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*Radiological and Nonradiological Effects  
after the Cerro Grande Fire*



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*Radiological and Nonradiological Effects  
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# **RADIOLOGICAL AND NONRADIOLOGICAL EFFECTS AFTER THE CERRO GRANDE FIRE**

by

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## **ABSTRACT**

The Cerro Grande Fire began as a prescribed burn in early May 2000, got out of control, and eventually burned almost 43,000 acres along the east-facing side of the Jemez Mountains, including approximately 7,000 acres on Los Alamos National Laboratory (LANL). The fire enhanced the possibility of flooding in watersheds that have residual contamination from early LANL operations. If contaminated sediments in the canyons were mobilized during runoff and redeposited downstream in the lower parts of these canyons or transported into the Rio Grande, people could have been exposed to these contaminated sediments or to contaminated water in the Rio Grande. Our objective was to estimate 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 fraction of those effects was caused by current or past LANL operations.

Observations and sampling have shown that the aftereffects of the Cerro Grande Fire resulted in increased concentrations of radiological and nonradiological chemicals in runoff and in sediments deposited during CY 2000. The predominance of these effects was caused by the increased mobilization of locally deposited worldwide fallout or of naturally occurring substances that were concentrated by the fire. Where increases were seen, we were not able to identify LANL as the source for these increases. However, for many of them we were not able to preclude the possibility that legacy LANL wastes in canyons and the area surrounding LANL contributed to the increases. We therefore calculated effects independent of their source if we could not determine the source.

None of the radiological or nonradiological effects we calculated for residents of Totavi or for direct or indirect users of Rio Grande water are believed to cause health effects in the exposed individuals for exposures received during CY 2000. If individuals were exposed for long periods of time at some of the potential maximum concentrations we calculated, some health effects could be possible.

---

## **1.0 INTRODUCTION**

The Cerro Grande Fire was begun as a prescribed burn in early May 2000. Because of unexpectedly high winds and other complicating factors, the fire got out of control and spread quickly, eventually burning almost 43,000 acres along the east-facing side of the Jemez Mountains (Figure 1). The fire burned approximately 7,000 acres on Los Alamos National Laboratory (LANL) property, destroying buildings and other properties, and potentially burning, vaporizing, or lofting and dispersing contaminated materials or sediments remaining from earlier operations.

During the Cerro Grande Fire, inhalation of airborne material dominated potential exposure pathways. An assessment was made of radiological doses that might have been received by members of the public, including those involved with the firefighting effort in and around Los Alamos, and those residing in Española, the most affected of the nearby communities (Kraig et al. 2001). That study

indicated that the doses received were very small and were caused by increases in airborne natural radioactivity during the fire. Impacts from dispersal of contaminated material from LANL were either nonexistent or too small to be observed, especially relative to the significant increases in airborne natural radioactivity. Several assessments of potential nonradiological effects have also been undertaken (CDC 2001, ATSDR 2001).

Exposure pathways in addition to inhalation developed after the fire and had to be evaluated for their potential to human exposure. Because many acres of trees and ground cover burned during the Cerro Grande Fire, the possibility of enhanced flooding was created in the canyons draining the east-facing side of the Jemez Mountains. Several of these watersheds (Los Alamos/Pueblo, Mortandad, and, to a lesser extent, Pajarito and Water Canyons) have residual contamination from early LANL operations. If contaminated sediments in the canyons were mobilized during runoff and redeposited downstream in the lower parts of these canyons or transported into the Rio Grande, people could have been exposed to these contaminated sediments or to contaminated water in the Rio Grande.

The mobilization of LANL-related contamination is one source for exposure following the fire. However, during the past 50 years or so, radioactive fallout (from worldwide uses of radioactive materials) has accumulated in soils, vegetation, and duff, and represents a much larger source term available for mobilization by rainfall and runoff. Metals, plant nutrients, and other chemicals have also accumulated in trees and other plant material. Organic chemicals that are products of incomplete combustion are present in environmental media following fires.

We approached this assessment in two stages. First, we evaluate sampling and other data to determine if there has been an effect from the Cerro Grande Fire. We ask the question, have the concentrations of selected potentially hazardous radiological and nonradiological analytes increased in sediments, Rio Grande waters, or in biota directly as a result of the Cerro Grande Fire?

If there is no increase, that is the end of our analysis because no effects assessment would be warranted. If we do see an increase in radiological or nonradiological analytes resulting from the fire, we evaluate potential effects. And, we attempt to discern whether part or all of the increase has been caused by the mobilization of LANL legacy wastes or is in some way traceable to past or present LANL operations. If we are able to identify a LANL increment in the broader Cerro Grande Fire impacts, we will quantify and report that increment and its effect. We don't evaluate effects where there has been a decrease in chemical or radionuclide concentrations.

There is evidence that LANL has contributed somewhat to the existing levels of  $^{239}\text{Pu}$  and other radionuclides in areas within a few miles of LANL (Fresquez et al. 1998). These LANL-caused additions to fallout radionuclide components cannot be distinguished from fallout when measured in sediments deposited downstream. Unless we can demonstrate that a chemical of potential concern is definitely not of LANL origin, its contribution will be included in the effects assessment. Thus, we include all analytes in our assessment that are seen at concentrations above those that existed before the Cerro Grande Fire unless they are shown to be of non-LANL origin.

We evaluated the possibility that humans were exposed during 2000 to increased environmental concentrations of radiological materials and chemicals as a result of the Cerro Grande Fire. Our analysis considers two principal exposure scenarios: (1) a resident who may have lived near contaminated sediments transported by post-Cerro Grande Fire runoff and (2) individuals who may have been exposed directly or indirectly by Rio Grande water contaminated by runoff events. The resident described in the preceding sentence is assumed to live in lower Los Alamos Canyon, as those residences are closest to potential Cerro Grande Fire impacts and to movable sources of LANL contamination. Finally, although we consider potential effects to wildlife to be important, we did not evaluate such effects in this paper.

There are several other groups that have looked or are looking at Cerro Grande Fire effects. Each group approaches the complicated task of evaluating potential fire effects differently. There are many ways to interpret sampling data and different ways to calculate effects. Thus, it is likely that even if everyone agreed on a data set to use as a basis for analysis, each group would reach different conclusions from those data. Perhaps most important, the guiding philosophy behind the assessments can be very different. Very conservative assessments can be done to describe bounding, worst-case impacts and these

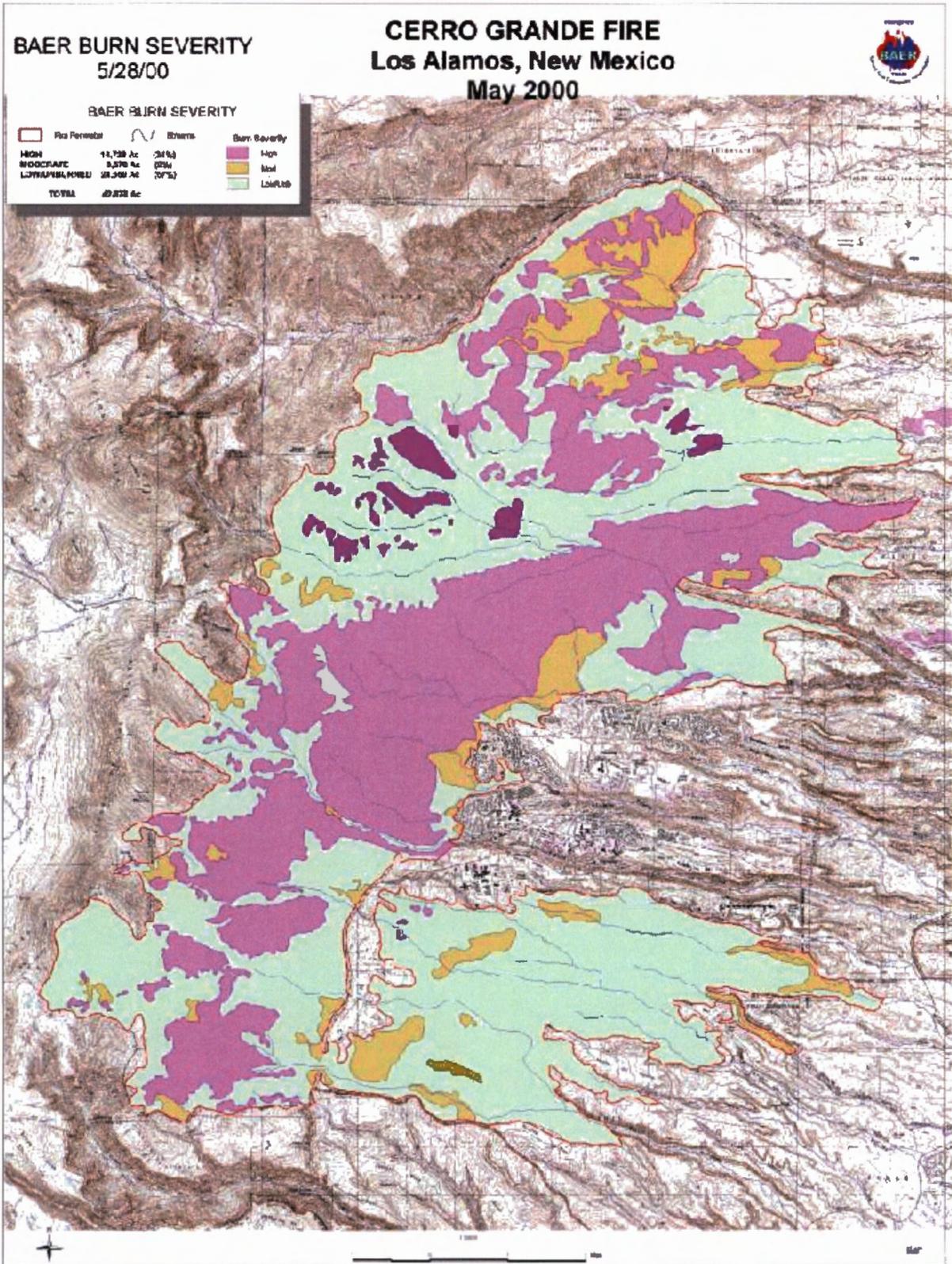


Figure 1. Burn severity and total area burned by the Cerro Grande Fire.

can overestimate potential effects. We have chosen to do as realistic an assessment as possible, but to incorporate conservatism such that we can conclude actual effects are very unlikely to be greater than those we describe. Because of the variability in methods, data assessment, and assessment philosophy, it is unlikely that the results of the different effects assessments will be the same or even directly comparable. As the various assessments are published, we anticipate future efforts will be important to compare and reconcile the conclusions.

## **2.0 GENERAL APPROACH**

Our objective was to estimate 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 we 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. This means that, in general, the doses and effects presented below are overestimates of those that actually occurred. To reduce uncertainty, wherever possible we based these calculations on actual measurements of the potentially affected media. We felt this preferable to a more theoretical approach based on modeling to assess amounts of soil, sediment, or debris transported and redeposited in various locations. Finally, as described above, we limited our evaluation to potential effects from the Cerro Grande Fire and its aftermath, and we tried to discern a LANL impact from the larger Cerro Grande Fire impact.

We have separated radiological from nonradiological impact assessments in this report. We did this because the methods for assessing radiological impacts are fundamentally different from those used for nonradiological impacts. By treating and describing these assessments separately, we hope to reduce confusion as to our methodology. We hope that this organization will allow readers to more easily understand the impacts of interest to them without sifting through information they might consider extraneous. In this section we describe the data that were available or that were generated to allow us to complete these assessments. Then, in Section 3.0 we present the radiological impacts assessment, which is followed by the nonradiological assessment in Section 4.0. Finally, Section 5.0 is dedicated to presenting our evaluation of potential future impacts.

## **2.1 Description of Data for Effects Assessment**

### **2.1.1 Totavi Sampling**

During latter 2000, rainstorms caused runoff throughout the Los Alamos Canyon watershed, which includes Acid, DP, Pueblo, Rendija, Guaje, and Los Alamos Canyons. In lower Los Alamos Canyon, an area with several residences known collectively as Totavi, late-season floods deposited layers of ash and sediment. An evaluation was conducted in March 2001 to assess the degree that these floods deposited sediment in the area behind the convenience store and residences in lower Los Alamos Canyon at Totavi. The study was conducted over a channel distance of approximately 300 m. We determined that sediments were deposited in the area during moderate floods that were generated by October rainfall. These recent flood deposits covered approximately 25% of the floodplain area along the 300-m reach. Thickness of the deposits varied, but was generally less than about 20 cm. More details on the Totavi sampling are presented in Appendix A.

We collected samples from the channel and floodplain 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 post-fire storm water deposits. Thus they were biased toward sampling ashy Cerro Grande Fire deposits rather than sampling equally all sedimentary deposits. Samples from the Totavi area were analyzed for radionuclides ( $^{241}\text{Am}$ ,  $^{137}\text{Cs}$ , isotopic plutonium,  $^{90}\text{Sr}$ , isotopic uranium) and inorganic constituents (including total cyanide). Samples were also collected just upstream of the low-head weir structure in Los Alamos Canyon at the Laboratory boundary in September 2000. These samples were analyzed for the same radionuclides and inorganic constituents as at Totavi and also for semivolatile

organic compounds (SVOCs; including dioxins and furans). The chemicals and radionuclides selected for analysis included those that could conceivably have been released by LANL at some time and could pose environmental concerns if present at high enough levels.

Detailed results from the sampling are presented in Appendix A. The concentrations and analytes detected in these flood deposits are similar to those reported from ash and muck (muck is ash that has been picked up, transported, and redeposited in runoff) samples collected west of the Laboratory boundary (ESP 2000). To evaluate potential fire and LANL effects, we compare Totavi results with sediment data collected in reach LA-4 East (or LA-4E) by LANL's Environmental Restoration Project (Reneau et al. 1998a, b, and c) and with soil and sediment background data collected from many areas not affected by LANL operations. Reach LA-4E is located approximately 0.6 km upstream of the Totavi area. There are no tributary drainages or contaminated sites that affect Los Alamos Canyon between LA-4 East and Totavi; pre-fire contaminant concentrations from the two areas should be comparable. Therefore, we use the pre-fire sediment concentrations from LA-4 East as surrogates for pre-fire sediment concentrations at Totavi.

Appendix A presents statistical and visual (box plot) comparisons of sampling data. Statistical tests allowed us to conclude which analyte concentrations were elevated at Totavi relative to background or LA-4 East concentrations. If these tests indicate that the concentration of an analyte is higher at Totavi than the LA-4 East concentrations, then we conclude that concentration of that analyte has increased as a result of the fire. Specific radiological and nonradiological analyses are discussed in Sections 3.0 and 4.0, respectively.

### **2.1.2 Sampling of Rio Grande Waters**

In the Rio Grande exposure scenario, radiological and nonradiological constituents are carried into the river by floods from Laboratory property and the Cerro Grande burn area. Highest concentrations of these constituents in the Rio Grande will likely occur during the brief several-hour period when the floodwaters enter the river.

During the 2000 runoff season, the U.S. Geological Survey (USGS) collected several post-fire samples of the river for LANL and for the U.S. Army Corps of Engineers. Because of logistical constraints, however, not all runoff events could be sampled and usually only one location could be sampled per day. The specific analyses available to date are somewhat limited. There are no <sup>137</sup>Cs data during periods of runoff, and some metals concentrations in unfiltered samples are not yet available. The USGS data, although useful, are not sufficient to describe the peak concentrations for all the analytes of interest. We therefore calculated what the maximum concentrations might have been in the Rio Grande from storm water samples collected in tributary canyons. If possible, the USGS results are compared with the modeled concentrations.

To estimate concentrations of potential contaminants in the Rio Grande, we need to know the contaminant concentrations in runoff water entering the Rio Grande and the volume of this runoff relative to the Rio Grande flow. To describe the increases from runoff from the Pajarito Plateau, we assume the Rio Grande had zero concentration of these contaminants before mixing with the runoff. The dilution factor (Eq. 1) is calculated according to the flow in the Rio Grande relative to runoff volume from the Pajarito Plateau. When the dilution factor is a minimum, the potential contaminant concentrations in the Rio Grande are at their maxima.

To calculate the minimum dilution factor, we identified the date(s) with the smallest difference in flows between the Rio Grande and the LANL canyons (October 23 and 24). The dilution factor is calculated by assuming that all of the runoff from LANL canyons for that day is delivered to the Rio Grande in approximately a 2-hour period. The 2-hour runoff period corresponds to runoff from an intense, short-lived thunderstorm. During this pulse, we will see the peak concentrations in the Rio Grande from LANL inflows.

The dilution factor is calculated as follows:

$$DF = (V_{RG} + V_{LANL}) * (V_{LANL})^{-1} , \quad [1]$$

where  $DF$  = dilution factor from runoff mixing with Rio Grande flows,  
 $V_{RG}$  = volume passing the Rio Grande Otowi gauge during a 2-hour period, and  
 $V_{LANL}$  = volume of runoff from LANL canyons for a day.

Mean daily flows for the Rio Grande at Otowi gauge (L. Beal, USGS, personal communication, February 22, 2001) were used to evaluate when the dilution factor was at a minimum. During the runoff season June through October, the flow ranged from 320 to 1550 cfs. The Laboratory's Water Quality and Hydrology Group (D. Shaull, personal communication, February 26, 2001) developed mean daily flow records for the LANL canyons. The flows are summed from individual gauges in Pueblo, Los Alamos, Sandia, Mortandad, Pajarito, Potrillo, Water, and Ancho Canyons and Cañada del Buey. These gauging stations are near where the canyons discharge from LANL (Figure 2). Daily total flows across the Laboratory's downstream boundary are shown relative to Rio Grande flows in Figure 3. Peak runoff volumes from the LANL canyons on June 28th were 12 cfs. Figure 4 shows how the dilution factor varied throughout most of CY 2000.

For most of the summer months, flows in the Rio Grande were typically several hundred times greater than flows from the LANL canyons. The smallest difference in flows occurred on October 23 and 24, resulting in calculated dilution factors of 3.5 and 7, respectively. For simplicity, we chose a dilution factor of 4.

From Eq. 1, we see that the greater the runoff is relative to the Rio Grande flow, the smaller the dilution factor. Thus, there is less dilution of runoff water. To estimate maximum radionuclide concentrations in the Rio Grande, we calculated a minimum dilution factor of 4. We assume that the maximum concentrations measured in storm water throughout the entire runoff season always entered the Rio Grande during the time that the dilution factor was at its minimum. Mathematically, this is expressed as follows:

$$RG_{max} = RO_{max} * DF_{min}^{-1} , \quad [2]$$

where  $RG_{max}$  = peak concentration in the Rio Grande from runoff sources,  
 $RO_{max}$  = maximum concentration measured in runoff, and  
 $DF_{min}$  = minimum dilution factor.

The peak concentration in the Rio Grande represents the maximum concentration change from baseline levels that could be attributable to the runoff.

This process of calculating maximum predicted concentrations in the Rio Grande and applying them in exposure scenarios is highly conservative for several key reasons.

- The minimum dilution factor is derived from flows in late October, a period of reduced irrigation. Selection of a dilution factor from earlier summer months, when irrigation and recreation were more likely, would yield factors at least 5 times larger, resulting in Rio Grande concentrations 1/5 of those we calculated.
- The scenario assumes that all flows in the LANL canyons arrive simultaneously at the Rio Grande, with no reduction in stream flow in transit from the LANL gauges to the river. This assumes that all runoff reached the Rio Grande. We know this did not occur.

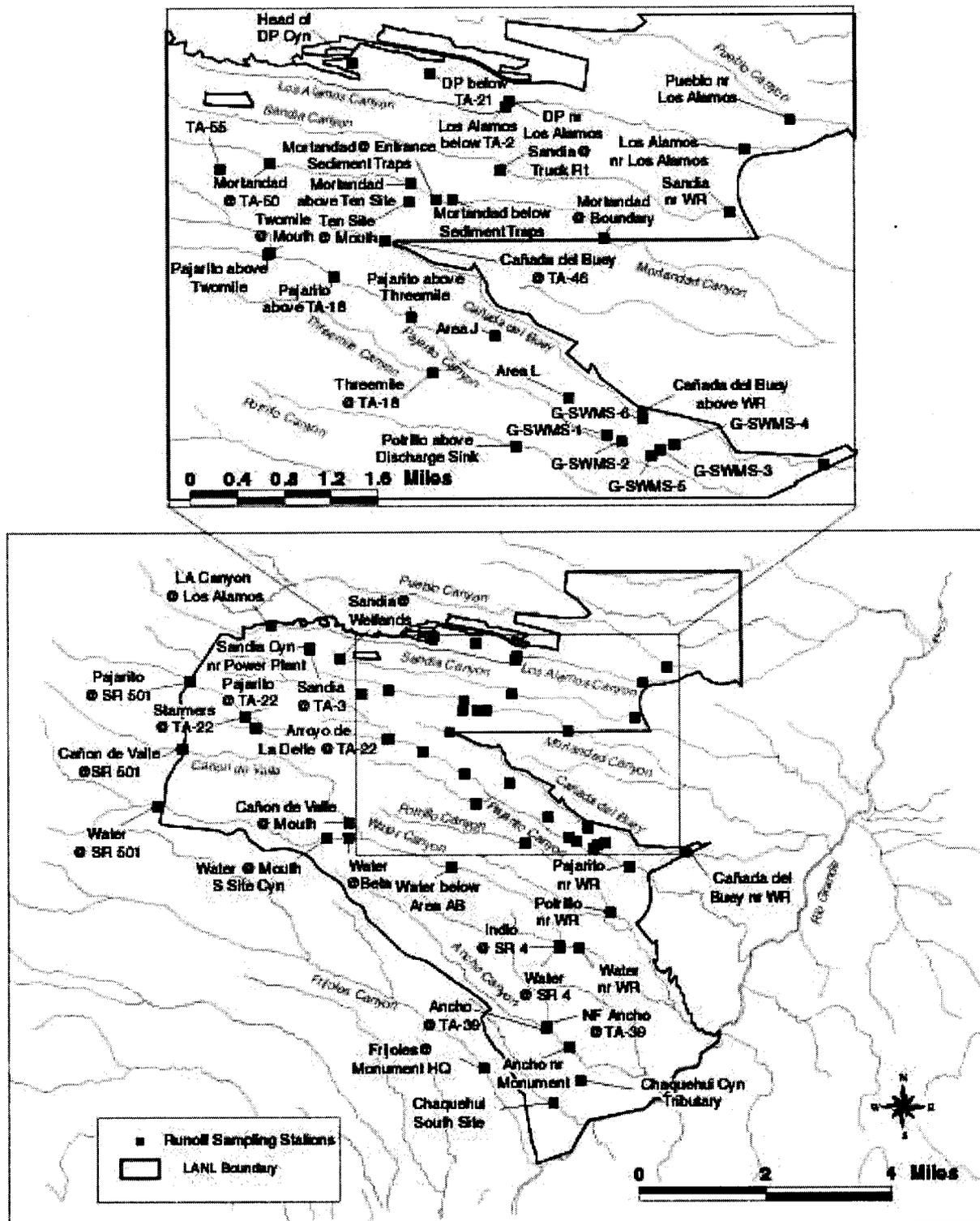


Figure 2. Location map of automated storm water quality sampling stations operated by the Los Alamos National Laboratory.

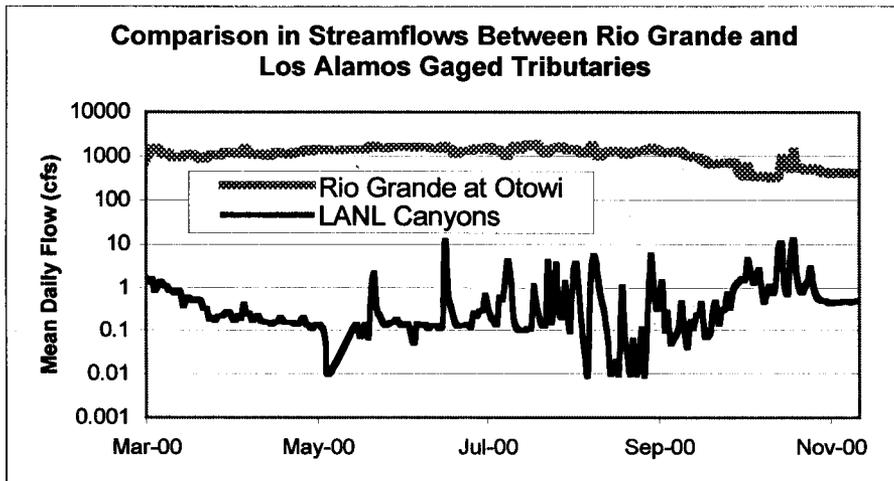


Figure 3. Comparison in streamflows between the Rio Grande at Otowi Bridge and the combined flows from LANL-gauged tributaries during part of CY 2000.

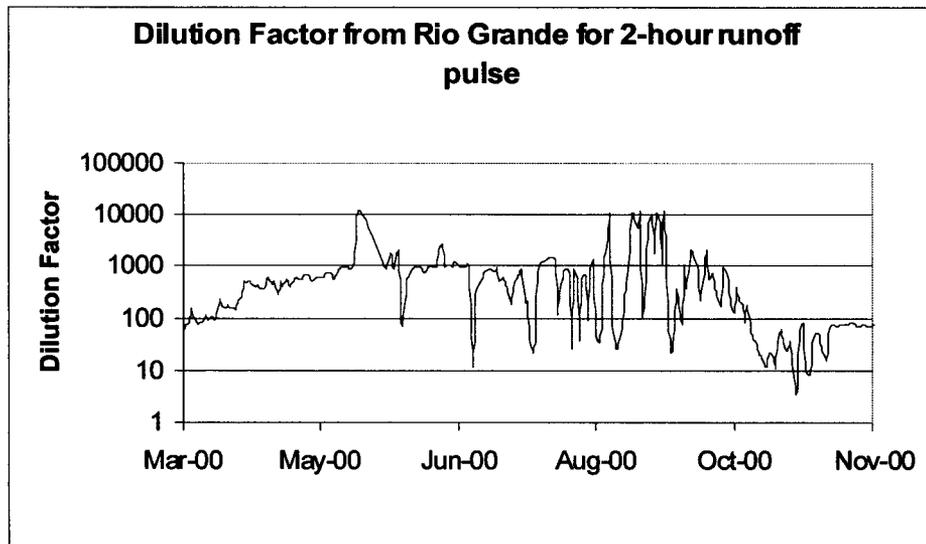


Figure 4. Dilution factors resulting from LANL-canyon runoff mixing with Rio Grande flows over a 2-hour period during part of CY 2000. Minimum dilution occurs on October 23.

The dilution factor chosen provides a margin of safety that accounts for runoff produced from large storms encompassing several large watercourses, including watercourses north of the Laboratory. These factors yield a maximum theoretical concentration in the Rio Grande.

#### 2.1.2.1 Use of Data from Guaje Canyon as Background Concentrations

We calculated the potential maximum concentration in the Rio Grande based on storm water runoff from LANL-affected canyons or from Guaje Canyon. We wanted to be able to compare canyons that are known to contain wastes from LANL operations with canyons that don't so that we could discern LANL effects from the broader Cerro Grande Fire effects. Guaje Canyon, fairly distant from the Laboratory, was

chosen to represent a canyon environment unaffected by LANL operations. The concentrations predicted for the Rio Grande from Guaje Canyon runoff would then be assumed to represent fire effects only, and not contain LANL additions. We were concerned, however, that long-term air emissions from LANL could have affected radionuclide concentrations in Guaje Canyon soils, thus making it unsuitable for use as background. To assess this possibility, data from pre-fire soils surveys were reviewed (Fresquez et al. 1998). Although soils data were not available for Guaje Canyon, soil samples collected around the perimeter of LANL, near LANL, and as far away as several miles, were used as indicators of whether soil contamination might exist farther afield. If select radionuclides and other analytes of interest were elevated above background at some distance from the LANL sources, we could not be sure how far away such effects might be seen. On the other hand, if sampling around LANL's perimeter indicated nothing above background concentrations, then we could conclude that locations even more distant from LANL also would show no LANL impact.

The detailed soil sampling study indicated that most radionuclides, trace elements, metals, and organic chemicals were not higher around the perimeter of LANL than in areas that are distant from LANL and unaffected by its operations. Post-fire sampling of organic chemicals in soils around LANL indicated none were above detection limits, except 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin, which is detectable everywhere in northern New Mexico and not related to LANL activities (Fresquez et al. 2000). Based on these data, we infer that concentrations of potential LANL contaminants were also not elevated in Guaje Canyon. The one radionuclide that showed elevated concentrations near LANL was  $^{239}\text{Pu}$ . We believe that the slight elevation in  $^{239}\text{Pu}$  at perimeter locations does not extend as far away as Guaje Canyon, but we cannot demonstrate that with existing data. The predicted maximums we calculated for  $^{239}\text{Pu}$  for the Rio Grande show higher values for storm water runoff from the LANL-affected canyons than for runoff from Guaje Canyon, which is consistent with LANL  $^{239}\text{Pu}$  in LANL canyons. All areas have some  $^{239}\text{Pu}$ , primarily from worldwide fallout from atmospheric testing of nuclear weapons.

#### *2.1.2.2 Comparison of Pre-fire with Post-fire Runoff Concentrations*

Beginning in 1995, storm water along the eastern segment of the Laboratory was sampled primarily with automated sampling stations collocated with gauging stations (Figure 2). We sampled some runoff events manually (grab samples) to supplement the results obtained using automated samplers. The automated sampling stations are near the edge of the Laboratory boundary. Pre-fire concentrations of radionuclides, metals, and organic chemicals are reported in the Laboratory's annual environmental surveillance reports (ESP 1996, 1997, 1998, 1999, and 2000).

Post-fire runoff samples were collected in Pueblo, Los Alamos, Potrillo, and Water Canyons and Cañada del Buey. Additional samples were collected manually from Rendija and Guaje Canyons, which are north of LANL. Post-fire runoff samples were collected June through October. Samples were analyzed for radionuclides ( $^{137}\text{Cs}$  by gamma spectroscopy; isotopic plutonium and uranium, and  $^{241}\text{Am}$  by alpha spectroscopy; and  $^{90}\text{Sr}$  by beta counting), inorganic chemicals (metals and cyanide), and organic chemicals (SVOCs, volatile organic compounds [VOCs], high explosives [HE], and dioxins/furans). Maximum detected concentrations for these LANL canyon stations are listed in tables in the appropriate sections of this report (radiological in Section 3.0 and nonradiological in Section 4.0). A similar list of maximum values for Guaje Canyon is shown. Guaje Canyon maximum values are used because baseline samples taken there will help determine if constituents were strictly fire-related or had a possible LANL contribution.

Average and peak concentrations in unfiltered runoff leaving LANL during the months of June and July in 2000 were significantly greater than pre-fire levels for nearly every analyte. The peak concentrations of these radionuclides increased by factors of approximately 2, while many of the metals increased by a factor of 5 or more. Several organic chemicals were detected in runoff for the first time in the post-fire samples.

Our comparison of upstream to downstream water quality in runoff indicates that Laboratory and fire-related impacts were seen in CY 2000 storm events (Gallaher et al. in preparation). The presence of contributing sources from LANL was seen in the small-magnitude runoff events of June 2 and 3

(Johansen et al. 2001). However, in larger runoff events that occurred later in other watercourses, the major changes in water quality were due primarily to physical and chemical factors caused by the Cerro Grande Fire. The fire-related impacts were substantial, but consistent with those observed in studies of fires elsewhere. Forest fires cause increases in sediment loads, water yield, and concentrations of metals and naturally occurring and worldwide fallout radionuclides in ash (Bitner et al. 2001, Gallaher and Eford, in preparation).

Cerro Grande Fire impacts were evident in sediment from locations upstream of LANL influence and in canyons north of the Laboratory. For example, in Guaje Canyon, concentrations of  $^{137}\text{Cs}$  in suspended sediment in a July 9 runoff sample were approximately 10 times greater than background levels (9.7 versus 1 pCi  $\text{g}^{-1}$ ). The largest suspended sediment concentration of 76,000  $\text{mg L}^{-1}$  that was measured on the Pajarito Plateau during 2000 was recorded for a sample collected in Guaje Canyon on August 8. *We infer from this that fire effects dominated the changes in water quality (as opposed to LANL effects) and that Guaje Canyon was more affected by the fire than were LANL canyons. This conclusion appears to be consistent with maps of fire range and intensity, which show that the greatest fire effects occurred outside of LANL-affected drainages.*

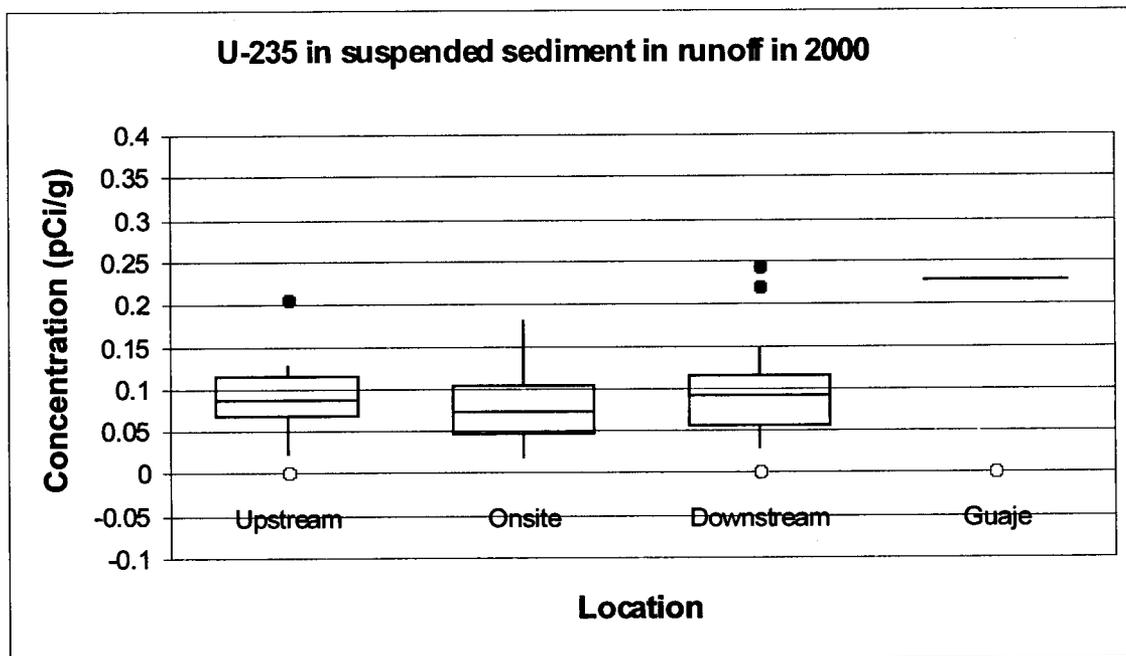
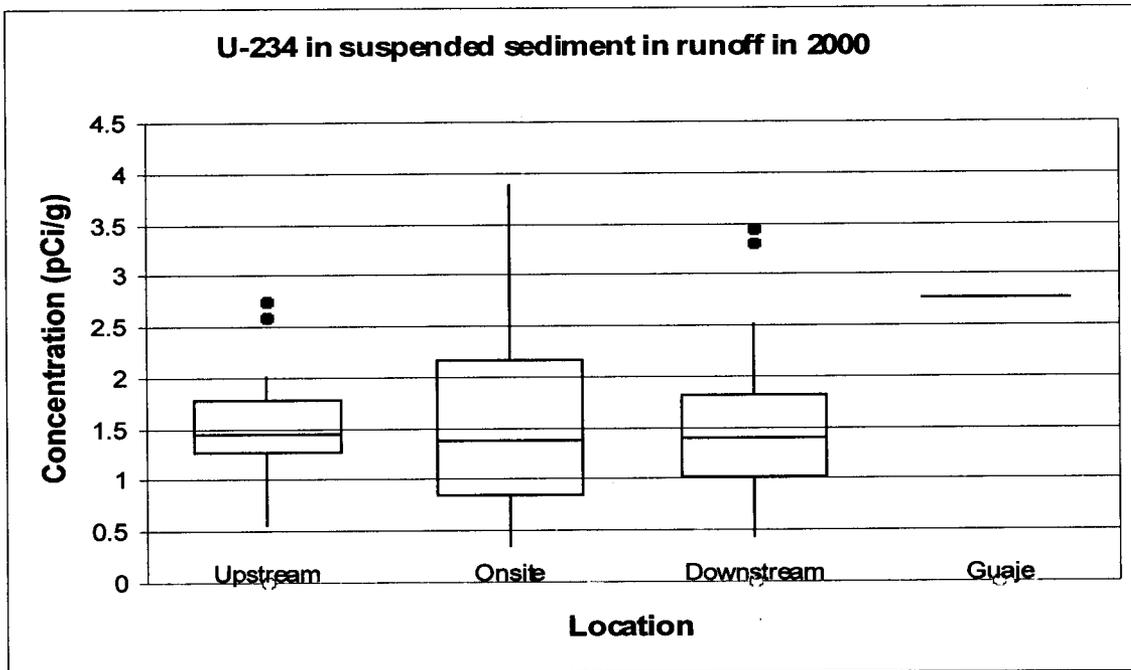
Several of the organic compounds are end products of combustion. Samples of runoff contain an admixture of Laboratory-associated and of fire-associated constituents, in uncertain proportions for many analytes. To be comprehensive, therefore, we have included all of the analytes in the effects assessments, unless compelling evidence exists that specifically eliminates or identifies the Laboratory as being a likely significant source. The radionuclides  $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$  are not included in the dose calculations because the Laboratory-derived proportion does not appear to be significant in CY 2000 runoff samples. This conclusion is supported by the following observations.

- Concentrations of uranium in runoff leaving the Laboratory are similar to those measured in runoff entering the Laboratory. Median concentrations of uranium in the suspended sediment carried by the runoff leaving the Laboratory are similar to those above the Laboratory (Figure 5). This indicates that there was no distinctive addition from Laboratory sources as runoff traversed the Laboratory.
- Runoff samples collected along the Laboratory's downstream boundary were predominantly of a natural uranium isotopic composition. Only 2 of 18 samples contained uranium of nonnatural composition (95% confidence interval). Enriched uranium was detected in runoff from Los Alamos Canyon during the June 2 and 3 storms, but these were relatively small-magnitude runoff events and their impact in Rio Grande water is believed to have been negligible. Depleted uranium was not detected in the samples.
- Historically, LANL-derived uranium composed a small fraction of the total uranium found in LANL and Rio Grande stream sediments (Gallaher et al. 1997, 1999, and in preparation). This conclusion is based on mass spectrometry analyses of LANL stream sediments and of Cochiti Reservoir bottom sediments collected before the fire.

Some organic compounds detected in runoff are of Laboratory origin, whereas others appear to be fire associated. The SVOCs benzoic acid and pyridine are thought to be end products of combustion of forest fuels. Both compounds were detected throughout the runoff season in many fire-affected drainages upstream of LANL and in canyons north of the Laboratory. Several VOCs were detected at low concentrations and appear to have a humanmade (non-fire) origin. We don't normally detect these organic compounds in runoff at these locations. Measuring them after the fire does not allow us to conclude what their source is. These kinds of chemicals, such as toluene, are typically seen in urban settings and, although a LANL source cannot be ruled out, it seems very unlikely, given the absence of these chemicals in pre-fire sampling/analyses.

Laboratory effects were seen in HE compounds in runoff. Relatively small concentrations (low parts-per-billion) of HE compounds were detected in runoff in the Water Canyon drainage system. One of these compounds, HMX, was detected in Indio Canyon at Highway 4 on June 28. HMX and RDX were

detected in a runoff sample collected in lower Water Canyon at Highway 4 in late October. We believe that earlier apparent detections of several other HE compounds (tetryl and several isomers of nitrobenzene



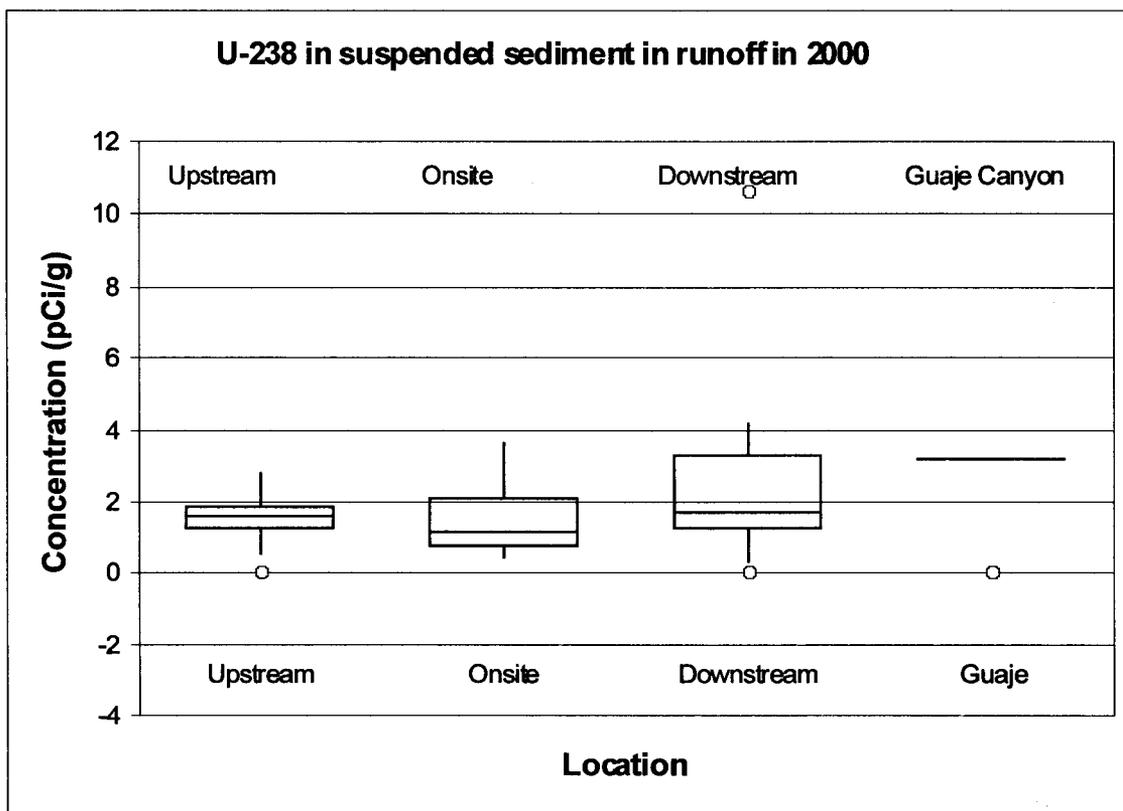


Figure 5. Concentrations of uranium isotopes in suspended sediment carried by runoff in LANL canyons and in Guaje Canyon. These box plots are useful for evaluating differences among groups of data. We use the plots to summarize the distribution of concentrations in sediments in locations upstream (of LANL), LANL onsite, downstream, and at Guaje Canyon for reference. The horizontal line in the middle of the box represents the median concentration. The upper and lower ends of the box delimit the spread of the data by including the middle 50% of the values. Possible statistical outliers are shown with circles.

and nitrotoluene) are false. The original analytical method used resulted in interference effects caused by the high ash content of the samples. Use of an alternative method (ultraviolet diode array), which is not susceptible to ash effects, revealed no HE detections. We conclude that the original results are suspect and are not included in our health effects assessment.

### 2.1.2.3 Comparison of Measured versus Predicted Concentrations

Pre-fire water quality in the Rio Grande was characterized at several locations by the Laboratory's Environmental Surveillance Program. The most complete records are for the Rio Grande at Otowi and Frijoles Canyon stations. Records from the Frijoles Canyon station are used to describe pre-fire levels downstream of LANL. Summaries of Rio Grande at Frijoles radiological water quality data from the years 1993 through 1999 and predicted maximum concentrations potentially caused by post-fire runoff are provided in Sections 3.0 and 4.0 of this report.

### 2.1.3 Sampling of Biota to Evaluate Cerro Grande Fire Effects

We conducted sampling to evaluate whether the Cerro Grande Fire had affected radionuclide and nonradiological concentrations in the biota (fish) in reservoirs of the Rio Grande near LANL (Fresquez et al. 2001a). To look for fire effects, we compared concentrations in Cochiti Reservoir from before and after the fire. If we discerned fire effects, we would then attempt to determine if these effects were related

to LANL impacts by comparing concentrations in Cochiti Reservoir, where LANL impacts might be seen, with concentrations from Abiquiu Reservoir. Abiquiu Reservoir is located on the Rio Chama, upstream from the confluence of the Rio Grande and intermittent streams that cross Laboratory lands and has not been affected by LANL operations. A comparison of radionuclide concentrations in fish collected from Cochiti Reservoir before and after the fire showed that radionuclide concentrations were not statistically higher after the fire than before.

Similarly, a comparison of bottom-feeding fish before and after the fire showed that most trace elements, including mercury, in fish collected from Cochiti Reservoir after the fire were similar to those in fish collected from Cochiti Reservoir before the fire. Only silver, barium, and cadmium concentrations in fish collected from Cochiti Reservoir in 2000 were significantly higher than in fish collected in 1999. These same elements, however, were higher in fish collected from Abiquiu Reservoir after the fire than before the fire. Because Abiquiu Reservoir does not collect water from canyons that were affected by the fire, we conclude that the apparent elevation in these concentrations was not related to the fire. The interpretation presented with the data is that these data may be biased high and that they are not a reliable measure of these analytes.

Cyanide, a compound ion, was detected in elevated concentrations in storm water runoff as a result of the fire (Johansen et al. 2001). However, there was no statistically significant difference in cyanide concentrations in Abiquiu and Cochiti Reservoirs. This comparison indicates that the cyanide compounds in the runoff had no measurable effect on the water quality in Cochiti Reservoir. Additionally, there were no elevated cyanide concentrations in fish during CY 2000 (Fresquez et al. 2001a). Because of these sampling studies, we believe that fish collected and eaten from the Rio Grande or Cochiti Reservoir during 2000 would not have caused a fire-related health effect.

#### **2.1.4 Sampling of Soils and Plants from an Irrigated Field Downstream of Cochiti Reservoir**

After the Cerro Grande Fire, but before the irrigation season, we sampled soil from a cultivated field downstream of Cochiti to evaluate whether LANL effects could be seen in this medium (Fresquez et al. 2001b). Because there were concerns that LANL constituents could wash out of LANL-affected canyons, or that Cerro Grande ash may contain other constituents of potential concern, we resampled the same area after completion of the 2001 irrigation season to evaluate these potential effects. We analyzed for radionuclides and nonradioactive metals. We found no difference in the post-irrigation samples compared with the samples taken before the irrigation season started.

### **3.0 RADIOLOGIC EFFECTS FOR CALENDAR YEAR 2000 RUNOFF<sup>1</sup>**

The potential for doses and potential health effects from radionuclides in post-fire sediments and water is evaluated in this section. The intent of this assessment is to consider the possible health effects of CY 2000 changes in radionuclide concentrations in sediment and water as a result of the Cerro Grande Fire.

#### **3.1 Exposure Assessment for Totavi**

##### **3.1.1 Description of Scenario**

Sediment and soils data from the Los Alamos area were used to provide information on pre-Cerro Grande Fire background values (BVs). Our approach was to compare the data from Totavi with those from LA-4 East and background soils and sediment data (Table 1). Appendix A presents results of

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<sup>1</sup> Dave Kraig is the primary author for Section 3.0 and should be contacted directly with questions regarding this material. He is employed at Los Alamos National Laboratory and can be reached at 505-665-8884.

Table 1. Comparison of radionuclide concentrations. We use LA-4 East as a surrogate to evaluate pre-Cerro Grande concentrations at Totavi. Cesium-137 was the only radionuclide that was higher at Totavi than at LA-4 East and background locations.

Sampling Location or Group	<sup>90</sup> Sr			<sup>137</sup> Cs			<sup>238</sup> Pu			<sup>239, 240</sup> Pu			<sup>241</sup> Am <sup>a</sup>		
	<u>count<sup>b</sup></u>	<u>mean</u>	<u>2 s</u>	<u>count<sup>b</sup></u>	<u>mean</u>	<u>2 s</u>									
Sediment	24	0.23	0.35	24	0.21	0.31	24	0.0021	0.0016	24	0.025	0.040	24	0.026	0.025
Background															
Soil Background	42	0.36	0.30	56	0.42	0.41	56	0.0054	0.0060	56	0.015	0.013	27	0.0064	0.0031
LA-4 East	10	0.054	0.43	28	<b>0.45</b>	0.46	28	0.016	0.015	28	1.1	1.41	28	0.056	0.20
Totavi	8	0.31	0.26	8	<b>1.15</b>	0.72	8	0.008	0.013	8	0.51	0.56	8	-0.039	0.10

<sup>a</sup>By gamma spectroscopy for LA-4 East and Totavi samples.

<sup>b</sup>Number of samples included in mean.

statistical analyses of these data and also provides box plots to allow visual interpretation. The conclusion reached from statistical and visual methods described in Appendix A was the same. Cesium-137 was the only radionuclide seen in the Totavi area that was above background and pre-Cerro Grande Fire concentrations. Therefore,  $^{137}\text{Cs}$  is the only radionuclide considered in the radiological dose assessment (below) of potential Cerro Grande Fire impacts at Totavi. We did not calculate a dose decrement for those radionuclides whose concentrations appear to have decreased since the Cerro Grande Fire.

The average  $^{137}\text{Cs}$  concentrations near Totavi of  $1.15 \text{ pCi g}^{-1}$  were approximately  $0.7 \text{ pCi g}^{-1}$  above the pre-Cerro Grande Fire concentrations measured at LA-4 East of  $0.45 \text{ pCi g}^{-1}$ . Therefore, the dose calculations presented below are based on the net  $0.7 \text{ pCi g}^{-1}$  of  $^{137}\text{Cs}$  attributable to the Cerro Grande Fire. Because we are unable to determine how much of the  $0.7 \text{ pCi g}^{-1}$  of incremental  $^{137}\text{Cs}$  is from LANL sources, our dose calculations are based on the entire increment.

Contaminated sediments derived from up-canyon may have been deposited with the ash on the low floodplain adjacent to the active channel behind (south) the Totavi residences. No recent deposits occurred outside the existing low floodplain, which is approximately 2 m below the level of the residences. There are no agricultural activities within the areas of recent deposition, so farming or production of fruits or vegetables for domestic use were not included in this exposure scenario. If contaminants from the sedimentary deposits became airborne and landed on the plants or in the garden beds of Totavi residents, a small amount of contamination could have been consumed. It is unlikely that a significant exposure could occur through this specific pathway, as described further below. We believe that the exposure scenario presented below (which does not include ingestion of locally grown fruits or vegetables) is realistic. Additionally, we believe it is conservative because the hypothetically exposed individuals who spent time in the streambed were in much more intimate contact with the contamination than those who remained in the residences.

Our scenario considers the hypothetical situation of children playing in the stream area among potentially contaminated sediments. The children are assumed to spend 4.4 hours each day (EPA 1997, Table 5-4) in an area 300 m long and 10 m wide encompassing 300 m along the stream, including the floodplains and banks 5 m on both sides. The scenario is presented according to the various exposure pathways.

### 3.1.2 Inhalation Pathway

While playing, the children would breathe at a rate of  $1.9 \text{ m}^3$  per hour. This rate is an average respiration level for children doing heavy activities (EPA 1997, Table 5-23). The dust in the air they breathe is assumed to come from the local (10-m by 300-m) area. This dust-laden air is assumed to not mix with air outside the  $3000\text{-m}^2$  area. We used dust-loading measurements from the Los Alamos area as a basis to estimate the amount of local sediments and soils that would become airborne and available for inhalation. These measurements indicated that the average number of particles in the respirable size range ( $<10 \mu\text{m}$ ) in ambient air was  $10 \mu\text{g m}^{-3}$ , and that maximum values were approximately  $30 \mu\text{g m}^{-3}$  (data published in annual environmental surveillance reports 1990–1999 and compiled by Steve Reneau, personal communication, 3-10-00). For our calculations, we assumed  $100 \mu\text{g m}^{-3}$ , a very conservative value that we consider an upper limit. By multiplying the concentration of a contaminant in soil by the dust-loading value, we calculate the concentration in air of that contaminant. The amount of dust that was assumed to become airborne was calculated to be proportional to the exposed surface area of each exposed sedimentary horizon. Then, we summed the contributions to the ambient air for all horizons to calculate the total air concentration of each radionuclide.

Because  $^{137}\text{Cs}$  was the only radionuclide that appears to have been elevated in this area from effects of the Cerro Grande Fire, it is the only radionuclide that we included in the inhalation dose calculation. After we calculate the air concentration for a radionuclide, we can calculate the inhalation dose associated with that radionuclide. The inhalation dose is calculated by multiplying the air concentration by the amount of air breathed, and then by a dose conversion factor (DOE 1988) that tells how much dose is received for each intake of radioactive material.

The equation is as follows:

$$D_{inh} = C_{air} * R * T * DCF \quad , \quad [3]$$

where  $D_{inh}$  = the inhalation dose from a radionuclide (mrem),  
 $C_{air}$  = concentration in air of that radionuclide (pCi m<sup>-3</sup>),  
 $R$  = breathing rate (m<sup>3</sup> h<sup>-1</sup>),  
 $T$  = duration that the air concentration was respired (h), and  
 $DCF$  = dose conversion factor from DOE 1988 (mrem pCi<sup>-1</sup>).

Cesium-137 at the incremental soil concentration of 0.7 pCi g<sup>-1</sup> was the only contributor to the inhalation dose as described above.

### 3.1.3 Soil Ingestion Pathway

A soil ingestion rate of 200 mg day<sup>-1</sup>, which is considered a conservative mean estimate (EPA 1997), is assumed. This overestimates the soil potentially ingested in the Totavi area because it assumes that all of the soil the children would hypothetically ingest would come from the stream area behind the Totavi homes. In reality, they would be expected to have ingested soil in other locations, thus decreasing the relative contribution from Totavi and reducing the dose. We weighted the soils similarly as for the inhalation pathway; the amount of soil ingested from each sedimentary unit was proportional to the surface exposure of that unit. As described for inhalation, <sup>137</sup>Cs was the only radionuclide above background (and above pre-Cerro Grande Fire) that contributed to the dose. The dose was calculated according to the equation:

$$D_{ing} = C_{soil} * I * DCF \quad , \quad [4]$$

where  $D_{ing}$  = dose from ingestion of a radionuclide (mrem),  
 $C_{soil}$  = concentration in soil of that radionuclide (pCi g<sup>-1</sup>),  
 $I$  = amount ingested per month (g), and  
 $DCF$  = dose conversion factor from DOE 1988 (mrem pCi<sup>-1</sup>).

### 3.1.4 Direct Exposure Pathway

Some radioactive materials, such as <sup>137</sup>Cs, emit radiation that can cause exposures at some distance from the material. To calculate the exposure potential from these types of materials, a residual radioactive (RESRAD) (Yu et al. 1993) run was performed. The RESRAD (5.82) computer code we use was developed to allow assessment of radiological effects from various exposure pathways. For the run, only the direct-exposure pathway was used. The contamination was assumed to be 9 cm deep spread uniformly over the surface of a 3000-m<sup>2</sup> circular area. The deepest sample was 9 cm deep, so assuming the contaminated zone is this deep everywhere is a conservative assumption. The area was assumed to be circular, even though it is actually rectangular, because that maximizes the calculated direct exposure. Assuming the contamination was all on the surface (as opposed to buried) is also conservative. The radiation emitted by buried radionuclides (in this case <sup>137</sup>Cs) is partially shielded by overlying sediment. Thus, less of the radiation reaches the surface and results in exposure. A person is assumed to be in the area for 4.4 hours per day, unshielded from the radiation.

### 3.1.5 Radiological Doses

The radiological doses calculated according to the method described above were as follows.

<u>Exposure Pathway</u>	Dose per Month of Exposure after September 2000 (mrem)
Inhalation	0.00000008
Ingestion	0.00004
Direct Penetrating Radiation	<u>0.005</u>
Total	0.005

Because the increased local  $^{137}\text{Cs}$  concentration that would cause these dose increments did not occur until October runoff events, a receptor would have been exposed to less than three months at this exposure rate during CY 2000. Three months of exposure would have given a total CY 2000 radiological dose from Cerro Grande Fire effects at Totavi of 0.015 mrem. It is important to note that the majority of this dose was from direct exposure to  $^{137}\text{Cs}$  in the soil/sediment, and that the inhalation dose experienced by children playing directly in the streambed was significantly less. Air concentrations from suspension of contaminated sediment were negligible, which means that indoor residents, who are farther from the source material than the children, inhaled very little  $^{137}\text{Cs}$ , and that very small amounts of the radionuclide were deposited on garden produce in the area.

As surface deposits are eroded in this area, the dose should decrease in the future. As described above, these dose estimates represent total radiological effects from the Cerro Grande Fire and may include an increment from LANL-related contamination that deposited in this area.

### 3.2 Exposure Assessment for Rio Grande Water Users

As sediments wash out of the canyons draining the Jemez Mountains, they may be transported with the water or sediment in the Rio Grande. People downstream can be exposed to radionuclides by swimming in the river, drinking from it, by ingesting fish that have assimilated radionuclides, or by using affected water to irrigate their crops or water livestock. Potential exposure scenarios are dependent on where along the Rio Grande the exposure assessment is considered. Upstream of Cochiti Reservoir, the exposure pathways we have identified include drinking from and/or swimming in the Rio Grande during a runoff event or someone consuming meat from cattle that have drunk from the Rio Grande during runoff. Below Cochiti Reservoir, the primary exposure scenario involves irrigation using Rio Grande water. Although, the same potential exposure scenarios described for above Cochiti also exist below the reservoir, the dose below the dam would be less than above because of increased dilution and mixing as the waters get farther from their source. In fact, as described above, sampling data indicate that there has been no discernable effect in radionuclide concentrations in fields irrigated by post-fire water from the Rio Grande (Fresquez et al. 2001b). However, we cannot disregard the possibility that the sampled field was irrigated only when runoff wasn't occurring. Conditions could occur where some effect would be possible. We wished to calculate maximum potential irrigation effects, which would happen if irrigation only occurred when storm water was in the Rio Grande.

Earlier, we described a method we used to calculate maximum radionuclide concentrations in the Rio Grande from runoff of canyons draining the Jemez Mountains and Pajarito Plateau. Some radionuclide concentration data are available from the USGS post-fire sampling of the Rio Grande for June 28, July 5, July 7, July 11, October 24, and October 26. The maximum concentrations from this sampling are listed in Table 2, as well as the results of the calculations we performed. Unfortunately, we have only one measured radionuclide maximum from the USGS data;  $^{90}\text{Sr}$  at  $12.6 \text{ pCi L}^{-1}$ . This value is of the same magnitude as that predicted during peak runoff ( $16 \text{ pCi L}^{-1}$ ). This comparison indicates that the water

concentrations used in the dose calculations appear to be consistent with the maximum measured value. We use the values shown under “post-fire predicted maximums” in our Rio Grande dose scenarios. Uranium is not considered in this dose assessment because, as discussed earlier, there appears to be negligible LANL or Cerro Grande Fire contribution to the uranium in the Rio Grande.

Table 2. Comparison of predicted peak concentrations in unfiltered water samples from the Rio Grande from runoff pulse with pre- and post-fire measured concentrations. All values are in units of pCi L<sup>-1</sup>.

Analyte	Pre-fire LANL Measurements <sup>a</sup>		Post-fire Predicted Maximums		Post-fire USGS Measurements
	Mean	Max	LANL Canyons	Guaje Canyon	Maximum
<sup>90</sup> Sr	1	9	16	20	12.6
<sup>137</sup> Cs	1	1.1	27	90	N/A <sup>b</sup>
<sup>238</sup> Pu	0.00	0.02	1	0.31	N/A
<sup>239,240</sup> Pu	0.02	0.15	6	4	N/A
<sup>241</sup> Am	0.014	0.05	1	1	N/A

<sup>a</sup>From the Rio Grande at Frijoles sampling station.

<sup>b</sup>No applicable samples are available.

### 3.2.1 Irrigation Scenario

Downstream from Cochiti Reservoir, there is considerable use of irrigation water that could have been affected by runoff since the Cerro Grande Fire. Irrigation water drawn from the river during runoff events and spread on crop fields, fruit trees, or pasture may represent an exposure pathway to humans.

We use the predicted maximum concentrations from the table above and assume that concentrations measured in Rio Grande water above Cochiti remain the same as the water travels through the reservoir. This overestimates effects because mixing with waters in and downstream of the reservoir is likely to provide significant dilution to the concentrations measured or predicted above the reservoir.

The irrigation scenario is based on the following assumptions.

- All irrigation is by flooding (not overhead spraying).
- The irrigation event covers the irrigated area 1-ft deep in water.
- All the radionuclides in the water are deposited in the top 30 cm (1 ft) of soil, and there is no soil cover over the recent deposits.
- The roots of all plants growing in the deposits are in the top 30 cm of soil.
- None of the radionuclides wash off or are leached out of the top 30 cm of soil. Therefore, all radionuclides remain in the rooting zone and the zone available for air dispersion and soil ingestion.
- The farmer lives on-site and consumes meat (cattle and poultry), cow milk, fruits, and vegetables grown there; the cattle and poultry are fed with locally grown grains.
- The farmer consumes 100 mg of soil daily from her/his field.
- The cattle consume 0.5 kg of soil daily from the field.

We used default consumption values provided in RESRAD 5.82 (Yu et al. 1993). These and the rest of the exposure and modeling parameters are shown in the RESRAD output file included as Appendix B.

This scenario is conservative for a number of reasons, including the following:

- It is assumed that all irrigation water used was at the highest predicted post-runoff concentrations. We know that the runoff periods when radionuclide concentrations were at a maximum represent a small fraction of the time the Rio Grande flowed and also a small fraction of the time that irrigation was occurring. The concentrations in the river will be lower during nonflood periods, and use of the river water during these times would reduce the doses calculated below.

- It is assumed that the concentrations in the mixture of these flood-impacted waters remain at the same, undiluted concentrations during their transport down the river to potential exposure locations. This is very conservative because we know some mixing will occur and reduce contaminant concentrations.

Based on the concentrations assuming the source of the flood runoff was LANL-affected canyons, the dose was calculated to be 0.09 mrem per irrigation event. The dose from non-LANL affected canyons was 0.2 mrem. The majority of the dose in both cases is from  $^{137}\text{Cs}$  exposure. It may seem counterintuitive that the dose would be smaller from canyons that have LANL-contaminated sediments than from those that are free of such contamination. We believe that the fundamental cause(s) of the higher cesium and strontium in the non-LANL canyons are related to aspects of the fire such as burn duration, burn intensity and heat, amount of biomass burned, and the length of transport to the Rio Grande. Even though LANL may have added some small increment of plutonium, americium, cesium, or strontium to the flow of the Rio Grande, that increment was so much smaller than the incremental cesium from fire effects that the LANL effect is dwarfed by the fire effect. Perhaps more importantly, some non-LANL canyons were more affected by the fire than LANL canyons, so their contribution to the river is higher than that from LANL canyons. Finally, as we mentioned earlier, actual sampling of one field that was irrigated since the fire showed no discernable increases in the concentrations of radionuclides in soils in the field or on the plants grown in those soils.

### 3.2.2 Evaluation of Drinking Water from or Swimming or Fishing in the Rio Grande

Assuming someone drank unfiltered water from the Rio Grande during the runoff with the highest radionuclide concentrations (values from Table 1 above), their dose would be 0.04 mrem per liter consumed from potential LANL-affected canyons, or 0.03 mrem from canyons not affected by LANL operations. The largest dose contributor in either case would be  $^{239}\text{Pu}$ .

If someone swam in the Rio Grande during the time of highest radionuclide concentration, their dose (based on input from canyons potentially affected by LANL) would be approximately 0.00002 mrem per hour of swimming, or approximately 0.00006 mrem per hour based on floodwater concentrations from non-Laboratory affected canyons. Essentially all of this dose would result from direct exposure to  $^{137}\text{Cs}$ .

As described earlier, fish collected from Cochiti Reservoir did not show increases in radionuclide concentrations after the fire. Therefore, we believe that fish collected and eaten from the Rio Grande or Cochiti Reservoir during CY 2000 would not have caused a fire-related dose increment.

### 3.2.3 Cattle Watering Scenario

Livestock watered in the Rio Grande after it was affected by storm water runoff. If these cattle drank contaminated water from the Rio Grande, the consumption of their meat by humans could result in a radiation dose. We can calculate this dose by evaluating the amount of radionuclides that the cattle consumed, how much of the radionuclides that were consumed ended up in the cattle tissues, and how much of these radionuclides would be passed to humans if they consumed meat from the cattle.

The maximum potential radiation dose from all radionuclides to humans from this pathway was estimated conservatively by the following equation:

$$D_{cati} = RG_{max} * Q * F_i * U_m * DCF_i \quad [5]$$

- where
- $D_{cati}$  = the calculated monthly radiation dose (mrem) from intake of radionuclide  $i$ ,
  - $RG_{max}$  = the predicted highest concentration for radionuclide  $i$  in the Rio Grande (pCi L<sup>-1</sup>),
  - $Q$  = the water intake rate of 50 L d<sup>-1</sup> by cattle (Kennedy and Streng 1992, p. 6.19),
  - $F_i$  = the intake-to-meat transfer factor (Kennedy and Streng 1992, p. 6.29), which is the ratio of the radionuclide concentration in meat (pCi kg<sup>-1</sup>) to the daily radionuclide intake (pCi d<sup>-1</sup>), for radionuclide  $i$ ,

- $U_m$  = meat consumption rate by humans of  $4.9 \text{ kg month}^{-1}$  (taken from the  $59 \text{ kg y}^{-1}$  value in Kennedy and Streng [1992], 6.38), and
- $DCF_i$  = the dose conversion factor, including appropriate unit conversion factors, (DOE 1988) for radionuclide  $i$  ( $\text{mrem pCi}^{-1}$ ).

The total dose to a human from ingesting cattle that watered exclusively during runoff from LANL canyons is then found by summing the dose ( $D_{\text{cati}}$ ) from each of the radionuclides. This dose estimate is conservative because it

- uses the highest predicted concentration for each radionuclide in water, including the suspended sediment and the dissolved fraction,
- assumes that the radioactive material in the suspended sediment is as biologically available for uptake by the cattle as is the radioactive material dissolved in the water,
- assumes that the radionuclide concentration in the meat has reached equilibrium with the maximum daily intake, so it can be described by the transfer factor. This is unlikely to have taken place in the short time since the runoff occurred from potentially LANL-affected canyons,
- assumes that all the cattle's water comes from the Rio Grande and that the cattle drink only when the predicted concentrations are at their maximum. We know that the runoff periods when radionuclide concentrations were elevated represent a small fraction of the time the Rio Grande flowed, and also a small fraction of the time the cattle watered there.

The dose calculations shown in Table 3 indicate that the dose from eating meat from cattle that have watered in the Rio Grande after flooding caused by runoff from LANL canyons is less than 0.01 mrem. Perspective on this conservatively calculated dose and the others above is provided below.

Table 3. Potential monthly doses to a human from ingestion of meat from cattle that have watered in the Rio Grande, drinking diluted runoff from LANL canyons. For comparison, the predicted monthly dose form Guaje Canyon runoff, which does not flow through LANL property, is also presented.

Radionuclide	Concentration in Rio Grande Water ( $\text{pCi L}^{-1}$ )		Transfer Factor ( $\text{pCi kg}^{-1}$ per $\text{pCi d}^{-1}$ ) <sup>a</sup>	Dose Conversion Factor ( $\text{mrem pCi}^{-1}$ ) <sup>b</sup>	Effective Dose Equivalent (mrem)	
	LANL	GUAJE			LANL	GUAJE
<sup>90</sup> Sr	16	20	3.0E-04	0.00013	0.00015	0.00019
<sup>137</sup> Cs	27	90	2.0E-02	0.00005	0.0066	0.022
<sup>238</sup> Pu	1	0.31	5.0E-07	0.0038	$4.7 \times 10^{-7}$	$1.5 \times 10^{-7}$
<sup>239, 240</sup> Pu	6	4	5.0E-07	0.0043	$3.2 \times 10^{-6}$	$2.1 \times 10^{-6}$
<sup>241</sup> Am	1	1	3.5E-06	0.0045	$3.9 \times 10^{-6}$	$3.9 \times 10^{-6}$
				Total	0.007	0.02

<sup>a</sup>Kennedy and Streng (1992), p. 6.29.

<sup>b</sup>DOE 1988.

Table 4 shows the radiological doses calculated for all the scenarios we evaluated quantitatively. The doses from Guaje Canyon runoff are shown to indicate effects independent of LANL influences.

Table 4. Summary dose table for potential radiological exposures in 2000 in the aftermath of the Cerro Grande Fire. All doses are in units of mrem.

Exposure Location or Scenario	Dose at Totavi	Dose from Runoff from LANL Canyons	Dose from Runoff from Guaje Canyon	Dose Explanation
Dose at Totavi	0.005	N/A <sup>a</sup>	N/A	per month of exposure, no exposure before October
Rio Grande Irrigation	N/A	0.09	0.2	per irrigation event assumed to cover field one foot deep in water
Rio Grande Drinking	N/A	0.04	0.03	per liter of unfiltered Rio Grande water ingested during runoff event
Rio Grande Swimming	N/A	0.00002	0.00006	per hour of swimming in Rio Grande during runoff event
Cattle Watering	N/A	0.007	0.02	per month of ingestion of affected cattle
<b>TOTAL</b>	<b>0.005<sup>b</sup></b>	<b>0.14</b>	<b>0.25</b>	<b>Per exposure as described above</b>

<sup>a</sup>N/A = not applicable.

<sup>b</sup>Assuming no other exposure routes other than Totavi residential.

### 3.3 Cerro Grande Radiological Dose Perspective

To put some perspective on these doses, a person traveling on a two-hour flight in a jet airliner would receive approximately 1 mrem, and people living in the Los Alamos area receive approximately 360 mrem from natural sources each year. No adverse health effects are expected from the short-term increase in natural or other radioactivity associated with the Cerro Grande Fire.

## 4.0 NONRADIOLOGICAL EFFECTS FOR CALENDAR YEAR 2000 RUNOFF<sup>2</sup>

The potential for adverse health effects from chemicals in post-fire sediments and water is evaluated in this section. Chemicals may have carcinogenic or noncarcinogenic effects. Assessments of possible carcinogenic effects are based on long-term exposure (chronic). The possible health effects from noncarcinogens also are typically assessed based on long-term exposures. The intent of this assessment is to consider the possible adverse health effects of CY 2000 increases in the concentrations of potentially hazardous chemicals in sediment and water. Thus, the time period evaluated in this assessment (3 to 6 months post-fire in 2000) is much less than the time frame typically considered for chronic exposures (for example, chronic exposure to a resident is considered over a 30-year period). Considerations related to acute and chronic exposures will be addressed as related to sediment and water assessments.

### 4.1 Exposure Assessment for Totavi

#### 4.1.1 General Scenario Description

As discussed in the radiological effects section, sediments derived from up-canyon have been deposited with the ash on the low floodplain adjacent to the active channel behind (south) the Totavi residences. No recent deposits occurred outside the existing low floodplain, which is approximately 2 m below the level of the residences. There are no agricultural activities within the areas of recent deposition, so farming or production of fruits or vegetables for domestic use were not included in this exposure scenario.

<sup>2</sup> Randall Ryti is the primary author for Section 4.0 and should be contacted directly with questions regarding this material. He is employed at Neptune and Company, Inc., Los Alamos New Mexico, 505-662-0707.

The constituents measured in post-fire sediment samples at Totavi are provided in Table 5. Detailed comparisons of post-fire sediment concentrations to pre-fire levels are provided in Appendix A. Metals were measured in samples collected at Totavi, and organic chemicals/cyanide were measured in sediments at the weir in Los Alamos Canyon. Pre-fire concentrations in Los Alamos Canyon (reach LA-4E, Reneau et al. 1998c) and general background levels (sediment BVs; Rytí et al. 1998) are also provided in Table 5. The pre-fire values for LA-4 East are believed to be representative of pre-fire conditions at Totavi. Comparing sediment concentrations at Totavi with those at LA-4 East indicates if increases have been seen at Totavi, those increases could be attributed to the fire effects. Concentrations of these constituents may be elevated in post-fire sediments at Totavi due to the Cerro Grande Fire, or increases could reflect mobilization of contaminants from Laboratory sources. Although it is most likely that only fire effects are reflected in these concentrations, we will evaluate the maximum concentrations of all chemicals in Table 5 because we cannot rule out a Laboratory contribution for these analytes.

#### **4.1.2 Scenario for Exposure to Nonradionuclides at Totavi**

Exposure pathways considered in the radiological effects assessment for Totavi included inhalation and ingestion of sediment and direct exposure (external radiation). For nonradiological assessments, dermal absorption should also be considered because it is an important pathway for some lipophilic organic chemicals that were detected. However, direct exposure need not be considered for these nonradiological chemicals.

Because acute health effects for chemicals in soil are not considered routinely, we chose to evaluate concentrations of these chemicals in terms of their potential chronic health effects. This introduces considerable conservatism because it carries the implicit assumption that exposures have occurred over a long time period when, in fact, they haven't. A general, screening level assessment of chronic health risks associated with residential exposure pathways was completed to evaluate whether detailed site-specific assessments for CY 2000 effects are warranted. Potential adverse health effects are considered separately for chemical carcinogens and noncarcinogens.

To evaluate the potential adverse health effects of these chemicals, their maximum concentrations were compared with residential soil screening levels derived by the New Mexico Environment Department (NMED; NMED 2000a). NMED guidance on human health screening assessments advocates using maximum values (NMED 2000b). Screening levels are based on chronic exposure scenarios that assume incidental soil ingestion, inhalation of particulates or vapors, and dermal contact. These pathways are possible in lower Los Alamos Canyon, but the intensity and frequency of exposure are likely overestimated compared with CY 2000 exposures. The frequency and magnitude of exposure to these pathways are based on daily contact for 6 years for noncarcinogens and 30 years for carcinogens. Carcinogen exposure integrates exposure to children (6 years) and adult (24 years). *Thus, use of screening levels calculated for chronic exposure to evaluate possible adverse health effects from only a part of one year will greatly overestimate possible adverse health effects. In addition, selection of the maximum value will also overestimate chronic exposure, which is much more likely to be based on exposure to average concentrations.*

Seven chemical carcinogens were identified at Totavi above pre-fire concentrations in post-fire CY 2000 sediment deposits (Table 6). To evaluate the carcinogenic risk potential of these chemicals, their concentrations were compared with soil screening levels derived by the NMED (NMED 2000a). Soil screening levels for carcinogens are calculated based on a target risk level of one in one hundred thousand (stated numerically as  $1 \times 10^{-5}$ ). For one chemical, 2,3,7,8-TCDD equivalents, there is no NMED screening level and the value from Environmental Protection Agency (EPA) Region 6 was used (EPA 2000b). The EPA value was multiplied by 10 because EPA uses a target risk level of one in a million ( $1 \times 10^{-6}$ ). This adjustment to the 2,3,7,8-TCDD screening value put all carcinogens on the same target risk basis.

Twenty-two chemicals with noncarcinogenic effects were identified at Totavi above pre-fire concentrations in post-fire CY 2000 sediment deposits (Table 6). To evaluate the potential health effects

of these chemicals, their concentrations were compared with soil screening levels derived by NMED 2000a). However, there is no NMED screening level for lead, and the value from EPA Region 6 was used (EPA 2000a).

In addition, there are four chemicals without residential soil screening levels that were identified above pre-fire concentrations in CY 2000 sediment deposits (Table 6).

Table 5. Concentrations of nonradiological constituents in sediment. Bolded values in last column are those that are greater than their pre-fire equivalent.

Analyte	Pre-fire Concentrations		Post-fire Concentrations
	Sediment BV (mg kg <sup>-1</sup> )	Reach LA-4E maximum (mg kg <sup>-1</sup> )	Totavi maximum (mg kg <sup>-1</sup> )
Aluminum	15400	5480	<b>8900</b>
Arsenic	3.98	2.9	<b>3.4</b>
Barium	127	104	<b>230</b>
Calcium	4420	6980	<b>14000</b>
Chromium, total	10.5	5.3	<b>9</b>
Cobalt	4.73	4.4	<b>6.3</b>
Copper	11.2	10.8	<b>16</b>
Cyanide, total	0.82	N/A <sup>a</sup>	<b>2.5<sup>b</sup></b>
Iron	13800	7530	<b>13000</b>
Lead	19.7	13.2	<b>31</b>
Magnesium	2370	1940	<b>3100</b>
Manganese	543	364	<b>1000</b>
Nickel	9.38	7.1	<b>11</b>
Potassium	2690	1530	<b>2000</b>
Selenium	0.3	0.83	0.49
Vanadium	19.7	13.1	<b>20</b>
Zinc	60.2	31.6	<b>87</b>
Benzo(a)anthracene	N/A	N/A	0.25 <sup>b</sup>
Benzo(a)pyrene	N/A	N/A	0.26 <sup>b</sup>
Benzo(b)fluoranthene	N/A	N/A	0.33 <sup>b</sup>
Benzo(g,h,i)perylene	N/A	N/A	0.16 <sup>b</sup>
Chrysene	N/A	N/A	0.27
Fluoranthene	N/A	N/A	0.52
Methylphenol[4-]	N/A	N/A	2
Naphthalene	N/A	N/A	0.25
Phenanthrene	N/A	N/A	0.46
Pyrene	N/A	N/A	0.58
Summed 2,3,7,8-TCDD Equivalent	N/A	N/A	3.45 × 10 <sup>-6</sup>

<sup>a</sup>N/A = not analyzed.

<sup>b</sup>Sample collected from the weir in Los Alamos Canyon.

Table 6. List of analytes evaluated in nonradiological health assessments of lower Los Alamos Canyon CY 2000 flood deposits.

Analyte	Basis of NMED Soil Screening Levels
Aluminum	Noncarcinogen
Arsenic	Carcinogen and noncarcinogen
Barium	Noncarcinogen
Calcium	No toxicity value
Chromium, total	Carcinogen
Cobalt	Noncarcinogen
Copper	Noncarcinogen
Cyanide, total	Noncarcinogen
Iron	Noncarcinogen
Lead	Noncarcinogen
Magnesium	No toxicity value
Manganese	Noncarcinogen
Nickel	Noncarcinogen
Potassium	No toxicity value
Selenium	Noncarcinogen
Vanadium	Noncarcinogen
Zinc	Noncarcinogen
Benzo(a)anthracene	Carcinogen and noncarcinogen
Benzo(a)pyrene	Carcinogen and noncarcinogen
Benzo(b)fluoranthene	Carcinogen and noncarcinogen
Benzo(g,h,i)perylene	No toxicity value
Chrysene	Carcinogen and noncarcinogen
Fluoranthene	Noncarcinogen
Methylphenol[4-]	Noncarcinogen
Naphthalene	Noncarcinogen
Phenanthrene	Noncarcinogen
Pyrene	Noncarcinogen
Summed 2,3,7,8-TCDD Equivalent	Carcinogen

#### 4.1.2.1 Results: Chemical Carcinogens

Results of a comparison of maximum post-fire values with soil screening levels for carcinogens are summarized in Table 7. None of the concentrations for individual chemical carcinogens at Totavi are greater than their respective soil screening levels.

After determining that no individual chemical at Totavi had a concentration above its corresponding screening level, we needed to evaluate whether the risk from all chemicals combined could present significant risk. Additive risk for these carcinogens was evaluated by summing the ratios of the maximum detected value to the soil screening concentration. Because the NMED soil screening level for carcinogens is calculated based on a target risk of one in one hundred thousand ( $1 \times 10^{-5}$ ), a normalized sum of one equates to that target risk level under the assumption of chronic exposure. For Totavi area, the sum is 1.5, which equates to a chronic risk level of 15 cancers in one million ( $1.5 \times 10^{-5}$ ) for an exposure duration of 30 years. Thus, under the protective assumptions of residential exposure and use of maximum values (which carries the implicit assumption that sediment concentrations remain at their maximum levels), the predicted chronic cancer risk for carcinogens from Totavi sediment is greater than the target risk of one in one hundred thousand ( $1 \times 10^{-5}$ ) used by NMED.

More than one-half of the potential chronic cancer risk is associated with arsenic, and it is worth considering this chemical in more detail. Arsenic is a naturally occurring trace mineral and was measured

in pre-fire sediment samples from reach LA-4E and also measured in background sediments. Thus, one can assess the incremental change in chronic cancer risks from pre-fire sediment concentrations to post-fire levels. Considering only arsenic, the difference in predicted chronic cancer risks for the maximum concentrations from pre-fire to post-fire levels is approximately one additional cancer per million ( $1 \times 10^{-6}$ , based on  $[0.87-0.74] \times 1 \times 10^{-5}$ ). The normalized sum for the background values is approximately 1 and the normalized sum for reach LA-4E is approximately 0.8 (Table 7).

Overall chronic incremental cancer risks may be computed as the difference between the post-fire normalized sum and these pre-fire sums. Because the target risk level should be based on an incremental (or excess) risk, risks associated with ambient levels of chemicals in soil should be considered in evaluating cancer risks. The estimated incremental risks associated with post-fire concentrations are in the range of 5 to 7 in one million ( $5 \times 10^{-6}$  to  $7 \times 10^{-6}$ ), which is less than the target risk level selected by NMED for calculating soil screening levels.

Increased concentrations of some carcinogens are likely from combustion of wood and other organic material burned during the Cerro Grande Fire. Such fire-related chemicals include arsenic, chromium, and TCDD. However, the majority of the change in estimated cancer risks are associated with benzo(a)pyrene and other carcinogenic polycyclic aromatic hydrocarbons (PAHs). PAHs may be pyrogenic in origin but these PAHs are more typically petrogenic in origin. These detected concentrations of PAHs are low compared with other parts of the watershed in closer proximity to urban runoff sources, e.g., upper DP Canyon (Katzman et al. 1999). Thus, one possible source for these carcinogenic PAHs is non-point source urban or industrial runoff from the Los Alamos townsite.

Increased cancer risks are possible for post-fire sediment deposits near Totavi. However, the levels of these risks are less than those considered unacceptable by NMED ( $1 \times 10^{-5}$  target risk) and EPA (risk range of  $1 \times 10^{-4}$  to  $1 \times 10^{-6}$ ). Because the screening level assessment of chemical carcinogens under protective exposure assumptions (use of maximum concentration and daily exposure) and chronic duration yielded risk estimates less than established criteria, further site-specific characterization of risks does not appear to be warranted.

Table 7. Comparison of maximum post-fire concentrations with soil screening levels for carcinogens.

Analyte	Totavi Maximum (mg kg <sup>-1</sup> )	Sediment BV (mg kg <sup>-1</sup> )	NMED		Totavi ratio (max SSL <sup>-1</sup> )	BV ratio (BV SSL <sup>-1</sup> )	Reach LA-4E ratio (LA-4E SSL <sup>-1</sup> )
			Reach LA-4E maximum (mg kg <sup>-1</sup> )	Soils Screening Level (SSL) (mg kg <sup>-1</sup> )			
Arsenic	3.4	3.98	2.9	3.9	0.872	1.021	0.744
Chromium, total	9	10.5	5.3	310	0.029	0.034	0.017
Benzo(a)anthracene	0.25 <sup>a</sup>	N/A <sup>b</sup>	N/A	6.2	0.040	N/C <sup>c</sup>	N/C
Benzo(a)pyrene	0.26 <sup>a</sup>	N/A	N/A	0.62	0.419	N/C	N/C
Benzo(b)fluoranthene	0.33 <sup>a</sup>	N/A	N/A	6.2	0.053	N/C	N/C
Chrysene	0.27 <sup>a</sup>	N/A	N/A	610	0.000	N/C	N/C
Summed 2,3,7,8-TCDD Equivalent	$3.5 \times 10^{-6a}$	N/A	N/A	$3.9 \times 10^{-5d}$	0.089	N/C	N/C
<b>Total</b>					<b>1.50</b>	<b>1.05</b>	<b>0.76</b>

<sup>a</sup>Concentration is taken from samples collected near the weir in Los Alamos Canyon.

<sup>b</sup>N/A = not analyzed.

<sup>c</sup>N/C = not calculated, one or more values needed for calculation are not available.

<sup>d</sup>Value for 2,3,7,8-TCDD is from EPA Region 6 and was multiplied by 10 to shift the risk level to  $1 \times 10^{-5}$ .

#### 4.1.2.2 Results: Noncarcinogens

Maximum post-fire values are compared with soil screening levels for noncarcinogens in Table 8. None of the concentrations for individual noncarcinogens are greater than their respective soil screening levels. Potential additive effects were evaluated by summing the ratios of the maximum detected value to the soil screening concentration. This normalized sum is equivalent to the hazard index under an

assumption of simple additivity across different types of noncarcinogenic effects. If the normalized sum is less than 1.0, then no cumulative effects of noncarcinogens are indicated. A sum greater than 1.0 would trigger further evaluation to determine the organ systems affected by the individual chemicals. The sum of ratios for the Totavi data is 1.2, which is the same as the sum for the BVs and approximately twice the sum for reach LA-4E.

The change in hazard index between Totavi and pre-fire levels (reach LA-4E) is primarily from changes in the concentrations of metals. Two metals, iron and manganese, contribute most of the change in the hazard index (0.32 of the 0.49 change in hazard index between Totavi and Reach LA-4E). There is evidence from post-fire sampling of the Cerro Grande Fire ash, as well from literature reports of other fires, that metals in general and these metals in particular are increased by combustion of wood and other organic material (LANL 2000; Bitner et al. 2001).

One metal, iron, contributes approximately one-half of the total normalized sum and it is worth considering this analyte in more detail (Table 8). The NMED soil screening value for iron is based on a provisional reference dose that is set at the upper end of the mean dietary iron intake ( $0.3 \text{ mg kg}^{-1} \text{ day}^{-1}$  from EPA 1996). The iron reference dose is set at the upper end of its beneficial range as a nutrient because there is some evidence that higher doses lead to gastrointestinal upset, but there are inadequate data to set a reliable effect threshold for other adverse health effects (EPA 1996). The iron maximum concentration yields a ratio of 0.57 (equal to a dose of  $0.17 \text{ mg kg}^{-1} \text{ d}^{-1}$ ) for sediments from Totavi. This value is well within the intake level of 0.15 to  $0.27 \text{ mg kg}^{-1} \text{ d}^{-1}$  that is sufficient to protect against iron deficiency and insufficient to cause toxic effects (EPA 1996).

Because of the apparent lack of adverse effects associated with iron at the concentrations observed at Totavi, we calculate the normalized sum for all chemicals excluding iron. The sum of ratios, excluding iron, for the Totavi data is 0.6, which is the same as the sum for the BVs and approximately twice the sum for reach LA-4E. These normalized totals are not suggestive of any chronic adverse health effects from noncarcinogens, either individually or in aggregate under an assumption of additivity of effects. Thus, given the absence of unacceptable chronic noncarcinogenic effects, no site-specific assessment is needed for exposure to CY 2000 flood deposits.

#### *4.1.2.3 Results: Chemicals without Toxicity Information*

There is no toxicity information for four chemicals that were detected in post-fire CY 2000 sediment deposits (Table 9). Three of these chemicals, calcium, magnesium, and potassium, are essential macronutrients, and based upon EPA guidance (EPA 1989), do not require further consideration for possible adverse health effects if the concentrations measured are not substantially different from natural levels. The concentrations differ statistically from background or pre-fire levels, but the difference in maximum concentrations between pre-fire (LA4-E) and post-fire is less than a factor of 2. Another essential macronutrient, iron, was evaluated with the noncarcinogens because a provisional reference dose based on the upper bound of average dietary intake has been developed (EPA 1996). The other chemical without toxicity information, benzo(g,h,i)perylene, is a PAH and is classified by EPA as a Class D carcinogen (inadequate evidence of carcinogenicity). Few chemicals are classified as Class E, or demonstrated not carcinogenic, because of the difficulty in showing no carcinogenic or mutagenic effects in animal studies. Thus, it is appropriate to only consider possible noncarcinogenic effects of benzo(g,h,i)perylene. One may consider pyrene as a surrogate based on structural similarity to benzo(g,h,i)perylene, and because pyrene has the most protective reference dose among the noncarcinogenic PAHs. If one uses pyrene as a surrogate for benzo(g,h,i)perylene, the maximum post-fire concentration represents less than 0.1% of the pyrene screening level.

Thus, there are no apparent adverse chronic health effects at these concentrations for those chemicals that lack toxicity information. No further assessment of site-specific exposures to CY 2000 flood deposits is needed.

Table 8. Comparison of maximum post-fire concentrations with soil screening levels for noncarcinogens.

Analyte	Totavi maximum (mg kg <sup>-1</sup> )	Sediment BV (mg kg <sup>-1</sup> )	Reach	NMED Soils	Totavi ratio	BV ratio	Reach
			LA-4E maximum (mg kg <sup>-1</sup> )	Screening Level (mg kg <sup>-1</sup> )			LA-4E ratio
Aluminum	8900	15400	5480	74000	0.120	0.208	0.074
Arsenic	3.4	3.98	2.9	22	0.155	0.181	0.132
Barium	230	127	104	5200	0.044	0.024	0.020
Cobalt	6.3	4.73	4.4	4500	0.001	0.001	0.001
Copper	16	11.2	10.8	2800	0.006	0.004	0.004
Cyanide, total	2.5 <sup>a</sup>	0.82	N/A <sup>b</sup>	1200	0.002	0.001	N/A
Iron	13000	13800	7530	23000	0.565	0.600	0.327
Lead	31	19.7	13.2	400 <sup>c</sup>	N/C <sup>d</sup>	N/C	N/C
Manganese	1000	543	364	7800	0.128	0.070	0.047
Nickel	11	9.38	7.1	1500	0.007	0.006	0.005
Selenium	0.49	0.3	0.83	380	0.001	0.001	0.002
Vanadium	20	19.7	13.1	530	0.038	0.037	0.025
Zinc	87	60.2	31.6	23000	0.004	0.003	0.001
Benzo(a)anthracene	0.25 <sup>a</sup>	N/A	N/A	1700	<0.001	N/C	N/C
Benzo(a)pyrene	0.26 <sup>a</sup>	N/A	N/A	1700	<0.001	N/C	N/C
Benzo(b)fluoranthene	0.33 <sup>a</sup>	N/A	N/A	1700	<0.001	N/C	N/C
Chrysene	0.27 <sup>a</sup>	N/A	N/A	1700	<0.001	N/C	N/C
Fluoranthene	0.52 <sup>a</sup>	N/A	N/A	2300	<0.001	N/C	N/C
4-Methylphenol	2 <sup>a</sup>	N/A	N/A	310	0.006	N/C	N/C
Naphthalene	0.25 <sup>a</sup>	N/A	N/A	53	0.005	N/C	N/C
Phenanthrene	0.46 <sup>a</sup>	N/A	N/A	1800	<0.001	N/C	N/C
Pyrene	0.58 <sup>a</sup>	N/A	N/A	1800	<0.001	N/C	N/C
<b>Total</b>					<b>1.16</b>	<b>1.18</b>	<b>0.67</b>
<b>Total without Iron</b>					<b>0.60</b>	<b>0.58</b>	<b>0.34</b>

<sup>a</sup>Concentration is taken from samples collected near the weir in Los Alamos Canyon.

<sup>b</sup>N/A = not analyzed.

<sup>c</sup>Value for lead is from EPA Region 6.

<sup>d</sup>N/C = not calculated, one or more values needed for calculation are not available.

Table 9. Compilation of maximum post-fire concentrations for analytes without toxicity information.

Analyte	Totavi maximum (mg kg <sup>-1</sup> )	Sediment BV (mg kg <sup>-1</sup> )	Reach LA-4E maximum (mg kg <sup>-1</sup> )
Calcium	14000	4420	6980
Magnesium	3100	2370	1940
Potassium	2000	2690	1530
Benzo(g,h,i)perylene	0.16 <sup>a</sup>	N/A <sup>b</sup>	N/A

<sup>a</sup>Concentration is taken from samples collected near the weir in Los Alamos Canyon.

<sup>b</sup>N/A = not analyzed.

## 4.2 Exposure Assessment for Rio Grande Water Users

### 4.2.1 General Scenario Description

As discussed in Section 3.0, as sediments wash out of the canyons draining the Jemez Mountains, they may be transported with the water or sediment into the Rio Grande. People downstream may be exposed to chemicals by swimming in the river, drinking from it, by ingesting fish that have assimilated potentially hazardous chemicals, or by using affected water to irrigate their crops or water livestock. Upstream of Cochiti Reservoir, the exposure pathways we have identified include drinking from and/or swimming in the Rio Grande during a runoff event or someone consuming meat from cattle that have

drunk from the Rio Grande during runoff. Below Cochiti Reservoir, the primary exposure scenario involves irrigation using Rio Grande water. Although the same potential exposure scenarios described for above Cochiti also exist below the reservoir, any potential health effects from chemicals in water below the dam would be less than above because of increased dilution and mixing as the waters get farther from their source. As described earlier, sampling data indicate that fields irrigated with Rio Grande water since the Cerro Grande Fire show no discernable difference from before the fire (Fresquez et al. 2001). However, this lack of an effect could be explained if the irrigation did not occur when Cerro Grande-related flood runoff was in the Rio Grande system. Because we cannot disregard the possibility that other fields, which were not sampled, may have had been affected by irrigation water, we calculated maximum potential irrigation effects that would happen if all the irrigation water from the Rio Grande was taken during storm-water runoff.

Earlier, we described a method used to calculate maximum chemical concentrations in the Rio Grande from runoff of canyons draining the Jemez Mountains and Pajarito Plateau. The results of those calculations and the applicable comparisons are tabulated in Table 10. These are the results from unfiltered samples. Table 11 provides results from filtered samples.

We use the values under "Predicted Post-Fire" in our Rio Grande dose scenarios below. These various scenarios and the major exposure parameters are described individually below. We also are including the results from filtered water samples to allow comparison with water quality standards derived for filtered water.

#### **4.2.2 Irrigation Scenarios**

Downstream from Cochiti Reservoir, there is considerable use of irrigation water that could have been affected by runoff since the Cerro Grande Fire. Irrigation water drawn from the river during runoff events and spread on crop fields, fruit trees, or pasture represents a potential exposure pathway to humans.

We use the predicted maximum concentrations from the table above and assume that concentrations measured in Rio Grande water above Cochiti remain the same as the water travels through the reservoir. This is a highly conservative assumption (overestimates potential effects) because mixing with waters in and downstream of the reservoir is likely to provide significant dilution to the concentrations measured above the reservoir.

For the radionuclide effect assessment, the dose based on a flood irrigation event was calculated based on family farm scenario. Exposure pathways were the same as those used at Totavi, with the addition of vegetable, fruit, meat (poultry and beef), and milk from cows that were pastured on fields irrigated with floodwaters. The assessment of dose from these pathways was evaluated through use of the RESRAD model (Yu et al. 1993). Evaluation of potential health effects from nonradionuclides in pathways such as vegetable and meat ingestion, would require a forward calculation of risks and noncarcinogenic effects. Key inputs to this calculation are the uptake and transfer factors from water or soil to plants and animals. In lieu of a forward risk calculation, the possible adverse health effects are evaluated in a semiquantitative way.

The irrigation scenario is based on the same assumptions identified for the radiological assessment above with the following additions and clarifications.

- The resulting chemical concentrations in soil represent an increment to the background levels in soil.
- Background levels of chemicals in the agricultural fields are the same as the Laboratory sediment background values.

The change in possible adverse health effects is related to the ratio of the irrigation increment to the background concentrations.

Table 10. Unfiltered water data. Concentrations of nonradiological constituents in unfiltered Rio Grande water. The bolding of values in the predicted post-fire concentration columns indicates the higher of the two values.

Analyte	Measured pre-fire ( $\mu\text{g L}^{-1}$ )			Predicted post-fire ( $\mu\text{g L}^{-1}$ )		Measured Maximum in Rio Grande post-fire (USGS; $\mu\text{g L}^{-1}$ )
	Mean	Max	Count	From flows in Guaje Canyon	From flows in LANL Canyons	
Aluminum	13100	76200	9	<b>249000</b>	104000	6930
Antimony	2	4	9	1	<b>4</b>	1
Arsenic	7	26	9	<b>34</b>	22	3
Barium	388	1770	9	<b>5180</b>	4340	146
Beryllium	3	10	9	<b>17</b>	9	
Boron	45	66	9	73	<b>118</b>	32
Cadmium	4	7	9	<b>8</b>	5	0.007
Chromium	10	32	9	<b>128</b>	62	3
Cobalt	12	42	9	<b>119</b>	38	0.22
Copper	23	84	9	<b>151</b>	92	4
Cyanide (amenable for chlorination)				0	<b>12</b>	
Cyanide, total	11	15	9	<b>44</b>	26	0.02
Iron	7430	40400	9	<b>140000</b>	71300	3790
Lead	18	60	9	<b>295</b>	253	3
Manganese	611	3260	9	<b>25500</b>	11300	122
Mercury	0.18	0.2	9		<b>0.26</b>	0.17
Molybdenum	13	30	9	1	<b>6</b>	2
Nickel	24	73	9	<b>207</b>	65	4
Selenium	3	7	9	2	<b>11</b>	9
Silver	8	10	9		<b>43</b>	
Strontium	454	1460	9	1200	<b>1280</b>	329
Tin	33	60	9	3	<b>49</b>	
Titanium				560	<b>588</b>	
Thallium	2	3	9			0.11
Uranium	3	7	9	23	<b>37</b>	2
Vanadium	33	130	9	<b>134</b>	113	8
Zinc	87	210	9	<b>903</b>	428	52
NO <sub>3</sub> +NO <sub>2</sub> -N	648	5100	9	233	<b>250</b>	95
1,4- Dichlorobenzene				<b>0.06</b>	0.03	
4-Methylphenol				1.1	<b>2.75</b>	
Benzoic acid				16.8	<b>475</b>	
Benzyl alcohol				<b>1.33</b>		
Bis(2- ethylhexyl)phthalate				<b>16.8</b>	2.35	2
Ethylbenzene				0.02	<b>0.03</b>	
Methylene chloride					<b>0.28</b>	
Phenol				1.85	<b>4.75</b>	
Pyridine				4	<b>9.25</b>	
Toluene					<b>0.24</b>	
HMX (HE)					<b>0.55</b>	
RDX (HE)					<b>0.19</b>	

Table 11. Filtered water data. Predicted maximum concentrations of metals in filtered Rio Grande water. The bolded value in the predicted post-fire concentration columns is the higher of the two values.

Analyte	Measured pre-fire ( $\mu\text{g L}^{-1}$ )			Predicted post-fire ( $\mu\text{g L}^{-1}$ )		Measured Maximum in Rio Grande post-fire (USGS; $\mu\text{g L}^{-1}$ )
	Mean	Max	Count	From flows in Guaje Canyon	From flows in LANL Canyons	
Aluminum	67	133.8	5	116	<b>1210</b>	43.6
Antimony	3	3	5	0.17	<b>1.30</b>	
Arsenic	5.2	20	6	1.6	<b>2.2</b>	2.8
Barium	46	90	5	27	<b>138</b>	85.9
Beryllium	3	3	5	0.01	<b>0.06</b>	
Boron	32	45	5	30	<b>48</b>	40.4
Cadmium					<b>0.03</b>	
Chromium	7	7	5		<b>0.5</b>	3.1
Cobalt	8	8	5	0.5	<b>2.8</b>	0.28
Copper	10	10	5	1.1	<b>2.3</b>	1.5
Iron	69	136	5	68	<b>628</b>	13
Lead	3	3	5	0.1	<b>1.0</b>	
Manganese	5.8	11.9	5	191	<b>340</b>	33.1
Mercury	0.2	0.2	2		<b>0.003</b>	
Molybdenum	30	30	5	1.3	<b>4</b>	4.4
Nickel	20	20	5	0.7	<b>2.5</b>	1.6
Selenium	3	3	2		<b>1.0</b>	
Silver	10	10	5		<b>0.2</b>	
Strontium	191	318	5	53	<b>148</b>	
Tin	30	30	5		<b>0.6</b>	
Titanium				0.9	<b>14.1</b>	
Thallium	3	3	5	0.007	<b>1.0</b>	
Uranium				0.6	<b>0.9</b>	7.3
Vanadium	9	13	5	0.5	<b>1.9</b>	
Zinc	50	50	5	0.8	<b>41</b>	

Based on these assumptions, metal/organic concentrations were converted from water to soil via the following equation:

$$C_s = E * CF * C_w * D^{-1}, \text{ or } C_s = 0.00062 * C_w \quad , \quad [6]$$

where

- $C_s$  = concentration in soil ( $\text{mg kg}^{-1}$ ),
- $E$  = irrigation events = 1,
- $CF$  = conversion factor =  $1 \times 10^{-3} \text{ mg } \mu\text{g}^{-1}$ ,
- $C_w$  = concentration in water ( $\mu\text{g L}^{-1}$ ), and
- $D$  = soil density =  $1.6 \text{ kg L}^{-1}$ .

The estimated soil concentrations based on the irrigation mass transfer model are provided in Table 12. These estimated soil concentrations represent a possible maximum increment in concentrations in a field or pasture after an irrigation event. The estimated soil concentrations would add to existing or background concentrations in the soil. The sediment BVs are also provided in Table 12 for comparison. For some chemicals, primarily organic chemicals, there is no BV and the calculated soil concentrations are compared with the contract-required quantification limit (CRQL; LANL 1995). The CRQL values are

set at concentrations that are routinely attainable for analytical laboratories using standard methods for the analysis of soil or sediment. The CRQLs are not risk-based concentrations, although they are much lower than risk-based screening concentrations in most cases. The CRQLs are selected for comparison with calculated concentrations of organic chemicals because they are akin to background for metals in that the CRQLs are the expected "baseline" concentration for organic chemicals. For all chemicals with BVs, the estimated soil concentration is less than 3% of the sediment BV. For nearly all chemicals without BVs, the estimated soil concentration is less than the CRQL and would not be detectable in soil. Estimated soil concentrations for nitrogen and phosphorous measures are comparable to the CRQL, but soil concentrations of less than one part per million of these essential plant nutrients are not associated with adverse human health effects. These same nutrients are often applied as soil amendments at concentrations many times greater than the parts per million range. Thus, even with a conservative assumption of 100% mass transfer from floodwater to soil, the estimated soil concentrations represent a small fraction of the concentration in soil at background levels, or a small fraction of measurable levels (for chemicals without background data). If some nonradiological effects are directly related to soil concentration, the small increase in concentration estimated from the irrigation model would cause a small increment to the potential adverse health effects from background levels. This semiquantitative risk evaluation suggests that incremental cancer risks from irrigating fields or pastures with post-fire floodwaters are small.

A quantitative risk evaluation with irrigation would not lead to a different final risk estimate because risks are typically reported to one significant figure due to the inherent uncertainty in such estimates. Actual increments would be orders of magnitude less than the background risk in most cases. As an example, consider the results of the Totavi assessment for chemicals that could be expected to contribute the largest fraction to carcinogenic risk. For the Totavi assessment, arsenic, benzo(a)pyrene, and TCDD equivalents contributed nearly all of the estimated carcinogenic risk. Of these chemicals only arsenic was detected in floodwaters and the estimated arsenic concentration is 1% of the BV. Thus, carcinogenic risks from arsenic would be 1.01\* background risk, which, rounded off to one significant figure (1.0), is simply the background risk.

Another consideration is the predicted difference in post-fire floodwater concentration versus historical values measured in the Rio Grande. Arsenic was measured in pre-fire base-flow unfiltered water samples in the Rio Grande (Rio Grande at Frijoles Canyon arsenic mean =  $7.2 \mu\text{g L}^{-1}$  and maximum =  $26 \mu\text{g L}^{-1}$ , 1993 to 1999 samples, Table 10. Unfiltered water data.). Thus, arsenic is predicted to be modestly elevated in post-fire floodwaters by a factor of approximately 1 to 5 over base-flow concentrations. Another relevant comparison is the concentration of arsenic from Guaje Canyon floods, which is thought to represent a reference (non-LANL impacted) canyon, to arsenic concentrations in canyons that drain LANL technical areas. The maximum value used in the assessment ( $34 \mu\text{g L}^{-1}$ ) is from Guaje Canyon (as are the maximum values for most chemicals), and the largest value in canyons that drain LANL technical areas is  $22 \mu\text{g L}^{-1}$  (from Water Canyon). Thus, using arsenic as an example of a carcinogen that may be responsible for some increased chronic cancer risk, the most reasonable source is from the Cerro Grande Fire. One possible source for elevated metals in post-fire floodwaters is ash. The fire may have changed flow regimes to increase concentrations of metals and other constituents in floods compared with base-flow concentrations.

Because the potential health effects assessment for the irrigation scenario is qualitative, our conclusions apply to short-term exposures to these predicted elevated concentrations in post-fire floodwaters. If elevated concentrations are found to persist over several years, then possible chronic health effects would also be addressed through this type of assessment. However, it may be advisable to reduce the uncertainty in the assessment and collect measurements of the soil in fields or pastures, plants, and livestock to evaluate potential adverse health effects and provide a comparison to the irrigation scenario mass-transfer model.

Table 12. Estimated soil concentrations for the Rio Grande irrigation scenario.

Analyte	Water Concentration ( $\mu\text{g L}^{-1}$ )	Estimated Soil Concentration ( $\text{mg kg}^{-1}$ )	Sediment BV ( $\text{mg kg}^{-1}$ )	CRQL ( $\text{mg kg}^{-1}$ )	% of BV (or CRQL)
Aluminum	249000	154	15400	N/U <sup>a</sup>	1%
Antimony	4	0.002	0.83	N/U	<1%
Arsenic	34	0.021	3.98	N/U	1%
Barium	5180	3.21	127	N/U	3%
Beryllium	17	0.011	1.31	N/U	1%
Boron	118	0.073	4.1	N/U	2%
Cadmium	8	0.005	0.4	N/U	1%
Chromium, total	128	0.079	10.5	N/U	1%
Cobalt	119	0.074	4.73	N/U	2%
Copper	151	0.094	11.2	N/U	1%
Cyanide, amenable to chlorination	12	0.007	N/A <sup>b</sup>	0.05	15%
Cyanide, total	44	0.027	0.82	N/U	3%
Iron	140000	86.8	13800	N/U	1%
Lead	295	0.183	19.7	N/U	1%
Manganese	25500	15.8	543	N/U	3%
Mercury	0.26	<0.001	0.1	N/U	<1%
Molybdenum	6	0.004	N/A	2.5	<1%
Nickel	207	0.128	9.38	N/U	1%
Selenium	11	0.007	0.3	N/U	2%
Silver	43	0.027	1	N/U	3%
Strontium	1280	0.8	52.1 <sup>c</sup>	N/U	2%
Tin	49	0.03	N/A	2.5	1%
Titanium	588	0.365	439	N/U	<1%
Uranium	37	0.023	1.62	N/U	1%
Vanadium	134	0.083	19.7	N/U	<1%
Zinc	903	0.56	60.2	N/U	1%
Ammonia reported as nitrogen	1230	0.76	N/A	2	38%
Nitrate + nitrite reported as nitrogen	250	0.155	N/A	2	8%
Phosphate reported as phosphorous	3630	2.25	N/A	2	112%
Total nitrogen by Kjeldahl Method of Analysis	16000	9.92	N/A	10	99%
1,4-Dichlorobenzene	0.06	<0.001	N/A	0.33	<1%
4-Methylphenol	2.75	0.002	N/A	0.33	1%
Benzoic acid	325	0.202	N/A	3.3	6%
Benzyl alcohol	1.33	0.001	N/A	1.3	<1%
Bis(2-ethylhexyl)phthalate	16.8	0.01	N/A	0.33	3%
Ethylbenzene	0.03	<0.001	N/A	0.00 <sup>d</sup>	<1%
Methylene chloride	0.28	<0.001	N/A	0.00 <sup>d</sup>	3%
Phenol	4.75	0.003	N/A	0.33	1%
Pyridine	9.25	0.006	N/A	0.33	2%
Toluene	0.24	<0.001	N/A	0.00 <sup>d</sup>	3%
HMX (HE)	0.55	<0.001	N/A	2	<1%
RDX (HE)	0.19	<0.001	N/A	1	<1%

<sup>a</sup>N/U = not used, the CRQL is not used where a BV is available.

<sup>b</sup>N/A = not available.

<sup>c</sup>Value is from TA-21 Baseline (Ryti 1997).

### **4.2.3 Drinking Water from or Swimming or Fishing in the Rio Grande**

Predicted Rio Grande water concentrations were compared with acute health advisory levels (EPA 2000b) to evaluate possible adverse health effects of drinking floodwaters. The one-day acute health advisory levels developed for a 10-kg child were used in this comparison (EPA 2000b). These values are to be used in comparison with drinking water, which is typically low in suspended sediments and more similar to filtered river water than unfiltered river water. However, our acute exposure scenario assumes that someone drinks water directly from the river without passing it through a filter or collecting it in a container and waiting for the sediments to settle out of solution before drinking. Because of these factors, we compared both the filtered and unfiltered predicted Rio Grande concentrations with the one-day acute health advisory levels.

Results of the comparison of predicted unfiltered and filtered Rio Grande water concentrations with health advisory levels are provided in Table 13. None of the predicted filtered concentrations are greater than the one-day health advisory level. The predicted unfiltered concentration of one chemical, barium, is greater than its one-day health advisory level. However, the measured post-fire unfiltered USGS value for barium is less than the one-day health advisory level. Thus, there may be some concern for acute health effects based on a one-time consumption of unfiltered post-fire floodwater, if one assumes maximum predicted concentrations for the exposure. It is worth noting that the maximum unfiltered predicted barium concentration in the Rio Grande used in the assessment ( $5180 \mu\text{g L}^{-1}$ ) is based on runoff from Guaje Canyon (as are the maximum unfiltered values for most chemicals), and the largest predicted Rio Grande concentration from canyons that drain LANL technical areas is  $4340 \mu\text{g L}^{-1}$ . We conclude that any potential acute effects of drinking floodwater are a direct result of Cerro Grande Fire impacts, independent of LANL. One possible source for elevated metals in post-fire floodwaters is ash. The fire may have changed flow regimes to increase concentrations of metals and other constituents in floods relative to base flow concentrations.

Exposures to chemicals during swimming primarily occur through dermal contact and incidental ingestion of water. Acute exposures from a single swimming event will not be modeled to evaluate possible adverse health effects. Instead, the acute drinking water scenario evaluated previously will be used as an upper bound estimate for possible adverse health effects during swimming. Using drinking water as a surrogate assessment ignores dermal exposure. However, the amount of water ingested during a lengthy swimming event is less than 10% of the daily drinking water intake, and using the higher drinking water intake should more than compensate for ignoring dermal exposure during swimming. The conclusion of the acute drinking water evaluation was that there are no potential acute effects of drinking floodwater.

As described above, fish collected in Cochiti Reservoir before and after the fire showed no differences (other than as stated above). Therefore, we believe that fish collected and eaten from the Rio Grande or Cochiti Reservoir during 2000 would not have resulted in a fire-related adverse health effect.

### **4.2.4 Cattle Watering Scenario**

Predicted Rio Grande water concentrations were compared with New Mexico Water Quality Control Commission (WQCC) standards (WQCC 2000) to evaluate possible adverse effects on cattle (Table 14). Livestock watering standards were used in this comparison (WQCC 2000), and livestock watering "means a surface water of the state used as a supply of water for consumption by livestock" (WQCC 2000). These standards, although applied to cattle watering, were developed to be protective of public health or welfare (Section 20.6.4.6.b of WQCC 2000). These values are mostly based on dissolved concentrations, except for one analyte, mercury, that is based on total concentrations. Filtered samples are used to be representative of dissolved concentrations, and the unfiltered concentrations are used to represent total chemical concentration. None of the predicted concentrations of these chemicals is greater than the livestock watering standard. Thus, we concluded that there are no concerns for public health from the consumption of beef from cattle that have consumed Rio Grande water.

Table 13. Comparison of predicted Rio Grande concentrations with acute concentration thresholds. Bolded value indicates exceedance of screening level.

Analyte	Predicted Unfiltered	Predicted Filtered Rio	One-day Health Advisory Level ( $\mu\text{g L}^{-1}$ )
	Rio Grande Concentration ( $\mu\text{g L}^{-1}$ )	Grande Concentration ( $\mu\text{g L}^{-1}$ )	
Antimony	4	1.3	10
Barium	<b>5180</b>	138	700
Beryllium	17	0.063	30000
Boron	118	47.5	4000
Cadmium	8	0.03	40
Chromium	128	0.48	1000
Cyanide, total	44	N/A <sup>a</sup>	200
Mercury	0.26	0.0028	2
Molybdenum	6	4	80
Nickel	207	2.5	1000
Silver	43	0.24	200
Strontium	1280	148	25000
Zinc	903	41	6000
Nitrate + nitrite (expressed as nitrogen)	250	N/A	1000 <sup>b</sup>
1,4-Dichlorobenzene	0.06	N/A	11000
Ethylbenzene	0.03	N/A	30000
Phenol	4.75	N/A	6000
Toluene	0.24	N/A	20000
HMX (high explosive)	0.55	N/A	5000
RDX (high explosive)	0.19	N/A	100

<sup>a</sup>N/A = not analyzed, analyte is not measured in filtered water samples from runoff so is not available for the calculation of this value.

<sup>b</sup>Value is for nitrites.

Table 14. Comparison of predicted Rio Grande concentrations to livestock standards.

Analyte	Predicted Filtered Rio	WQCC Livestock Watering
	Grande Concentration ( $\mu\text{g L}^{-1}$ )	Standard for Dissolved Metals ( $\mu\text{g L}^{-1}$ )
Aluminum	1200	5000
Arsenic	2.23	200
Boron	47.5	5000
Cadmium	0.03	50
Chromium	0.48	1000
Cobalt	2.83	1000
Copper	2.28	500
Lead	1.01	100
Mercury	0.26 <sup>a</sup>	10 <sup>a</sup>
Selenium	0.95	50
Vanadium	1.92	100
Zinc	41	25000

<sup>a</sup>Standard is for total mercury, so unfiltered mercury result is provided.

## 5.0 POTENTIAL FUTURE EFFECTS FROM FLOODING<sup>3</sup>

As a result of the Cerro Grande Fire, the likelihood of large flash floods in the more severely burned watersheds is significantly increased (BAER 2000, Veenhuis 1999). Sections 3.0 and 4.0 of this report discuss the radiological and nonradiological effects during CY 2000 from potential exposure related to flooding exacerbated by the Cerro Grande Fire. This section presents a discussion of the potential future effects related to possible flooding in CY 2001 and later years. This assessment of potential future adverse health effects associated with flooding considers (1) the observed increase in the frequency and magnitude of large floods generated from the burn area and the likely duration of the conditions that lead to the generation of large floods, (2) the amount of ash generated by the fire, the constituents contained within ash, and the fate of the ash, and (3) sediments deposits that contain contamination from legacy LANL releases. The assessment focuses on sediment rather than surface water because concentrations of chemicals in sediment deposits may represent the greater potential for chronic effects. It should be noted that predictions of future effects have uncertainty associated with the difficulty of predicting the nature of high-intensity rainfall events and the downstream geomorphic response from runoff (i.e., magnitude and location of erosion or deposition).

The assessment is based on three lines of evidence. One line of evidence comes from a review of scientific literature reports of the magnitude and duration of changes in hydrologic conditions and chemical concentrations in various media. A second line of evidence is the concentration, inventory (amount), and origin of various chemicals in ash and sediment, and amount of ash and sediment that has moved downstream from the burned areas. Third, is the change in concentrations of chemicals noted in sediment during the first year after the Cerro Grande Fire. These lines of evidence will be used to base a qualitative assessment of possible future adverse health effects especially as related to Laboratory-derived contaminants in the Los Alamos Canyon watershed.

### 5.1 Wildfire Effects Literature Review

Studies have been conducted on the initial hydrologic response and subsequent recovery following two historical wildfires near Los Alamos (Veenhuis 1999). The La Mesa Fire occurred in 1977 and burned in the Frijoles watershed, and the 1996 Dome Fire burned in the Capulin watershed. Veenhuis documented that hydrologic changes triggered by loss of vegetative cover and associated forest litter (duff) (and presumably development of hydrophobic soil conditions) resulted in large increases in the frequency and magnitude of floods in the burned watersheds. Peak discharge during the first 1 to 2 years following each of these fires was 2 orders of magnitude greater than the peak discharge measured before the fires. Runoff in subsequent years decreased as vegetation recovered in the burned area. Peak discharge was 10 to 15 times the pre-fire maximum in the second year, and down to only 3 to 5 times the pre-fire maximum by the third year. Of course, the nature and location of high-intensity monsoonal precipitation events in a given year is a key factor for evaluating runoff in canyons.

Bitner et al. (2001) compiled information on changes in chemical concentrations in various media. Many studies were reviewed, but few provided quantitative information on the magnitude and the duration of the changes in water, soil, sediments, or ash. The studies that provided some quantitative information are summarized in Figure 6. We have plotted a curve on Figure 6 that connects the pre-fire starting ratio of 1 (representing no change) with the geometric mean of 19 post-fire to pre-fire ratios from the first post-fire year and the geometric mean of four studies from year two post-fire. Although there is considerable uncertainty, this information indicates a fairly rapid return to pre-fire concentrations, at least for the constituents monitored in these studies. Although this line of evidence is insufficient for providing strong predictive information on the duration of chemical changes post-fire, it does provide some information on the magnitude of change seen directly after a fire. This information suggests that change in concentration up to 1 order of magnitude is possible after a fire.

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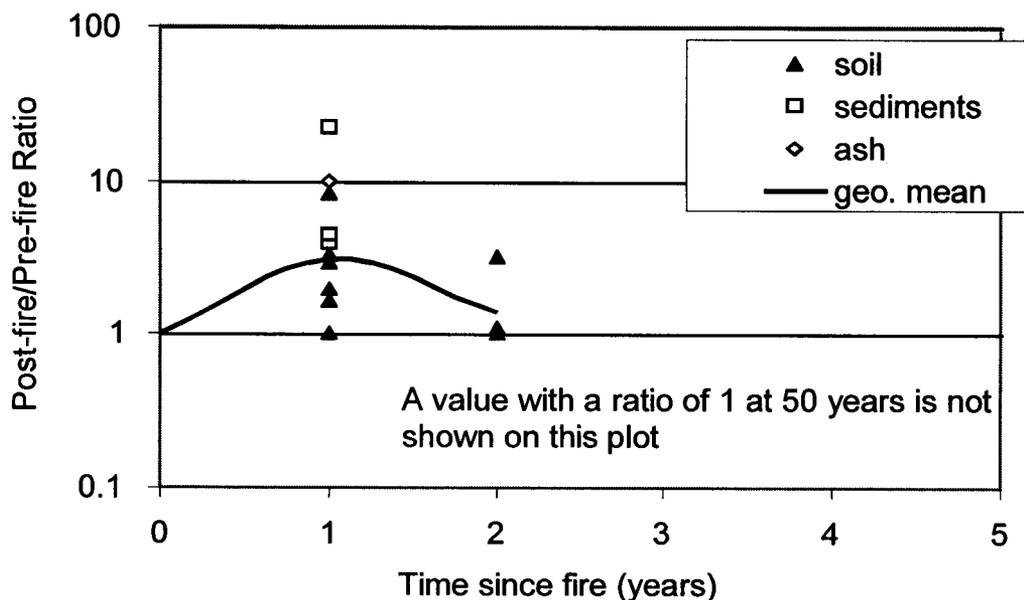


Figure 6. Compilation of changes seen post-fire in various media for metals and radionuclides (studies on nutrients like carbon and nitrogen were excluded from this compilation).

## 5.2 Legacy and Fire-Related Radionuclides

A key consideration in assessing future flood effects and related potential adverse health effects is the nature, concentration, and mobility of legacy contaminants in LANL canyons and chemicals detected in ash and flood deposits. The increased potential for more frequent and larger floods results in a greater potential for ash and legacy contaminants to be eroded and transported during floods and deposited offsite on floodplains or in the Rio Grande. The key question is whether these conditions also relate to potential increase in risk relative to pre-fire conditions. This analysis will focus on the Los Alamos Canyon watershed since, of the fire-affected watersheds, the Los Alamos Canyon watershed (which includes Los Alamos, Pueblo, Rendija, and Guaje Canyons) has the highest amount of historical Laboratory contamination susceptible to erosion and offsite transport from large floods. It also has the largest depositional area (i.e., floodplain) between the Laboratory boundary and the Rio Grande where sediments could be deposited during floods. Mortandad Canyon also has significant contamination; although burned, that watershed is not significantly more susceptible to erosion and transport of contaminants offsite because the canyon heads on the Pajarito Plateau as opposed to high on the mountain front and the watershed experienced less severe burning than the Los Alamos Canyon watershed. Historic large floods in Mortandad Canyon typically attenuated in the area around the existing sediment traps. The historical Laboratory contamination within the Los Alamos watershed is essentially limited to Los Alamos and Pueblo Canyons, but potential transport of ash to downstream areas and the Rio Grande is important in all of the subbasins in the Los Alamos Canyon watershed. Investigations of the geomorphology and the associated concentration and distribution of Laboratory-derived chemicals are largely completed in these canyons. Several reports (Reneau et al. 1998a, b, and c; Katzman et al. 1999) have documented the nature and extent of contamination related primarily to early Manhattan Project- and Cold War-era operations in the watershed.

To address the issue of potential future effects resulting from flooding, two key sources of data are used. The first source of data is the geomorphic model for variations in contamination presented in the canyon reach reports, which were used to support the assessment of potential future impacts from flooding (Reneau et al. 1998a, b, and c; Katzman et al. 1999). The geomorphic model is based on analytical data from samples and sediment age determined from examination of sequential aerial

photographs, radioisotope ratios, and tree-ring analysis. The model is developed from data on sediment deposits representing erosion and transport during the 50 years that Laboratory operations have impacted the Los Alamos Canyon watershed. Discharges of contaminants into Los Alamos and Pueblo Canyons initially resulted in widely dispersed concentrations of contaminants within the canyons. The existing data show that average contaminant concentrations in sediment generally decrease with increasing distance of transport from the original source area and also have decreased over time due to the cessation of releases into the canyons and mixing of contaminated sediments with noncontaminated sediments during floods. Figure 7 illustrates the result of the sediment transport processes. Average  $^{137}\text{Cs}$  concentrations for coarse- and fine-grained particle-size classes in the Los Alamos Canyon watershed are plotted as a function of distance from the Rio Grande. The average  $^{137}\text{Cs}$  concentrations along the length of the canyon represent the average concentration of sediments of various ages within each discrete sampling area. The decreasing trend in average concentration down-canyon reflects mixing of sediments that contain higher concentrations of  $^{137}\text{Cs}$  in up-canyon areas with sediments containing little or no  $^{137}\text{Cs}$ , resulting in lower concentrations when deposited downstream. This geomorphic model reflects transport associated with floods of varying magnitude, including large floods known to have occurred in Pueblo Canyon in the early 1950s. Additional large floods, including those generated off the Cerro Grande Fire burn area, could accelerate the processes of erosion and deposition of sediments, but are not likely to fundamentally change the processes leading to reduced average concentrations of contaminants associated with flood transport. Instead, because of increased erosion in the burn area, the supply of sediment from the burn area on the mountain front is anticipated to further dilute the concentration of LANL-related contaminants in flood deposits. The result should be the transport and deposition of sediment with lower average concentrations of LANL-derived contaminants than before the fire.

The second key source of information for evaluating potential future effects from flooding is the analytical data that characterize the constituents found in the ash produced by the fire. Samples of ash and ash-rich sediment were collected from locations representative of background conditions upstream of known Laboratory releases and predominantly upwind from airborne releases from stacks at Laboratory facilities. These locations were chosen to characterize the nature and concentration of chemicals associated with the Cerro Grande Fire. It was expected that detectable radionuclide concentrations associated with global fallout from aboveground nuclear testing conducted primarily in the 1950s and 1960s would be present, and likely concentrated, in the ash.

The ash data are used to estimate the inventory (or total amount) of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  contained in ash in the burned areas of the upper watersheds for comparison with the inventory of the same radionuclides in sediment on LANL. Only the inventory of  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  are estimated here because they are present in ash deposits and in contaminated sediments related to historical releases from the Laboratory, and because they are the radionuclides that represent the highest potential for adverse health effects related to post-Cerro Grande flooding (Table 15). In addition,  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  are the radionuclides detected greater than pre-fire concentrations in lower Los Alamos Canyon sediments. Inventory estimates are available for these radionuclides in the Los Alamos Canyon watershed based on pre-fire sediment sampling. Inventory of the radionuclides associated with the Cerro Grande Fire is estimated by multiplying the area of the watershed that received high- and moderate-severity burn, the estimated average thickness of ash, the average concentration of each radionuclide, and the average bulk density of ash, where

- total area of moderate- and high-severity burn in the Los Alamos Canyon watershed is  $37.1 \text{ km}^2$ ,
- estimated average thickness of ash is 2 cm,
- average calculated concentration of  $^{137}\text{Cs}$  in ash is  $4.5 \text{ pCi g}^{-1}$  (Table 16 and Smith 2000),
- average calculated concentration of  $^{90}\text{Sr}$  in ash is  $2.6 \text{ pCi g}^{-1}$  (Table 16 and Smith 2000), and
- average measured bulk density of the ash is  $0.65 \text{ g cm}^{-3}$ .

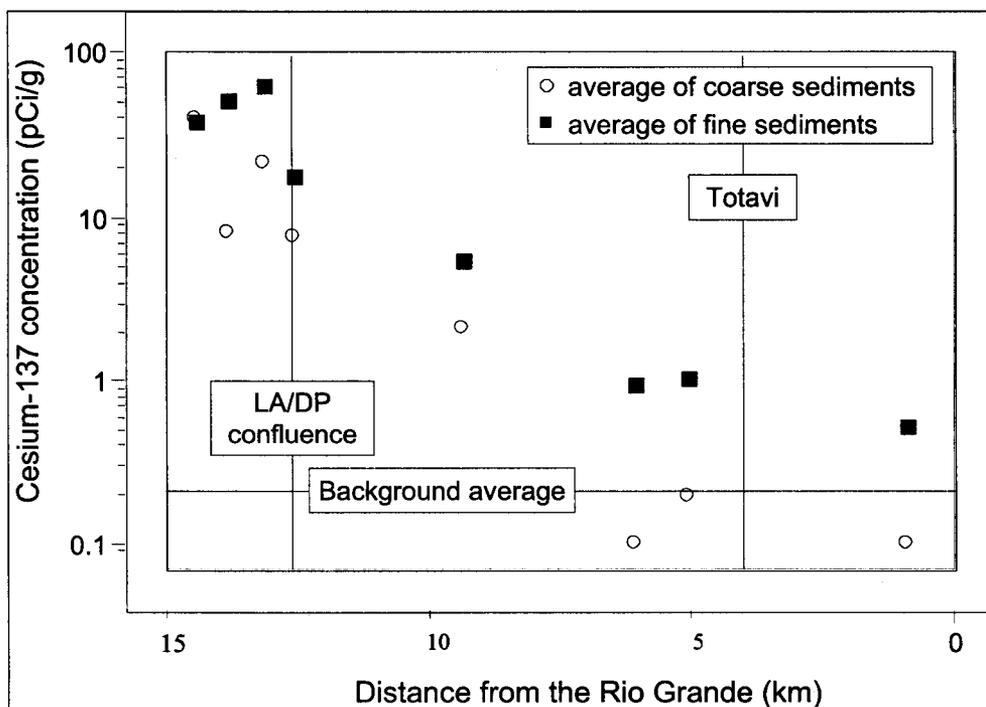


Figure 7. Plot of  $^{137}\text{Cs}$  concentrations by particle size from DP Canyon [the PRS 21-011(k) outfall] to the Rio Grande. Background is the average of coarse- and fine-grained sediments.

Table 15. Radionuclide inventories.

**Estimated Inventory in Los Alamos Basin  
(mCi)**

Analyte	Ash-Derived	Legacy Contamination in Canyon Floor
Cesium-137	2180	350
Strontium-90	1260	100*

\*Estimated from ratio of average concentrations of  $^{90}\text{Sr}$  to  $^{137}\text{Cs}$  in reaches LA-2E and LA-3 (Reneau et al. 1998c) (the ratios for coarse and fine sediments ranged between 3% and 30%, and 30% was selected as an upper bound for the  $^{90}\text{Sr}$  inventory estimate)

Table 16. Baseline ash samples.

Sample ID	Cesium-137 (pCi g <sup>-1</sup> )	Strontium-90 (pCi g <sup>-1</sup> )
CABG-00-0066	4.97	3.01
CABG-00-0067	4.78	3.48
CABG-00-0068	3.61	2.06
CABG-00-0070	4.68	1.93

One important effect of the fire was the combustion of ground cover in the upper watersheds and generation of ash with high susceptibility to erosion due to runoff. This means that the inventory of fallout radionuclides is highly available for transport in floods onto and across LANL to offsite locations. One implication is that the inventory of certain radionuclides could increase on Laboratory property due to onsite deposition of ash-rich sediment. The evaluation of radionuclides in ash is important because the most significant risk-related effect associated with the CY 2000 floods is related to the transport of ash containing  $^{137}\text{Cs}$  (see Section 3.0 of this report). Although many other constituents are present in the ash,

the  $^{137}\text{Cs}$  appears to be the most persistent, meaning that the concentrations do not change much with increasing distance of transport. Future changes in concentrations of  $^{137}\text{Cs}$  over time in flood deposits are therefore partially a function of the amount of ash remaining in the burn area and the susceptibility of this ash to transport. Consequently, understanding the flushing of ash from the burn area is key to evaluating future impacts from flooding. It was observed during field reconnaissance in spring 2001 that roughly two-thirds of the ash was transported by runoff from the upper watersheds in the first year after the fire. A relatively small amount of the transported ash was deposited on floodplains along the length of the canyons within the Los Alamos Canyon watershed, suggesting that most of the ash and associated constituents were transported directly to the Rio Grande during CY 2000. Therefore, concentrations of ash-derived constituents in floods and flood deposits are expected to decrease during subsequent years.

### 5.3 Post-fire Monitoring

Samples of ash-rich sediments deposited by floods during CY 2000 were collected from floodplain areas along the canyons (including at the Los Alamos Canyon delta to the Rio Grande) to evaluate spatial trends in chemical concentrations and to evaluate the potential contribution of Laboratory contaminants (Katzman et al. 2001). Because sediment deposits represent the greater potential for chronic risk compared with surface water, we present information on spatial and temporal trends in concentrations of chemicals in sediment. We also focus on two radionuclides that are known to be elevated in Cerro Grande Fire ash and that are also present in contaminated sediments on LANL. We show spatial trends based on the distance of a sampling location from the Rio Grande and overlay with post-fire fine-grained sediment sample results and the pre-fire average concentrations in Los Alamos and Pueblo Canyons from previous investigations (Reneau et al. 1998a, b, c).

A plot of post-fire  $^{137}\text{Cs}$  concentrations shows little spatial variation in concentration (Figure 8). Current evaluations of the spatial trends could be reflecting some effect related to temporal trends in concentrations due to solubility. The data shown in Figure 8 represent texturally similar sediment deposits all containing high concentrations of ash. The data show that concentrations of  $^{137}\text{Cs}$  in the ash-laden deposits are similar along the length of the canyons, indicating little or no mixing of sediment downstream of the burn area. Cesium-137 concentrations in sediment containing ash from the burn area might be expected to increase down-canyon if higher concentrations of Laboratory-derived  $^{137}\text{Cs}$  from canyon sediments were being incorporated during floods along with no mixing of noncontaminated sediments. The data also indicate that the  $^{137}\text{Cs}$  in ash is relatively insoluble. Thus, the large inventory of  $^{137}\text{Cs}$  in ash is the most likely source for the  $^{137}\text{Cs}$  found in down-canyon areas. This analysis also leads to the conclusion that  $^{137}\text{Cs}$  concentrations in flood deposits will decrease as the amount of ash contained within flood sediments decreases.

Plots of post-fire  $^{90}\text{Sr}$  concentrations show a slight decrease with distance of transport (Figure 9). This analysis is also potentially confounded by possible changes in  $^{90}\text{Sr}$  concentrations over time related to solubility. The data shown in Figure 9 represent texturally similar sediment deposits all containing high concentrations of ash. The data show that concentrations of  $^{90}\text{Sr}$  generally decrease with distance of transport. As with  $^{137}\text{Cs}$ , the spatial trend for  $^{90}\text{Sr}$  indicates little or no contribution from Laboratory sources of contamination.

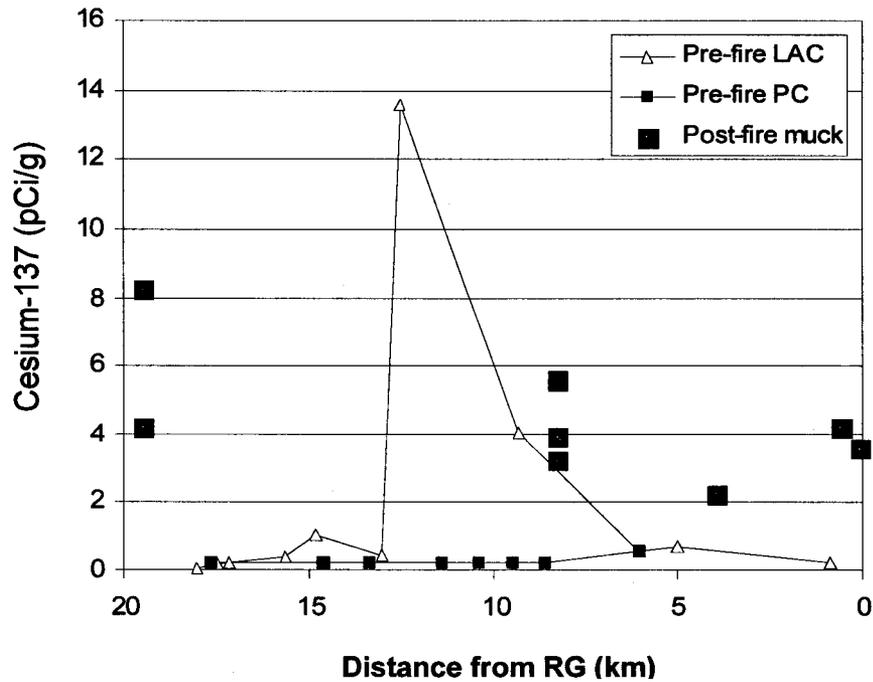


Figure 8. Cesium-137 spatial plot for Los Alamos and Pueblo Canyons sediment concentrations. Pre-fire data from Reneau et al. (1998a, b, and c). LAC = Los Alamos Canyon, PC = Pueblo Canyon, RG = Rio Grande.

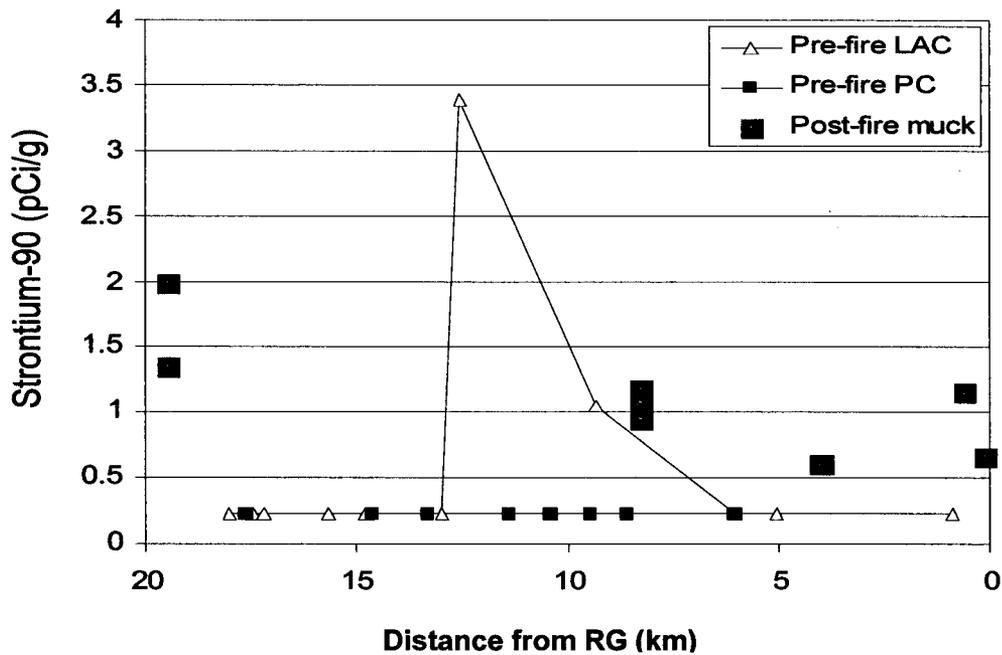


Figure 9. Strontium-90 spatial plot for Los Alamos and Pueblo Canyons sediment concentrations. Pre-fire data from Reneau et al. (1998a, b, and c). LAC = Los Alamos Canyon, PC = Pueblo Canyon, RG = Rio Grande.

Reconnaissance of the upper burned portions of the Los Alamos Canyon watershed indicates that up to two-thirds of the ash generated by the fire was eroded and transported out of the upper watershed during summer and early fall of CY 2000. Some deposition of ash-rich sediments occurred along floodplains (e.g., near Totavi, see discussion in Section 3.0), but most of the ash was flushed through the canyons during floods and into the Rio Grande. This suggests that possibly up to 1400 mCi of  $^{137}\text{Cs}$  and 850 mCi of  $^{90}\text{Sr}$  were transported to the Rio Grande in CY 2000, an amount far greater than the legacy Laboratory contamination in sediments in the Los Alamos Canyon watershed (Reneau et al. 1998c). This reduction in the amount of  $^{137}\text{Cs}$ - and  $^{90}\text{Sr}$ -laden ash from the upper watershed will therefore likely result in decreasing concentrations of these and other constituents associated with ash in ensuing years. Because the source for elevated levels of these radionuclides is the ash, the rapid loss of this material is consistent with the information obtained from the literature on the magnitude and duration of fire effects.

#### **5.4 Integration of Lines of Evidence**

Limited information on the effects of fire from the literature show that increases in concentrations of various chemicals (e.g.,  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  as well as related inorganic constituents and organic compounds) are relatively short in duration and the maximum value may be expected in the first few years post-fire. For two representative chemicals in both ash and contaminated sediments on LANL, there is about an order of magnitude more inventory in ash compared with sediment deposits on LANL. In addition, all of the ash is susceptible for transport. Thus, considering susceptibility for transport and the amount (inventory) available for transport, the ash from the fire represents the dominant source for downstream effects. And, given that most of the ash was mobilized during the first year, the effect is expected to be minimal during subsequent years. Lastly, existing data for sediments deposited from CY 2000 floods seem to be consistent with data on concentrations of these chemicals in the ash and also show little or no Laboratory contribution. Large floods that may occur in the future could contain large amounts of sediment derived from erosion in the upper watersheds. These eroded sediments are not likely to contain significant ash content, and thus are expected to have lower concentrations of fallout radionuclides than were detected in CY 2000. Other factors, such as the manner in which the upper Los Alamos Canyon reservoir reduces the peak of flood discharge in that canyon and the natural flood attenuation that is likely to occur in the lower Pueblo Canyon wetlands area, should minimize erosion and transport of contaminated sediments in those canyons. In conclusion, it seems unlikely that continued monitoring will detect higher concentrations of these chemicals or any chemicals associated with historical Laboratory releases that are greater than what was measured in CY 2000.

The only considerations of possible adverse health effects from future concentrations of chemicals in flood deposits compared with CY 2000 concentrations are the continued exposure time and possibility of additional exposure pathways in the future. However, in considering the lack of any notable Laboratory contribution to possible CY 2000 health effects, we view the consideration of additional exposure pathways as too speculative to be warranted in this report. However, the exposure time for radiological effects should be considered for a full CY in 2001 and beyond. Thus, our best estimate for lower Los Alamos Canyon sediment-related dose is 0.06 mrem per year of exposure at the concentrations measured in 2001. Nonradiological assessments would not be affected as they already considered possible adverse health effects from chronic residential exposure (30 years). Although this assessment indicates that the potential for significant future adverse health effects related to flooding is negligible, monitoring should be continued. If monitoring data show significant increases (even short term) in the concentrations of radionuclides or chemicals in various media, then additional risk assessments may be warranted.

#### **6.0 OVERALL CONCLUSIONS**

Observations and sampling have shown that the after effects of the Cerro Grande Fire resulted in increased concentrations of radiological and nonradiological chemicals in runoff and in sediments deposited during CY 2000. Our analyses indicate that the predominance of these effects was caused by

the increased mobilization of locally deposited worldwide fallout or of naturally occurring substances that were concentrated by the fire. Where increases were seen, we were not able to identify LANL as the source for these increases. However, for many of them we were not able to preclude the possibility that legacy LANL wastes in canyons and the area surrounding LANL contributed to the increases. We therefore calculated effects independent of their source if we could not determine the source.

None of the radiological or nonradiological effects we calculated for residents of Totavi or for direct or indirect users of Rio Grande water are believed to cause health effects in the exposed individuals for exposures received during CY 2000. If individuals were exposed for long periods of time at some of the potential maximum concentrations we calculated, some health effects could be possible. Evaluation of these hypothetical long-term exposures may be warranted, depending on future sampling and assessments.

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## APPENDIX A. SAMPLING DATA AND ANALYSIS OF RESULTS FOR TOTAVI AREA

### A-1.0 Samples Collected and Analytical Results

During latter 2000, rainstorms caused runoff throughout the Los Alamos Canyon watershed, which includes Pueblo, Rendija, and Guaje Canyons. In lower Los Alamos Canyon, an area with several residences, late-season floods deposited layers of ash and sediment. Samples were collected on March 6, 2001, to assess the radionuclide and nonradiological content of these flood-deposited sediments in the area behind the convenience store and residences in Los Alamos Canyon at Totavi (Table A-1). The study was conducted over a channel distance of approximately 300 m. We determined that sediments were deposited in the area during moderate floods generated by rainfall in October. The timing of the flood deposits is based on the observation that flood debris was found along a flood mark located on top of rock structures that were built in September for bank stabilization behind the convenience store. Observations during sampling indicated that these recent flood deposits covered approximately 25% of the floodplain area along the 300 m reach. Thickness of the deposits varied, but was generally less than approximately 20 cm (Table A-1). Some of the flood sediment that contained ash was preserved in small local areas within the channel, but the majority was preserved at relatively shallow depths on the floodplain. The deposits are highly stratified and include 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.

Samples were collected from representative locations in the reach near Totavi from layers representing a variety of sediment sizes within the deposits (Table A-1). All samples included one or more layers of ash-rich sediment typical of post-Cerro Grande Fire storm water deposits. Samples from the Totavi area were analyzed for  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{241}\text{Am}$ , isotopic plutonium and uranium, and inorganic constituents. Analytical results for these samples are provided in Table A-2.

Samples were also collected just upstream of the low-head weir structure in Los Alamos Canyon at the Laboratory boundary on September 11, 2000. These samples were analyzed for the same radionuclides and inorganic constituents as at Totavi and also for total cyanide and semivolatile organic constituents (including dioxins and furans). Analytical results for these samples are provided in Table A-3. We use the total cyanide and organic chemical results from Table A-3 to supplement the radionuclide and inorganic chemical results from Totavi presented in Table A-2.

The concentrations and analytes detected in these flood deposits are similar to those reported from ash and muck samples collected west of the Laboratory boundary (LANL 2000). Maximum concentrations of these post-fire sediment samples are provided in Table A-4. Pre-fire concentrations are also shown in Table A-4 for comparison.

### A-2.0 Data Analysis Methods

We used statistical and graphical analyses to compare post-fire radionuclide and metal concentrations from Los Alamos Canyon with Laboratory-wide sediment background concentrations and pre-fire concentrations for Los Alamos Canyon. These analyses are used to identify the radionuclide and metal analytes that will be evaluated for possible adverse health effects. We supplement this list of analytes with total cyanide results and the detected organic chemicals from sediment samples collected just upstream from the low-head weir.

Laboratory-wide sediment background data are presented in "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998). Results for Los Alamos Canyon from pre-fire sediment characterizations were reported in Reneau et al. (1998a, b, and c), and specific samples used were from reach LA-4 east (or LA-4E). Reach LA-4E is located 0.6 km upstream of the Totavi area. There are no tributary drainages or contaminated sites that affect Los Alamos canyon between LA-4E and Totavi, therefore pre-fire contaminant concentrations from the two areas should be comparable. In our evaluations of Cerro Grande effects at Totavi, we assume that the pre-fire concentrations of constituents at LA-4 East are the same as

the pre-fire concentrations at Totavi. In other words, the LA-4 East concentrations are used as surrogates to evaluate pre-fire conditions at Totavi.

Note that the phrase background values (BVs), where applied to nonradiological constituents, refers to estimates of the upper limit of Laboratory-wide background levels, as presented in Ryti et al. (1998). For comparisons of radionuclides, backgrounds were calculated as the numerical average of the individual soil or sediment BVs. These analyses were used to determine if post-fire sediment shows evidence of a systematic increase in the concentration of one or more analytes to levels greater than the concentrations observed in either the Laboratory-wide background data or pre-fire concentrations at reach LA-4E.

Two types of data analyses were used to evaluate the concentrations of radionuclides and metals in post-fire sediment samples data as compared with pre-fire concentrations. In the first type, a graphical comparison is made between Totavi (or LA-4 East as a surrogate) sample data and background sample data. In the second type, the results of formal statistical testing are presented. Each of these methods is discussed below in more detail.

### A-2.1 Graphical Comparisons of Analytical Results

These graphical comparisons use displays called box plots, which show the reported concentrations for radionuclides and metals. The ends of each box delimit the "interquartile" range of the data distribution, which is specified by the 25th percentile and 75th percentile of the data. The horizontal line above each box represents the 90th percentile, and the line beneath the box represents the 10th percentile of the sample results. The horizontal line within each box is the median (the 50th percentile) of the data distribution (if the number of samples is four or fewer, the horizontal line is not displayed). Thus, each box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes. If most of the data are represented by a single concentration value (usually the detection limit), the box is reduced to a single line. These plots also contain a horizontal line across the entire plot that represents the overall average concentration of all data groups.

In these statistical plots, one can compare pre-fire background sediment concentrations (background) to pre-fire reach LA-4E (as surrogates for pre-fire Totavi conditions) concentrations. The plots also show the concentrations of samples collected in post-fire ash and muck samples (baseline post-fire, see LANL 2000 for more information) and samples collected in post-fire sediment deposits in lower Los Alamos Canyon. Analytes are considered to represent fire impacted concentrations if the post-fire lower Los Alamos Canyon concentrations are greater than pre-fire concentrations (reach LA-4E values). The sample results for each of these data groups are plotted along with the other components of the box plot mentioned above. Also note that nondetected sample results for metals are plotted as the detection limit value and that radionuclide concentrations are plotted as reported from the analytical laboratory (not censored at the detection limit).

### A-2.2 Statistical Testing

Because the data for these analytes do not typically satisfy conditions of statistical normality, nonparametric statistical tests are preferred. Thus, the nonparametric Wilcoxon Rank Sum test or the Gehan test were used for statistical testing. The purpose of these tests was to detect if the post-fire data show evidence of a systematic increase in analytes' concentrations, relative to concentrations observed in pre-fire data. The tests pool pre-fire and post-fire data into one set and determine whether the average rank of post-fire data is greater than that of the pre-fire data. These tests are most sensitive to detecting cases where most of the post-fire data are greater than the average or median value observed in the pre-fire data. The Gehan test is a variation on the Wilcoxon Rank Sum test that handles nondetected sample results in a statistically valid manner. More discussion of these tests is contained in Ryti et al. (1996).

The metrics used to determine if a statistically significant difference exists between post-fire and pre-fire data are the calculated significance levels (p-values) for the tests. A low p-value (near 0) indicates that Totavi sampling results are greater than pre-fire data; a p-value approaching 1 indicates no difference

between Totavi and pre-fire data. If a p-value is less than some small probability (0.05), there is some reason to suspect that the Totavi concentrations are elevated above pre-fire concentrations; otherwise, no difference is indicated.

### A-3.0 Results

The results of the statistical analyses suggest that post-fire concentrations of one radionuclide ( $^{137}\text{Cs}$ ) at Totavi and 16 metals are greater than their pre-fire concentrations at that location. The metals included aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, vanadium, and zinc. Readers can review box plots of these comparisons, included as Figures A-1 through A-28. The box plots depict four data groups that include "background" or pre-fire sediment background concentrations (Ryti et al. 1998); "baseline muck" or post-fire samples of ash and muck collected west of the Laboratory (ESP 2000); reach LA-4E or pre-fire sediment concentration in lower Los Alamos Canyon (Reneau et al. 1998a, b, and c); and lower Los Alamos Canyon or post-fire CY 2000 sediment deposits in lower Los Alamos Canyon at Totavi.

Statistical analyses suggested that post-fire concentrations of four radionuclides ( $^{241}\text{Am}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$ , and  $^{90}\text{Sr}$ ) and two metals (beryllium and sodium) were not different from pre-fire values (Tables A-5 and A-6). Six metals are not detected with sufficient frequency to make statistical testing meaningful. For these metals (antimony, cadmium, mercury, selenium, silver, and thallium), the maximum concentration from post-fire sampling was compared with the sediment BV (Table A-3). Only the maximum concentration for selenium was greater than the BV, suggesting an increase over pre-fire concentrations.

In summary, one radionuclide ( $^{137}\text{Cs}$ ) and sixteen metals (aluminum, arsenic, barium, calcium, total chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, vanadium, and zinc) were identified as having concentrations greater than pre-fire levels based on Totavi sediment samples. In addition, samples from the low-head weir identified total cyanide as being greater than pre-fire levels. Eleven detected 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) will also be evaluated as possible post-fire sediment constituents. Thus, 29 analytes (one radionuclide, 16 metals, total cyanide, and 11 organic chemicals) will be evaluated for possible adverse health effects based on exposure to post-fire sediment deposits.

### A-4.0 References

- Reneau, S., R. Ryti, M. Tardiff, and J. Linn, 1998, "Evaluation of Sediment Contamination in Lower Los Alamos Canyon: Reaches LA-4 and LA-5," Los Alamos National Laboratory report LA-UR-98-3975.
- Ryti, R., P. Longmire, and E. McDonald, 1996, "Application of LANL Background Data to ER Project Decision-Making, Part I: Inorganics in Soils, Sediments, and Tuff," Los Alamos National Laboratory report LA-UR-96-1534.
- Ryti, R., P.A. Longmire, D.E. Broxton, S.L. Reneau, and E.V. McDonald, 1998, "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-98-4847.
- Smith, C.H., 2000, "Post-Cerro Grande Fire Environmental Sampling Data: Baseline Ash and Muck Samples," Los Alamos National Laboratory report LA-UR-00-4362.

Table A-1. Post-fire sediment sample descriptions.

<b>Location</b>	<b>Sample ID</b>	<b>Location ID</b>	<b>Texture</b>	<b>Comments</b>
Totavi	CALA-01-0004	LA-10042	sandy muck	Sample 0–5 cm, 0–4 cm = med sand, 4–5 cm = silty muck
	CALA-01-0005	LA-10043	silty muck	Sample 0–2 cm, silty muck with some fine sand
	CALA-01-0006	LA-10044	silty muck	Sample 0–6 cm, 0–4 cm = fine sandy silt, 4–6 cm = muck
	CALA-01-0007	LA-10045	silty muck	Sample 0–5 cm, silty muck
	CALA-01-0008	LA-10046	sandy muck	Sample 0–8 cm, 0–4 cm = slightly ashy fine sand, 4–6 cm = med-coarse sand w/ v. little ash, 6–8 = silty muck
	CALA-01-0011	LA-10047	sandy muck	sample 0–9 cm, 0–7 cm = slightly ashy fine-med sand, 7–7.5 = slightly silty muck, 7.5–8 = fine sand, 8–9 cm = silty muck
	CALA-01-0012	LA-10047	sandy muck	duplicate of CALA-01-0011
	CALA-01-0009	LA-10048	sandy muck	sample = 2–5.5 cm, 2–5 cm = med sand w/ some gravel, 5–5.5 cm = silty muck
	CALA-01-0010	LA-10049	sandy muck	sample 0–7 cm, 0–6 cm = mostly med-coarse sand, 6–7 cm = muck
Near low-head weir	CALA-00-0111	LA-10009	muck	clayey muck, 0–30 cm
	CALA-00-0112	LA-10010	muck	silty muck, 0–3 cm

Table A-2. Analytical results for Los Alamos Canyon at Totavi samples.

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNCERT.	QUALIFIER <sup>b</sup>
CALA-01-0004	8396R	LA-10042	Aluminum	5100		
CALA-01-0005	8396R	LA-10043	Aluminum	6100		
CALA-01-0006	8396R	LA-10044	Aluminum	8900		
CALA-01-0007	8396R	LA-10045	Aluminum	7100		
CALA-01-0008	8396R	LA-10046	Aluminum	5500		
CALA-01-0009	8396R	LA-10048	Aluminum	2000		
CALA-01-0010	8396R	LA-10049	Aluminum	4800		
CALA-01-0011	8396R	LA-10047	Aluminum	5000		
CALA-01-0004	8396R	LA-10042	Antimony	0.45		
CALA-01-0005	8396R	LA-10043	Antimony	0.41		
CALA-01-0006	8396R	LA-10044	Antimony	0.67		
CALA-01-0007	8396R	LA-10045	Antimony	0.46		U
CALA-01-0008	8396R	LA-10046	Antimony	0.51		
CALA-01-0009	8396R	LA-10048	Antimony	0.26		
CALA-01-0010	8396R	LA-10049	Antimony	0.52		
CALA-01-0011	8396R	LA-10047	Antimony	0.31		U
CALA-01-0004	8396R	LA-10042	Arsenic	2		
CALA-01-0005	8396R	LA-10043	Arsenic	2.7		
CALA-01-0006	8396R	LA-10044	Arsenic	3.4		
CALA-01-0007	8396R	LA-10045	Arsenic	3.2		
CALA-01-0008	8396R	LA-10046	Arsenic	1.9		
CALA-01-0009	8396R	LA-10048	Arsenic	0.91		
CALA-01-0010	8396R	LA-10049	Arsenic	1.6		
CALA-01-0011	8396R	LA-10047	Arsenic	1.0		
CALA-01-0004	8396R	LA-10042	Barium	120		
CALA-01-0005	8396R	LA-10043	Barium	130		
CALA-01-0006	8396R	LA-10044	Barium	230		
CALA-01-0007	8396R	LA-10045	Barium	140		
CALA-01-0008	8396R	LA-10046	Barium	130		
CALA-01-0009	8396R	LA-10048	Barium	64		
CALA-01-0010	8396R	LA-10049	Barium	110		
CALA-01-0011	8396R	LA-10047	Barium	94		
CALA-01-0004	8396R	LA-10042	Beryllium	0.57		
CALA-01-0005	8396R	LA-10043	Beryllium	0.85		
CALA-01-0006	8396R	LA-10044	Beryllium	1.1		
CALA-01-0007	8396R	LA-10045	Beryllium	1.2		
CALA-01-0008	8396R	LA-10046	Beryllium	0.63		
CALA-01-0009	8396R	LA-10048	Beryllium	0.24		
CALA-01-0010	8396R	LA-10049	Beryllium	0.52		
CALA-01-0011	8396R	LA-10047	Beryllium	0.55		
CALA-01-0004	8396R	LA-10042	Cadmium	0.027		U
CALA-01-0005	8396R	LA-10043	Cadmium	0.03		U
CALA-01-0006	8396R	LA-10044	Cadmium	0.078		
CALA-01-0007	8396R	LA-10045	Cadmium	0.039		U
CALA-01-0008	8396R	LA-10046	Cadmium	0.03		U
CALA-01-0009	8396R	LA-10048	Cadmium	0.022		U
CALA-01-0010	8396R	LA-10049	Cadmium	0.027		U
CALA-01-0011	8396R	LA-10047	Cadmium	0.026		U
CALA-01-0004	8396R	LA-10042	Calcium	5000		
CALA-01-0005	8396R	LA-10043	Calcium	5200		
CALA-01-0006	8396R	LA-10044	Calcium	14000		
CALA-01-0007	8396R	LA-10045	Calcium	6400		
CALA-01-0008	8396R	LA-10046	Calcium	7800		

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNCERT.	QUALIFIER <sup>b</sup>
CALA-01-0009	8396R	LA-10048	Calcium	1800		
CALA-01-0010	8396R	LA-10049	Calcium	6200		
CALA-01-0011	8396R	LA-10047	Calcium	5200		
CALA-01-0004	8396R	LA-10042	Chromium, Total	6.4		
CALA-01-0005	8396R	LA-10043	Chromium, Total	7.2		
CALA-01-0006	8396R	LA-10044	Chromium, Total	9		
CALA-01-0007	8396R	LA-10045	Chromium, Total	8.6		
CALA-01-0008	8396R	LA-10046	Chromium, Total	6.2		
CALA-01-0009	8396R	LA-10048	Chromium, Total	4.3		
CALA-01-0010	8396R	LA-10049	Chromium, Total	5.9		
CALA-01-0011	8396R	LA-10047	Chromium, Total	6		
CALA-01-0004	8396R	LA-10042	Cobalt	4.7		
CALA-01-0005	8396R	LA-10043	Cobalt	4.6		
CALA-01-0006	8396R	LA-10044	Cobalt	6.3		
CALA-01-0007	8396R	LA-10045	Cobalt	5.3		
CALA-01-0008	8396R	LA-10046	Cobalt	4.4		
CALA-01-0009	8396R	LA-10048	Cobalt	2.9		
CALA-01-0010	8396R	LA-10049	Cobalt	5.3		
CALA-01-0011	8396R	LA-10047	Cobalt	3.8		
CALA-01-0004	8396R	LA-10042	Copper	7.7		
CALA-01-0005	8396R	LA-10043	Copper	13		
CALA-01-0006	8396R	LA-10044	Copper	16		
CALA-01-0007	8396R	LA-10045	Copper	16		
CALA-01-0008	8396R	LA-10046	Copper	8.9		
CALA-01-0009	8396R	LA-10048	Copper	13		
CALA-01-0010	8396R	LA-10049	Copper	6.5		
CALA-01-0011	8396R	LA-10047	Copper	7.3		
CALA-01-0004	8396R	LA-10042	Iron	11000		
CALA-01-0005	8396R	LA-10043	Iron	10000		
CALA-01-0006	8396R	LA-10044	Iron	13000		
CALA-01-0007	8396R	LA-10045	Iron	12000		
CALA-01-0008	8396R	LA-10046	Iron	12000		
CALA-01-0009	8396R	LA-10048	Iron	8600		
CALA-01-0010	8396R	LA-10049	Iron	10000		
CALA-01-0011	8396R	LA-10047	Iron	9900		
CALA-01-0004	8396R	LA-10042	Lead	14		
CALA-01-0005	8396R	LA-10043	Lead	23		
CALA-01-0006	8396R	LA-10044	Lead	27		
CALA-01-0007	8396R	LA-10045	Lead	31		
CALA-01-0008	8396R	LA-10046	Lead	15		
CALA-01-0009	8396R	LA-10048	Lead	5.9		
CALA-01-0010	8396R	LA-10049	Lead	12		
CALA-01-0011	8396R	LA-10047	Lead	15		
CALA-01-0004	8396R	LA-10042	Magnesium	1700		
CALA-01-0005	8396R	LA-10043	Magnesium	1900		
CALA-01-0006	8396R	LA-10044	Magnesium	3100		
CALA-01-0007	8396R	LA-10045	Magnesium	2100		
CALA-01-0008	8396R	LA-10046	Magnesium	2000		
CALA-01-0009	8396R	LA-10048	Magnesium	950		
CALA-01-0010	8396R	LA-10049	Magnesium	1800		
CALA-01-0011	8396R	LA-10047	Magnesium	1800		
CALA-01-0004	8396R	LA-10042	Manganese	470		
CALA-01-0005	8396R	LA-10043	Manganese	540		
CALA-01-0006	8396R	LA-10044	Manganese	1000		

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNCERT.	QUALIFIER <sup>b</sup>
CALA-01-0007	8396R	LA-10045	Manganese	640		
CALA-01-0008	8396R	LA-10046	Manganese	550		
CALA-01-0009	8396R	LA-10048	Manganese	280		
CALA-01-0010	8396R	LA-10049	Manganese	460		
CALA-01-0011	8396R	LA-10047	Manganese	340		
CALA-01-0004	8396R	LA-10042	Mercury	0.0035		U
CALA-01-0005	8396R	LA-10043	Mercury	0.04		
CALA-01-0006	8396R	LA-10044	Mercury	0.020		
CALA-01-0007	8396R	LA-10045	Mercury	0.069		
CALA-01-0008	8396R	LA-10046	Mercury	0.0097		
CALA-01-0009	8396R	LA-10048	Mercury	0.0028		U
CALA-01-0010	8396R	LA-10049	Mercury	0.0035		U
CALA-01-0011	8396R	LA-10047	Mercury	0.016		
CALA-01-0004	8396R	LA-10042	Nickel	6.4		
CALA-01-0005	8396R	LA-10043	Nickel	7.4		
CALA-01-0006	8396R	LA-10044	Nickel	11		
CALA-01-0007	8396R	LA-10045	Nickel	8.6		
CALA-01-0008	8396R	LA-10046	Nickel	6.7		
CALA-01-0009	8396R	LA-10048	Nickel	4.3		
CALA-01-0010	8396R	LA-10049	Nickel	6.7		
CALA-01-0011	8396R	LA-10047	Nickel	5.9		
CALA-01-0004	8396R	LA-10042	Potassium	1200		
CALA-01-0005	8396R	LA-10043	Potassium	1400		
CALA-01-0006	8396R	LA-10044	Potassium	2000		
CALA-01-0007	8396R	LA-10045	Potassium	1600		
CALA-01-0008	8396R	LA-10046	Potassium	1300		
CALA-01-0009	8396R	LA-10048	Potassium	490		
CALA-01-0010	8396R	LA-10049	Potassium	1100		
CALA-01-0011	8396R	LA-10047	Potassium	1200		
CALA-01-0004	8396R	LA-10042	Selenium	0.33		U
CALA-01-0005	8396R	LA-10043	Selenium	0.37		U
CALA-01-0006	8396R	LA-10044	Selenium	0.38		
CALA-01-0007	8396R	LA-10045	Selenium	0.49		
CALA-01-0008	8396R	LA-10046	Selenium	0.37		U
CALA-01-0009	8396R	LA-10048	Selenium	0.27		U
CALA-01-0010	8396R	LA-10049	Selenium	0.34		U
CALA-01-0011	8396R	LA-10047	Selenium	0.32		U
CALA-01-0004	8396R	LA-10042	Silver	0.064		U
CALA-01-0005	8396R	LA-10043	Silver	0.30		
CALA-01-0006	8396R	LA-10044	Silver	0.13		
CALA-01-0007	8396R	LA-10045	Silver	0.65		
CALA-01-0008	8396R	LA-10046	Silver	0.071		U
CALA-01-0009	8396R	LA-10048	Silver	0.052		U
CALA-01-0010	8396R	LA-10049	Silver	0.065		U
CALA-01-0011	8396R	LA-10047	Silver	0.062		U
CALA-01-0004	8396R	LA-10042	Sodium	210		
CALA-01-0005	8396R	LA-10043	Sodium	240		
CALA-01-0006	8396R	LA-10044	Sodium	340		
CALA-01-0007	8396R	LA-10045	Sodium	200		
CALA-01-0008	8396R	LA-10046	Sodium	210		
CALA-01-0009	8396R	LA-10048	Sodium	74		
CALA-01-0010	8396R	LA-10049	Sodium	130		
CALA-01-0011	8396R	LA-10047	Sodium	180		
CALA-01-0004	8396R	LA-10042	Thallium	0.37		U

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNCERT.	QUALIFIER <sup>b</sup>
CALA-01-0005	8396R	LA-10043	Thallium	0.41		U
CALA-01-0006	8396R	LA-10044	Thallium	0.41		U
CALA-01-0007	8396R	LA-10045	Thallium	0.54		U
CALA-01-0008	8396R	LA-10046	Thallium	0.42		U
CALA-01-0009	8396R	LA-10048	Thallium	0.3		U
CALA-01-0010	8396R	LA-10049	Thallium	0.38		U
CALA-01-0011	8396R	LA-10047	Thallium	0.36		U
CALA-01-0004	8396R	LA-10042	Vanadium	17		
CALA-01-0005	8396R	LA-10043	Vanadium	15		
CALA-01-0006	8396R	LA-10044	Vanadium	20		
CALA-01-0007	8396R	LA-10045	Vanadium	17		
CALA-01-0008	8396R	LA-10046	Vanadium	17		
CALA-01-0009	8396R	LA-10048	Vanadium	13		
CALA-01-0010	8396R	LA-10049	Vanadium	18		
CALA-01-0011	8396R	LA-10047	Vanadium	15		
CALA-01-0004	8396R	LA-10042	Zinc	46		
CALA-01-0005	8396R	LA-10043	Zinc	58		
CALA-01-0006	8396R	LA-10044	Zinc	87		
CALA-01-0007	8396R	LA-10045	Zinc	75		
CALA-01-0008	8396R	LA-10046	Zinc	53		
CALA-01-0009	8396R	LA-10048	Zinc	30		
CALA-01-0010	8396R	LA-10049	Zinc	34		
CALA-01-0011	8396R	LA-10047	Zinc	40		
CALA-01-0004	8397R	LA-10042	Americium-241	-0.04	0.87	U
CALA-01-0005	8397R	LA-10043	Americium-241	0.01	0.27	U
CALA-01-0006	8397R	LA-10044	Americium-241	-0.04	0.405	U
CALA-01-0007	8397R	LA-10045	Americium-241	-0.22	0.465	U
CALA-01-0008	8397R	LA-10046	Americium-241	-0.13	1.08	U
CALA-01-0009	8397R	LA-10048	Americium-241	0.1	0.21	U
CALA-01-0010	8397R	LA-10049	Americium-241	-0.04	0.24	U
CALA-01-0011	8397R	LA-10047	Americium-241	0.05	0.315	U
CALA-01-0012	8397R	LA-10047	Americium-241	0.21	0.855	U
CALA-01-0004	8397R	LA-10042	Cesium-137	0.9	0.39	
CALA-01-0005	8397R	LA-10043	Cesium-137	1.05	0.66	
CALA-01-0006	8397R	LA-10044	Cesium-137	2.27	0.735	
CALA-01-0007	8397R	LA-10045	Cesium-137	2.23	0.66	
CALA-01-0008	8397R	LA-10046	Cesium-137	1.04	0.375	
CALA-01-0009	8397R	LA-10048	Cesium-137	0.31	0.225	
CALA-01-0010	8397R	LA-10049	Cesium-137	0.58	0.24	
CALA-01-0011	8397R	LA-10047	Cesium-137	0.8	0.315	
CALA-01-0012	8397R	LA-10047	Cesium-137	0.72	0.3	
CALA-01-0004	8397R	LA-10042	Plutonium-238	-0.001	0.021	U
CALA-01-0005	8397R	LA-10043	Plutonium-238	0.017	0.0225	U
CALA-01-0006	8397R	LA-10044	Plutonium-238	0.009	0.0195	U
CALA-01-0007	8397R	LA-10045	Plutonium-238	0.037	0.033	
CALA-01-0008	8397R	LA-10046	Plutonium-238	0.0033	0.01425	U
CALA-01-0009	8397R	LA-10048	Plutonium-238	0.0011	0.01335	U
CALA-01-0010	8397R	LA-10049	Plutonium-238	-0.0009	0.0144	U
CALA-01-0011	8397R	LA-10047	Plutonium-238	0	0.01485	U
CALA-01-0012	8397R	LA-10047	Plutonium-238	0.0087	0.01485	U
CALA-01-0004	8397R	LA-10042	Plutonium-239	0.201	0.0885	
CALA-01-0005	8397R	LA-10043	Plutonium-239	1.3	0.315	
CALA-01-0006	8397R	LA-10044	Plutonium-239	0.352	0.1185	
CALA-01-0007	8397R	LA-10045	Plutonium-239	1.51	0.345	

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNCERT.	QUALIFIER <sup>b</sup>
CALA-01-0008	8397R	LA-10046	Plutonium-239	0.226	0.0885	
CALA-01-0009	8397R	LA-10048	Plutonium-239	0.148	0.066	
CALA-01-0010	8397R	LA-10049	Plutonium-239	0.052	0.0405	
CALA-01-0011	8397R	LA-10047	Plutonium-239	0.313	0.111	
CALA-01-0012	8397R	LA-10047	Plutonium-239	0.217	0.084	
CALA-01-0004	8397R	LA-10042	Strontium-90	0.09	0.36	U
CALA-01-0005	8397R	LA-10043	Strontium-90	0.39	0.405	U
CALA-01-0006	8397R	LA-10044	Strontium-90	0.85	0.435	
CALA-01-0007	8397R	LA-10045	Strontium-90	0.38	0.36	
CALA-01-0008	8397R	LA-10046	Strontium-90	0.42	0.39	
CALA-01-0009	8397R	LA-10048	Strontium-90	0.1	0.315	U
CALA-01-0010	8397R	LA-10049	Strontium-90	0.06	0.315	U
CALA-01-0011	8397R	LA-10047	Strontium-90	0.2	0.345	U
CALA-01-0012	8397R	LA-10047	Strontium-90	0.1	0.315	U

<sup>a</sup>mg kg<sup>-1</sup> for nonradionuclides, pCi g<sup>-1</sup> for radionuclides

<sup>b</sup>U = The analyte was analyzed for, but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit. For radionuclide analyses, the reported value is the best estimate of the analyte concentration, even when that estimate is less than the detection limit. For statistical reasons, the estimates may sometimes be given as negative results.

Table A-3. Analytical results for Los Alamos Canyon at the low-head weir samples.

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT	UNC.	QUALIFIER <sup>b</sup>
				(mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>		
CALA-00-0111	7434R	LA-10009	Aluminum	13000		J-
CALA-00-0112	7434R	LA-10010	Aluminum	9900		J-
CALA-00-0111	7434R	LA-10009	Antimony	0.59		J-
CALA-00-0112	7434R	LA-10010	Antimony	0.69		J-
CALA-00-0111	7434R	LA-10009	Arsenic	5		
CALA-00-0112	7434R	LA-10010	Arsenic	4.1		
CALA-00-0111	7434R	LA-10009	Barium	370		
CALA-00-0112	7434R	LA-10010	Barium	280		
CALA-00-0111	7434R	LA-10009	Beryllium	1.7		
CALA-00-0112	7434R	LA-10010	Beryllium	1.4		
CALA-00-0111	7434R	LA-10009	Cadmium	0.59		J
CALA-00-0112	7434R	LA-10010	Cadmium	0.49		J
CALA-00-0111	7434R	LA-10009	Calcium	15000		
CALA-00-0112	7434R	LA-10010	Calcium	11000		
CALA-00-0111	7434R	LA-10009	Chromium, Total	11		
CALA-00-0112	7434R	LA-10010	Chromium, Total	8.9		
CALA-00-0111	7434R	LA-10009	Cobalt	8.1		
CALA-00-0112	7434R	LA-10010	Cobalt	6.5		
CALA-00-0111	7434R	LA-10009	Copper	26		
CALA-00-0112	7434R	LA-10010	Copper	20		
CALA-00-0111	7434R	LA-10009	Cyanide, Total	2.5		
CALA-00-0112	7434R	LA-10010	Cyanide, Total	2.2		
CALA-00-0111	7434R	LA-10009	Iron	16000		
CALA-00-0112	7434R	LA-10010	Iron	13000		
CALA-00-0111	7434R	LA-10009	Lead	53		
CALA-00-0112	7434R	LA-10010	Lead	42		
CALA-00-0111	7434R	LA-10009	Magnesium	2800		
CALA-00-0112	7434R	LA-10010	Magnesium	2200		
CALA-00-0111	7434R	LA-10009	Manganese	2100		
CALA-00-0112	7434R	LA-10010	Manganese	1500		
CALA-00-0111	7434R	LA-10009	Mercury	0.094		J
CALA-00-0112	7434R	LA-10010	Mercury	0.085		J
CALA-00-0111	7434R	LA-10009	Nickel	14		
CALA-00-0112	7434R	LA-10010	Nickel	11		
CALA-00-0111	7434R	LA-10009	Potassium	2400		J-
CALA-00-0112	7434R	LA-10010	Potassium	1900		J-
CALA-00-0111	7434R	LA-10009	Selenium	1.7		
CALA-00-0112	7434R	LA-10010	Selenium	1.2		
CALA-00-0111	7434R	LA-10009	Silver	0.085		U
CALA-00-0112	7434R	LA-10010	Silver	0.056		U
CALA-00-0111	7434R	LA-10009	Sodium	220		
CALA-00-0112	7434R	LA-10010	Sodium	170		
CALA-00-0111	7434R	LA-10009	Thallium	1.4		U
CALA-00-0112	7434R	LA-10010	Thallium	0.91		U
CALA-00-0111	7434R	LA-10009	Vanadium	22		
CALA-00-0112	7434R	LA-10010	Vanadium	17		
CALA-00-0111	7434R	LA-10009	Zinc	140		
CALA-00-0112	7434R	LA-10010	Zinc	110		
CALA-00-0111	7433R	LA-10009	Acenaphthene	0.6		U
CALA-00-0112	7433R	LA-10010	Acenaphthene	0.42		U
CALA-00-0111	7433R	LA-10009	Acenaphthylene	0.6		U
CALA-00-0112	7433R	LA-10010	Acenaphthylene	0.42		U

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT		QUALIFIER <sup>b</sup>
				(mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNC.	
CALA-00-0111	7433R	LA-10009	Aniline	1.2		U
CALA-00-0112	7433R	LA-10010	Aniline	0.83		U
CALA-00-0111	7433R	LA-10009	Anthracene	0.6		U
CALA-00-0112	7433R	LA-10010	Anthracene	0.42		U
CALA-00-0111	7433R	LA-10009	Azobenzene	1.2		U
CALA-00-0112	7433R	LA-10010	Azobenzene	0.83		U
CALA-00-0111	7433R	LA-10009	Benzidine	0.6		UJ
CALA-00-0112	7433R	LA-10010	Benzidine	0.42		UJ
CALA-00-0111	7433R	LA-10009	Benzo(a)anthracene	0.6		U
CALA-00-0112	7433R	LA-10010	Benzo(a)anthracene	0.25		J
CALA-00-0111	7433R	LA-10009	Benzo(a)pyrene	0.6		U
CALA-00-0112	7433R	LA-10010	Benzo(a)pyrene	0.26		J
CALA-00-0111	7433R	LA-10009	Benzo(b)fluoranthene	0.6		U
CALA-00-0112	7433R	LA-10010	Benzo(b)fluoranthene	0.33		J
CALA-00-0111	7433R	LA-10009	Benzo(g,h,i)perylene	0.6		U
CALA-00-0112	7433R	LA-10010	Benzo(g,h,i)perylene	0.16		J
CALA-00-0111	7433R	LA-10009	Benzo(k)fluoranthene	0.6		U
CALA-00-0112	7433R	LA-10010	Benzo(k)fluoranthene	0.42		UJ
CALA-00-0111	7433R	LA-10009	Benzoic Acid	3		U
CALA-00-0112	7433R	LA-10010	Benzoic Acid	2.1		U
CALA-00-0111	7433R	LA-10009	Benzyl Alcohol	1.2		U
CALA-00-0112	7433R	LA-10010	Benzyl Alcohol	0.83		U
CALA-00-0111	7433R	LA-10009	Bis(2-chloroethoxy)methane	0.6		U
CALA-00-0112	7433R	LA-10010	Bis(2-chloroethoxy)methane	0.42		U
CALA-00-0111	7433R	LA-10009	Bis(2-chloroethyl)ether	0.6		U
CALA-00-0112	7433R	LA-10010	Bis(2-chloroethyl)ether	0.42		U
CALA-00-0111	7433R	LA-10009	Bis(2-ethylhexyl)phthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Bis(2-ethylhexyl)phthalate	0.42		U
CALA-00-0111	7433R	LA-10009	Bromophenyl-phenylether[4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Bromophenyl-phenylether[4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Butylbenzylphthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Butylbenzylphthalate	0.42		U
CALA-00-0111	7433R	LA-10009	Carbazole	0.6		U
CALA-00-0112	7433R	LA-10010	Carbazole	0.42		U
CALA-00-0111	7433R	LA-10009	Chloro-3-methylphenol[4-]	1.2		U
CALA-00-0112	7433R	LA-10010	Chloro-3-methylphenol[4-]	0.83		U
CALA-00-0111	7433R	LA-10009	Chloroaniline[4-]	1.2		U
CALA-00-0112	7433R	LA-10010	Chloroaniline[4-]	0.83		U
CALA-00-0111	7433R	LA-10009	Chloronaphthalene[2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Chloronaphthalene[2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Chlorophenol[2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Chlorophenol[2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Chlorophenyl-phenyl[4-] Ether	0.6		U
CALA-00-0112	7433R	LA-10010	Chlorophenyl-phenyl[4-] Ether	0.42		U
CALA-00-0111	7433R	LA-10009	Chrysene	0.6		U
CALA-00-0112	7433R	LA-10010	Chrysene	0.27		J
CALA-00-0111	7433R	LA-10009	Dibenz(a,h)anthracene	0.6		U
CALA-00-0112	7433R	LA-10010	Dibenz(a,h)anthracene	0.42		UJ
CALA-00-0111	7433R	LA-10009	Dibenzofuran	0.6		U
CALA-00-0112	7433R	LA-10010	Dibenzofuran	0.42		U
CALA-00-0111	7433R	LA-10009	Dichlorobenzene[1,2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dichlorobenzene[1,2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Dichlorobenzene[1,3-]	0.6		U

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT		
				(mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNC.	QUALIFIER <sup>b</sup>
CALA-00-0112	7433R	LA-10010	Dichlorobenzene[1,3-]	0.42		U
CALA-00-0111	7433R	LA-10009	Dichlorobenzene[1,4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dichlorobenzene[1,4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Dichlorobenzidine[3,3'-]	1.2		U
CALA-00-0112	7433R	LA-10010	Dichlorobenzidine[3,3'-]	0.83		U
CALA-00-0111	7433R	LA-10009	Dichlorophenol[2,4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dichlorophenol[2,4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Diethylphthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Diethylphthalate	0.42		U
CALA-00-0111	7433R	LA-10009	Dimethyl Phthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Dimethyl Phthalate	0.42		U
CALA-00-0111	7433R	LA-10009	Dimethylphenol[2,4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dimethylphenol[2,4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Di-n-butylphthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Di-n-butylphthalate	0.42		U
CALA-00-0111	7433R	LA-10009	Dinitro-2-methylphenol[4,6-]	3		U
CALA-00-0112	7433R	LA-10010	Dinitro-2-methylphenol[4,6-]	2.1		U
CALA-00-0111	7433R	LA-10009	Dinitrophenol[2,4-]	3		U
CALA-00-0112	7433R	LA-10010	Dinitrophenol[2,4-]	2.1		U
CALA-00-0111	7433R	LA-10009	Dinitrotoluene[2,4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dinitrotoluene[2,4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Dinitrotoluene[2,6-]	0.6		U
CALA-00-0112	7433R	LA-10010	Dinitrotoluene[2,6-]	0.42		U
CALA-00-0111	7433R	LA-10009	Di-n-octylphthalate	0.6		U
CALA-00-0112	7433R	LA-10010	Di-n-octylphthalate	0.42		UJ
CALA-00-0111	7433R	LA-10009	Fluoranthene	0.6		U
CALA-00-0112	7433R	LA-10010	Fluoranthene	0.52		
CALA-00-0111	7433R	LA-10009	Fluorene	0.6		U
CALA-00-0112	7433R	LA-10010	Fluorene	0.42		U
CALA-00-0111	7433R	LA-10009	Hexachlorobenzene	0.6		U
CALA-00-0112	7433R	LA-10010	Hexachlorobenzene	0.42		U
CALA-00-0111	7433R	LA-10009	Hexachlorobutadiene	0.6		U
CALA-00-0112	7433R	LA-10010	Hexachlorobutadiene	0.42		U
CALA-00-0111	7433R	LA-10009	Hexachlorocyclopentadiene	0.6		UJ
CALA-00-0112	7433R	LA-10010	Hexachlorocyclopentadiene	0.42		UJ
CALA-00-0111	7433R	LA-10009	Hexachloroethane	0.6		U
CALA-00-0112	7433R	LA-10010	Hexachloroethane	0.42		U
CALA-00-0111	7433R	LA-10009	Indeno(1,2,3-cd)pyrene	0.6		U
CALA-00-0112	7433R	LA-10010	Indeno(1,2,3-cd)pyrene	0.42		UJ
CALA-00-0111	7433R	LA-10009	Isophorone	0.6		U
CALA-00-0112	7433R	LA-10010	Isophorone	0.42		U
CALA-00-0111	7433R	LA-10009	Methylnaphthalene[2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Methylnaphthalene[2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Methylphenol[2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Methylphenol[2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Methylphenol[4-]	2		
CALA-00-0112	7433R	LA-10010	Methylphenol[4-]	1.5		
CALA-00-0111	7433R	LA-10009	Naphthalene	0.6		U
CALA-00-0112	7433R	LA-10010	Naphthalene	0.25		J
CALA-00-0111	7433R	LA-10009	Nitroaniline[2-]	3		U
CALA-00-0112	7433R	LA-10010	Nitroaniline[2-]	2.1		U
CALA-00-0111	7433R	LA-10009	Nitroaniline[3-]	3		UJ
CALA-00-0112	7433R	LA-10010	Nitroaniline[3-]	2.1		UJ

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT		
				(mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNC.	QUALIFIER <sup>b</sup>
CALA-00-0111	7433R	LA-10009	Nitroaniline[4-]	1.2		U
CALA-00-0112	7433R	LA-10010	Nitroaniline[4-]	0.83		U
CALA-00-0111	7433R	LA-10009	Nitrobenzene	0.6		U
CALA-00-0112	7433R	LA-10010	Nitrobenzene	0.42		U
CALA-00-0111	7433R	LA-10009	Nitrophenol[2-]	0.6		U
CALA-00-0112	7433R	LA-10010	Nitrophenol[2-]	0.42		U
CALA-00-0111	7433R	LA-10009	Nitrophenol[4-]	3		U
CALA-00-0112	7433R	LA-10010	Nitrophenol[4-]	2.1		U
CALA-00-0111	7433R	LA-10009	Nitrosodimethylamine[N-]	0.6		U
CALA-00-0112	7433R	LA-10010	Nitrosodimethylamine[N-]	0.42		U
CALA-00-0111	7433R	LA-10009	Nitroso-di-n-propylamine[N-]	0.6		U
CALA-00-0112	7433R	LA-10010	Nitroso-di-n-propylamine[N-]	0.42		U
CALA-00-0111	7433R	LA-10009	Nitrosodiphenylamine[N-]	0.6		U
CALA-00-0112	7433R	LA-10010	Nitrosodiphenylamine[N-]	0.42		U
CALA-00-0111	7433R	LA-10009	Oxybis(1-chloropropane)[2,2'-]	0.6		U
CALA-00-0112	7433R	LA-10010	Oxybis(1-chloropropane)[2,2'-]	0.42		U
CALA-00-0111	7433R	LA-10009	Pentachlorophenol	3		U
CALA-00-0112	7433R	LA-10010	Pentachlorophenol	2.1		U
CALA-00-0111	7433R	LA-10009	Phenanthrene	0.6		U
CALA-00-0112	7433R	LA-10010	Phenanthrene	0.46		U
CALA-00-0111	7433R	LA-10009	Phenol	0.6		U
CALA-00-0112	7433R	LA-10010	Phenol	0.42		U
CALA-00-0111	7433R	LA-10009	Pyrene	0.28		J
CALA-00-0112	7433R	LA-10010	Pyrene	0.58		U
CALA-00-0111	7433R	LA-10009	Pyridine	0.6		U
CALA-00-0112	7433R	LA-10010	Pyridine	0.42		U
CALA-00-0111	7433R	LA-10009	Trichlorobenzene[1,2,4-]	0.6		U
CALA-00-0112	7433R	LA-10010	Trichlorobenzene[1,2,4-]	0.42		U
CALA-00-0111	7433R	LA-10009	Trichlorophenol[2,4,5-]	3		U
CALA-00-0112	7433R	LA-10010	Trichlorophenol[2,4,5-]	2.1		U
CALA-00-0111	7433R	LA-10009	Trichlorophenol[2,4,6-]	0.6		U
CALA-00-0112	7433R	LA-10010	Trichlorophenol[2,4,6-]	0.42		U
CALA-00-0111	7433R	LA-10009	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	6.46E-05		
CALA-00-0112	7433R	LA-10010	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	5.81E-05		
CALA-00-0111	7433R	LA-10009	Heptachlorodibenzodioxins (Total)	1.25E-04		
CALA-00-0112	7433R	LA-10010	Heptachlorodibenzodioxins (Total)	1.05E-04		
CALA-00-0111	7433R	LA-10009	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	1.98E-05		
CALA-00-0112	7433R	LA-10010	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	1.82E-05		
CALA-00-0111	7433R	LA-10009	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	1.65E-06		J
CALA-00-0112	7433R	LA-10010	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	1.37E-06		J
CALA-00-0111	7433R	LA-10009	Heptachlorodibenzofurans (Total)	5.12E-05		
CALA-00-0112	7433R	LA-10010	Heptachlorodibenzofurans (Total)	4.82E-05		
CALA-00-0111	7433R	LA-10009	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	1.24E-06		J
CALA-00-0112	7433R	LA-10010	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	1.10E-06		
CALA-00-0111	7433R	LA-10009	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	2.80E-06		

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT (mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNC.	QUALIFIER <sup>b</sup>
CALA-00-0112	7433R	LA-10010	8-] Hexachlorodibenzodioxin[1,2,3,6,7,	3.02E-06		
CALA-00-0111	7433R	LA-10009	8-] Hexachlorodibenzodioxin[1,2,3,7,8,	2.13E-06		J
CALA-00-0112	7433R	LA-10010	9-] Hexachlorodibenzodioxin[1,2,3,7,8,	2.59E-06		
CALA-00-0111	7433R	LA-10009	Hexachlorodibenzodioxins (Total)	2.34E-05		
CALA-00-0112	7433R	LA-10010	Hexachlorodibenzodioxins (Total)	2.32E-05		
CALA-00-0111	7433R	LA-10009	Hexachlorodibenzofuran[1,2,3,4,7,8	1.61E-06		J
CALA-00-0112	7433R	LA-10010	-] Hexachlorodibenzofuran[1,2,3,4,7,8	1.59E-06		J
CALA-00-0111	7433R	LA-10009	-] Hexachlorodibenzofuran[1,2,3,6,7,8	1.33E-06		J
CALA-00-0112	7433R	LA-10010	-] Hexachlorodibenzofuran[1,2,3,6,7,8	1.11E-06		J
CALA-00-0111	7433R	LA-10009	-] Hexachlorodibenzofuran[1,2,3,7,8,9	3.06E-06		U
CALA-00-0112	7433R	LA-10010	-] Hexachlorodibenzofuran[1,2,3,7,8,9	1.57E-07		U
CALA-00-0111	7433R	LA-10009	-] Hexachlorodibenzofuran[2,3,4,6,7,8	1.49E-06		J
CALA-00-0112	7433R	LA-10010	-] Hexachlorodibenzofuran[2,3,4,6,7,8	1.45E-06		J
CALA-00-0111	7433R	LA-10009	Hexachlorodibenzofurans (Total)	2.62E-05		
CALA-00-0112	7433R	LA-10010	Hexachlorodibenzofurans (Total)	2.34E-05		
CALA-00-0111	7433R	LA-10009	Octachlorodibenzodioxin[1,2,3,4,6,7	6.84E-04		J+
CALA-00-0112	7433R	LA-10010	,8,9-] Octachlorodibenzodioxin[1,2,3,4,6,7	5.48E-04		J+
CALA-00-0111	7433R	LA-10009	,8,9-] Octachlorodibenzofuran[1,2,3,4,6,7,	5.25E-05		
CALA-00-0112	7433R	LA-10010	8,9-] Octachlorodibenzofuran[1,2,3,4,6,7,	4.49E-05		
CALA-00-0111	7433R	LA-10009	8,9-] Pentachlorodibenzodioxin[1,2,3,7,8-	3.96E-07		J
CALA-00-0112	7433R	LA-10010	] Pentachlorodibenzodioxin[1,2,3,7,8-	4.88E-07		J
CALA-00-0111	7433R	LA-10009	] Pentachlorodibenzodioxins (Total)	3.37E-06		
CALA-00-0112	7433R	LA-10010	Pentachlorodibenzodioxins (Total)	2.75E-06		
CALA-00-0111	7433R	LA-10009	Pentachlorodibenzofuran[1,2,3,7,8-]	3.89E-07		J
CALA-00-0112	7433R	LA-10010	Pentachlorodibenzofuran[1,2,3,7,8-]	3.95E-07		J
CALA-00-0111	7433R	LA-10009	Pentachlorodibenzofuran[2,3,4,7,8-]	9.70E-07		J
CALA-00-0112	7433R	LA-10010	Pentachlorodibenzofuran[2,3,4,7,8-]	9.67E-07		J
CALA-00-0111	7433R	LA-10009	Pentachlorodibenzofurans (Totals)	1.20E-05		
CALA-00-0112	7433R	LA-10010	Pentachlorodibenzofurans (Totals)	1.37E-05		
CALA-00-0111	7433R	LA-10009	Tetrachlorodibenzodioxin[2,3,7,8-]	1.65E-07		U
CALA-00-0112	7433R	LA-10010	Tetrachlorodibenzodioxin[2,3,7,8-]	1.13E-07		U
CALA-00-0111	7433R	LA-10009	Tetrachlorodibenzodioxins (Total)	3.36E-06		
CALA-00-0112	7433R	LA-10010	Tetrachlorodibenzodioxins (Total)	2.55E-06		
CALA-00-0111	7433R	LA-10009	Tetrachlorodibenzofuran[2,3,7,8-]	9.32E-07		
CALA-00-0112	7433R	LA-10010	Tetrachlorodibenzofuran[2,3,7,8]	9.82E-07		

SAMPLE ID	REQUEST NUMBER	LOCATION ID	ANALYTE NAME	RESULT		
				(mg kg <sup>-1</sup> or pCi g <sup>-1</sup> ) <sup>a</sup>	UNC.	QUALIFIER <sup>b</sup>
CALA-00-0111	7433R	LA-10009	Tetrachlorodibenzofurans (Totals)	1.02E-05		
CALA-00-0112	7433R	LA-10010	Tetrachlorodibenzofurans (Totals)	9.23E-06		
CALA-00-0111	7436R	LA-10009	Americium-241	1	1.15	U
CALA-00-0112	7436R	LA-10010	Americium-241	-0.04	0.13	U
CALA-00-0111	7436R	LA-10009	Cesium-134	0.03	0.05	U
CALA-00-0112	7436R	LA-10010	Cesium-134	0.03	0.06	U
CALA-00-0111	7436R	LA-10009	Cesium-137	4.77	0.37	
CALA-00-0112	7436R	LA-10010	Cesium-137	3.04	0.265	
CALA-00-0111	7436R	LA-10009	Cobalt-60	0.019	0.041	U
CALA-00-0112	7436R	LA-10010	Cobalt-60	-0.02	0.06	U
CALA-00-0111	7436R	LA-10009	Europium-152	-0.01	0.18	U
CALA-00-0112	7436R	LA-10010	Europium-152	-0.08	0.16	U
CALA-00-0111	7436R	LA-10009	Plutonium-238	0.018	0.01	U
CALA-00-0112	7436R	LA-10010	Plutonium-238	0.019	0.0095	U
CALA-00-0111	7436R	LA-10009	Plutonium-239	1.19	0.105	
CALA-00-0112	7436R	LA-10010	Plutonium-239	1.28	0.11	
CALA-00-0111	7436R	LA-10009	Ruthenium-106	-0.2	0.55	U
CALA-00-0112	7436R	LA-10010	Ruthenium-106	-0.3	0.7	U
CALA-00-0111	7436R	LA-10009	Sodium-22	-0.02	0.055	U
CALA-00-0112	7436R	LA-10010	Sodium-22	-0.02	0.075	U
CALA-00-0112	7436R	LA-10010	Strontium-90	1.14	0.225	
<b>DUP</b>						
CALA-00-0111	7436R	LA-10009	Strontium-90	1.24	0.225	
CALA-00-0111	7436R	LA-10009	Tritium	0.2	0.095	U
CALA-00-0112	7436R	LA-10010	Tritium	0.013	0.015	U
CALA-00-0112	7436R	LA-10010	Uranium-234	1.45	0.13	
CALA-00-0111	7436R	LA-10009	Uranium-234	1.59	0.14	
CALA-00-0111	7436R	LA-10009	Uranium-235	0.122	0.0275	U
CALA-00-0112	7436R	LA-10010	Uranium-235	0.133	0.275	U
CALA-00-0111	7436R	LA-10009	Uranium-238	1.61	0.145	
CALA-00-0112	7436R	LA-10010	Uranium-238	1.51	0.135	

<sup>a</sup>mg kg<sup>-1</sup> for non radionuclides, pCi g<sup>-1</sup> for radionuclides

<sup>b</sup>U = The analyte was analyzed for, but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit. For radionuclide analyses, the reported value is the best estimate of the analyte concentration, even when that estimate is less than the detection limit. For statistical reasons, the estimates may sometimes be given as negative results.

J = The reported value should be regarded as estimated.

J+ = The reported value should be regarded as estimated and biased high.

J- = The reported value should be regarded as estimated and biased low.

UJ = The analyte was analyzed for, but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.

Table A-4. Summary of maximum values in pre-fire and post-fire sediment samples.

Analyte	Units	Pre-fire		Post-fire		
		Sediment BV	Reach LA-4E	Totavi	Low-head weir	Baseline Muck
Americium-241	pCi g <sup>-1</sup>	0.04	0.602	0.21	1	0.203
Cesium-137	pCi g <sup>-1</sup>	0.9	1.81	2.27	4.77	5.16
Plutonium-238	pCi g <sup>-1</sup>	0.006	0.051	0.037	0.019	0.042
Plutonium-239,240	pCi g <sup>-1</sup>	0.068	6.02	1.51	1.28	0.7
Strontium-90	pCi g <sup>-1</sup>	1.04	0.57	0.85	1.24	3.48
Aluminum	mg kg <sup>-1</sup>	15400	5480	8900	13000	17000
Antimony	mg kg <sup>-1</sup>	0.83	4.9	0.67	0.69	0.68
Arsenic	mg kg <sup>-1</sup>	3.98	2.9	3.4	5	6.6
Barium	mg kg <sup>-1</sup>	127	104	230	370	1300
Beryllium	mg kg <sup>-1</sup>	1.31	1.3	1.2	1.7	1
Cadmium	mg kg <sup>-1</sup>	0.4	0.49	0.078	0.59	0.96
Calcium	mg kg <sup>-1</sup>	4420	6980	14000	15000	90000
Chromium, total	mg kg <sup>-1</sup>	10.5	5.3	9	11	11
Cobalt	mg kg <sup>-1</sup>	4.73	4.4	6.3	8.1	8.9
Copper	mg kg <sup>-1</sup>	11.2	10.8	16	26	45
Cyanide, total	mg kg <sup>-1</sup>	0.82	n/a	n/a	2.5	n/a
Iron	mg kg <sup>-1</sup>	13800	7530	13000	16000	15000
Lead	mg kg <sup>-1</sup>	19.7	13.2	31	53	75
Magnesium	mg kg <sup>-1</sup>	2370	1940	3100	2800	6100
Manganese	mg kg <sup>-1</sup>	543	364	1000	2100	8200
Mercury	mg kg <sup>-1</sup>	0.1	0.035	0.069	0.094	0.04
Nickel	mg kg <sup>-1</sup>	9.38	7.1	11	14	11
Potassium	mg kg <sup>-1</sup>	2690	1530	2000	2400	8800
Selenium	mg kg <sup>-1</sup>	0.3	0.83	0.49	1.7	4.7
Silver	mg kg <sup>-1</sup>	1	0.49	0.65	0.085	0.64
Sodium	mg kg <sup>-1</sup>	1470	572	340	220	870
Thallium	mg kg <sup>-1</sup>	0.73	0.88	0.54	1.4	4.1
Vanadium	mg kg <sup>-1</sup>	19.7	13.1	20	22	25
Zinc	mg kg <sup>-1</sup>	60.2	31.6	87	140	180
Benzo(a)anthracene	mg kg <sup>-1</sup>	N/A <sup>a</sup>	N/A	N/A	0.25	nd <sup>b</sup>
Benzo(a)pyrene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.26	nd
Benzo(b)fluoranthene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.33	nd
Benzo(g,h,i)perylene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.16	nd
Benzoic Acid	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	5.9
Chrysene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.27	nd
Dibenzofuran	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	0.75
Dimethylphenol[2,4-]	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	0.46
Fluoranthene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.52	nd
Methylnaphthalene[2-]	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	0.2
Methylphenol[2-]	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	0.96
Methylphenol[4-]	mg kg <sup>-1</sup>	N/A	N/A	N/A	2	3
Naphthalene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.25	1.5
Phenanthrene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.46	0.98
Phenol	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	5.4
Pyrene	mg kg <sup>-1</sup>	N/A	N/A	N/A	0.58	nd
Pyridine	mg kg <sup>-1</sup>	N/A	N/A	N/A	nd	7.1
Summed 2,3,7,8-TCDD equivalent	mg kg <sup>-1</sup>	N/A	N/A	N/A	3.5 x 10 <sup>-6</sup>	4.7 x 10 <sup>-7</sup>

<sup>a</sup>N/A = not analyzed.

<sup>b</sup>nd = not detected.

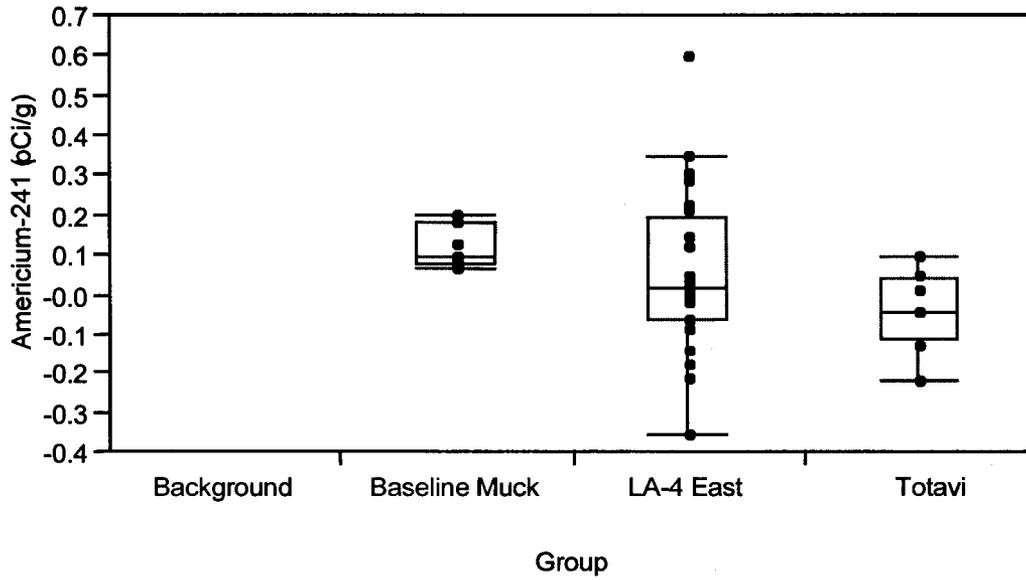


Figure A-1. Box plot for americium-241 (note - there are no background data for americium-241 by gamma spectroscopy - the analytical method used for other data groups).

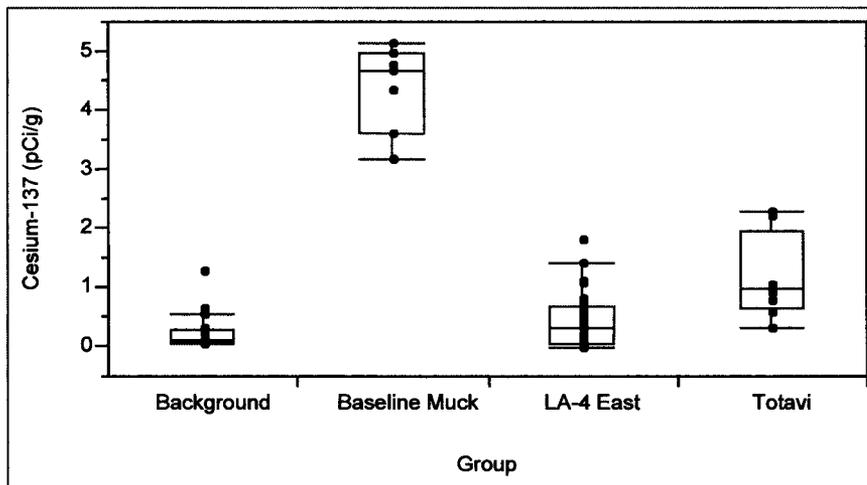


Figure A-2. Box plot for cesium-137.

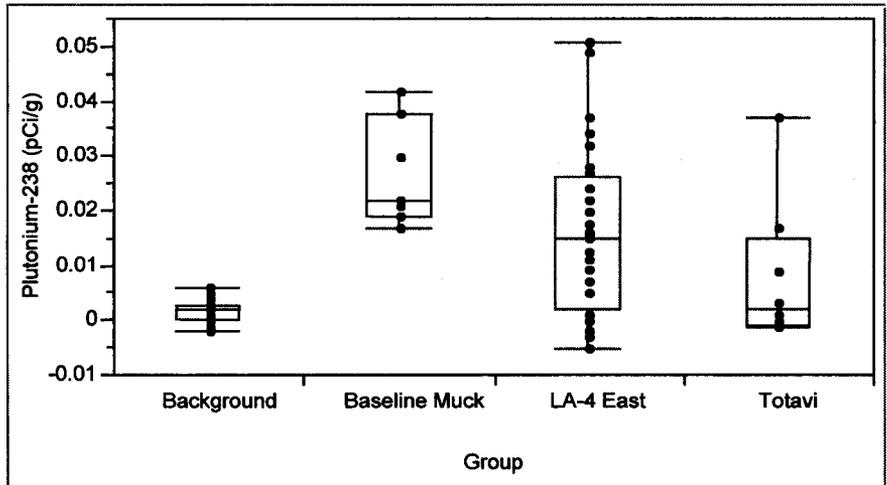


Figure A-3. Box plot for plutonium-238.

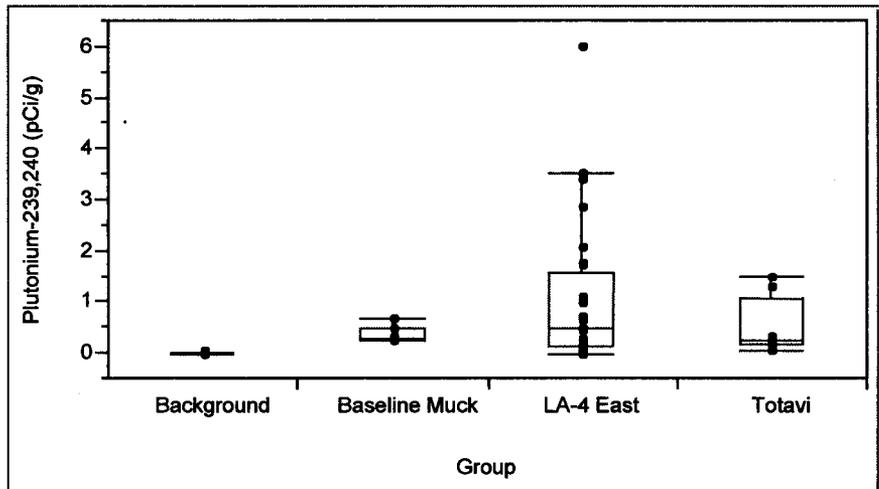


Figure A-4. Box plot for plutonium-239,240

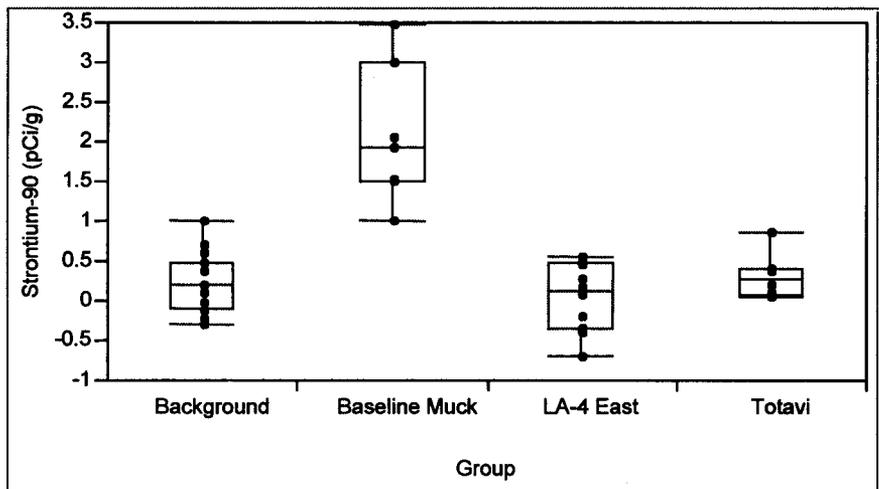


Figure A-5. Box plot for strontium-90

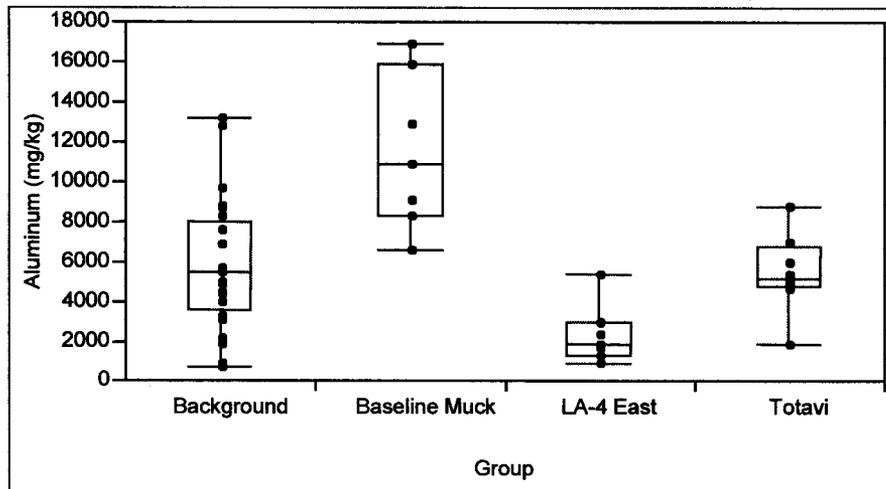


Figure A-6. Box plot for aluminum.

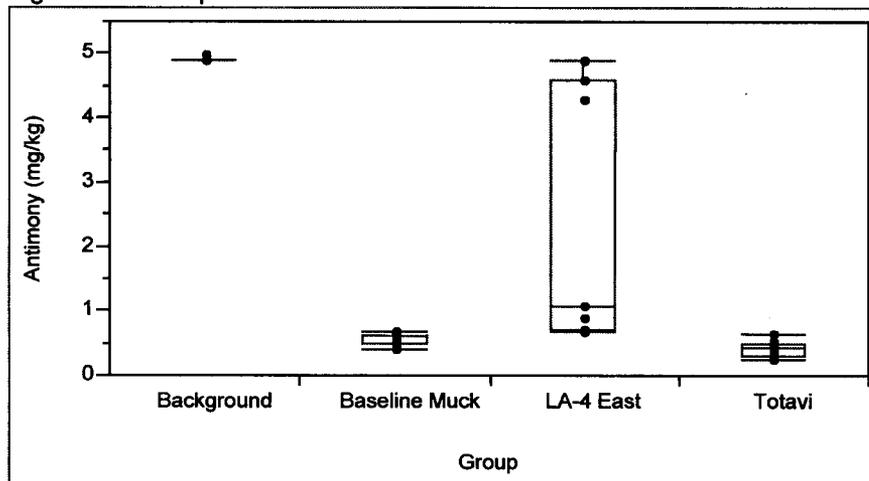


Figure A-7. Box plot for antimony (note that the background data for antimony were obtained from an analytical method with an insufficient detection limit, which is also the case for some results for LA-4 East).

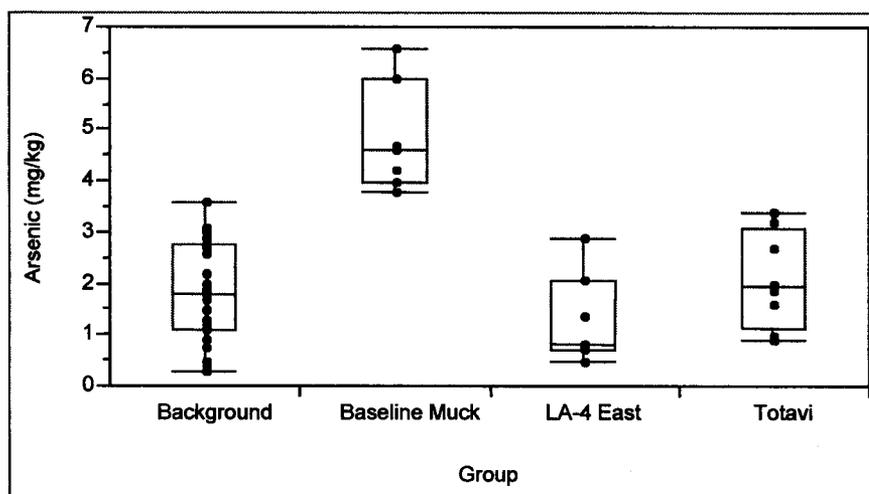


Figure A-8. Box plot for arsenic.

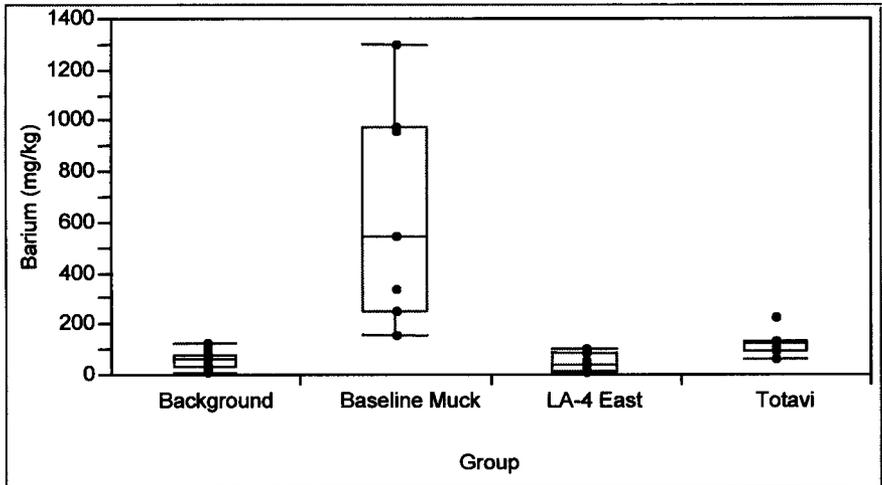


Figure A-9. Box plot for barium.

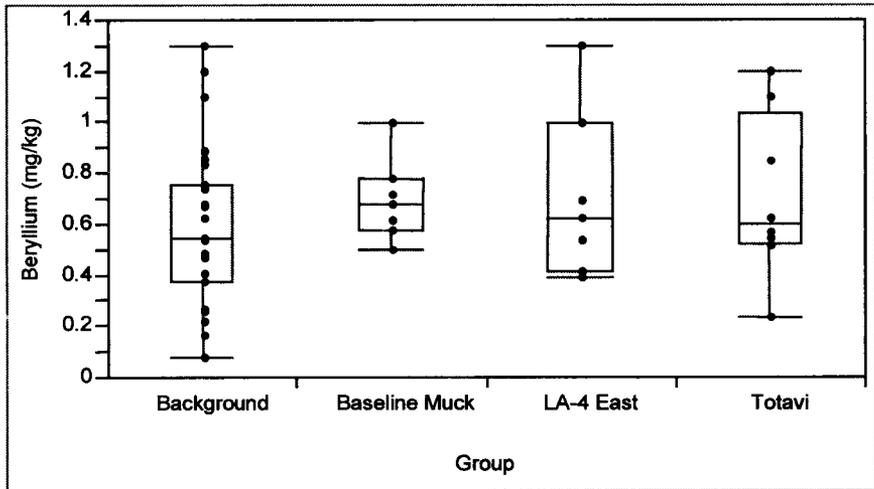


Figure A-10. Box plot for beryllium.

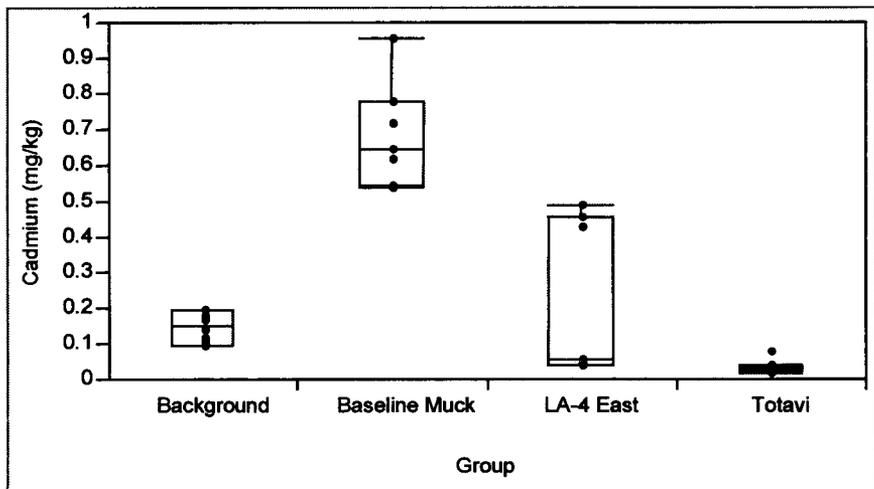


Figure A-11. Box plot for cadmium.

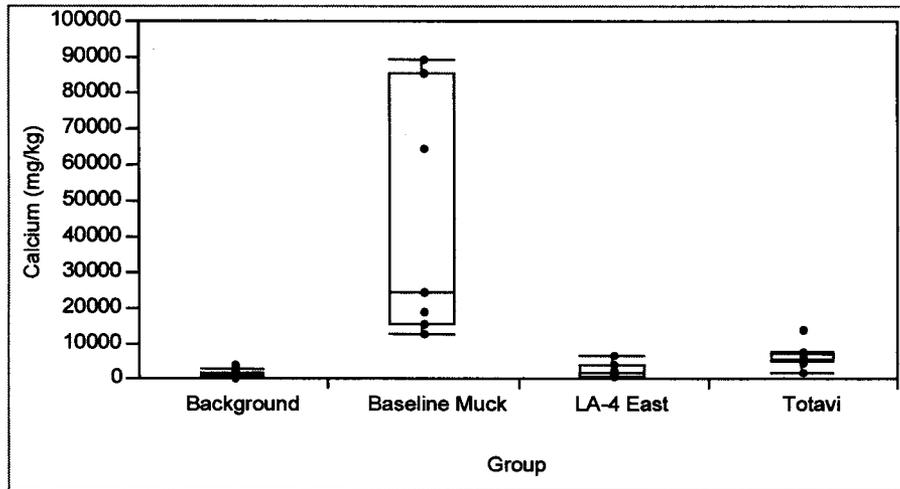


Figure A-12. Box plot for calcium.

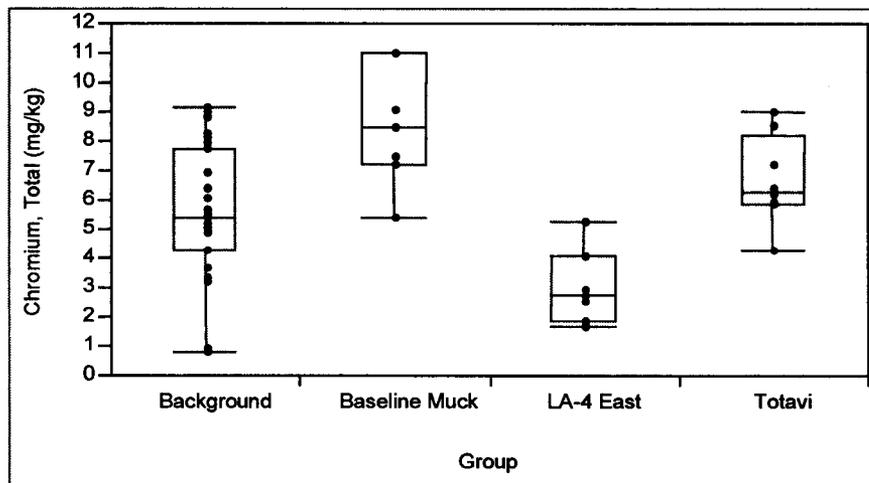


Figure A-13. Box plot for total chromium.

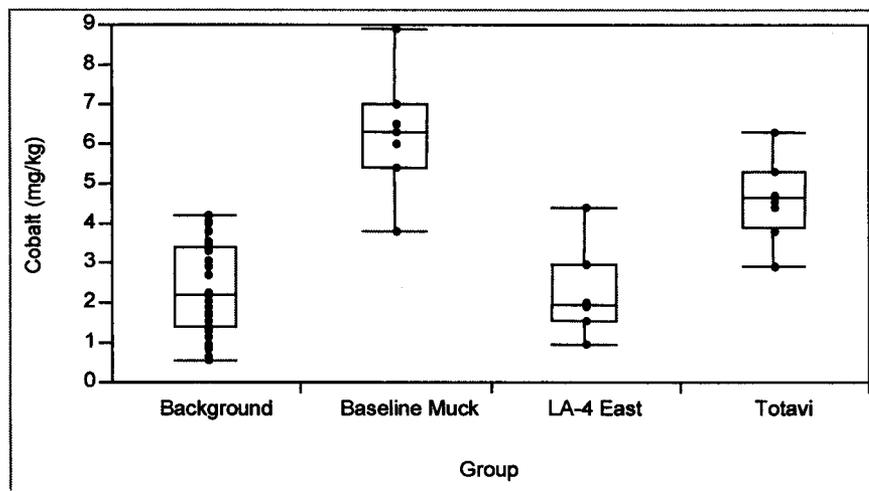


Figure A-14. Box plot for cobalt.

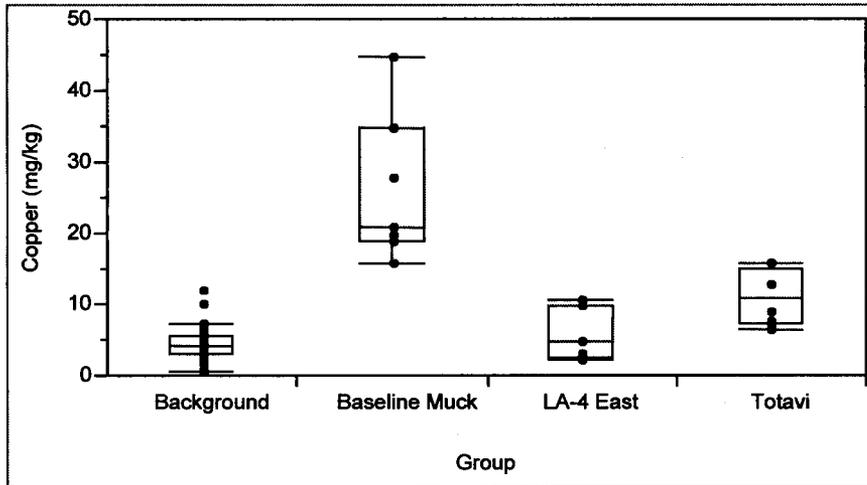


Figure A-15. Box plot for copper.

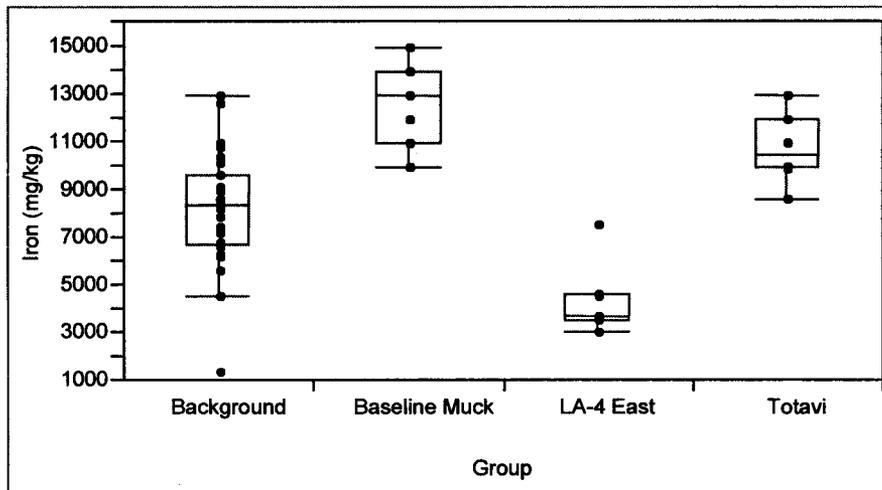


Figure A-16. Box plot for iron.

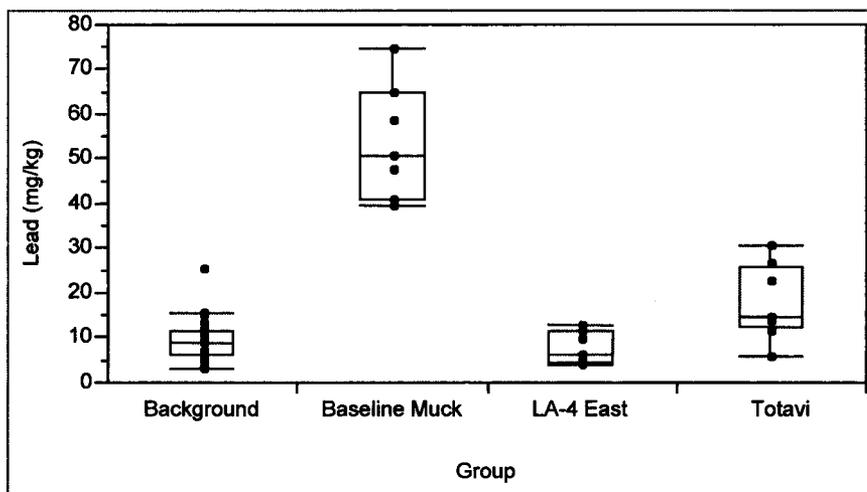


Figure A-17. Box plot for lead.

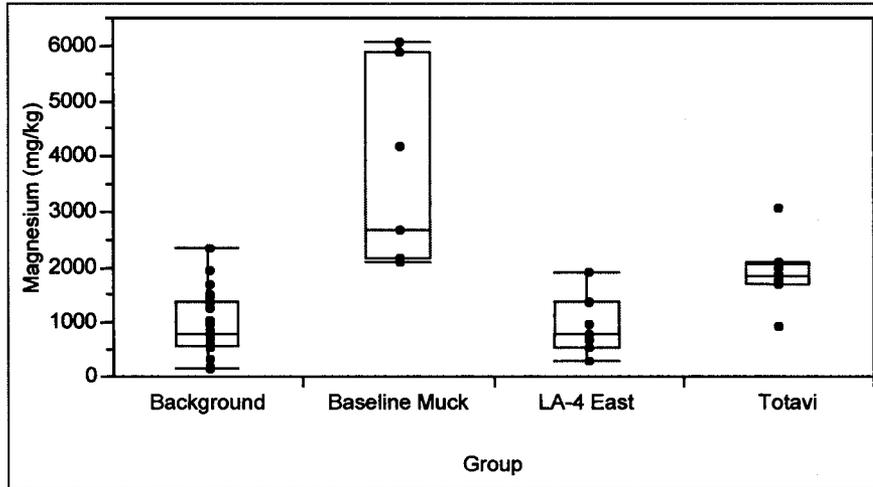


Figure A-18. Box plot for magnesium.

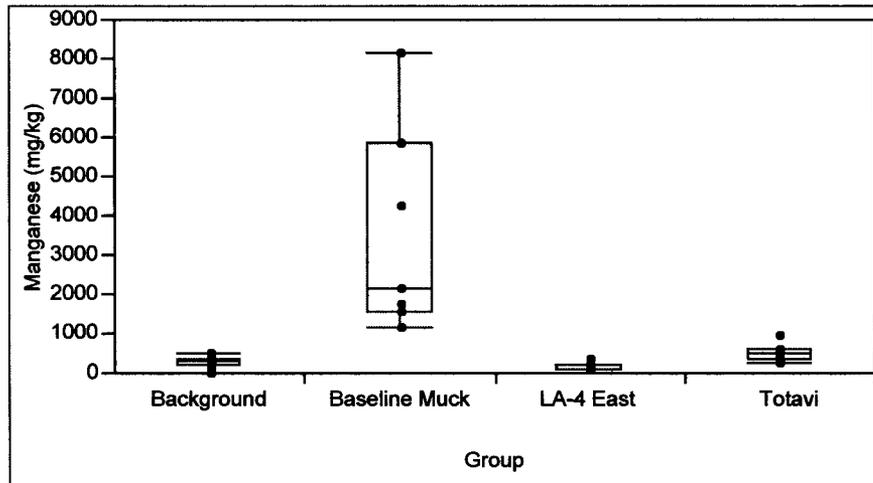


Figure A-19. Box plot for manganese.

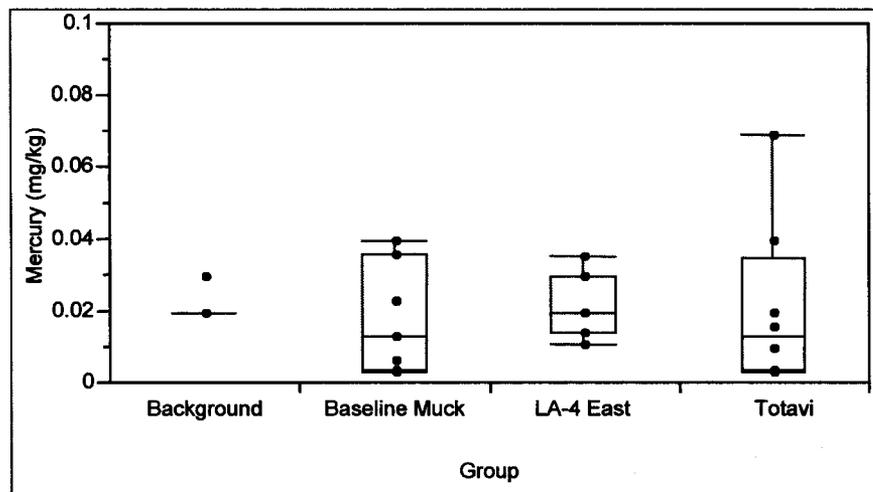


Figure A-20. Box plot for mercury.

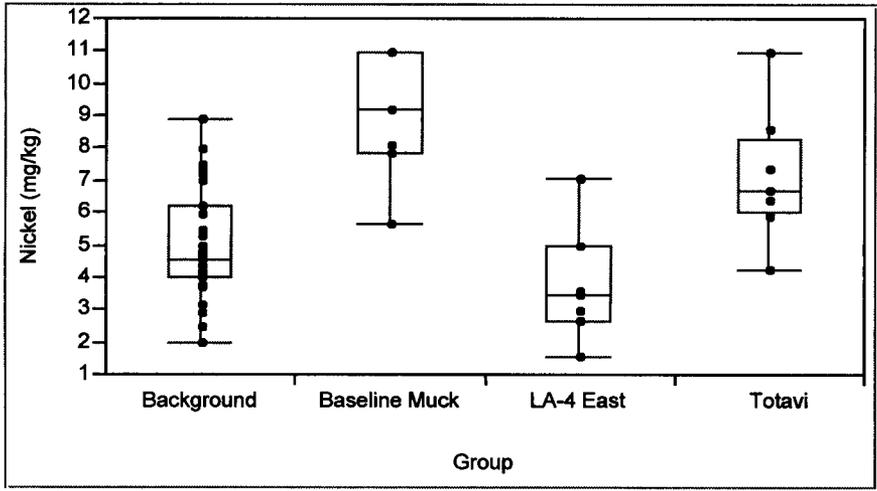


Figure A-21. Box plot for nickel

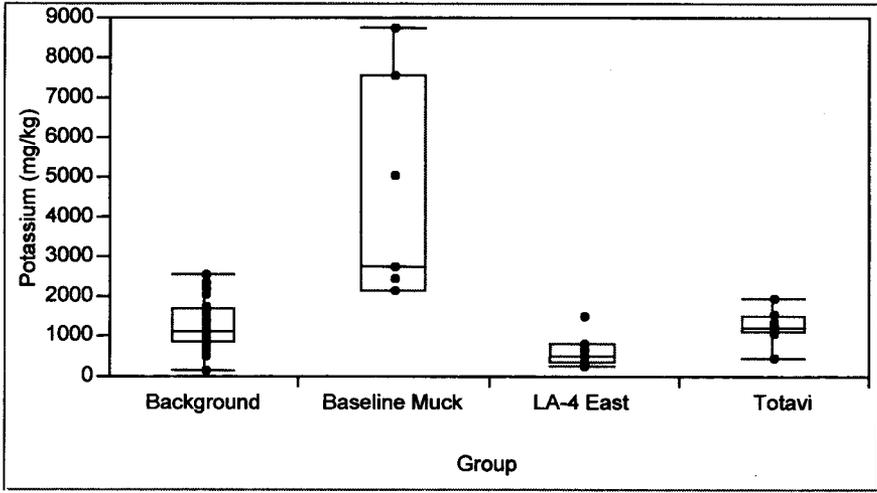


Figure A-22. Box plot for potassium.

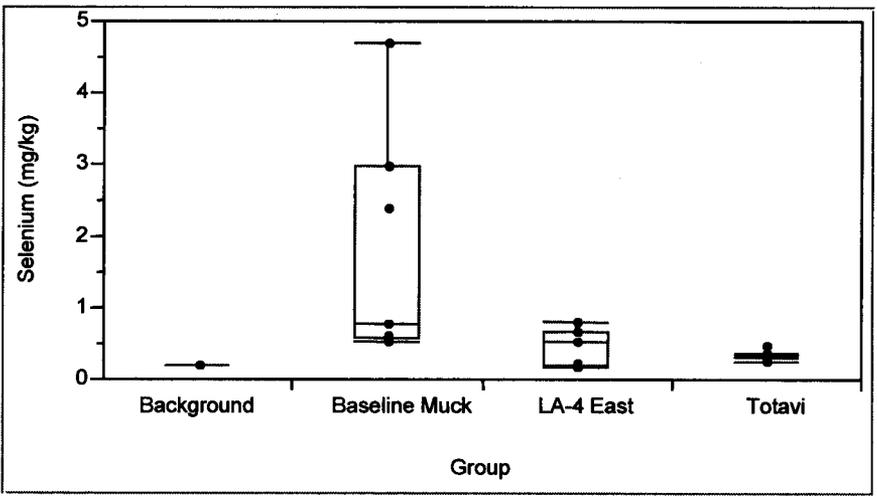


Figure A-23. Box plot for selenium.

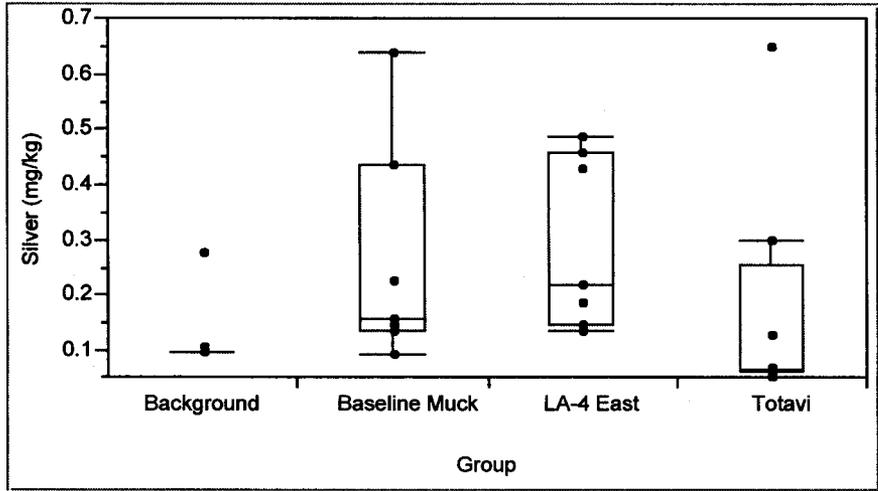


Figure A-24. Box plot for silver.

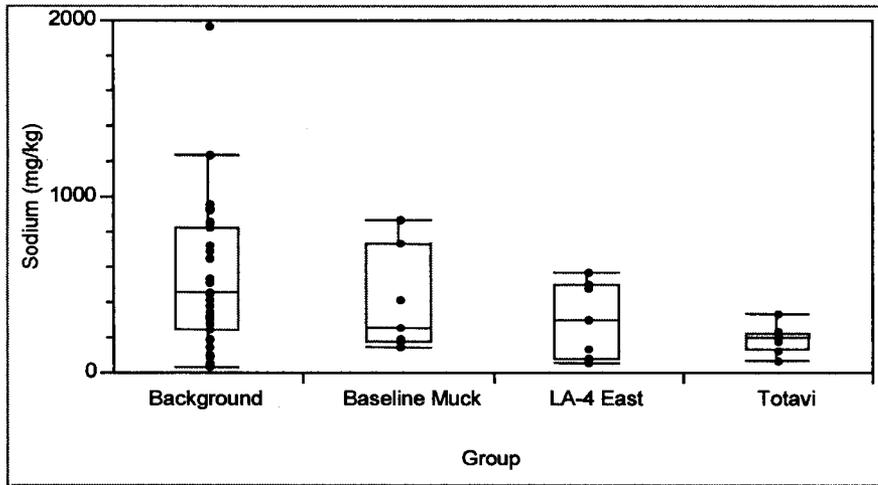


Figure A-25. Box plot for sodium.

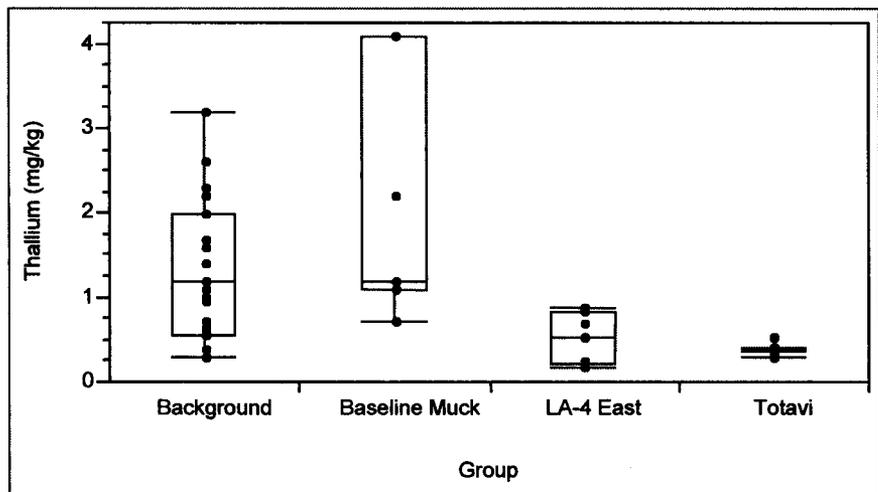


Figure A-26. Box plot for thallium (note that the background data for thallium were obtained from an analytical method with an insufficient detection limit).

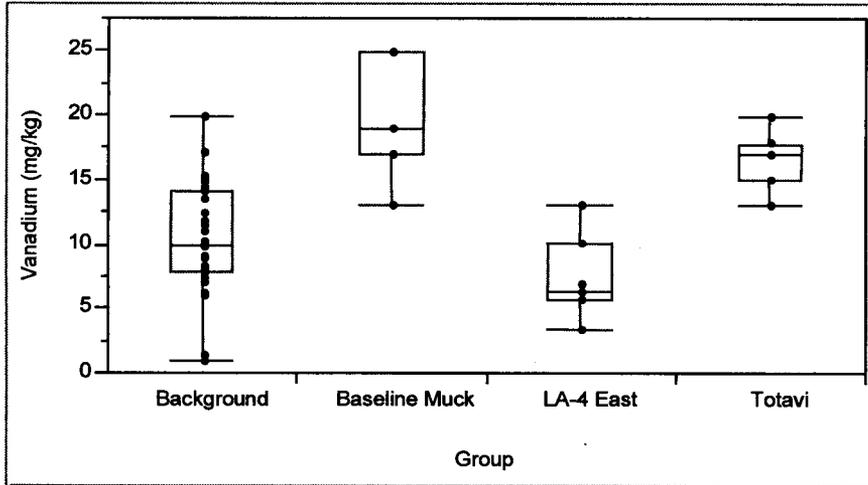


Figure A-27. Box plot for vanadium.

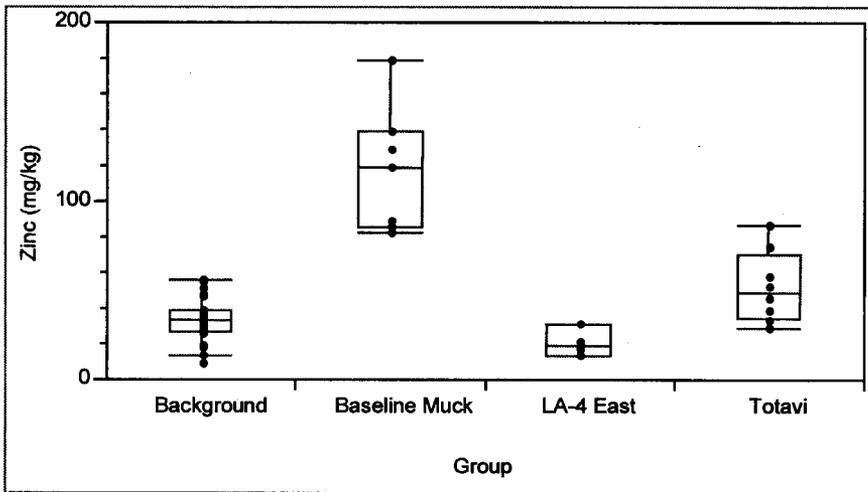


Figure A-28. Box plot for zinc.

Table A-5. Summary of the P-values from the Wilcoxon Rank Sum statistical testing. Bolded values indicate that reach sample results are significantly greater than Laboratory-wide concentrations, background concentrations, or pre-fire concentrations.

Analyte	Laboratory Background Versus Totavi	Reach LA-4 East Versus Totavi
Americium-241	ND <sup>a</sup>	0.209
Cesium-137	<0.001 <sup>b</sup>	<b>0.002</b>
Plutonium-238	0.568	0.223
Plutonium-239,240	<0.001	0.513
Strontium-90	0.600	0.374

<sup>a</sup>ND = no background data for americium-241 by gamma spectroscopy.

<sup>b</sup>Gehan test was used because the Laboratory background data were censored at the detection limit.

Table A-6. Summary of the P-values from the Gehan statistical testing. Bolded values indicate that post-fire sample results are significantly greater than Laboratory-wide sediment background concentrations or pre-fire concentrations.

Analyte	Laboratory Background Versus Totavi	Reach LA-4 East Versus Totavi
Aluminum	0.442	<b>0.005</b>
Antimony	ND <sup>a</sup>	—
Arsenic	0.283	<b>0.047</b>
Barium	<b>&lt;0.001</b>	<b>0.002</b>
Beryllium	0.183	0.076
Cadmium	— <sup>b</sup>	—
Calcium	<b>&lt;0.001</b>	<b>0.016</b>
Chromium, total	0.059	<b>&lt;0.001</b>
Cobalt	<b>&lt;0.001</b>	<b>0.003</b>
Copper	<b>&lt;0.001</b>	<b>0.012</b>
Iron	<b>0.002</b>	<b>&lt;0.001</b>
Lead	<b>0.003</b>	<b>0.005</b>
Magnesium	<b>&lt;0.001</b>	<b>0.009</b>
Manganese	<b>&lt;0.001</b>	<b>&lt;0.001</b>
Mercury	—	—
Nickel	<b>0.009</b>	<b>0.006</b>
Potassium	0.377	<b>0.016</b>
Selenium	—	—
Silver	—	—
Sodium	0.994	0.774
Thallium	ND	—
Vanadium	<b>&lt;0.001</b>	<b>0.001</b>
Zinc	<b>0.006</b>	<b>0.002</b>

<sup>a</sup>ND = no background data.

<sup>b</sup>A dash in the table means “not applicable” (statistical tests are not appropriate because of the high frequency of nondetected values).

Table A-7. Comparison of the maximum post-fire concentrations with background values. Bolded values indicate that reach sample results are greater than Laboratory-wide sediment background values.

Analyte	Totavi Maximum Concentration (mg kg <sup>-1</sup> )	Sediment Background Value (mg kg <sup>-1</sup> )
Antimony	0.67	0.83
Cadmium	0.078	0.4
Mercury	0.069	0.1
Selenium	<b>0.49</b>	0.3
Silver	0.65	1
Thallium	0.54	0.73

# APPENDIX B. OUTPUT FILE FROM RESRAD RUN TO CALCULATE DOSE FROM FARMING WITH IRRIGATION WATER OBTAINED DURING RUNOFF

1RESRAD, Version 5.82 T\* Limit = 0.5 year 05/14/01 17:01 Page 1  
 Summary : Rio Grande Scenario Assuming 1 pci per liter in Water  
 File : SITE1.RAD

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 Summary : Rio Grande Scenario Assuming 1 pci per liter in Water  
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## Dose Conversion Factor (and Related) Parameter Summary

File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
B-1 Dose conversion factors for inhalation, mrem/pCi:				
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF2 ( 1)
B-1	Am-241	4.440E-01	4.440E-01	DCF2 ( 2)
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2 ( 3)
B-1	Np-237+D	5.400E-01	5.400E-01	DCF2 ( 4)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2 ( 5)
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2 ( 6)
B-1	Pu-238	3.920E-01	3.920E-01	DCF2 ( 7)
B-1	Pu-239	4.290E-01	4.290E-01	DCF2 ( 8)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2 ( 9)
B-1	Sr-90+D	1.310E-03	1.310E-03	DCF2 (10)
B-1	Th-229+D	2.160E+00	2.160E+00	DCF2 (11)
B-1	Th-230	3.260E-01	3.260E-01	DCF2 (12)
B-1	U-233	1.350E-01	1.350E-01	DCF2 (13)
B-1	U-234	1.320E-01	1.320E-01	DCF2 (14)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2 (15)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2 (16)
D-1 Dose conversion factors for ingestion, mrem/pCi:				
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF3 ( 1)
D-1	Am-241	3.640E-03	3.640E-03	DCF3 ( 2)
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3 ( 3)
D-1	Np-237+D	4.440E-03	4.440E-03	DCF3 ( 4)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3 ( 5)
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3 ( 6)
D-1	Pu-238	3.200E-03	3.200E-03	DCF3 ( 7)
D-1	Pu-239	3.540E-03	3.540E-03	DCF3 ( 8)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3 ( 9)
D-1	Sr-90+D	1.530E-04	1.530E-04	DCF3 (10)
D-1	Th-229+D	4.030E-03	4.030E-03	DCF3 (11)
D-1	Th-230	5.480E-04	5.480E-04	DCF3 (12)
D-1	U-233	2.890E-04	2.890E-04	DCF3 (13)
D-1	U-234	2.830E-04	2.830E-04	DCF3 (14)
D-1	U-235+D	2.670E-04	2.670E-04	DCF3 (15)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3 (16)
D-34 Food transfer factors:				
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF ( 1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF ( 1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF ( 1,3)
D-34	Am-241 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF ( 2,1)
D-34	Am-241 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-05	5.000E-05	RTF ( 2,2)
D-34	Am-241 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-06	2.000E-06	RTF ( 2,3)
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF ( 3,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF ( 3,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF ( 3,3)

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 Summary : Rio Grande Scenario Assuming 1 pci per liter in Water

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Dose Conversion Factor (and Related) Parameter Summary (continued)  
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	Np-237+D , plant/soil concentration ratio, dimensionless	2.000E-02	2.000E-02	RTF( 4,1)
D-34	Np-237+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF( 4,2)
D-34	Np-237+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF( 4,3)
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF( 5,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF( 5,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF( 5,3)
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF( 6,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF( 6,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF( 6,3)
D-34	Pu-238 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF( 7,1)
D-34	Pu-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF( 7,2)
D-34	Pu-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF( 7,3)
D-34	Pu-239 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF( 8,1)
D-34	Pu-239 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF( 8,2)
D-34	Pu-239 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF( 8,3)
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF( 9,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF( 9,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF( 9,3)
D-34	Sr-90+D , plant/soil concentration ratio, dimensionless	3.000E-01	3.000E-01	RTF(10,1)
D-34	Sr-90+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-03	8.000E-03	RTF(10,2)
D-34	Sr-90+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-03	2.000E-03	RTF(10,3)
D-34	Th-229+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(11,1)
D-34	Th-229+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(11,2)
D-34	Th-229+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(11,3)
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(12,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(12,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(12,3)
D-34	U-233 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(13,1)
D-34	U-233 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(13,2)
D-34	U-233 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(13,3)
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(14,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(14,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(14,3)
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(15,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(15,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(15,3)

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Summary : Rio Grande Scenario Assuming 1 pCi per liter in Water  
File : SITE1.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)  
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(16,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(16,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(16,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC( 1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC( 1,2)
D-5	Am-241 , fish	3.000E+01	3.000E+01	BIOFAC( 2,1)
D-5	Am-241 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC( 2,2)
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC( 3,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC( 3,2)
D-5	Np-237+D , fish	3.000E+01	3.000E+01	BIOFAC( 4,1)
D-5	Np-237+D , crustacea and mollusks	4.000E+02	4.000E+02	BIOFAC( 4,2)
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC( 5,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC( 5,2)
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC( 6,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC( 6,2)
D-5	Pu-238 , fish	3.000E+01	3.000E+01	BIOFAC( 7,1)
D-5	Pu-238 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC( 7,2)
D-5	Pu-239 , fish	3.000E+01	3.000E+01	BIOFAC( 8,1)
D-5	Pu-239 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC( 8,2)
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC( 9,1)

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D-5 Ra-226+D , crustacea and mollusks          2.500E+02 2.500E+02 BIOFAC( 9,2)
D-5
D-5 Sr-90+D , fish                             6.000E+01 6.000E+01 BIOFAC(10,1)
D-5 Sr-90+D , crustacea and mollusks          1.000E+02 1.000E+02 BIOFAC(10,2)
D-5
D-5 Th-229+D , fish                             1.000E+02 1.000E+02 BIOFAC(11,1)
D-5 Th-229+D , crustacea and mollusks          5.000E+02 5.000E+02 BIOFAC(11,2)
D-5
D-5 Th-230 , fish                              1.000E+02 1.000E+02 BIOFAC(12,1)
D-5 Th-230 , crustacea and mollusks          5.000E+02 5.000E+02 BIOFAC(12,2)
D-5
D-5 U-233 , fish                               1.000E+01 1.000E+01 BIOFAC(13,1)
D-5 U-233 , crustacea and mollusks          6.000E+01 6.000E+01 BIOFAC(13,2)
D-5
D-5 U-234 , fish                               1.000E+01 1.000E+01 BIOFAC(14,1)
D-5 U-234 , crustacea and mollusks          6.000E+01 6.000E+01 BIOFAC(14,2)
D-5
D-5 U-235+D , fish                             1.000E+01 1.000E+01 BIOFAC(15,1)
D-5 U-235+D , crustacea and mollusks          6.000E+01 6.000E+01 BIOFAC(15,2)
D-5

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File : SITEL.RAD

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Dose Conversion Factor (and Related) Parameter Summary (continued)  
File: DOSFAC.BIN

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0
Menu - Parameter - Current Value - Default - Parameter Name
#####
D-5 U-238+D , fish 1.000E+01 1.000E+01 BIOFAC(16,1)
D-5 U-238+D , crustacea and mollusks 6.000E+01 6.000E+01 BIOFAC(16,2)
#####

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Summary : Rio Grande Scenario Assuming 1 pci per liter in Water
File : SITEL.RAD

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Site-Specific Parameter Summary

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0
Menu - Parameter - User Input - Default - (If different from user input) - Used by RESRAD - Parameter Name
#####
R011 Area of contaminated zone (m**2) 1.000E+04 1.000E+04 --- --- AREA
R011 Thickness of contaminated zone (m) 3.000E-01 2.000E+00 --- --- THICK0
R011 Length parallel to aquifer flow (m) 1.000E+02 1.000E+02 --- --- LCZPAQ
R011 Basic radiation dose limit (mrem/yr) 3.000E+01 3.000E+01 --- --- BRDL
R011 Time since placement of material (yr) 0.000E+00 0.000E+00 --- --- TI
R011 Times for calculations (yr) 1.000E+00 1.000E+00 --- --- T( 2)
R011 Times for calculations (yr) 3.000E+00 3.000E+00 --- --- T( 3)
R011 Times for calculations (yr) 1.000E+01 1.000E+01 --- --- T( 4)
R011 Times for calculations (yr) 3.000E+01 3.000E+01 --- --- T( 5)
R011 Times for calculations (yr) 1.000E+02 1.000E+02 --- --- T( 6)
R011 Times for calculations (yr) 3.000E+02 3.000E+02 --- --- T( 7)
R011 Times for calculations (yr) 1.000E+03 1.000E+03 --- --- T( 8)
R011 Times for calculations (yr) not used 0.000E+00 --- --- T( 9)
R011 Times for calculations (yr) not used 0.000E+00 --- --- T(10)

R012 Initial principal radionuclide (pCi/g): Am-241 6.200E-04 0.000E+00 --- --- SI( 2)
R012 Initial principal radionuclide (pCi/g): Cs-137 6.200E-04 0.000E+00 --- --- SI( 3)
R012 Initial principal radionuclide (pCi/g): Pu-238 6.200E-04 0.000E+00 --- --- SI( 7)
R012 Initial principal radionuclide (pCi/g): Pu-239 6.200E-04 0.000E+00 --- --- SI( 8)
R012 Initial principal radionuclide (pCi/g): Sr-90 6.200E-04 0.000E+00 --- --- SI(10)
R012 Initial principal radionuclide (pCi/g): U-234 6.200E-04 0.000E+00 --- --- SI(14)
R012 Initial principal radionuclide (pCi/g): U-235 6.200E-04 0.000E+00 --- --- SI(15)
R012 Initial principal radionuclide (pCi/g): U-238 6.200E-04 0.000E+00 --- --- SI(16)
R012 Concentration in groundwater (pCi/L): Am-241 not used 0.000E+00 --- --- WI( 2)
R012 Concentration in groundwater (pCi/L): Cs-137 not used 0.000E+00 --- --- WI( 3)
R012 Concentration in groundwater (pCi/L): Pu-238 not used 0.000E+00 --- --- WI( 7)
R012 Concentration in groundwater (pCi/L): Pu-239 not used 0.000E+00 --- --- WI( 8)
R012 Concentration in groundwater (pCi/L): Sr-90 not used 0.000E+00 --- --- WI(10)
R012 Concentration in groundwater (pCi/L): U-234 not used 0.000E+00 --- --- WI(14)
R012 Concentration in groundwater (pCi/L): U-235 not used 0.000E+00 --- --- WI(15)
R012 Concentration in groundwater (pCi/L): U-238 not used 0.000E+00 --- --- WI(16)

R013 Cover depth (m) 0.000E+00 0.000E+00 --- --- COVER0
R013 Density of cover material (g/cm**3) not used 1.500E+00 --- --- DENSCV
R013 Cover depth erosion rate (m/yr) not used 1.000E-03 --- --- VCV
R013 Density of contaminated zone (g/cm**3) 1.500E+00 1.500E+00 --- --- DENSCZ
R013 Contaminated zone erosion rate (m/yr) 1.000E-06 1.000E-03 --- --- V CZ
R013 Contaminated zone total porosity 4.000E-01 4.000E-01 --- --- TFCZ
R013 Contaminated zone effective porosity 2.000E-01 2.000E-01 --- --- EPCZ
R013 Contaminated zone hydraulic conductivity (m/yr) 1.000E+01 1.000E+01 --- --- HCCZ
R013 Contaminated zone b parameter 5.300E+00 5.300E+00 --- --- BCZ
R013 Average annual wind speed (m/sec) 2.000E+00 2.000E+00 --- --- WIND
R013 Humidity in air (g/m**3) not used 8.000E+00 --- --- HUMID
R013 Evapotranspiration coefficient 9.900E-01 5.000E-01 --- --- EVAPTR
R013 Precipitation (m/yr) 2.000E-01 1.000E+00 --- --- PRECIP
R013 Irrigation (m/yr) 0.000E+00 2.000E-01 --- --- RI
R013 Irrigation mode overhead overhead --- --- IDITCH
R013 Runoff coefficient 0.000E+00 2.000E-01 --- --- RUNOFF
R013 Watershed area for nearby stream or pond (m**2) 1.000E-04 1.000E+06 --- --- WAREA
R013 Accuracy for water/soil computations 1.000E-03 1.000E-03 --- --- EPS

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Summary : Rio Grande Scenario Assuming 1 pci per liter in Water
File : SITEL.RAD

```

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD	Parameter Name
(If different from user input)					
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VNT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Am-241	---	---	---	---
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(2)
R016	Unsat. zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.206E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Cs-137	---	---	---	---
R016	Contaminated zone (cm**3/g)	1.000E+03	1.000E+03	---	DCNUCC(3)
R016	Unsat. zone 1 (cm**3/g)	1.000E+03	1.000E+03	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	1.000E+03	1.000E+03	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.444E-06	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for Pu-238	---	---	---	---
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCC(7)
R016	Unsat. zone 1 (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.222E-06	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for Pu-239	---	---	---	---
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCC(8)
R016	Unsat. zone 1 (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.222E-06	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD	Parameter Name
(If different from user input)					
R016	Distribution coefficients for Sr-90	---	---	---	---
R016	Contaminated zone (cm**3/g)	3.000E+01	3.000E+01	---	DCNUCC(10)
R016	Unsat. zone 1 (cm**3/g)	3.000E+01	3.000E+01	---	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	3.000E+01	3.000E+01	---	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.474E-04	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)
R016	Distribution coefficients for U-234	---	---	---	---
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(14)
R016	Unsat. zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(14,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(14)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.864E-05	ALEACH(14)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(14)
R016	Distribution coefficients for U-235	---	---	---	---
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(15)
R016	Unsat. zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(15,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(15)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.864E-05	ALEACH(15)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(15)
R016	Distribution coefficients for U-238	---	---	---	---
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(16)
R016	Unsat. zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(16,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(16)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.864E-05	ALEACH(16)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(16)
R016	Distribution coefficients for daughter Ac-227	---	---	---	---
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(1)
R016	Unsat. zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.206E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Np-237	---	---	---	---



R017	Ring 9	not used	0.000E+00	---	FRACA ( 9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET (1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET (2)
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01	---	DIET (3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET (4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET (5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET (6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.500E+00	FMEAT
R018	Contamination fraction of milk	-1	-1	0.500E+00	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI

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Menu	Parameter	User	Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	---	MLFD
R019	Depth of soil mixing layer (m)	3.000E-01	1.500E-01	---	---	DM
R019	Depth of roots (m)	3.000E-01	9.000E-01	---	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	---	C12CE
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):					
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	---	TPFL

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Menu	Parameter	User	Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the cover material	not used	5.000E-02	---	---	PH2OCV



Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
 As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years  
 Water Independent Pathways (Inhalation excludes radon)

0	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil
Radio-Nuclide	mrem/yr fract.						
Am-241	1.575E-05 0.0027	1.758E-05 0.0031	0.000E+00 0.0000	1.962E-04 0.0342	2.016E-06 0.0004	1.151E-07 0.0000	6.167E-05 0.0107
Cs-137	1.173E-03 0.2042	1.237E-09 0.0000	0.000E+00 0.0000	1.054E-04 0.0183	9.218E-05 0.0160	3.010E-05 0.0052	8.292E-07 0.0001
Pu-238	5.519E-08 0.0000	1.543E-05 0.0027	0.000E+00 0.0000	1.715E-04 0.0298	3.524E-06 0.0006	5.029E-08 0.0000	5.388E-05 0.0094
Pu-239	1.063E-07 0.0000	1.702E-05 0.0030	0.000E+00 0.0000	1.912E-04 0.0333	3.929E-06 0.0007	5.606E-08 0.0000	6.008E-05 0.0105
Sr-90	8.898E-06 0.0015	5.075E-08 0.0000	0.000E+00 0.0000	2.417E-03 0.4208	4.878E-04 0.0849	1.449E-04 0.0252	2.535E-06 0.0004
U-234	1.450E-07 0.0000	5.237E-06 0.0009	0.000E+00 0.0000	3.818E-05 0.0066	1.260E-06 0.0002	3.088E-06 0.0005	4.803E-06 0.0008
U-235	2.713E-04 0.0472	4.881E-06 0.0008	0.000E+00 0.0000	3.614E-05 0.0063	1.212E-06 0.0002	2.914E-06 0.0005	4.535E-06 0.0008
U-238	4.835E-05 0.0084	4.681E-06 0.0008	0.000E+00 0.0000	3.629E-05 0.0063	1.197E-06 0.0002	2.935E-06 0.0005	4.565E-06 0.0008
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	1.518E-03 0.2642	6.489E-05 0.0113	0.000E+00 0.0000	3.192E-03 0.5556	5.931E-04 0.1032	1.841E-04 0.0320	1.929E-04 0.0336

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
 As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years  
 Water Dependent Pathways

0	Water	Fish	Radon	Plant	Meat	Milk	All Pathways*
Radio-Nuclide	mrem/yr fract.						
Am-241	0.000E+00 0.0000	2.934E-04 0.0511					
Cs-137	0.000E+00 0.0000	1.402E-03 0.2440					
Pu-238	0.000E+00 0.0000	2.444E-04 0.0425					
Pu-239	0.000E+00 0.0000	2.724E-04 0.0474					
Sr-90	0.000E+00 0.0000	3.061E-03 0.5329					
U-234	0.000E+00 0.0000	5.271E-05 0.0092					
U-235	0.000E+00 0.0000	3.209E-04 0.0559					
U-238	0.000E+00 0.0000	9.801E-05 0.0171					
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	0.000E+00 0.0000	5.745E-03 1.0000					

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
 As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years  
 Water Independent Pathways (Inhalation excludes radon)

0	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil
Radio-Nuclide	mrem/yr fract.						
Am-241	1.569E-05 0.0028	1.752E-05 0.0032	0.000E+00 0.0000	1.955E-04 0.0353	2.009E-06 0.0004	1.147E-07 0.0000	6.144E-05 0.0111
Cs-137	1.120E-03 0.2024	1.181E-09 0.0000	0.000E+00 0.0000	1.007E-04 0.0182	8.802E-05 0.0159	2.874E-05 0.0052	7.918E-07 0.0001
Pu-238	5.432E-08 0.0000	1.519E-05 0.0027	0.000E+00 0.0000	1.688E-04 0.0305	3.469E-06 0.0006	4.951E-08 0.0000	5.304E-05 0.0096
Pu-239	1.063E-07 0.0000	1.702E-05 0.0031	0.000E+00 0.0000	1.912E-04 0.0345	3.929E-06 0.0007	5.605E-08 0.0000	6.008E-05 0.0109
Sr-90	8.482E-06 0.0015	4.837E-08 0.0000	0.000E+00 0.0000	2.304E-03 0.4164	4.650E-04 0.0840	1.381E-04 0.0250	2.417E-06 0.0004
U-234	1.451E-07 0.0000	5.236E-06 0.0009	0.000E+00 0.0000	3.817E-05 0.0069	1.259E-06 0.0002	3.088E-06 0.0006	4.802E-06 0.0009
U-235	2.712E-04 0.0490	4.883E-06 0.0009	0.000E+00 0.0000	3.638E-05 0.0066	1.263E-06 0.0002	2.913E-06 0.0005	4.543E-06 0.0008
U-238	4.834E-05 0.0087	4.681E-06 0.0008	0.000E+00 0.0000	3.628E-05 0.0066	1.197E-06 0.0002	2.935E-06 0.0005	4.564E-06 0.0008
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	1.464E-03 0.2646	6.458E-05 0.0117	0.000E+00 0.0000	3.071E-03 0.5550	5.661E-04 0.1023	1.760E-04 0.0318	1.917E-04 0.0346

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
 As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years  
 Water Dependent Pathways

0	Water	Fish	Radon	Plant	Meat	Milk	All Pathways*
Radio-Nuclide	mrem/yr fract.						
Am-241	0.000E+00 0.0000	2.923E-04 0.0528					
Cs-137	0.000E+00 0.0000	1.338E-03 0.2419					
Pu-238	0.000E+00 0.0000	2.406E-04 0.0435					
Pu-239	0.000E+00 0.0000	2.723E-04 0.0492					
Sr-90	0.000E+00 0.0000	2.918E-03 0.5273					
U-234	0.000E+00 0.0000	5.270E-05 0.0095					
U-235	0.000E+00 0.0000	3.212E-04 0.0580					
U-238	0.000E+00 0.0000	9.800E-05 0.0177					
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	0.000E+00 0.0000	5.534E-03 1.0000					

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
 As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years  
 Water Independent Pathways (Inhalation excludes radon)

0	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil
Radio-Nuclide	mrem/yr fract.						
Am-241	1.549E-05 0.0032	1.730E-05 0.0036	0.000E+00 0.0000	1.930E-04 0.0397	1.984E-06 0.0004	1.132E-07 0.0000	6.066E-05 0.0125
Cs-137	9.529E-04 0.1958	1.005E-09 0.0000	0.000E+00 0.0000	8.562E-05 0.0176	7.487E-05 0.0154	2.445E-05 0.0050	6.735E-07 0.0001
Pu-238	5.140E-08 0.0000	1.437E-05 0.0030	0.000E+00 0.0000	1.597E-04 0.0328	3.282E-06 0.0007	4.691E-08 0.0000	5.018E-05 0.0103

Pu-239	1.063E-07	0.0000	1.702E-05	0.0035	0.000E+00	0.0000	1.911E-04	0.0393	3.928E-06	0.0008	5.604E-08	0.0000	6.006E-05	0.0123
Sr-90	7.173E-06	0.0015	4.091E-08	0.0000	0.000E+00	0.0000	1.948E-03	0.4003	3.932E-04	0.0808	1.168E-04	0.0240	2.044E-06	0.0004
U-234	1.457E-07	0.0000	5.234E-06	0.0011	0.000E+00	0.0000	3.815E-05	0.0078	1.259E-06	0.0003	3.086E-06	0.0006	4.800E-06	0.0010
U-235	2.711E-04	0.0557	4.895E-06	0.0010	0.000E+00	0.0000	3.726E-05	0.0077	1.444E-06	0.0003	2.912E-06	0.0006	4.573E-06	0.0009
U-238	4.831E-05	0.0099	4.678E-06	0.0010	0.000E+00	0.0000	3.626E-05	0.0074	1.196E-06	0.0002	2.933E-06	0.0006	4.562E-06	0.0009
iiiiiii	iiiiiii	iiiiiii												
Total	1.295E-03	0.2661	6.353E-05	0.0131	0.000E+00	0.0000	2.690E-03	0.5526	4.812E-04	0.0989	1.504E-04	0.0309	1.876E-04	0.0385

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.										
Am-241	0.000E+00	0.0000	2.886E-04	0.0593										
Cs-137	0.000E+00	0.0000	1.139E-03	0.2339										
Pu-238	0.000E+00	0.0000	2.276E-04	0.0468										
Pu-239	0.000E+00	0.0000	2.723E-04	0.0559										
Sr-90	0.000E+00	0.0000	2.468E-03	0.5070										
U-234	0.000E+00	0.0000	5.267E-05	0.0108										
U-235	0.000E+00	0.0000	3.222E-04	0.0662										
U-238	0.000E+00	0.0000	9.794E-05	0.0201										
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	0.000E+00	0.0000	4.867E-03	1.0000										

\*Sum of all water independent and dependent pathways.  
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Summary : Rio Grande Scenario Assuming 1 pci per liter in Water  
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.494E-05	0.0043	1.668E-05	0.0048	0.000E+00	0.0000	1.861E-04	0.0537	1.914E-06	0.0006	1.091E-07	0.0000	5.848E-05	0.0169
Cs-137	6.002E-04	0.1732	6.327E-10	0.0000	0.000E+00	0.0000	5.393E-05	0.0156	4.716E-05	0.0136	1.540E-05	0.0044	4.242E-07	0.0001
Pu-238	4.390E-08	0.0000	1.227E-05	0.0035	0.000E+00	0.0000	1.363E-04	0.0393	2.802E-06	0.0008	4.021E-08	0.0000	4.284E-05	0.0124
Pu-239	1.063E-07	0.0000	1.700E-05	0.0049	0.000E+00	0.0000	1.910E-04	0.0551	3.925E-06	0.0011	5.600E-08	0.0000	6.002E-05	0.0173
Sr-90	4.443E-06	0.0013	2.533E-08	0.0000	0.000E+00	0.0000	1.207E-03	0.3482	2.435E-04	0.0703	7.232E-05	0.0209	1.266E-06	0.0004
U-234	1.516E-07	0.0000	5.226E-06	0.0015	0.000E+00	0.0000	3.809E-05	0.0110	1.256E-06	0.0004	3.080E-06	0.0009	4.792E-06	0.0014
U-235	2.708E-04	0.0781	4.959E-06	0.0014	0.000E+00	0.0000	3.999E-05	0.0115	1.958E-06	0.0006	2.908E-06	0.0008	4.690E-06	0.0014
U-238	4.822E-05	0.0139	4.669E-06	0.0013	0.000E+00	0.0000	3.620E-05	0.0104	1.194E-06	0.0003	2.928E-06	0.0008	4.553E-06	0.0013
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	9.389E-04	0.2709	6.083E-05	0.0176	0.000E+00	0.0000	1.888E-03	0.5449	3.037E-04	0.0876	9.684E-05	0.0279	1.771E-04	0.0511

\*Sum of all water independent and dependent pathways.  
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Summary : Rio Grande Scenario Assuming 1 pci per liter in Water  
File : SITE1.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.										
Am-241	0.000E+00	0.0000	2.783E-04	0.0803										
Cs-137	0.000E+00	0.0000	7.171E-04	0.2069										
Pu-238	0.000E+00	0.0000	1.943E-04	0.0561										
Pu-239	0.000E+00	0.0000	2.721E-04	0.0785										
Sr-90	0.000E+00	0.0000	1.528E-03	0.4410										
U-234	0.000E+00	0.0000	5.259E-05	0.0152										
U-235	0.000E+00	0.0000	3.253E-04	0.0939										
U-238	0.000E+00	0.0000	9.776E-05	0.0282										
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	0.000E+00	0.0000	3.466E-03	1.0000										

\*Sum of all water independent and dependent pathways.  
1RESRAD, Version 5.82 T<sub>1/2</sub> Limit = 0.5 year 05/14/01 17:01 Page 19  
Summary : Rio Grande Scenario Assuming 1 pci per liter in Water  
File : SITE1.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)  
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Am-241	1.316E-05	0.0085	1.467E-05	0.0095	0.000E+00	0.0000	1.639E-04	0.1062	1.687E-06	0.0011	9.606E-08	0.0001	5.146E-05	0.0333
Cs-137	1.191E-04	0.0771	1.255E-10	0.0000	0.000E+00	0.0000	1.070E-05	0.0069	9.352E-06	0.0061	3.054E-06	0.0020	8.413E-08	0.0001
Pu-238	2.527E-08	0.0000	7.056E-06	0.0046	0.000E+00	0.0000	7.840E-05	0.0508	1.611E-06	0.0010	2.359E-08	0.0000	2.464E-05	0.0160
Pu-239	1.060E-07	0.0001	1.696E-05	0.0110	0.000E+00	0.0000	1.905E-04	0.1234	3.916E-06	0.0025	5.587E-08	0.0000	5.988E-05	0.0388
Sr-90	8.309E-07	0.0005	4.737E-09	0.0000	0.000E+00	0.0000	2.256E-04	0.1462	4.553E-05	0.0295	1.352E-05	0.0088	2.367E-07	0.0002
U-234	2.190E-07	0.0001	5.200E-06	0.0034	0.000E+00	0.0000	3.794E-05	0.0246	1.251E-06	0.0008	3.062E-06	0.0020	4.768E-06	0.0031
U-235	2.701E-04	0.1750	5.331E-06	0.0035	0.000E+00	0.0000	5.059E-05	0.0328	3.745E-06	0.0024	2.898E-06	0.0019	5.234E-06	0.0034
U-238	4.792E-05	0.0310	4.640E-06	0.0030	0.000E+00	0.0000	3.597E-05	0.0233	1.187E-06	0.0008	2.910E-06	0.0019	4.525E-06	0.0029
iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii	iiiiiii
Total	4.514E-04	0.2924	5.387E-05	0.0349	0.000E+00	0.0000	7.936E-04	0.5141	6.829E-05	0.0442	2.562E-05	0.0166	1.508E-04	0.0977

\*Sum of all water independent and dependent pathways.  
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Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Table with columns: OParent, Product, Branch, Fraction\* t=, DSR(j,t), (mrem/yr)/(pCi/g). Includes radionuclides like Am-241, Pu-238, Sr-90, U-238, etc. with various numerical values and branch fractions.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 30 mrem/yr

Table with columns: ONuclide, t=, and 9 columns of numerical values representing soil guidelines for various radionuclides.

Table with columns: ONuclide, Initial pCi/g, tmin (years), DSR(i,tmin), G(i,tmin), DSR(i,tmax), G(i,tmax). Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g) and Single Radionuclide Soil Guidelines G(i,t) in pCi/g.

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Summary : Rio Grande Scenario Assuming 1 pci per liter in Water
File : SITE1.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Table with columns: ONuclide, Parent, BRF(i), t=, and 9 columns of numerical values representing individual nuclide doses.



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