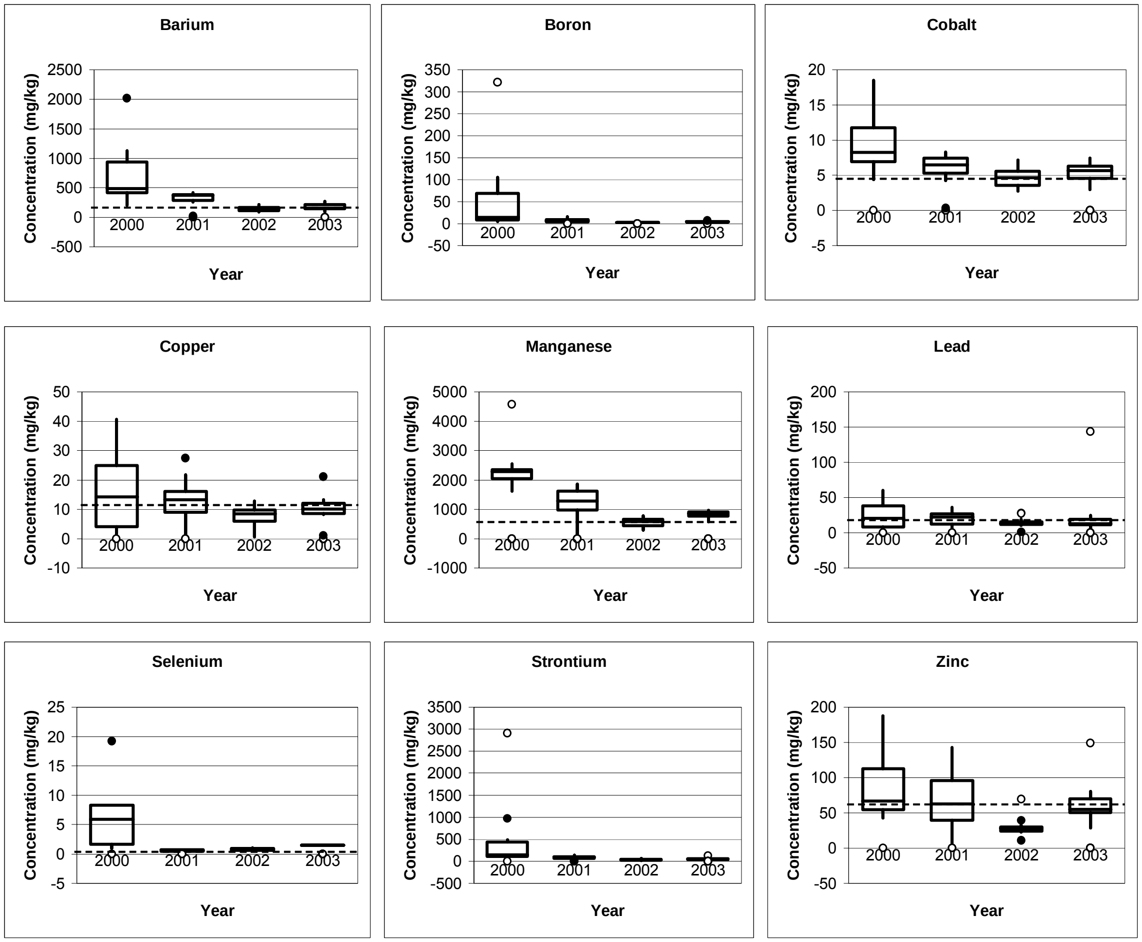
Figure 6.1-2. Time series of dissolved calcium and total cyanide concentrations in runoff, 1997–2003.

Minor constituent and radionuclide concentrations (calculated) in suspended sediment at runoff stations located upstream of LANL and in drainages north of LANL also show recovery to near baseline conditions after two runoff seasons. Yearly concentration distributions of minor constituent concentrations in suspended sediment (calculated and measured) downstream of burned areas and upstream of LANL operations are illustrated in Figure 6.1-3, and suspended radionuclide concentrations are shown in Figure 6.1-4. The concentrations were calculated as the total minor constituent or radionuclide concentration measured in a water sample divided by the TSS concentration (dissolved concentrations are small relative to the total—commonly 1% of the total—and thus were not factored in the calculation). Postfire suspended sediment concentrations were compared against BVs for stream sediments in LANL canyons (Ryti et al. 1998).

Concentrations of minor constituents in suspended sediment in runoff upstream of LANL were 5 to 10 times above background values in 2000 due to the ash and sediment load in runoff from fire-impacted areas. Concentrations in 2001 were typically 1 to 3 times the background values, and by 2002 and 2003 most minor constituents in suspended sediment were within BVs.

Figure 6.1-4 shows calculated radionuclide concentrations in suspended sediment in runoff downstream of fire-impacted areas and upstream of LANL operations for drainages at LANL and for Guaje Canyon, which is located about two to three miles north of LANL. Suspended sediment concentrations in runoff from the burned areas were elevated 5 to 10 times background values in 2000 but declined each subsequent year since the fire, suggesting that erosion and transport of material from the burned areas and erosion of ash-rich sediment in downstream canyons continued for one to two years after the initial stripping of the ashy surface soils. Suspended sediment concentrations of cesium-137, plutonium-238, and plutonium-239,240, remained elevated above sediment background values about one year longer in upstream LANL runoff relative to upstream Guaje Canyon runoff, possibly indicating an additional contribution from LANL historic activities to the biomass proximal to LANL, although the specific cause is uncertain.

Figure 6.1-5 shows the estimated annual activity of cesium-137 and strontium-90 transported in upstream and downstream runoff and the estimated prefire average for the total downstream runoff. Sufficient data are not available to determine the prefire (1990 to 1999) upstream and downstream Pueblo Canyon transport in runoff; most runoff data for this period are for LANL downstream locations south of Pueblo Canyon. Both cesium-137 and strontium-90 were significantly elevated in upstream runoff in 2000,



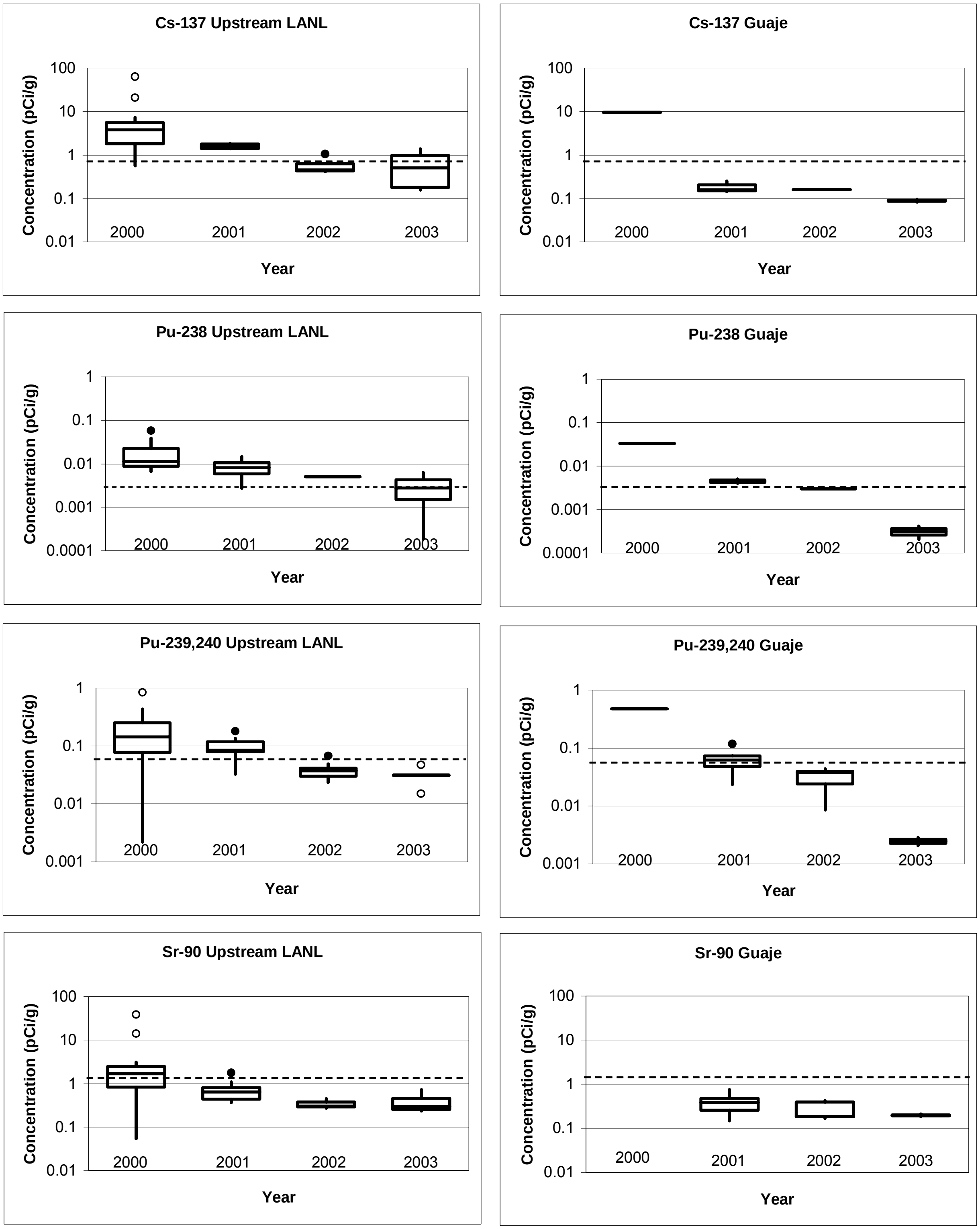
Note: Dashed lines represent sediment upper statistical range background values (Ryti et al. 1986)

Figure 6.1-3. Minor constituent concentrations in suspended sediment in upstream runoff.

showing the impact of the ash-laden runoff immediately after the fire. The activity of these radionuclides greatly declined in subsequent years after the fire. Most of the activity of these radionuclides in downstream Pueblo Canyon runoff in 2001 was also attributable to fire effects.

6.1.3 Summary of Inorganic Constituents in Fire-Impacted Runoff

Table 6-1 lists the inorganic constituents identified as likely elevated in runoff due to forest fire effects. To discern fire-associated impacts from any LANL impacts, we reviewed sampling data collected upstream or north of LANL, with a few exceptions. We examined the data for changes in concentrations of constituents both dissolved in and carried by storm runoff (particulates and sediment). Fire effects were indicated if the postfire concentrations were substantially elevated above prefire levels and showed downward trends in concentrations during the postfire recovery period. For dissolved constituents, we compared postfire (2000–2003) concentrations against prefire (1990–1999) concentrations collected from all locations, including those on LANL. Changes in detection limits precluded comparison of pre- to postfire dissolved concentration data for 10 minor constituents (cobalt, chromium, copper, molybdenum, nickel, lead, antimony, tin, vanadium, and zinc). To increase the sample size of dissolved concentration data, on-site samples from the initial postfire runoff events also were included in the analysis because these flows originated from burned areas and were sufficiently large to dwarf any LANL effects. For suspended sediment concentrations, there is not an adequate prefire data set to compare with, so



Note: Dashed line represents sediment upper statistical range background value from Ryti et al. (1998)

Figure 6.1-4. Suspended sediment radionuclide concentrations in LANL upstream runoff and Guaje Canyon upstream runoff.

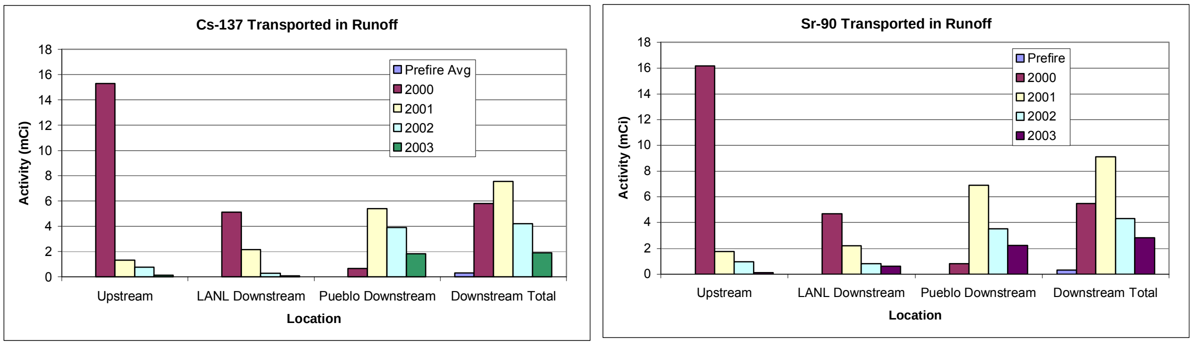


Figure 6.1-5. Estimated transport of fire-generated cesium-137 and strontium-90 in upstream and downstream runoff.

postfire concentrations were examined for trends and compared with LANL-wide stream sediment BVs (Ryti et al. 1998). A constituent was probably fire impacted if significantly elevated above background levels immediately after the fire and the concentrations decline over time to near background levels. Samples of ash-rich sediments deposited by floods during 2000 were collected from floodplain areas along the canyons downstream of LANL operations and compared against prefire sediment levels at that location (Kraig et al. 2002). Also, the LANL ER Project compiled a data set of baseline postfire sediment samples from upstream Los Alamos and Pueblo Canyons and canyons north of LANL (LANL 2004).

6.1.4 Summary of Organic Constituents in Fire-Impacted Runoff

Some organic compounds detected in runoff appear to be fire associated. The semivolatile organic compounds benzoic acid, benzyl alcohol, 4-methylphenol (p-cresol), and pyridine are thought to be end products of combustion of forest fuels. These compounds were detected throughout the 2000 runoff season in many fire-affected drainages upstream of LANL and in canyons north of LANL. Because the number of prefire analyses of organic compounds in runoff is limited, these compounds are tentatively identified as being possibly impacted by the fire. Eleven organic compounds were detected in samples of ash-rich sediments deposited in lower Los Alamos Canyon floodplains (Kraig et al. 2002). Most of these compounds were PAHs which are formed during the incomplete combustion of organic matter including wood and fossil fuels (such as gasoline, oil, and coal). Thus, there are several potential sources for the PAHs; it cannot be determined whether the PAHs are solely associated with forest fire without extensive prefire data or more detailed forensics. Additional relevant data have been provided by the LANL ER Project (LANL 2004). Table 6-2 summarizes the list of 14 organic compounds that may have been generated by the fire.

6.1.5 Summary of Fire Impacts to Runoff

In summary, six radionuclides, 15 minor constituents, and seven major water quality constituents were identified as having concentrations greater than prefire levels due to fire effects. In addition, 14 organic compounds are possibly fire impacted. Amongst these 42 analytes, the constituents whose concentrations were most elevated by Cerro Grande fire effects appear to be

- three fallout radionuclides (cesium-137, plutonium-239,240, and strontium-90),
- three minor constituents (barium, manganese, and strontium), and
- seven major water quality constituents (bicarbonate, calcium, cyanide, magnesium, nitrogen, phosphorous, and potassium).

Table 6-1. Fire-Associated Inorganic Constituents in Runoff.

Analyte	Dissolved Concentrations in Runoff Increased due to fire[a]	Suspended Sediment Concentrations in Runoff Increased due to fire	Deposited Stream Sediments Concentrations Increased due to fire[b]	Ash and Fire-Affected Baseline Sediment Samples[c]	Observed in Scientific Literature?[d]
Common minerals, nutrients, and cyanide					
Bicarbonate	Yes				Yes
Calcium	Yes	Yes	Yes vvv	Yes	Yes
Cyanide	Yes	Yes	Yes	Yes	Yes
Magnesium	Yes		Yes vvv	Yes?	Yes
Nitrogen	Yes				Yes
Phoshorous	Yes				Yes
Potassium	Yes			Yes?	Yes
Metals					
Aluminum			Yes vv	Yes	
Arsenic			Yes v		
Barium	Yes	Yes vvv	Yes vvv	Yes	
Boron		Yes vv			
Cadmium				Yes	
Chromium			Yes vvv		
Cobalt		Yes vv	Yes vvv		
Copper			Yes vvv	Yes	Yes (dissolved)
Iron			Yes vvv		
Lead		Yes v	Yes vv	Yes	
Manganese	Yes	Yes vvv	Yes vvv	Yes	Yes
Nickel			Yes vv	Yes?	
Selenium		Yes vv	Yes vv	Yes	
Strontium	Yes	Yes vvv			
Vanadium			Yes vvv		
Zinc	yes	Yes vv	Yes vv	Yes	Yes (dissolved)
Radionuclides					
Americium-241		Yes vv		Yes	
Cesium-137		Yes vvv	Yes vvv	Yes	Yes
Plutonium-238		Yes vv		Yes?	
Plutonium-239,240		Yes vvv	Yes vvv	Yes	
Strontium-90		Yes vvv		Yes	
Uranium	Yes	Yes vv		Yes?	

[a]Gallaher et al. 2002, Bitner et al. 2001
[b]Kraig et al. 2002
[c]LANL 2004, Appendix Figure D-1.7-1; Yes? = constituent increased concentration in fire-related sediment questionable
Statistical significance: √ - p <.1; √√ - p <.01, √√√ - p<.001. For suspended sediment (calculated) concentrations from upstream LANL boundary stations and Guaje Canyon, CY 2000 results were compared against combined CY 2001 and CY 2002 results. For deposited sediment results, CY 2000 results were compared against prefire results collected in the same area.
[d]Bitner et al. 2001

Table 6-2. Organic Compounds Possibly Created by Cerro Grande Fire.

Organic Compound	Detected in multiple runoff samples upstream or north of LANL	Detected in ash-rich floodplain sediment deposits in lower Los Alamos Canyon
Benzoic acid	√	
Benzyl Alcohol	√	
4-Methylphenol (p-cresol)	√	√
Pyridine	√	
Benzo(a)anthracene		√
Benzo(a)pyrene		√
Benzo(b)fluoranthene		√
Benzo(g,h,I)perylene		√
Chrysene		√
Fluoranthene		√
Naphthalene		√
Phenanthrene		√
Pyrene		√
Summed 2,3,7,8-TCDD equivalent		√

6.2 LANL-Related Impacts to Runoff

The most significant impact to runoff from LANL was increased concentrations and transport of radionuclides in the high-volume runoff that occurred after the Cerro Grande fire. Some increases in transport of americium-241 and plutonium-238 occurred due to the increased runoff after the fire, but the most notable LANL impact to runoff after the fire was the erosion and transport of sediments in Pueblo Canyon that contained plutonium-239,240. The FWA concentration of plutonium-239,240 in runoff downstream of LANL increased nearly two orders of magnitude from the prefire average of 2.3 pCi/L to 105 pCi/L in 2002 (Figure 6.2-1). The FWA concentrations of cesium-137 and strontium-90 increased primarily due to fire effects, but the increased concentrations of plutonium-238 and plutonium-239,240 were from LANL impacts.

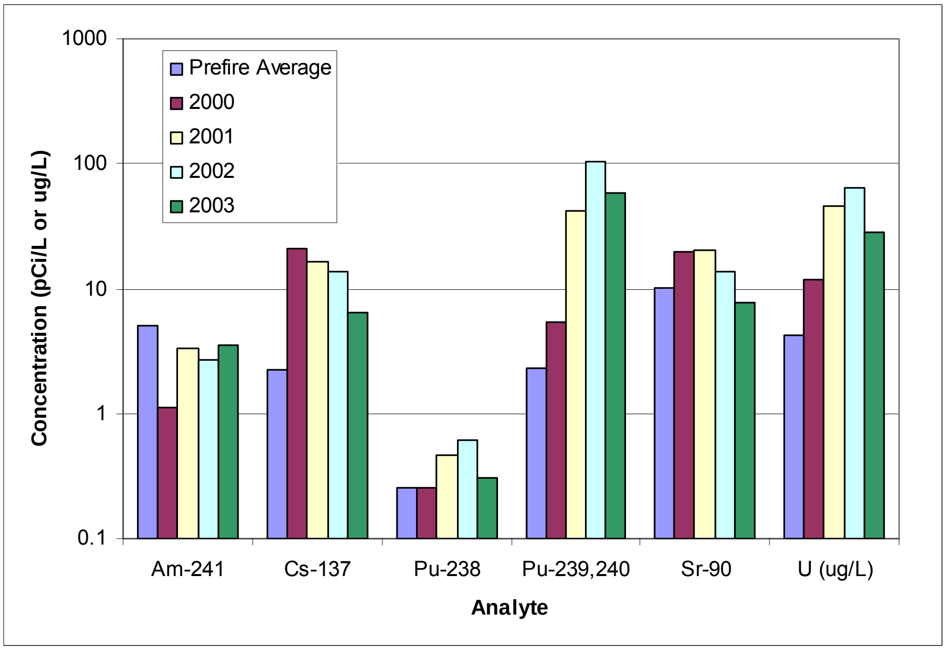


Figure 6.2-1. Flow-weighted average concentrations of radionuclides, prefire to 2003.

Figure 6.2-2 shows the increased transport of plutonium-239,240 that occurred in suspended sediment in storm runoff after the fire. The high-volume runoff in 2001, 2002, and 2003 from Pueblo Canyon caused downstream transport two orders of magnitude higher than the average annual prefire runoff (1995 to 1999). From 2000 through 2003, an estimated total of 64 mCi of plutonium-239,240 were transported in suspended sediment in runoff downstream of Pueblo Canyon. This represents about 6% of the estimated inventory of plutonium-239,240 (1.1 Ci) in Acid and Pueblo Canyons in 2000 (Reneau et al. 2003b).

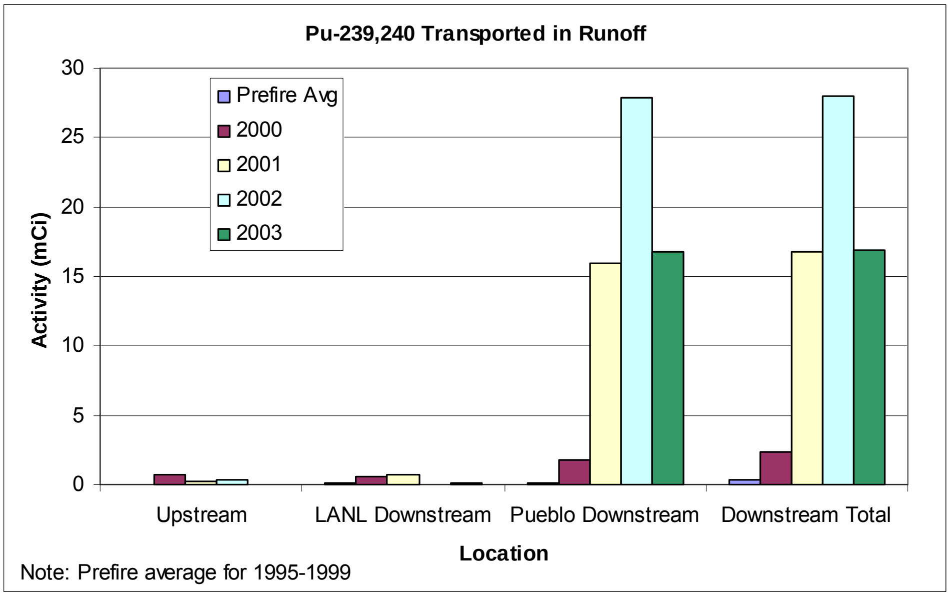


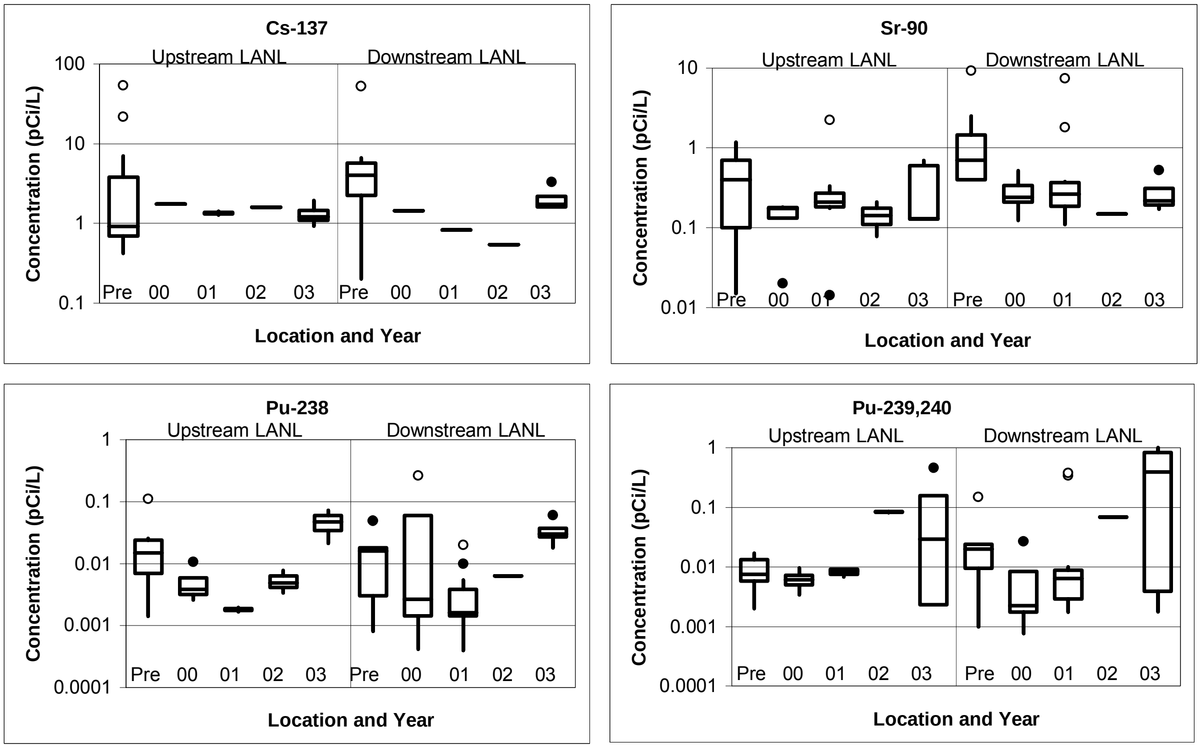
Figure 6.2-2. Estimated transport of plutonium-239,240 in suspended sediment downstream LANL runoff, prefire to 2003.

6.3 Fire-Related Impacts to the Rio Grande

During the 2000 runoff season, the USGS collected postfire samples of the Rio Grande for LANL and for the U.S. Army Corps of Engineers. Because of logistical constraints, however, not all runoff events from the Pajarito Plateau could be sampled and usually only one location could be sampled per day after a runoff event (Kraig et al. 2002). Thus, most samples of the Rio Grande were primarily baseflow; however, NMED collected samples from the Rio Grande in 2001 and baseflow/runoff samples collected from the Rio Grande in 2003 contain a component of storm runoff from the Pajarito Plateau.

Previous sections of this report have included pertinent results of the WQH, USGS, and NMED sampling of the Rio Grande for constituents that were found to be elevated in runoff from fire-impacted areas, or that were also elevated in runoff from LANL, such as for cesium-137, plutonium-238, plutonium-239,240, and strontium-90. For all constituents, the concentrations observed in samples from the Rio Grande were significantly lower than concentrations in runoff from the Pajarito Plateau (see Section 2.2.3).

Figure 6.3-1 shows the concentration distributions of selected radionuclides in unfiltered surface water samples collected from the Rio Grande upstream and downstream of canyons draining the Los Alamos area before the fire (1995 to 1999) and for the years 2000 through 2003 after the fire. Upstream LANL samples include samples from Otowi Bridge and upstream to Embudo on the Rio Grande and Chamita on the Rio Chama. Downstream LANL samples include samples collected downstream of Los Alamos Canyon to Cochiti Reservoir. For surface water samples collected from the Rio Grande and Rio Chama after the Cerro Grande fire, the results for cesium-137, strontium-90, plutonium-238, and plutonium-239,240 do not indicate that runoff from the Cerro Grande fire or from LANL caused elevated



Note: Prefire data and data for years 2000 and 2002 are baseflow samples from the Rio Grande; some samples in 2001 and 2003 contain a component of runoff in the Rio Grande, not necessarily exclusively from the Pajarito Plateau or LANL. MDA values posted for results <0.

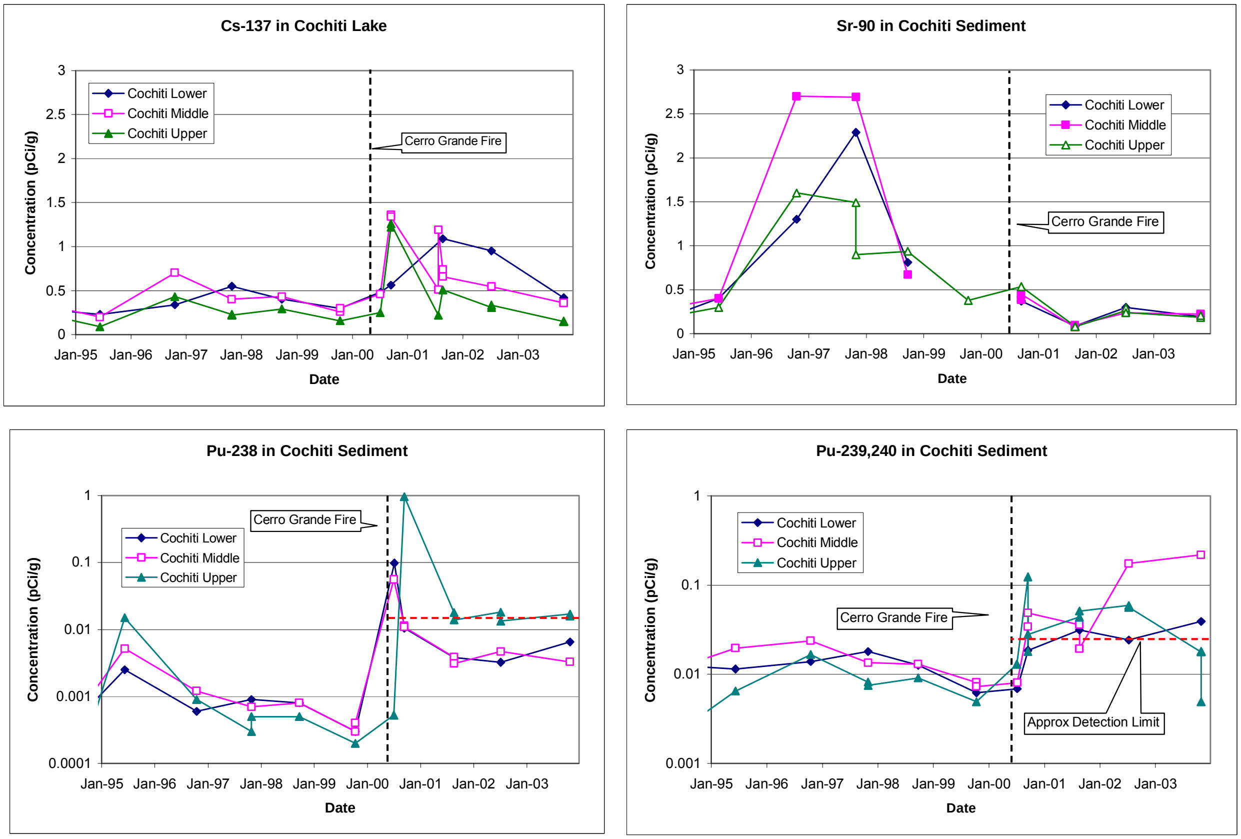
Figure 6.3-1. Distribution of concentrations of selected radionuclides in unfiltered surface water samples from the Rio Grande, prefire and 2000–2003.

concentrations in the Rio Grande. However, samples of runoff collected in the Rio Grande in 2001 and 2003 show higher concentrations of each radionuclide both upstream and downstream of LANL. The median concentration of plutonium-239,240 downstream of LANL in 2003 was about one order of magnitude higher than upstream of LANL, likely indicating a contribution from runoff from Pueblo Canyon.

As discussed in Section 2.1.3, baseflow in the Rio Grande is typically two to three orders of magnitude greater than the largest runoff events from the Los Alamos area that occurred after the Cerro Grande fire. The mixing of runoff from the Los Alamos area with the Rio Grande baseflow would tend to dilute runoff concentrations by two or three orders of magnitude. Surface water samples collected from the Rio Grande that contained a component of runoff in 2001 and 2003, whether from areas affected by the Cerro Grande fire, LANL, or from other upstream sources, contained higher concentrations of constituents in unfiltered samples due to the higher TSS concentrations in runoff compared with baseflow.

Although surface water samples collected from the Rio Grande were not significantly affected by runoff from the Cerro Grande fire and LANL, we collected annual samples of bottom sediments from Cochiti Reservoir, which is on the Rio Grande downstream of LANL and Cerro Grande fire runoff, to determine if there was an impact from the fire. Figure 6.3-2 shows the time series of radionuclide concentrations in the bottom sediment from Cochiti Reservoir from 1995 through 2003.

The results of samples collected after the fire suggest an increase in cesium-137, plutonium-238, and plutonium-239 concentrations ranging from 3 to 10 times prefire concentrations. Cesium-137 concentrations in Cochiti Reservoir bottom sediment in 2000 were about four times higher than prefire years; concentrations have declined each year since 2000, and in 2003 concentrations were approximately prefire levels. The pattern of sediment cesium-137 concentrations indicates that the source of elevated concentrations from 2000 through 2002 is likely ash carried from burned areas in runoff.



Note: horizontal dashed lines represent approximate detection limit.

Figure 6.3-2. Time series of radionuclide concentrations in Cochiti Reservoir sediment

The concentrations of plutonium-239,240 in Cochiti Reservoir bed sediment increased 5 to 10 times prefire levels in 2000 after the fire. Another increase in plutonium-239,240 concentrations in 2002 likely resulted from erosion and transport of LANL-impacted sediments in Pueblo Canyon. The concentrations of cesium-137 and plutonium-239,240 in the bottom sediment are below risk screening levels.

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Appendix A. Summary of Storm Runoff Samples Collected, 2000–2003.

Note: PA = Pajarito Canyon, LA = Los Alamos Canyon, WA = Water Canyon, CDV = Cañon de Valle, PU = Pueblo Canyon, PUN = north fork of Pueblo Canyon, CDB = Cañada del Buey, PO = Potrillo Canyon, SA = Sandia Canyon, DP = DP Canyon, RG = Rio Grande, WR = White Rock, AC = Acid Canyon, GU = Guaje Canyon, UN = Unnamed tributary to Pajarito Canyon. Numbers represent distance in miles from downstream confluence. Tables show number of filtered (F) and unfiltered (UF) analytic results.

Table A-1. Summary of Storm Runoff Samples Collected in Fire-Related Streams in 2000.

WQH			
Date	Location Name	F	UF
6/2/2000	Los Alamos above DP Canyon		172
6/2/2000	Los Alamos above SR-4		93
6/3/2000	Los Alamos above Ice Rink	85	172
6/3/2000	Los Alamos above SR-4	85	174
6/28/2000	Canon de Valle above SR-501		209
6/28/2000	Indio at SR-4	88	211
6/28/2000	Pajarito above SR-4	86	210
6/28/2000	Pajarito above Starmers	85	143
6/28/2000	Pajarito below SR-501	85	219
6/28/2000	Pajarito near G-1	50	57
6/28/2000	Pajarito SR-4 Culvert	87	211
6/28/2000	Starmers above Pajarito	85	181
6/28/2000	Water above SR-501		108
6/28/2000	Water at SR-4		3
6/28/2000	Water below SR-4	123	209
7/9/2000	Guaje Canyon at SR-502	85	248
7/9/2000	Los Alamos above SR-4	89	282
7/17/2000	Rendija 3rd Crossing	86	120
7/18/2000	Los Alamos above Ice Rink	92	238
7/19/2000	Los Alamos above Ice Rink		4
7/29/2000	Canada del Buey above SR-4	27	119
7/29/2000	Water below SR-4	61	207
8/9/2000	Canada del Buey above SR-4		66
8/9/2000	Potrillo above SR-4		107
8/12/2000	Water below SR-4		93
8/18/2000	Ancho below SR-4		59
8/18/2000	Canada del Buey above SR-4	137	116
8/18/2000	Water below SR-4	47	214
8/24/2000	Pajarito Retention Pond	121	170
9/8/2000	Guaje Canyon at SR-502	155	287
9/8/2000	Pajarito below SR-501	270	369
9/12/2000	Los Alamos above Ice Rink	160	294
10/11/2000	Canada del Buey above SR-4		40
10/12/2000	Los Alamos above SR-4		80
10/23/2000	Ancho below SR-4	1	49
10/23/2000	Canada del Buey above SR-4	2	137
10/23/2000	Canada del Buey near TA-46		35
10/23/2000	Canon de Valle above SR-501	102	249
10/23/2000	Los Alamos above SR-4	103	120
10/23/2000	Pajarito below SR-501	107	343
10/23/2000	Potrillo above SR-4	105	114
10/23/2000	Pueblo above SR-502	27	117
10/23/2000	Starmer's Gulch above SR-501	109	241
10/23/2000	Water above SR-501	102	250
10/23/2000	Water below SR-4	32	277
10/24/2000	Los Alamos above DP Canyon		37
10/24/2000	Pajarito above SR-4	107	256

WQH			
Date	Location Name	F	UF
10/27/2000	Los Alamos above SR-4	30	77
10/27/2000	Pajarito above SR-4	103	125
10/27/2000	Pueblo above SR-502	70	77
10/27/2000	Water at SR-4	35	94
10/27/2000	Water below SR-4	100	106
10/28/2000	Ancho below SR-4	2	34
10/28/2000	Canada del Buey above S	32	54
10/28/2000	Pajarito above SR-4		2
10/28/2000	Water at SR-4		3
10/30/2000	Los Alamos above SR-4		6

LANL ER			
Date	Location Name	F	UF
6/3/2000	Los Alamos above Weir		8
6/3/2000	Los Alamos above SR-4		8
7/24/2000	Pueblo at ?		1
8/2/2000	Pueblo above Hamilton		4
8/12/2000	Pueblo above Acid		139
8/12/2000	Pueblo 2E		47
9/8/2000	Pueblo above Acid		27
9/8/2000	Pueblo above Hamilton		54
10/12/2000	LA above DP	39	41
10/12/2000	LA below Weir	39	41
10/12/2000	LA above SR-4	39	41
10/12/2000	Pueblo above Acid	80	84
10/12/2000	Pueblo 2E	120	126
10/23/2000	Threemile Canyon		78
10/23/2000	LA below Weir	78	82
10/23/2000	Pueblo above Acid	80	84
10/23/2000	Pueblo 2E	80	84
10/27/2000	LA below Weir	39	41
10/27/2000	LA above SR-4	39	41
10/28/2000	LA below Weir	39	41
11/2/2000	LA below Weir	40	42
11/2/2000	LA above SR-4	40	
11/2/2000	LA below Ice Rink	40	42

NMED			
Date	Location Name	F	UF
6/29/2000	PA-10.6	26	69
6/29/2000	PA-6.7	137	52
7/21/2000	LA-5.0	26	46
8/14/2000	WA-2.9		24
8/16/2000	CDV-5.6	4	14
8/18/2000	CDB-1.9		25
8/24/2000	PA-6.7	116	124
9/8/2000	AC-0.5	68	4
9/8/2000	GU-0.01	63	5
9/8/2000	PA-10.4	61	2
9/8/2000	PU-2.0	88	13
9/8/2000	PU-6.7	88	13
9/8/2000	PUN-0.01	89	14
9/8/2000	SFAC-0.01	68	4
9/12/2000	LA-5.0	85	12
9/26/2000	PA-0.01		8
10/12/2000	AC-0.5	64	4
10/12/2000	SFAC-0.01	64	4
10/13/2000	SFAC-0.01	64	4
10/23/2000	CDB-1.9	47	2
10/23/2000	CDB-5.4	46	2
10/23/2000	MO-7.2	45	3
10/23/2000	PA-4.8	46	2
10/23/2000	PO-1.8	44	2
10/23/2000	SA-5.6	44	2
10/23/2000	SFAC-0.01	71	5
10/23/2000	UN-0.01	45	2
10/23/2000	WA-2.9	45	2
10/23/2000	WA-4.5	22	
10/24/2000	RG at WR Gage	52	8
10/24/2000	WA-2.9	45	2
10/27/2000	LA-6.6A	33	11
10/27/2000	LA-6.6B	33	11
10/27/2000	LA-6.6C	33	11
10/28/2000	LA-10.5	56	12
10/28/2000	LA-5.0	42	13
10/28/2000	PA-10.4	45	12
10/28/2000	PA-2.2	46	12
10/28/2000	PU-2.0	43	13
10/28/2000	PUN-0.01	15	12
10/28/2000	PUN-0.1	31	
10/28/2000	RG at WR Gage	29	2
10/28/2000	SA-5.6		7
10/28/2000	TM-3.1	47	12
10/28/2000	WA-2.9	47	12
10/28/2000	WA-9.9	44	12
11/2/2000	PA-10.6	6	43

Note: WQH = Water Quality and Hydrology, ER = Environmental Restoration Project, NMED = New Mexico Environment Department, F = Filtered Samples, UF = Unfiltered Samples, the numbers in the F/UF columns are the number of analytical results for each sample type.

Table A-2. Summary of Storm Runoff Samples Collected in Fire-Related Streams in 2001.

WQH			
Date	Location Name	F	UF
6/27/2001	Pajarito above SR-4	103	114
7/2/2001	Los Alamos above DP Canyon	95	113
7/2/2001	Los Alamos above SR-4	25	109
7/2/2001	Los Alamos below Ice Rink	176	218
7/2/2001	Pajarito above TA-18	95	101
7/2/2001	Pueblo above SR-502	95	76
7/2/2001	Rendija above Guaje	45	101
7/13/2001	Los Alamos below Ice Rink	203	221
7/14/2001	Los Alamos above DP Canyon	95	103
7/14/2001	Los Alamos above SR-4	25	106
7/22/2001	Canon de Valle above SR-501	69	75
7/22/2001	Water above S Site Canyon		3
7/22/2001	Water above SR-501	25	62
7/26/2001	Canon de Valle above SR-501	25	38
7/26/2001	Los Alamos above DP Canyon	191	212
7/26/2001	Los Alamos above SR-4		33
7/26/2001	Los Alamos below LA Weir	25	38
7/26/2001	Pajarito above Starmers	70	75
7/26/2001	Pajarito below SR-501		75
7/26/2001	Pueblo above SR-502	70	83
7/26/2001	Water at SR-4	8	55
7/26/2001	Water below MDA AB	95	103
8/1/2001	Los Alamos above SR-4	25	39
8/3/2001	S Site Canyon above Water	25	33
8/3/2001	Water at SR-4	25	141
8/3/2001	Water below MDA AB	105	111
8/3/2001	Water below SR-4	96	150
8/4/2001	Los Alamos above SR-4	104	111
8/4/2001	Pueblo above SR-502		67
8/5/2001	Canon de Valle above Water	25	109
8/5/2001	Los Alamos above DP Canyon	107	112
8/5/2001	Pajarito above Starmers	32	113
8/5/2001	Pajarito above TA-18	25	33
8/5/2001	Sandia below Wetlands	25	103
8/6/2001	Pajarito above SR-4	195	163
8/8/2001	Guaje above Rendija	33	108
8/8/2001	Los Alamos above SR-4	25	
8/8/2001	Water below MDA AB	95	113
8/9/2001	Canon de Valle above Water	103	112
8/9/2001	Guaje above Rendija	70	103
8/9/2001	Los Alamos above DP Canyon	142	210
8/9/2001	Los Alamos above SR-4		38
8/9/2001	Los Alamos below Ice Rink	103	112
8/9/2001	Los Alamos below LA Weir	25	42
8/9/2001	Pajarito above SR-4	135	204
8/9/2001	Pajarito below SR-501	25	38
8/9/2001	Pueblo above SR-502	103	113

WQH			
Date	Location Name	F	UF
8/9/2001	Water at SR-4	103	111
8/9/2001	Water below SR-4	33	108
8/11/2001	Guaje above Rendija	100	114
8/11/2001	Pajarito above Starmers	25	111
8/11/2001	Pueblo above SR-502	104	112
8/13/2001	Pueblo above Acid		72
8/14/2001	Guaje above Rendija	138	213
8/16/2001	Guaje above Rendija	71	78
8/16/2001	Los Alamos above DP Canyon	136	219
8/16/2001	Los Alamos above SR-4	128	142
8/16/2001	Los Alamos below LA Weir	25	38
8/16/2001	Pajarito above SR-4	105	113
8/16/2001	Pueblo above SR-502	103	110

LANL ER			
Date	Location Name	F	UF
7/2/2001	LA-10036		28
7/2/2001	LA above Weir		14
7/2/2001	LA-10158		10
7/13/2001	LA-10158		10
7/14/2001	LA-10036		16
7/14/2001	LA-10158		2
7/26/2001	LA-10036		24
7/26/2001	LA above Weir		8
7/26/2001	LA-10158		20
8/4/2001	Pueblo 2E		54
8/9/2001	LA above Acid		135
8/9/2001	Pueblo above Hamilton		108
8/14/2001	Pueblo above Hamilton		54
8/16/2001	Pueblo 2E		135

NMED			
Date	Location Name	F	UF
7/2/2001	LA Weir	114	247
7/3/2001	LA Weir		7
7/22/2001	Water below SR-4	180	382
7/26/2001	Pueblo above SR-4		1
7/26/2001	Water below SR-4		6
8/3/2001	Water below SR-4	223	490
8/5/2001	Pajarito below SR-501	72	158
8/5/2001	Pajarito below TA-18	144	396
8/11/2001	Pueblo above SR-4	254	575
8/16/2001	LA Weir	223	590
8/16/2001	Pueblo above SR-4	144	401
8/17/2001	Pueblo above SR-4		2

Note: WQH = Water Quality and Hydrology, ER = Environmental Restoration Project, NMED = New Mexico Environment Department, F = Filtered Samples, UF = Unfiltered Samples, the numbers in the F/UF columns are the number of analytical results for each sample type.

Table A-3. Summary of Storm Runoff Samples Collected in Major Drainages in 2002.

WQH			
Date	Location Name	F	UF
6/21/2002	La Delfe above Pajarito		10
6/21/2002	Los Alamos above DP Canyon		10
6/21/2002	Los Alamos below Ice Rink		81
6/21/2002	Pajarito above Threemile	195	128
6/21/2002	Pajarito above Twomile		10
6/21/2002	Pueblo above Acid		10
6/21/2002	Starmers above Pajarito		8
6/21/2002	Water above S Site Canyon		2
6/21/2002	Water below MDA AB		8
6/22/2002	Canon de Valle above SR-501		16
6/22/2002	Guaje above Rendija	100	77
6/22/2002	Los Alamos above SR-4		8
6/22/2002	Pajarito above SR-4		105
6/22/2002	Pueblo above SR-502		17
6/22/2002	Sandia above Firing Range		10
6/22/2002	Water at SR-4	100	113
7/4/2002	Guaje above Rendija	124	132
7/4/2002	Guaje at SR-502	104	75
7/4/2002	Sandia below Wetlands	7	116
7/14/2002	La Delfe above Pajarito		31
7/14/2002	Sandia below Wetlands	9	13
7/14/2002	Water above S Site Canyon		1
7/14/2002	Water at SR-4	124	3
7/14/2002	Water below MDA AB		10
7/14/2002	Water below SR-4		15
7/22/2002	Sandia below Wetlands	39	119
7/25/2002	Canon de Valle above SR-501	30	29
7/25/2002	Pajarito above Starmers		4
7/31/2002	Rendija above Guaje		10
8/7/2002	Los Alamos above DP Canyon		10
8/7/2002	Sandia above Firing Range		9
8/7/2002	Sandia below Wetlands	39	125
8/8/2002	Pajarito above Starmers	40	39
8/28/2002	Canada del Buey above SR-4	110	136
8/28/2002	Pajarito above SR-4		1
8/28/2002	Water at SR-4	7	22
9/9/2002	Canada del Buey above SR-4	30	41
9/9/2002	Pajarito above Starmers	71	93
9/10/2002	Guaje above Rendija	114	149
9/10/2002	Pajarito above Threemile	39	50
9/10/2002	Pueblo above SR-502		1
9/10/2002	Sandia above Firing Range	30	37
9/10/2002	Water below SR-4		3
10/23/2002	Guaje above Rendija	74	137
10/28/2002	Pueblo above SR-502		1

LANL ER			
Date	Location Name	F	UF
7/18/2002	PU-02-20850		11
7/18/2002	PU-02-20851		8
7/18/2002	Pueblo above Acid		1
7/25/2002	PU-02-20848		12
7/25/2002	PU-02-20849		2
7/25/2002	PU-02-20850		18
7/25/2002	PU-02-20851		12
7/25/2002	PU-02-20852		14
7/25/2002	PU-02-20854		1
7/25/2002	Pueblo above Acid		7
7/31/2002	PU-02-20848		6
7/31/2002	PU-02-20849		4
7/31/2002	PU-02-20851		11
7/31/2002	PU-02-20852		12
7/31/2002	PU-02-20854		1
7/31/2002	Pueblo above Acid		7
8/7/2002	PU-02-20848		8
8/7/2002	PU-02-20850		12
9/10/2002	PU-02-20848		12
10/9/2002	PU-02-20853		6
10/10/2002	PU-02-20849		6
10/10/2002	PU-02-20852		2
10/10/2002	PU-02-20853		13

NMED			
Date	Location Name	F	UF
6/22/2002	Pueblo above SR-502		55
7/14/2002	Pajarito at TA-18	30	161
7/18/2002	Pueblo above SR-502	90	523
7/18/2002	Pueblo above Acid	30	213
7/18/2002	Pueblo above bridge	30	199
7/18/2002	Pueblo North	30	168
7/25/2002	Pueblo above Acid	30	167
7/26/2002	Pueblo above SR-502	61	416
7/31/2002	Guaje above SR-502	61	373
7/31/2002	Sandia near TA-53	30	114
7/31/2002	Sandia near TA-3	30	180
8/8/2002	Pajarito above SR-501	30	168
8/28/2002	CDB above SR-4	30	199
9/10/2002	Pueblo above SR-502	90	249
9/10/2002	Pueblo Above STP		5
9/10/2002	Pueblo Above STP		5
9/10/2002	Pueblo above Acid	30	112
9/10/2002	Pueblo above bridge	1	55
10/26/2002	Pueblo above Acid		34

Table shows number of filtered (F) and unfiltered (UF) analytical results.

Table A-4. Summary of Storm Runoff Samples Collected in Major Drainages in 2003.

WQH			
Date	Location Name	F	UF
5/24/2003	Acid above Pueblo		10
5/24/2003	DP above TA-21		79
5/25/2003	Canada del Buey above SR-4	36	262
5/26/2003	Ancho below SR-4		31
5/26/2003	Canada del Buey near MDA G		18
5/26/2003	Potrillo above SR-4		10
5/26/2003	Water below SR-4		31
6/1/2003	Guaje above Rendija	103	31
6/17/2003	DP above TA-21	58	107
6/17/2003	Guaje at SR-502	30	107
7/26/2003	Sandia below Wetlands	30	142
8/2/2003	DP above TA-21	5	9
8/7/2003	Acid above Pueblo		73
8/7/2003	Sandia below Wetlands	54	118
8/9/2003	Rio Grande at Otowi Bridge		5
8/11/2003	Acid above Pueblo		11
8/11/2003	DP above TA-21	53	11
8/11/2003	DP below Meadow at TA-21	30	82
8/11/2003	Los Alamos above DP Canyon	14	9
8/11/2003	Pajarito above Starmers	14	86
8/11/2003	Pajarito below SR-501		5
8/11/2003	Pueblo above Acid	34	36
8/11/2003	Starmers above Pajarito	14	9
8/16/2003	DP above TA-21	119	254
8/19/2003	Potrillo above SR-4		12
8/22/2003	Pueblo above SR-502	123	277
8/23/2003	Acid above Pueblo	62	33
8/23/2003	Canada del Buey near TA-46	35	47
8/23/2003	DP above Los Alamos Canyon		3
8/23/2003	DP below Meadow at TA-21	35	44
8/23/2003	Guaje above Rendija		78
8/23/2003	Guaje at SR-502	43	106
8/23/2003	Los Alamos above DP Canyon	118	111
8/23/2003	Los Alamos above SR-4	1	30

WQH			
Date	Location Name	F	UF
8/23/2003	Los Alamos below Ice Rink		4
8/23/2003	Los Alamos Canyon near Otowi		28
8/23/2003	Pajarito above Starmers	46	105
8/23/2003	Sandia above Firing Range	43	106
8/23/2003	Sandia below Wetlands	120	260
8/23/2003	Threemile above Pajarito		10
8/25/2003	Canada del Buey above SR-4	117	201
8/25/2003	Canada del Buey near MDA G		14
8/25/2003	Potrillo above SR-4	44	130
8/25/2003	Rio Grande at Otowi Bridge		84
8/25/2003	Rio Grande below Ancho		77
8/26/2003	Pueblo above Acid	47	187
8/26/2003	Pueblo above SR-502	117	251
8/28/2003	Pajarito above Starmers		10
8/28/2003	Starmers above Pajarito		6
8/29/2003	Sandia below Wetlands	45	186
8/30/2003	Pueblo above Acid	157	265
9/3/2003	Acid above Pueblo	2	2
9/3/2003	Guaje above Rendija	102	26
9/3/2003	Pueblo above Acid	118	114
9/3/2003	Sandia below Wetlands	91	81
9/6/2003	Acid above Pueblo	62	106
9/6/2003	Los Alamos above SR-4	52	34
9/6/2003	Los Alamos below Ice Rink	44	108
9/6/2003	Pajarito above Threemile	122	109
9/6/2003	Pueblo above Acid	118	188
9/6/2003	Pueblo above SR-502	108	114
9/6/2003	Rio Grande at Otowi Bridge	218	115
9/6/2003	Rio Grande below Espanola		4
9/6/2003	Rio Grande near White Rock	120	116
9/10/2003	Rio Chama at Chamita		4
9/10/2003	Rio Grande at Otowi Bridge		5
9/10/2003	Rio Grande below Espanola		4

LANL ER			
Date	Location Name	F	UF
5/30/2003	PU-02-20848	2	
5/30/2003	PU-02-20850	2	
5/30/2003	PU-02-20851	4	
5/30/2003	PU-02-20852	2	
5/30/2003	PU-02-20854	2	

NMED			
Date	Location Name	F	UF
8/18/2003	Los Alamos above DP Canyon		29
8/23/2003	Los Alamos above DP Canyon		113
9/3/2003	Los Alamos above DP Canyon		29

Table shows number of filtered (F) and unfiltered (UF) analytical results.

Table A-5. Summary of USGS Sampling of Rio Grande, 2000–2001.

2000	
Date	Location
28-Jun-00	Rio Grande near White Rock
05-Jul-00	Cochiti Reservoir Delta
05-Jul-00	Rio Grande at Mortandad
06-Jul-00	Cochiti Reservoir Site B
06-Jul-00	Rio Grande at Otowi
07-Jul-00	Rio Grande near White Rock
08-Jul-00	Cochiti Reservoir Site A
11-Jul-00	Rio Grande below Cochiti Dam
17-Jul-00	Rio Grande near White Rock
19-Jul-00	Cochiti Reservoir Site A
19-Jul-00	Rio Grande below Cochiti
24-Oct-00	Rio Grande near White Rock
25-Oct-00	Cochiti Reservoir Site A
28-Oct-00	Rio Grande near White Rock

2001	
Date	Location
24-Jul-01	Cochiti Reservoir Delta
24-Jul-01	Cochiti Reservoir Site B
25-Jul-01	Cochiti Reservoir Site A
25-Jul-01	Cochiti Reservoir Site B
26-Jul-01	Rio Grande near White Rock
27-Jul-01	Rio Grande at Otowi
28-Jul-01	Rio Grande near White Rock
30-Jul-01	Rio Grande below Cochiti Dam
06-Aug-01	Rio Grande below Cochiti Dam
08-Aug-01	Rio Grande at Otowi
09-Aug-01	Rio Grande near White Rock
16-Aug-01	Rio Grande below Cochiti Dam
25-Sep-01	Rio Grande near White Rock
26-Sep-01	Rio Grande at Otowi
26-Sep-01	Rio Grande below Cochiti Dam
26-Sep-01	Rio Grande near White Rock

Appendix B. Summary of Storm Runoff Samples Collected for Major Water Quality Constituents.

Table B-1. Summary of LANL WQH Major Water Quality Data for Storm Runoff in Major Drainages, 2000–2003.

2000			
		Field Prep	
Date	Location	F	UF
02-Jun-00	Los Alamos above DP Canyon		13
02-Jun-00	Los Alamos above SR-4		12
03-Jun-00	Los Alamos above Ice Rink	4	13
03-Jun-00	Los Alamos above SR-4	4	13
28-Jun-00	Canon de Valle above SR-501		13
28-Jun-00	Pajarito at G-1		2
28-Jun-00	Indio at SR-4		13
28-Jun-00	Pajarito above SR-4	4	13
28-Jun-00	Pajarito above Starmers	4	14
28-Jun-00	Pajarito below SR-501	4	13
28-Jun-00	Pajarito SR-4 Culvert	4	14
28-Jun-00	Starmers above Pajarito	4	13
28-Jun-00	Water above SR-501		13
28-Jun-00	Water below SR-4	4	13
09-Jul-00	Guaje Canyon at SR-502	4	13
09-Jul-00	Los Alamos above SR-4	4	20
17-Jul-00	Rendija 3rd Crossing	4	12
18-Jul-00	Los Alamos above Ice Rink	4	15
19-Jul-00	Los Alamos above Ice Rink		2
21-Jul-00	Los Alamos Weir	1	9
29-Jul-00	Canada del Buey above SR-4	2	12
29-Jul-00	Water below SR-4		19
09-Aug-00	Canada del Buey above SR-4		3
09-Aug-00	Potrillo above SR-4		10
12-Aug-00	Water below SR-4		3
18-Aug-00	Ancho above north fork Ancho		5
18-Aug-00	Ancho below SR-4		6
18-Aug-00	Canada del Buey above SR-4	3	20
18-Aug-00	Water below SR-4	3	16
24-Aug-00	Pajarito Retention Pond	27	19
31-Aug-00	Los Alamos Reservoir	18	14
31-Aug-00	Upper Los Alamos Reservoir	16	11
08-Sep-00	Guaje Canyon at SR-502	8	10
08-Sep-00	Pajarito below SR-501	12	15
12-Sep-00	Los Alamos above Ice Rink	8	14
11-Oct-00	Canada del Buey above SR-4		14
12-Oct-00	Los Alamos above SR-4		7
23-Oct-00	Ancho below SR-4	1	21
23-Oct-00	Canada del Buey above SR-4	2	15
23-Oct-00	Canada del Buey near TA-46		10
23-Oct-00	Canon de Valle above SR-501	8	15
23-Oct-00	Los Alamos above SR-4	8	12
23-Oct-00	Pajarito below SR-501	8	33
23-Oct-00	Potrillo above SR-4	8	16
23-Oct-00	Pueblo above SR-502	3	18
23-Oct-00	Starmer's Gulch above SR-501	8	18
23-Oct-00	Twomile above SR-501	11	15
23-Oct-00	Water above SR-501	8	16
23-Oct-00	Water below SR-4	8	19
24-Oct-00	Los Alamos above DP Canyon		11
24-Oct-00	Pajarito above SR-4	11	19
27-Oct-00	Los Alamos above SR-4	6	5

2000			
		Field Prep	
Date	Location	F	UF
27-Oct-00	Pajarito above SR-4	8	13
27-Oct-00	Pueblo above SR-502		6
27-Oct-00	Water at SR-4	11	17
27-Oct-00	Water below SR-4	6	8
28-Oct-00	Ancho above north fork Ancho	8	8
28-Oct-00	Ancho below SR-4	2	8
28-Oct-00	Canada del Buey above SR-4	8	14
28-Oct-00	Pajarito above SR-4		2
28-Oct-00	Water at SR-4		3
30-Oct-00	Los Alamos above SR-4		6
2001			
		Field Prep	
Date	Location	F	UF
06/27/01	Pajarito above SR-4	9	19
07/02/01	Los Alamos above DP Canyon	1	17
07/02/01	Los Alamos above SR-4	1	9
07/02/01	Los Alamos below Ice Rink	13	28
07/02/01	Pajarito above TA-18	1	6
07/02/01	Pueblo above SR-502	1	5
07/13/01	Los Alamos below Ice Rink	15	32
07/14/01	Los Alamos above DP Canyon	1	8
07/14/01	Los Alamos above SR-4	1	10
07/22/01	Water above S Site Canyon		3
07/22/01	Water above SR-501	1	19
07/26/01	Los Alamos above DP Canyon	15	31
07/26/01	Los Alamos above SR-4		9
07/26/01	Los Alamos below LA Weir	1	14
07/26/01	Pajarito above Starmers		5
07/26/01	Pajarito below SR-501		5
07/26/01	Pueblo above SR-502		13
07/26/01	Water at SR-4	1	14
07/26/01	Water below MDA AB	1	9
08/01/01	Los Alamos above SR-4	1	15
08/03/01	Acid above Pueblo	1	5
08/03/01	Water at SR-4	1	22
08/03/01	Water below MDA AB	10	16
08/03/01	Water below SR-4	1	30
08/04/01	Los Alamos above SR-4	9	16
08/04/01	Pueblo above SR-502		5
08/05/01	Los Alamos above DP Canyon	12	17
08/05/01	Pajarito above Starmers	8	18
08/05/01	Pajarito above TA-18	1	9
08/05/01	Potrillo tributary Study Area		5
08/05/01	Sandia below Wetlands	1	9
08/06/01	Pajarito above SR-4	16	31
08/08/01	Los Alamos above SR-4	1	
08/08/01	Water below MDA AB	1	18
08/09/01	Los Alamos above DP Canyon	16	32
08/09/01	Los Alamos above SR-4		14
08/09/01	Los Alamos below Ice Rink	9	17
08/09/01	Los Alamos below LA Weir	1	17
08/09/01	Pajarito above SR-4	14	30

2001			
		Field Prep	
Date	Location	F	UF
08/09/01	Pajarito below SR-501	1	14
08/09/01	Pueblo above SR-502	9	18
08/09/01	Water at SR-4	9	16
08/09/01	Water below SR-4	9	14
08/11/01	Pajarito above Starmers	1	17
08/11/01	Potrillo tributary Study Area	1	9
08/11/01	Pueblo above SR-502	10	17
08/13/01	Pueblo above Acid		2
08/16/01	Los Alamos above DP Canyon	17	32
08/16/01	Los Alamos above SR-4	10	23
08/16/01	Los Alamos below LA Weir	1	14
08/16/01	Pajarito above SR-4	9	18
08/16/01	Pueblo above SR-502	9	15
08/30/01	Potrillo tributary Study Area	13	20
2002			
		Field Prep	
Date	Location	F	UF
06/21/02	Los Alamos above DP Canyon		5
06/21/02	Los Alamos below Ice Rink		1
06/21/02	Pajarito above Threemile	24	21
06/21/02	Pajarito above Twomile		4
06/21/02	Pueblo above Acid		4
06/21/02	Water above S Site Canyon		2
06/21/02	Water below MDA AB		2
06/22/02	Los Alamos above SR-4		2
06/22/02	Pajarito above SR-4		5
06/22/02	Pueblo above SR-502		5
06/22/02	Sandia above Firing Range		4
06/22/02	Water at SR-4	5	17
07/04/02	Guaje at SR-502	5	2
07/04/02	Sandia below Wetlands		13
07/14/02	Sandia below Wetlands	9	4
07/14/02	Water above S Site Canyon		1
07/14/02	Water at SR-4		1
07/14/02	Water below MDA AB		4
07/14/02	Water below SR-4		1
07/22/02	Sandia below Wetlands	15	20
07/25/02	Pajarito above Starmers		3
07/26/02	Potrillo tributary Study Area	6	30
08/07/02	Los Alamos above DP Canyon		4
08/07/02	Sandia above Firing Range		4
08/07/02	Sandia below Wetlands	15	17
08/08/02	Pajarito above Starmers	16	15
08/28/02	Pajarito above SR-4		1
08/28/02	Potrillo tributary Study Area	15	18
08/28/02	Water at SR-4	6	
08/28/02	Water tributary Study Area		1
09/09/02	Pajarito above Starmers		1
09/09/02	Potrillo tributary Study Area		2
09/10/02	Pajarito above Threemile	15	24
09/10/02	Pueblo above SR-502		1
09/10/02	Sandia above Firing Range	6	7

2002			
		Field Prep	
Date	Location	F	UF
09/10/02	Water below SR-4		3
09/28/02	Potrillo tributary Study Area	22	15
10/23/02	Potrillo tributary Study Area	29	26
10/28/02	Pueblo above SR-502		1
2003			
		Field Prep	
Date	Location	F	UF
5/25/2003	Canada del Buey above SR-4	36	262
5/26/2003	Ancho below SR-4		31
5/26/2003	Canada del Buey near MDA G		18
5/26/2003	Potrillo above SR-4		10
5/26/2003	Water below SR-4		31
6/1/2003	Guaje above Rendija	103	31
6/17/2003	Guaje at SR-502	30	107
7/26/2003	Sandia below Wetlands	30	142
8/7/2003	Sandia below Wetlands	54	118
8/9/2003	Rio Grande at Otowi		5
8/11/2003	Los Alamos above DP Canyo	14	9
8/11/2003	Pajarito above Starmers	14	86
8/11/2003	Pajarito below SR-501		5
8/11/2003	Pueblo above Acid	34	36
8/11/2003	Starmers above Pajarito	14	9
8/19/2003	Potrillo above SR-4		12
8/23/2003	Canada del Buey near TA-46		18
8/23/2003	Los Alamos below Ice Rink		4
8/23/2003	Pajarito above Starmers	11	
8/25/2003	Canada del Buey above SR-4	117	201
8/25/2003	Canada del Buey near MDA G		14
8/25/2003	Potrillo above SR-4	44	130
8/25/2003	Rio Grande at Otowi Bridge		84
8/25/2003	Rio Grande below Ancho		77
8/26/2003	Pueblo above Acid	47	187
8/26/2003	Pueblo above SR-502	117	251
8/28/2003	Pajarito above Starmers		10
8/28/2003	Starmers above Pajarito		6
8/29/2003	Sandia below Wetlands	45	186
8/30/2003	Pueblo above Acid	157	265
9/3/2003	Guaje above Rendija	102	26
9/3/2003	Pueblo above Acid	118	114
9/3/2003	Sandia below Wetlands	91	81
9/6/2003	Los Alamos above SR-4	52	34
9/6/2003	Los Alamos below Ice Rink	44	108
9/6/2003	Pajarito above Threemile	122	109
9/6/2003	Pueblo above Acid	118	188
9/6/2003	Pueblo above SR-502	108	114
9/6/2003	Rio Grande at Otowi Bridge	218	115
9/6/2003	Rio Grande below Espanola		4
9/6/2003	Rio Grande near White Rock	120	116
9/10/2003	Rio Chama at Chamita		4
9/10/2003	Rio Grande at Otowi		5
9/10/2003	Rio Grande below Espanola		4

Table B-2. Summary of LANL ER Project Major Water Quality Data for Storm Runoff, 2000–2002.

2000					2001					2002				
			Field Prep					Field Prep					Field Prep	
Date	Location	Location ID	F	UF	Date	Location	Location ID	F	UF	Date	Location	Location ID	F	UF
6/3/2000	Los Alamos below Weir	LA-10038		8	7/2/2001	Los Alamos above DP	LA-10036		28	7/18/2002		PU-02-20850		11
6/3/2000	Los Alamos above SR-4	LA-10040		8	7/2/2001	Los Alamos above Weir	LA-10138		14	7/18/2002		PU-02-20851		8
7/24/2000		PU-10161		1	7/2/2001		LA-10158		10	7/18/2002	Pueblo above Acid	PU-10159		1
8/2/2000	Pueblo above Hamilton	PU-10162		2	7/13/2001		LA-10158		10	7/25/2002		PU-02-20848		12
8/12/2000	Pueblo above Acid	PU-10159		9	7/14/2001		LA-10036		16	7/25/2002		PU-02-20849		2
8/12/2000	Pueblo 2E	PU-10160		5	7/14/2001		LA-10158		2	7/25/2002		PU-02-20850		18
9/8/2000	Pueblo above Acid	PU-10159		1	7/26/2001	Los Alamos above DP	LA-10036		24	7/25/2002		PU-02-20851		12
9/8/2000	Pueblo above Hamilton	PU-10162		2	7/26/2001	Los Alamos above Weir	LA-10138		8	7/25/2002		PU-02-20852		14
10/12/2000	Los Alamos above DP	LA-10036		2	7/26/2001		LA-10158		20	7/25/2002		PU-02-20854		1
10/12/2000	Los Alamos below Weir	LA-10037		2	8/4/2001	Pueblo 2E	PU-10160		2	7/25/2002	Pueblo above Acid	PU-10159		7
10/12/2000	Los Alamos above Weir	LA-10038		2	8/9/2001	Pueblo above Acid	PU-10159		5	7/31/2002		PU-02-20848		6
10/12/2000	Pueblo above Acid	PU-10159		4	8/9/2001	Pueblo above Hamilton	PU-10162		4	7/31/2002		PU-02-20849		4
10/12/2000	Pueblo 2E	PU-10160		6	8/14/2001	Pueblo above Hamilton	PU-10162		2	7/31/2002		PU-02-20851		11
10/23/2000	Threemile Canyon	18-10109		4	8/16/2001	Pueblo 2E	PU-10160		5	7/31/2002		PU-02-20852		12
10/23/2000	Los Alamos below Weir	LA-10037		4						7/31/2002		PU-02-20854		1
10/23/2000	Pueblo above Acid	PU-10159		4						7/31/2002	Pueblo above Acid	PU-10159		7
10/23/2000	Pueblo 2E	PU-10160		4						8/7/2002		PU-02-20848		8
10/27/2000	Los Alamos below Weir	LA-10037		2						8/7/2002		PU-02-20850		12
10/27/2000	Los Alamos above Weir	LA-10038		2						9/10/2002		PU-02-20848		12
10/28/2000	Los Alamos below Weir	LA-10037		2						10/9/2002		PU-02-20853		6
11/2/2000	Los Alamos below Weir	LA-10037	1	3						10/10/2002		PU-02-20849		6
11/2/2000	Los Alamos above Weir	LA-10039	1							10/10/2002		PU-02-20852		2
11/2/2000	Los Alamos below Rink	LA-10040	1	3						10/10/2002		PU-02-20853		13

Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table B-3. Summary of NMED Major Water Quality Data for Storm Runoff, 2000–2003.

2000

Date	Location	Syn	Field Prep F	Field Prep UF
6/29/2000	PA-10.6	E240	5	7
6/29/2000	PA-6.7	E243	10	14
7/21/2000	LA-5.0	E050	7	16
8/14/2000	WA-2.9	E263		5
8/16/2000	CDV-5.6	E253	4	14
8/18/2000	CDB-1.9	E230		6
8/24/2000	PA-6.7	E243	14	23
9/8/2000	AC-0.5	E056	5	2
9/8/2000	GU-0.01	E099	4	2
9/8/2000	PA-10.4	E240	4	2
9/8/2000	PU-2.0	E058	9	10
9/8/2000	PU-6.7	E051	9	11
9/8/2000	PUN-0.01	E051A	9	11
9/8/2000	SFAC-0.01	E056	5	2
9/12/2000	LA-5.0	E050	9	10
9/26/2000	PA-0.01	PARG		5
10/12/2000	AC-0.5	E056	5	2
10/12/2000	SFAC-0.01	E056	5	2
10/13/2000	SFAC-0.01	E056	5	2
10/23/2000	CDB-1.9	E230	4	2
10/23/2000	CDB-5.4	E218	4	2
10/23/2000	MO-7.2	E201	4	3
10/23/2000	PA-4.8	E245.9	4	2
10/23/2000	PO-1.8	E267	4	2
10/23/2000	SA-5.6	E124	4	2
10/23/2000	SFAC-0.01	E056	4	3
10/23/2000	UN-0.01	E250.1	4	2
10/23/2000	WA-2.9	E263	4	2
10/23/2000	WA-4.5	E262	4	
10/24/2000	RG at WR Gage	E3268	8	4
10/24/2000	WA-2.9	E263	4	2

2000

Date	Location	Syn	Field Prep F	Field Prep UF
10/27/2000	LA-6.6A	E030	8	11
10/27/2000	LA-6.6B	E030	8	11
10/27/2000	LA-6.6C	E030	8	11
10/28/2000	LA-10.5	E026	6	12
10/28/2000	LA-5.0	E050	6	12
10/28/2000	PA-10.4	E240	6	12
10/28/2000	PA-2.2	E250	6	12
10/28/2000	PU-2.0	E058	6	13
10/28/2000	PUN-0.01	E051A	2	12
10/28/2000	PUN-0.1	E051A	4	
10/28/2000	RG at WR G	E3268	4	2
10/28/2000	SA-5.6	E124		6
10/28/2000	TM-3.1	TM31	6	12
10/28/2000	WA-2.9	E263	6	12
10/28/2000	WA-9.9	E252	6	12
11/2/2000	PA-10.6	E240	5	19

2001

Date	Location	Syn	Field Prep F	Field Prep UF
7/2/2001	LA-5.0	E050	5	52
7/3/2001	LA-5.0	E050		7
7/22/2001	WA-2.9	E263	10	33
7/26/2001	PU-0.3	E060		1
7/26/2001	WA-2.9	E263		6
8/3/2001	WA-2.9	E263	15	47
8/5/2001	PA-10.4	E240	5	23
8/5/2001	PA-4.54	E245.9	10	49
8/11/2001	PU-0.3	E060	15	53
8/16/2001	LA-5.0	E050	15	71
8/16/2001	PU-0.3	E060	10	54
8/17/2001	PU-0.3	E060		2

2002

Date	Location	Syn	Field Prep F	Field Prep UF
6/22/2002	PU-0.3	E060		4
7/14/2002	PA-4.54	E245.9	5	20
7/18/2002	PU-0.3	E060	15	60
7/18/2002	PU-5.5	E055	5	20
7/18/2002	PU-6.7	E051	5	20
7/18/2002	PUN-0.01	E051A	5	22
7/25/2002	PU-5.5	E055	5	20
7/26/2002	PU-0.3	E060	10	44
7/31/2002	GU-0.01	E099	10	40
7/31/2002	SA-8.5	E123	5	19
7/31/2002	SA-9.0	E121	5	25
8/8/2002	PA-10.4	E240	5	20
8/28/2002	CDB-2.01	E230	5	25
9/10/2002	AC-0.01	E056	5	9
9/10/2002	PU-0.3	E060	15	27
9/10/2002	PU-1.5	E060		1
9/10/2002	PU-3.8	E060		1
9/10/2002	PU-5.5	E055	5	14
9/10/2002	PU-6.7	E051		3
10/26/2002	AC-0.01	E056		5
10/26/2002	PU-5.5	E055		6

2003

Date	Location	Syn	Field Prep F	Field Prep UF
8/18/2003	Los Alamos	E030		4
8/23/2003	Los Alamos	E030		8
9/3/2003	Los Alamos	E030		4

Note: AC = Acid Canyon; CDB = Cañada del Buey; GU = Guaje Canyon; LA = Los Alamos Canyon; PA = Pajarito Canyon; PU = Pueblo Canyon; PUN = Pueblo Canyon north fork; SA = Sandia Canyon; WA = Water Canyon, AN = Ancho Canyon. Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table B-4. Summary of USGS Major Water Quality Data for Rio Grande Samples, 2000–2001.

Date	Location	F	UF
2000			
05-Jul-00	Cochiti Reservoir Delta	12	12
05-Jul-00	Rio Grande at Mortandad		19
06-Jul-00	Cochiti Reservoir Site B	12	12
06-Jul-00	Rio Grande at Otowi	12	12
07-Jul-00	Rio Grande near White Rock	12	12
08-Jul-00	Cochiti Reservoir Site A	23	24
11-Jul-00	Rio Grande below Cochiti Dam	12	12
2001			
24-Jul-01	Cochiti Reservoir Delta		24
24-Jul-01	Cochiti Reservoir Site B		13
25-Jul-01	Cochiti Reservoir Site A	12	13
25-Jul-01	Cochiti Reservoir Site B	12	22
26-Jul-01	Rio Grande near White Rock	12	13
27-Jul-01	Rio Grande at Otowi	12	13
30-Jul-01	Rio Grande below Cochiti Dam	12	13
06-Aug-01	Rio Grande below Cochiti Dam	12	13
08-Aug-01	Rio Grande at Otowi	12	13
09-Aug-01	Rio Grande near White Rock	24	23
16-Aug-01	Rio Grande below Cochiti Dam	12	13
25-Sep-01	Rio Grande near White Rock	12	13
26-Sep-01	Rio Grande at Otowi	12	13
26-Sep-01	Rio Grande below Cochiti Dam	23	
26-Sep-01	Rio Grande near White Rock	24	26

Table shows number of filtered (F) and unfiltered (UF) analytic results.

Appendix C. Summary of Samples Collected for Radionuclide Analysis in Storm Runoff, 2000–2003.

Table C-1. Summary of Storm Runoff Samples Collected for Radionuclide analysis in 2000.

Date	Location Name	Syn	Source C	F	UF
06/02/00	DP above Los Alamos Canyon	E040	WQH		51
06/02/00	Los Alamos above DP Canyon	E030	WQH		51
06/02/00	Los Alamos above SR-4	E042	WQH		51
06/03/00	Los Alamos above Ice Rink	E025	WQH	51	51
06/03/00	Los Alamos above SR-4	E042	WQH	51	53
06/28/00	Canon de Valle above SR-501	E253	WQH		54
06/28/00	Indio at SR-4	E264	WQH	88	51
06/28/00	Pajarito above SR-4	E250	WQH	52	54
06/28/00	Pajarito above Starmers	E241	WQH	51	95
06/28/00	Pajarito below SR-501	E240	WQH	51	54
06/28/00	Pajarito near G-1	EPG1	WQH	50	53
06/28/00	Pajarito SR-4 Culvert	ES4C	WQH	53	54
06/28/00	Starmers above Pajarito	E242	WQH	51	54
06/28/00	Water above SR-501	E252	WQH		57
06/28/00	Water at SR-4	E263	WQH		3
06/28/00	Water below SR-4	E265	WQH	89	54
06/29/00	PA-10.6	E240	NMED		43
06/29/00	PA-6.7	E243	NMED	85	
07/09/00	Guaje Canyon at SR-502	EGS4	WQH	51	86
07/09/00	Los Alamos above SR-4	E042	WQH	54	88
07/17/00	Rendija 3rd Crossing	ER3X	WQH	51	57
07/18/00	Los Alamos above Ice Rink	E025	WQH	57	105
07/21/00	LA-5.0	E050	NMED		9
07/25/00	DP below Meadow at TA-21	E039	WQH	1	1
07/29/00	Canada del Buey above SR-4	E230	WQH	1	2
07/29/00	Water below SR-4	E265	WQH	61	116
08/02/00	Pueblo above Hamilton	PU-10162	ER		2
08/09/00	Canada del Buey above SR-4	E230	WQH		61
08/09/00	Potrillo above SR-4	E267	WQH		63
08/12/00	PU-10159	E055	ER		130
08/12/00	Pueblo 2E	PU-10160	ER		42
08/12/00	Water below SR-4	E265	WQH		49
08/18/00	Ancho below SR-4	E275	WQH		2
08/18/00	Canada del Buey above SR-4	E230	WQH	111	68
08/18/00	Water below SR-4	E265	WQH	21	21
08/24/00	PA-6.7	E243	NMED	54	53
08/24/00	Pajarito Retention Pond	EPRP	WQH	70	124
09/08/00	AC-0.5	E056	NMED	45	
09/08/00	GU-0.01	E099	NMED	40	1
09/08/00	Guaje Canyon at SR-502	EGS4	WQH	123	120
09/08/00	PA-10.4	E240	NMED	38	
09/08/00	Pajarito below SR-501	E240	WQH	233	173
09/08/00	PU-10159	E055	ER		26
09/08/00	PU-2.0	E058	NMED	53	
09/08/00	PU-6.7	E051	NMED	53	
09/08/00	Pueblo above Hamilton	PU-10162	ER		52
09/08/00	PUN-0.01	E051A	NMED	53	
09/08/00	SFAC-0.01	E056	NMED	45	
09/12/00	LA-5.0	E050	NMED	49	
09/12/00	Los Alamos above Ice Rink	E025	WQH	129	122
09/26/00	PA-0.01	PARG	NMED		3
10/11/00	Canada del Buey above SR-4	E230	WQH		1
10/12/00	AC-0.5	E056	NMED	42	
10/12/00	DP above Los Alamos Canyon	E040	WQH		70
10/12/00	LA-10036	E030	ER	39	39
10/12/00	LA-10037	E050	ER	39	39
10/12/00	LA-10038	E042	ER	39	39
10/12/00	Los Alamos above SR-4	E042	WQH		70
10/12/00	PU-10159	E055	ER	80	80
10/12/00	Pueblo 2E	PU-10160	ER	120	120
10/12/00	SFAC-0.01	E056	NMED	42	
10/13/00	SFAC-0.01	E056	NMED	42	

Date	Location Name	Syn	Source	F	UF
10/23/00	Ancho below SR-4	E275	WQH		1
10/23/00	Canada del Buey above SR-4	E230	WQH		72
10/23/00	Canada del Buey near TA-46	E218	WQH		1
10/23/00	Canon de Valle above SR-501	E253	WQH	71	75
10/23/00	CDB-1.9	E230	NMED	24	
10/23/00	CDB-5.4	E218	NMED	23	
10/23/00	DP above Los Alamos Canyon	E040	WQH		1
10/23/00	DP below Meadow at TA-21	E039	WQH		2
10/23/00	LA-10037	E050	ER	78	78
10/23/00	Los Alamos above SR-4	E042	WQH	72	72
10/23/00	MO-7.2	E201	NMED	23	
10/23/00	PA-4.8	E245.9	NMED	23	
10/23/00	Pajarito below SR-501	E240	WQH	76	127
10/23/00	PO-1.8	E267	NMED	21	
10/23/00	Potrillo above SR-4	E267	WQH	74	72
10/23/00	PU-10159	E055	ER	80	80
10/23/00	Pueblo 2E	PU-1016(	ER	80	80
10/23/00	Pueblo above SR-502	E060	WQH	1	74
10/23/00	SA-5.6	E124	NMED	22	
10/23/00	SFAC-0.01	E056	NMED	49	
10/23/00	Starmer's Gulch above SR-501	E240.1	WQH	78	72
10/23/00	Threemile Canyon	18-10109	ER		74
10/23/00	Twomile above SR-501	E243.1	WQH	74	72
10/23/00	UN-0.01	E250.1	NMED	22	
10/23/00	WA-2.9	E263	NMED	22	
10/23/00	Water above SR-501	E252	WQH	71	74
10/23/00	Water below SR-4	E265	WQH	1	75
10/24/00	Los Alamos above DP Canyon	E030	WQH		1
10/24/00	Pajarito above SR-4	E250	WQH	73	79
10/24/00	RG at WR Gage	E3268	NMED	8	
10/24/00	WA-2.9	E263	NMED	22	
10/27/00	DP above Los Alamos Canyon	E040	WQH	77	2
10/27/00	DP below Meadow at TA-21	E039	WQH	2	1
10/27/00	DP-0.01	E040	NMED	2	1
10/27/00	LA-10037	E050	ER	39	39
10/27/00	LA-10038	E042	ER	39	39
10/27/00	LA-6.6A	E030	NMED	1	
10/27/00	LA-6.6B	E030	NMED	1	
10/27/00	LA-6.6C	E030	NMED	1	
10/27/00	Los Alamos above SR-4	E042	WQH	1	72
10/27/00	Pajarito above SR-4	E250	WQH	72	72
10/27/00	Pueblo above SR-502	E060	WQH	70	71
10/27/00	Water at SR-4	E263	WQH	1	3
10/27/00	Water below SR-4	E265	WQH	71	72
10/28/00	Ancho below SR-4	E275	WQH		1
10/28/00	Canada del Buey above SR-4	E230	WQH	1	1
10/28/00	LA-10.5	E026	NMED	31	
10/28/00	LA-10037	E050	ER	39	39
10/28/00	LA-5.0	E050	NMED	18	
10/28/00	PA-10.4	E240	NMED	20	
10/28/00	PA-2.2	E250	NMED	21	
10/28/00	PU-2.0	E058	NMED	19	
10/28/00	PUN-0.01	E051A	NMED	13	
10/28/00	PUN-0.1	E051A	NMED	9	
10/28/00	RG at WR Gage	E3268	NMED	7	
10/28/00	TM-3.1	TM31	NMED	22	
10/28/00	WA-2.9	E263	NMED	22	
10/28/00	WA-9.9	E252	NMED	20	
11/02/00	LA-10037	E050	ER	39	39
11/02/00	LA-10039	E042	ER	39	
11/02/00	LA-10040	E026	ER	39	39
11/02/00	PA-10.6	E240	NMED		1

Note: AC = Acid Canyon; CDB = Cañada del Buey; GU = Guaje Canyon; LA = Los Alamos Canyon; PA = Pajarito Canyon; PU = Pueblo Canyon; PUN = Pueblo Canyon north fork; SA = Sandia Canyon; WA = Water Canyon, AN = Ancho Canyon. Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table C-2. Summary of Storm Runoff Samples Collected for Radionuclide Analysis in 2001.

Date	Location Name	Syn	Source O	F	UF
5/13/2001	DP above Los Alamos Canyon	E040	WQH		77
5/13/2001	DP above TA-21	E038	WQH		125
5/28/2001	DP above Los Alamos Canyon	E040	WQH	1	1
5/28/2001	DP above TA-21	E038	WQH	1	2
6/27/2001	DP above Los Alamos Canyon	E040	WQH	71	72
6/27/2001	DP above TA-21	E038	WQH	1	1
6/27/2001	DP below Meadow at TA-21	E039	WQH	1	1
6/27/2001	Pajarito above SR-4	E250	WQH	71	72
7/2/2001	DP above TA-21	E038	WQH	2	71
7/2/2001	DP below Meadow at TA-21	E039	WQH	1	1
7/2/2001	LA-5.0	E050	NMED	87	133
7/2/2001	Los Alamos above DP Canyon	E030	WQH	71	73
7/2/2001	Los Alamos above SR-4	E042	WQH	1	77
7/2/2001	Los Alamos below Ice Rink	E026	WQH	140	144
7/2/2001	Pajarito above TA-18	E245	WQH	71	72
7/2/2001	Pueblo above SR-502	E060	WQH	71	71
7/2/2001	Rendija above Guaje	E090	WQH	1	71
7/13/2001	Los Alamos below Ice Rink	E026	WQH	142	143
7/14/2001	Los Alamos above DP Canyon	E030	WQH	71	72
7/14/2001	Los Alamos above SR-4	E042	WQH	1	73
7/22/2001	Canon de Valle above SR-501	E253	WQH	69	73
7/22/2001	WA-2.9	E263	NMED	128	263
7/22/2001	Water above SR-501	E252	WQH	1	2
7/26/2001	Canon de Valle above SR-501	E253	WQH	1	1
7/26/2001	Los Alamos above DP Canyon	E030	WQH	130	135
7/26/2001	Los Alamos above SR-4	E042	WQH		1
7/26/2001	Los Alamos below LA Weir	E050	WQH	1	1
7/26/2001	Pajarito above Starmers	E241	WQH	70	70
7/26/2001	Pajarito below SR-501	E240	WQH		70
7/26/2001	Pueblo above SR-502	E060	WQH	70	70
7/26/2001	Water at SR-4	E263	WQH	1	1
7/26/2001	Water below MDA AB	E262.5	WQH	71	71
8/1/2001	DP above TA-21	E038	WQH	1	1
8/1/2001	Los Alamos above SR-4	E042	WQH	1	1
8/3/2001	Acid above Pueblo	E056	WQH	1	70
8/3/2001	S Site Canyon above Water	E261	WQH	1	1
8/3/2001	WA-2.9	E263	NMED	142	308
8/3/2001	Water at SR-4	E263	WQH	1	73
8/3/2001	Water below MDA AB	E262.5	WQH	72	72
8/3/2001	Water below SR-4	E265	WQH	72	74
8/4/2001	DP above Los Alamos Canyon	E040	WQH	1	1
8/4/2001	DP above TA-21	E038	WQH	1	2
8/4/2001	Los Alamos above SR-4	E042	WQH	72	72

Date	Location Name	Syn	Source O	F	UF
8/4/2001	Pueblo 2E	PU-10160	ER		52
8/4/2001	Pueblo above SR-502	E060	WQH		62
8/5/2001	Canon de Valle above Water	E262	WQH	1	71
8/5/2001	Los Alamos above DP Canyon	E030	WQH	72	72
8/5/2001	PA-10.4	E240	NMED	45	90
8/5/2001	PA-4.54	E245.9	NMED	90	186
8/5/2001	Pajarito above Starmers	E241	WQH	1	72
8/5/2001	Pajarito above TA-18	E245	WQH	1	1
8/5/2001	Sandia below Wetlands	E123	WQH	1	71
8/6/2001	Pajarito above SR-4	E250	WQH	133	86
8/8/2001	Guaje above Rendija	E089	WQH	1	71
8/8/2001	Los Alamos above SR-4	E042	WQH	1	
8/8/2001	Water below MDA AB	E262.5	WQH	71	72
8/9/2001	Canon de Valle above Water	E262	WQH	71	72
8/9/2001	Guaje above Rendija	E089	WQH	70	72
8/9/2001	Los Alamos above DP Canyon	E030	WQH	80	132
8/9/2001	Los Alamos above SR-4	E042	WQH		1
8/9/2001	Los Alamos below Ice Rink	E026	WQH	71	72
8/9/2001	Los Alamos below LA Weir	E050	WQH	1	2
8/9/2001	Pajarito above SR-4	E250	WQH	75	128
8/9/2001	Pajarito below SR-501	E240	WQH	1	1
8/9/2001	PU-10159	E055	ER		130
8/9/2001	Pueblo above Hamilton	PU-10162	ER		104
8/9/2001	Pueblo above SR-502	E060	WQH	71	72
8/9/2001	Water at SR-4	E263	WQH	71	72
8/9/2001	Water below SR-4	E265	WQH	1	71
8/11/2001	Guaje above Rendija	E089	WQH	71	73
8/11/2001	Pajarito above Starmers	E241	WQH	1	71
8/11/2001	PU-0.3	E060	NMED	173	316
8/11/2001	Pueblo above SR-502	E060	WQH	71	72
8/13/2001	Pueblo above Acid	E055	WQH		70
8/14/2001	Guaje above Rendija	E089	WQH	76	137
8/14/2001	Pueblo above Hamilton	PU-10162	ER		52
8/16/2001	DP above TA-21	E038	WQH	1	2
8/16/2001	Guaje above Rendija	E089	WQH	71	72
8/16/2001	LA-5.0	E050	NMED	142	270
8/16/2001	Los Alamos above DP Canyon	E030	WQH	73	141
8/16/2001	Los Alamos above SR-4	E042	WQH	72	73
8/16/2001	Los Alamos below LA Weir	E050	WQH	1	1
8/16/2001	Pajarito above SR-4	E250	WQH	73	72
8/16/2001	PU-0.3	E060	NMED	90	186
8/16/2001	Pueblo 2E	PU-10160	ER		130
8/16/2001	Pueblo above SR-502	E060	WQH	71	72

Note: AC = Acid Canyon; CDB = Cañada del Buey; GU = Guaje Canyon; LA = Los Alamos Canyon; PA = Pajarito Canyon; PU = Pueblo Canyon; PUN = Pueblo Canyon north fork; SA = Sandia Canyon; WA = Water Canyon, AN = Ancho Canyon. Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table C-3. Summary of Storm Runoff Samples Collected for Radionuclide Analysis, 2002–2003.

Date	Location Name	Syn	Source O	F	UF
6/21/2002	Los Alamos below Ice Rink	E026	WQH		1
6/21/2002	Pajarito above Threemile	E245.5	WQH	130	84
6/22/2002	Guaje above Rendija	E089	WQH	72	74
6/22/2002	PU-0.3	E060	NMED		51
6/22/2002	Water at SR-4	E263	WQH	72	73
7/4/2002	Guaje above Rendija	E089	WQH	73	86
7/4/2002	Guaje at SR-502	E099	WQH	76	73
7/4/2002	Sandia below Wetlands	E123	WQH	1	1
7/14/2002	La Delfe above Pajarito	E242.5	WQH		2
7/14/2002	PA-4.54	E245.9	NMED	2	94
7/14/2002	Sandia below Wetlands	E123	WQH		1
7/14/2002	Water at SR-4	E263	WQH	124	2
7/18/2002	PU-0.3	E060	NMED	6	322
7/18/2002	PU-5.5	E055	NMED	2	146
7/18/2002	PU-6.7	E051	NMED	2	132
7/18/2002	PUN-0.01	E051A	NMED	2	99
7/22/2002	Sandia below Wetlands	E123	WQH	1	1
7/23/2002	DP above TA-21	E038	WQH	81	1
7/25/2002	Canon de Valle above SR-501	E253	WQH	1	2
7/25/2002	Pajarito above Starmers	E241	WQH		1
7/25/2002	PU-5.5	E055	NMED	2	100
7/26/2002	PU-0.3	E060	NMED	5	278
7/31/2002	GU-0.01	E099	NMED	4	239
7/31/2002	SA-8.5	E123	NMED	2	48
7/31/2002	SA-9.0	E121	NMED	2	87
8/7/2002	Sandia below Wetlands	E123	WQH	1	2
8/8/2002	DP above TA-21	E038	WQH	1	2
8/8/2002	PA-10.4	E240	NMED	2	101
8/8/2002	Pajarito above Starmers	E241	WQH	1	1
8/28/2002	Canada del Buey above SR-4	E230	WQH	72	3
8/28/2002	CDB-2.01	E230	NMED	2	104
8/28/2002	Water at SR-4	E263	WQH	1	
9/9/2002	Canada del Buey above SR-4	E230	WQH	1	1
9/9/2002	Pajarito above Starmers	E241	WQH	71	92
9/10/2002	AC-0.01	E056	NMED	2	49
9/10/2002	Guaje above Rendija	E089	WQH	72	83
9/10/2002	Pajarito above Threemile	E245.5	WQH	1	2
9/10/2002	PU-0.3	E060	NMED	6	153
9/10/2002	PU-1.5	E060	NMED		4
9/10/2002	PU-3.8	E060	NMED		4
9/10/2002	PU-5.5	E055	NMED	2	52
9/10/2002	PU-6.7	E051	NMED	1	52
9/10/2002	Sandia above Firing Range	E124	WQH	1	3
10/23/2002	Guaje above Rendija	E089	WQH	74	135
10/26/2002	AC-0.01	E056	NMED		12
10/26/2002	PU-5.5	E055	NMED		28

Date	Location Name	Syn	Source O	F	UF
5/25/2003	Canada del Buey above SR-4	E230	WQH		139
5/30/2003	PU-02-20848	E060	ER	2	
5/30/2003	PU-02-20850	E060	ER	2	
5/30/2003	PU-02-20851	E060	ER	4	
5/30/2003	PU-02-20852	E060	ER	2	
5/30/2003	PU-02-20854	E060	ER	2	
6/1/2003	Guaje above Rendija	E089	WQH	73	1
7/26/2003	Sandia below Wetlands	E123	WQH		1
8/2/2003	DP above TA-21	E038	WQH		1
8/7/2003	Acid above Pueblo	E056	WQH		73
8/11/2003	DP above TA-21	E038	WQH		1
8/11/2003	DP below Meadow at TA-21	E039	WQH		1
8/11/2003	Pajarito above Starmers	E241	WQH		77
8/16/2003	DP above TA-21	E038	WQH	80	73
8/18/2003	Los Alamos above DP Canyon	E030	NMED		6
8/22/2003	Pueblo above SR-502	E060	WQH	76	131
8/23/2003	DP below Meadow at TA-21	E039	WQH		1
8/23/2003	Guaje above Rendija	E089	WQH		72
8/23/2003	Guaje at SR-502	E099	WQH		72
8/23/2003	Los Alamos above DP Canyon	E030	NMED		67
8/23/2003	Los Alamos above DP Canyon	E030	WQH	75	76
8/23/2003	Los Alamos above SR-4	E042	WQH		1
8/23/2003	Pajarito above Starmers	E241	WQH		72
8/23/2003	Sandia above Firing Range	E124	WQH		72
8/23/2003	Sandia below Wetlands	E123	WQH	72	75
8/25/2003	Canada del Buey above SR-4	E230	WQH	73	1
8/25/2003	Potrillo above SR-4	E267	WQH		1
8/25/2003	Rio Grande at Otowi Bridge	OGR	WQH		80
8/25/2003	Rio Grande below Ancho	AGR	WQH		73
8/26/2003	Pueblo above Acid	E055	WQH		1
8/26/2003	Pueblo above SR-502	E060	WQH	73	74
8/29/2003	Sandia below Wetlands	E123	WQH		1
8/30/2003	Pueblo above Acid	E055	WQH	73	76
9/3/2003	Guaje above Rendija	E089	WQH	72	1
9/3/2003	Los Alamos above DP Canyon	E030	NMED		6
9/3/2003	Pueblo above Acid	E055	WQH	77	76
9/3/2003	Sandia below Wetlands	E123	WQH	75	73
9/6/2003	Acid above Pueblo	E056	WQH		72
9/6/2003	Los Alamos below Ice Rink	E026	WQH		1
9/6/2003	Pajarito above Threemile	E2455	WQH	76	74
9/6/2003	Pueblo above Acid	E055	WQH	74	74
9/6/2003	Pueblo above SR-502	E060	WQH	72	74
9/6/2003	Rio Grande at Otowi Bridge	OGR	WQH	136	75
9/6/2003	Rio Grande near White Rock	WGR	WQH	73	78

Note: AC = Acid Canyon; CDB = Cañada del Buey; GU = Guaje Canyon; LA = Los Alamos Canyon; PA = Pajarito Canyon; PU = Pueblo Canyon; PUN = Pueblo Canyon north fork; SA = Sandia Canyon; WA = Water Canyon, AN = Ancho Canyon. Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table C-4. Summary of Samples Collected by USGS for Radionuclide Analysis in Rio Grande, 2000–2001.

Sample Date	Location Name	F	UF	Sample Date	Location Name	F	UF
2000				2001			
07/05/00	Cochiti Lake Delta	13	12	07/24/01	Cochiti Lake Delta	19	11
07/05/00	Rio Grande at Mortandad	11	7	07/24/01	Cochiti Lake Site B	11	11
07/06/00	Cochiti Lake Site B	11	5	07/25/01	Cochiti Lake Site A	4	25
07/06/00	Rio Grande at Otowi	12	12	07/25/01	Cochiti Lake Site B	18	22
07/07/00	Rio Grande near White Rock	12	13	07/26/01	Rio Grande near White Rock	12	8
07/08/00	Cochiti Lake Site A	12	15	07/27/01	Rio Grande at Otowi	12	13
07/11/00	Rio Grande below Cochiti Dam	11	13	07/30/01	Rio Grande below Cochiti Dam	6	12
				08/06/01	Rio Grande below Cochiti Dam	1	12
				08/08/01	Rio Grande at Otowi	6	12
				08/09/01	Rio Grande near White Rock	24	28
				08/16/01	Rio Grande below Cochiti Dam	23	12
				09/25/01	Rio Grande near White Rock	1	1
				09/26/01	Rio Grande at Otowi	13	12
				09/26/01	Rio Grande below Cochiti Dam	22	
				09/26/01	Rio Grande near White Rock	35	35

Table shows number of filtered (F) and unfiltered (UF) analytic results.

Appendix D. Summary of Samples Collected for Minor Constituent Analysis in Major Canyons, 2000–2003.

Table D-1. Summary of WQH Samples Collected for Minor Constituent Analyses in Storm Runoff, 2000–2001.

Date	Location Name	F	UF	Date	Location Name	F	UF
2000				2001			
06/02/00	DP above Los Alamos Canyon		30	05/13/01	DP above Los Alamos Canyon		23
06/02/00	Los Alamos above DP Canyon		30	05/28/01	DP above Los Alamos Canyon	23	23
06/02/00	Los Alamos above SR-4		30	05/28/01	DP above TA-21	23	46
06/03/00	Los Alamos above Ice Rink	30	30	06/27/01	DP above Los Alamos Canyon	23	23
06/03/00	Los Alamos above SR-4	30	30	06/27/01	DP above TA-21	23	23
06/28/00	Canon de Valle above SR-501		24	06/27/01	DP below Meadow at TA-21	23	23
06/28/00	Indio at SR-4		29	06/27/01	Pajarito above SR-4	23	23
06/28/00	Pajarito above SR-4	30	25	06/27/01	Sandia trib at Heavy Equipment	46	27
06/28/00	Pajarito above Starmers	30	25	07/02/01	DP above TA-21	27	23
06/28/00	Pajarito below SR-501	30	24	07/02/01	DP below Meadow at TA-21	23	23
06/28/00	Pajarito SR-4 Culvert	30	24	07/02/01	Los Alamos above DP Canyon	23	23
06/28/00	Starmers above Pajarito	30	24	07/02/01	Los Alamos above SR-4	23	23
06/28/00	Water above SR-501		25	07/02/01	Los Alamos below Ice Rink	23	46
06/28/00	Water below SR-4	30	24	07/02/01	Pajarito above TA-18	23	23
07/09/00	Guaje Canyon at SR-502	30	31	07/02/01	Pueblo above SR-502	23	
07/09/00	Los Alamos above SR-4	31	55	07/02/01	Rendija above Guaje	42	23
07/17/00	Rendija 3rd Crossing	31	48	07/13/01	Los Alamos below Ice Rink	46	46
07/17/00	Sandia left fork at Asphalt Plant		31	07/14/01	Los Alamos above DP Canyon	23	23
07/18/00	Los Alamos above Ice Rink	31	38	07/14/01	Los Alamos above SR-4	23	23
07/25/00	DP below Meadow at TA-21	24	25	07/22/01	Water above SR-501	23	41
07/29/00	Canada del Buey above SR-4	24	25	07/26/01	Canon de Valle above SR-501	23	23
07/29/00	Water below SR-4		49	07/26/01	Los Alamos above DP Canyon	46	46
08/09/00	Potrillo above SR-4		25	07/26/01	Los Alamos above SR-4		23
08/12/00	Water below SR-4		25	07/26/01	Los Alamos below LA Weir	23	23
08/18/00	Ancho above north fork Ancho		25	07/26/01	Sandia trib at Heavy Equipment	23	23
08/18/00	Ancho below SR-4		49	07/26/01	Water at SR-4	6	40
08/18/00	Canada del Buey above SR-4	23	25	07/26/01	Water below MDA AB	23	23
08/18/00	Water below SR-4	23	43	08/01/01	DP above TA-21	23	23
08/24/00	Pajarito Retention Pond	24	25	08/01/01	Los Alamos above SR-4	23	23
08/31/00	Upper Los Alamos Reservoir	23	25	08/01/01	Sandia trib at Heavy Equipment	23	23
09/08/00	Guaje Canyon at SR-502	23	25	08/03/01	Acid above Pueblo	23	
09/08/00	Pajarito below SR-501	23	49	08/03/01	S Site Canyon above Water	23	23
09/12/00	Los Alamos above Ice Rink	23	25	08/03/01	Water at SR-4	23	46
10/11/00	Canada del Buey above SR-4		25	08/03/01	Water below MDA AB	23	23
10/11/00	Sandia left fork at Asphalt Plant	23	48	08/03/01	Water below SR-4	23	46
10/23/00	Ancho below SR-4		25	08/04/01	DP above Los Alamos Canyon	23	23
10/23/00	Canada del Buey above SR-4		25	08/04/01	DP above TA-21	23	23
10/23/00	Canada del Buey near TA-46		24	08/04/01	Los Alamos above SR-4	23	23
10/23/00	Canon de Valle above SR-501	23	25	08/05/01	Canon de Valle above Water	23	23
10/23/00	DP above Los Alamos Canyon		23	08/05/01	Los Alamos above DP Canyon	23	23
10/23/00	DP below Meadow at TA-21		23	08/05/01	Pajarito above Starmers	23	23
10/23/00	Los Alamos above SR-4	23	25	08/05/01	Pajarito above TA-18	23	23
10/23/00	Pajarito below SR-501	23	49	08/05/01	Sandia below Wetlands	23	23
10/23/00	Potrillo above SR-4	23	25	08/06/01	Pajarito above SR-4	46	46
10/23/00	Pueblo above SR-502	23	24	08/08/01	Guaje above Rendija	23	23
10/23/00	Starmer's Gulch above SR-501	23	25	08/08/01	Los Alamos above SR-4	23	
10/23/00	Twomile above SR-501	23	25	08/08/01	Water below MDA AB	23	23
10/23/00	Water above SR-501	23	25	08/09/01	Canon de Valle above Water	23	23
10/23/00	Water below SR-4	23	49	08/09/01	Guaje above Rendija		23
10/24/00	Los Alamos above DP Canyon		24	08/09/01	Los Alamos above DP Canyon	46	46
10/24/00	Pajarito above SR-4	23	24	08/09/01	Los Alamos above SR-4		23
10/27/00	DP above Los Alamos Canyon	23	23	08/09/01	Los Alamos below Ice Rink	23	23
10/27/00	DP below Meadow at TA-21	46	23	08/09/01	Los Alamos below LA Weir	23	23
10/27/00	Los Alamos above SR-4	23		08/09/01	Pajarito above SR-4	46	46
10/27/00	Pajarito above SR-4	23	25	08/09/01	Pajarito below SR-501	23	23
10/27/00	Water at SR-4	23	48	08/09/01	Pueblo above SR-502	23	23
10/27/00	Water below SR-4	23	26	08/09/01	Water at SR-4	23	23
10/28/00	Ancho above north fork Ancho		24	08/09/01	Water below SR-4	23	23
10/28/00	Ancho below SR-4		24	08/11/01	Guaje above Rendija	23	23
10/28/00	Canada del Buey above SR-4	23	24	08/11/01	Pajarito above Starmers	23	23
				08/11/01	Potrillo tributary Study Area	23	23
				08/11/01	Pueblo above SR-502	23	23
				08/12/01	Ancho Spring trib below SR-4	23	23
				08/14/01	Guaje above Rendija	48	44
				08/16/01	DP above TA-21	23	23
				08/16/01	Los Alamos above DP Canyon	46	46
				08/16/01	Los Alamos above SR-4	46	46
				08/16/01	Los Alamos below LA Weir	23	23
				08/16/01	Pajarito above SR-4	23	23
				08/16/01	Pueblo above SR-502	23	23
				08/30/01	Potrillo tributary Study Area	23	41

Note: Table shows number of filtered (F) and unfiltered (UF) analytic reusults.

Table D-2. Summary of WQH Samples Collected for Minor Constituent Analyses in Storm Runoff, 2002–2003.

Date	Location Name	F	UF	Date	Location Name	F	UF
2002				2003			
06/04/02	Twomile tributary at TA-3		9	05/24/03	Acid above Pueblo		6
06/21/02	DP above TA-21		1	05/25/03	Canada del Buey above SR-4	28	23
06/21/02	DP below Meadow at TA-21		6	05/26/03	Ancho below SR-4		23
06/21/02	La Delfe above Pajarito		6	05/26/03	Canada del Buey near MDA G		11
06/21/02	Los Alamos above DP Canyon		5	05/26/03	Potrillo above SR-4		6
06/21/02	Mortandad below Effluent Canyon		6	05/26/03	Water below SR-4		23
06/21/02	Pajarito above Threemile	41	23	06/01/03	Guaje above Rendija	23	23
06/21/02	Pajarito above Twomile		6	06/17/03	DP above TA-21	45	23
06/21/02	Pueblo above Acid		6	06/17/03	Guaje at SR-502	23	23
06/21/02	Sandia right fork at Power Plant		7	07/26/03	Sandia below Wetlands	23	45
06/21/02	Sandia Tributary below Sigma		2	08/07/03	Sandia below Wetlands	28	23
06/21/02	Starmers above Pajarito		6	08/11/03	Acid above Pueblo		7
06/21/02	Twomile tributary at TA-3		9	08/11/03	DP above TA-21	41	1
06/21/02	Water below MDA AB		6	08/11/03	DP below Meadow at TA-21	23	1
06/22/02	Guaje above Rendija	23	1	08/11/03	Pueblo above Acid	22	22
06/22/02	Los Alamos above SR-4		6	08/16/03	DP above TA-21	23	23
06/22/02	Pajarito above SR-4		7	08/19/03	Potrillo above SR-4		7
06/22/02	Pueblo above SR-502		12	08/22/03	Pueblo above SR-502	23	46
06/22/02	Sandia above Firing Range		6	08/23/03	Acid above Pueblo	44	22
06/22/02	Water at SR-4	23	23	08/23/03	Canada del Buey near TA-46	22	34
07/04/02	Guaje above Rendija	41	23	08/23/03	DP below Meadow at TA-21	23	23
07/04/02	Guaje at SR-502	23		08/23/03	Guaje at SR-502	22	22
07/04/02	Sandia below Wetlands	6	23	08/23/03	Los Alamos above DP Canyon	22	22
07/04/02	Sandia right fork at Power Plant		7	08/23/03	Los Alamos above SR-4	1	23
07/04/02	Ten Site at TA-50		6	08/23/03	Los Alamos Canyon near Otowi Bridge		22
07/04/02	Twomile tributary at TA-3		11	08/23/03	Pajarito above Starmers	22	22
07/12/02	Ten Site below MDA C		6	08/23/03	Sandia above Firing Range	22	22
07/14/02	DP above TA-21		6	08/23/03	Sandia below Wetlands	23	23
07/14/02	La Delfe above Pajarito		6	08/23/03	Threemile above Pajarito		6
07/14/02	Sandia Tributary below Sigma		11	08/25/03	Canada del Buey above SR-4	23	23
07/14/02	Twomile tributary at TA-3	23	24	08/25/03	Canada del Buey near MDA G		11
07/14/02	Water below MDA AB		6	08/25/03	Potrillo above SR-4	23	23
07/18/02	Twomile tributary at TA-3	41	41	08/26/03	Pueblo above Acid	23	23
07/22/02	Sandia below Wetlands	23	23	08/26/03	Pueblo above SR-502	23	23
07/23/02	DP below Meadow at TA-21		6	08/29/03	Sandia below Wetlands	23	23
07/23/02	Sandia right fork at Power Plant	27	23	08/30/03	Pueblo above Acid	46	23
07/25/02	Canon de Valle above SR-501	23	23	09/03/03	Acid above Pueblo	2	1
07/25/02	Twomile tributary at TA-3	23	23	09/03/03	Guaje above Rendija	23	23
07/26/02	Potrillo tributary Study Area	23	46	09/03/03	Pueblo above Acid	28	23
07/31/02	Rendija above Guaje		6	09/06/03	Acid above Pueblo	44	22
08/07/02	Los Alamos above DP Canyon		6	09/06/03	Los Alamos above SR-4	22	22
08/07/02	Sandia above Firing Range		5	09/06/03	Los Alamos below Ice Rink	23	24
08/07/02	Sandia below Wetlands	23	23	09/06/03	Pajarito above Threemile	22	22
08/07/02	Twomile tributary at TA-3	48	23	09/06/03	Pueblo above Acid	23	23
08/08/02	DP above TA-21	23	23	09/06/03	Pueblo above SR-502	23	23
08/08/02	Pajarito above Starmers	23	23	09/06/03	Pueblo above SR-502	23	23
08/20/02	Sandia left fork at Asphalt Plant		9				
08/28/02	Canada del Buey above SR-4	23	23				
08/28/02	Potrillo tributary Study Area	23	23				
08/28/02	Sandia left fork at Asphalt Plant	23	23				
08/28/02	Water at SR-4		22				
09/04/02	Canon de Valle trib at Burn Grounds		6				
09/04/02	Sandia left fork at Asphalt Plant	24	23				
09/07/02	Sandia left fork at Asphalt Plant	23	23				
09/09/02	Canada del Buey above SR-4	23	22				
09/10/02	Guaje above Rendija	23	41				
09/10/02	Mortandad below Effluent Canyon	23	49				
09/10/02	Pajarito above Threemile	23	24				
09/10/02	Sandia above Firing Range	23	27				
09/10/02	Sandia left fork at Asphalt Plant	1					
09/28/02	Potrillo tributary Study Area	23	23				
10/01/02	Sandia left fork at Asphalt Plant		9				
10/22/02	Sandia left fork at Asphalt Plant	23	23				
10/23/02	Potrillo tributary Study Area	42	27				
10/23/02	Ten Site at TA-50		7				
10/23/02	Ten Site below MDA C		6				
10/23/02	Twomile tributary at TA-3		9				

Table D-3. Summary of NMED Samples Collected for Minor Constituent Analyses in Storm Runoff, 2000–2003.

Date	Location Name	F	UF
06/29/00	PA-10.6	21	19
06/29/00	PA-6.7	42	38
07/21/00	LA-5.0	19	21
08/14/00	WA-2.9		19
08/18/00	CDB-1.9		19
08/24/00	PA-6.7	48	48
09/08/00	AC-0.5	18	2
09/08/00	GU-0.01	19	2
09/08/00	PA-10.4	19	
09/08/00	PU-2.0	24	2
09/08/00	PU-6.7	24	2
09/08/00	PUN-0.01	25	2
09/08/00	SFAC-0.01	18	2
09/12/00	LA-5.0	25	2
10/12/00	AC-0.5	17	2
10/12/00	SFAC-0.01	17	2
10/13/00	SFAC-0.01	17	2
10/23/00	CDB-1.9	19	
10/23/00	CDB-5.4	19	
10/23/00	MO-7.2	18	
10/23/00	PA-4.8	19	
10/23/00	PO-1.8	19	
10/23/00	SA-5.6	18	
10/23/00	SFAC-0.01	18	2
10/23/00	UN-0.01	19	
10/23/00	WA-2.9	19	
10/23/00	WA-4.5	18	
10/24/00	RG at WR Gage	36	4
10/24/00	WA-2.9	19	
10/27/00	LA-6.6A	24	
10/27/00	LA-6.6B	24	
10/27/00	LA-6.6C	24	
10/28/00	LA-10.5	19	
10/28/00	LA-5.0	18	
10/28/00	PA-10.4	19	
10/28/00	PA-2.2	19	
10/28/00	PU-2.0	18	
10/28/00	PUN-0.1	18	
10/28/00	RG at WR Gage	18	
10/28/00	TM-3.1	19	
10/28/00	WA-2.9	19	
10/28/00	WA-9.9	18	
11/02/00	PA-10.6	1	23

Date	Location Name	F	UF
07/02/01	LA-5.0	22	43
07/22/01	WA-2.9	42	42
08/03/01	WA-2.9	66	66
08/05/01	PA-10.4	22	22
08/05/01	PA-4.54	44	44
08/11/01	PU-0.3	66	66
08/16/01	LA-5.0	66	87
08/16/01	PU-0.3	44	44

Date	Location Name	F	UF
07/14/02	PA-4.54	23	47
07/18/02	PU-0.3	69	141
07/18/02	PU-5.5	23	47
07/18/02	PU-6.7	23	47
07/18/02	PUN-0.01	23	47
07/25/02	PU-5.5	23	47
07/26/02	PU-0.3	46	94
07/31/02	GU-0.01	47	94
07/31/02	SA-8.5	23	47
07/31/02	SA-9.0	23	68
08/08/02	PA-10.4	23	47
08/28/02	CDB-2.01	23	70
09/10/02	AC-0.01	23	23
09/10/02	PU-0.3	69	69
09/10/02	PU-5.5	23	46

Date	Location Name	F	UF
08/18/03	Los Alamos above DP Canyon		19
08/23/03	Los Alamos above DP Canyon		38
09/03/03	Los Alamos above DP Canyon		19

Note: AC = Acid Canyon; CDB = Cañada del Buey; GU = Guaje Canyon; LA = Los Alamos Canyon; PA = Pajarito Canyon; PU = Pueblo Canyon; PUN = Pueblo Canyon north fork; SA = Sandia Canyon; WA = Water Canyon, AN = Ancho Canyon. Table shows number of filtered (F) and unfiltered (UF) analytic results.

Table D-4. Summary of USGS Samples Collected for Minor Constituent Analyses in Rio Grande Surface Water Samples, 2000–2001.

Sample Date	Location Name	F	UF
2000			
7/5/2000	Cochiti Lake Delta	23	24
7/5/2000	Rio Grande at Mortandad		36
7/6/2000	Cochiti Lake Site B	23	23
7/6/2000	Rio Grande at Otowi	23	23
7/7/2000	Rio Grande near White Rock	23	23
7/8/2000	Cochiti Lake Site A	45	45
7/11/2000	Rio Grande below Cochiti Dam	23	23
2001			
7/24/2001	Cochiti Lake Delta		36
7/24/2001	Cochiti Lake Site B		22
7/25/2001	Cochiti Lake Site A	23	23
7/25/2001	Cochiti Lake Site B	23	36
7/26/2001	Rio Grande near White Rock	23	22
7/27/2001	Rio Grande at Otowi	23	23
7/30/2001	Rio Grande below Cochiti Dam	23	23
8/6/2001	Rio Grande below Cochiti Dam	23	23
8/8/2001	Rio Grande at Otowi	23	23
8/9/2001	Rio Grande near White Rock	46	42
8/16/2001	Rio Grande below Cochiti Dam	23	23
9/25/2001	Rio Grande near White Rock	23	23
9/26/2001	Rio Grande at Otowi	23	23
9/26/2001	Rio Grande below Cochiti Dam	34	
9/26/2001	Rio Grande near White Rock	46	46

Note: Table shows number of filtered (F) and unfiltered (UF) analytic results.

Appendix E. Summary of Organic Chemical Detections in Waters and Sediments

Table E-1. Organic Compounds Detected in Surface Waters of the Pajarito Plateau and the Rio Grande.

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Min.	Avg.	Max.	Unit	Surface Water Screening Level	Ground Water Screening Level	Ratio: Max value / Min Screen
Dioxins/Furans											
Hexachlorodibenzofurans (Total)	RG Below LANL	40	1	3%	0.0001	0.0	0.0001	µg/L	5.00E-07		200.00
Octachlorodibenzodioxin [1,2,3,4,6,7,8,9-]	RG Above LANL	4	1	25%	0.0001	0.0001	0.0001	µg/L	5.00E-05		2.00
Octachlorodibenzodioxin [1,2,3,4,6,7,8,9-]	RG Below LANL	20	1	5%	0.0001	0.0001	0.0001	µg/L	5.00E-05		2.00
Tetrachlorodibenzodioxins (Total)	RG Below LANL	20	1	5%	2.1E-05	2.1E-05	2.1E-05	µg/L	5.00E-08		420
High Explosives Residuals											
Amino-2,6-dinitrotoluene [4-]	PP Above LANL	40	1	3%	0.33	0.33	0.33	µg/L			
Amino-4,6-dinitrotoluene [2-]	PP Above LANL	40	1	3%	0.31	0.31	0.31	µg/L			
Dinitrotoluene[2,4-]	PP Below LANL	115	2	2%	0.95	1.2	1.4	µg/L	34	73	0.04
Dinitrotoluene[2,6-]	PP Above LANL	90	1	1%	0.33	0.3	0.33	µg/L		37	0.01
Dinitrotoluene[2,6-]	PP Below LANL	117	1	1%	2.1	2.1	2.1	µg/L		37	0.06
HMX	PP Below LANL	46	8	17%	0.29	1.7	3.8	µg/L		1825	0.00
Nitrotoluene[2-]	PP Below LANL	46	1	2%	0.82	0.8	0.82	µg/L			
Nitrotoluene[3-]	PP Below LANL	46	1	2%	0.28	0.3	0.28	µg/L		61	0.00
High Explosives Residuals (cont.)											
Nitrotoluene[4-]	PP Below LANL	46	1	2%	0.27	0.3	0.27	µg/L		61	0.00
RDX	PP Below LANL	46	6	13%	0.26	0.8	1.5	µg/L		6	0.25
Trinitrotoluene[2,4,6-]	PP Below LANL	45	1	2%	0.35	0.4	0.35	µg/L		18	0.02
PCBs											
Aroclor-1254	PP Below LANL	79	1	1%	0.078	0.078	0.078	µg/L	0.00064	1.0	121.88
Aroclor-1260	PP Below LANL	79	2	3%	0.11	0.11	0.11	µg/L	0.00064	1.0	171.88
Insecticides											
BHC[alpha-]	RG Below LANL	19	1	5%	0.01	0.01	0.01	µg/L	0.049	0.11	0.20
BHC[beta-]	RG Below LANL	19	1	5%	0.01	0.01	0.01	µg/L	0.17	0.37	0.06

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Min.	Avg.	Max.	Unit	Surface Water Screening Level	Ground Water Screening Level	Ratio: Max value / Min Screen
BHC[delta-]	RG Below LANL	19	1	5%	0.01	0.01	0.01	µg/L			
BHC[gamma-]	RG Below LANL	19	1	5%	0.01	0.01	0.01	µg/L	0.63	0.52	0.02
DDD[4,4'-]	RG Below LANL	19	1	5%	0.18	0.18	0.18	µg/L	0.0022	2.8	81.82
DDE[4,4'-]	RG Below LANL	19	2	11%	0.0062	0.02	0.04	µg/L	0.0022	2.0	18.18
DDT[4,4'-]	RG Below LANL	19	1	5%	0.82	0.82	0.82	µg/L	0.0022	2.0	372.73
Dieldrin	RG Below LANL	19	1	5%	0.030	0.030	0.030	µg/L	0.00054	0.042	55.56
Endosulfan I	RG Below LANL	19	2	11%	0.01	0.03	0.05	µg/L	89		0.00
Insecticides (cont.)											
Endosulfan II	RG Below LANL	19	1	5%	0.11	0.1	0.11	µg/L	89		0.00
Endosulfan Sulfate	RG Below LANL	19	1	5%	0.1	0.1	0.1	µg/L	89		0.00
Endrin	RG Below LANL	19	1	5%	0.06	0.06	0.06	µg/L	0.81	11	0.07
Heptachlor Epoxide	RG Below LANL	19	1	5%	0.0098	0.0	0.0098	µg/L	0.00039	0.07	25.13
Methoxychlor[4,4'-]	RG Below LANL	19	1	5%	0.19	0.2	0.19	µg/L		183	0.00
Toxaphene (Technical Grade)	RG Below LANL	19	1	5%	5.1	5.1	5.1	µg/L	0.0028	0.61	1821
Semi-volatile Organic Compounds											
Acenaphthene	PP Above LANL	50	1	2%	0.71	0.71	0.71	µg/L	990	365	0.00
Acenaphthene	PP Below LANL	71	2	3%	0.53	0.58	0.63	µg/L	990	365	0.00
Acenaphthylene	PP Above LANL	50	1	2%	0.65	0.65	0.65	µg/L			
Acenaphthylene	PP Below LANL	71	2	3%	0.46	0.55	0.63	µg/L			
Anthracene	PP Above LANL	50	1	2%	0.7	0.70	0.7	µg/L	40000	1825	0.00
Anthracene	PP Below LANL	71	2	3%	0.57	0.59	0.61	µg/L	40000	1825	0.00
Anthracene	RG Above LANL	13	1	8%	0.14	0.14	0.14	µg/L	40000	1825	0.00
Benzo(a)anthracene	PP Above LANL	50	1	2%	0.81	0.81	0.81	µg/L	0.18	0.92	4.50
Semi-volatile Organic Compounds (cont.)											
Benzo(a)anthracene	PP Below LANL	71	2	3%	0.65	0.72	0.79	µg/L	0.18	0.92	4.39
Benzo(a)pyrene	PP Above LANL	50	1	2%	0.74	0.74	0.74	µg/L	0.18	0.09	8.03
Benzo(a)pyrene	PP Below LANL	71	2	3%	0.56	0.60	0.63	µg/L	0.18	0.09	6.84
Benzo(b)fluoranthene	PP Above LANL	50	1	2%	0.72	0.72	0.72	µg/L	0.18	0.92	4.00
Benzo(b)fluoranthene	PP Below LANL	71	2	3%	0.49	0.54	0.58	µg/L	0.18	0.92	3.22

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Min.	Avg.	Max.	Unit	Surface Water Screening Level	Ground Water Screening Level	Ratio: Max value / Min Screen
Benzo(g,h,i)perylene	PP Above LANL	50	1	2%	0.58	0.58	0.58	µg/L			
Benzo(g,h,i)perylene	PP Below LANL	71	2	3%	0.54	0.56	0.58	µg/L			
Benzo(k)fluoranthene	PP Above LANL	50	1	2%	0.83	0.83	0.83	µg/L	0.18	9.2	4.61
Benzo(k)fluoranthene	PP Below LANL	71	2	3%	0.73	0.75	0.77	µg/L	0.18	9.2	4.28
Benzoic Acid	PP Above LANL	46	10	22%	21	394	1800	µg/L		146000	0.01
Benzoic Acid	PP Below LANL	63	9	14%	13.5	969	1900	µg/L		146000	0.01
Benzyl Alcohol	PP Above LANL	49	8	16%	2.9	28	129	µg/L		10950	0.01
Benzyl Alcohol	PP Below LANL	68	2	3%	2.5	12	22	µg/L		10950	0.00
Benzyl Alcohol	RG Below LANL	3	1	33%	2.13	2.1	2.13	µg/L		10950	0.00
Semi-volatile Organic Compounds (cont.)											
Bis(2-ethylhexyl)phthalate	PP Above LANL	51	11	22%	0.081	0.25	0.74	µg/L	22	48	0.03
Bis(2-ethylhexyl)phthalate	PP Below LANL	71	19	27%	0.16	2.3	7.1	µg/L	22	48	0.32
Bis(2-ethylhexyl)phthalate	RG Above LANL	13	5	38%	0.3	334	1080	µg/L	22	48	49.09
Bis(2-ethylhexyl)phthalate	RG Below LANL	26	4	15%	1.8	2.8	5.1	µg/L	22	48	0.23
Chloronaphthalene[2-]	PP Above LANL	50	1	2%	0.66	0.7	0.66	µg/L	1600	487	0.00
Chloronaphthalene[2-]	PP Below LANL	71	2	3%	0.42	0.5	0.6	µg/L	1600	487	0.00
Chrysene	PP Above LANL	50	1	2%	0.8	0.8	0.8	µg/L	0.18	92	4.44
Chrysene	PP Below LANL	71	2	3%	0.63	0.66	0.69	µg/L	0.18	92	3.83
Dibenz(a,h)anthracene	PP Above LANL	50	1	2%	0.51	0.51	0.51	µg/L	0.18	0.092	5.54
Dibenz(a,h)anthracene	PP Below LANL	71	1	1%	0.43	0.43	0.43	µg/L	0.18	0.092	4.67
Diethylphthalate	RG Below LANL	27	4	15%	2.3	3.8	6.5	µg/L	44000	29200	0.00
Di-n-butylphthalate	PP Above LANL	50	2	4%	2.1	2.7	3.2	µg/L	4500	3650	0.00
Di-n-butylphthalate	PP Below LANL	71	1	1%	2.3	2.3	2.3	µg/L	4500	3650	0.00
Semi-volatile Organic Compounds (cont.)											
Fluoranthene	PP Above LANL	50	1	2%	0.68	0.7	0.68	µg/L	140	1460	0.00
Fluoranthene	PP Below LANL	71	2	3%	0.51	0.6	0.63	µg/L	140	1460	0.00
Fluoranthene	RG Above LANL	13	2	15%	0.36	10.9	21.5	µg/L	140	1460	0.15
Fluorene	PP Above LANL	50	1	2%	0.66	0.7	0.66	µg/L	5300	243	0.00
Fluorene	PP Below LANL	71	2	3%	0.47	0.5	0.58	µg/L	5300	243	0.00

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Min.	Avg.	Max.	Unit	Surface Water Screening Level	Ground Water Screening Level	Ratio: Max value / Min Screen
Indeno(1,2,3-cd)pyrene	PP Above LANL	50	1	2%	0.54	0.54	0.54	µg/L	0.18	0.92	3.00
Indeno(1,2,3-cd)pyrene	PP Below LANL	71	2	3%	0.47	0.52	0.57	µg/L	0.18	0.92	3.17
Methylnaphthalene[2-]	PP Above LANL	50	1	2%	0.68	0.7	0.68	µg/L			
Methylnaphthalene[2-]	PP Below LANL	72	2	3%	0.36	0.5	0.58	µg/L			
Methylphenol[2-]	PP Above LANL	50	1	2%	2.7	2.7	2.7	µg/L		1825	0.00
Methylphenol[2-]	PP Below LANL	67	1	1%	13.4	13.4	13.4	µg/L		1825	0.01
Methylphenol[4-]	PP Above LANL	48	2	4%	4.4	9.7	15	µg/L		183	0.08
Methylphenol[4-]	PP Below LANL	63	2	3%	2.4	6.7	11	µg/L		183	0.06
Semi-volatile Organic Compounds (cont.)											
Phenanthrene	PP Above LANL	50	1	2%	0.75	0.8	0.75	µg/L			
Phenanthrene	PP Below LANL	71	2	3%	0.68	0.7	0.68	µg/L			
Phenanthrene	RG Above LANL	13	1	8%	0.43	0.4	0.43	µg/L			
Phenol	PP Above LANL	47	2	4%	7.4	28.7	50	µg/L	1700000	5	10.00
Phenol	PP Below LANL	66	2	3%	0.64	9.8	19	µg/L	1700000	5	3.80
Pyrene	PP Above LANL	50	1	2%	0.82	0.8	0.82	µg/L	4000	183	0.00
Pyrene	PP Below LANL	71	2	3%	0.55	0.6	0.68	µg/L	4000	183	0.00
Pyrene	RG Above LANL	13	2	15%	0.68	10.5	20.4	µg/L	4000	183	0.11
Pyridine	PP Above LANL	47	2	4%	16	32.5	49	µg/L		37	1.34
Pyridine	PP Below LANL	66	2	3%	3.4	20.2	37	µg/L		37	1.01
Volatile Organic Compounds											
Acetone	PP Below LANL	16	6	38%	3.3	30.1	76	µg/L		608	0.12
Acetone	RG Above LANL	6	5	83%	3	6.6	16	µg/L		608	0.03
Acetone	RG Below LANL	21	13	62%	1.7	3.2	7.7	µg/L		608	0.01
Benzene	PP Above LANL	51	7	14%	0.27	0.32	0.39	µg/L		10	0.04
Bromodichloromethane	PP Above LANL	50	1	2%	1.4	1.4	1.4	µg/L	170	1.8	0.77
Volatile Organic Compounds (cont.)											
Bromomethane	PP Above LANL	50	1	2%	2.1	2.1	2.1	µg/L	1500	9	0.24
Bromomethane	RG Below LANL	23	1	4%	2.1	2.1	2.1	µg/L	1500	9	0.24
Butanone[2-]	RG Above LANL	6	1	17%	4.6	4.6	4.6	µg/L		1904	0.00

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Min.	Avg.	Max.	Unit	Surface Water Screening Level	Ground Water Screening Level	Ratio: Max value / Min Screen
Butanone[2-]	RG Below LANL	20	2	10%	2.1	2.2	2.3	µg/L		1904	0.00
Chlorodibromomethane	PP Above LANL	50	1	2%	0.18	0.2	0.18	µg/L	130	1.3	0.13
Chloroform	PP Above LANL	50	1	2%	5.2	5.2	5.2	µg/L	4700	100	0.05
Chloroform	PP Below LANL	65	4	6%	0.2	0.3	0.4	µg/L	4700	100	0.00
Chloromethane	PP Above LANL	50	1	2%	0.45	0.5	0.5	µg/L		15	0.03
Chloromethane	PP Below LANL	65	1	2%	0.79	0.8	0.8	µg/L		15	0.05
Chloromethane	RG Below LANL	23	1	4%	5.4	5.4	5.4	µg/L		15	0.36
Dichlorobenzene[1,4-]	PP Above LANL	98	3	3%	0.15	0.3	0.69	µg/L	2600	4.7	0.15
Dichlorobenzene[1,4-]	PP Below LANL	132	8	6%	0.12	0.2	0.37	µg/L	2600	4.7	0.08
Dichlorobenzene[1,4-]	RG Above LANL	26	2	8%	0.27	0.3	0.3	µg/L	2600	4.7	0.06
Dichlorobenzene[1,4-]	RG Below LANL	49	3	6%	0.15	0.2	0.23	µg/L	2600	4.7	0.05
Dinitrobenzene[1,3-]	PP Below LANL	45	1	2%	0.048	0.048	0.048	µg/L		3.7	0.01
Volatile Organic Compounds (cont.)											
Ethylbenzene	PP Above LANL	51	2	4%	0.068	0.1	0.073	µg/L	29000	750	0.00
Ethylbenzene	PP Below LANL	65	1	2%	0.15	0.2	0.15	µg/L	29000	750	0.00
Ethylbenzene	RG Above LANL	13	1	8%	0.22	0.2	0.22	µg/L	29000	750	0.00
Methylene Chloride	PP Above LANL	50	9	18%	0.99	4.2	14	µg/L	5900	100	0.14
Methylene Chloride	PP Below LANL	65	12	18%	1	3.7	15	µg/L	5900	100	0.15
Methylene Chloride	RG Below LANL	23	2	9%	1.4	2.6	3.8	µg/L	5900	100	0.04
Naphthalene	PP Above LANL	55	1	2%	0.64	0.6	0.64	µg/L		30	0.02
Naphthalene	PP Below LANL	83	3	4%	0.19	0.4	0.56	µg/L		30	0.02
Styrene	RG Above LANL	6	1	17%	1.9	1.9	1.9	µg/L		1641	0.00
Toluene	PP Above LANL	50	7	14%	0.36	0.5	0.87	µg/L	200000	750	0.00
Toluene	PP Below LANL	65	5	8%	0.26	0.9	1.3	µg/L	200000	750	0.00
Toluene	RG Above LANL	13	1	8%	0.23	0.2	0.23	µg/L	200000	750	0.00

Table E-2. Organic Compounds Detected in Sediment Samples on the Pajarito Plateau and in the Rio Grande.

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg)			Sediment Screening Levels (ug/kg)			Ratio: Max Value to Min. Screen Level
					Min.	Avg.	Max.	Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	
Dioxins/Furans											
Dibenzofuran	PP Above LANL	29	3	10%	3.8	4.4	4.9		290569	5066789	0.00
Dibenzofuran	PP Below LANL	81	7	9%	3.4	132	434		290569	5066789	0.00
Heptachlorodibenzodioxin [1,2,3,4,6,7,8-]	RG Below LANL	17	3	18%	0.0041	0.007	0.011				
Heptachlorodibenzodioxins (Total)	RG Below LANL	17	3	18%	0.0085	0.013	0.02	2.15	3.90	31	0.01
Octachlorodibenzodioxin [1,2,3,4,6,7,8,9-]	RG Above LANL	4	2	50%	0.0084	0.011	0.014	21.5	39	308	0.00
Octachlorodibenzodioxin [1,2,3,4,6,7,8,9-]	RG Below LANL	17	7	41%	0.011	0.035	0.065	21.5	39	308	0.00
Tetrachlorodibenzodioxins (Total)	RG Below LANL	17	3	18%	0.0014	0.003	0.0067	0.0215	0.04	0.38	0.31
High Explosives Residuals											
HMX	PP Above LANL	23	2	9%	94.4	337	580		3055155	100000000	0.00
HMX	PP Below LANL	42	1	2%	699	699	699		3055155	100000000	0.00
Nitrotoluene[2-]	PP Above LANL	23	1	4%	27.2	27	27.2				

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg) Min.	Avg.	Max.	Sediment Screening Levels (ug/kg) Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	Ratio: Max Value to Min. Screen Level
High Explosives Residuals (cont.)											
RDX	PP Above LANL	23	3	13%	115	303	664		44240	520133	0.02
RDX	PP Below LANL	42	2	5%	14.4	444	874		44240	520133	0.02
Trinitrotoluene[2,4,6-]	PP Above LANL	23	1	4%	106	106	106		162213	1907154	0.00
Trinitrotoluene[2,4,6-]	PP Below LANL	42	3	7%	20.4	74	152		162213	1907154	0.00
PCBs											
Aroclor-1242	PP Below LANL	89	2	2%	4.7	5	5	189	2220	28607	0.03
Aroclor-1254	PP Below LANL	87	16	18%	1.1	28	185	189	2220	28607	0.98
Aroclor-1260	PP Above LANL	30	4	13%	7	8	9	189	2220	28607	0.05
Aroclor-1260	PP Below LANL	89	22	25%	1.5	26	213	189	2220	28607	1.13
Aroclor-1260	RG Above LANL	24	1	4%	12	12	12	189	2220	28607	0.06
Insecticides											
Aniline	PP Above LANL	28	2	7%	84.1	297	509		853754	10037651	0.00
BHC[beta-]	PP Below LANL	30	1	3%	0.39	0.39	0.39	1.38	3158	31786	0.28
Chlordane[alpha-]	PP Below LANL	29	1	3%	2.1	2.1	2.1	4.79			0.44

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg) Min.	Avg.	Max.	Sediment Screening Levels (ug/kg) Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	Ratio: Max Value to Min. Screen Level
Insecticides (cont.)											
DDD[4,4'-]	PP Below LANL	29	1	3%	1.8	1.8	1.8	7.81	24371	238394	0.23
DDE[4,4'-]	PP Above LANL	4	4	100%	1.5	2.4	4.1	15	17203	168278	0.27
DDE[4,4'-]	PP Below LANL	29	1	3%	2.1	2.1	2.1	15	17203	168278	0.14
DDT[4,4'-]	PP Above LANL	4	1	25%	5.7	5.7	5.7	46.1	17203	168278	0.12
Heptachlor	PP Below LANL	30	1	3%	0.33	0	0.33		1081	12714	0.00
Semi-volatile Organic Compounds											
Acenaphthene	PP Below LANL	81	8	10%	7.5	120	406	1300	3683396	38415553	0.31
Anthracene	PP Above LANL	29	7	24%	5.5	10	25.1	1100	21899672	100000000	0.02
Anthracene	PP Below LANL	81	19	23%	4.8	47	429	1100	21899672	100000000	0.39
Benzo(a)anthracene	PP Above LANL	29	5	17%	19.2	28	45.8	693	6219	78390	0.07
Benzo(a)anthracene	PP Below LANL	80	17	21%	17.6	207	1260	693	6219	78390	1.82
Benzo(a)pyrene	PP Above LANL	29	3	10%	16.2	17	18.6	782	622	7839	0.03
Benzo(a)pyrene	PP Below LANL	80	16	20%	13	190	938	782	622	7839	1.51
Benzo(b)fluoranthene	PP Above LANL	29	2	7%	19.5	20	21.4		6219	78390	0.00
Benzo(b)fluoranthene	PP Below LANL	80	14	18%	6.6	295	1670		6219	78390	0.27

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg)			Sediment Screening Levels (ug/kg)			Ratio: Max Value to Min. Screen Level
					Min.	Avg.	Max.	Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	
Semi-volatile Organic Compounds (cont.)											
Benzo(g,h,i)perylene	PP Above LANL	29	1	3%	13	13	13				
Benzo(g,h,i)perylene	PP Below LANL	80	10	13%	17.9	171	692				
Benzo(k)fluoranthene	PP Above LANL	29	2	7%	13.3	22	31.5		62188	783899	0.00
Benzo(k)fluoranthene	PP Below LANL	81	13	16%	6.8	123	701		62188	783899	0.01
Benzoic Acid	PP Above LANL	29	2	7%	366	370	374		100000000	100000000	0.00
Benzoic Acid	PP Below LANL	81	1	1%	488	488	488		100000000	100000000	0.00
Bis(2-chloroethyl)ether	PP Below LANL	81	1	1%	220	220	220		2112	6210	0.10
Bis(2-ethylhexyl)phthalate	PP Above LANL	29	11	38%	15.2	52	118	2650	347600	4086758	0.04
Bis(2-ethylhexyl)phthalate	PP Below LANL	81	37	46%	8.8	83	1120	2650	347600	4086758	0.42
Bis(2-ethylhexyl)phthalate	RG Above LANL	23	8	35%	8.7	100	300	2650	347600	4086758	0.11
Bis(2-ethylhexyl)phthalate	RG Below LANL	42	13	31%	9.8	66	310	2650	347600	4086758	0.12
Butylbenzylphthalate	PP Above LANL	29	1	3%	68.3	68	68.3	11000	240477	240477	0.01
Butylbenzylphthalate	PP Below LANL	81	2	2%	30	38	45.2	11000	240477	240477	0.00
Carbazole	PP Below LANL	15	1	7%	71.8	72	71.8		243320	2860730	0.00

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg)			Sediment Screening Levels (ug/kg)			Ratio: Max Value to Min. Screen Level
					Min.	Avg.	Max.	Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	
Semi-volatile Organic Compounds (cont.)											
Chrysene	PP Above LANL	29	6	21%	16.3	33	65.1	862	621877	7838988	0.08
Chrysene	PP Below LANL	80	18	23%	17.2	210	1160	862	621877	7838988	1.35
Dibenz(a,h)anthracene	PP Below LANL	81	1	1%	38.4	38	38.4	260	622	7839	0.15
Dichlorobenzene[1,4-]	PP Below LANL	81	1	1%	21.6	22	21.6	350	31975	74879	0.06
Diethylphthalate	PP Below LANL	81	1	1%	44.4	44	44.4	630	48882478	100000000	0.07
Diethylphthalate	RG Below LANL	42	1	2%	52	52	52	630	48882478	100000000	0.08
Di-n-butylphthalate	PP Below LANL	81	7	9%	23.5	39	59	11000	6110310	100000000	0.01
Di-n-butylphthalate	RG Above LANL	23	1	4%	37.6	38	37.6	11000	6110310	100000000	0.00
Di-n-butylphthalate	RG Below LANL	42	3	7%	51.4	86	137	11000	6110310	100000000	0.01
Di-n-octylphthalate	PP Below LANL	81	1	1%	97.1	97	97.1		1222062	40867578	0.00
Fluoranthene	PP Above LANL	29	12	41%	3.5	36	120	6200	2293610	81735156	0.02
Fluoranthene	PP Below LANL	80	33	41%	4.5	232	2810	6200	2293610	81735156	0.45
Fluoranthene	RG Above LANL	23	1	4%	256	256	256	6200	2293610	81735156	0.04
Fluoranthene	RG Below LANL	42	1	2%	140	140	140	6200	2293610	81735156	0.02

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg) Min.	Avg.	Max.	Sediment Screening Levels (ug/kg) Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	Ratio: Max Value to Min. Screen Level
Semi-volatile Organic Compounds (cont.)											
Fluorene	PP Above LANL	29	4	14%	3.4	4.3	4.9	144	2644486	33175916	0.03
Fluorene	PP Below LANL	81	10	12%	5.5	129	401	144	2644486	33175916	2.78
Fluorene	RG Below LANL	42	1	2%	7.8	8	7.8	144	2644486	33175916	0.05
Indeno(1,2,3-cd)pyrene	PP Above LANL	29	1	3%	10.3	10.3	10.3		6219	78390	0.00
Indeno(1,2,3-cd)pyrene	PP Below LANL	81	10	12%	7.7	151	507		6219	78390	0.08
Methylnaphthalene[2-]	PP Above LANL	29	1	3%	5.1	5.1	5.1	201			0.03
Methylnaphthalene[2-]	PP Below LANL	81	2	2%	5.6	8	11	201			0.05
Methylphenol[4-]	PP Above LANL	28	4	14%	8	293	1110		305515	10216895	0.00
Methylphenol[4-]	PP Below LANL	79	2	3%	46.8	122	198		305515	10216895	0.00
Methylphenol[4-]	RG Below LANL	24	7	29%	15.2	308	965		305515	10216895	0.00
Pentachlorophenol	PP Above LANL	29	1	3%	220	220	220		29819	476788	0.01
Phenanthrene	PP Above LANL	29	10	34%	13.3	34	95	1100			0.09
Phenanthrene	PP Below LANL	80	25	31%	4.3	205	2150	1100			1.95
Phenanthrene	RG Below LANL	42	1	2%	63	63	63	1100			0.06

Analyte	General Location (PP = Pajarito Plateau; RG = Rio Grande)	# Samples	# Detects	Rate of Detection (%)	Measured Concentrations (ug/kg) Min.	Avg.	Max.	Sediment Screening Levels (ug/kg) Aquatic Life	Residential Soil Screening Level	Industrial Outdoor Worker Soil Screen	Ratio: Max Value to Min. Screen Level
Semi-volatile Organic Compounds (cont.)											
Phenol	PP Above LANL	29	2	7%	12.7	17	21		18331473	100000000	0.00
Phenol	RG Below LANL	42	1	2%	184	184	184		18331473	100000000	0.00
Pyrene	PP Above LANL	29	11	38%	16.9	98	382	1398	2308756	54239604	0.27
Pyrene	PP Below LANL	80	25	31%	12	375	2410	1398	2308756	54239604	1.72
Pyrene	RG Above LANL	23	1	4%	110	110	110	1398	2308756	54239604	0.08
Pyrene	RG Below LANL	42	1	2%	140	140	140	1398	2308756	54239604	0.10
Volatile Organic Compounds											
Naphthalene	PP Above LANL	29	3	10%	8.4	10	12.7	470	124798	188955	0.03
Naphthalene	PP Below LANL	81	3	4%	8.6	15	18.6	470	124798	188955	0.04

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