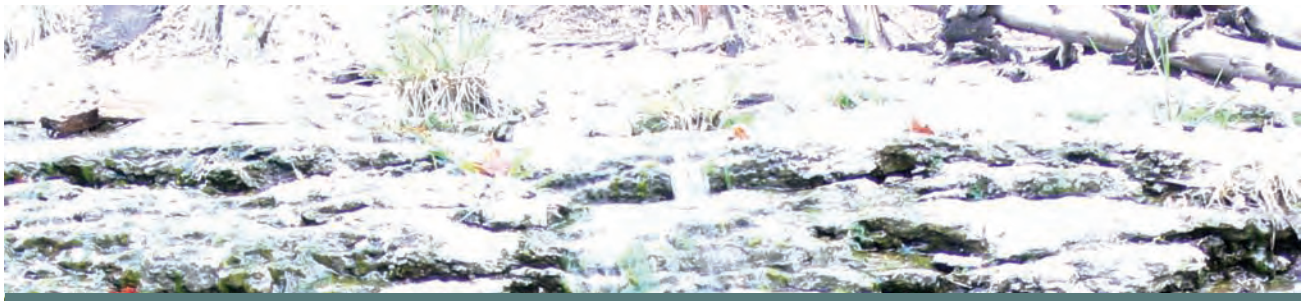


6. Watershed Monitoring

6. Watershed Monitoring

contributing author:
Bruce M. Gallaher

To Read About **Turn to Page**

Introduction 195
Hydrologic Setting 195
Surface Water and Sediment Standards 196
Sampling Locations and Data Analysis Methods 201
Watershed Sampling Results by Constituents 209
Impacts to the Rio Grande 215
Canyon-Specific Contamination 217
Quality Assurance 227
References 228

A. INTRODUCTION

The Laboratory monitors the quality of surface water and stream sediment throughout northern New Mexico (NM) to evaluate the potential environmental effects of Laboratory operations. The Laboratory analyzes samples for several parameters, including radionuclides, explosive compounds, inorganic chemicals, a wide range of organic compounds, and general chemistry of surface water. In this chapter, the effects of Laboratory operations are evaluated over time. Additionally, the sampling results are compared with criteria established to protect human health and the aquatic environment.

In addition to monitoring to assess the radiological impacts from the Laboratory, LANL also monitors stream sediment, surface water, and storm water for the nonradiological impacts. The nonradiological monitoring and assessments are done in conformance with agreements with federal and state regulatory agencies. The agreements require a widespread monitoring of both perennial and ephemeral stream flows for an extensive list of constituents. As a result, increased sampling of base flow has resulted from the Compliance Order on Consent (the Consent Order), discussed in Chapter 2. Additionally, increased sampling of storm runoff and snowmelt has resulted from the Federal Facility Compliance Agreement (FFCA) and Administrative Order (AO) (EPA 2005a, b). Sampling is conducted at dozens of locations. The total surface water monitoring effort has yielded a substantial amount of water quality data. The principal focus of this chapter is on environmental conditions in the canyon floors, or watercourses, with limited references to individual sites.

B. HYDROLOGIC SETTING

Watersheds that drain Laboratory property are dry for most of the year. No perennial surface water extends completely across Laboratory land in any canyon. The canyons consist of over 85 miles of watercourses located within the Laboratory and immediately upstream of the Laboratory within Los Alamos Canyon. Of the 85 miles of watercourse, approximately two miles are naturally perennial, and approximately three miles are perennial waters created by effluent.

The remaining 80 or more miles of watercourse are dry for varying lengths of time. The driest segments may flow in response only to local precipitation or snowmelt, and the streambed is always above the water table. The flow in these streams is ephemeral. Other streams may sometimes have the water table higher than the streambed and/or extensive snowmelt in the watershed and are said to be intermittent. Intermittent streams

may flow for several weeks to a year or longer. To aid in water quality interpretation, we divide stream flow into three types or matrices. Each of the three flow types might be sampled at a single location within a time span of as little as a week, depending on weather conditions. At times, the flow might represent a combination of several of these flow types.

The three types are

- Base flow—persistent stream flow, but not necessarily perennial water. (This stream flow is present for periods of weeks or longer. The water source may be effluent discharge or shallow groundwater that discharges in canyons.)
- Snowmelt—flowing water present because of melting snow. (This type of water often may be present for a week or more and in some years may not be present at all.)
- Storm water runoff—flowing water present in response to rainfall. (These flow events are generally very short lived, with flows lasting from less than an hour to—rarely—several days.)

Because base flow is present for extended periods of time, it is available for potentially longer-term exposures, such as wildlife watering. Storm water runoff or snowmelt may provide a short-term water source for wildlife. Storm water is capable of moving Laboratory-derived constituents off-site and possibly into the Rio Grande.

None of the streams within Laboratory boundaries average more than one cubic ft per second (cfs) of flow annually. It is unusual for the combined mean daily flow from all LANL canyons to be greater than 10 cfs. By comparison, flow in the Rio Grande commonly averages approximately 800 to 1,000 cfs. Although most of the watercourses at LANL are dry throughout the year, occasional floods can redistribute sediment in a streambed to locations downstream. Streamflow in 2006 on the Pajarito Plateau was record setting and dominated by large rainfall events in August. Total precipitation for the month was approximately six inches which is nearly double the long-term average. Snowmelt for the year was negligible. The total storm runoff volume in 2006 of 168 ac-ft was measured at downstream gages in the watersheds crossing LANL lands. This runoff measurement was the second largest since 1995 and was attributable to large runoff events on August 8 and 25.

The August 8 storm was centered over the community of Los Alamos and produced the largest peak runoff event of record in Pueblo Canyon at 1930 cfs (Romero et al. 2007). The storm delivered approximately two inches of rainfall in one hour, which corresponds to between a 50 and 100 year return interval (NOAA 2006). Flow volumes in lower Pueblo Canyon were 25% larger than that of the other LANL canyons combined. The August 25 storm was centered over the central part of the Laboratory and produced a peak runoff of 628 cfs in Two Mile Canyon. The storm produced 2.15 inches of precipitation in three hours, approaching the intensity for a 100-year rainfall event. As a result of the two storms, new peak discharges were recorded at more than 20 stream gages across the Laboratory.

Hydrologic conditions in all LANL canyons and in upper Pueblo Canyon have recovered to near pre-fire levels. However, recovery after the fire has been somewhat counteracted in Pueblo Canyon by urbanization adjacent to the upper reaches. The increased pavement and roofs shed more local precipitation into the canyon. The increased runoff within Pueblo Canyon is discussed in more detail in Section G.2.

C. SURFACE WATER AND SEDIMENT STANDARDS

Table 6-1 summarizes the standards used to evaluate the monitoring data. The suite of standards varies, depending on the stream flow conditions and established or potential uses. To evaluate Laboratory impacts, we compare analytical results for surface water and sediment samples with regulatory water quality criteria or with risk-based screening levels.

Table 6-1
Application of Surface Water Standards and Sediment Screening Values to Monitoring Data

Medium	Standard	Risk- or Dose-Based Screening Level	Reference	Location	Notes
Surface water					
Radionuclides	State water quality standards for surface water (New Mexico Water Quality Control Commission, NMWQCC, 2005)	Biota Concentration Guides (BCGs) NM Radiation Protection Regulations	DOE Technical Standard 20.3.4 NMAC	On-site and off-site	Surface water is present sporadically or are not available for long-term access and do not provide persistent drinking water. The actual exposure pathway is to plants/animals, and not to humans. BCGs based on 1 rad/day exposure limit for aquatic animals and terrestrial plants, and 0.1 rad/day for terrestrial animals. Comparison with radionuclide criteria based on time-weighted average over the year per DOE Order 5400.5 and 20.3.4 NMAC.
			20.6.4 NMAC	On-site and off-site	Based on the protection of livestock watering for Ra-226 + Ra-228, tritium, and gross alpha radiation. NMWQCC standards are not specific about exposure frequency or duration; for screening purposes, compare single sample results with numeric criteria.
Nonradionuclides	State water quality standards for surface water		20.6.4 NMAC	On-site ephemeral, intermittent streams	Single sample results are compared with numeric water quality criteria corresponding to livestock watering, wildlife habitat, and limited aquatic life standards (including acute aquatic life and human health criteria for persistent pollutants).
				On-site perennial streams	Single sample results are compared with numeric water quality criteria corresponding to livestock watering, Wildlife Habitat, and coldwater aquatic life standards (including chronic aquatic life and human health criteria). For screening purposes, single sample results are compared with 1.5 times the chronic aquatic life criteria (NMED 2006a).
				Off-site	Single sample results are compared with numeric water quality criteria corresponding to designated uses contained in NMWQCC water quality standards.
	State water quality standards for ground water		20.6.2 NMAC	On-site and off-site	Single sample result comparisons with groundwater quality criteria are used to determine potential for stream flows to impact underlying bodies.

Table 6-1 (continued)

Medium	Standard	Risk- or Dose-Based Screening Level	Reference	Location	Notes
Sediment					
Radionuclides	None	Human health screening levels	LANL	On-site and off-site	Screening levels derived to determine if more detailed assessment is needed to evaluate impacts to the public; comparisons are made for recreational or industrial exposure parameters; based on a dose rate limit of 15 mrem/year (LANL 2005). Recreational levels are appropriate for Laboratory lands because of public access. There are no residential uses of LANL lands and residential use is impractical at most locations (e.g., many canyon bottoms).
		Biota concentration guides	DOE technical standard	On-site and off-site	Dose limit to biota same as for surface water. Individual results compared to BCGs.
		Background	LANL (1998) or McLin (2004)		Results from Pajarito Plateau stations are compared to plateau-specific background levels (LANL 1998). Results from regional stations are compared to background levels specific to the major rivers within the Rio Grande drainage system (McLin 2004).
Nonradionuclides	None	Human health screening levels	NMED, EPA Region 6, or LANL	On-site and off-site	Recreational or industrial screening levels derived to determine if more detailed assessment is needed to evaluate impacts to the public.
		Background	LANL (1998) or McLin (2004)		Results from Pajarito Plateau stations are compared to plateau-specific background levels (LANL 1998). Results from regional stations are compared to background levels specific to the major rivers within the Rio Grande drainage system (McLin 2004).

1. Applicable New Mexico Surface Water Standards

The NM Water Quality Control Commission (NMWQCC) establishes surface water standards for waters of the state in Standards for Interstate and Intrastate Surface Waters (NMWQCC 2005). Certain watercourses may be 'classified' and have segment-specific designated uses. A designated use may be an attainable or an existing use (e.g., livestock watering, aquatic life) for the surface water. Nonclassified surface water is described as ephemeral, intermittent, or perennial, each of which also has corresponding designated uses. The designated uses for surface water are associated with use-specific water quality criteria, including numeric criteria.

Significant changes were made in the NMWQCC stream standards that became effective July 17, 2005. The most significant change, with respect to surface water monitoring at the Laboratory, is the classification of all surface water with segment-specific designated uses within the Laboratory boundary. Four segments, with designated uses of coldwater aquatic life, livestock watering, wildlife habitat, and secondary contact, are classified as perennial (Figure 6-1). The remaining segments, with designated uses of limited aquatic life, livestock watering, wildlife habitat, and secondary contact, are classified as ephemeral or intermittent.

The surface water within the Laboratory is not a source of municipal, industrial, or irrigation water, though wildlife does use the water. While direct use of the surface water is minimal within the Laboratory, stream flow may extend beyond the LANL boundaries where the potential is greater for more direct use of the water. Stream flows may extend onto Pueblo de San Ildefonso tribal land. Spring water may be used traditionally and ceremonially by San Ildefonso tribal members, and uses may include ingestion or direct contact.

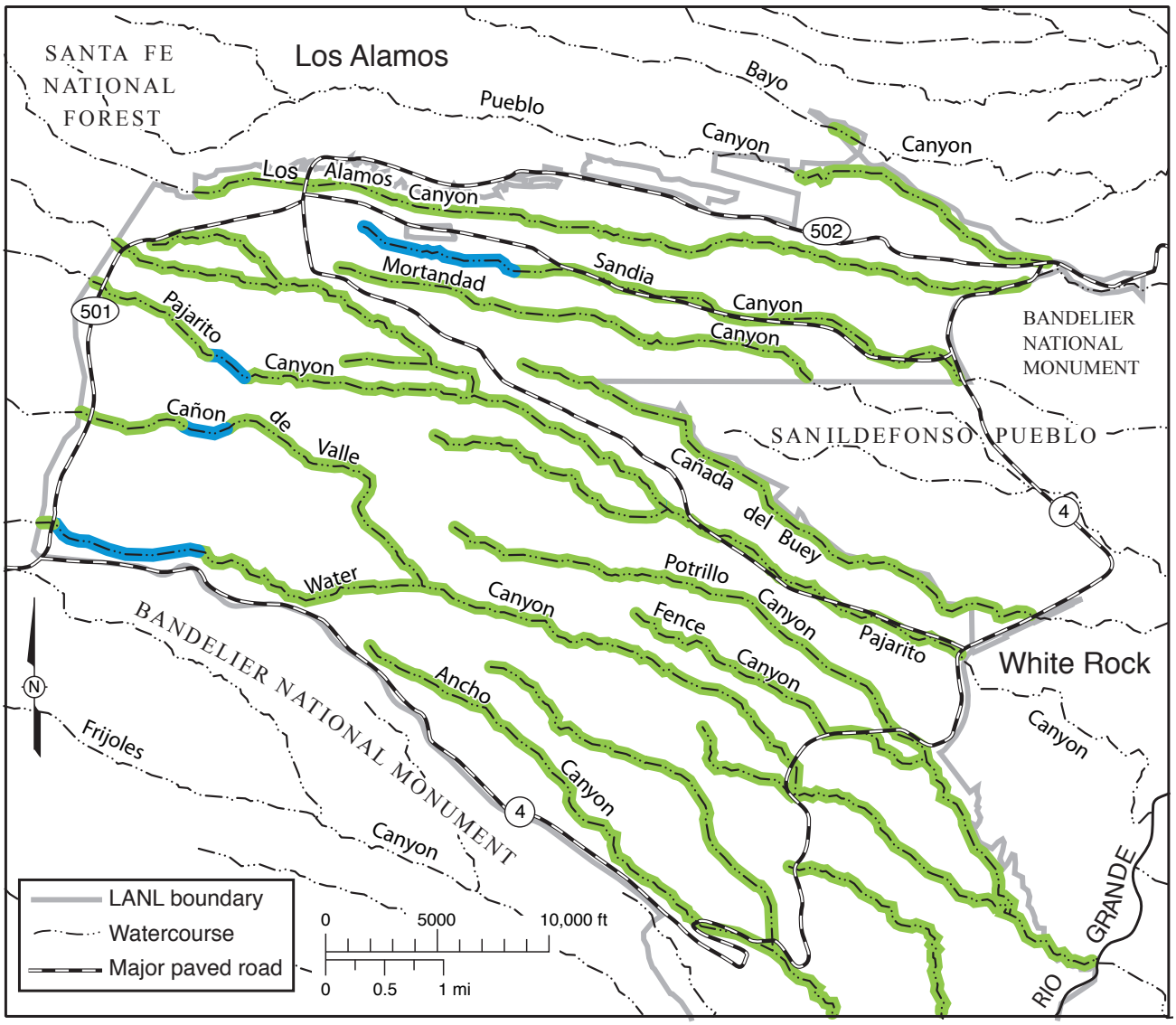
2. Radionuclides in Surface Water

DOE Order 5400.5 prescribes total dose limits associated with exposure to radionuclides in environmental media. There are no drinking water systems on the Pajarito Plateau that rely on surface water supplies because of the limited extent of stream flow. The emphasis of our radiological assessment of surface water is, therefore, on potential exposures to aquatic organisms and terrestrial plants and animals, rather than to humans. For protection of biota population, we compare concentrations of radionuclides in surface water with the US Department of Energy (DOE) Biota Concentration Guides (BCGs) (DOE 2002). Comparison of water quality results to BCGs is done based on annual flow-weighted radionuclide content of the water rather than on individual samples.

Surface water analytical results are also compared with the NMWQCC water quality standard for protection of livestock watering use, which is a designated use for surface water within the Laboratory boundary (NMWQCC 2005). NMWQCC standards are not specific about exposure frequency or duration; for screening purposes, we compare single sample results with numeric criteria for radium-226 + radium-228 and tritium, as discussed in Section 3.

3. Nonradioactive Constituents in Surface Water

Surface water concentrations of nonradioactive constituents are also compared with the NMWQCC (2005) numeric water quality criteria that correspond to the designated uses for the stream. All surface water within the Laboratory boundary have the designated uses of livestock watering and wildlife habitat. For classified ephemeral and intermittent watercourses, the limited aquatic life use applies, along with the acute (short-term) aquatic life criteria and the human health criteria for persistent pollutants. The NMWQCC human health criteria are based on the US Environmental Protection Agency (EPA) criteria for "consumption of organisms only." Within the classified perennial waters, the coldwater-designated use applies, together with both the acute and chronic (long-term) aquatic life criteria and the human health criteria for toxic pollutants, including persistent and carcinogenic pollutants. Hardness-dependent aquatic life numeric criteria are calculated using a water hardness value of 100 mg $CaCO_3$/L.



Stream Type Designated Uses

Perennial (NM 20.6.4.126): Coldwater Aquatic Life, Livestock Watering, Wildlife Habitat, Secondary Contact Ephemeral and Intermittent (20.6.4.128): Limited Aquatic Life, Livestock Watering, Wildlife Habitat, Secondary Contact

Perennial

Ephemeral and Intermittent

Figure 6-1. Designated stream segments and uses at Los Alamos National Laboratory.

For evaluating the potential impact of chronic exposure to surface water constituents on aquatic life, the Laboratory uses the protocol employed by the NMED for assessing standards attainment in waters of the state (NMED 2006a). For designated perennial stream segments, single sample results are compared with the chronic screening level that is 1.5 times the chronic aquatic life criterion. Surface water quality results are lastly compared with the NMWQCC groundwater standards to evaluate the potential for stream flows to impact underlying groundwater bodies (NMWQCC 2002).

4. Sediment

Sediment analytical results are compared to screening levels to identify concentrations that may require further assessment. The Laboratory's Environment Remediation and Support Services Division uses residential, industrial, construction worker, or recreational screening action levels (SALs) to identify radionuclide activity levels of interest (LANL 2005). Comparisons with SALs are used to readily distinguish the areas with the most potential concern: concentrations below the SALs are not of concern to public health, whereas concentrations greater than the SALs would trigger more detailed investigations. Residential uses do not occur on Laboratory land. Recreation is the dominant use in most areas of the Laboratory watercourses. Concentrations of nonradioactive compounds in sediment are compared with recreational or industrial soil-screening levels developed by NMED (2006b), EPA Region 6 (EPA 2007), or LANL (2007). All of these screening levels are conservative (protective) because they are calculated based on the assumption that humans will be exposed to the chemicals or radionuclides for extended periods of time, which is not the case on LANL property. For sediment stations located on the Pajarito Plateau, sediment data are also compared with established plateau-specific background levels of metals or background activities of radionuclides that are naturally occurring or result from atmospheric fallout (LANL 1998) and sources other than LANL. Data from regional sediment stations are compared to background levels established for the major drainages of the area, the Rio Grande, Rio Chama, and Jemez River (McLin 2004).

D. SAMPLING LOCATIONS AND DATA ANALYSIS METHODS

1. Regional Monitoring Locations

Regional base flow and sediment sampling stations (Figure 6-2) are located in northern NM. Samples from regional stations reflect background concentrations and provide a basis for evaluating Laboratory impacts to the Rio Grande drainage system. Regional sediment samples were obtained from stations on the Rio Grande and the Jemez River, from Abiquiu Reservoir on the Rio Chama, and from Cochiti Reservoir on the Rio Grande. Sampling stations in the Rio Grande drainage system are located up to approximately 60 km upstream of the Laboratory.

2. On-Site and Perimeter Monitoring Locations

Surface water and sediment are sampled in all major canyons that cross current or former Laboratory lands. Stream sediment is sampled to evaluate the accumulation of undissolved contaminants in the aquatic environment (DOE 1991). Surface water samples are collected across the Pajarito Plateau within and near the Laboratory, with particular emphasis placed on monitoring at the Laboratory boundaries. We collect base-flow grab samples from locations where effluent discharges or natural springs maintain stream flow (Figure 6-3).

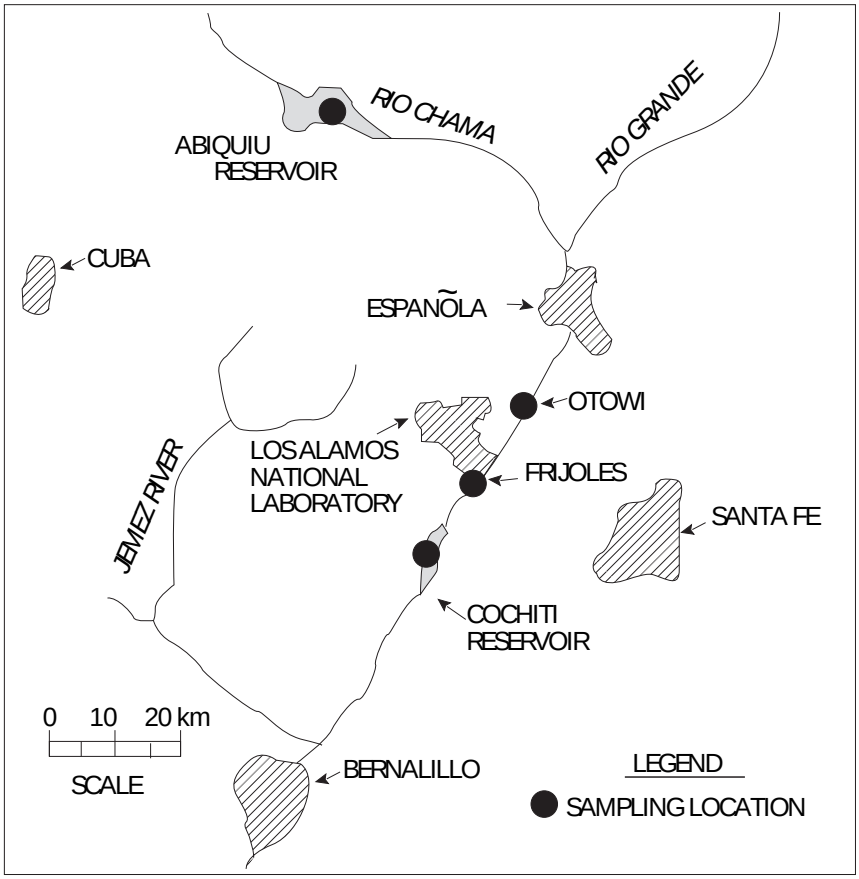


Figure 6-2. Regional base flow and sediment-sampling locations.

Storm water runoff samples in watercourses are collected at stream-gaging stations using automated samplers (Figure 6-4). Many gaging stations are located where drainages cross the Laboratory's boundaries. Storm water runoff is also sampled at many mesa-top sites which allows the Laboratory to evaluate runoff from specific Laboratory activities (Figure 6-5). These sites usually have negligible runoff from other sources.

Sediment stations on the Pajarito Plateau (Figure 6-6) are located within approximately four km of Laboratory boundaries, with the majority located within Laboratory boundaries. Many of the sediment-sampling stations on the Pajarito Plateau are located within canyons to monitor sediment contamination in the active channel related to past and/or present effluent discharges. Three major canyons were extensively characterized in 2006 (Pueblo, Los Alamos, and Mortandad Canyons) that have experienced past or present liquid radioactive releases; samples are collected from above the Laboratory to their confluence with the Rio Grande.

Sediment from drainages was collected downstream of two material disposal areas (MDAs), MDA G and MDA AB. Material Disposal Area G at Technical Area (TA)-54 is an active waste storage and disposal area. Sampling stations were established outside its perimeter fence in 1982 (Figure 6-7) to monitor possible transport of radionuclides from the area. MDA AB at TA-49 was the site of underground nuclear weapons testing from 1959 to 1961 (Purtymun and Stoker 1987; ESP 1988). The tests involved high explosives (HEs) and fissionable material. We established stations in 1972 to monitor surface sediment in drainages adjacent to MDA AB (Figure 6-8).

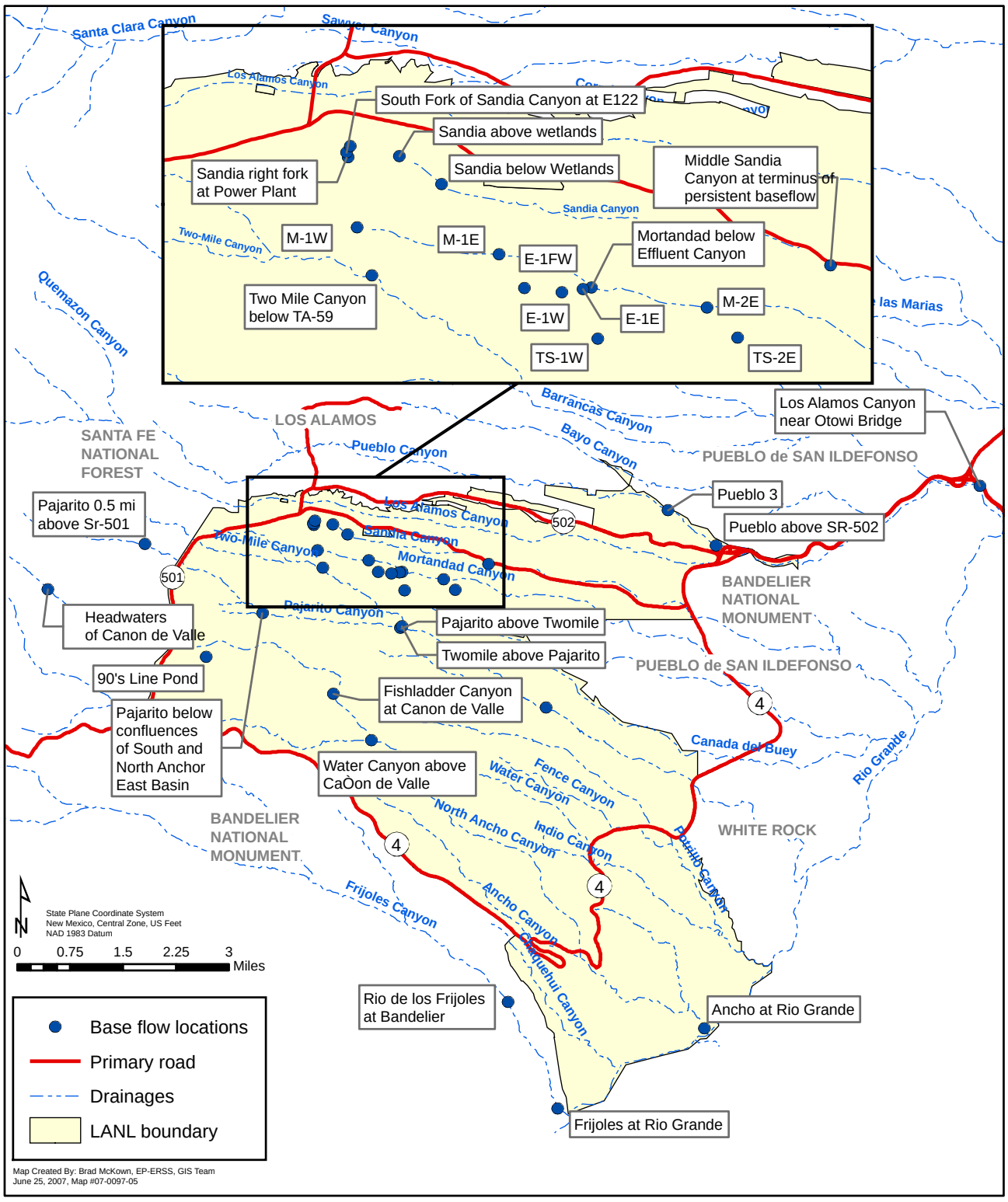


Figure 6-3. Base flow sampling locations in the vicinity of Los Alamos National Laboratory.

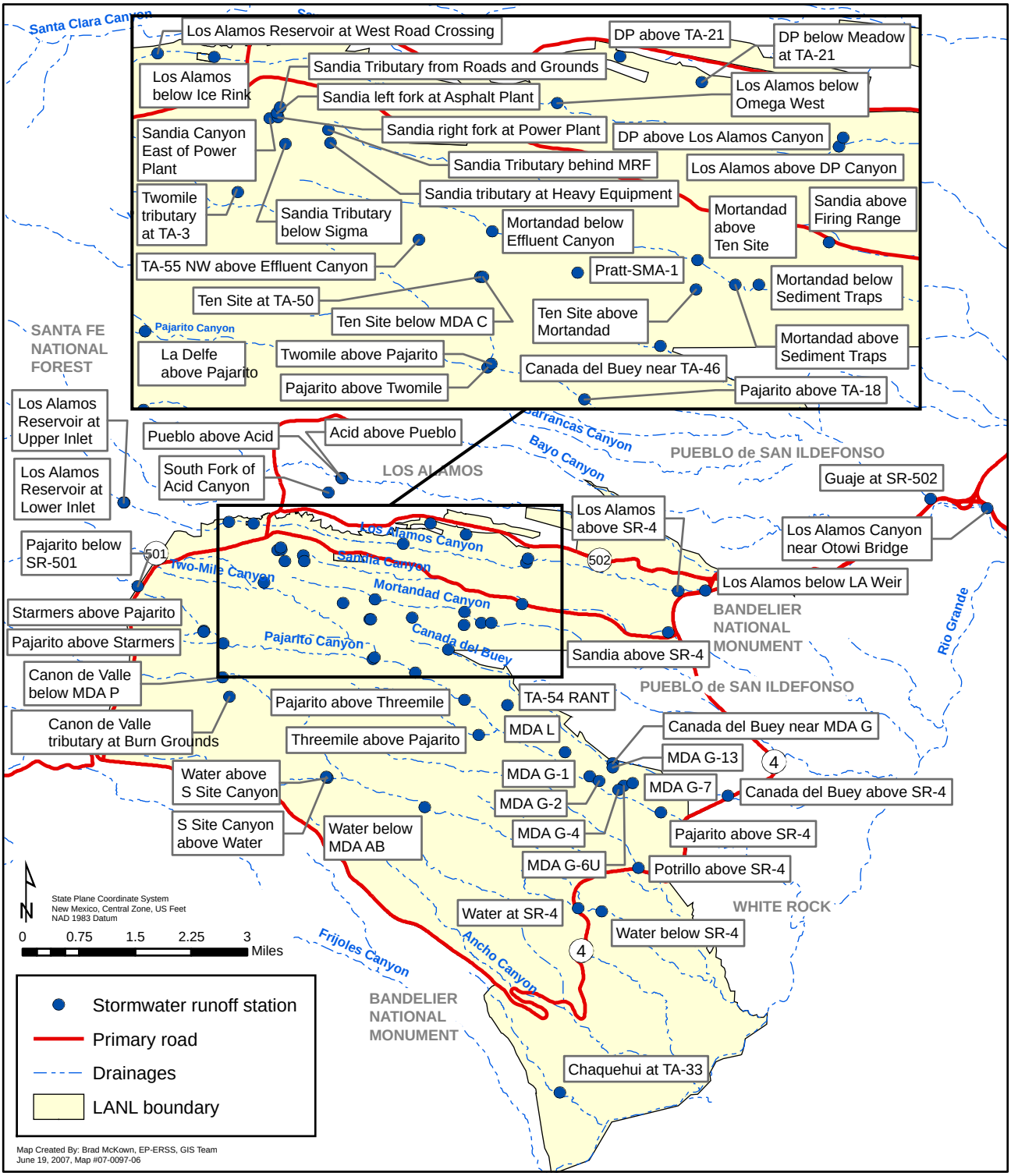


Figure 6-4. Storm water runoff sampling (gage) stations in the vicinity of Los Alamos National Laboratory.

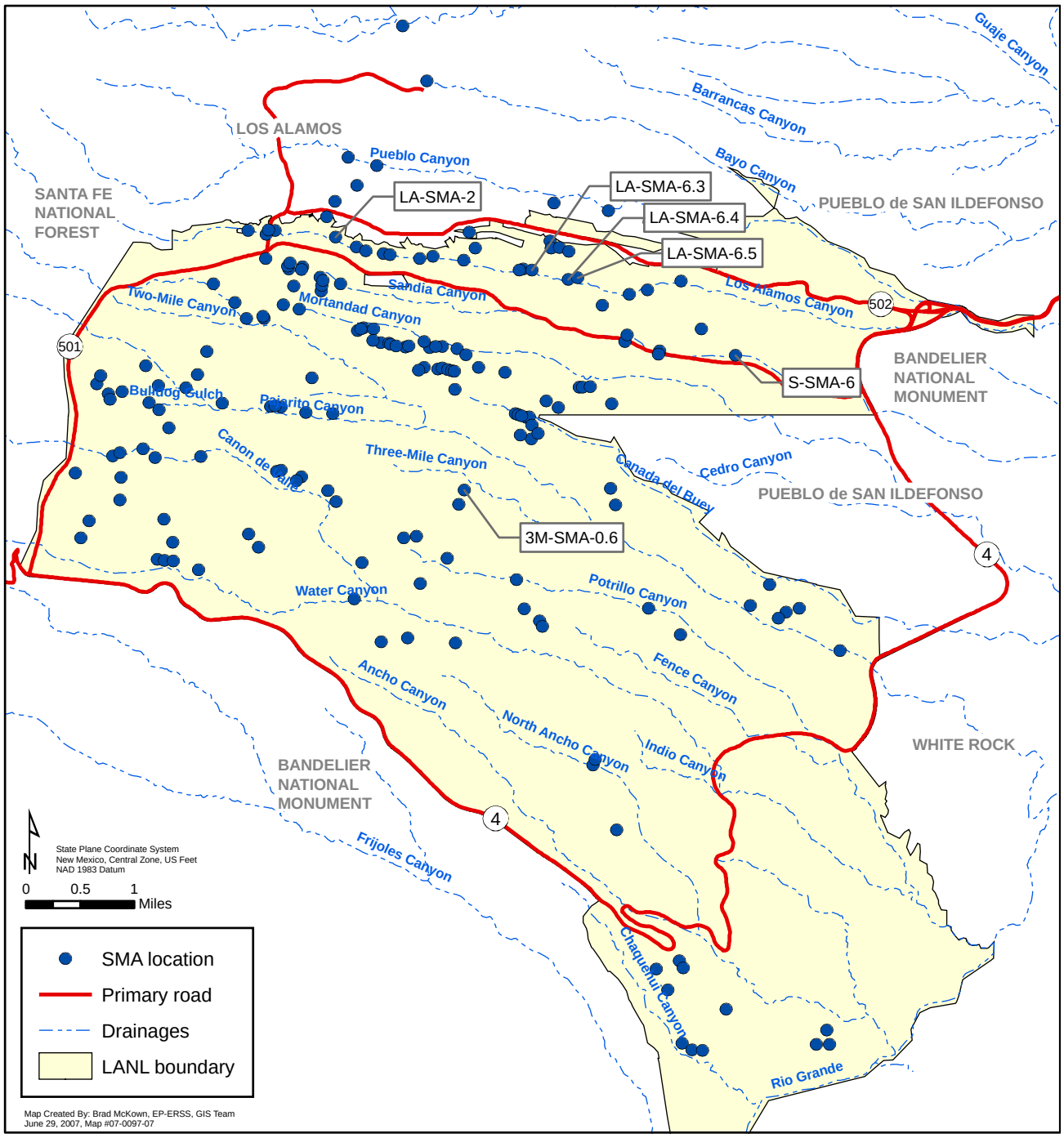


Figure 6-5. Site-specific storm water runoff sampling stations in 2006 in the vicinity of Los Alamos National Laboratory.

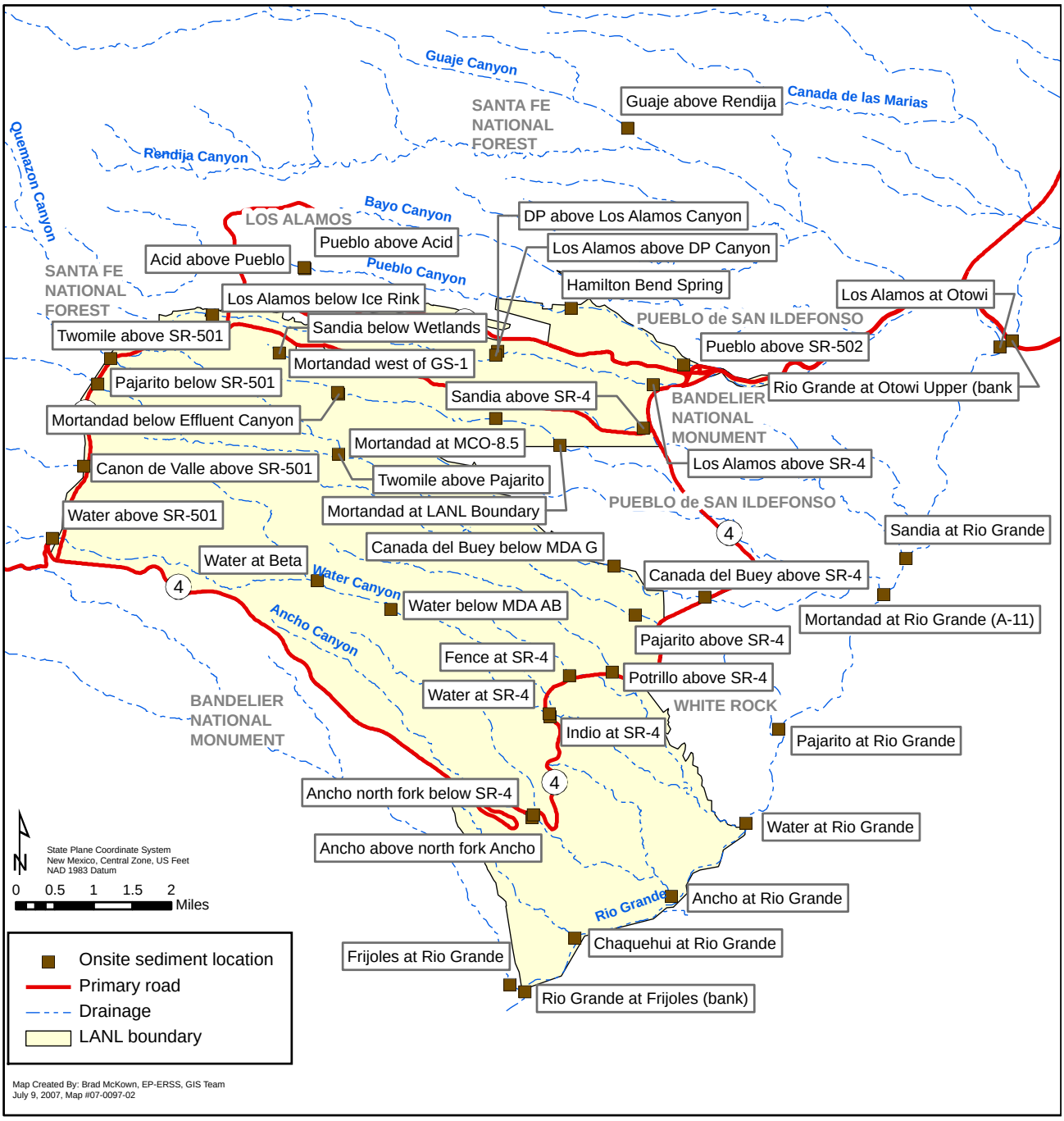


Figure 6-6. **Sediment sampling locations in the vicinity of Los Alamos National Laboratory. Material disposal areas with multiple sampling locations are shown in Figures 6-7 and 6-8.**

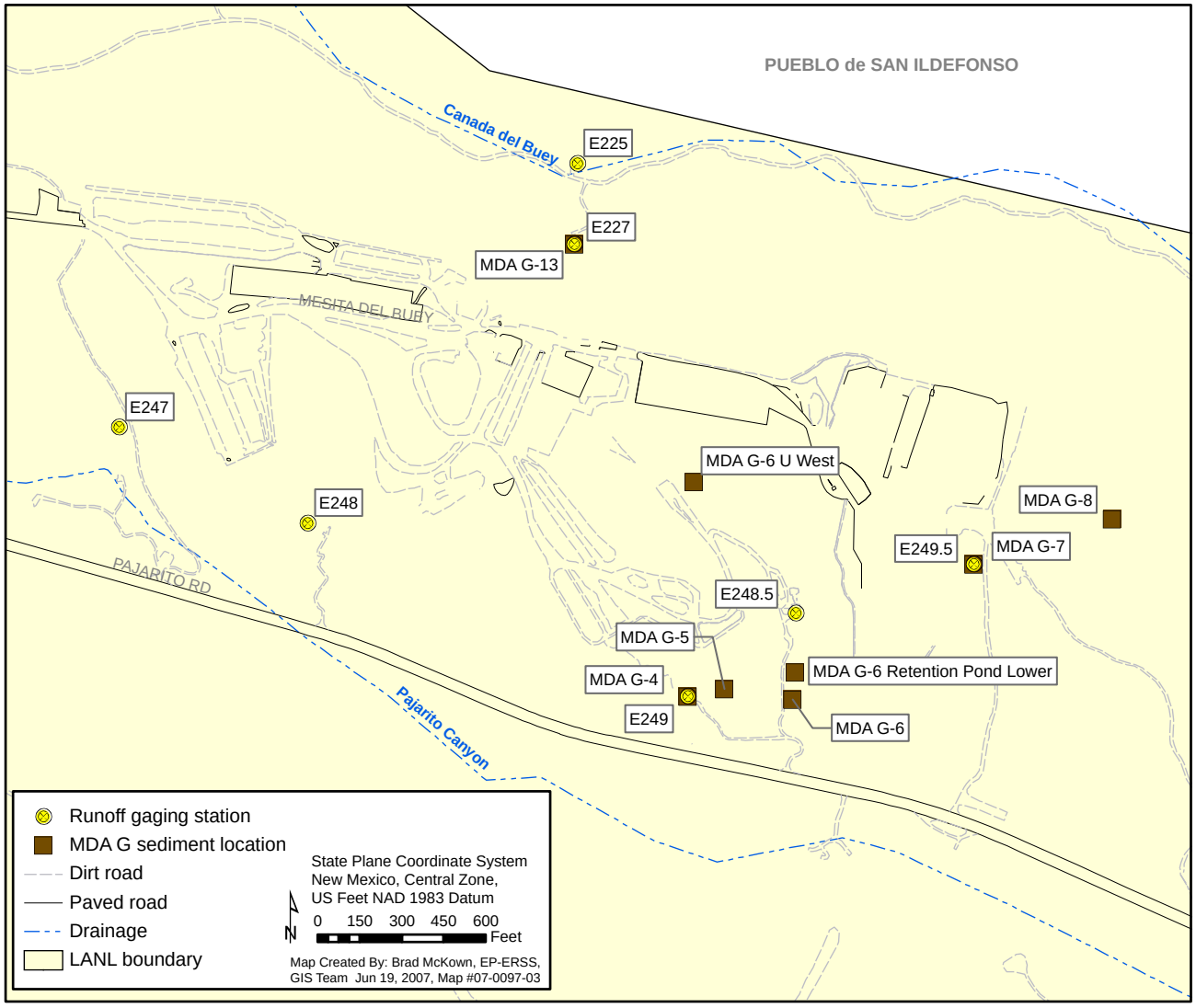


Figure 6-7. Sediment and storm water runoff sampling stations at TA-54, MDA L, and MDA G.

Additionally, surface water and sediment were sampled at several locations on Pueblo de San Ildefonso lands. DOE entered into a Memorandum of Understanding with the Pueblo de San Ildefonso and the Bureau of Indian Affairs in 1987 to conduct environmental sampling on pueblo land. The watershed drainages that pass through LANL onto Pueblo lands are Los Alamos/Pueblo, Sandia, Mortandad, and Cañada del Buey Canyons.

3. Sampling and Analysis Procedures

Our procedures for sampling and analysis depend on the type of stream flow and location. We collect grab samples of base flow and snowmelt runoff from free-flowing streams near the bank. We filter and preserve grab samples in the field. The storm runoff (gage) stations, located mostly in canyon bottoms, are equipped with automated samplers that are activated at the start of significant flow events. Typically, the automated samplers collect water from the first 30 minutes of the runoff event to sample the first flush of storm water. This is the third year that the first flush has been sampled and it is a significant change from previous years.

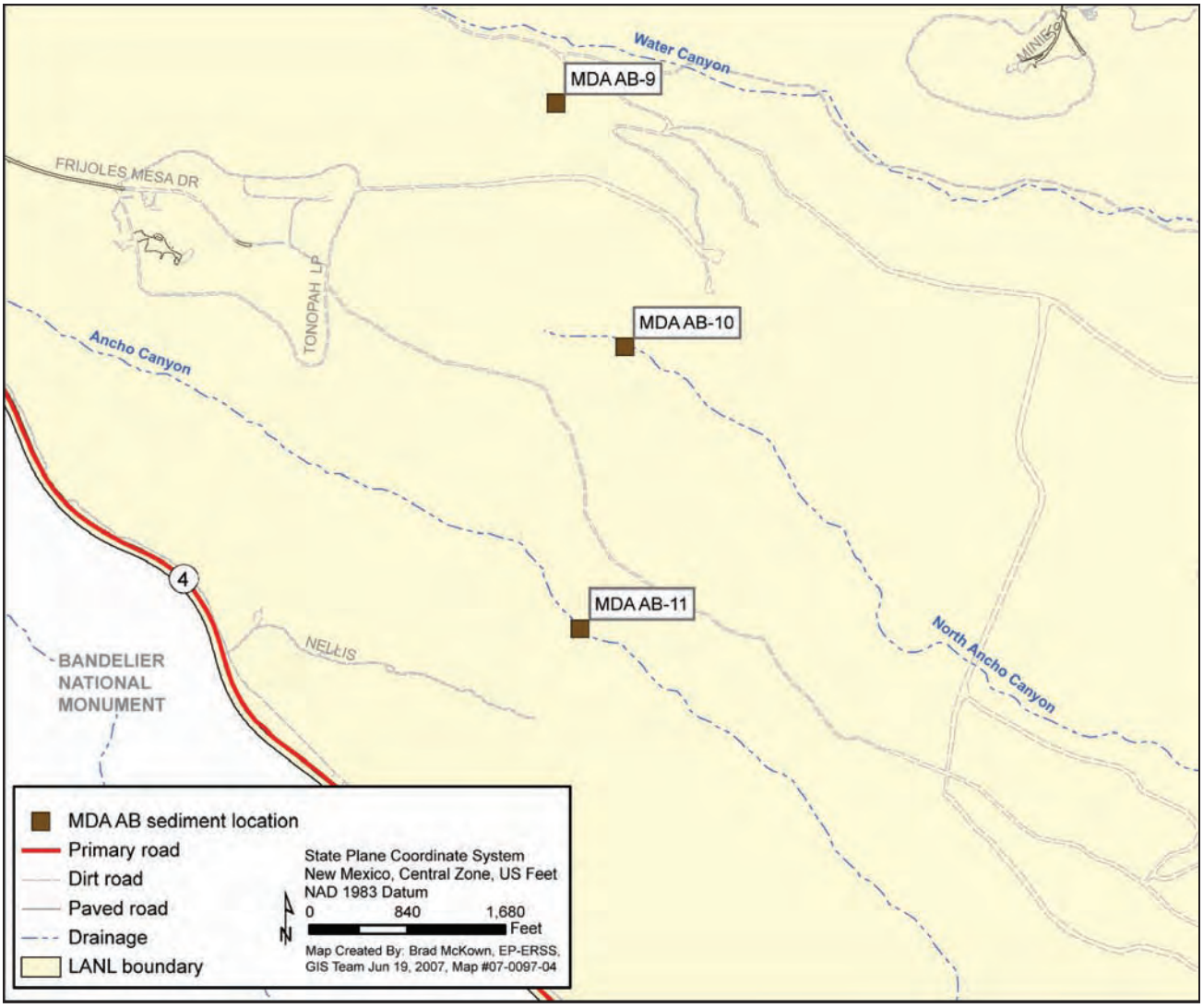


Figure 6-8. Sediment sampling stations at Area AB, TA-49.

Previously, samples were collected over a two-hour period. Higher concentrations are expected in the first flush compared to the average concentration during a flow event, so the post-2004 data are not directly comparable to data from previous years.

Storm water runoff samples from mesa tops are collected with buried single-stage runoff samplers. Individual storm runoff sample bottles are filtered and preserved at LANL. Base flow and snow melt samples are filtered and preserved in the field; storm flow samples are filtered and preserved in LANL's storm water operations facility, because filtering highly sediment-laden waters in the field is difficult. Samples are then shipped to the commercial analytical laboratory as is, without compositing or splitting. Sediment samples are collected from the edge of the main channels of flowing streams. To collect samples from the beds of intermittently flowing streams, a disposable scoop is used to collect fine-textured sediment across the main channel to a depth of 20 mm.

E. WATERSHED SAMPLING RESULTS BY CONSTITUENTS

The supplemental data tables on the included compact disk present all the 2006 watershed-related surface water and sediment analytical results. In the tables, radiological results are presented in sequence for each of these media, followed by the results for major chemical quality analytes, metals, and organic compounds.

Surface water and sediment samples are analyzed for gross alpha, gross beta, and selected radionuclides (americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, uranium isotopes, and tritium, cobalt-60, potassium-40, neptunium-237, radium-226, radium-228, and sodium-22). Table S6-1 in the Data Supplement lists the results of radiochemical analyses of surface water for 2006. The table also lists the total propagated one-sigma analytical uncertainty and the analysis-specific minimum detectable activity, where available. Uranium is analyzed by isotopic methods. For most radionuclide measurements, a detection is an analytical result that does not include an analytical laboratory (or in some cases, secondary validation) qualifier codes of X or U (indicating nondetect). Trace-level tritium measurement results for surface water samples are presented in Table S6-2. The results of radiochemical analyses of sediment appear in Table S6-3.

Concentrations of major chemical constituents in surface water are listed in Table S6-4. Table S6-5 and S6-6 present results of metals analyses for surface water and sediment, respectively.

The scope and results of organic analyses are presented in Tables S6-7 through S6-10. Table S6-7 presents the number and type of organic analyses performed on surface water samples, and Table S6-8 presents results for any organic chemical detected in surface water. Similarly, Tables S6-9 and S6-10 present summaries of organic analyses of stream sediment.

Qualifier codes are shown in some tables to provide additional information on analytical results that are not detections: in some cases, for example, the analyte was found in the laboratory blank, or there were other analytical issues. The tables show two categories of qualifier codes: those from the analytical laboratory and those from secondary validation (Tables S5-5, S5-6, and S5-7).

The overall quality of most surface water in the Los Alamos area is good, with low levels of dissolved solutes. Of the more than 100 analytes measured in sediment and surface water within the Laboratory, most are at concentrations far below regulatory standards or risk-based levels. However, nearly every major watershed indicates some effect from Laboratory operations, often for just a few analytes. In the following sections, we first present a Laboratory-wide overview on surface water and sediment quality, and then the key findings are discussed in more detail on a watershed-by-watershed basis.

The contaminant distribution maps show contaminant locations extrapolated beyond the area covered by sampling stations. This extrapolation takes into account the location of contaminant sources and stream flow within each watershed. Question marks on the maps indicate where contaminant extent is inferred, but not confirmed by monitoring coverage. The extent of contamination lateral to the canyon is not to scale: much of the contamination is limited to the canyon bottom alluvium and is quite narrow at the map scale.

1. Radioactivity in Surface Water and Sediment

In 2006, there were no new locations with radiological contamination, and levels of radioactivity were within ranges measured in recent years. Other than for naturally occurring radionuclides (for example, radium-226), none of the radionuclide activities or concentrations were greater than applicable DOE standards or guidelines.

Approximately 8 of 10 surface water samples in 2006 contained gross alpha activity greater than the NM regulatory standard of 15 pCi/L for livestock watering. However, the vast majority of the alpha activity is due to natural sediment and soil from uncontaminated areas carried in storm water runoff, and Laboratory impacts are relatively small.

Decay of naturally occurring isotopes in sediment is a source of gross alpha activity, which is supported by the strong correlation between gross alpha and suspended sediment concentrations (SSC) shown in Figure 6-9. The relationship between gross alpha activity and SSC in stations within LANL is identical to stations upstream of LANL, with the exception of Mortandad Canyon. Mortandad Canyon receives effluent from a radioactive liquid waste treatment plant for radioactive materials. Therefore the elevation above the upper 95% confidence level for background stations shown in Figure 6-9 could be attributed to anthropogenic sources in storm water runoff.

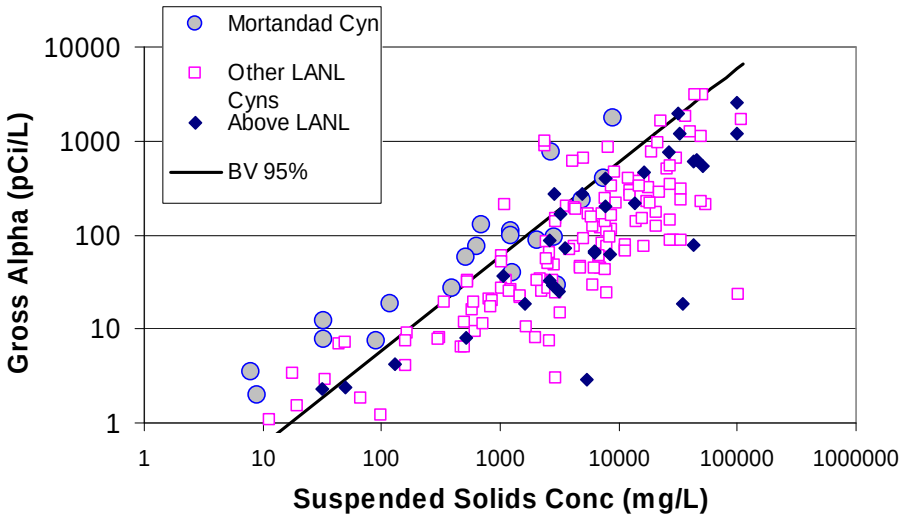


Figure 6-9. Relationship between gross alpha particle activity and suspended solids concentrations in surface water, 2000 - 2006. The line represents the upper 95th percentile level of activities that would arise naturally from background stream sediment (McDonald et al., 2003).

Gross alpha activities measured across the Pajarito Plateau have declined substantially since the 2000 Cerro Grande fire as stream flows are reduced with recovery in the burned areas (Figure 6-10), which has resulted in reduced concentrations of suspended solids.

Gross alpha radioactivity is a general screening measurement of limited value in assessing radiological hazards because specific alpha emitters in the water cannot be identified or quantified. Therefore, gross alpha results are not discussed in detail in this report. Instead, specific individual radionuclides identified in LANL waste streams (Watkins and Del Signore 2005) or known to be associated with the nuclear industry (Langmuir 1997) are analyzed. A listing of gross alpha concentrations measured in surface water is provided in Supplemental Table S6-1.

Table 6-2 compares the annual average concentrations of specific radionuclides in surface water at Los Alamos against the DOE's BCGs. In order to compare surface water sample data with the DOE BCGs, we calculated the time-weighted average annual radioactivity in waters, focusing on the wetter stream segments.

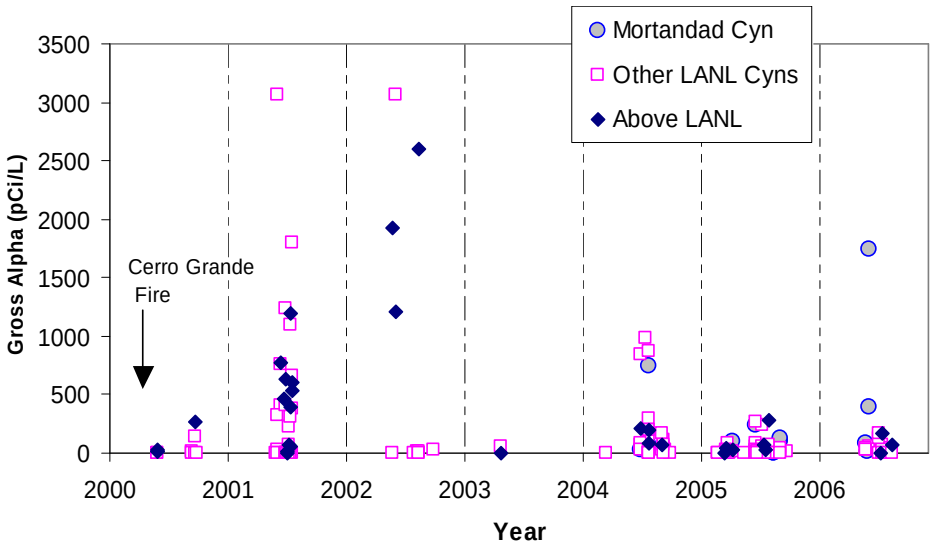


Figure 6-10. Time trends in total gross alpha activity in surface water.

Time-weighted average concentrations were calculated for the individual radionuclides of primary concern on the landscape at Los Alamos: americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, tritium, and uranium isotopes. Concentrations measured during base flow periods and during storm runoff periods were weighted proportionally after reviewing stream flow records (Romero et al., 2007) to distinguish the flow regimes; periods with no flow were assigned concentrations of zero.

This approach is consistent with DOE guidance (DOE 2003). For waters containing more than one radionuclide, a ratio for each radionuclide is calculated by dividing the concentration of each radionuclide by its particular BCG. To be consistent with DOE Order 5400.5, the sum of the ratios should not exceed 1.0 (DOE 1990). Because the calculations are often based on limited sample sets and hydrologic interpretation, these results should be viewed as approximations.

The time weighted annualized concentrations, and sum of ratios, for unfiltered surface water in the major canyons were well below the BCGs. Table 6-2 shows that concentrations of all of the individual isotopes were less than 5 percent of their respective BCGs, except for radium-226 at 40 percent of the BCG. When the mixtures of isotopes are considered, the largest sums of the ratios were found in the Los Alamos Canyon drainage system at between 25 to 43 percent of the standard.

Approximately 95 percent of the calculated potential radiological dose to biota is attributable to radium-226. Although radium-226 is probably of natural origin, it is of concern because it has the most stringent BCG for all the radionuclides monitored. The BCG was established to protect riparian animals that ingest radium-226 in calcium-deficient waters. However, surface water at Los Alamos is calcium-abundant and the resultant dose from radium-226 is considerably less than calculated as the calcium interferes with the uptake of radium-226.

2. Metals in Surface Water and Sediment

In 2006, all metals concentrations in sediment were below screening levels for recreational and residential uses. In surface water, the vast majority of results were below the most stringent applicable state stream standards, other than for metals of natural origin (for example, aluminum.)

The NM Surface Water Quality Standards (NMWQCC 2005) vary across the Laboratory depending on the designated uses for a particular stream segment, as discussed in Section C.3. To evaluate how 2006

Table 6-2
Estimated Annual Average Unfiltered Surface Water Concentrations of Radionuclides in Selected Canyons with the Biota Concentration Guides

Radionuclide	BCGs[a] (pCi/L)	Pueblo above Acid	Lower Pueblo Canyon	DP Canyon below TA-21	LA Canyon between DP and SR-4	LA Canyon at Rio Grande	Mortandad Canyon below Effluent Canyon	Max percent of BCG[a]
Am-241	400		0.01	0.1	0.5	0.01	9	2%
Cs-137[b]	20,000	0.1	0.2	2	2	0.3	33	0.2%
H-3	300,000,000		43	21	7	26	294	<0.01%
Pu-238	200		0.001	0.01	0.04	0.01	5	2%
Pu-239,240	200	0.01	0.3	0.1	0.5	0.04	7	4%
Sr-90	300	0.1	0.01	12	0.8	0.4	4	1%
U-234	200	0.3	0.4	0.6	1.3	1.5	2	1%
U-235,236	200	0.01	0.01	0.02	0.1	0.1	2	0.1%
U-238	200	0.4	1.0	0.4	1.3	1.4	0.1	1%
Ra-226	4	0.2	0.9	0.2	0.9	1.6	0.2	40%
Sum of ratios to BCGs		0.05	0.06	0.05	0.25	0.43	0.15	

[a] BCG = DOE Biota Concentration Guides (DOE 1992)

[b] The BCG for Cs is a site-specific modified BCG from McNaughton 2005

Blank cells indicate no analytical laboratory detection in 2006

monitoring results compare to the state standards, the applicable standards were compared to results for each specific location. During 2006, 580 sampling events were conducted at 169 locations. The monitoring included 86 site-specific (mesa top or hillside) sites and 79 watercourse (canyon floor) sites on the Pajarito Plateau. The testing program varied by watershed but surface water samples typically were tested for more than 100 analytes.

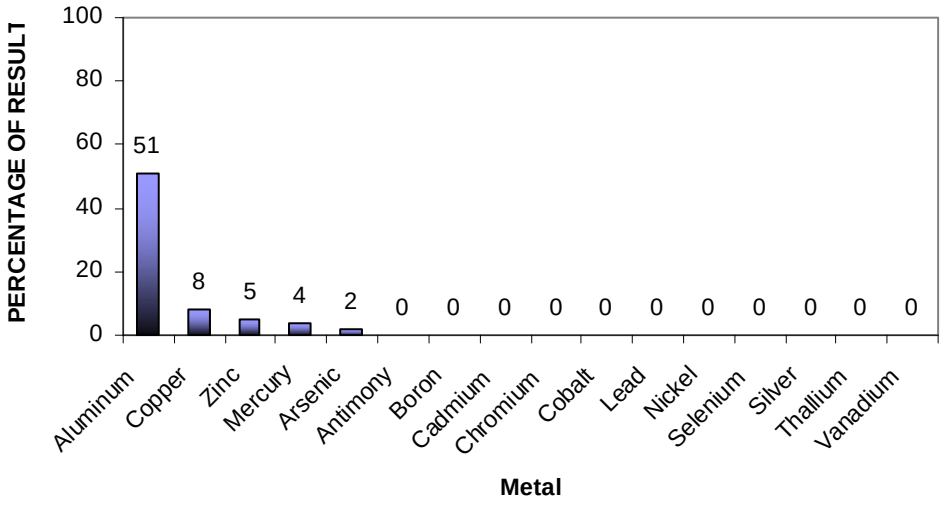


Figure 6-11. Frequency of metals results from watercourse stations above the most-restrictive NM stream standards.

About 50 percent of surface water samples contained concentrations of dissolved aluminum higher than the acute aquatic life standard (Figure 6-11). Aluminum is a natural component of soil and not derived from Laboratory operations in any significant quantity. In the slightly alkaline waters at Los Alamos, aluminum rarely occurs in solution in natural water at concentrations greater than a few tens to hundreds of micrograms per liter (Hem 1986). Consequently, a large majority of these results greater than the standard are probably due to the presence of particulate aluminum (colloids) that pass through the filter, rather than being dissolved in the water column which is the basis of the standard. No other metal was present at concentrations greater than the standard in more than 10 percent of the samples. The metals data indicate a minimal overall impact from the Laboratory, although a few localized areas appear to contain elevated copper (Figure 6-12), mercury, and zinc concentrations.

Following the Cerro Grande fire, numerous watercourses across the Laboratory were identified as water-quality impaired with total recoverable selenium concentrations above the NM wildlife habitat standard and added to the federal Clean Water Act §303(d) list (NMWQCC 2004). Selenium concentrations have progressively declined since the fire (Figure 6-13) and no values greater than the wildlife habitat standard of 5 µg/L were measured in 2006. The water quality trends indicate that the elevated selenium concentrations were due to natural sources, probably the ash from the fire. These data indicate that drainages near the Laboratory are no longer impaired with elevated selenium concentrations.

3. Organic Compounds in Surface Water or Sediment

The concentrations of organic compounds were analyzed in approximately 50 watercourse surface water stations and 50 active channel sediment stations. PCBs were generally found in two canyons above regulatory standards and are the principal class of organic compounds detected. Figure 6-14 shows where PCBs have recently been detected in surface water. In sediment, none of the organic compounds were detected at concentrations greater than recreational or residential soil screening levels.

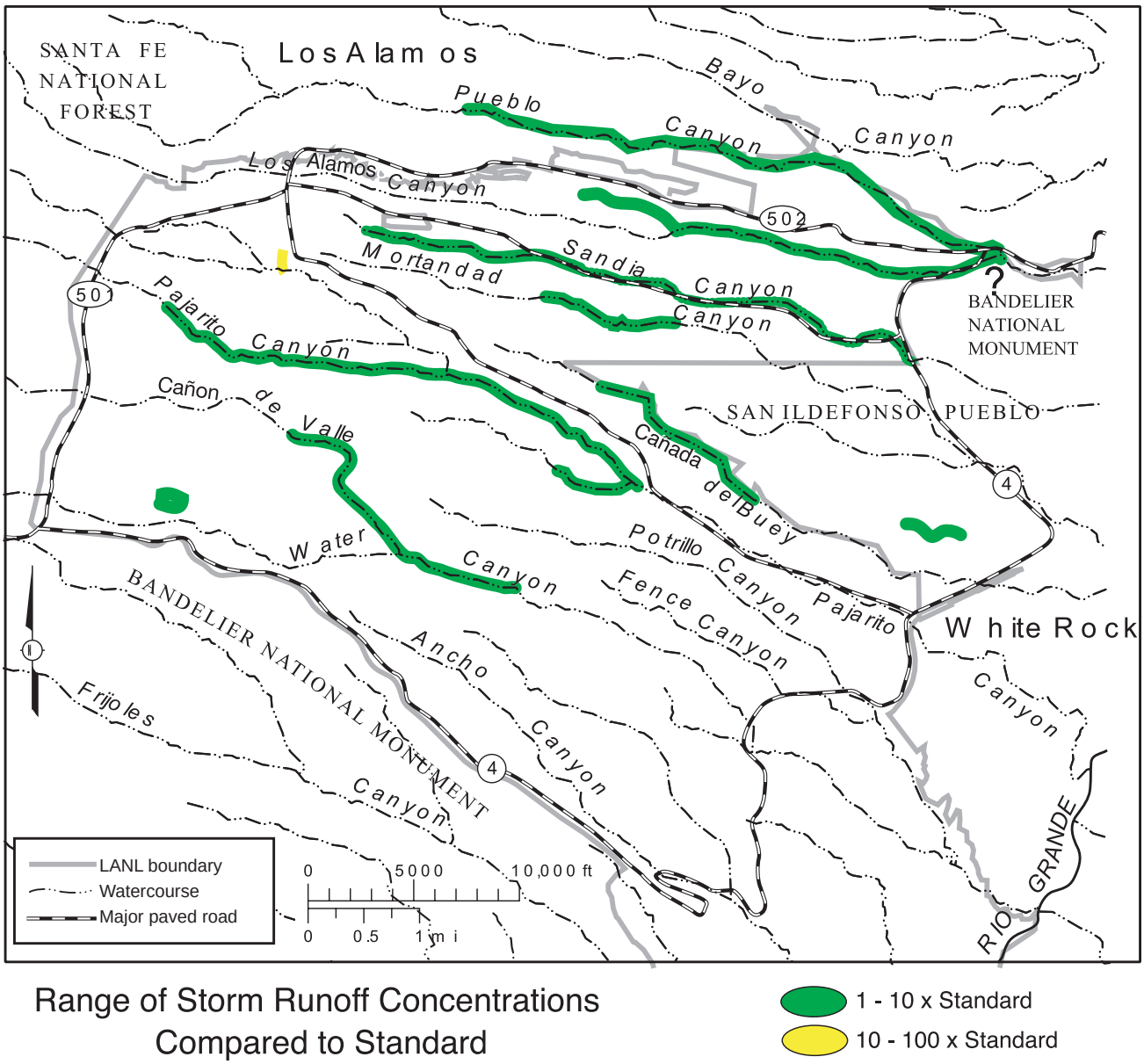


Figure 6-12. Location of surface water with levels of dissolved copper greater than stream standards.

The types of organic compounds analyzed for varied depending on the location and typically included the following suites: pesticides/PCBs, explosives compounds, volatile organics compounds, and semi-volatile organics compounds. On average, more than 70 different organic compounds were assessed at each site. PCBs were the only class of organic compounds that were definitively detected at concentrations greater than the NM water quality standards and are likely Laboratory-derived in part.

Surface water was analyzed for PCBs in 14 watercourses and detected in 6. Consistent with previous years, multiple PCB detections were reported in Sandia and Los Alamos Canyons. Sandia Canyon accounted for about half of the detections and Los Alamos Canyon an additional one-third. The PCB human health standards protect people from ingesting contamination through aquatic life consumption. The main sources of PCBs on Laboratory lands are likely predominantly from past spills and leaks of transformers, rather than current effluent discharges.

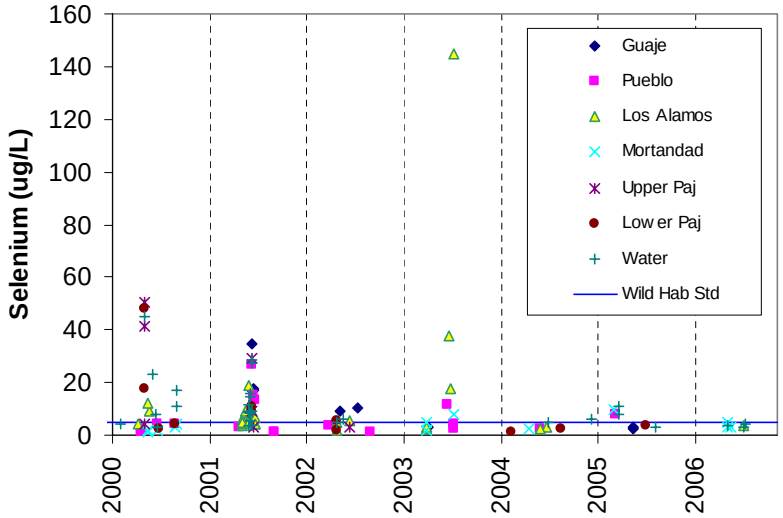


Figure 6-13. Trends in total recoverable selenium concentrations in surface water.

F. IMPACTS TO THE RIO GRANDE

Laboratory impacts to the Rio Grande were assessed in 2006 by comparing contaminant concentrations in sediment at locations upstream and downstream of LANL. River sediment was collected from the active channel of the river at the Otowi gage (upstream of LANL) and at the confluence with Frijoles Canyon in Bandelier National Monument (downstream). Additionally, samples of bottom sediment were collected at three separate locations each in Abiquiu Reservoir (upstream) and in Cochiti Reservoir (downstream), and analyzed for radioactivity and metals. Samples of Cochiti Reservoir bottom sediment were also analyzed for organic compounds.

All measurements of radioactivity in the Rio Grande and in Cochiti Reservoir were orders of magnitude below recreational or residential screening levels. In river sediment, no appreciable differences in radioactivity were measured above and below the Laboratory. Plutonium-239,240 concentrations were below analytical detection limits in the Rio Grande at both Frijoles and Otowi stations.

Plutonium-239,240 concentrations in bottom sediment from Cochiti Reservoir were comparable to those measured in 2005— near or slightly elevated above regional fallout levels (Figure 6-15). Though the 2006 sampling of Cochiti Reservoir was performed within one month following the August 8 record flood in Pueblo Canyon, plutonium-239,240 concentrations were not appreciably different than those measured since 2000. Metals concentrations in Rio Grande and Cochiti Reservoir bottom sediment were consistent with previous measurements. For example, 2006 Cochiti Reservoir mercury concentrations were within the ranges measured upstream at Abiquiu Reservoir (Figure 6-16), and below national median concentrations measured in reservoir studies across the country (Gillom et al. 1997).

No detections were found in Cochiti Reservoir sediment of pesticides, PCBs, semi-volatile organic analytes, or high explosive compounds. The pesticides DDE and DDT were detected in sediment collected at the Rio Grande at Frijoles station. These compounds have been historically detected in water samples taken from Frijoles creek and are not from Laboratory sources.

Natural stream flow and sediment loading in the Rio Grande is quite large compared to those from Los Alamos area streams. These factors reduce the possibility of identifying significant impacts from the

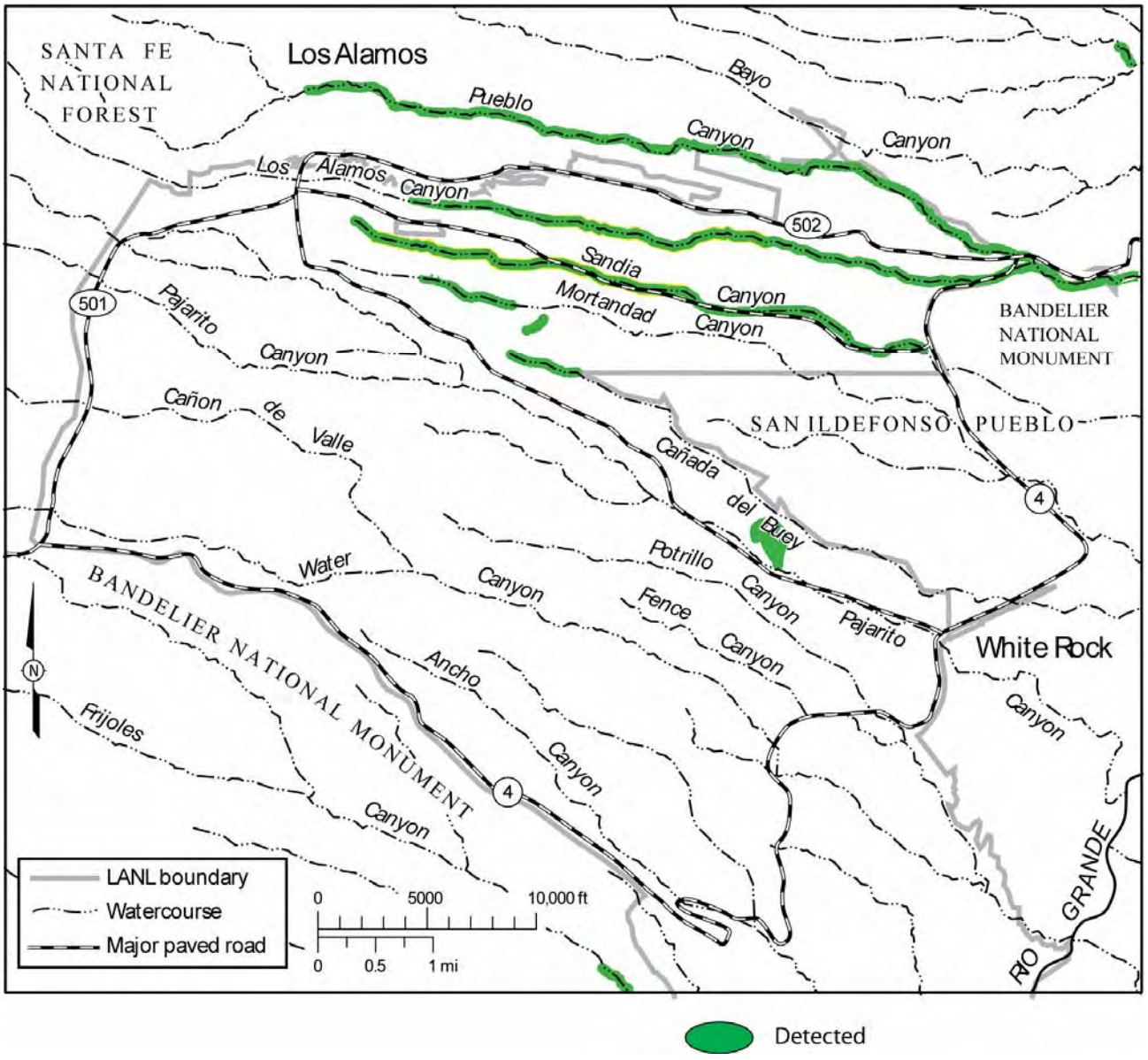


Figure 6-14. Location of surface water with detected PCBs.

Laboratory in the Rio Grande. A hydrographic comparison of 2006 flows in Los Alamos area canyons to flows in the Rio Grande is shown in Figure 6-17. Water flow in the Rio Grande at the Otowi gage was commonly a thousand times larger than that for all of the Los Alamos area canyons combined. Los Alamos area flows exceeded 10 cfs only on August 8 and 25. Similarly, the annual budget of suspended sediment and bed sediment passing the Otowi gage station were calculated to be 1,000 and 100 times that contributed by Los Alamos Canyon (Graf 1997). Large inputs of sediment from undeveloped parts of the Rio Grande watershed dilute the anthropogenic inputs from urban, industrial, and agricultural areas (Wilson and Van Metre 2000).

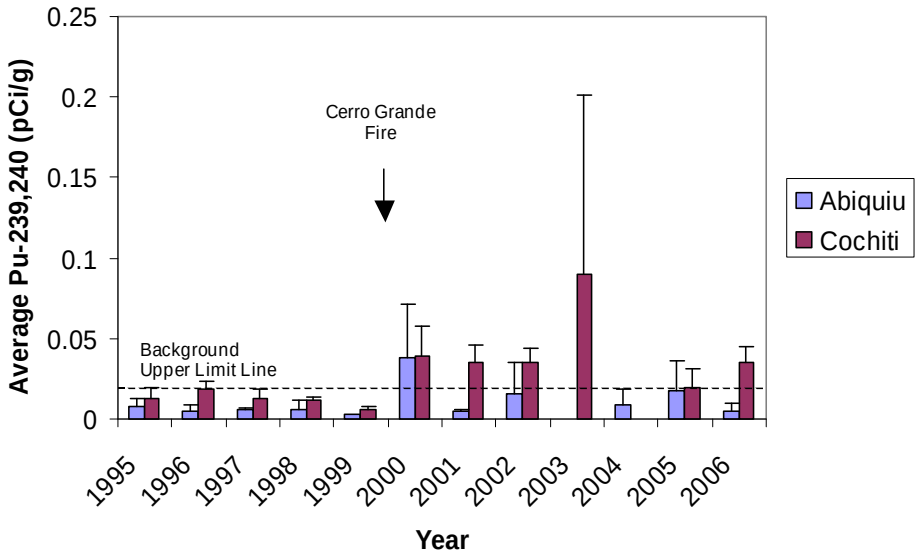


Figure 6-15. Plutonium-239,240 concentration (mean ±1 standard deviation) trends in Abiquiu and Cochiti Reservoir bottom sediment, 1995-2006.

G. CANYON-SPECIFIC CONTAMINATION

1. Guaje Canyon (includes Rendija and Barrancas Canyons)

Guaje Canyon is a major tributary in the Los Alamos Canyon watershed that heads in the Sierra de los Valles and lies north of Laboratory land. The canyon has not received any effluents from LANL activities. Concentrations of metals, organic chemicals, and radionuclides in Guaje Canyon storm water were below NM and DOE standards. Active channel sediment contained background ranges of metals and radionuclides (LANL 1998).

2. Los Alamos Canyon (includes Bayo, Acid, Pueblo, and DP Canyon)

Los Alamos Canyon has a large drainage that heads in the Sierra de los Valles. The Laboratory has used the land in the Los Alamos Canyon watershed continuously since the mid-1940s, with operations conducted at some time in all of the sub-drainages. Each of the canyons draining the watershed also receives urban runoff from the Los Alamos town site, and lower Pueblo Canyon receives treated sanitary municipal wastewater.

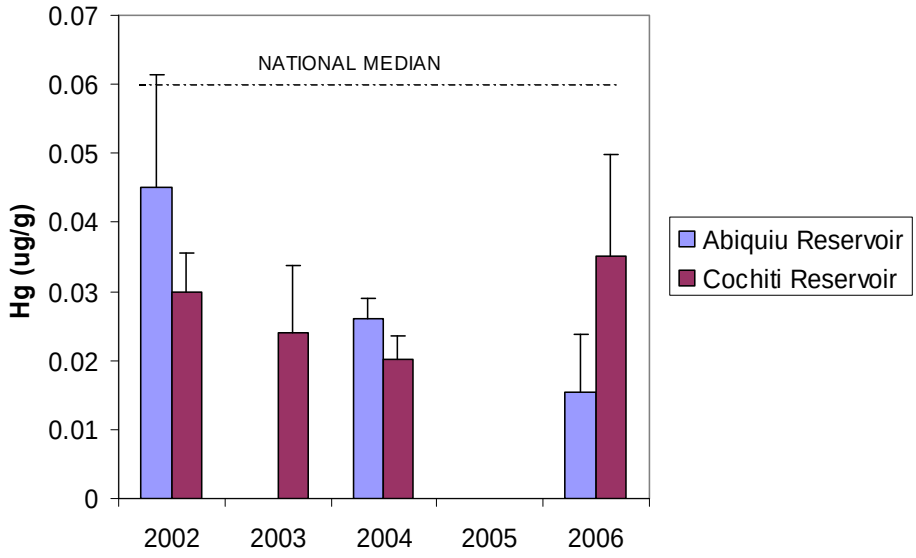


Figure 6-16. **Median mercury concentration (± IQR) trends in Abiquiu and Cochiti Reservoirs bottom sediment, 2002 –2006. National median value is from the US Geological Survey (Gilliom et al. 1997).**

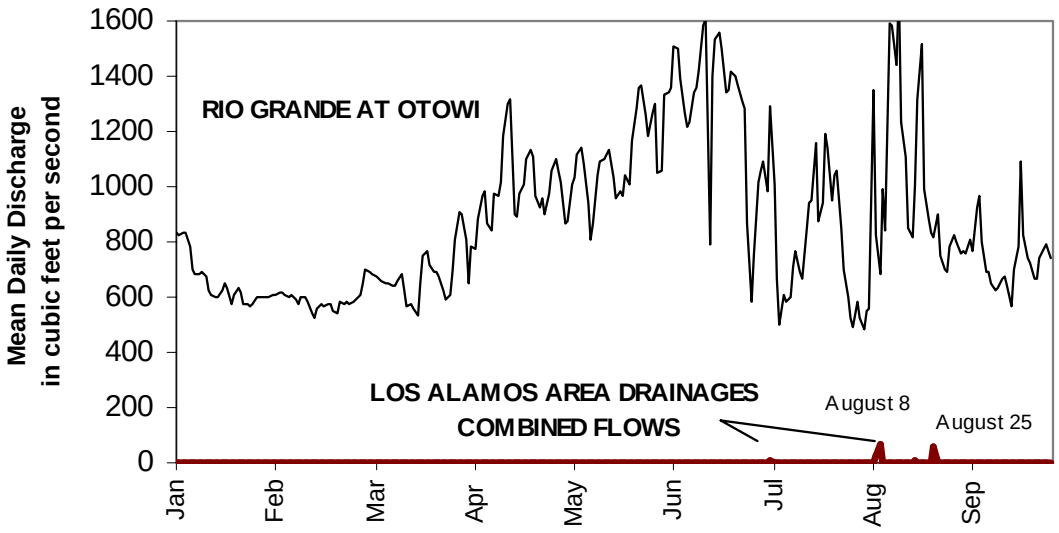


Figure 6-17. **Discharge from Los Alamos drainages in comparison to discharge at the Rio Grande at Otowi streamflow gaging station.**

Past release of radioactive liquid effluents into Pueblo (via tributary Acid Canyon), DP, and Los Alamos Canyons has introduced americium-241, cesium-137, plutonium-238, plutonium-239,240, strontium-90, and tritium, among other radionuclides, into the canyon. Many of these radionuclides bind to stream sediment and persist at levels several orders of magnitude above worldwide fallout levels. Elevated levels of radioactivity can be found in those canyons in both surface water and sediment. Plutonium has moved down Pueblo Canyon, through Los Alamos Canyon, off-site across Pueblo de San Ildefonso lands, and to the Rio Grande near the Otowi Bridge (Graf 1997; Reneau et al., 1998). Plutonium-239,240 from historic Acid Canyon discharges has been traced in stream sediment more than 55 km to lower Cochiti Reservoir (Gallaher and

Efurd 2002). Several contaminated sediment removal efforts have been conducted in Acid Canyon. In 2005, additional stabilization of sediment was performed in Pueblo Canyon to retard transport downstream. The installation of 3,000 linear feet of jute matting along channel banks that contained elevated radionuclide concentrations, and the planting of 3,000 willow plants to provide additional stream bank support, was completed in 2005 (PPWP 2005).

Most of the contaminant load in the Los Alamos Canyon drainage system is associated with sediment. None of the radionuclide, metal, or organic compound concentrations in sediment exceeded recreational or residential screening levels in 2006 samples. Nonetheless, concerns arise when the sediment is moved downstream and has the potential to enter the Rio Grande, depending on the runoff passing through the drainage. Because total runoff in 2005 and 2006 increased from previous years, downstream transport also increased. However, as noted earlier, no appreciable changes in contaminant concentrations have been detected in the Rio Grande sediment following these wet years.

Hillside sampling stations in middle Los Alamos canyon in 2006 contained elevated concentrations of radionuclides, mercury, and PCBs, consistent with past years. The highest concentrations were measured in storm runoff from channels below the Manhattan Project-era plutonium research buildings at TA-1 (station LA-SMA-2 and –4) and DP site at TA-21 (LA-SMA-6.3 and –6.5). Concentrations measured in the canyon floor were considerably lower than at these hillside sites. Still, mercury and PCBs were detected at concentrations above NM human health standards throughout the watershed and extending to the confluence with the Rio Grande near Otowi.

Because radionuclides, mercury, and PCBs are associated with sediment, rather than dissolved in the water column, the impact these individual hillside sites have on the watershed can be tracked by examining changes in the suspended contaminant concentrations. Figures 6-18 and 6-19 shows the plutonium-239,240

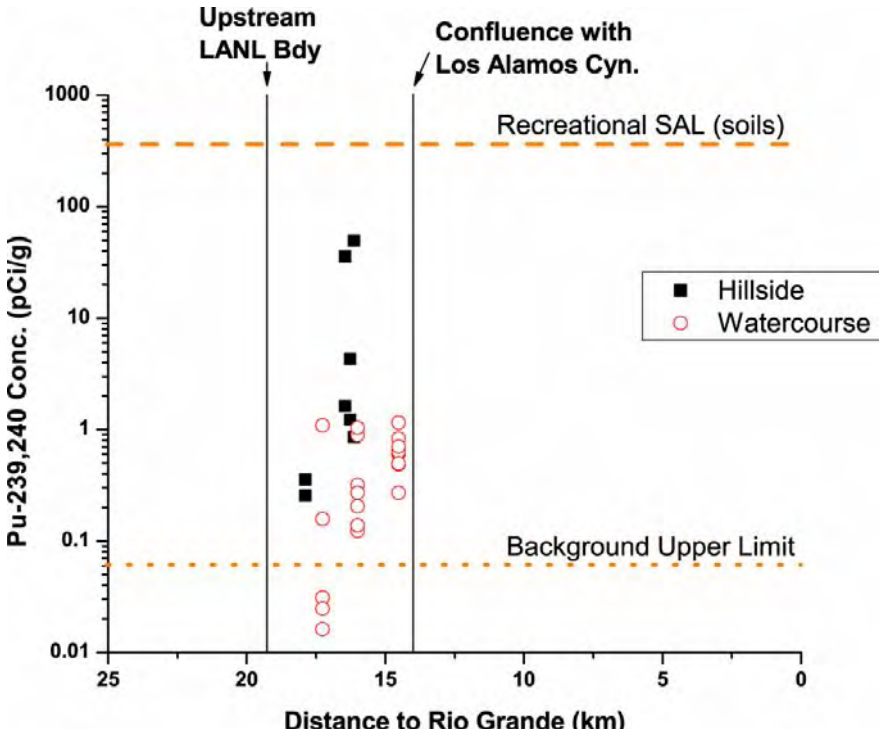


Figure 6-18. Plutonium-239,240 concentration spatial trends in DP Canyon suspended sediment, 2004–2005.

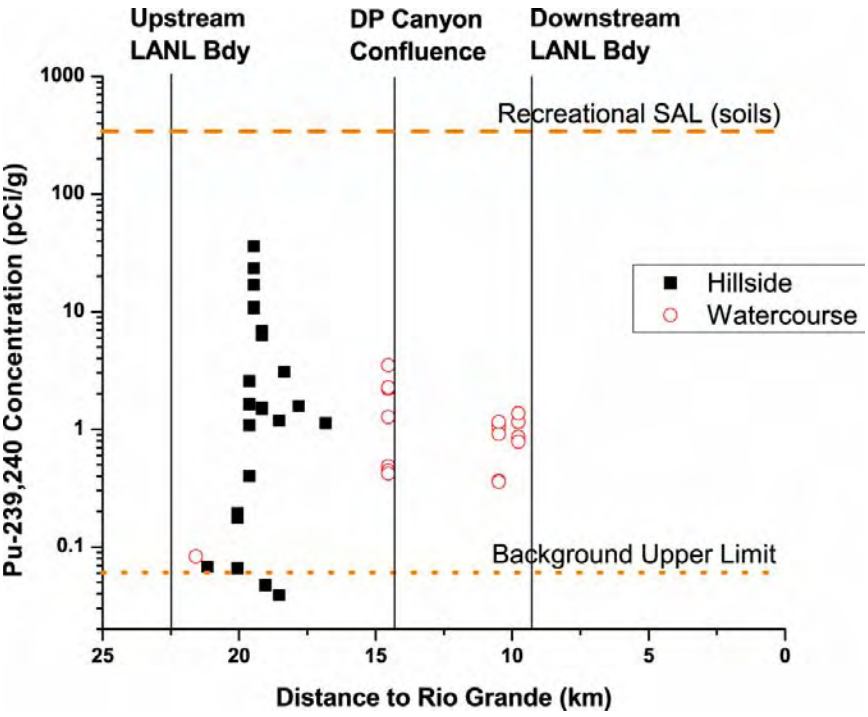


Figure 6-19. **Plutonium-239,240 concentration spatial trends in Los Alamos Canyon suspended sediment, 2004–2005.**

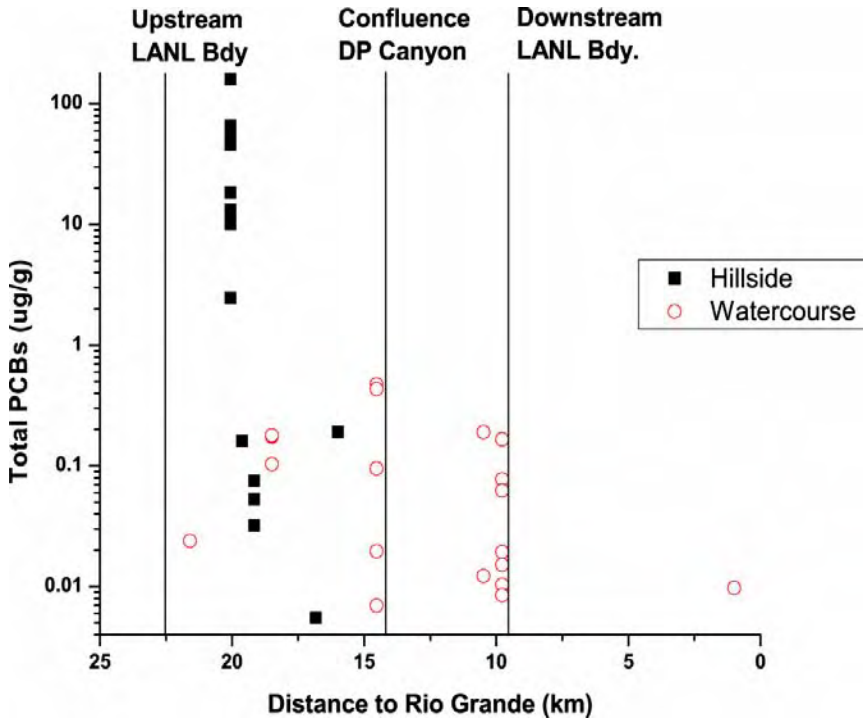


Figure 6-20. **Total PCBs concentration spatial trends in Los Alamos Canyon suspended sediment, 2004–2005.**

concentrations calculated in suspended sediment at various locations within DP and Los Alamos Canyons, respectively. Stations located below a specific suspected release site are labeled as "Hillside" stations. Stations located in the canyon bottom (stream gage sites) are labeled as "Watershed". The graphs show that plutonium-239,240 concentrations at the hillside sites have been measured at near 60 pCi/g. Concentrations in the canyon floor are above-background but substantially lower than at the hillside sites, averaging approximately 1 pCi/g. The plots indicate that there is relatively small variation in suspended plutonium concentrations in the canyon floors, compared to the contributing hillsides. A plot for total PCBs shows a similar pattern (Figure 6-20).

The dioxin 2,3,7,8-TCDD was detected in a base flow sample in lower Pueblo Canyon. As discussed in Chapter 5, this result is highly uncertain and additional research must be performed to establish any confidence in the detection. The reported concentration is indistinguishable from the typical analytical detection limit, and it was not detected in a separate sample collected on the same date in the immediate vicinity (Pueblo 3 vs Pueblo above State Road 502).

Since the Cerro Grande fire, there has been substantial reduction in the amount of sediment in middle Los Alamos Canyon carried beyond the Laboratory's eastern boundary. It is estimated that the low-head weir has captured more than half of the suspended sediment load since its installation in late 2000. The reduction in sediment transport has occurred through a reduction in stream flow velocity in the weir basin, and an associated settling of suspended sediment.

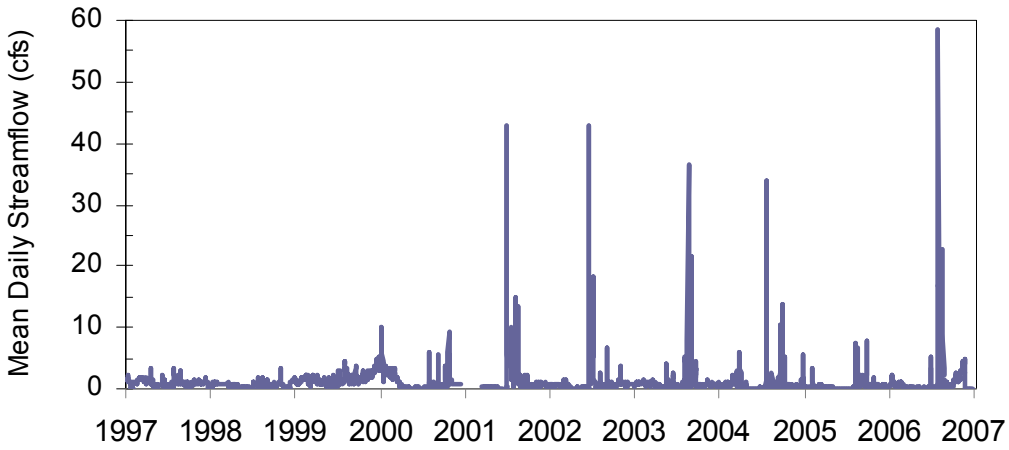


Figure 6-21. Mean daily discharge (cfs) at stream gage E060, lower Pueblo Canyon near State Road 502.

In contrast to middle Los Alamos Canyon, stream flow in Pueblo Canyon has recently become more dynamic and flashy (Figure 6-21). In the five years before the Cerro Grande fire, mean daily discharges rarely exceeded 4 cfs. Since 2000, daily discharges greater than 10 cfs occurred several times per year. There are multiple probable causes for the hydrologic changes in Pueblo Canyon:

- The lack of vegetation cover after the fire allowed for increased runoff from the hills above Los Alamos.
- Increased urban development in the upper portion of the canyon, with increased roof area and more efficient drainage systems. The increased pavement and roofs shed more local precipitation into the canyon.
- Re-engineering of a drainage culvert at the toe of the earthen bridge across upper Pueblo Canyon. Before the fire, stream flows from the upper portion of the canyon were highly restricted from passing into the lower canyon by the presence of a relatively small (18-inch) culvert at the base of the earthen

embankment. After the fire, the culvert was replaced with an 8-foot diameter culvert, and later enlarged to 12-feet. Flows from the upper canyon now readily pass to the lower canyon.

- The large, near-100 year rainfall events that hit the Los Alamos townsite area on July 2, 2001 and August 8, 2006.

Analysis of rainfall/runoff responses indicate that the hills draining into upper Pueblo Canyon recovered from the fire substantially by the end of 2004. Consequently, it is likely that the combination of increased urbanization and the larger culvert remain principal factors in the sustained alteration of Pueblo Canyon hydrology. When compared to other canyon systems on the Laboratory, Pueblo Canyon yields approximately 10 times the amount of runoff, per given drainage area and rainfall amount during the years 2003 through 2006 (Figure 6-22).

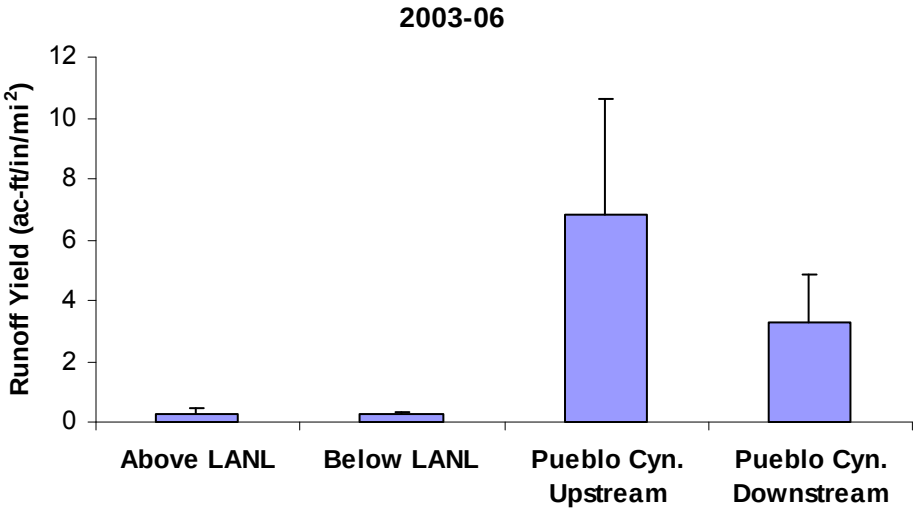


Figure 6-22. Average (±1 standard deviation) summer runoff yields for 2003 through 2006. The yields indicate how efficiently rainfall is shed from the landscape, after adjusting for the contributing drainage area and amount of local rainfall.

The importance of the alteration of Pueblo Canyon hydrology relates to the potential for downstream movement of legacy-contaminated sediment stored within the canyon floor. A few large runoff events can carry a substantial fraction of the entire sediment load for the year.

Long-term radionuclide trend plots for Pueblo and Los Alamos Canyons channel sediment are presented in Figures 6-23 through 26. Most stations show no appreciable change compared to previous years. An increase in plutonium-239,240 concentration was seen in lower Los Alamos Canyon (at Otowi) sediment near the confluence with the Rio Grande, to a level approximately 10 times greater than recently recorded measurements. However, the plutonium-239,240 concentration at the Otowi site is well below recreational or residential screening levels. Because the lower Los Alamos Canyon (Otowi) sample was collected August 14, it is likely that the increase reflects downstream transport of Pueblo Canyon sediment from the August 8 large runoff event. The impact of the August 8 runoff event on Pueblo Canyon sediment can not be described because sampling was conducted before the event. Thus the August 8 storm effects are not reflected in the long-term radionuclide plots for Pueblo Canyon.

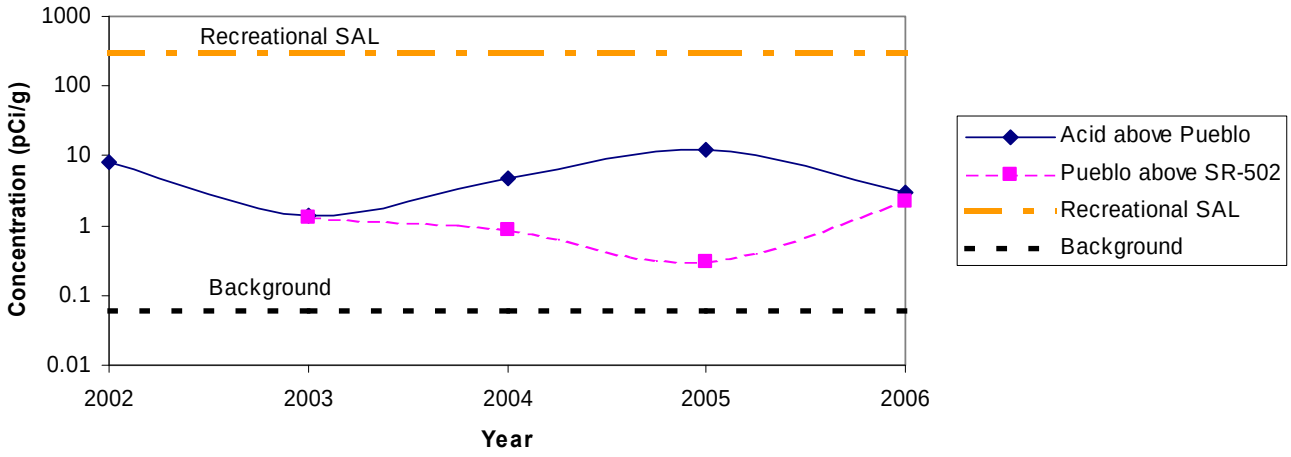


Figure 6-23. Long-term plutonium-239,240 trends in Pueblo Canyon sediment.

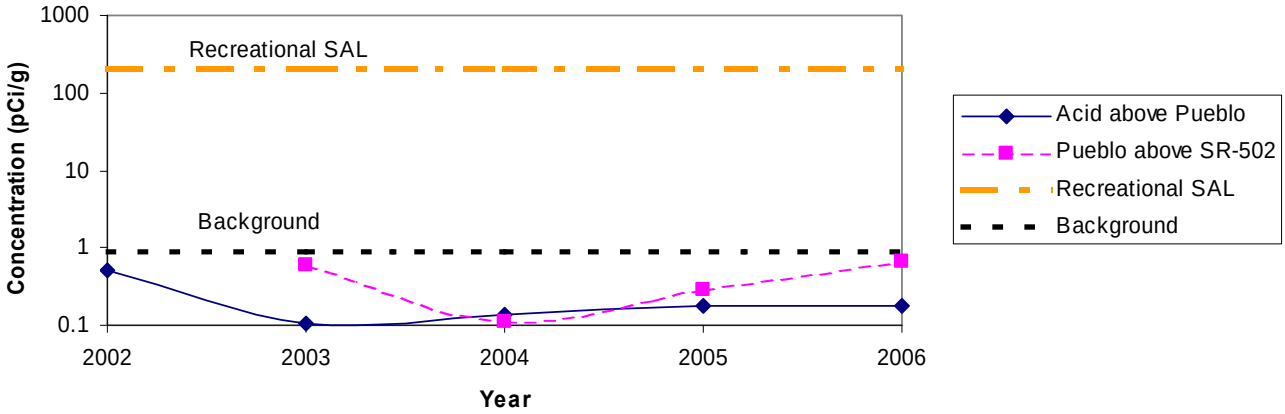


Figure 6-24. Long-term cesium-137 trends in Pueblo Canyon sediment.

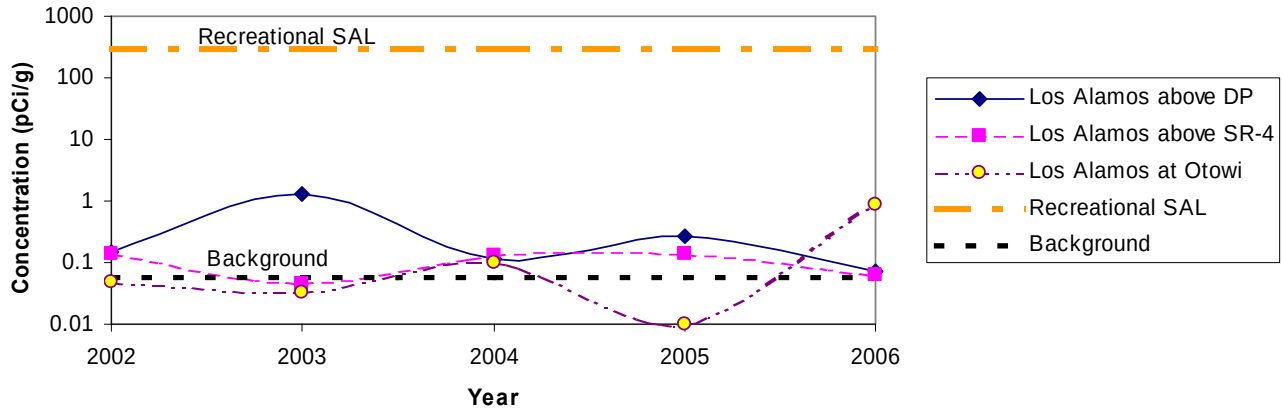


Figure 6-25. Long-term plutonium-239,240 trends in Los Alamos Canyon sediment.

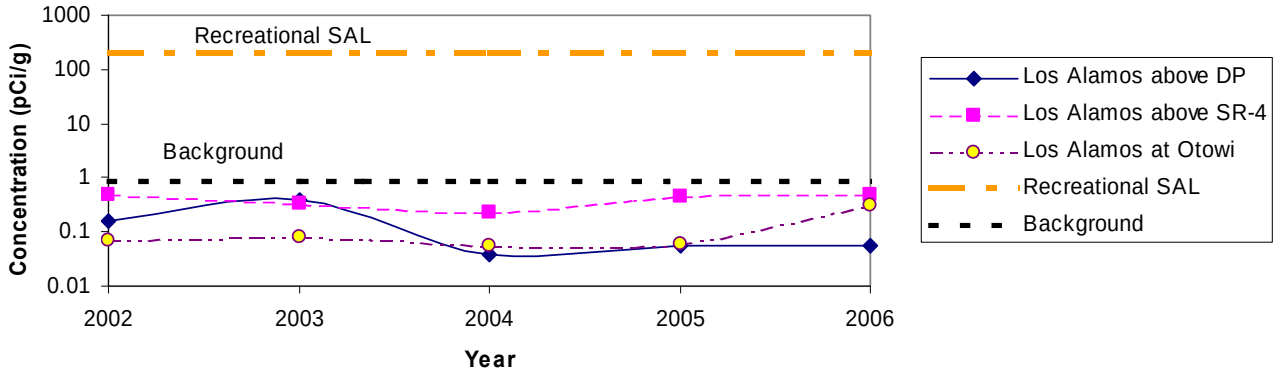


Figure 6-26. Long-term cesium-137 trends in Los Alamos Canyon sediment.

3. Sandia Canyon

Sandia Canyon heads on the Pajarito Plateau within the Laboratory's TA-3 area and has a total drainage area of about 5.5 mi^2. This relatively small drainage extends eastward across the central part of the Laboratory and crosses Pueblo de San Ildefonso land before joining the Rio Grande. Effluent discharges primarily from power plant blowdown create perennial flow conditions along a 2-mile reach below TA-3. Only two days of runoff was recorded at the Laboratory boundary in 2006 (Romero et al., 2007). Monitoring results have consistently shown minimal off-site contamination from the Laboratory in Sandia Canyon.

PCBs were detected throughout the watershed from near the Laboratory's main technical area at TA-3 to the LANL downstream boundary at SR-4. Unlike the Los Alamos Canyon watershed, however, there is minimal off-site stream flow in Sandia Canyon. While most detection were in storm water samples, three base flow samples collected near the Sandia Canyon wetlands also detected PCBs. Surface water samples near the wetlands contain the highest PCB concentrations in suspended sediment (Figure 6-27), and appear to be higher than at the site-specific hillside monitoring stations in Sandia Canyon. The human health standard is intended to protect people from ingesting contamination through fish consumption, but there are no fish in Sandia Canyon. Further, flows from the canyon have little probability of reaching the Rio Grande. In addition to PCBs at watercourse sampling stations, PCBs were reported at two site-specific monitoring stations in upper Sandia Canyon, particularly at station S-SMA-6.

Sediment samples collected in the upper portion of Sandia Canyon contained PCB concentrations at 1% the recreational soil screening level. Downstream sediment concentrations of PCBs decline quickly and usually are not detected at the downstream boundary.

Above-background concentrations of chromium, copper, lead, mercury, silver, and zinc in surface water and sediment are found along an approximately two-mile segment of Sandia Canyon below TA-3. Storm water runoff occasionally contains concentrations above regulatory standards. Unlike previous years, results in 2006 found none of these metals above NM water quality standards in storm water.

4. Mortandad Canyon (includes Ten Site Canyon and Cañada del Buey)

Mortandad Canyon heads on the Pajarito Plateau near the main Laboratory complex at TA-3. The canyon crosses Pueblo de San Ildefonso land before joining the Rio Grande.

The annual time-weighted average concentrations of americium-241, plutonium-238, and plutonim-239,240 are well below the BCGs in unfiltered surface water collected below Effluent Canyon (Table 6-2). When the

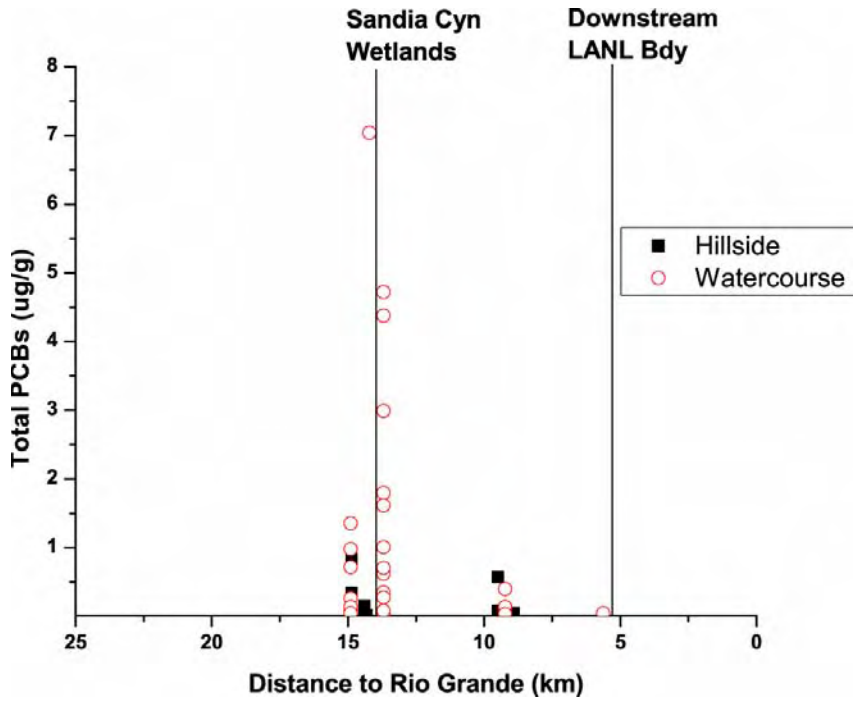


Figure 6-27. Spatial trends of PCB concentrations in Sandia Canyon suspended sediment.

mixture of radionuclides is considered (see discussion in D.4), the surface water in Mortandad Canyon below Effluent Canyon was at 15% of the BCGs.

Radioactivity concentrations in sediment just below the RLWTF have not changed appreciably in the past decade. Concentrations in Mortandad Canyon at the LANL boundary are less than DOE's allowable discharge limits and within background levels (LANL 1998).

Stream sediment in Mortandad Canyon downstream of Effluent Canyon as far as the sediment traps, and downstream to near well MCO-8.5, contains above background concentrations of plutonium-238, plutonium-239,240, and cesium-137 (Figures 6-28 and 6-29). Cesium-137 concentrations in active channel sediment upstream of the sediment traps were 5% of the recreational SAL (LANL 2005) (Figure 6-29), and gradually trending downward over time. The sediment traps are located approximately two miles upstream of the Laboratory's eastern boundary. Despite the history of releases into the Mortandad Canyon watershed, radioactivity in sediment at the Laboratory's eastern boundary for the past two years was within background levels. Americium-241, cesium-137, and plutonium-239,240 concentrations in sediment at the boundary are orders of magnitude lower than at upstream stations closer to the RLWTF discharge. The rarity of stream flow within Mortandad Canyon for two miles upstream of the Laboratory boundary is the main reason for the lower sediment radioactivity in downstream sediment.

In 2006, approximately 50 surface water samples were collected from watercourse and hillside sites and analyzed for PCBs within Mortandad Canyon and its tributaries: Cañada del Buey, Ten Site Canyon, and Pratt Canyon. Only two samples contained detected concentrations of PCBs, both in middle Mortandad Canyon. These results indicate that PCB concentrations in the drainage are relatively small but are occasionally detected.

The dioxin 2,3,7,8-TCDD was detected in two base flow samples in Mortandad Canyon. As discussed with regard to Pueblo Canyon, these results are highly uncertain and additional investigation is needed to establish confidence in the detections.

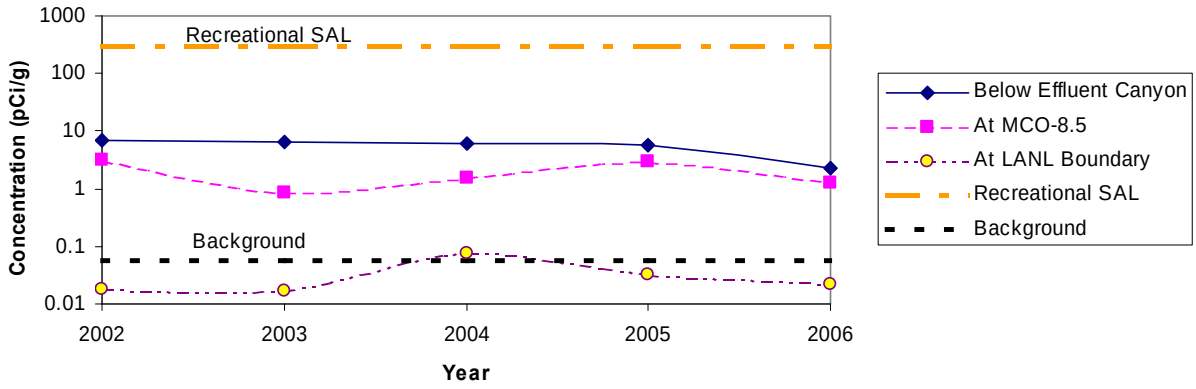


Figure 6-28. Long-term plutonium-239,240 trends in Mortandad Canyon sediment.

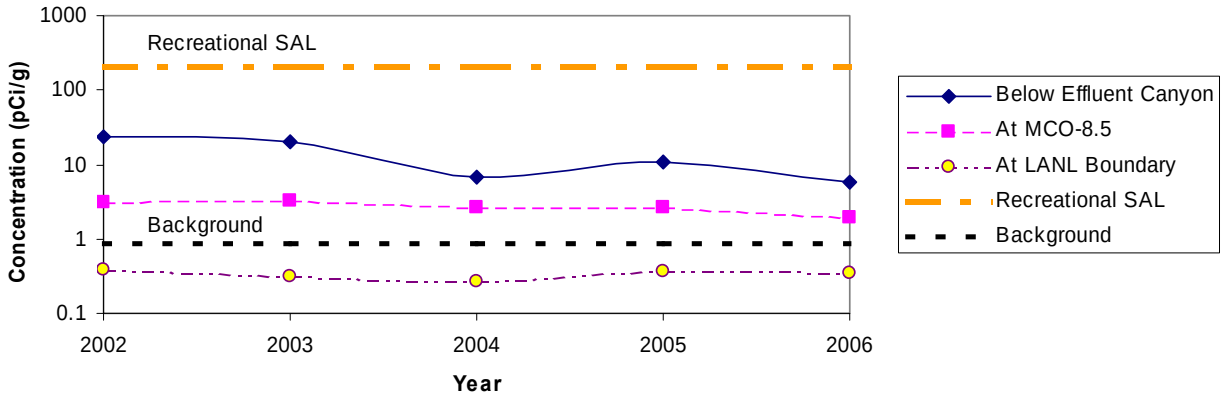


Figure 6-29. Long-term cesium-137 trends in Mortandad Canyon sediment.

Radioactivity in sediment around MDA G and in Cañada del Buey was generally consistent in 2006 with previous years. All results are well below the recreational and residential SALs. No significant trends are evident.

5. Pajarito Canyon (includes Twomile and Threemile Canyons)

Pajarito Canyon heads on the flanks of the Sierra de los Valles on US Forest Service lands. The canyon crosses the central part of the Laboratory before entering Los Alamos County lands near White Rock.

Consistent with past years, americium-241, plutonium-238, and plutonium-239,240 concentrations were greater than background in sediment samples from channels draining MDA G. Concentrations of these radionuclides were commonly 5 to 10 times background. All of the radionuclides were at concentrations below recreational and residential SALs.

Concentrations of copper and zinc greater than standards were detected at the Twomile tributary at TA-3 station. That station monitors drainage from a large paved area and the Laboratory's main machine shop. These results are consistent with previous years.

In Three Mile Canyon, elevated concentrations of uranium-238 were detected in three samples collected below a high explosive firing site (station 3M-SMA-0.6) (Figure 6-5). The samples indicate the presence of depleted uranium, as activity ratios of uranium-238 to uranium-234 were not unity.

In 2006, no PCBs were detected in 18 storm runoff samples from stations along the Pajarito Canyon edge of MDA G.

6. Water Canyon (includes Cañon de Valle, Potrillo, Fence, and Indio Canyons)

Water Canyon heads on the flanks of the Sierra de los Valles on US Forest Service land and extends across the Laboratory to the Rio Grande. Water Canyon and its tributary Cañon de Valle pass through the southern portion of the Laboratory where explosives development and testing take place. Elevated concentrations of barium, HMX, and RDX have previously been measured in sediment and surface water. RDX is principally detected only within Cañon de Valle. As shown in Figure 6-30, RDX is rarely detected below the confluence with Water Canyon; since 2004, only 1 of 18 storm runoff samples from Water Canyon contained detectable levels of RDX. This area is being investigated under a RCRA corrective measures evaluation.

Area AB at TA-49 was the site of underground nuclear-weapons testing from 1959 to 1961 (Purtymun and Stoker 1987; ESP 1988). These tests involved HEs and fissionable material insufficient to produce a nuclear reaction. Area AB drains into Ancho and Water Canyons. Legacy surface contamination is responsible for above-background fallout concentrations of plutonium-238 and –239,240 and americium-241 present in the sediment downstream of this site. No above-background plutonium-238 or –239,240 concentrations extend more than about 100 yards beyond Area AB.

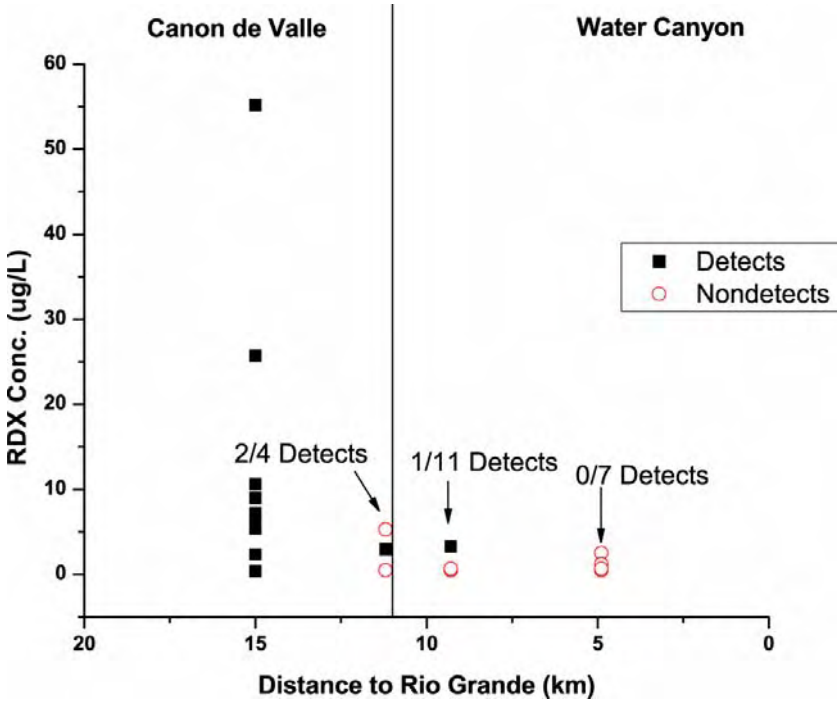


Figure 6-30. RDX spatial trends in Cañon de Valle and Water Canyon surface water, 2004-2006. Data from watercourse stations only.

H. QUALITY ASSURANCE

To process watershed samples, we used the same quality assurance (QA) protocols and analytical laboratories described in Chapter 5. QA performance for the year is also described in Chapter 5.

I. REFERENCES

DOE 1990: "Radiation protection of the public and the environment," US Department of Energy Order 5400.5, Washington D.C.

DOE 1991: "Environmental regulatory guide for radiological effluent monitoring and environmental surveillance," DOE/EH-0173 (January 1991).

DOE 2002: "A graded approach for evaluating radiation dose to aquatic and terrestrial biota," DOE-STD-1153-2002.

DOE 2003: "Strategy for evaluation of surface water quality relative to DOE Order 5400.5," Department of Energy memorandum from Rex J. Borders, Albuquerque Operations Office, to G. Turner, Los Alamos Site Office, January 9, 2003.

EPA 2005a: United States Environmental Protection Agency Region 6, In the Matter of United States Department of Energy and the Los Alamos National Laboratory, NPDES Nos. NMR05A735, NMR05A734, and NM0028355, Federal Facility Compliance Agreement, Docket No.CWA-06-2005-1701. (February 2005) http://www.epa.gov/region6/6xa/lanl.pdf

EPA 2005b: United States Environmental Protection Agency Region 6, In the Matter of University of California, Permittee, NPDES No. NMR05A734, Administrative Order, Docket No.CWA-06-2005-1734. (March 2005)

EPA 2007: US Environmental Protection Agency Region 6, "EPA Region 6 Human Health Medium-Specific Screening Levels" (May 2007), http://www.epa.gov/arkansas/6pd/rcra_c/pd-n/screen.htm

Gallaher and Efurd 2002: B. M. Gallaher and D. W. Efurd, "Plutonium and uranium from Los Alamos National Laboratory in sediments of the Northern Rio Grande Valley," Los Alamos National Laboratory report LA-13974 (August 2002).

Gallaher and Koch 2004: B. M. Gallaher and R. J. Koch, "Cerro Grande fire impacts to water quality and stream flow near Los Alamos National Laboratory: results of four years of monitoring," Los Alamos National Laboratory report LA-14177.

Gilliom et al. 1997: R.J. Gilliom, D.K. Mueller, and L.H. Nowell, "Methods for Comparing Water-Quality Conditions Among Water-Quality Study Units, 1992-1995," U.S. Geological Survey Open-File Report 97-589.

Graf 1997: W. L. Graf, Plutonium and the Rio Grande: Environmental Change and Contamination in the Nuclear Age (Oxford University Press, New York, 1997).

Hem, J.D. 1986: "Study and Interpretation of the Chemical Characteristics of Natural Water," U.S. Geological Survey Water-Supply Paper 2254.

Langmuir 1997: D. Langmuir, "Aqueous Environmental Geochemistry," Prentice Hall, Inc., ISBN 0-02-367412-1.

LANL 1998: "Inorganic and radionuclide background data for soils, canyon sediments, and Bandelier Tuff at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-98-4847 (September 1998).

LANL 2004: "Los Alamos and Pueblo Canyon investigation report," Los Alamos National Laboratory document LA-UR-04-2714 (April 2004).

LANL 2005: "Derivation and Use of Radionuclide Screening Action Levels, Revision 1," Los Alamos National Laboratory report LA-UR-05-1849 (May 2005).

LANL 2006: "Los Alamos National Laboratory Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan," Los Alamos National Laboratory report LA-UR-06-1840.

LANL 2007: "Technical Approach for Calculating Recreational Soil Screening Levels for Chemicals," Los Alamos National Laboratory report LA-UR-06-8826 (January 2007).

McNaughton 2005: "Biota dose assessment at LANL," Los Alamos National Laboratory document LA-UR-05-4699.

McLin 2004: McLin, S.G., "Background Radioactivity in Sediments near Los Alamos, New Mexico," Science of the Total Environment 328:143-159.

NMED 2003a: "Approved 2002–2004 State of New Mexico §303(d) list for assessed river/stream reaches requiring total maximum daily loads (TMDLs)," New Mexico Environment Department Surface Water Quality Bureau (June 2003).

NMWQCC 2002: New Mexico Water Quality Control Commission, "Ground and surface water protection," 20.6.2 NMAC (September 15, 2002).

NMED 2006a: State of New Mexico, "State of New Mexico Procedures for Assessing Standards Attainment for Section §303(d)/§305(b) Water Quality Monitoring and Assessment Report: Assessment Protocol." (January 2006) http://www.nmenv.state.nm.us/swqb/protocols/AssessmentProtocol.pdf, accessed July 19, 2006.

NMED 2006b: "Technical Background Document for Development of Soil Screening Levels, Revision 6.0," June 2006. ftp://ftp.nmenv.state.nm.us/hwbdocs/HWB/guidance_docs/NMED_June_2006_SSG.pdf

NMWQCC 2004: New Mexico Water Quality Control Commission, "2004-2006 State of New Mexico Integrated Clean Water Act 303(d)/305(b) Report" (2004).
http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/index.html

NMWQCC 2005: New Mexico Water Quality Control Commission, "State of New Mexico standards for interstate and intrastate surface waters," 20.6.4 NMAC (as amended through July 17, 2005).
http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf

NOAA 2006: "Precipitation-Frequency Atlas of the United States," NOAA Atlas 14, Volume 1, Version 4, National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, Maryland.

PPWP 2005: Pajarito Plateau Watershed Partnership/Los Alamos County 319 Grant Quarterly Report, April to June, 2005.

Purtymun and Stoker 1987: W. D. Purtymun and A. K. Stoker, "Environmental status of Technical Area 49, Los Alamos, New Mexico," Los Alamos National Laboratory report LA-11135-MS (November 1987).

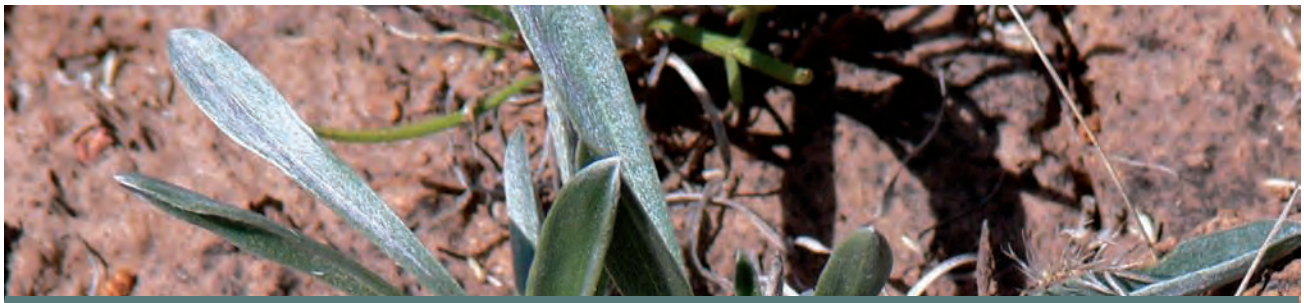
Reneau et al. 1998: S. Reneau, R. Ryti, M. Tardiff, and J. Linn, "Evaluation of sediment contamination in Pueblo Canyon," Los Alamos National Laboratory document LA-UR-98-3324 (September 1998).

Reneau et al. 2007: S. Reneau, D. Katzman, G. Kuyumjian, A. Lavine, D. Malmon, "Sediment delivery after a fire," *Geology*, February 2007; v. 35; no. 2; p. 151-154.

Romero et al. 2007: Romero, R.P., D. Ortiz, and M.R. Alexander, "Surface Water Data at Los Alamos National Laboratory: 2006 Water Year," Los Alamos National Laboratory Progress Report LA-14328-PR (August 2007).

Watkins and Del Signore 2005: "RLWTF annual report for 2004," Los Alamos National Laboratory document LA-UR-05-4395.

Wilson and Van Metre 2000: J.T. Wilson and P.C. Van Metre, "Deposition and Chemistry of Bottom Sediments in Cochiti Lake, North-Central New Mexico," U.S. Geological Survey Water-Resources Investigations Report 99-4258.



7. Soil Monitoring

7. Soil Monitoring

contributing author:
Philip Fresquez

To Read About **Turn to Page**

Introduction *233*
Soil Comparison Levels *234*
Institutional Monitoring *235*
Facility Monitoring *239*
Special Monitoring Studies *244*
Quality Assurance for the Soil, Foodstuffs, and Nonfoodstuffs Biota Monitoring Program *245*
References *247*

A. INTRODUCTION

A soil sampling and analysis program offers the most direct means of determining the concentration, distribution, and long-term trends of radionuclides and other chemicals around nuclear facilities (DOE 1991). The soil characterization program provides information about potential pathways (e.g., soil ingestion, food ingestion, re-suspension into the air, and groundwater contamination) that may deliver radioactive materials or chemicals to humans.

The overall soil surveillance program at Los Alamos National Laboratory (LANL or the Laboratory) consists of

(1) An institutional component that monitors soil within and around the perimeter of LANL in accordance with US Department of Energy (DOE) Orders 450.1 (DOE 2003) and 5400.5 (DOE 1993); and

(2) A facility component that monitors soil (and sediment) within and around the perimeter of the Laboratory's

- Principal radioactive waste disposal area (Area G) in accordance with DOE Orders 435.1 (DOE 1999a) and M 435.1-1 (DOE 1999b), and
- Principal explosive test facility (Dual Axis Radiographic Hydrodynamic Test [DARHT]) in accordance with the Mitigation Action Plan (DOE 1996).

The objectives of LANL's soil surveillance program are to determine the following:

(1) Radionuclide and nonradionuclide (inorganic and organic chemicals) concentrations in soil collected from potentially impacted areas (Laboratory-wide and facility-specific);

(2) Trends over time (i.e., whether radionuclide and nonradionuclide concentrations are increasing or decreasing over time); and

(3) The committed effective dose equivalent potentially received by surrounding area residents (see Chapter 3 for the potential radiation doses that individuals may receive from exposure to soil).

B. SOIL COMPARISON LEVELS

To evaluate Laboratory impacts from radionuclides and nonradionuclides, we first compare the analytical results of soil samples collected from the Laboratory's on-site and perimeter areas with regional background levels (RSRLs). Where the results exceed these background levels, we then compare the concentrations with the screening levels (SLs) and, finally, if needed, with the appropriate standard. A description of the levels and/or the standard used to evaluate the results of radionuclides and nonradionuclides in soil are as follows, and an overall summary can be found in Table 7-1.

- Regional Statistical Reference Levels: RSRLs are the upper-level background concentration (mean plus three standard deviations = 99% confidence level) for radionuclides and nonradionuclides calculated from soil data collected from regional locations away from the influence of the Laboratory over at least the last five sampling periods. RSRLs, which represent natural and fallout sources, are calculated as data becomes available and can be found in the supplemental data tables of this report.
- Screening Levels: SLs for radionuclides are set below the DOE single-pathway dose limit of 25 mrem/yr so that potential concerns may be identified in advance of major problems, i.e., a "yellow flag." If a radionuclide exceeds the SL, then we investigate the reason. LANL's Environment and Remediation Support Services Division developed SLs to identify chemicals of potential concern on the basis of a 15-mrem/yr protective dose limit for a residential scenario (LANL 2005) using the residual radioactive (RESRAD) computer model (Yu et al. 1995). We compared nonradionuclides to the New Mexico Environment Department (NMED) soil screening levels that are set at a 10^{-5} risk level for carcinogens or a hazard quotient (HQ) of 1 for non-carcinogens (NMED 2006). The SLs for a residential scenario were used for soil collected from perimeter areas and SLs for an occupational scenario were used for soil collected from Laboratory areas.
- Standard: If an SL for a radionuclide is exceeded, then a dose to a person is calculated using RESRAD and all of the measured radionuclide concentrations available from supplemental data Table S7-1. The calculated dose is based on a residential scenario with soil ingestion, inhalation of suspended dust, external irradiation, and ingestion of homegrown fruits and vegetables as the exposure pathways. Unit conversions, input parameters, model and parameter assumptions, and the uncertainty analysis we used can be found in Fresquez et al. 1996. This calculated dose is compared to the 25-mrem/yr DOE dose constraint (DOE 1993; DOE 1999c).

Table 7-1
Application of Soil Standards and Other Reference Levels to LANL Monitoring Data

Constituent	Sample Location	Standard	Screening Level	Background Level
Radionuclides	Perimeter, On-site, Area G, and DARHT	25 mrem	15 mrem (residential)	RSRL/BSRL[a]
Nonradionuclides	Perimeter		10^{-5} risk (residential) or HQ = 1	RSRL
	DARHT, On-site, Area G		10^{-5} risk (occupational) or HQ = 1	RSRL/BSRL[a]

[a] Baseline Statistical Reference Levels (BSRL) and a discussion of these levels can be found in Section D.3.

C. INSTITUTIONAL MONITORING

1. Monitoring Network

Surface soil samples are collected from 17 on-site, 11 perimeter, and six regional (background) locations on a triennial basis (every third year) (Figure 7-1). Areas sampled at LANL are not from contaminated areas referred to as solid waste management units (SWMUs) or areas of concern (AOCs). Instead, the majority of on-site soil sampling stations are located on mesa tops close to and, if possible, downwind from major facilities or operations at LANL in an effort to assess soil that may have been contaminated from stack emissions and fugitive dust (the re-suspension of dust from SWMUs/AOCs and active firing sites).

Samples were collected from Technical Area (TA)-16 (S-Site), TA-21 (DP-Site), near TA-33, north of TA-50/35 at TA-60, TA-51, west of TA-53, east of TA-53, east of TA-54, Potrillo Drive at TA-36, near Test Well DT-9 at TA-49, R Site Road east at TA-15, and Two-Mile Mesa at TA-06. This year we collected five additional soil samples from along the south side of State Road (SR) 502 within the TA-73 boundary—these points are downwind of TA-21 (the former plutonium processing facility) and associated SWMUs/AOCs including Material Disposal Areas (MDAs) A, B, and T.

The 11 perimeter stations, located within 2.5 mi of the Laboratory, were sampled to determine the soil conditions of the inhabited areas to the north (North Mesa, Sportsman's Club, Quemazon Trail, west airport, and east airport) and east of the Laboratory (White Rock, San Ildefonso, Otowi, and Tsankawi/PM-1). Additional samples were collected west of US Forest Service property (across from TA-8) and south on Bandelier National Monument property (near TA-49) to provide comprehensive coverage.

Soil samples from on-site and perimeter stations are compared with soil samples collected from regional locations in northern New Mexico that surround the Laboratory in all major directions and where radionuclides, metals, and organic chemicals are mostly from natural sources or worldwide fallout events. These areas are located near Ojo Sarco, Dixon, Borrego Mesa (near Santa Cruz dam) to the northeast; Rowe Mesa (near Pecos) to the southeast; Youngsville to the northwest; and Jemez to the southwest. All locations are at similar elevations to LANL, are more than 20 mi away from the Laboratory, and are beyond the range of potential influence from normal Laboratory operations as required by the DOE (DOE 1991).

At all sites, soil surface samples were collected with a stainless steel soil ring 4 in. in diameter pushed 2 in. deep at the center and corners of a 33 ft x 33 ft square area. The five samples per site were combined and mixed thoroughly in a large Ziploc® bag to form a composite sample. Composite samples were placed in pre-labeled 500 mL polyethylene bottles, fitted with chain-of-custody tape, and placed into individual Ziploc® bags. All samples were handled and shipped under full chain-of-custody procedures to Paragon Analytics Inc., for analysis. Samples were analyzed for tritium, plutonium-238, plutonium-239,240, strontium-90, americium-241, cesium-137, uranium-234, uranium-235, and uranium-238. The soil samples were also analyzed for 23 target analyte list (TAL) inorganic chemicals, polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), and high explosives (HE). The results from these sample analyses are presented in supplemental Tables S7-1 to Table S7-3. (Note: We report on the analyses of vegetation collected from these same sites in Chapter 8, Section B.3.)

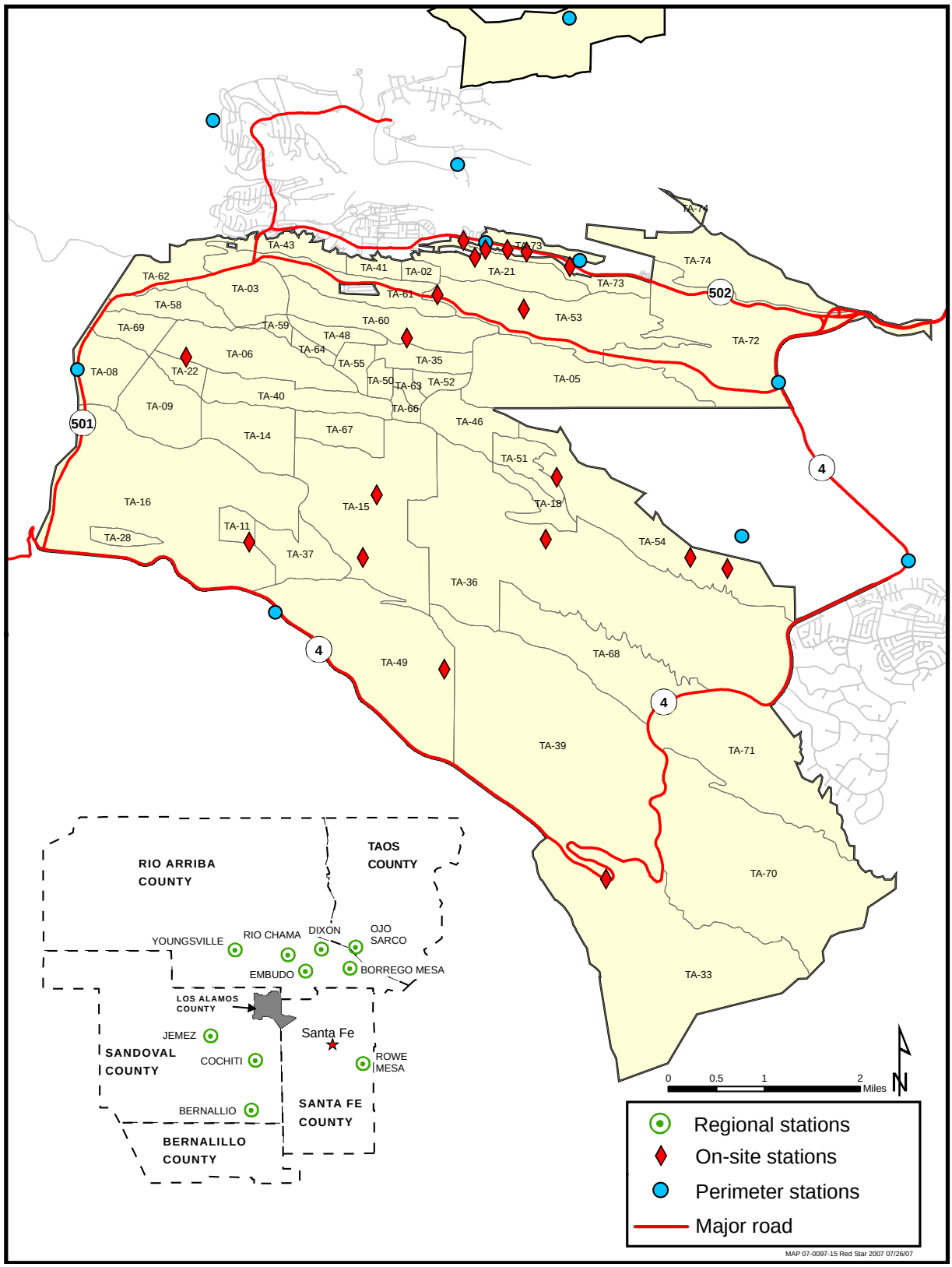


Figure 7-1. On-site Laboratory, perimeter, and off-site regional soil sampling locations.

2. Radionuclide Analytical Results

All of the radionuclide (activity) concentrations in soil collected from on-site and perimeter areas in 2006 were low (pCi range), and most were either not detected or below RSRLs (Table S7-1). A nondetected value is one in which the result is lower than three times the counting uncertainty and is not significantly ($\alpha = 0.01$, or 99% confidence level) different from zero (Keith 1991, Corely et al. 1981).

The few detected radionuclides above RSRLs in soil collected from perimeter areas included cesium-137 and plutonium-239,240 at the TA-8 location (GT Site), plutonium-239,240 at the west airport location, and uranium-234 and -238 at the Tsankawi/PM-1 location. All of the radionuclide concentrations in these samples were slightly above the RSRLs and were below residential SLs and do not pose a potential unacceptable dose to the public. The uranium in soil at the Tsankawi/PM-1 location was naturally occurring as the distribution of uranium-234 and uranium-238 were at equilibrium.

With respect to the detected radionuclides in soil collected from the on-site areas, there were two general locations within the Laboratory that contained amounts of plutonium-239,240 and americium-241 above RSRLs. One of these areas, based on the locations sampled at TA-21 (DP-Site) and along SR 502 at TA-73, included the northern part of the Laboratory downwind of the former plutonium processing facility (and/or its associated SWMUs/AOCs) at TA-21. Although the concentrations of plutonium-239,240 and americium-241 in soil from these areas were above RSRLs, they were still within the range of concentrations reported in previous years, are not increasing over time (Figures 7-2 and 7-3) (Fresquez et al. 1998), and are far below residential SLs. Thus, the levels of plutonium and americium detected in soil samples, particularly along the Laboratory's northern perimeter, do not pose a potential unacceptable dose to the public.

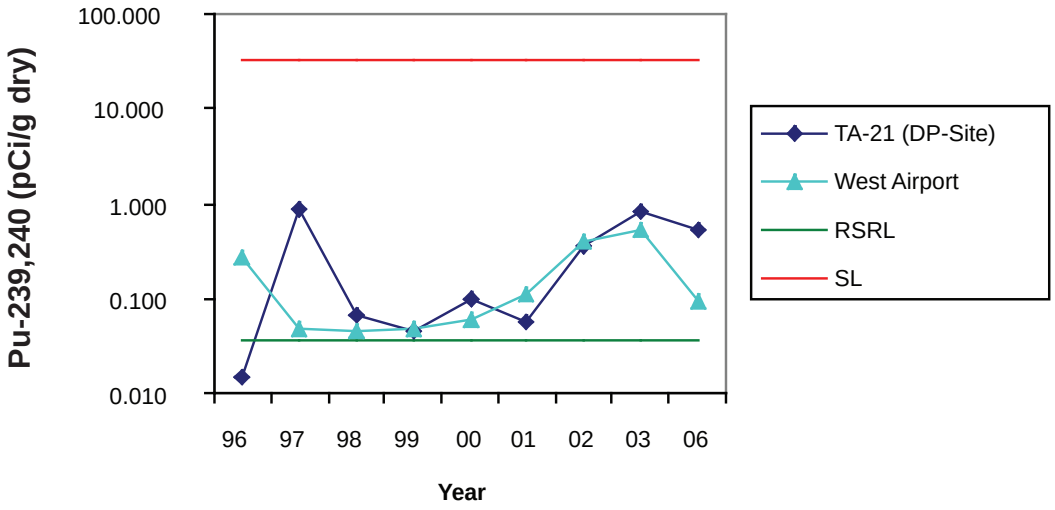


Figure 7-2. Plutonium-239,240 concentrations in soil samples collected from the west airport and TA-21 (DP-Site) stations from 1996 through 2006 as compared with the regional statistical reference level (RSRL) and the screening level (SL).

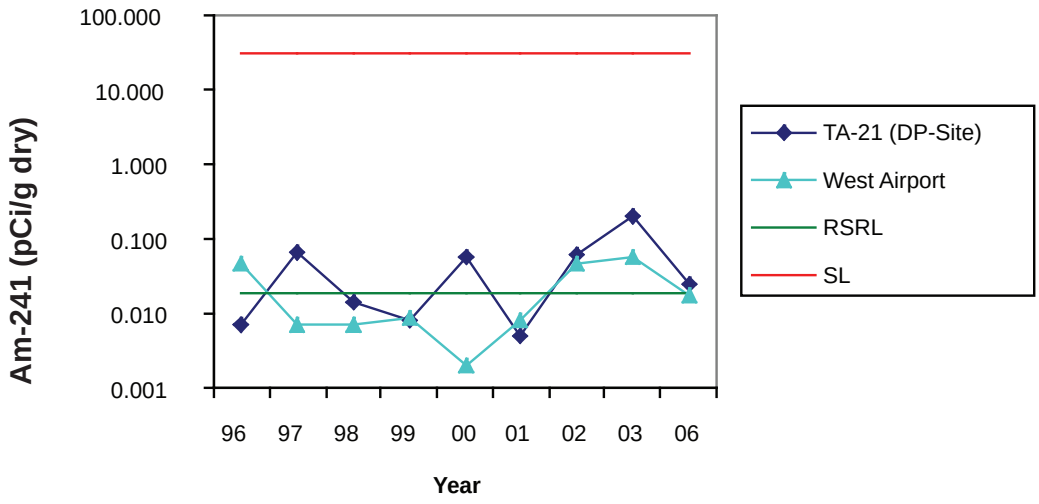


Figure 7-3. Americium-241 concentrations in soil samples collected from the west airport and TA-21 (DP-Site) stations from 1996 through 2006 as compared with the regional statistical reference level (RSRL) and the screening level (SL).

The other area with elevated plutonium-239,240 and americium-241 levels was located near the eastern side of the Laboratory downwind of Area G at TA-54. A more detailed description of the sampling of potential contaminants occurring around the perimeter of this site can be found in Section D.1 of this chapter.

3. Nonradionuclide Analytical Results: Trace and Abundant Elements

Supplemental data Table S7-2 shows the results of the inorganic chemical analyses in surface soil collected from perimeter, on-site, and regional background areas in 2006. Nearly all of the inorganic chemical concentrations from on-site and perimeter areas were below RSRLs. The few heavy metals above the RSRLs included mercury (0.046 mg/kg vs. RSRL of 0.039 mg/kg dry) at the Sportsman's Club location north of LANL and thallium (0.31 mg/kg dry vs. RSRL of 0.25 mg/kg dry) at the Two-Mile Mesa location at TA-06. The concentrations detected are slightly above the RSRLs and far below the appropriate SLs and do not pose a potential hazard to human health.

4. Nonradionuclide Analytical Results: PCBs, HE, and SVOCs

All PCBs, HE, and nearly all SVOCs in soil from perimeter and on-site locations were below detection limits (supplemental data Table S7-3). Only one site showed some detected SVOCs. This site, TA-73/SR 502 (west), is located on the south side of SR 502 and east of the Los Alamos Fire Department and an inspection of the site showed considerable amounts of asphalt scattered throughout the sampling area. Asphalt, a petroleum-based product, contains a host of polyaromatic hydrocarbons (PAHs), but the amounts detected were below the occupational SLs and do not pose a potential risk to human health.

D. FACILITY MONITORING

1. Monitoring Network for Area G at TA-54

The Laboratory conducts facility-specific soil monitoring on an annual basis at Area G (Lopez 2002). Area G is a 63-acre radioactive waste processing area located on the east end of Mesa del Buey at TA-54 (Figure 7-4). Area G was established in 1957 and is the Laboratory's primary radioactive solid waste burial and storage site (Hansen et al. 1980, Soholt 1990). Tritium, plutonium, americium, uranium, and a variety of fission and activation products are the main radionuclides in waste materials disposed of at Area G (DOE 1979). Monitoring at Area G includes the collection and analysis of air, sediment, surface water runoff, soil, vegetation, and small mammals for contaminants. Section D.2, below, reports on the 21 soil surface samples collected in 2006 at designated locations around the perimeter of Area G at TA-54. Three of these locations around the northwestern corner of Area G (locations 58-01, 15-01, and 54-01) were sampled again after elevated levels of plutonium-239,240 and tritium were detected at an air monitoring (AIRNET) station located north of Pit 38 in May and July, respectively. Apparently, the radionuclides in question were from soil material from TA-21, and the container bags holding the waste soil may have ruptured during their placement in the pit.

Other samples from Area G included four collected along a transect, starting from the northeast portion of Area G to the Pueblo de San Ildefonso fence line in a northeasterly direction (the primary wind direction). (Note: The Pueblo de San Ildefonso fence line is approximately 150 ft north of the LANL/pueblo boundary line.) These samples were collected at approximately the 160-, 500-, 800-, and 930-ft distance from Area G.

The soil (grab) samples were collected from the 0- to 6-in. depth with disposable polystyrene scoops. Samples for analysis of radionuclides (tritium; plutonium-238; plutonium-239,240; americium-241; uranium-234; uranium-235; and uranium-238) and inorganic chemicals (TAL metals) were placed into 500-mL poly bottles, and samples for PCB analysis were placed into 500-mL amber glass bottles. All sample bottles were secured with chain-of-custody tape, placed into individual Ziploc® bags, cooled to approximately 4ºC, and submitted to Paragon Analytics, Inc. The results from these samples are presented in supplemental Tables S7-4 to S7-7. (Note: We report on the analyses of vegetation collected at Area G in Chapter 8, Section 4.a.)

2. Radionuclide and Nonradionuclide Analytical Results for Area G

a. Perimeter Results. With respect to the 21 soil samples collected around the perimeter of Area G in March 2006, concentrations of tritium were detected above the RSRL of 0.86 pCi/mL in 13 of the 21 samples (Table S7-4) (Fresquez 2007b). The highest tritium concentrations (104 pCi/mL and 690 pCi/mL) were collected in the southern portion of Area G where the tritium shafts are located and are similar to concentrations detected in past years at these locations (Fresquez et al. 2004a, Fresquez and Lopez 2004, Fresquez et al. 2005). Also, tritium concentrations in soil at these locations compare well with the vegetation data collected on the south side of Area G (see Chapter 8, Section 4.a). Although tritium is consistently detected above the RSRL in soil samples in the southern portion of Area G, the concentrations are far below the residential SL of 5,400 pCi/mL, and the migration of tritium from the Area G boundary, at least at surface and subsurface depths, is not extensive. In a recent study at Area G, for example, tree samples were collected along a transect starting from the southern portion at various distances (approximately 33, 165, 330, 490, and 660 ft) from the perimeter fence line (Fresquez et al. 2003). Results showed that the concentrations of tritium in trees collected nearest the perimeter boundary (33 to 53 ft) were higher than the RSRL for vegetation. From there, the concentrations of tritium in trees decreased greatly with distance, and at about 330 ft away, the concentrations were similar to the RSRL.

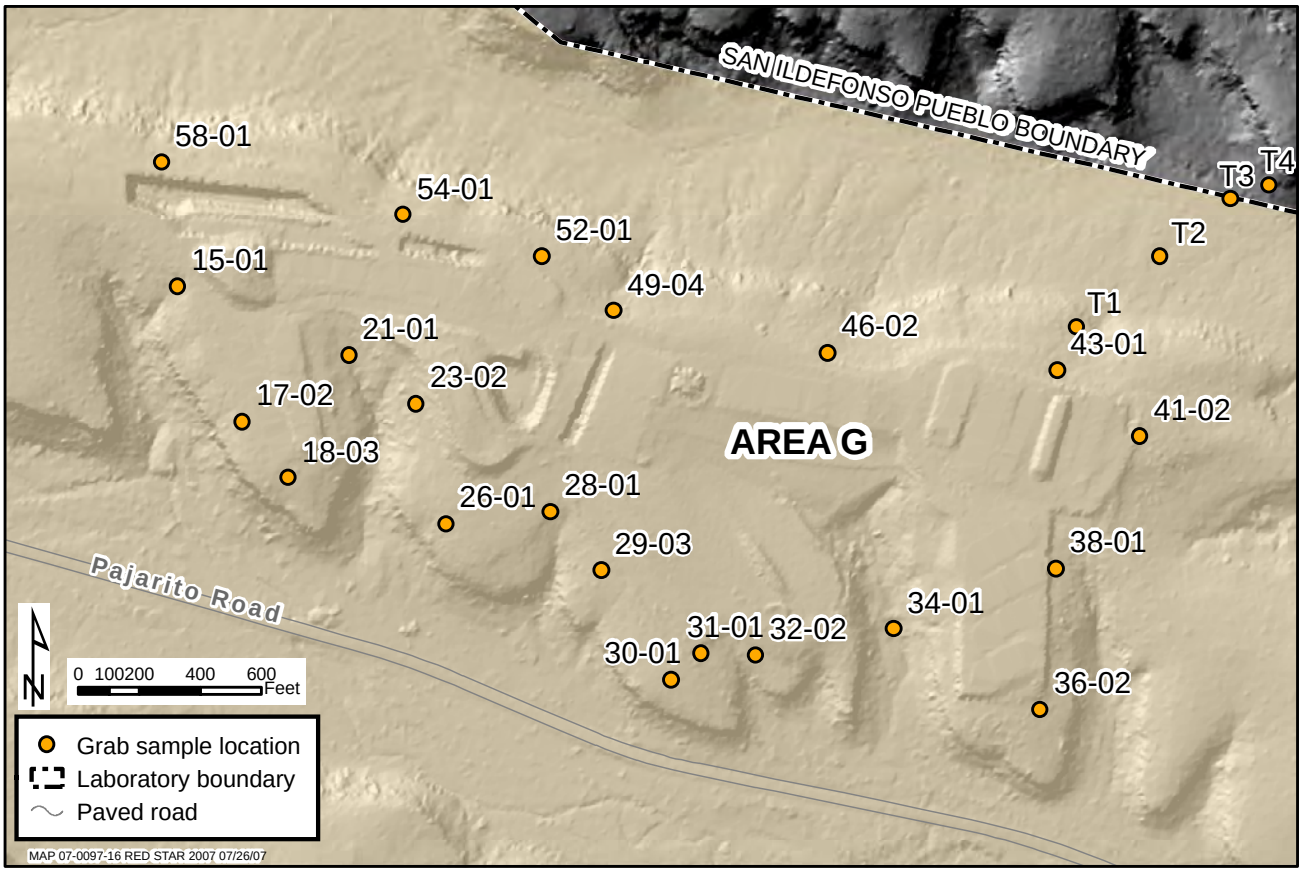


Figure 7-4. Sample locations of soil at Area G.

Many of the soil samples collected at Area G, particularly around the perimeter of the northern, northeastern, and eastern sections, contained detected concentrations of americium-241 (10 out of 21 samples), plutonium-238 (eight out of 21 samples), and plutonium-239,240 (nine out of 21 samples) above RSRLs (Table S7-4). The highest concentrations of americium-241 (1.2 pCi/g dry) and plutonium-239,240 (5 pCi/g dry) were detected in a soil sample (location 38-01) located on the perimeter of the eastern side of Area G near the Transuranic Waste Inspection Project (TWISP) domes. All concentrations were below residential SLs and do not pose a potential unacceptable dose to human health.

Three additional soil samples were collected in October around the northwestern section of Area G after elevated tritium and plutonium-239,240 concentrations were detected in air samples earlier in the year. The concentrations of tritium in all three soil samples were higher than concentrations of tritium recorded in March. In particular, location 15-01 contained tritium, americium-241, plutonium-238, and plutonium-239,240 two to nearly six times higher than previous results. However, all concentrations of radionuclides were far below residential SLs and do not pose a potential unacceptable dose to humans.

Most of the inorganic chemicals detected in soil near the perimeter of Area G were below RSRLs (478 out of 483 measurements) (Table S7-5). The only heavy metals detected above the RSRL were zinc (120 mg/kg dry compared to the RSRL of 69 mg/kg dry in one sample located at site 21-01 just east of the mixed waste dome) and antimony (0.39 mg/kg dry compared with the RSRL of 0.27 mg/kg dry in one sample at location 38-01 just east of the TWISP domes). All concentrations of these heavy metals were far below the industrial/occupational SLs and do not pose a potential hazard to human health.

Only one soil sample of 21 samples collected contained PCBs—these detections were found at location 26-01, which is on the south side of Area G. Aroclor-1254 and Aroclor-1260 in this one soil sample were detected at concentrations of 0.067 and 0.094 mg/kg dry, respectively. These levels are far below the industrial/occupational SL of 8.3 mg/kg dry.

With reference to concentration trends over time (1996–2006), Figures 7-5 and 7-6 show the concentrations of tritium and plutonium-239,240 in soil from areas that have had the highest amounts detected year after year. The results for tritium at locations 29-03 and 31-01 show an increase in concentrations that peak in 2002 and then decrease to those commonly observed in recent years (Figure 7-5). The plutonium-239,240 concentrations, which are located mostly on the northeastern part (locations # 41-02 and 43-01), are not increasing over time and are below the SL (Figure 7-6).

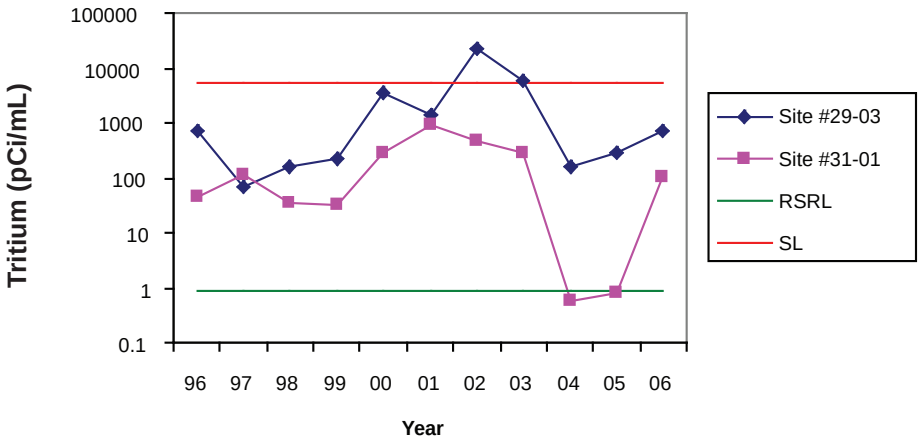


Figure 7-5. Tritium in surface soil collected from the southern portions of Area G at TA-54 from 1996 to 2006 as compared with the regional statistical reference level (RSRL) and screening level (SL).

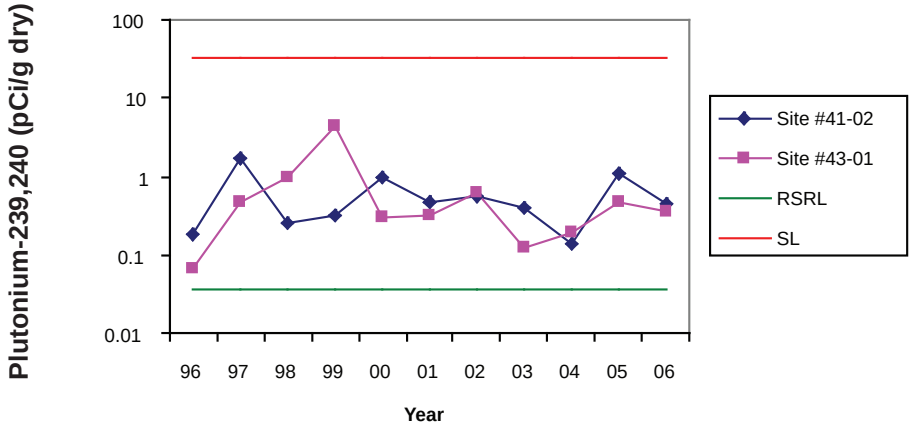


Figure 7-6. Plutonium-239,240 in surface soil collected from the northeastern portions of Area G at TA-54 from 1996 to 2006 as compared with the regional statistical reference level (RSRL) and screening level (SL).

b. Transect Results from Area G to the Pueblo de San Ildefonso Boundary. Concentrations of americium-241, plutonium-238, and plutonium-239,240 in most of the soil samples collected along a transect starting from the northeast portion of Area G and extending to the Pueblo de San Ildefonso fence line were above the RSRLs (Table S7-6). All concentrations are far below the residential SLs, and concentrations of all radionuclides decrease to RSRLs within a relatively short distance from the Pueblo fence line. Soil samples collected from 1996 through 2006 as part of the institutional monitoring program (see Section C.1, above) about 800 ft northeast of the Pueblo de San Ildefonso fence line (the "San Ildefonso" site) show that most samples (nine out of 11) contained plutonium-239,240 concentrations below the RSRL (Fresquez, 2005a and Table S7-1). Although uranium-234 and uranium-238 concentrations were slightly above the RSRLs in the soil sample collected near the fence line, the levels of these isotopes closer to Area G were below the RSRLs, and the distribution of uranium-234 and uranium-238 indicates that the uranium is naturally occurring.

All inorganic chemicals, including all heavy metals, in soil samples collected along a transect from Area G to the Pueblo de San Ildefonso fence line were below the RSRLs (Table S7-7). No PCBs were detected in any of the soil samples collected from the transect.

3. Monitoring Network for DARHT at TA-15

The Laboratory conducts facility-specific soil and sediment monitoring on an annual basis at DARHT (Nyhan et al. 2001). Approximately 20 acres in size, DARHT is located at R-Site (TA-15) at the Laboratory's southwestern end. Activities at DARHT include the utilization of very intense X-rays to radiograph a full-scale non-nuclear mock-up of a nuclear weapon's primary during the late stages of the explosively driven implosion of the device (DOE 1995). Possible contaminants include radionuclides, beryllium, and heavy metals.

Soil samples are collected around the perimeter of the DARHT facility at a 0- to 2-in. depth on the north, east, south, and west sides (Figure 7-7). An additional soil sample is collected on the north side near the firing point. Sediment samples are collected at a 0- to 6-in. depth on the north, east, south, and southwest sides. All samples are placed into 500-mL poly bottles, fitted with chain-of-custody tape, and submitted to Paragon Analytics, Inc., under strict chain-of-custody procedures for the analysis of tritium; plutonium-238; plutonium-239,240; strontium-90; americium-241; cesium-137; uranium-234; uranium-235; uranium-238; and for TAL metals. (Note: We report on the analyses of vegetation, small mammals, birds, and bees collected around the DARHT facility in Chapter 8, Section 4.b.)

We compared the radionuclide and nonradionuclide results in soil and sediment from the DARHT sampling to both RSRLs and baseline statistical reference levels (BSRLs). BSRLs are the concentrations of radionuclides and nonradionuclides (mean plus three standard deviations) in soil and sediment collected from around the DARHT facility (1996 through 1999) before the start up of operations (Fresquez et al. 2001), as per the DARHT Mitigation Action Plan (DOE 1996). The use of both reference levels is employed because the BSRLs for some elements may be biased as a result of changes in (pre- and post-) sampling locations and the change in analytical techniques. A comparison of BSRLs with RSRLs, for example, has shown that some baseline radionuclides, like cesium-137, may be biased low and some inorganic chemicals, like silver, may be biased high. Also, some TAL metals that have been analyzed recently have no baselines at all. To accommodate parking spaces and storage areas within the DARHT complex after operations began, soil sampling locations were moved from within the fenced perimeter boundary (<100 ft from the facility) to sites located outside the perimeter fence boundary (>300 ft from the facility). This may have affected the concentrations of some radionuclides, particularly cesium-137, because the pre-operation samples were collected in mostly disturbed soil and the post-operation samples are collected in mostly undisturbed soil.

Higher amounts of fallout radionuclides would be expected in the undisturbed soil rather than the disturbed soil because of the mixing associated with disturbed soil. Also, the change in analytical techniques may have

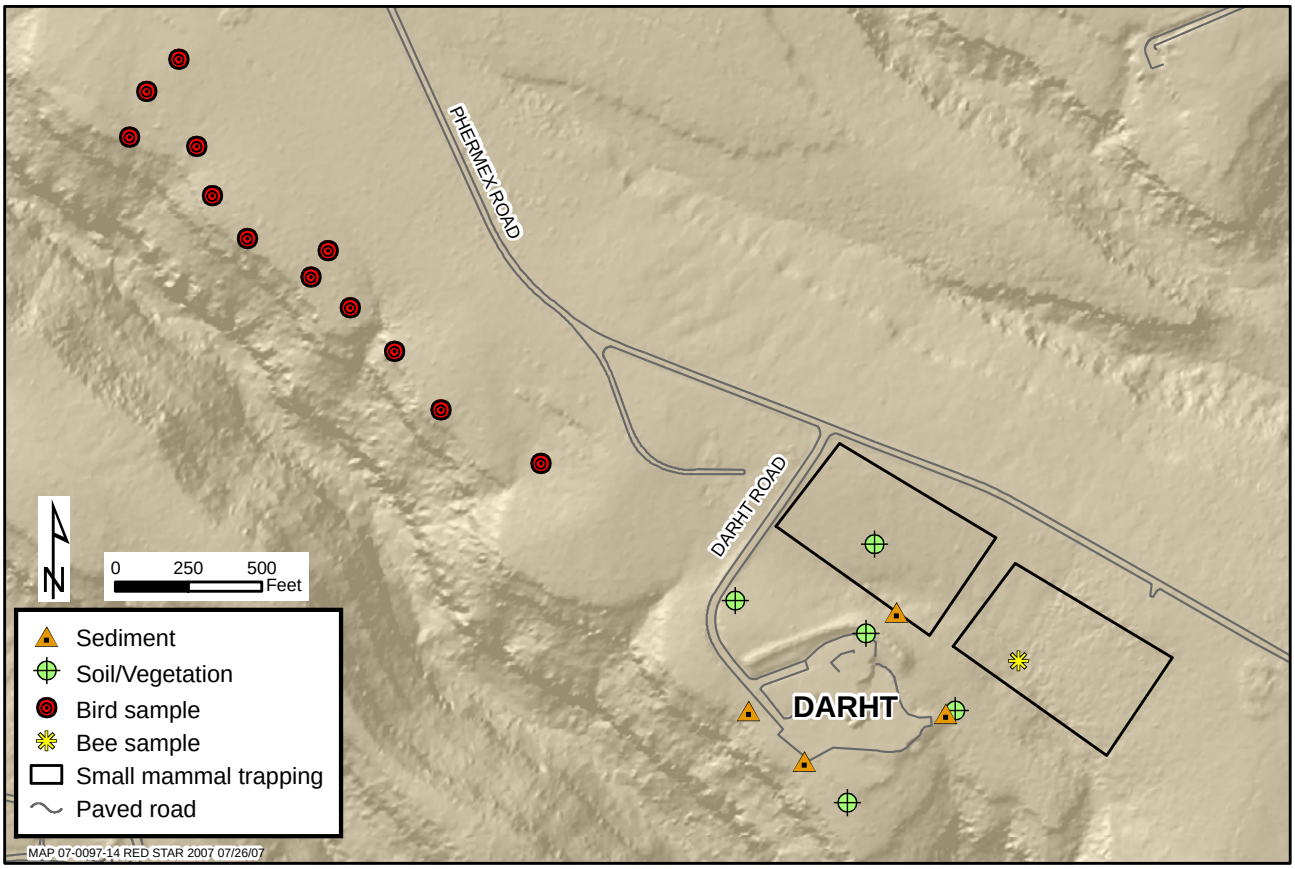


Figure 7-7. Sample locations of soil, sediment, vegetation, bees, and birds at DARHT.

improved the reporting levels of some elements, namely that of silver. The use of inductively coupled plasma mass spectrometry instrumentation to analyze post operation samples, for example, significantly decreased the detection limits of silver from 2 to 0.2 mg/kg.

4. Radionuclide and Nonradionuclide Analytical Results for DARHT

Most of the soil and sediment collected from within and around the perimeter of the DARHT facility contained concentrations of radionuclides and nonradionuclides that were either not detected or below BSRLs and/or RSRLs (Table S7-8 and Table S7-9). The very few radionuclide and inorganic chemicals detected above both the statistical reference levels were uranium-238 and beryllium in the soil sample collected nearest the firing point. Whereas the beryllium concentration was slightly above the BSRL (Figure 7-8), the concentration of uranium-238 was approximately an order of magnitude above the BSRL and appears to be increasing over time (Figure 7-9). Also, the distribution of uranium-234 to uranium-238 shows that the uranium in this soil sample was depleted uranium. Depleted uranium, a metal used as a substitute for the enriched uranium in weapon components tested at LANL, has also been detected in vegetation (Fresquez 2004), bees (Hathcock and Haarmann 2004), and small mammals (Fresquez 2007a) around the DARHT facility in previous years.

Although the concentrations of uranium-238 and beryllium in the soil sample collected near the firing point were above BSRLs, the levels were still far below residential and occupational SLs respectively, and do not pose a potential unacceptable dose or hazard to human health. Moreover, the concentrations of these elements are not elevated past the perimeter fence line.

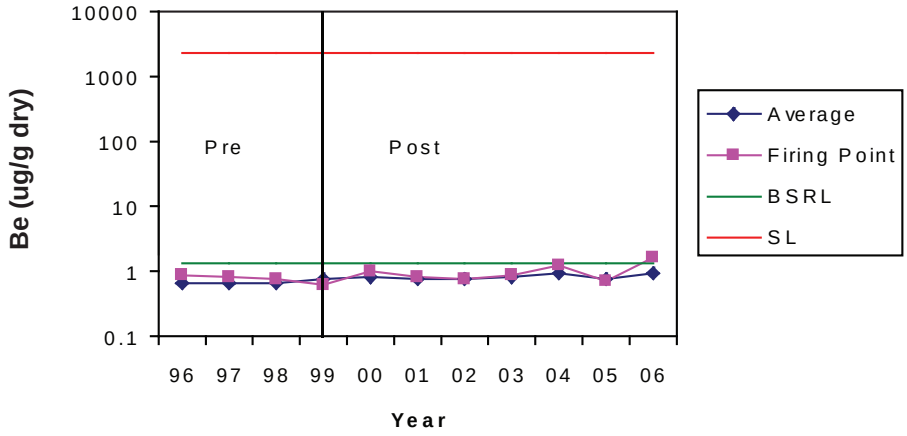


Figure 7-8. **Beryllium concentrations in soil collected within (near the firing point) and around (n = 4) the DARHT facility at TA-15 from 1996-1999 (pre-operation) to 2000-2006 (post-operation) as compared with the baseline statistical reference level (BSRL) and screening level (SL).**

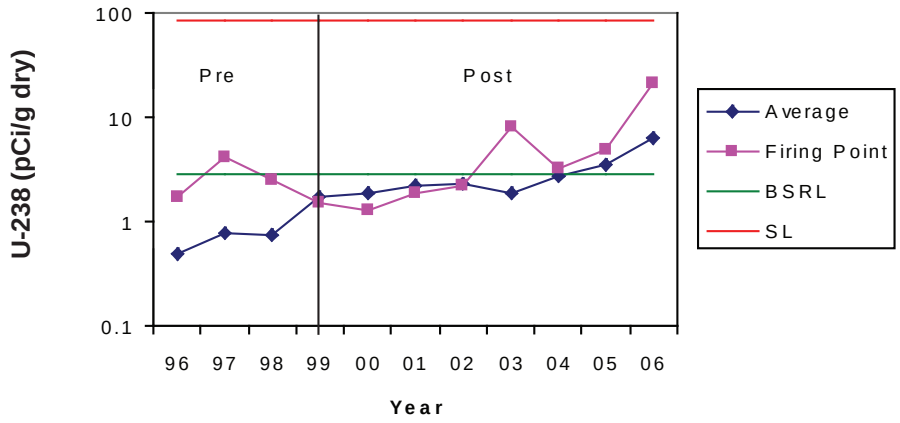


Figure 7-9. **Uranium-238 concentrations in soil collected within (near the firing point) and around (n = 4) the DARHT facility at TA-15 from 1996-1999 (pre-operation) to 2000-2006 (post-operation) as compared with the regional statistical reference level (BSRL) and screening level (SL).**

E. SPECIAL MONITORING STUDIES

1. Los Alamos Canyon Weir and Pajarito Flood Control Structure

Two special monitoring studies of sediment were conducted at the Los Alamos Canyon Weir and the Pajarito Canyon Flood Control Structure. The Los Alamos Canyon Weir is located at the northeastern boundary of LANL within TA-72 near the junction of NM State Road 4 and NM State Road 502. The Pajarito Canyon Flood Control Structure is located downstream of the confluence of Two-Mile and Pajarito Canyons at TA-18. Sediment samples along with vegetation and small mammals were collected behind (upstream of) the

structures to assess potential impacts to the biota as a result of potentially contaminated surface water runoff and sediment. Because sediment was collected and analyzed in support of the biota monitoring, the results are presented in Chapter 8, Section C.1 and C.2.

2. Beryllium in Surface Soil Collected Within and Around LANL: 1992-2006

A summary of beryllium concentrations in soil collected from all of the on-site and perimeter areas identified in Section C.1 from 1992 to 2006 was made and reported in Fresquez 2007c. Results show that the concentrations of beryllium from on-site (n = 153) and perimeter (n = 111) areas over the years ranged from 0.27 to 1.8 mg/kg (mean = 0.72 mg/kg) and from 0.20 to 1.3 mg/kg (mean = 0.65 mg/kg), respectively (Table S7-10). Most (97%) of the beryllium concentrations from LANL areas were below the RSRL of 1.2 mg/kg, and the few values that were above the RSRL were far below the industrial/occupational SL of 2,250 mg/kg. Mean beryllium concentration in soil from around Area G was 0.57 mg/kg and from DARHT was 0.78 mg/kg; both below the RSRL. There are no significant ($\alpha = 0.05$) increasing trends in beryllium concentrations in any of the samples from on-site or perimeter sites over time.

F. QUALITY ASSURANCE FOR THE SOIL, FOODSTUFFS, AND NONFOODSTUFFS BIOTA MONITORING PROGRAM

1. Quality Assurance Program Development

The soil sampling team conducts soil, foodstuffs, and nonfoodstuffs biota (SFB) sampling according to written, standard quality assurance and quality control procedures and protocols. These procedures and protocols are identified in the LANL Quality Assurance Project Plan for the Soil, Foodstuffs, and Biota Monitoring Project and in the following LANL standard operating procedures:

- Produce Sampling
- Fish Sampling
- Game Animal Sampling
- Processing and Submitting Samples
- Soil Sampling
- Chain-of-Custody Data for Soil, Foodstuffs, and Biota Samples
- Sampling Soil and Vegetation at Facility Sites
- Analytical Chemistry Data Management and Review for Soil, Foodstuffs and Biota

These procedures, which are available on the LANL web (http://www.lanl.gov/environment/all/qa.shtml), ensure that the collection, processing, and chemical analysis of samples, the validation and verification of data, and the tabulation of analytical results are conducted in a consistent manner from year to year. Stations and samples have unique identifiers to provide chain-of-custody control from the time of collection through analysis and reporting.

2. Field Sampling Quality Assurance

Overall quality of field sampling is maintained through the rigorous use of carefully documented procedures, listed above, that govern all aspects of the sample-collection program.

The team collects all samples under strict chain-of-custody procedures, which minimize the chances of data transcription errors. We hand-deliver samples to the LANL Sample Management Office where they are directly shipped to an external analytical laboratory under full chain-of-custody. The LANL project leader tracks all samples and upon delivery of data back from the laboratory via electronic and hard copy means, a LANL chemist assesses the completeness of the field sample process along with other variables. A quality assessment document is created and attached to the data packet and provided to the LANL project leader.

3. Analytical Laboratory Quality Assessment

Specific statements of work are written to govern the acquisition and delivery of analytical-chemistry services after the Data Quality Objective process has identified and quantified the program objectives. These statements of work are sent to potentially qualified analytical laboratories, which undergo a pre-award, on-site assessment by experienced and trained quality systems and chemistry laboratory assessors. Statement of work specifications, professional judgment, and quality-system performance at each laboratory (including recent past performance on nationally conducted performance-evaluation programs) are primarily used to award contracts for specific types of radiochemical, inorganic chemical, and organic chemical analyses.

Each analytical laboratory conducts chain-of-custody and analytical processes under its own quality plans and analytical procedures. Each laboratory returns data by e-mail in an electronic data deliverable with a specified format and content. The analytical laboratory also submits a full set of paper records that serves as the legal copy of the data. Each set of samples contains all the internal quality control data the analytical laboratory generates during each phase of chemical analysis (including laboratory control standards, method blanks, matrix spikes, duplicates, and replicates, when applicable). The electronic data are uploaded into the database and immediately subjected to a variety of quality and consistency checks. Analytical completeness is determined, tracking and trending of all blank and control-sample data is performed, and all the data are included in the quality assessment memo mentioned in the field sampling section. We track all parts of the data-management process electronically and prepare periodic reports to management.

4. Field Data Quality Assessment Results

Field data completeness for SFB in 2006 was 100%.

5. Analytical Data Quality Assessment Results

Analytical data completeness for all SFB sampling programs was >95%. We track, trend, and report all quality control data in specific quality evaluation memos that we submit to project staff along with each set of analytical data received from our chemistry laboratories. The overall results of the 2006 quality program indicate that all analytical laboratories maintained the same high level of control that has been observed in the past several years.

6. Analytical Laboratory Assessments

During 2006, two external laboratories performed all chemical analyses reported for SFB samples:

- Paragon Analytics, Inc., Fort Collins, Colorado, provided radiological, trace element, and organic chemical analysis of soil and sediment.
- Severn Trent Laboratories, St. Louis, Missouri, provided radionuclide and inorganic chemical analyses in vegetation, bees, and small mammals.

We performed an assessment of Paragon Analytics, Inc., during 2004. The laboratory participated in national performance-evaluation studies during 2004 and 2005. The detailed results of these performance evaluations are included in the assessment report. Overall, the study sponsors judged the analytical laboratory to have acceptable performance for almost all analytes attempted in all matrices.

7. Program Audits

In 2005, we hosted a data quality assessment and evaluation to evaluate whether the procedures in various programs are being implemented as written. The auditors (Time Solutions 2) were external quality assurance professional experts (ISO 9000 and 14000 certified) and examined all aspects of the SFB program as it relates to procedures. While it was noted that improvements have been made to the SFB program since the last audit (completed by auditors external to the sampling group but internal to LANL), several observations were made to improve processes. These observations include keeping procedures up-to-date and meeting internal commitments made in our quality assurance plans. Since the quality assessment, we have implemented all recommendations resulting from the observations.

G. REFERENCES

Corely et al. 1981: J. P. Corely, D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite, "A Guide for Environmental Radiological Surveillance at US Department of Energy Installations," Department of Energy report DOE/EP-0023 (1981).

DOE 1979: US Department of Energy, "Final Environmental Impact Statement: Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico," US Department of Energy report DOE/EIS-0018 (1979).

DOE 1991: US Department of Energy, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance," US Department of Energy report DOE/EH-0173T (January 1991).

DOE 1993: US Department of Energy, "Radiation Protection of the Public and the Environment," US Department of Energy Order 5400.5 (1993).

DOE 1995: US Department of Energy, "Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement," US Department of Energy report USDOE/EIS-0228 (1995).

DOE 1996: US Department of Energy, "Dual-Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Mitigation Action Plan," USDOE/EIS-0228 (1996).

DOE 1999a: US Department of Energy, "Radioactive Waste Management," US Department of Energy Order 435.1 (July 9, 1999).

DOE 1999b: US Department of Energy, "Radioactive Waste Management Manual," US Department of Energy report DOE M 435.1-1 (July 9, 1999).

DOE 1999c: US Department of Energy, "The Long-Term Control of Property: Overview of Requirements in Orders DOE 5400.1 & DOE 5400.5, EH-412-0014/1099" (October 1999)

DOE 2003: US Department of Energy, "General Environmental Protection Program," US Department of Energy Order 450.1 (2003).

Fresquez 2004: P. R. Fresquez, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation around the DARHT Facility during 2004," Los Alamos National Laboratory report LA-14176-PR (2004).

Fresquez 2007a: P. R. Fresquez, "Radionuclides in Small Mammals Collected at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility During 2001–2006: Revision 1," Los Alamos National Laboratory report LA-14320 (2007).

Fresquez 2007b: P. R. Fresquez, "Radionuclide, Heavy Metal, and Polychlorinated Biphenyl Concentrations in Soils at Low-Level Radioactive Waste Disposal Area G during the 2006 Growing Season," Los Alamos National Laboratory report LA-14323-PR (2007).

Fresquez 2007c: P. R. Fresquez, "Beryllium in Surface Soils Collected Within and Around Los Alamos National Laboratory: 1992-2006," Los Alamos National Laboratory report LA-14318 (2007).

Fresquez and Lopez: P. R. Fresquez and E. Lopez, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2004 Growing Season," Los Alamos National Laboratory report LA-14181-PR (2004).

Fresquez et al.1996: P. R. Fresquez, D. R. Armstrong, and M. A. Mullen, "Radionuclides and Radioactivity in Soils within and around Los Alamos National Laboratory, 1974 through 1994: Concentrations, Trends, and Dose Comparisons," Los Alamos National Laboratory report LA-13149-MS (1996).

Fresquez et al.1998: P. R. Fresquez, D. R. Armstrong, and M. A. Mullen, "Radionuclides and Radioactivity in Soils Collected from within and around Los Alamos National Laboratory: 1974–1996," J. Environ. Sci. Heal. A 33 (2), pp. 263–278 (1998).

Fresquez et al. 2001: P. R. Fresquez, J. W. Nyhan, and H. T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, and Vegetation Around the DARHT Facility," in Nyhan et al., "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees Around the DARHT Facility: Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001), pp. 48–76.

Fresquez et al. 2003: P. R. Fresquez, L. Vasquez-Tator, and E. A. Lopez, "Tritium Concentrations in Vegetation as a Function of Distance from a Low-Level Waste Site at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-14091-MS (2003).

Fresquez et al. 2004a: P. R. Fresquez, J. W. Nyhan, and E. Lopez, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2003 Growing Season," Los Alamos National Laboratory report LA-14108-PR (2004).

Fresquez et al. 2005: P. R. Fresquez, M. W. McNaughton, and M. J. Winch, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during 2005," Los Alamos National Laboratory report LA-14251-PR (2005).

Hansen et al. 1980: W. R. Hansen, D. L. Mayfield, and L. J. Walker, "Interim Environmental Surveillance Plan for LASL Radioactive Waste Areas," Los Alamos Scientific Laboratory report LA-UR-80-3110 (1980).

Hathcock and Haarmann 2004: C. D. Hathcock and T. K. Haarmann, "Concentrations of Radionuclides and Trace Elements in Honey Bee Samples Collected Near DARHT in 2003," Los Alamos National Laboratory document LA-UR-04-8349 (2004).

Keith 1991: L. H. Keith, *Environmental Sampling and Analysis: A Practical Guide* (CRC Press, Inc., Baca Raton, Fl., 1991).

LANL 2005: "Derivation and Use of Radionuclide Screening Action Levels, Revision 1," Los Alamos National Laboratory report LA-UR-05-1849 (2005).

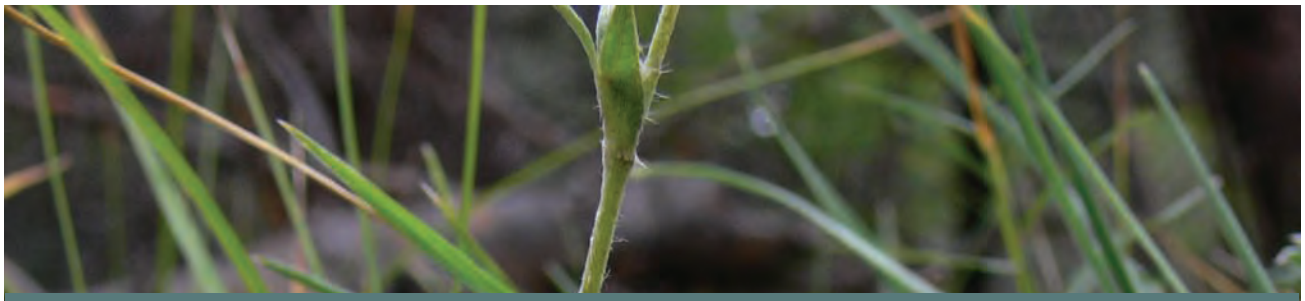
Lopez 2002: E. Lopez, "MDA G and L Environmental Monitoring Plan for FY 2002," Los Alamos National Laboratory report LA-UR-02-6128 (2002).

NMED 2006: "Technical Background Document for Development of Soil Screening Levels, Rev. 4.0," New Mexico Environment Department report (2006).

Nyhan et al. 2001: J. W. Nyhan, P. R. Fresquez, K. D. Bennett, J. R. Biggs, T. K. Haarmann, D. C. Keller, and H. T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility: Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).

Soholt 1990: L. F. Soholt, "Environmental Surveillance of Low-Level Radioactive Waste Management Areas at Los Alamos during 1987," Los Alamos National Laboratory report LA-UR-90-3283 (1990).

Yu et al. 1995: C. Yu, A. J. Zielen, J. J. Cheng, T. C. Yuan, L. G. Jones, D. J. Lepoire, Y. Y. Wang, C. O. Loueiro, E. Gnanapragasam, J. E. Faillace, A. Wallo III, W. A. Williams, and H. Peterson, "A Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.60," Argonne National Laboratory report ANL/EAD/LD-2 (1995).



8. Foodstuffs and Biota Monitoring

8. Foodstuffs and Biota Monitoring

contributing authors:
Philip Fresquez, Chuck Hathcock, Dave Keller

To Read About **Turn to Page**

Foodstuffs Biota Monitoring 253
Nonfoodstuffs Biota Monitoring 256
Special Studies of Nonfoodstuffs Biota 262
Quality Assurance for the Soil, Foodstuffs and Nonfoodstuffs Biota Program 263
References 264

A. FOODSTUFFS BIOTA MONITORING

1. Introduction

A wide variety of wild and domestic edible vegetables, fruits, grains, and animal products are harvested in the area surrounding the Los Alamos National Laboratory (LANL or the Laboratory). Ingestion of foodstuffs constitutes an important exposure pathway by which radionuclides (Whicker and Schultz 1982) and nonradionuclides (inorganic and organic chemicals) (Gough et al. 1979) may be transferred to humans. Over the years, we have collected a variety of foodstuff samples (e.g., vegetables, grains, fruits, fish, milk, eggs, honey, herbal teas, mushrooms, piñon nuts, domestic ungulates, and small and large game animals) from the surrounding area and communities to determine whether Laboratory operations have impacted human health via the food chain. US Department of Energy (DOE) Orders 450.1 (DOE 2003) and 5400.5 (DOE 1993) mandate this monitoring program, and the guidance for assessing impacts to foodstuffs is presented in the DOE's guidance for environmental surveillance (DOE 1991).

The objectives of the program are as follows:

(1) Measure radioactive and nonradioactive concentrations in foodstuffs from on-site (within LANL property) and perimeter areas, and compare these results with regional (background) areas;

(2) Determine concentration trends over time; and

(3) Provide data used to estimate dose and risk from the consumption of the foodstuffs (see Chapter 3 for dose and risk estimates to individuals from the ingestion of foodstuffs).

In general, major foodstuffs like food crops and fish are collected on a triennial basis. The next full-scale assessment for crops (and milk) is scheduled for 2007. (Note: Fish were collected in 2005.) This year, we focused on the collection and analysis of radionuclides and inorganic chemicals in two wild edible plants, common lambsquarters and pigweed amaranth, collected from Mortandad Canyon on Pueblo de San Ildefonso land.

2. Foodstuffs Comparison Levels

To evaluate potential Laboratory impacts on foodstuffs plants from radionuclides and nonradionuclides, we first compared analytical results with regional statistical reference levels (RSRLs). Where the levels exceeded RSRLs, we then compared the concentrations to screening levels (SLs) and standards, if available.

A description of the levels and/or the standard used to evaluate the results of radionuclides and nonradionuclides in foodstuffs plants are as follows, and an overall summary can be found in Table 8-1.

- Regional background levels: RSRLs are the upper-level background concentration (mean plus three standard deviations = 99% confidence level) calculated from foodstuffs data collected from regional locations away from the influence of the Laboratory (>9 miles away) (DOE 1991) over at least the last five sampling periods. RSRLs represent natural and fallout sources, are calculated as data becomes available, and can be found in the supplemental data tables S8-1 and S8-2 of this report.
- Screening levels (SLs): SLs are set below federal regulations so that potential concerns may be identified in advance of major problems, i.e., a "yellow flag." If a constituent exceeds an SL, the reason for that increase is thoroughly investigated. For radionuclides, the dose assessment team at the Laboratory developed SLs on the basis of a conservative 1 mrem protective annual dose limit (this is 4% of the 25 mrem/yr DOE single-pathway constraint (DOE 1999). We are not aware of any specific SLs for most inorganic chemicals in foodstuff plants (FDA 2000), but comparisons were made to toxicity values (TV) obtained from the literature.
- Standard: Based on the concentrations of radionuclides in foodstuffs, we calculate a dose to a person (Chapter 3). We compare this dose with the 25-mrem/yr DOE single-pathway dose constraint (DOE 1999). There are no standards for inorganic chemicals in foodstuff plants.

Table 8-1
Standards and Other Reference Levels Applied to Foodstuffs

Constituent	Sample Location	Media	Standard	Screening Level	Background Level
Radionuclides	On-site and perimeter	Foodstuffs Plants	25 mrem/yr	1.0 mrem/yr	RSRLs
Nonradionuclides (Inorganic Chemicals)	On-site and perimeter	Foodstuffs Plants		TVs	RSRLs

3. Wild Edible Plants

a. Monitoring Network. For several years, we have collected wild food plants within Mortandad Canyon on the eastern side of LANL on Pueblo de San Ildefonso land. Mortandad Canyon has been the primary release area of treated liquid radioactive waste from the Laboratory (Gallaher et al. 1997), and radionuclides have been detected in biota in the upper reaches of Mortandad Canyon on Laboratory property closer to the source (Bennett et al. 1996). Subsequently, samples of edible plant foods were collected on Pueblo de San Ildefonso land as near to the LANL fence line as possible and have included piñon nuts and Navajo Tea (Fresquez and Gonzales 2000); prickly pear fruit (Fresquez et al. 2001a, Fresquez et al. 2002); and common purslane, acorns, and common lambsquarters (Fresquez et al. 2005a, 2006). This year, in addition to common lambsquarters (*Chenopodium sp.*), we collected pigweed amaranth (*Amaranth sp*.) from both Mortandad Canyon and from background locations. Pigweed amaranth seed is used for baking and for cereal type porridge and the greens are eaten like those of common lambsquarters (TNM 2004). Two samples of each crop were collected approximately 16 to 160 ft from the LANL fence line. Samples were analyzed for tritium, plutonium-238, plutonium-239,240, strontium-90, americium-241, cesium-137, uranium-234, uranium-235, and uranium-238. Also, 23 target analyte list (TAL) metals were analyzed.

b. Radionuclide and Nonradionuclide Analytical Results. Most (activity) concentrations of radionuclides in two wild food plants, common lambsquarters and pigweed amaranth, collected within Mortandad Canyon on Pueblo de San Ildefonso land, either were not detected or were below the RSRLs (Table S8-1). A nondetected value is one in which the result is lower than three times the counting uncertainty and is not significantly ($\alpha = 0.01$) different from zero (Keith 1991, Corely et al. 1981).

The only radionuclide detected above the RSRL in both common lambsquarters and pigweed amaranth was strontium-90 (Figure 8-1.) Strontium-90 concentrations in these plants are similar to other wild food plants collected from this same location in previous years. The higher strontium-90 concentrations in plants from Mortandad Canyon as compared with background plants are not related to elevated strontium-90 levels in the soil; the concentrations of strontium-90 in soil from Mortandad Canyon on Pueblo de San Ildefonso land are similar to RSRLs (Figure 8-2) (Fresquez et al. 2006). Instead, the higher levels of strontium-90 in plants from Mortandad Canyon may be related to the lower calcium content in the soil (Figure 8-3). Lower calcium concentrations in soil are usually reflected by higher strontium-90 levels in plant tissues because both elements are chemically similar and the plants do not differentiate between the two (Whicker and Schultz 1982). The highest strontium-90 concentration in common lambsquarters (0.36 pCi/g dry) and pigweed amaranth (0.22 pCi/g dry) in Mortandad Canyon are still below the SL of 1 pCi/g dry (i.e., <1 mrem/yr) and do not pose a potential unacceptable dose to humans who ingest these plants.

All inorganic chemical concentrations in common lambsquarters and pigweed amaranth samples collected from within Mortandad Canyon on Pueblo de San Ildefonso land were either below the reporting limits (i.e., they were not detected) or below RSRLs (supplemental data Table S8-2).

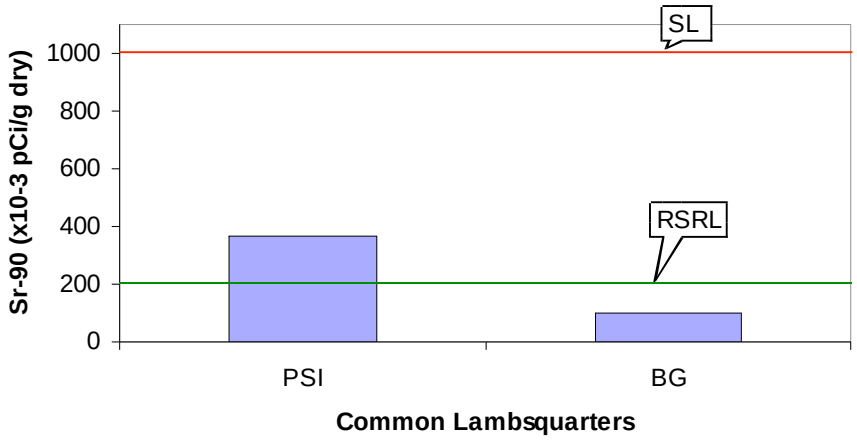


Figure 8-1. The highest strontium-90 concentration in common lambsquarters collected within Mortandad Canyon on Pueblo de San Ildefonso (PSI) land as compared with a background sample (BG), the regional statistical reference level (RSRL), and screening level (SL).

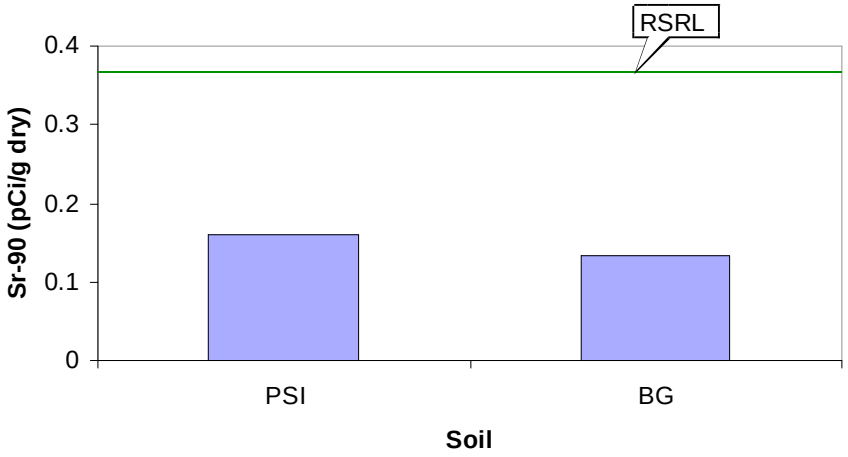


Figure 8-2. **The average strontium-90 concentrations in soil collected from Mortandad Canyon on Pueblo de San Ildefonso (PSI) land as compared with background (BG) and the regional statistical reference level (RSRL).**

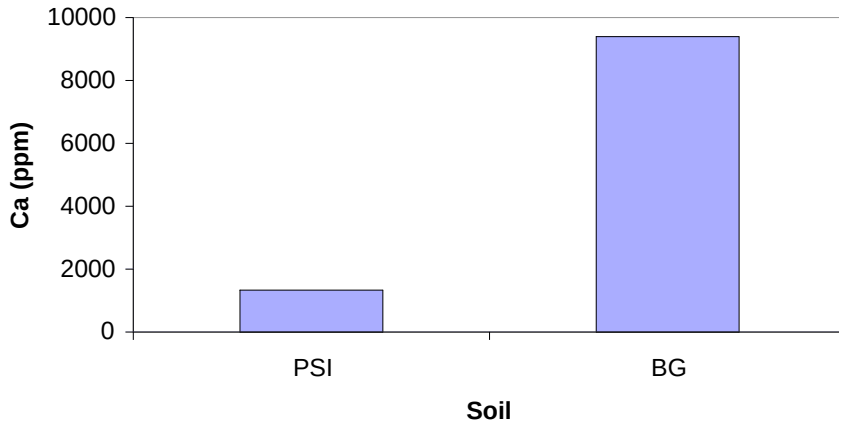


Figure 8-3. **The average calcium concentrations in soil collected from Mortandad Canyon on Pueblo de San Ildefonso (PSI) land as compared with background (BG).**

B. NONFOODSTUFFS BIOTA MONITORING

1. Introduction

DOE Orders 450.1 (DOE 2003) and 5400.5 (DOE 1993) mandate the monitoring of nonfoodstuffs biota for the protection of ecosystems. Although monitoring of biota, mostly in the form of facility-specific or site-specific studies, began in the 1970s with the Environmental Surveillance Program, site-wide vegetation monitoring started in 1994. Presently, in addition to vegetation, we also monitor small mammals, amphibians, reptiles, birds, and bees within and around LANL on a systematic basis or for special studies.

The three objectives of the nonfoodstuffs biota program are to determine

(1) Radionuclide and nonradionuclide concentrations in biota from on-site (LANL property) and perimeter areas, and compare these results to regional (background) areas,

(2) Determine concentration trends over time, and

(3) Estimate potential dose to plants and animals.

Chapter 3 includes the results of the 2006 biota dose assessments at LANL.

2. Nonfoodstuffs Biota Comparison Levels

To evaluate whether there are Laboratory impacts from radionuclides and nonradionuclides in nonfoodstuffs biota, we first compared the analytical results of biota samples collected from on-site and perimeter areas with RSRLs. If the levels exceed RSRLs, we compare the concentrations with SLs, if available, and then to standards, if available. A discussion of these comparison levels is as follows and a summarization can be found in Table 8-2:

- Regional background levels: RSRLs are the upper-level background concentrations (mean plus three standard deviations) for radionuclides and nonradionuclides calculated from nonfoodstuffs biota data collected from regional locations away from the influence of the Laboratory (>9 miles away) (DOE 1991) over the past five sampling periods. RSRLs represent natural and fallout sources, are calculated annually, and can be found in the supplemental data tables S8-3 through S8-25 of this report.
- Screening levels: SLs are set below federal regulatory standards so that potential concerns may be identified in advance of potential ecological health problems—a "yellow flag." If a constituent exceeds an SL, then the reason for that exceedance is thoroughly investigated. For radionuclides in nonfoodstuffs biota, SLs were set at 10% of the standard by the dose assessment team at the Laboratory to identify the potential contaminants of concern (McNaughton 2006). Nonradionuclides are compared with TVs obtained from the literature.
- Standards: Based on the concentrations of radionuclides in biota, we calculate a dose and compare it with the 1 rad/d DOE dose standard for terrestrial plants and aquatic biota and 0.1 rad/d for terrestrial animals (DOE 2002).

Table 8-2
Standards and Other Reference Levels Applied to Nonfoodstuffs Biota

Constituent	Sample Location	Media	Standard	Screening Level	Background Level
Radionuclides	On-site and perimeter	Terrestrial plants	1 rad/d	0.1 rad/d	RSRLs
	DARHT	Terrestrial plants	1 rad/d	0.1 rad/d	BSRLs[a]
	On-site and perimeter	Terrestrial animals	0.1 rad/d	0.01 rad/d	RSRLs
	DARHT	Terrestrial animals	0.1 rad/d	0.01 rad/d	BSRLs
Nonradionuclides	On-site and perimeter	Biota		TVs	RSRLs
	DARHT	Biota		TVs	BSRLs

[a] Baseline Statistical Reference Levels (BSRL) and a discussion of these levels can be found in Section 4.b.i.

3. Institutional Monitoring

Native understory vegetation are collected on a triennial basis at the same time and at the same locations (17 on-site, 11 perimeter, and six regional locations) as the soil sampling program described in Chapter 7, Section C.1 (Figure 7-1). Previous understory sampling occurred in 1998 (Gonzales et al. 2000) and in 2003 (Fresquez and Gonzales 2004). In 2006, samples were submitted to Severn Trent Laboratories, Inc., under full chain-of-custody procedures for the analysis of tritium, plutonium-238, plutonium-239,240, strontium-90, americium-241, cesium-137, uranium-234, uranium-235, uranium-238, and TAL metals.

a. Radionuclide and Nonradionulclide Results of Native Vegetation. Most activity concentrations of radionuclides in native understory plants collected from both on-site and perimeter areas were either not detected or below RSRLs (Table S8-3). The very few detected radionuclides in vegetation from on-site and perimeter areas that were higher than RSRLs included strontium-90 and plutonium-238 in a sample collected east of Area G at TA-54; cesium-137 in a sample collected east of White Rock; tritium in a sample collected along State Road 502 at Technical Area (TA)-73; and plutonium-239,240 in a sample collected west of the former plutonium processing facility at TA-21. All of these detected concentrations were below SLs and do not result in adverse effects to the vegetation.

The results of the inorganic chemical analysis in native vegetation from on-site and perimeter areas as compared with RSRLs are presented in Table S8-4. Most inorganic chemicals in native vegetation from on-site and perimeter areas were below RSRLs. The few inorganic chemicals in native vegetation from on-site and perimeter areas above RSRLs included mostly zinc and cadmium. While all of the concentrations of zinc in native vegetation from perimeter and on-site locations were slightly above the RSRL, the amount of cadmium in a plant sample east of TA-54 at Area G was detected in higher concentrations than the RSRL (1.2 mg/kg dry vs. the RSRL of 0.63 mg/kg dry). The concentration of cadmium in this plant sample was below the SL of 3.0 mg/kg dry (Allaway 1968) and not a significant hazard to the plant(s).

4. Facility Monitoring

a. Area G at TA-54.

i. Monitoring Network. The Laboratory conducts facility-specific vegetation monitoring on an annual basis at Area G (Lopez 2002). A description of the area and the types of waste disposed of at Area G is presented in Chapter 7 Section D.1. This year, two understory vegetation samples—one from the southern area of Area G (location G-29-03) and one from the northeastern area of Area G (location G-43-01)—were collected. Historically, the southern area has had tritium activity and the northeastern area has had plutonium activity compared with other areas around the perimeter of Area G (Fresquez and Lopez 2004, Fresquez et al. 2004, 2005b). Plant understory samples were analyzed for tritium, cesium-137, strontium-90, americium-241, plutonium isotopes, uranium isotopes, and TAL metals.

ii. Vegetation Results for Area G. Tritium concentrations from understory vegetation sample location G-29-03 collected from the southern perimeter of Area G near the tritium shafts was above the RSRL (511 pCi/mL vs. the RSRL of 0.56 pCi/mL) (Table S8-5). Similarly, the vegetation sample collected near the northeastern corner of Area G (location G-43-01) had a plutonium-239,240 concentration higher than the RSRL (0.32 pCi/g ash vs the RSRL of 0.017 pCi/g ash). All tritium and plutonium-239,240 concentrations above the RSRLs were below the SL of 0.1 rad/day for terrestrial understory plants (e.g., <345,000 pCi/mL for tritium and <578 pCi/g ash for plutonium isotopes). These data correlate very well with the soil data (Chapter 7, section D.2) and are similar to previous years (Figures 8-4 and 8-5).

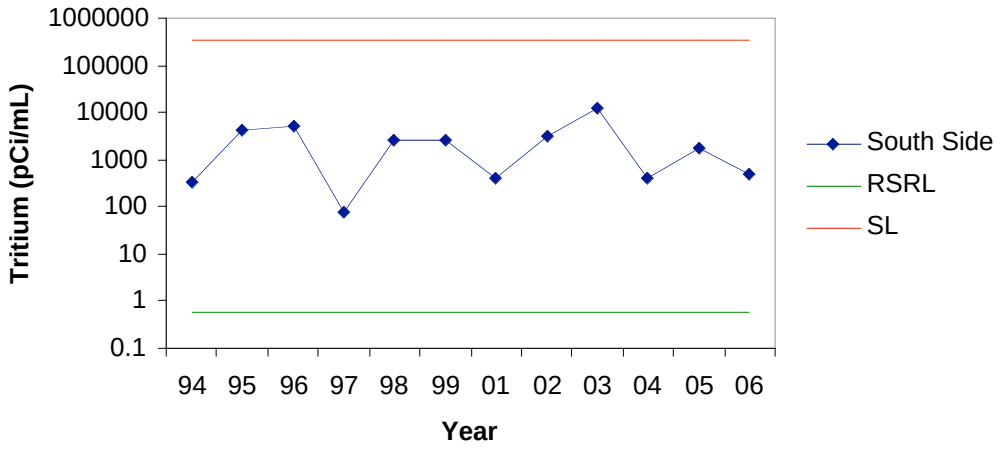


Figure 8-4. **Tritium in understory vegetation collected from the south side (see Figure 7-4 for location information associated with G-29-03) outside of Area G at TA-54 from 1994 through 2006 compared with the regional statistical reference levels (RSRL) and screening level (SL).**

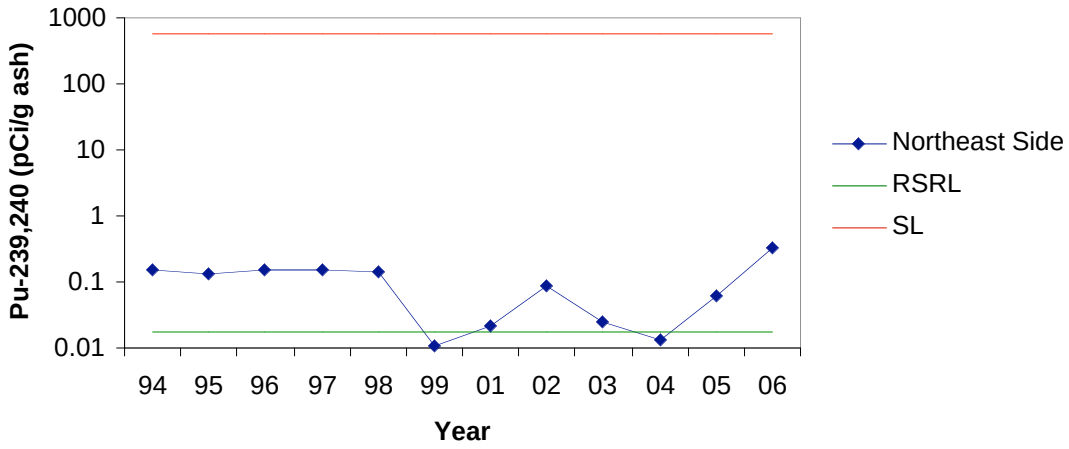


Figure 8-5. **Plutonium-239,240 in understory vegetation collected from a selected location (see Figure 7-4 for location information associated with G-43-01) outside of Area G at TA-54 from 1994 through 2006 compared with the regional statistical reference levels (RSRL) and screening level (SL).**

All concentrations of inorganic chemicals, with the exception of zinc in both vegetation samples, were either not detected or below the RSRLs (Table S8-6). The highest zinc concentration was detected in a vegetation sample from location G-43-01(93 mg/kg dry vs. the RSRL of 50 mg/kg dry). Nevertheless, the concentration of zinc was below the SL (400 mg/kg dry) (Chapman 1966) and is not a significant concern.

b. DARHT at TA-15

i. Monitoring Network. The Laboratory conducts facility-specific biota monitoring on an annual basis at DARHT (Nyhan et al. 2001). In 2006, the biota samples collected at DARHT included vegetation, small mammals, birds, and bees (Figure 7-7).

Overstory and understory vegetation samples are collected near the same four locations as the soil samples collected on the north, south, west, and east sides of the complex (see Chapter 7, Section D.2. or Figure 7-7 for sample locations). We used snap traps to collect samples of deer mice (*Peromyscus* spp.) from two sample grids located on the north and northeast side of the DARHT facility. We conducted bird sampling using mist net traps—setting 12 mist capture nets starting from about 200 ft to 1,600 ft outward from the west side of the DARHT facility. Spacing of the nets was about 150 ft from one another. In addition, we set mist nets in Jemez Springs and Nambé to capture birds for background comparisons. Finally, we collected honey bees from five hives located just northeast of the DARHT facility.

All biota samples were submitted to Severn Trent Laboratories, Inc., and analyzed for concentrations of tritium; plutonium-238; plutonium-239,240; strontium-90; americium-241; cesium-137; uranium-234; uranium-235; uranium-238; and TAL metals. Results of the vegetation, small mammals, birds, and bee samples were compared with either RSRLs or baseline statistical reference levels (BSRLs). BSRLs are the upper-limit baseline data established over a four-year period (1996–1999) prior to the start-up of DARHT operations in 2000. The BSRLs, at the three sigma level, are based on data from Fresquez et al. (2001b) for vegetation, Bennett et al. (2001) for small mammals, and Haarmann (2001) for bees. BSRLs for birds are not available. The bird samples collected in 2006 from DARHT were compared to bird samples collected from regional background (RSRLs) areas and can be found in the present data. Also, RSRLs were used in other media where BSRLs were not available.

ii. Vegetation Results at DARHT. All radionuclide concentrations, with the exception of uranium-238 in vegetation collected from around the DARHT facility, were either not detected or below BSRLs (Table S8-7). The highest concentrations of uranium-238 were detected in overstory vegetation collected from the north and east sides of the complex and the distribution of uranium-234 to uranium-238 was consistent with that of depleted uranium. Depleted uranium, a metal used as a substitute for the enriched uranium in weapon components tested at LANL, has also been detected in soil (Fresquez 2004), bees (Hathcock and Haarmann 2004), and small mammals (Fresquez 2005) at DARHT in previous years. All concentrations of uranium-238 in vegetation at DARHT were below the SL (<889 pCi/g ash) and do not pose a potential unacceptable dose to the plants.

A plot of uranium-238 concentrations in understory vegetation over the past 11 years shows that the levels are steady and mostly below the BSRL (Figure 8-6). Conversely, the levels of uranium-238 in overstory vegetation are higher than the understory vegetation, are above the BSRL in recent samples, and are significantly ($\alpha = 0.05$) increasing over time, especially since operations began in 2000 on the eastern side. Concentrations of uranium-238 in overstory vegetation at DARHT will be closely monitored over time.

A comparison of the 23 TAL metals in vegetation collected from around the DARHT facility with the BSRLs (or RSRLs when BSRL data was not available) show that most were either not detected or below statistical levels (Table S8-8). The only inorganic chemical detected above either of the reference levels was arsenic in one overstory plant sample collected on the south side of the DARHT facility. The detected arsenic concentration (2.3 mg/kg vs the BSRL of 0.35 mg/kg) was within the range of 2.1 mg/kg to 8.2 mg/kg considered toxic to plants (Gough et al. 1979). It is not clear why this tree sample contained an elevated concentration of arsenic as the amounts of arsenic in all other vegetation samples in the area around the DARHT grounds showed no other arsenic detections. Also, the arsenic concentrations in the soil and sediment samples collected in this vicinity were at background levels (Table S7-5). We will continue to monitor the vegetation at this location for arsenic in the future.

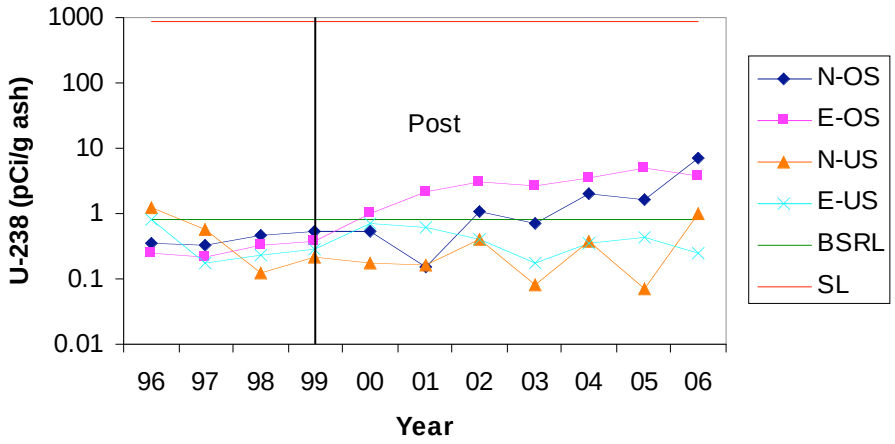


Figure 8-6. **Uranium-238 in overstory (OS) and understory (US) vegetation collected from the north (N) and east (E) side of the DARHT facility at TA-15 from 1996 (pre-operational) through 2006 (post-operational) compared with the baseline statistical reference levels (BSRL), and the screening level (SL).**

iii. Small Mammal Results at DARHT. With the exception of uranium-234 in the whole body of mice collected downwind of DARHT, radionuclides were either not detected or below BSRLs (Table S8-9) (Fresquez 2007). The highest level of uranium-234 (0.55 pCi/g vs the BSRL of 0.28 pCi/g ash), however, was far below the SL and does not pose a hazard to the mice. The distribution of uranium-234 and uranium-238 indicate that the uranium in mice was depleted uranium.

iv. Bird Results at DARHT. All radionuclides in bird samples collected west of the DARHT facility were either not detected or below the RSRLs (Table S8-10). In contrast, there were many inorganic chemicals detected above RSRLs in one (spotted towhee sample) of the two bird samples collected west of the DARHT facility (Table S8-11). The inorganic chemicals above the RSRLs in the one spotted towhee sample included aluminum, barium, beryllium, iron, manganese, vanadium, arsenic, lead, and silver. It is not clear why only one of the two bird samples collected near the DARHT facility contained inorganic chemical concentrations above RSRLs because there is no evidence of these metals being elevated around the DARHT facility. Instead, the source of metals in birds may be from surface waters from Canon de Valle, a tributary just below the bird collection points near DARHT. For example, base flow and storm water runoff within Canon de Valle contain silver (by two to three times) above the NM acute aquatic life standards. Past discharges from photography laboratories are cited as the probable source of the silver.

v. Bee Results from DARHT. Most concentrations of radionuclides (Table S8-12) and all nonradionuclides (Table S8-13) in bees sampled from four hives located northeast of the DARHT facility were below the BSRLs. The only radionuclide concentrations above the BSRLs were for uranium-234 and uranium-238 in three of the four bee samples. The distribution of these isotopes showed that one of these samples contained depleted uranium. All concentrations of uranium-234 and uranium-238 were below the SL of 0.01 rad/day and, therefore, do not contribute significant doses to the bees.

C. SPECIAL STUDIES OF NONFOODSTUFFS BIOTA

1. Characterization of Biotic and Abiotic Media Upstream of the Los Alamos Canyon Weir and the Pajarito Flood Control Retention Structure

In May 2000, a prescribed burn at Bandelier National Monument went out of control and burned nearly 50,000 acres of federal and pueblo land, including approximately 7,500 acres on LANL property. Because the Cerro Grande Fire burned substantial amounts of vegetative cover, the Laboratory became concerned about increased sediment (and potential contaminant) transport from LANL to off-site locations. As a preventive measure, the U.S. Army Corps of Engineers constructed two large erosion control structures to control storm water runoff and sediment from burned areas. These structures consist of (1) a low-head, rock-filled gabion weir that lies across the stream bed in Los Alamos Canyon near the junction of State Roads 4 and 502, and (2) a large cement flood retention structure located downstream of the confluence of Two-Mile and Pajarito Canyons.

As part of the Special Environmental Analysis of actions taken in response to the Cerro Grande Fire at LANL (DOE 2000), the DOE identified various mitigation measures that must be implemented under the Mitigation Action Plan as an extension of the fire suppression, erosion, and flood control actions. One of the tasks identified in the Mitigation Action Plan Section 2.1.7, "Mitigation Action for Soil, Surface and Ground Water, and Biota," mandates the monitoring of soil, surface water, groundwater, and biota at areas of silt or water retention behind (upstream) flood control structures, within silt retention basins, and within sediment traps to determine if there has been an increase in contaminant concentrations in these areas. To this end, we collected samples of sediment (0- to 6-in. depth), native grasses and forbs (unwashed), and deer mice (*Peromyscus sp.*) in the areas behind the Los Alamos Canyon Weir (LACW) in 2005 (Fresquez 2006a, Fresquez 2006b) and 2006 and behind the Pajarito Canyon Flood Retention Structure in 2006. Samples were analyzed for some or all of the following constituents: radionuclides, TAL metals, HE, SVOCs, and PCBs. The following two sections report the 2006 results.

a. The Los Alamos Canyon Weir. Cesium-137, plutonium-238, plutonium-239,240, and americium-241 (Table S8-14); silver, mercury, and lead (Table S8-15); and Aroclor-1260 (Table S8-16) in sediment upstream of the Los Alamos Canyon weir were detected at higher concentrations than the RSRLs. Also, strontium-90, plutonium-239,240, americium-241 (Table S8-17) and lead (Table S8-18) in overstory plants and plutonium-239,240, americium-241, uranium-234 and uranium-238 in whole body mice collected upstream of the LACW were at higher concentrations than RSRLs. These concentrations in 2006 were higher than reported in 2005. All constituents in these media, however, were below SLs and do not pose a potential unacceptable dose to humans or to the other biota sampled. These results are consistent with the human health risk assessment and the baseline ecological risk assessment conducted as part of the Los Alamos/Pueblo Canyons Investigation (LANL 2004).

b. The Pajarito Canyon Flood Retention Structure. Results of radionuclide and nonradionuclide analysis of sediment, vegetation, and small mammal samples collected upstream of the Pajarito Canyon Flood Retention Structure are presented in Table S8-20 through Table S8-25. In general, sediment concentrations of cesium-137, plutonium-239,240, uranium-234, uranium-238, copper, cadmium, silver, mercury, and Aroclor-1254 were above RSRLs; vegetation had concentrations of uranium-234, uranium-238, lead, and silver above RSRLs; and the small mammals had concentrations of plutonium isotopes, americium-241, uranium-234, and uranium-238 above RSRLs. All concentrations of radionuclides and nonradionuclides in all media, however, were below SLs and do not pose a potential unacceptable dose to human health or to the other biota sampled.

2. Radionuclide Concentrations in Trees Growing Along the North Side of MDA B

Four composite samples were collected from trees growing along the north perimeter fence line of MDA B (Figure 8-7). Samples consisted of tree shoot tips collected from every tree growing along a 100-yard section starting from the east end. Samples were submitted to Severn Trent Laboratories, Inc., and analyzed for tritium, strontium-90, cesium-137, plutonium-238, plutonium-239,240, americium-241, uranium-234, uranium-235, uranium-238, and TAL metals. The results of the radionuclide analysis show that most isotopes were either not detected or below RSRLs (Supplemental Data Table S8-26). The few radionuclides above RSRLs—cesium-137 in one sample and plutonium-239,240 in another sample—were below the 0.1 rad/day SL used to assess the dose to the trees. As for the heavy metals, chromium and nickel in one sample and zinc and lead in another sample were above RSRLs; differences between MDA B trees and regional trees were small. All elements were below SLs and do not pose a significant risk to the trees.

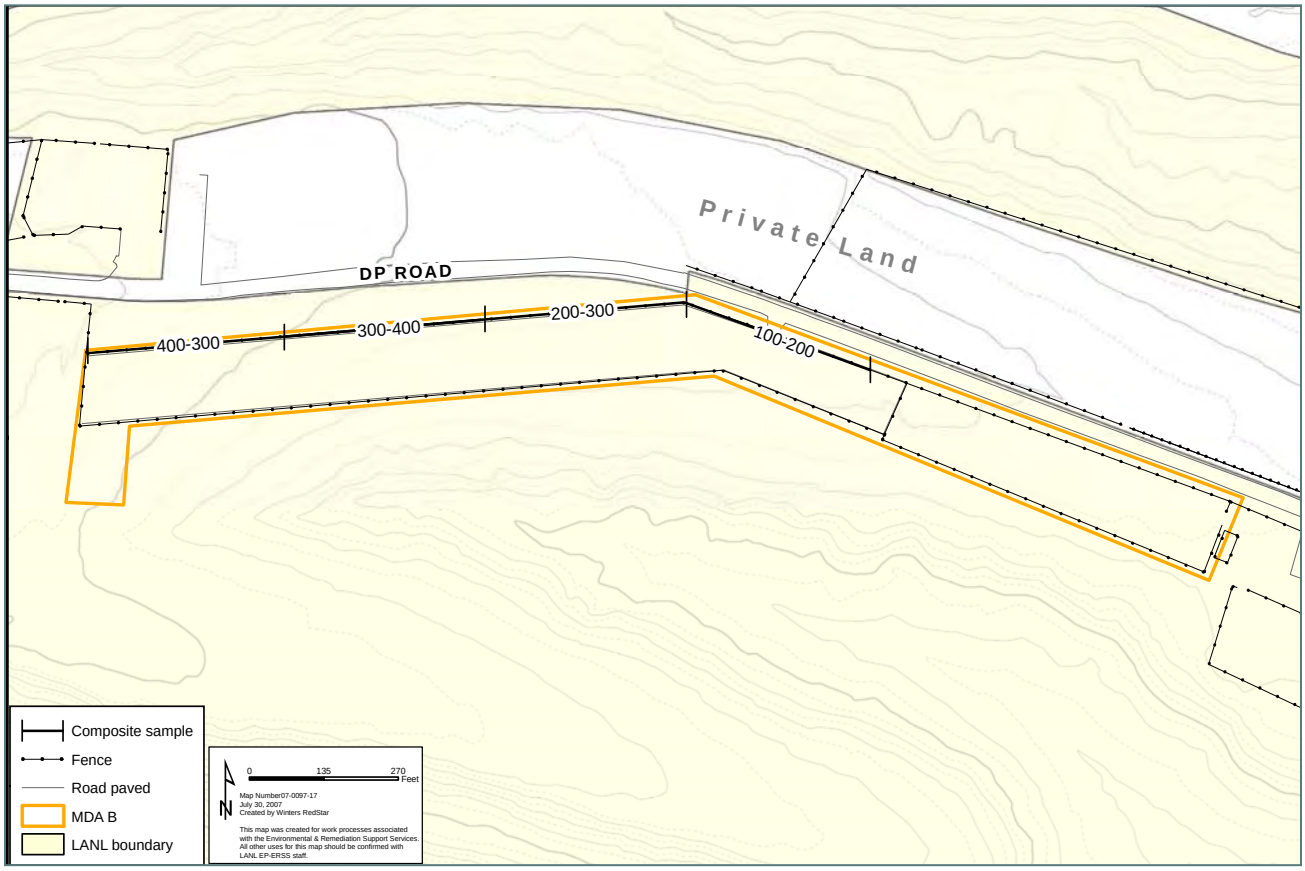


Figure 8-7. Location of composite tree samples collected near MDA B.

D. QUALITY ASSURANCE FOR THE SOIL, FOODSTUFFS AND NONFOODSTUFFS BIOTA PROGRAM

This program uses the same quality assurance (QA) protocols and analytical laboratories as described in Chapter 7.

E. REFERENCES

Allaway 1968: W. H. Allaway, "Agronomic Control over the Environmental Cycling of Trace Elements", in Norman, A.G., ed., Advances in Agronomy, v. 20: New York, Academic Press, p. 235-274 (1968).

Bennett et al. 1996: K. J. Bennett, J. Biggs, and P. Fresquez, "Radionuclide Contaminant Analysis of Small Mammals, Plants, and Sediments within Mortandad Canyon, 1994," Los Alamos National Laboratory report LA-13104-MS (1996).

Bennett et al. 2001: K. J. Bennett, J. Biggs, P. R. Fresquez, and H. T. Haagenstad, "DARHT facility small mammal baseline report for radionuclides (1997–1999)," pp. 41–50, in Baseline concentrations of radionuclides and trace elements in soils, sediments, vegetation, small mammals, birds, and bees around the DARHT facility: construction phase (1996 through 1999), Los Alamos National Laboratory report LA-13808-MS (2001).

Chapman 1966: H. D. Chapman, "Zinc," Chapter 33 in Chapman, H. D., ed., Diagnostic Criteria for Plants and Soil: Riverside, Univ. of Calif. Div. of Agr. Sci., p. 484–499 (1966).

Corely et al. 1981: J. P. Corely, D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite, "A Guide for Environmental Radiological Surveillance at US Department of Energy Installations," US Department of Energy report DOE/EP-0023 (1981).

DOE 1991: US Department of Energy, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance," US Department of Energy report DOE/EH-0173T (January 1991).

DOE 1993: US Department of Energy, "Radiation Protection of the Public and the Environment," US Department of Energy Order 5400.5 (1993).

DOE 1996: US Department of Energy, "Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Mitigation Action Plan," USDOE/EIS-0228 (1996).

DOE 1999: US Department of Energy, "The Long-Term Control of Property: Overview of Requirements in Orders DOE 5400.1 & DOE 5400.5, EH-412-0014/1099" (October 1999).

DOE 2000: US Department of Energy, "Special Environmental Analysis for the Department of Energy, National Nuclear Security Administration, Actions Taken in Response to the Cerro Grande Fire at Los Alamos National Laboratory," Los Alamos Area Office report, DOE/SEA-03, Los Alamos, NM. (2000).

DOE 2002: US Department of Energy, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," US Department of Energy Standard DOE-STD-1153-2002 (July 2002).

DOE 2003: US Department of Energy, "Environmental Protection Program," US Department of Energy Order 450.1 (2003).

FDA 2000: Food and Drug Administration, "Action Levels for Poisonous or Deleterious Substance in Human Food and Animal Feed," Washington, DC (2000).

Fresquez 2004: P. R. Fresquez, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation around the DARHT Facility during 2004," Los Alamos National Laboratory report LA-14176-PR (2004).

Fresquez 2005: P. R. Fresquez, "Radionuclides in Small Mammals Collected at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility during 2001–2003," Los Alamos National Laboratory report LA-14192-MS (2005).

Fresquez 2006a: P. R. Fresquez, "The Characterization of Biotic and Abiotic Media Upgradient and Downgradient of the Los Alamos Canyon Weir," Los Alamos National Laboratory report LA-14268-MS (2005).

Fresquez 2006b: P. R. Fresquez, "The Characterization of Biotic and Abiotic Media Up-Gradient and Down-Gradient of the Los Alamos Canyon Weir: Revision 1," Los Alamos National Laboratory report LA-14308-MS (2006).

Fresquez 2007: P.R. Fresquez, "Radionuclides in Small Mammals Collected at the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility During 2001–2006: Revision 1," Los Alamos National Laboratory report LA-14320 (2007).

Fresquez and Gonzales 2000: P. R. Fresquez and G. J. Gonzales, "Soil, Foodstuffs, and Associated Biota," p. 316. in Environmental Surveillance at Los Alamos during 1999, Los Alamos National Laboratory report LA-13775 (2000).

Fresquez and Gonzales 2004: P. R. Fresquez and G. J. Gonzales, "Radionuclide Concentrations in Vegetation at the Los Alamos National Laboratory in 2002/2003," Los Alamos National Laboratory report LA-14160-PR (2004).

Fresquez and Lopez 2004: P. R. Fresquez and E. Lopez, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2004 Growing Season," Los Alamos National Laboratory report LA-14181-PR.

Fresquez et al. 2001a: P. R. Fresquez, G. J. Gonzales, T. Haarmann, J. Nyhan, and B. Gallaher, "Soil, Foodstuffs, and Associated Biota," pp. 407–489, in Environmental Surveillance at Los Alamos during 2000, Los Alamos National Laboratory report LA-13861-ENV (2001).

Fresquez et al. 2001b: P. R. Fresquez, J. W. Nyhan, and H. T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, and Vegetation around the DARHT Facility," in Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility: Construction Phase (1996 through 1999), Nyhan et al., Los Alamos National Laboratory report LA-13808-MS (2001), pp. 48–76.

Fresquez et al. 2002: P. R. Fresquez, G. J. Gonzales, T. Haarmann, J. Nyhan, and B. Gallaher, "Soil, Foodstuffs, and Associated Biota," pp. 419-521, in Environmental Surveillance at Los Alamos during 2001, Los Alamos National Laboratory report LA-13979-ENV (2002).

Fresquez et al. 2004a: P. R Fresquez, J. W. Nyhan, and E. Lopez, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 2003 Growing Season," Los Alamos National Laboratory report LA-14108-PR (2004).

Fresquez et al. 2005a: P. R. Fresquez, G. Gonzales, and C. Hathcock, "Foodstuffs and Biota Monitoring," in Environmental Surveillance at Los Alamos during 2004, Los Alamos National Laboratory report LA-14239-ENV (2005), pp. 199–210.

Fresquez et al. 2005b: P. R. Fresquez, M.W. McNaughton, and M.J. Winch, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during 2005," Los Alamos National Laboratory report LA-14251-PR (2005).

Fresquez et al. 2006: P. R. Fresquez, G.J. Gonzales, M. McNaughton, C. Hathcock, and G. Vigil, "Foodstuffs and Biota Monitoring," pp. 213-230, in Environmental Surveillance at Los Alamos during 2005, Los Alamos National Laboratory report LA-14304-ENV (2006).

Fresquez et al. 2007: P. R. Fresquez, J. K. Ferenbaugh, and L. Naranjo, Jr., "Moisture Conversion Ratios for the Foodstuffs and (Nonfoodstuffs) Biota Environmental Surveillance Programs at Los Alamos National Laboratory, Revision 2," Los Alamos National Laboratory document LA-UR-07-0280 (2007).

Gallaher et al. 1997: B. M. Gallaher, D. W. Efurd, D. J. Rokop, T. M. Benjamin, and A. K. Stoker, "Survey of Plutonium and Uranium Atom Ratios and Activity Levels in Mortandad Canyon," Los Alamos National Laboratory report LA-13379-MS (1997).

Gonzales et al. 2000: G. J. Gonzales, P. R. Fresquez, M. A. Mullen, and L. Naranjo, Jr., "Radionuclide Concentrations in Vegetation at the Los Alamos National Laboratory in 1998," Los Alamos National Laboratory report LA-13704-PR (2000).

Gough et al. 1979: L. P. Gough, H. T. Shacklette, and A. A. Case, Element Concentrations Toxic to Plants, Animals, and Man, Geological Survey Bulletin 1466 (U.S. Government Printing Office, Washington, D.C. 1979).

Haarmann 2001: T. K. Haarmann, "Baseline Concentrations of Radionuclides and Heavy Metals in Honey Bee Samples Collected near DARHT." in J. Nyhan et al., Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility: Construction Phase (1996 through 1999), Los Alamos National Laboratory report LA-13808-MS (2001).

Hathcock and Haarmann 2004: C. D. Hathcock and T. K. Haarmann, "Concentrations of Radionuclides and Trace Elements in Honey Bee Samples Collected Near DARHT in 2003," Los Alamos National Laboratory report LA-UR-04-8349 (2004).

Keith 1991: L. H. Keith, *Environmental Sampling and Analysis: A Practical Guide* (CRC Press, Inc., Baca Raton, FL, 1991).

LANL 2004: "Los Alamos and Pueblo Canyons Investigation Report," Los Alamos National Laboratory report LA-UR-04-2714 (2004).

Lopez 2002: E. Lopez, "MDA G and L Environmental Monitoring Plan for FY 2002," Los Alamos National Laboratory report LA-UR-02-6128 (2002).

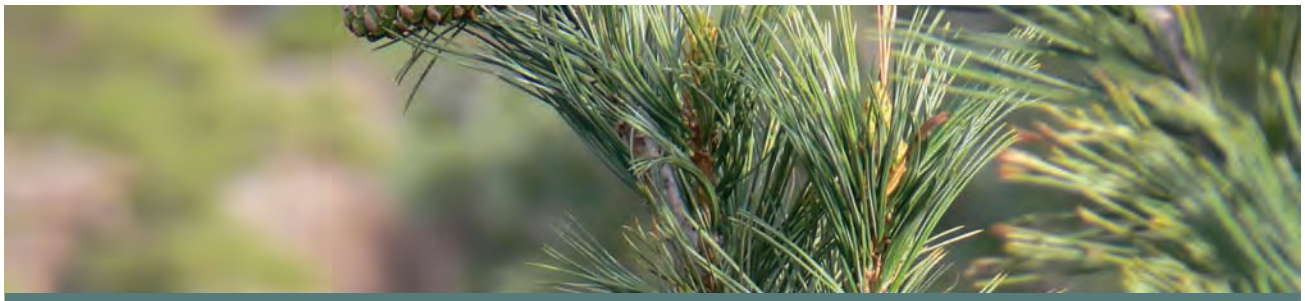
McNaughton 2006: M. McNaughton, "Calculating Dose to Non-Human Biota," ENV-MAQ-514, R1 (2006).

NMED 2006: "Technical Background Document for Development of Soil Screening Levels, Rev. 4.0," (2006).

Nyhan et al. 2001: J. W. Nyhan, P. R. Fresquez, K. D. Bennett, J. R. Biggs, T. K. Haarmann, D. C. Keller, and H. T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility: Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).

TNM 2004: "Dining on the Wild Side," Section C, page C-1 to C-2, *The Santa Fe New Mexican*, August 25, 2004.

Whicker and Schultz 1982: W. F. Whicker and V. Schultz, *Radioecology: Nuclear Energy and the Environment*, CRC Press, Inc., Boca Raton, FL (1982).



9. Environmental Restoration

contributing author:
Rich Mirenda

To Read About	Turn to Page
Introduction	*271*
Corrective Action Project	*278*
Water Stewardship Project	*289*
TA-21 Closure Project	*294*
Quality Assurance Program	*299*
References	*300*

A. INTRODUCTION

The Environmental Programs (EP) Directorate at Los Alamos National Laboratory (LANL or the Laboratory) is leading the Laboratory's participation in a national US Department of Energy (DOE) effort to clean up sites and facilities formerly involved in weapons research and development. The EP Directorate's goal is to ensure past operations do not threaten human or environmental health and safety in and around Los Alamos County. To achieve this goal, the Laboratory is investigating sites potentially contaminated by past operations; the sites under investigation are designated as consolidated units, solid waste management units (SWMUs), or areas of concern (AOCs).

The New Mexico Environment Department (NMED) regulates the cleanup of hazardous wastes and hazardous constituents under the New Mexico Hazardous Waste Act. Corrective actions for the releases of hazardous waste and hazardous constituents at the Laboratory are subject to the March 1, 2005 Compliance Order on Consent (the Consent Order). The Consent Order was issued pursuant to the NM Hazardous Waste Act (NM Statutes Annotated [NMSA] 1978, § 74-4-10) and the NM Solid Waste Act (NMSA 1978, §74-9-36[D]).

The DOE regulates the cleanup of radioactive contamination. Radionuclides are regulated under DOE Order 5400.5, "Radiation Protection of the Public and the Environment," and DOE Order 435.1, "Radioactive Waste Management." DOE is implementing corrective actions pursuant to the Atomic Energy Act for releases of radionuclides in conjunction with the activities required under the Consent Order.

1. 2006 Projects

Environmental restoration work is managed under three projects that encompass sites (consolidated units, SWMUs, and AOCs) slated for investigation and/or remediation. The projects collect, manage, and report environmental data, and utilize the data to support site decisions. Each of these projects is briefly described below.

a. Corrective Action Project. This project includes the investigation and possible remediation of consolidated units, SWMUs, and AOCs intermixed with active Laboratory operations as well as consolidated units, SWMUs, or AOCs located within the Los Alamos townsite (property currently owned by private citizens, businesses, or Los Alamos County) and on property administered by the US Forest Service (USFS), the National Park Service, and the DOE.

b. Water Stewardship Project. This project includes the canyons investigations, the groundwater monitoring program (implemented through the Interim Facility-Wide Groundwater Monitoring Plan [LANL 2006k]), storm water monitoring, the minimization of erosion, and the transport of contaminants from sites by storm water runoff.

c. Technical Area (TA)-21 Closure Project. This project includes the investigation and the implementation of corrective actions for Material Disposal Areas (MDAs) A, B, T, U, and V and a broad category of environmental sites (e.g., septic systems, outfalls, disposal areas, a polychlorinated biphenyl [PCB] container storage area, drum storage areas, and a historical waste treatment laboratory) referred to as the Delta Prime (DP) Site Aggregate Area at TA-21.

In addition to the sites investigated and/or remediated under the EP Directorate projects described above, several consolidated units, SWMUs, and AOCs were managed in 2006 under the direct supervision of the DOE Los Alamos Site Office. The work at these sites involved investigation and remediation activities at Consolidated Unit 73-002-99 and four interim measures conducted at SWMUs 03-010(a) and 03-001(e). In addition, engineered covers were constructed as the final remedies for SWMUs 73-001(a) and 73-001(d) (the Airport Landfill and Debris Disposal Area, respectively).

2. Work Plans and Reports

The projects wrote and/or revised 16 work plans and 14 reports and submitted them to NMED during 2006. The work plans propose investigation activities designed to characterize SWMUs, AOCs, consolidated units, aggregates, canyons, and watersheds. The data, which are presented in remedy completion or investigation reports, are used to determine if the nature and extent of contamination is defined and to determine the potential risks to human health and the environment posed by contaminants. Depending on the data and the assessment results, sites may require additional investigation, remediation, monitoring, or no further action.

Tables 9-1 and 9-2 summarize the work plans and reports submitted and approved in 2006, the work plans and reports submitted prior to 2006 but approved in 2006, and the work plans and reports submitted in 2006 but not yet approved. Table 9-3 summarizes the 28 SWMUs and AOCs that have been completed and for which NMED granted Certificates of Completion under the Consent Order through 2006. The remainder of this section presents summaries of the investigations for which activities were started, continued, and/or completed in 2006 and those investigations for which reports were submitted in 2006. Figure 9-1 shows the locations where significant environmental characterization or remediation work was performed.

Table 9-1
Work Plans Submitted and/or Approved in 2006

Document Title	Date Submitted	Date Approved	Status
Work Plan for the North Canyons	9/21/01	8/17/06[a]	Work plan activities started in 2006 and continuing in 2007
Investigation Work Plan for Middle Los Alamos Canyon Aggregate Area	12/22/2005	n/a[b]	Revised the investigation work plan
Investigation Work Plan for Middle Los Alamos Canyon Aggregate Area, Revision 1	5/3/2006	5/30/2006[a]	Scheduled to start in 2007
Investigation Work Plan for Guaje, Barrancas, Rendija Canyons Aggregate Areas	7/22/2005	1/5/2006[a]	Investigation activities started in 2006 and will be completed in 2007
Revisions to DP Site Aggregate Area Investigation Work Plan	7/29/2005	n/a	Work plan activities completed for five sites; investigation activities continuing in 2007

Table 9-1 (continued)

Document Title	Date Submitted	Date Approved	Status
Supplemental Investigation Work Plan for DP Site Aggregate Area at Technical Area 21	4/4/2006	n/a	Work plan activities completed for five sites; investigation activities continuing in 2007
Accelerated Corrective Action Work Plan for the Investigation and Remediation of Area of Concern 16-024(v) and Solid Waste Management Units 16-026(r) and 16-013(f) at Technical Area 16	1/20/2006	3/20/2006[a]	Work plan activities completed
Corrective Measures Evaluation Plan for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54	3/10/2006	—[c]	Deferred until investigation activities completed
Investigation/Remediation Work Plan for Material Disposal Area B, Solid Waste Management Unit 21-015, at Technical Area 21	3/27/2006	n/a	Work plan revised
Investigation/Remediation Work Plan for Material Disposal Area B, Solid Waste Management Unit 21-015, at Technical Area 21, Revision 1	10/23/2006	—	Under review in 2006
Investigation Work Plan for Chromium Contamination in Groundwater	3/31/2006	5/5/2006[a]	Work plan activities completed
Accelerated Corrective Action Work Plan for the Investigation and Remediation of SWMU 61-002	4/20/2006	5/2/2006[a]	Work plan activities completed
Investigation Work Plan for Upper Los Alamos Canyon Aggregate	4/28/2006	11/6/2006	Scheduled to start in 2008
Historical Investigation Report for Upper Los Alamos Canyon Aggregate	4/28/2006	n/a	n/a
Corrective Measures Evaluation Plan for Material Disposal Area G at Technical Area 54	5/3/2006	—	Deferred until investigation activities completed
Pajarito Canyon Biota Investigation Work Plan	8/1/2006	—	Under review in 2006
Work Plan for Supplemental Sampling at Material Disposal Area G, Consolidated Unit 54-013(b)-99	9/26/2006	11/13/2006	Scheduled to start in 2007
Investigation Work Plan for South Canyons	9/28/2006	—	Under review in 2006
Historical Investigation Report for South Canyons	9/28/2006	n/a	n/a
Cañon de Valle Aggregate Area Investigation Work Plan	9/29/2006	—	Under review in 2006
Historical Investigation Report for Cañon de Valle Aggregate Area	9/29/2006	n/a	n/a
Supplemental Investigation Work Plan for Sampling at Material Disposal Area L, Solid Waste Management Unit 54-006	10/27/2006	11/13/2006[a]	Scheduled to start in 2007
Sampling and Analysis Plan for Impoundments B, C, and D at Material Disposal Area L, Solid Waste Management Unit 54-006, Revision 1	10/27/2006	11/13/2006[a]	Scheduled to start in 2007

[a] Work plans approved with modifications and/or directions.

[b] n/a = Not applicable.

[c] "—" = Approval not received in 2006.

Table 9-2
Reports Submitted and/or Approved in 2006

Document Title	Date Submitted	Date Approved	Status
Voluntary Corrective Action Completion Report for SWMU 16-016(c)-99, Revision 1	11/26/2003	1/10/2006	Work completed
Voluntary Corrective Action Completion Report using Soil Vapor Extraction System (AOC 00-027)	6/3/2005	8/30/2006	Work completed
Corrective Measure Study Report for SWMU 16-021(c)-99, Revision 1	6/15/2005	n/a[a]	Final decision remedy selection rendered by NMED in 2006
Remedy Completion Report for former TA-19	7/29/2005	6/27/2006	Work completed
TA-53 Surface Impoundments [SWMU 53-002(a)-99 and AOC 53-008] Investigation Report, Revision 1	9/8/2005	7/25/2006	Work completed
Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54	9/8/2005	n/a	Additional sampling required; supplemental work plan submitted and approved in 2006 (see Table 9-1)
MDA L Investigation Report	9/13/2005	n/a	Additional sampling required
Investigation Report for Mortandad/Ten Site Canyons Aggregate Area	9/30/2005	n/a	Remediation and additional sampling required; revised investigation report due in 2007
Los Alamos and Pueblo Canyons Supplemental Investigation Report (revised risk assessment)	12/15/2005	—[b]	Provided additional information; under review in 2006
Remedy Completion Report for AOC 03-001(i) and SWMUs 03-029 and 61-002	12/15/2005	9/13/2006	Additional sampling and/or remediation required for SWMU 61-002
Investigation Report for the TA-16-340 Complex	1/31/2006	10/25/2006[c]	Additional sampling required
Investigation Report for Material Disposal Area U, Consolidated Unit 21-017(a)-99, at Technical Area 21	2/6/2006	n/a	Directed to revise report
Investigation Report for Material Disposal Area U, Consolidated Unit 21-017(a)-99, at Technical Area 21, Revision 1	9/8/2006	9/28/2006	Work completed
Investigation Report for Solid Waste Management Units 03-010(a) and 03-001(e) at Technical Area 3	4/20/2006	—	Additional investigation required; four interim measures implemented in 2006
Remedy Completion Report for the Investigation and Remediation of Solid Waste Management Unit 33-013	3/2/2006	8/30/2006	Work completed
Investigation Report for Material Disposal Area L, Revision 1	3/10/2006	—	Additional sampling required; supplemental work plan and a sampling and analysis plan submitted and approved in 2006 (see Table 9-1)
Summary of Pajarito Canyon Phase 1 Sediment Investigations	3/22/2006	n/a	Phase 2 sampling conducted
Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99	8/31/2006	11/29/2006[c]	Additional sampling and other activities required

Table 9-2 (continued)

Document Title	Date Submitted	Date Approved	Status
Investigation Report for Material Disposal Area T, Consolidated Unit 21-016(a)-99, at Technical Area 21	9/18/2006	—	Under review in 2006
Mortandad Canyon Investigation Report	10/27/2006	—	Under review in 2006
Investigation Report for Consolidated Unit 21-018(a)-99, Material Disposal Area V, at Technical Area 21	10/31/2006	n/a	Additional sampling and revised investigation report to be submitted in 2007
Investigation Report for Material Disposal Area A, Solid Waste Management Unit 21-014, at Technical Area 21	11/9/2006	—	Under review in 2006
Interim Measures Investigation Report for Chromium Contamination in Groundwater	11/30/2006	12/27/2006[c]	Additional investigation activities required
Investigation Report for Solid Waste Management Unit 50-009, Material Disposal Area C, at Technical Area 50	12/6/2006	—	Required sampling to be completed in 2007

[a] n/a = Not applicable.

[b] "—" = Approval not received in 2006.

[c] Reports approved with modifications and/or directions.

Table 9-3
SWMUs and AOCs Granted Certificates of Completion in 2006

Site	Corrective Action Complete with Controls	Corrective Action Complete without Controls	Date Approved
SWMU 16-006(e)		X	1/10/2006
SWMU 16-010(a)		X	1/10/2006
SWMU 16-016(c)		X	1/10/2006
SWMU 0-030(a)		X	2/23/2006
SWMU 0-030(b)		X	2/23/2006
SWMU 0-030(l)		X	2/23/2006
SWMU 0-030(m)		X	2/23/2006
SWMU 0-033(a)		X	2/23/2006
SWMU 0-033(b)		X	2/23/2006
AOC 0-004		X	2/23/2006
AOC 0-010(a)		X	2/23/2006
AOC 0-010(b)		X	2/23/2006
AOC 0-029(a)		X	2/23/2006
AOC 0-029(b)		X	2/23/2006
AOC 0-029(c)		X	2/23/2006
SWMU 19-001		X	6/27/2006
SWMU 19-002		X	6/27/2006
SWMU 19-003		X	6/27/2006
AOC C-19-001		X	6/27/2006
SWMU 33-013	X		8/30/2006
SWMU 21-017(a)	X		9/28/2006
SWMU 21-017(b)	X		9/28/2006
SWMU 21-017(c)	X		9/28/2006
SWMU 53-002(a)	X		9/13/2006
SWMU 53-002(b)	X		9/13/2006
AOC 3-001(i)	X		10/13/2006
AOC 0-030(k)		X	12/6/2006
AOC 0-034(a)		X	12/6/2006

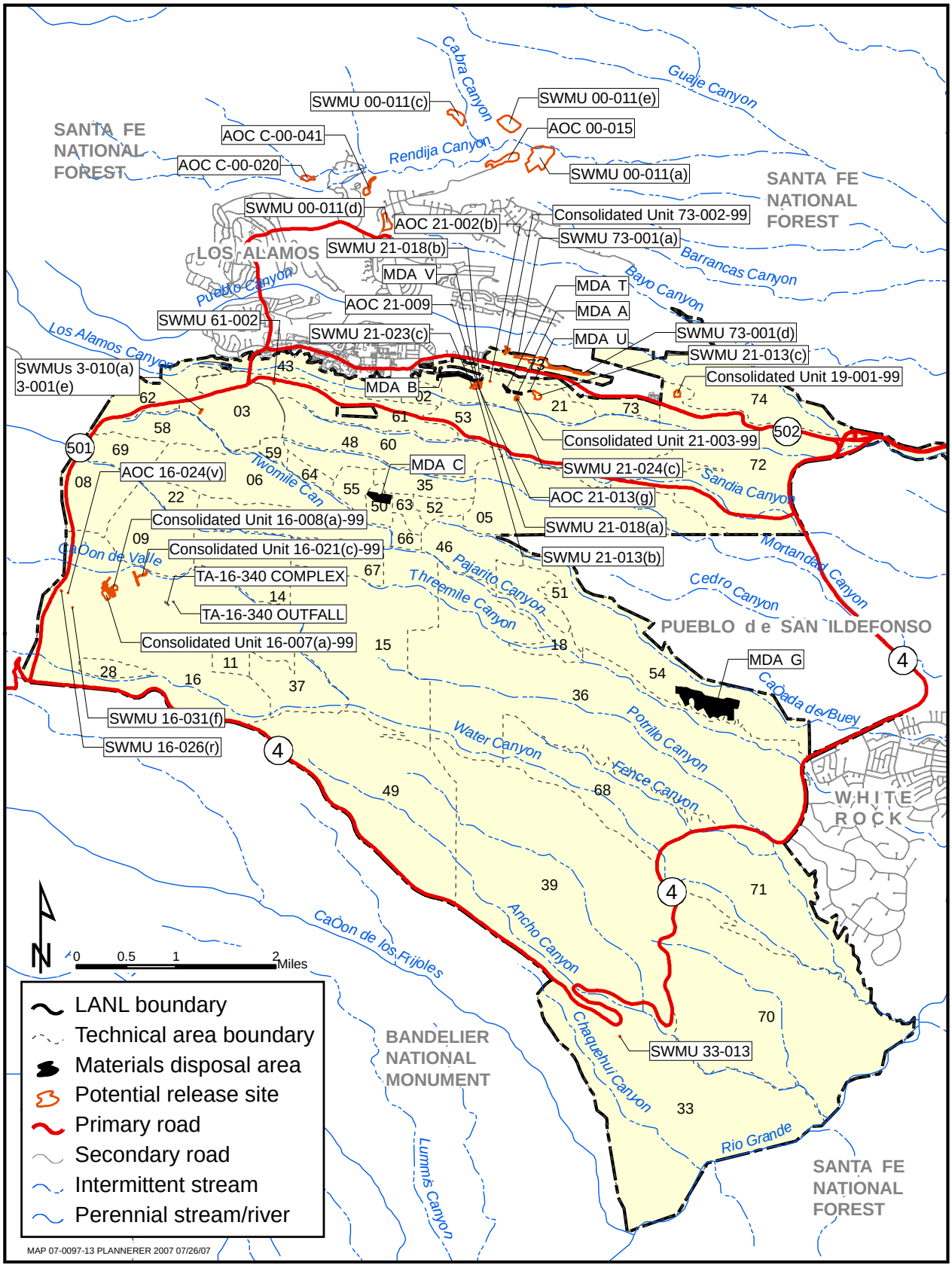


Figure 9-1. Location of MDAs and other SWMUs or AOCs where remediation and/or characterization work was performed in 2006.

B. CORRECTIVE ACTION PROJECT

The Laboratory and DOE conducted the following investigations and activities in 2006:

- Remedy completion report for SWMU 33-013 was submitted and approved.
- Additional samples were collected and results submitted for Consolidated Unit 19-001-99 and approved.
- Accelerated corrective action work plan for SWMU 61-002 was approved and the investigation and remediation were completed.
- Investigation activities were conducted and an investigation report for MDA C was submitted; required additional sampling to be completed.
- Investigation work plan for Guaje, Barrancas, Rendija Canyons Aggregate Area was approved with modifications and sampling activities were commenced.
- Field investigations for the Pueblo Canyon Aggregate Area were started and completed.
- The accelerated corrective action work plan for AOC 16-024(v) and SWMUs 16-026(r) and 16-031(f) was submitted and approved with modifications. The investigation and remediation activities were completed.
- Investigation report for the TA-16-340 Complex was submitted and approved with additional sampling required.
- Field investigations were commenced for Consolidated Units 16-007(a)-99 (30s Line) and 16-008(a)-99 (90s Line).
- Investigation report for groundwater associated with Consolidated Unit 16-021(c)-99 (260 Outfall) was submitted and approved with direction.
- Additional information and reports including periodic monitoring reports for MDAs H, L, and G were submitted.
- Investigation and remediation activities continued at Consolidated Unit 73-002-99.
- Interim measures conducted at SWMUs 03-010(a) and 03-001(e).
- Final remedy construction for the TA-73 Airport Landfill, SWMUs 73-001(a) and 73-001(d).

The following sections summarize the investigations started, continued, and/or completed in 2006.

1. SWMU 33-013

a. Site Description and History. SWMU 33-013 was an uncovered surface storage area for items awaiting disposal. The storage area was approximately 50 ft x 50 ft and was located on the asphalt surface inside the northeast corner of the fence surrounding the former TA-33 tritium facility (Building 33-86). Materials stored at SWMU 33-013 included vacuum pumps, drums containing oil contaminated with tritium and possibly with metals and solvents, and dumpsters of miscellaneous materials. The storage activities were discontinued in 1989.

b. Remediation and Sampling Activities. The Laboratory conducted investigation and remediation activities at SWMU 33-013 in accordance with the approved work plan (LANL 2005c; NMED 2005d). Field activities were completed in 2005 and the report was submitted to NMED in 2006. The *Remedy Completion Report for the Investigation and Remediation of Solid Waste Management Unit 33-013* (LANL 2006d) presents a complete description of the field activities, data review, and risk assessments for this site. Remediation

activities included the excavation and removal of base course, an asphalt pad, and soil potentially contaminated by storage activities. The activities resulted in a total excavated area of approximately 51 ft x 53 ft x 2 ft deep and approximately 540 yd^3 of soil and base course removed. Twenty confirmation samples were collected from 10 locations following the remediation of SWMU 33-013.

The excavation was backfilled with clean fill and base course. The fill was compacted and contoured to keep storm water from running off the pad site onto the surrounding mesa. No reseeding of the area was required.

c. Conclusions and Recommendations. The human health and ecological risk assessments determined that contaminant concentrations are below NMED and DOE target levels. The nature and extent of contamination at SWMU 33-013 is defined, and there is no potential unacceptable risk/dose under the industrial and construction worker scenarios or to ecological receptors.

NMED reviewed and subsequently approved the report. NMED determined that the requirements of the Consent Order have been satisfied for this SWMU and issued a Certificate of Completion for "Corrective Action Complete with Controls" for SWMU 33-013 (NMED 2006g). The controls require that the land occupied by SWMU 33-013 remain under industrial use. The Laboratory assumes responsibility for the controls specified for the site by NMED.

2. Consolidated Unit 19-001-99

a. Site Description and History. Consolidated Unit 19-001-99 (comprised of a septic system [SWMU 19-001], surface disposal area [SWMU 19-002], sewer drainline and outfall [SWMU 19-003], and potential soil contamination beneath buildings [AOC C-19-001]) is located on Los Alamos Mesa east of the Los Alamos County Airport and the East Gate industrial park. The site was used to conduct spontaneous-fission experiments and to store radioactive source material. It includes access to and a portion of Camp Hamilton Trail, a public recreational hiking trail.

b. Remediation and Sampling Activities. The Laboratory conducted an accelerated cleanup at Consolidated Unit 19-001-99 (LANL 2004a; NMED 2004b) in 2005. A complete description of the field activities, data review, and risk assessments for this site is presented in the *Remedy Completion Report for the Investigation and Remediation of Consolidated Unit 19-001-99* (LANL 2005g). Because the initial characterization sampling did not define the extent of inorganic chemicals for this consolidated unit, additional samples were collected from mesa top locations. The results were submitted to NMED in 2006.

c. Conclusions and Recommendations. The additional sampling did not detect cobalt and chromium above background levels at depth. Based on the results of all of the characterization activities at Consolidated Unit 19-001-99, the nature and extent of contamination is defined. The risk assessment presented in the original remedy completion report (LANL 2005g) showed no potential unacceptable risk under a residential scenario and no potential risk to ecological receptors.

NMED determined that the requirements of the Consent Order have been satisfied for the three SWMUs and one AOC that make up this consolidated unit. NMED issued Certificates of Completion for "Corrective Action Complete without Controls" for SWMUs 19-001, 19-002, and 19-003, and AOC C-19-001 (NMED 2006e). Corrective action complete without controls was granted because the sites have no potential unacceptable risk to human receptors under a residential land-use scenario.

3. SWMU 61-002

a. Site Description and History. SWMU 61-002 is a former storage area located east of the Radio Repair Shop on the south side of Jemez Road. The SWMU was historically used to store capacitors, transformers,

oil-filled containers, and unmarked containers. Before 1985, used oil contaminated with PCBs was stored in containers within the fenced area. The area was also used to store large spools of wire and cable.

b. Remediation and Sampling Activities. The Laboratory conducted corrective action activities at AOC 03-001(i) and SWMUs 03-029 and 61-002 because these sites were in the path of the security perimeter road and would be inaccessible after construction. A complete description of the field activities, data review, and risk assessments for this site is presented in the *Remedy Completion Report for the Investigation and Remediation of Area of Concern 03-001(i) and Solid Waste Management Units 03-029 and 61-002* (LANL 2005j).

During the 2005 investigation of SWMU 61-002, the Laboratory discovered an area of petroleum-contaminated soil and buried fuel lines in the northwest portion of the SWMU. The Laboratory submitted a work plan describing the approach for additional investigation activities at SWMU 61-002 to NMED (LANL 2006h), which approved the work plan with modifications (NMED 2006c).

Additional sampling was necessary to complete the characterization of the extent of the petroleum contamination and boreholes were drilled within and around the area to determine the lateral and vertical extent.

c. Conclusions and Recommendations. The Laboratory completed additional fieldwork at SWMU 61-002 in 2006 and submitted a remedy completion report to NMED in 2007 describing all the activities conducted in 2005 and 2006 and presenting the results.

4. MDA C

a. Site Description and History. MDA C, an inactive 11.8-acre landfill, is located within TA-50 at the head of Ten Site Canyon. MDA C consists of seven disposal pits and 108 shafts; the depths of the pits range from 12 to 25 ft and the shafts range from 10 to 25 ft below the original ground surface. Ten shafts in Shaft Group 3 (Shafts 98–107) are lined with 12-in.-thick concrete, while the rest of the pits and shafts are unlined. MDA C operated from May 1948 to April 1974 but received waste only intermittently from 1968 until it was decommissioned in 1974. Wastes disposed of at MDA C consisted of liquids, solids, and containerized gases generated from a broad range of nuclear energy research and development activities conducted at the Laboratory. These wastes included uncontaminated classified materials, metals, hazardous materials, and radioactively contaminated materials.

b. Remediation and Sampling Activities. Investigation activities at MDA C began in 2005 and concluded in 2006 according to the approved MDA C investigation work plan (LANL 2005i; NMED 2005b; NMED 2005k). A complete description of the field activities, data review, and risk assessments for this site is presented in the *Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50* (LANL 2006u). LANL conducted previous investigation work at MDA C in 1993, 1995, 1996, and 2004.

Thirty-three boreholes were drilled during the 2005–2006 subsurface investigation at MDA C. An additional three boreholes were drilled to collect paired core and pore-gas samples for the purpose of correlating volatile organic compound (VOC) concentrations in tuff with VOC concentrations in pore-gas. One borehole was drilled to a depth of 620 ft below ground surface (bgs) to define the vertical extent of contamination as well as to determine the nature and depth of fracture zones and any possible perched saturation zones. The remaining boreholes ranged in depth from 90 ft to 300 ft bgs. Subsurface core samples were collected from a minimum of five depths in each borehole. Additional samples were collected at fracture zones or zones of elevated moisture content.

c. Conclusions and Recommendations. Inorganic, organic, and radionuclide contaminants were identified at MDA C. MDA C was evaluated for potential risk and dose to human health under an industrial scenario. The

total excess cancer risk, hazard index (HI), and total dose were less than NMED and DOE target levels. We conducted an ecological risk screening assessment and found no potential risk to ecological receptors at MDA C.

Additional characterization activities at MDA C are necessary. The Laboratory will drill four vertical boreholes between Pits 1 through 4 in 2007. Additional surface samples will be collected to confirm the results of the screening-level data for inorganic chemicals and to define the nature and extent of potential contamination. The Laboratory will continue to monitor pore-gas at MDA C.

Following review of the investigation report by NMED, the Laboratory developed and submitted a Phase 2 investigation work plan. In the work plan, we proposed several existing boreholes be advanced deeper into the Otowi Member of the Bandelier Tuff and new boreholes be drilled to confirm the vertical extent of VOC pore-gas contamination.

5. Guaje/Barrancas/Rendija Canyons Aggregate Area

a. Site Description and History. The Guaje/Barrancas/Rendija Canyons Aggregate Area consists of the following seven sites:

- SWMU 00-011(a) is a 28.5-acre former mortar impact area used in the mid to late 1940s and located on General Services Administration (GSA) land east of the Sportsmen's Club in Rendija Canyon.
- SWMU 00-011(c) is a possible mortar impact area approximately 10 acres in size used in the 1940s and located on GSA and public land managed by the USFS in a tributary of Rendija Canyon north of the Sportsmen's Club.
- SWMU 00-011(d) is a former bazooka firing area approximately five acres in size used in the mid to late 1940s and largely located on Los Alamos County land, except for a small section on private property, in a small north-trending tributary of Bayo Canyon northeast of the intersection of San Ildefonso Road and Diamond Drive.
- SWMU 00-011(e) is a former ammunition impact area approximately 14 acres in size used in the mid to late 1940s and located on GSA and USFS land in a tributary of Rendija Canyon north-northeast of the Sportsmen's Club.
- AOC C-00-020 is a 30-acre possible mortar impact area used in the early 1940s located along the north valley wall of Rendija Canyon. Most of the site lies within the Santa Fe National Forest, except for a small area on the southeastern edge that is private property.
- AOC C-00-041 was the site of a former asphalt batch plant, which operated from the late 1940s to 1958. It is located in a 50- by 600-ft portion of a side slope and drainage channel that flows into Rendija Canyon on USFS land.
- AOC 00-015 is the Sportsmen's Club small-arms firing range, an active range approximately 30 acres in size located on GSA land in Rendija Canyon. The Club is leased to a nonprofit group from DOE. Operations started in 1966 and consist of several firing ranges built and operated by the Sportsmen's Club. The investigation of AOC 00-015 is deferred until the site is no longer active.

b. Remediation and Sampling Activities. NMED approved the Guaje/Barrancas/Rendija Canyons Aggregate Area investigation work plan with modifications (LANL 2005f; NMED 2006a). The Laboratory started field investigations in 2006 based on the approved work plan. Munitions and explosives surveys were completed at the sites to verify similar surveys conducted in the early 1990s. Both munitions and explosives of concern and geophysical surveys will be used to identify and remove any remaining mortar, small arms ammunition, or munitions debris from former impact/firing areas: SWMUs 00-011(a), 00-011(d), and 00-011(e). Although the Laboratory did not find any munitions and explosives of concern or munitions debris in previous surveys at

SWMU 00-011(c) and AOC C-00-020, new surveys will be conducted for verification. If no evidence is found during the prescribed surveys, these two sites will not be characterized further. Soil samples will be collected at sites with past and current munitions and explosives of concern and munitions debris recovery.

c. Conclusions and Recommendations. The Laboratory completed investigation activities and submitted the investigation report to NMED in 2007.

6. Pueblo Canyon Aggregate Area

a. Site Description and History. The Pueblo Canyon Aggregate Area consists of 45 SWMUs and AOCs, which are located within the Pueblo Canyon watershed or on the mesa top and discharged directly to the watershed. The sites include wastewater treatment plants, septic systems, outfalls and drainages, landfills, underground storage tanks, and manholes located in Pueblo Canyon or on former Laboratory property, which is now part of the Los Alamos townsite. In the approved work plan, the Laboratory proposed the investigation of 20 SWMUs/AOCs by the Corrective Action Project. DOE is investigating 11 SWMUs/AOCs, located at the Los Alamos County Airport, which will be reported on separately. Fourteen SWMUs/AOCs were not included because they either have been approved by EPA or have been approved or are pending approval by NMED.

b. Remediation and Sampling Activities. The Laboratory started and completed investigations in 2006 based on the approved work plan with modifications (LANL 2005d; NMED 2005h). The objectives of the investigations were to determine the nature and extent of contamination at the SWMUs and AOCs, provide site characterization data for evaluating potential corrective actions, and conduct characterization/confirmatory sampling. Investigation activities included the removal of septic tank structures and lines where permissible. Characterization/confirmation activities consisted of surface and shallow subsurface sampling, the drilling of angled and/or vertical boreholes, and subsequent sampling of core from the boreholes.

c. Conclusions and Recommendations. The Laboratory will present results of the investigation in the Pueblo Canyon Aggregate Area Investigation Report in 2008.

7. AOC 16-024(v) and SWMUs 16-026(r) and 16-031(f)

a. Site Description and History. AOC 16-024(v) and SWMUs 16-024(r) and 16-031(f) are located on a mesa top of the Pajarito Plateau in the western portion of TA-16.

AOC 16-024(v) is the location of a former high explosive (HE) storage magazine constructed in 1944 and located approximately 100 ft east of the TA-16 steam plant. The structure was used as an HE magazine until 1946 and then used for general storage until it was removed in 1968.

SWMU 16-026(r) is an inactive drainline and outfall from the oil-water separator at fire station #5. The fire station was built in 1952 and remains in use. The outfall area where the oil-water separator overflow line formerly discharged is an unpaved area approximately 70 ft south of the fire station. Currently, the oil-water separator and discharge line are inactive and the floor drains are rerouted to the sanitary sewer.

SWMU 16-031(f) is the former outfall from a decommissioned drinking water chlorination station. The building was constructed in 1944, was stripped of all usable equipment in 1953 when the new chlorination station was brought online, and was removed in 1992. The station was used to disinfect potable water using chlorine gas. Based on the nature of activities at SWMU 16-031(f) no release of hazardous waste or hazardous constituents is known or expected to have occurred.

b. Remediation and Sampling Activities. The Laboratory conducted an accelerated cleanup at AOC 16-024(v) and SWMU 16-024(r). The cleanups were conducted because AOC 16-024(v) and SWMU 16-

024(r) are located in areas that may be excavated for the installation of new utilities and will be inaccessible following construction activities. Characterization or remediation activities were not conducted at SWMU 16-031(f). The work plan (LANL 2006b) was submitted and approved (NMED 2006b) in 2006. The investigation and remediation activities were started and concluded in accordance with the approved work plan in 2006. Investigation activities at AOC 16-024(v) and SWMU 16-024(r) included collection of samples and removal of contaminated soil.

c. Conclusions and Recommendations. The Laboratory reported the results of the investigations in a remedy completion report, which was submitted to NMED in early 2007.

8. TA-16-340 Complex

a. Site Description and History. The TA-16-340 Complex is located near the eastern end of the TA-16 mesa, close to the head of Fishladder Canyon, and consists of Consolidated Unit 13-003(a)-99, the septic system associated with the western area of the P-Site Firing Site; Consolidated Unit 16-003(n)-99, the sump and drainline for former Building 16-342; SWMU 16-003(o), the sumps and drainlines for former Building 16-340; and SWMUs 16-029(f) and 16-026(j2), the sump and drainline for former Building 16-345.

The TA-16-340 Complex operated from 1952 to 1999 and processed and produced large quantities of plastic-bonded explosives. The plastic-bonded explosives were produced by slurrying HE and solvents together with inert binders. HE and solvent-contaminated washwater were routed to six sumps associated with Building 16-340 and to the single sump and outfall associated with Building 16-342. Historically, discharges from these sumps were routed to the Building 16-340 and 16-342 outfalls, respectively.

b. Remediation and Sampling Activities. Field investigations were completed in 2005 based on the approved work plan (LANL 2004c; NMED 2004a). A complete description of the field activities, data review, and risk assessments for this site is presented in the *Investigation Report for the TA-16-340 Complex Consolidated Units 13-003(a)-99 and 16-003(n)-99 and Solid Waste Management Units 16-003(o), 16-026(j2), and 16-029(f)* (LANL 2006a). The Laboratory conducted the initial investigation fieldwork at the TA-16-340 Complex in 1995. The investigation included the sampling of surface soil and sediment, subsurface soil, and subsurface tuff. Surface water samples were also collected at the Fishladder Seep and at the confluence of Fishladder Canyon and Cañon de Valle.

The frame, foundation, and infrastructure for Buildings 16-340, 16-342, and 16-345 were demolished and removed in 2006. Eight sumps, two manholes, and approximately 850 ft of interconnecting drainline were removed. The Laboratory removed approximately 100 yd^3 of contaminated soil from areas associated with removed fixtures and structures. The Laboratory collected 239 soil, fill, tuff, and sediment samples from the TA-16-340 Complex. Additional field activities included two intermediate-depth boreholes (200 ft bgs), two shallow boreholes (approximately 12 ft bgs), and three shallow alluvial groundwater monitoring wells installed in Fishladder Canyon. Surface water samples and pore-gas samples (two rounds) were also collected.

c. Conclusions and Recommendations. We identified inorganic chemicals and organic chemicals as contaminants in soil, sediment, and tuff but identified no radionuclides as contaminants. We detected several organic chemicals (including research department explosive or RDX [also known as hexahydro-1,3,5-trinitro-1,3,5-triazine]) and inorganic chemicals (including barium) above surface water standards or screening levels. We detected three inorganic chemicals above groundwater standards or screening levels. Several of these inorganic chemicals were sporadically detected above standards, primarily in earlier sampling rounds. Some of the inorganic chemicals likely represent naturally occurring material. We detected several VOCs sporadically in the pore-gas samples.

The total excess cancer risks for Consolidated Units 13-003(a)-99 and 16-003(n)-99 and SWMUs 16-026(j2) and 16-029(f) were below the NMED target level for an industrial scenario. For SWMU 16-003(o), the

total excess cancer risk was above the NMED target level for an industrial scenario. The HIs were less than the NMED target level for all consolidated units and SWMUs for an industrial scenario. The evaluation of contaminant concentrations overestimates the potential risk to ecological receptors.

To address the potential risk and extent issues, the Laboratory will conduct additional soil-removal actions and sampling. The alluvial groundwater monitoring wells will be inspected for the presence of water on a quarterly basis and sampled if groundwater is present.

Following review of the investigation report, NMED agreed that additional sampling is required to complete the investigation of the TA-16-340 Complex. LANL will submit a separate investigation report to NMED.

9. Consolidated Units 16-007(a)-99 (30s Line) and 16-008(a)-99 (90s Line)

a. Site Description and History. TA-16 is located in the southwest corner of the Laboratory and covers approximately 2,410 acres (3.8 mi^2). Consolidated Units 16-007(a)-99 (the 30s Line) and 16-008(a)-99 (the 90s Line) are located near the western end of TA-16. These consolidated units consist of former HE processing buildings, former materials storage buildings, production facilities, sumps, drainlines, and outfall systems (drainages) that were associated with the 30s and 90s Lines. Historically, the 30s and 90s Lines were used for HE-processing operations, including electroplating and machining. The settling ponds were used to store wastewater generated in the nearby buildings during HE-processing operations. All the ponds were/are unlined and likely received wastes contaminated with HE and barium and, possibly, uranium, organic cleaning agents, and machining oils.

Consolidated Unit 16-007(a)-99 operated from 1944 to the early 1950s and Consolidated Unit 16-008(a)-99 operated from 1950 to 1970. The 90s Line pond is all that remains of the 30s and 90s Line production facilities. Buildings associated with the discharge to the 30s Line ponds were destroyed by burning. The buildings associated with the discharge to the 90s Line pond were decommissioned. Decommissioning activities included the demolition of buildings and the removal of sumps, blast shields, drainlines, earthen berms, and asphalt roadways.

b. Remediation and Sampling Activities. NMED approved the investigation work plan that addressed the HE ponds areas, which include Consolidated Units 16-007(a)-99 (the 30s Line) settling ponds and 16-008(a)-99 (the 90s Line) at TA-16 (S-Site) (LANL 2005b; NMED 2005g). LANL started field investigations in 2006. Boreholes will be drilled at the 30s and 90s Line ponds and in areas associated with former structures and discharge areas. Samples will be collected during the installation of several types of borings: shallow hollow-stem auger (~15 ft bgs), intermediate-depth (~150 ft bgs), and shallow hand-augered or power-augered (~5 ft bgs).

c. Conclusions and Recommendations. We have planned the investigation activities to be concluded in 2007 and the report is scheduled to be submitted to NMED in late 2007.

10. Consolidated Unit 16-021(c)-99 (260 Outfall) Groundwater Investigation

a. Site Description and History. Building 16-260, located on the north side of TA-16, has been used for HE processing and machining since 1951. Wastewater from machining operations contained dissolved HE and may have contained entrained HE cuttings. At Building 16-260, wastewater treatment consisted of routing the water to 13 settling sumps for recovery of any entrained HE cuttings. From 1951 through 1996, the water from these sumps was discharged to the 260 Outfall, which drained into Cañon de Valle.

As a result of the discharge, both the 260 Outfall and the drainage channel from the outfall were contaminated with HE and barium. The sumps and drainlines of this facility are designated as SWMU 16-003(k), and the

260 Outfall and drainage are designated as SWMU 16-021(c), and comprise Consolidated Unit 16-021(c)-99. SWMU 16-021(c) consists of three portions: an upper drainage channel fed directly by the 260 Outfall, a former settling pond, and a lower drainage channel leading to Cañon de Valle.

b. Remediation and Sampling Activities. Previous Resource Conservation and Recovery Act facility investigations (RFIs) of the former 260 Outfall [Consolidated Unit 16-021(c)-99] found that the outfall and drainage into Cañon de Valle and the canyon are contaminated with HE and barium (LANL 1996; LANL 1998b; LANL 2003). As a result, LANL conducted an investigation to determine whether 260 Outfall discharges affected the intermediate and regional groundwater. A complete description of the field activities, data review, and risk assessments for this site are presented in the *Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99* (LANL 2006l).

The Laboratory installed two regional groundwater wells (wells CdV-R-15-3 and CdV-R-37-2) as part of the investigation. Other regional wells used in this investigation include wells R-18, R-19, R-25, R-26, and R-27, which were installed as part of the Laboratory's hydrogeologic work plan (LANL 1998a), and three existing municipal wells (PM-2, PM-4, and PM-5). The Laboratory installed four intermediate groundwater wells to characterize the hydrogeology of the intermediate zone between the alluvial and regional groundwater horizons—wells CdV-16-1(i), CdV-16-2(i), CdV-16-2(i)r, and CdV-16-3(i)—the last of which was completed as a boring only. Groundwater samples were of two types: boring samples collected during installation of boreholes and well samples collected (usually quarterly) from completed wells.

c. Conclusions and Recommendations. The groundwater analytical results show that the 260 Outfall discharges have affected intermediate and regional groundwater quality in limited areas, primarily by the introduction of RDX and 2,4,6-trinitrotoluene (TNT).

The intermediate groundwater samples had concentrations (less than 80 µg/L) of HE within the area defined by wells R-25, CdV-16-1(i), and CdV-16-2(i)r. In well CdV-16-1(i), RDX exceeded the EPA Region 6 tap water screening limit of 0.61 µg/L (not an applicable standard, for comparison purposes only) (EPA 2005).

For regional groundwater samples, results from well R-25 showed two types of HE, RDX and TNT, above EPA Region 6 tap water screening limits (0.61 and 2.2 µg/L, respectively) (EPA 2005). Concentrations of HE found in regional groundwater well R-25 do not extend to nearby wells located approximately 1.5 mi downgradient from R-25 (wells CdV-R-15-3 and CdV-R-37-2). HE was not detected in well CdV-R-15-3. HE and HE-breakdown products were detected at concentrations below screening limits in two downgradient regional monitoring wells (wells CdV-R-37-2 and R-19) but at low frequencies (approximately one detection in 50 samples collected). We detected RDX once in well R-19 during 2000 but at a concentration less than the tap water screening limit; RDX was not detected in any other LANL wells. Analytical data for HE (1998–2005) in municipal wells PM-2, PM-4, and PM-5 indicated single HE detections in PM-2 (RDX at 0.12 µg/L and 2,6-diamino-6-nitrotoluene at 0.3 µg/L) out of approximately 25 rounds of sampling.

Barium, a chemical of potential concern for the Cañon de Valle alluvial system, was not detected in intermediate or regional groundwater at levels above the NM Water Quality Control Commission groundwater standard (1000 µg/L). We detected tritium in five wells at concentrations well below the NM drinking water standard of 20,000 pCi/L.

The NMED reviewed the investigation report and issued an approval that includes direction and required actions (NMED 2006i). Prior to developing a corrective measures evaluation for this site, the Laboratory will complete a comprehensive assessment of each well or well screen intersecting intermediate and regional groundwater at TA-16. The Laboratory will also conduct an evaluation of each of the wells to determine if the wells are in the optimal locations for use in detection or compliance monitoring. A report summarizing the results of the well assessment will be submitted to NMED.

11. Consolidated Unit 73-002-99 (Airport Ashpile)

a. Site Description and History. Consolidated Unit 73-002-99 is located at the Los Alamos County Airport on the eastern end of the Los Alamos townsite. One portion of the site is located on the mesa top at the edge of Pueblo Canyon, and the other is located on the slope of Pueblo Canyon. Consolidated Unit 73-002-99 consists of four inactive SWMUs and one inactive AOC and includes the following:

- SWMU 73-002, a former waste incinerator, located in Building 73-02, and the ash surface disposal area located on the canyon slope north of the former waste incinerator building. The Laboratory operated the incinerator from 1947 to 1948 to destroy classified Laboratory documents, after which time it was used to burn municipal trash. The surface disposal area is located on the canyon-slope portion of the site and is presently open space accessible to the public.
- AOC 73-003, a former steam-cleaning facility (former Structure 00-1123) for garbage trucks, cans, and dumpsters used to collect municipal waste from the Los Alamos townsite. The Laboratory used the steam-cleaning facility from 1949 to 1970 and demolished it in 1971. The site is now overlain by the asphalt parking lot of the Los Alamos County Airport.
- SWMU 73-004(a), a former septic system (septic tank, drainline, and outfall) that received sanitary waste from toilets and showers in the incinerator building (Building 73-02). The inlet drainline and septic tank were removed in 1996. The mesa top portion is presently paved and is used as a parking lot for the Los Alamos County Airport. The canyon-slope portion of the site is presently open space and is accessible to the public.
- SWMU 73-004(b), a former septic system (septic tank, drainline, and outfall) that received wash water from the steam-cleaning facility (AOC 73-003). The mesa top portion is presently paved and is used as a parking lot for the Los Alamos County Airport. The canyon-slope portion of the site is presently open space and is accessible to the public.
- SWMU 73-006, two former drainlines that discharged to Pueblo Canyon from floor drains in the incinerator building (Building 73-02). The drains are presumed to have handled wash water and to have operated concurrently with the incinerator. The drainlines discharged directly onto the ash disposal area (SWMU 73-002).

b. Remediation and Sampling Activities. The primary objective of this investigation is to complete characterization of Consolidated Unit 73-002-99. Work was conducted in accordance with the approved investigation work plan (ITSI 2005; NMED 2005j).

The investigation activities specified in the approved work plan (ITSI 2005; NMED 2005j) were surface and shallow subsurface sampling, including sampling to define the nature and extent of contamination and confirmation sampling following remediation. Nature and extent sampling at SWMU 73-002 focused on the drainages below the former ash pile because runoff is the primary mechanism for the transport of contaminants from the site. For the mesa top SWMUs and AOC, the Laboratory conducted nature and extent drilling and sampling to augment previous sampling data and to complete the characterization of these sites.

The primary objective of the corrective action at SWMU 73-002 was to remove ash and associated debris from the disposal area on the south slope of Pueblo Canyon below the former incinerator. The Laboratory removed ash and associated debris from the canyon slope using several methods, including hand-picking, mechanical excavation, and vacuuming. The Laboratory performed field screening of the soil and tuff underlying the ash pile to guide waste removal and to aid in collecting soil and tuff samples to verify that cleanup levels had been achieved. The Laboratory performed confirmation sampling within the footprint of the former ash pile to verify that cleanup levels were met.

c. Conclusions and Recommendations. Remediation of contaminated soil and tuff at SWMUs 73-002, 73-004(b), and 73-006 continued into 2007. Additional sampling (confirmation and characterization) was also conducted in 2007 at these SWMUs to define the extent of contamination and to confirm that the cleanup goals were met. An investigation report for Consolidated Unit 73-002-99 was submitted in 2007.

12. SWMUs 03-010(a) and 03-001(e)

a. Site Description and History. SWMUs 03-010(a) and 03-001(e) are located within TA-3 next to the general warehouse (Building 03-0030). SWMU 03-010(a) is located about 30 ft west of Building 03-0030 and SWMU 03-001(e) is immediately adjacent to the western edge of Building 03-0030. Both SWMUs are operationally inactive.

SWMU 03-010(a) was a surface disposal site for vacuum-pump oil containing mercury and radionuclides, generated from a vacuum repair shop located in Building 03-0030 (LANL 1995). During the 1950s, it is estimated that the Laboratory discarded more than 100 lbs of mercury-contaminated vacuum-pump oil onto the canyon edge (LANL 1993).

SWMU 03-001(e) was an active storage area for vacuum-pump repair waste from 1957 to 1992. The Laboratory stored waste oil in drums on the ground and the drums periodically overflowed (LANL 1995).

b. Remediation and Sampling Activities. Several investigations of SWMU 03-010(a) have occurred over the past decade or so. The 2005 investigation of SWMUs 03-010(a) and 03-001(e) sought to establish the source of shallow groundwater, the nature and extent of groundwater contamination, the lateral extent of shallow groundwater, the hydraulic gradient, and groundwater flow rates. A complete description of the field activities, data review, and risk assessments are presented in the *Investigation Report for Solid Waste Management Units 03-010(a) and 03-001(e) at Technical Area 3* (DOE 2006).

Data collected from wells drilled during the 2005 investigation show the intermediate groundwater at Building 03-0030 is confined and the primary recharge source for the groundwater is in the immediate area of SWMU 03-001(e). However, additional data were needed to better define the source as well as to evaluate longer-term response actions of the Building 03-0030 intermediate groundwater body.

The Laboratory conducted four interim-measure activities at SWMUs 03-010(a) and 03-001(e) in 2006. The objective of the interim-measure activities is to obtain sufficient information to determine an effective control for the groundwater recharge system, thereby supporting a final remedy for the site. The four interim measures are as follows:

- Installation of pressure transducers in select monitoring wells to evaluate water-level changes over time in wells B-9, B-10, and B-13;
- Quarterly monitoring of the 2005 investigation wells (B-9, B-10, and B-13);
- A groundwater tracer study to identify the source(s) of groundwater recharge at the site; and
- Stable isotope characterization of the Building 03-0030 condensate water to determine if it may be the primary source for groundwater recharge.

c. Conclusions and Recommendations. We interpreted water-level measurements to indicate that wells B-10 and B-13 share a similar hydraulic connection to the recharge source(s). Well B-9 is either not as well hydraulically connected to the recharge source(s) when compared to wells B-10 and B-13 or is potentially not connected at all.

Quarterly groundwater sampling of wells B-9, B-10, and B-13 began on June 2006, as part of the perched-groundwater investigation of SWMUs 03-010(a) and 03-001(e). Lead was detected in filtered water samples at concentrations of 20 µg/L in well B-13 and 18.4 µg/L in well B-10, which are above the EPA maximum contaminant level (MCL) of 15 µg/L (LANL 2007) (used for comparison purposes only). Samples showed trichloroethane[1,1,1-] in well B-10 at a concentration of 94 µg/L and dichloroethene[1,1-] in well B-13 at a concentration of 5.39 µg/L, which are above the NM groundwater standards of 60 µg/L and 5 µg/L, respectively. Other organic chemicals detected included diesel range organics, trichloroethene, dioxane[1,4-], and chloroform at concentrations below standards or tap water screening levels (LANL 2007). Radionuclides detected included tritium, strontium-90, cesium-137, and plutonium-239 in either one or both wells B-10 and B-13 below standards or dose limits.

The tracer study results indicate the north-south and east-west drainages are not the sources of recharge to intermediate groundwater at SWMUs 03-010(a) and 03-001(e), but point to the building roof as a recharge source. Specifically, the results indicate the recharge to the groundwater is through the southern roof drain system.

The stable isotope data from the groundwater and condensate samples indicate a precipitation source for the perched groundwater. In addition, the results of the video-logging of the culvert leading from the roof drains on the southern half of the building show a significant break near the building foundation. This break may be the pathway that allows precipitation from the roof drains to recharge the perched groundwater.

The Laboratory plans to repair the culvert in 2007 and to continue sampling wells on a quarterly basis.

13. Airport Landfill

a. Site Description and History. SWMUs 73-001(a) and 73-001(d) are associated with TA-73 and are currently part of the Los Alamos County Airport.

SWMU 73-001(a) is a former landfill north of the airport runway and is approximately 12 acres in size. The Laboratory and Los Alamos townsite used the area as a landfill beginning in 1943. The Laboratory deposited sanitary waste and the townsite deposited municipal wastes into the landfill. Los Alamos County assumed operation of the landfill in 1965 and operated the landfill until it was closed in 1973.

SWMU 73-001(d) is a former landfill debris disposal area operated by the Laboratory from 1984 to 1986 and consisted of two roughly parallel trenches excavated to a depth of 35 ft. The Laboratory used the site in 1984 to bury debris excavated from the western portion of SWMU 73-001(a) and from SWMUs 73-001(b and c). The Laboratory covered the debris disposal area with soil in 1986 and reseeded it.

b. Remediation and Sampling Activities. The final remedy has been constructed for SWMUs 73-001(a) and 73-001(d), also referred to as the Airport Landfill and the Debris Disposal Area, respectively. The principal features of the work completed as part of the final remedy include the following:

- Regraded and compacted the main landfill surface as well as the north and east slopes
- Constructed five concrete hangar pads on the main landfill surface
- Constructed a MatCon asphalt cap on the main landfill surface
- Constructed a gas collection system beneath the MatCon surface
- Constructed a storm water collection system
- Constructed a lower concrete retaining wall and an upper mechanically stabilized earth wall at the toe of the east slope

- Constructed a low-permeability soil/geocomposite/vegetated soil cover on the upper east slope and the north slope
- Placement of additional cover soil, regarding, and revegetation of the Debris Disposal Area.

c. Conclusions and Recommendations. A description of the field activities, as-built drawings and specifications, and other associated information was presented in a remedy completion report submitted to NMED in 2007.

C. WATER STEWARDSHIP PROJECT

The Laboratory conducted the following investigations and activities in 2006:

- The Laboratory's work plan for investigations in Barrancas, Bayo, Guaje, and Rendija Canyons (North Canyons) was approved and Phase 1 field investigations of potentially contaminated sediment deposits were performed.
- Summary of Phase 1 sediment investigations in Pajarito Canyon was submitted and Phase 2 sediment investigations were conducted.
- Investigation report of the Mortandad Canyon watershed was submitted.
- Interim measures work plan for investigating chromium contamination in groundwater was submitted and approved. A work plan for installing regional well R-35 was submitted and approved. Interim measure field activities were completed and an interim measures investigation report was submitted and approved.
- The work plan for investigations in South Canyons was submitted.
- The Pajarito Canyon Biota Investigation Work Plan was submitted.
- Additional information and reports were submitted, including periodic monitoring reports, well completion reports, General Facility Information 2006, Interim Facility-Wide Groundwater Monitoring Plan, Revision 1, and Groundwater Background Investigation Report, Revision 1.

The following section includes brief summaries of the LANL investigation activities started, continued, or completed in 2006.

1. North Canyons

a. Site Description and History. The Bayo, Barrancas, Rendija, and Guaje Canyons systems are referred to as the "north canyons systems." These canyons head in the northern part of the Pajarito Plateau north of the Laboratory and are addressed by one work plan because of similarities common to all four canyons.

Bayo Canyon is located north of Pueblo Canyon and extends across Los Alamos County land, and Pueblo de San Ildefonso land to its confluence with Los Alamos Canyon. The Laboratory used former TA-10, which was located in middle Bayo Canyon, from 1943 to 1961 as a firing site to conduct experiments that used high explosives and radioactive materials. The Laboratory decontaminated and decommissioned the TA-10 site in 1963 and released the land to Los Alamos County in 1967. SWMUs and AOCs associated with TA-10 within the Bayo Canyon Aggregate Area will be addressed in the corresponding investigation work plan.

Barrancas Canyon is located north of Bayo Canyon and extends across Los Alamos County land, USFS land, Laboratory property, and San Ildefonso Pueblo land to its confluence with Guaje Canyon. No historical or current Laboratory structures or sites are present in Barrancas Canyon, although there is a potential for

dispersion of material from former TA-10 firing sites into the Barrancas Canyon watershed. Barrancas Canyon is undeveloped and the portion of the canyon on Los Alamos County and USFS land is open for recreational use by the public.

Rendija Canyon is located north of the Los Alamos townsite and extends across USFS land, private land, Los Alamos County land, and GSA land to its confluence with Guaje Canyon. Several SWMUs/AOCs are located within the watershed. Rendija Canyon is entirely open for recreational use and includes the site of the Los Alamos Sportsmen's Club, a sport-shooting range. Portions of Rendija Canyon along the north side of the Los Alamos townsite are residential areas.

Guaje Canyon is located north of Rendija Canyon and Barrancas Canyon and extends across USFS land and San Ildefonso Pueblo land to the confluence with Los Alamos Canyon. The Guaje well field in lower Guaje Canyon has been a major source of drinking water for Los Alamos since 1951.

b. Remediation and Sampling Activities. The Laboratory performed Phase 1 field investigations of sediment deposits in Barrancas, Bayo, Guaje, and Rendija Canyons following the *Work Plan for the North Canyons* (LANL 2001), as modified by agreements with the NMED (LANL 2005e; NMED 2005j; LANL 2006n). Field investigations included detailed geomorphic mapping, associated geomorphic characterization, and sediment sampling of 10 reaches specified in the work plan. Sediment sampling was also conducted in 2000 as part of post-Cerro Grande fire sediment characterization activities in one background reach in Guaje Canyon and in two reaches in Rendija Canyon.

c. Conclusions and Recommendations. We collected samples of post-fire sediment within or downcanyon from the Cerro Grande burn area. The presence of Cerro Grande ash in these samples complicates the process of identifying contaminants because ash contains elevated levels of many inorganic chemicals and radionuclides that exceed background values. Maximum concentrations of several inorganic chemicals and radionuclides in post-fire samples were obtained from the background reach, illustrating the effect of ash as a source. Some of the concentrations we detected may also represent naturally elevated background concentrations or may result from runoff from roads or residential areas and not releases from SWMUs or AOCs.

Comparison of the analytical results from north canyons sediment samples with analytical results from SWMUs and AOCs indicate releases from these sites have had little effect on concentrations in sediment in the north canyons.

Based on the Phase 1 sampling results, we proposed no additional sediment characterization prior to preparing the north canyons investigation report. The goals of the sediment sampling and analysis plan presented in the work plan (LANL 2001) and in subsequent agreements with NMED (LANL 2005e; NMED 2005j; LANL 2006n) have been met with the Phase 1 data. This recommendation is pending NMED approval.

2. Pajarito Canyon

a. Site Description and History. Pajarito Canyon is located in the central part of the Laboratory. The canyon heads in the Santa Fe National Forest west of the Laboratory boundary and empties into the Rio Grande in White Rock Canyon. The main channel is approximately 14.8 miles long and the watershed area is approximately 8 mi^2. In addition, Twomile Canyon and Threemile Canyon are major tributaries that join Pajarito Canyon and have watershed areas of 3.1 mi^2 and 1.7 mi^2, respectively. Sites within the Pajarito Canyon watershed are located at TAs 3, 8, 9, 12, 15, 18, 23, 27, 48, 54, 55, 59, 64, and 69.

b. Remediation and Sampling Activities. The Laboratory conducted a Phase 2 field investigation of sediment deposits in the Pajarito Canyon watershed in 2006 according to the NMED-modified Pajarito

Canyon Phase 1 summary report (LANL 2006e; NMED 2006j). Sediment samples were collected from 18 reaches in the Pajarito Canyon watershed in 2006. Prior to sampling, field investigations included detailed geomorphic mapping and associated geomorphic characterization.

c. Conclusions and Recommendations. One reach had maximum concentrations of several contaminants exceeding residential soil screening levels (SSLs). Additional sampling and analyses are proposed for this reach to improve concentration estimates. The proposed Phase 3 investigation, under NMED review, is focused on contaminants that contribute to potential carcinogenic, noncarcinogenic, and ecological risk for this reach.

In the Phase 2 sediment results in a reach downcanyon of releases from an incinerator ash pond, we detected dioxins and furans at concentrations greater than in the upcanyon reach. Therefore, proposed Phase 3 sampling and analysis will include dioxin and furan analyses in the next downcanyon reach and also will include all contaminants that contribute to potential risk in upcanyon reaches.

After we conducted Phase 2 sampling, the largest flood on record in the Pajarito Canyon watershed occurred on August 25, 2006. Because of the potential for remobilization and transport of contaminants, our proposed Phase 3 sampling and analysis will evaluate the concentrations of contaminants in August 2006 flood deposits in the impoundment above the flood retention structure and in downcanyon reaches. The recommendations for Phase 3 sampling are pending NMED approval.

3. Mortandad Canyon

a. Site Description and History. The investigation encompassed Mortandad, Effluent, and Ten Site Canyons, and an unnamed tributary canyon that heads in TA-5. This area is collectively referred to as the Mortandad Canyon watershed. Mortandad Canyon is located in the north-central part of the Laboratory and extends for approximately 10 mi from Diamond Drive in TA-3 east-southeast to the Rio Grande. Mortandad Canyon has a total watershed area (excluding Cañada del Buey) of about 6.0 mi^2. Primary tributary drainages on Laboratory land are Effluent Canyon, which heads in TA-48, and Ten Site Canyon, which heads in TA-50. Cañada del Buey, a major tributary of Mortandad Canyon, joins with Mortandad Canyon upstream of the Rio Grande and has a watershed area of 4.3 mi^2, will be the subject future investigations and reported on under the Sandia Canyon and Cañada del Buey investigations. The Mortandad Canyon watershed reported on here includes that portion west of State Road 4, which has a drainage area of 3.3 mi^2 of which 60% is on Laboratory land and 40% is on Pueblo de San Ildefonso land. Technical areas in the watershed include TAs 3, 4, 5, 35, 42, 48, 50, 52, 55, 60, and 63.

b. Remediation and Sampling Activities. The *Mortandad Canyon Investigation Report* (LANL 2006r) presents the results of investigations conducted from 1998 through 2005 of sediment, surface water, groundwater, and biota potentially impacted by SWMUs and AOCs located in the Mortandad Canyon watershed. Sediment investigations included geomorphic mapping, associated geomorphic characterization, and sediment sampling in 27 investigation reaches within the watershed. Surface water investigations included sampling of persistent water at nine locations in Effluent, Ten Site, and Mortandad Canyons. Groundwater investigations included installing nine alluvial wells, eight perched intermediate groundwater wells and boreholes, and seven regional groundwater wells within the watershed. Groundwater investigations also included surface and subsurface geophysical surveys, installation of piezometers, water level measurements, vector probe and flux meter analyses, and analyses of core samples and vadose zone pore water.

The Laboratory conducted a baseline ecological risk assessment to evaluate the potential for adverse effects to terrestrial and aquatic receptors and two threatened and endangered species: the Mexican spotted owl and the southwestern willow flycatcher. Ecological effects data were collected using small mammal trapping arrays, a

cavity nesting bird monitoring network, seedling germination tests, earthworm mortality and growth tests, and sediment and water toxicity tests. Concentrations of contaminants within insects, eggs, and small mammals were also measured. The Laboratory augmented the lines of evidence with breeding bird surveys, plant surveys, habitat analyses, and spatial modeling of wildlife exposure.

c. Conclusions and Recommendations. We identified contaminants in sediment, surface water, and groundwater within the watershed. The contaminants came from a variety of sources, including Laboratory SWMUs and AOCs, runoff from developed areas, and naturally occurring soil, sediment, and bedrock. Contaminant concentrations in sediment, surface water, and alluvial groundwater have generally decreased over time, indicating the initial SWMU and AOC sources are no longer major contributors to contamination. In contrast, contaminant concentrations in deeper perched intermediate and regional groundwater have increased over time, indicating the migration of mobile constituents from the alluvial zone into the vadose zone and into deeper zones of saturation.

The human health risk assessments indicated that under a recreational scenario (the current and reasonably foreseeable future land use in the canyons), no areas in the watershed had hazards and risks above NMED target levels in sediment and water. However, the radionuclide dose for one area in Effluent Canyon downcanyon from the TA-50 Radioactive Liquid Waste Treatment Facility outfall exceeded DOE's target dose for sediment; the target dose in water was not exceeded.

Although some chemicals of potential ecological concern were identified, the ecological risk assessment indicated no adverse effects to terrestrial and aquatic receptors in the Mortandad Canyon watershed.

Because of Effluent Canyon's relative inaccessibility, we proposed no remedial action to reduce the potential radiation dose to recreational users of the canyon. The reach is a short, steep, and rocky area that has no developed trail and is unlikely to be used in the same manner as normally assumed under a trail user land-use scenario. The area is posted as a soil contamination area stating that "access is restricted to workers on official business," discouraging recreational use.

Potential future changes in the vadose zone contamination and concentrations of contaminants in perched intermediate and regional groundwater are not well understood and a corrective measure evaluation is necessary to assess the need for corrective actions. A more detailed evaluation of chromium contamination in groundwater is summarized in *Interim Measures Investigation Report for Chromium Contamination in Groundwater* (LANL 2006t). Groundwater monitoring in the Mortandad Canyon watershed will continue and is described in the *Interim Facility-Wide Groundwater Monitoring Plan* (LANL 2006k).

4. Interim Measures Investigation of Chromium Contamination in Groundwater

a. Site Description and History. Several types of historical anthropogenic chromium sources are present in the Sandia, Los Alamos, and Mortandad watersheds. These sources include facilities for electroplating and photoprocessing and the use of chromate as a corrosion inhibitor in cooling tower systems. The highest chromium usage was as a corrosion inhibitor; most likely the largest amounts were used in the cooling tower blowdown for the TA-3 power plant at the head of Sandia Canyon. The blowdown was released as effluent and was discharged into upper Sandia Canyon. The cooling towers at the Omega West Reactor (TA-2) in Los Alamos Canyon also used high amounts of chromate. Chromium has also been discharged from TA-48 into Mortandad Canyon and may have been used in other smaller scale cooling systems at the Laboratory. The Laboratory stopped using chromate in the cooling tower systems in 1972.

b. Remediation and Sampling Activities. We detected chromium contamination in groundwater beneath Laboratory land. In 2006, the Laboratory submitted and NMED approved with modifications the *Interim Measures Work Plan for Chromium Contamination in Groundwater* (LANL 2006f; NMED 2006d). NMED's

approval with modification required the installation of a regional groundwater well (well R-35). The Laboratory also submitted and NMED approved a work plan for well R-35 (LANL 2006j, NMED 2006f). The Laboratory presented a complete description of the field activities and results of the interim measures investigation in the *Interim Measures Investigation Report for Chromium Contamination in Groundwater* (LANL 2006t), which was submitted to NMED in 2006.

The chromium groundwater investigations focus on characterizing the nature and extent of chromium in surface water, alluvial groundwater, the vadose zone, and perched intermediate groundwater in and beneath the Los Alamos, Sandia, and Mortandad watersheds. For these areas, the Laboratory also evaluated regional groundwater data. The data are used to evaluate spatial and temporal trends in chromium contamination at a multiple watershed scale, including variations in contaminant concentration at increasing distance from the source areas and as a function of time since chromium releases were halted.

The investigation activities include the following:

- Quarterly sampling of surface water, alluvial groundwater, perched intermediate ground water, and regional groundwater in Sandia and Mortandad Canyons,
- Investigation of surface water and alluvial groundwater infiltration in Sandia Canyon by using gauging station data and installing two piezometer sets,
- Determination of chromium distributions in the upper vadose zone of lower Sandia Canyon by drilling six new core holes,
- Determination of chromium distributions in the upper vadose zone from archival cores from Los Alamos, Sandia, Mortandad, and Ten Site Canyons,
- Determination of water quality and the extent of alluvial saturation in lower Sandia Canyon by installing five alluvial wells,
- Rehabilitation of regional well R-12 to serve as a monitoring site in Sandia Canyon, and
- Evaluation of seasonal water level variations in monitoring wells due to supply well production.

An investigation of background concentrations for total dissolved chromium and chromium(VI) was not necessary because sufficient data has already been collected.

c. Conclusions and Recommendations. Sampling data from regional groundwater monitoring wells and surrounding production wells show that only wells R-11 and R-28 contain clear evidence of Laboratory-derived chromium contamination; dissolved chromium concentrations are above groundwater standards in well R-28 and are approaching groundwater standards in well R-11. Other regional groundwater monitoring wells (e.g., well R-15) contained dissolved chromium concentrations slightly elevated above background.

The results of the interim measures investigation indicate that a significant portion of the mass of chromium is retained in the alluvium, especially in the Sandia Canyon wetland. The predominant zone of infiltration into the vadose zone occurs in the middle reaches of Sandia Canyon. However, the chromium does not remain in the vadose zone but is flushed through it into the regional aquifer.

The LANL report recommends that the interim measure phase of this investigation be concluded with the report and subsequent work be conducted under the Sandia Canyon and Cañada del Buey work plan. Additional data and wells are needed to define the extent of chromium and its impact on the regional aquifer. Installation of regional wells R-35a and R-35b will provide further information for the assessment of potential impacts to water supply well PM-3 (drilling plan for these wells was approved by NMED in 2006). In the

data collection under the modified work plan, the Laboratory will focus on characterization of the nature and extent of all contaminants (not just limited to chromium and related contaminants) sufficient to support risk assessments and remedy selection.

NMED reviewed the interim measures report and issued a notice of approval (NMED 2006l). The Laboratory is directed to submit a subsequent work plan to further investigate the present-day spatial distribution and mass of chromium in the near surface sediment and alluvium and to develop a numerical model to guide future investigation and potential remediation of the chromium contamination in the regional aquifer. The requirements will be incorporated into an addendum to the work plan for Sandia Canyon and Cañada del Buey and submitted to NMED in early 2007.

D. TA-21 CLOSURE PROJECT

Investigations and activities conducted in 2006 included the following:

- The investigation report for MDA U was submitted, revised, and approved.
- The investigation and remediation of MDA V were concluded and an investigation report was submitted.
- The investigation at MDA A was concluded and an investigation report was submitted.
- The investigation at MDA T was concluded and an investigation report was submitted.
- Investigation activities for five sites in the DP Site Aggregate Area were concluded.

The following sections summarize the investigations started, continued, and completed in 2006.

1. MDA U

a. Site Description and History. MDA U, located in the northeastern section of the DP Mesa within TA-21, consists of four SWMUs consolidated into 21-017(a)-99: SWMUs 21-017(a), 21-017(b), 21-017(c), and 21-022 (f). The Laboratory addressed SWMU 21-022(f) in conjunction with the DP Site Aggregate Area investigation (LANL 2004f) and did not investigate it with the other three SWMUs at MDA U.

The Laboratory operated MDA U from 1948 to 1968 as a subsurface disposal site for radioactively contaminated liquid wastes. Liquid effluent was discharged to the MDA U absorption beds from several buildings. In addition, the Laboratory disposed of oil from precipitrons (air filters) at MDA U. The western absorption bed received water from a cooling tower until approximately 1976.

b. Remediation and Sampling Activities. The Laboratory completed field investigations at MDA U in 2005 based on the approved work plan (LANL 2004d; NMED 2005a). A complete description of the field activities, data review, and risk assessments for these sites are presented in the *Investigation Report for Material Disposal Area U, Consolidated Unit 21-017(a)-99 at Technical Area 21* (LANL 2006c). In addition to the 2005 sampling activities, the Laboratory used previous RFI sampling results to characterize MDA U. The RFIs included 1992 DP Mesa-wide surface soil sampling, 1994 surface soil and sediment sampling, 1998 surface soil, subsurface tuff, subsurface pore-gas, and absorption bed sampling, and 2001 surface soil and absorption bed sampling.

Recent site characterization activities included drilling and sampling nine boreholes for chemical and geotechnical characterization of soil, tuff, and pore-gas. Nine surface samples (one from each borehole location before drilling began) and 46 subsurface samples were collected. Subsurface pore-gas samples from two depth intervals were collected from each of the nine boreholes.

c. Conclusions and Recommendations. We identified inorganic, organic, and radionuclide contaminants at MDA U. The nature and extent of contamination was defined and the human health risk screening assessments indicated no potential risk or dose under the industrial and construction worker scenarios. The HIs and the total excess cancer risks did not exceed NMED's target levels and the total doses did not exceed DOE's target dose. An ecological risk screening assessment for MDA U indicated no potential risk to ecological receptors.

After NMED reviewed the report, the Laboratory revised it (LANL 2006o), and NMED subsequently approved it (NMED 2006h). NMED determined that the requirements of the Consent Order have been satisfied for SWMUs 21-017(a), 21-017(b), and 21-017(c) and issued a Certificate of Completion for "Corrective Action Complete with Controls" (NMED 2006h; NMED 2006k). The controls require that the land use remain industrial and that the construction of structures at MDA U be prohibited unless it is shown that vapor intrusion does not pose a risk to human health.

2. MDA V

a. Site Description and History. Consolidated Unit 21-018(a)-99 is a 0.88-acre fenced area located on the south side of DP Road west of the TA-21 main gate. The consolidated unit is comprised of four SWMUs and one AOC, as described below:

- SWMU 21-018(a) (MDA V) received radioactive liquid waste derived from the TA-21 laundry facility (SWMU 21-018[b]) and was designed to enhance the infiltration of liquids into the tuff bedrock. The Laboratory constructed the absorption beds in 1945 and operated them until 1961.
- SWMU 21-018(b), the former laundry facility, was located south of DP Road, immediately west of the security fence that encloses TA-21 facilities to the east. The Laboratory operated the laundry facility from 1945 to 1961 for washing personal protective clothing and other reusable cloth items used in research and production operations involving radioactive materials at TA-21. The Laboratory estimated the laundry facility generated approximately 2 million gallons of effluent annually, which was discharged to MDA V.
- SWMU 21-023(c), a former septic system that consisted of a tank, inlet and outlet lines, and an outfall, served a waste treatment laboratory. The septic tank was located immediately west of the MDA V absorption beds and was 3.5 ft wide × 7 ft long × 5.8 ft deep. The outlet line was a 4-in. vitrified clay pipe that surfaced 40 ft southwest of the tank, approximately 30 ft from the canyon edge above BV Canyon. The Laboratory put the septic system into service in 1948 and removed it in 1965.
- SWMU 21-013(b) and AOC 21-013(g) are surface debris disposal sites located immediately south of MDA V on the south-facing slope above BV Canyon. It is not known how long these sites received building debris; however, they did not receive wastes later than 1994.

b. Remediation and Sampling Activities. The Laboratory began investigation activities at MDA V in 2005 and concluded the investigation in 2006, in accordance with the approved MDA V investigation work plan (LANL 2004e; NMED 2004c). A complete description of the field activities, the data review, and the risk assessments for these sites is presented in the *Investigation Report for Consolidated Unit 21-018(a)-99, Material Disposal Area V, at Technical Area 21* (LANL 2006r). In addition to the 2005–2006 sampling, the Laboratory used previous investigation results from 1992 to 2000 to characterize Consolidated Unit 21-018(a)-99.

For the remediation activities at SWMUs 21-018(a) and 21-018(b) in 2005–2006, the Laboratory removed the three absorption beds and all associated distribution lines. The excavated volume of absorption bed material totaled approximately 10,900 yd^3. For remediation activities at the surface debris disposal sites, SWMU 21-013(b) and AOC 21-013(g), the Laboratory removed concrete, asphalt, and metallic debris from the sites. The

Laboratory removed approximately 1,100 yd^3 of concrete and small amounts of asphalt and metal debris from the slope and stabilized the slope. At the septic system, SWMU 21-023(c), remediation activities included removing contaminated sediment from the outfall, with approximately 11 yd^3 of material removed from the area.

After excavating and removing the absorption bed material and septic system, the Laboratory collected shallow subsurface and borehole confirmation samples.

Twelve boreholes were drilled in and around MDA V, SWMU 21-018(a), to depths ranging from 40 to 380 ft bgs. Three boreholes were advanced to 40 ft bgs within the footprint of the former laundry facility, SWMU 21-018(b). Shallow subsurface samples were also collected from 2 to 10 ft bgs to characterize the base of shallow structures at the former laundry facility. A total of 1,160 linear ft were drilled and samples of core and pore-gas were collected from all boreholes.

At SWMU 21-023(c), samples were collected from beneath the former septic system inlet line, beneath the former septic system outlet line, the outfall, the outfall drainage, Consolidated Unit 21-027(d)-99, and in BV Canyon, upgradient and downgradient of SWMU 21-023(c). Confirmation samples were collected from eight locations where contaminated material was removed.

Following debris removal activities at SWMU 21-013(b) and AOC 21-013(g) a total of 89 samples were collected from 45 locations. Based on these analytical results, three additional locations were excavated.

c. Conclusions and Recommendations. We identified inorganic, organic, and radionuclide contaminants at MDA V. The nature and extent of contamination is defined for this consolidated unit. The human health risk screening assessments indicated no potential risks or doses under a residential scenario. The HIs and the total excess cancer risks did not exceed NMED's target levels and the total doses did not exceed DOE's target dose. The ecological risk screening assessment indicated no potential risk to ecological receptors.

We remediated Consolidated Unit 21-018(a)-99 by removing infrastructure and environmental media with concentrations of contaminants exceeding residential screening action levels (SALs) for radionuclides or residential SSLs for inorganic and organic chemicals. Currently, the site is located within an industrial area under Laboratory control and is expected to remain so for the foreseeable future. However, because the site may be transferred out of institutional control in the future, we remediated the consolidated unit to or below residential SALs and SSLs.

The report was reviewed by NMED and revised to include additional sampling results and other information requested by NMED. A revised investigation report was submitted to NMED in 2007.

3. MDA A

a. Site Description and History. MDA A is comprised of a 1.25-acre, fenced, and radiologically controlled area situated on the eastern end of DP Mesa between DP Canyon to the north and Los Alamos Canyon to the south. The Laboratory used MDA A between 1945 and 1978 to store solid and liquid wastes.

MDA A currently contains the following features:

- Two 50,000-gal. cylindrical steel storage tanks (referred to as the General's Tanks) are buried at the western end of MDA A. The tanks received waste solutions containing plutonium-239/240 and americium-241 from 1947 to 1974. Liquid waste was removed from the tanks in 1975 and 1976, but an unknown volume of sludge remains in the bottom of the tanks.

- Two 4-ft diameter, 65-ft deep vertical shafts located south of the General's Tanks. The shafts were intended to clarify rinse water generated by cleaning cement paste from a transfer hose between the pug mill and the General's Tanks. However, the General's Tanks were never filled with cement paste and the shafts were never used. The shafts were constructed in 1975 and filled with soil in 1977.
- Two eastern disposal pits were excavated to receive radioactive solid waste from DP East in 1945. The pits are approximately 18 ft wide, 125 ft long, and 12.5 ft deep. In 1946, crushed Bandelier Tuff was used to backfill and cover the pits.
- One central pit was excavated in the center of MDA A to receive and store TA-21 decontamination and decommissioning debris potentially contaminated with radionuclides. Asphalt was also disposed of in this pit. The pit was originally 40 ft wide, 150 ft long, and 22 ft deep but was later enlarged to measure 172 ft long by 134 ft wide. This pit received waste from 1969 to 1977. The pit was decommissioned in 1978 and a soil cover (crushed tuff) was placed over the pit.
- Several hundred 55-gal. drums containing iodide waste were stored on the surface at the eastern end of MDA A. These drums contained sodium hydroxide solution and stable iodine. The drum storage area was used from the late 1940s until 1960.

b. Remediation and Sampling Activities. The Laboratory began investigation activities at MDA A and concluded them in 2006, according to the approved MDA A investigation work plan (LANL 2005a; LANL 2006g; NMED 2005f). A complete description of the field activities, data review, and risk assessments for this site were presented in the *Investigation Report for Material Disposal Area A, Solid Waste Management Unit 21-014, at Technical Area 21* (LANL 2006s). As part of earlier investigations in 1992 and 1994, the Laboratory had collected surface and shallow-subsurface soil samples in the areas outside the MDA A fence line, both immediately surrounding and downslope from the facility to the north.

Sixteen boreholes, some angled, were drilled and sampled in 2006 to characterize potential contamination beneath MDA A. In addition to collecting surface and subsurface samples, the Laboratory sampled pore-gas from each core interval in each borehole. A total of 72 pore-gas samples were collected. Sixteen surface and shallow-subsurface locations were sampled on the DP Canyon slope north of MDA A in drainages and other areas of sediment deposition to evaluate potential downslope migration of contaminants from MDA A

c. Conclusions and Recommendations. We identified inorganic, organic, and radionuclide contaminants at MDA A and on the DP Canyon slope. The nature and extent of potential contaminants at MDA A and on the DP Canyon slope is defined. The human health risk screening assessments indicated no potential risks or doses under the industrial and recreational scenarios. The HIs and the total excess cancer risks did not exceed NMED's target levels and the total doses did not exceed DOE's target dose. The total estimated excess cancer risk under the construction worker scenario for MDA A was below the NMED target risk level. The construction worker HI for MDA A was above the NMED target level because of manganese. However, the manganese exposure concentration was similar to background. The construction worker HI without manganese is below the NMED target level. The total dose for a construction worker is below the DOE target dose limit. There is no potential unacceptable risk to ecological receptors.

Following review of the investigation report, NMED requested additional drilling and sampling for pore-gas. The evaluation will include the collection of tritium and VOC pore-gas samples from 15 ft bgs to 115 ft bgs. In addition, a second round of vapor-phase VOCs and tritium pore-gas samples will be collected from previously sampled depths in four boreholes. After the evaluation of the new pore-gas sampling results, including potential impacts to groundwater, a determination will be made as to whether a long-term vapor monitoring plan is needed for MDA A.

4. MDA T

a. Site Description and History. MDA T, Consolidated Unit 21-016(a)-99, is an area of approximately 2.2 acres located within TA-21 on DP Mesa. MDA T includes 25 SWMUs and AOCs associated with decommissioned radioactive liquid waste treatment facilities and various storage areas. The SWMUs and AOCs include inactive absorption beds, a retrievable waste storage area, asphalt-lined disposal shafts, sumps, acid holding tanks, acid sumps, effluent holding tanks, sodium hydroxide storage tank, an americium raffinate storage tank, acid valve pit manholes, underground steel tanks, a septic tank, grit chamber or settling tank, and airborne releases from incinerators used to burn waste oils and organics after testing (oil spills from the incinerators are known to have occurred). Also included are eight AOCs that are not part of Consolidated Unit 21-016(a)-99 but are within the footprint of the consolidated unit. These sites consist of four unintentional releases or one-time spills and four former storage and treatment tanks. The SWMUs and AOCs associated with MDA T were operational from 1945–1986. The Laboratory discharged approximately 18.3 million gallons of wastewater to the MDA T absorption beds between 1945 and 1967.

b. Remediation and Sampling Activities. The RFI activity at MDA T began in 1992 and included surface and near-surface sampling to evaluate contamination resulting from airborne stack emissions. Surface sampling was performed in 1993 and 1994 and included a small drainage leading into DP Canyon. An investigation was conducted in 1996–1997, which included the drilling of boreholes in and around MDA T, to define the nature and extent of subsurface contamination. Recent investigation activities at MDA T began in 2005 and concluded in 2006 according to the approved MDA T investigation work plan (LANL 2004b; NMED 2005e). A complete description of the field activities, data review, and risk assessments for this site is presented in the *Investigation Report for Material Disposal Area T, Consolidated Unit 21-016(a)-99, at Technical Area 21* (LANL 2006m).

In 2006, surface and shallow-subsurface samples were collected north of MDA T on the DP Canyon slope. A total of 25 samples were collected from 14 locations. Nine surface and shallow-subsurface samples were also collected from within MDA T. Thirty-two boreholes (shallow, 30–40 ft bgs; intermediate, up to 100 ft; and deep, up to 380 ft) were drilled and sampled (including pore-gas) to characterize the subsurface beneath MDA T associated with the absorption beds, shafts, and the Retrievable Waste Storage Area; Building 21-035; and Building 21-257.

c. Conclusions and Recommendations. Based on the investigation results, the nature and extent of contaminants at MDA T and on the DP Canyon slope is defined. There is no potential unacceptable dose or risk under the industrial and recreational scenarios and no potential risk to ecological receptors. The total excess cancer risk and HI under the construction worker scenario were also below NMED target levels. However, the dose for the construction worker was above the DOE target level as a result of cesium-137 activity in a single sample. Potential for exposure must be assessed and precautions must be taken during demolition activities in the vicinity of Building 21-257 to protect workers from elevated cesium-137 levels.

Following NMED review of the investigation report, we developed and submitted a Phase 2 investigation work plan. The work plan describes additional sampling activities to be conducted within the consolidated unit as well as on the DP Canyon slope. These activities will include surface and near-surface as well as subsurface sampling. We will submit a Phase 2 investigation report that presents all results, including the additional sample data, and revisions of any analyses and assessments (e.g., risk assessment) that change as a result of the supplemental investigation.

5. DP Site Aggregate Area

a. Site Description and History. The DP Site Aggregate Area consists of SWMUs and AOCs located throughout TA-21. TA-21 is located on DP Mesa on the northern boundary of LANL and is immediately east-southeast of the Los Alamos townsite.

The DP Site Aggregate Area sites addressed by 2006 field activities included the following:

- SWMU 21-013(c) was a surface disposal area located northeast of the high-temperature chemistry building (Building 21-209); the dates of operation are unknown.
- Consolidated Unit 21-003-99 consists of SWMUs 21-003 and 21-013(f) and was a PCB container storage area from 1978 to 1989. SWMU 21-003 was a PCB-container storage area inside Building 21-61, including the area immediately outside and east of the building. SWMU 21-013(f) was possibly a surface disposal area and is located within the boundaries of SWMU 21-003.
- SWMU 21-024(c) was a septic system installed to route sewage from Buildings 21-54 and 21-61 in the late 1940s and operated until 1966.
- SWMU 21-009 was a waste treatment laboratory constructed in 1948 and decommissioned in 1965.
- AOC 21-002(b) was a drum storage area built southeast of Building 21-31 used for drum storage; the contents of the drums are not known. The area was decommissioned in 1966.

b. Remediation and Sampling Activities. NMED approved the *Investigation Work Plan for Delta Prime Site Aggregate Area at Technical Area 21* with modifications (LANL 2004f; NMED 2005c). In addition, the Laboratory submitted revisions to the approved work plan to NMED in 2005 (LANL 2005h) and submitted a supplemental investigation work plan in 2006 (LANL 2006i). The Laboratory started and concluded field investigations for five sites in 2006 based on the approved work plan (LANL 2004f; NMED 2005c). Results of previous investigations were used to determine whether additional data were needed. Surface and subsurface soil samples were collected from numerous locations at all the sites.

c. Conclusions and Recommendations. The Laboratory will report the results of the characterization of the DP Site Aggregate Area investigation sites in an investigation report in 2007.

E. QUALITY ASSURANCE PROGRAM

1. Quality Assurance Program Development

The EP Directorate's quality assurance objectives are to perform work in a quality manner while minimizing potential hazards to the environment, public, or workers. All work is performed by using approved instructions, procedures, and other appropriate means that implement regulatory or contractual requirements for technical standards, administrative controls, and other hazard controls. The Quality Management Plan establishes the principles, requirements, and practices necessary to implement an effective quality assurance program.

The use of a graded approach determines the scope, depth, and rigor of implementing the quality assurance criteria for a specific activity. Activities are managed through systems that are commensurate with the quality requirements, risk, and hazards involved in the activity. Such a selective approach allows the Laboratory to apply extensive controls to certain elements of activities and limited controls to others. The control measures applied to any particular activity are covered in documents such as procedures, statements of work, project-specific work plans, and procurement contracts associated with the activity.

2. Field Sampling Quality Assurance

Overall quality is maintained through the rigorous use of carefully documented procedures that govern all aspects of the sample collection activities.

Soil, water, vapor, and biota samples are (1) collected under common EPA chain-of-custody procedures using field notebooks and sample collection logs and (2) prepared and stored in certified pre-clean sampling containers in a secure and clean area for shipment. Samples are delivered to analytical laboratories under full chain-of-custody, including secure FedEx shipment to all external vendors, and tracked at all stages of their collection and analysis.

3. Analytical Laboratory Quality Assessment

The Laboratory writes specific statements of work to govern the acquisition and delivery of analytical chemistry services after the Data Quality Objective process defines the project needs. These statements of work are sent to potentially qualified suppliers who are National Environmental Laboratory Accreditation Conference (NELAC)-certified for a pre-award assessment by experienced and trained quality systems and chemistry laboratory assessors. Statement of work specifications, professional judgment, and quality system performance at each laboratory (including recent past performance on nationally conducted performance-evaluation programs) are primarily used to award contracts for specific types of radiochemical, organic chemical, and inorganic chemical analyses.

Each analytical laboratory conducts its chain-of-custody and analytical processes under its own quality plans and analytical procedures. The analytical laboratory also submits a full set of hard copy records that serves as the legally binding copy of the data. Each set of samples contains all the internal quality assurance/quality control data the analytical laboratory generates during each phase of chemical analysis (including laboratory control standards, process blanks, matrix spikes, duplicates, and replicates, when applicable). The electronic data are uploaded into the database and verified and validated according to its corresponding variety of quality and consistency checks. All parts of the data-management process are tracked electronically, and periodic reports to management are prepared.

4. Analytical Laboratory Assessments

The EP Directorate has eight contracts with external analytical laboratories. The laboratories are audited as long as they keep their NELAC and DOE Contract Audit Program certifications. During 2006, five external laboratory audits were performed; St. Louis Severn Trent, Assaigi, Paragon Analytics, Inc., University of Miami, and Huffman Laboratories. All laboratories participated in national performance-evaluation studies during 2006 and the results are included in the assessment report. Overall, the study sponsors judged the analytical laboratories to have acceptable performance for almost all analytes attempted in all matrices.

5. Program Audits and Assessments

The Laboratory's Performance Assurance Division–Operations Support and the Facilities Division performed internal audits of the Sample Management Office (SMO). The Performance Assurance audit found no issues, while the Facilities audit required postings for radioactivity and quarterly radiological surveys of the SMO.

F. REFERENCES

DOE 2006: "Investigation Report for Solid Waste Management Units 03-010(a) and 03-001(e) at Technical Area 3," DOE Los Alamos Area Office document, ID 092669 (April 20, 2006).

EPA 2005: "EPA Region 6 Human Health Medium-Specific Screening Levels," (U.S. Environmental Protection Agency, Region 6, Dallas, Texas, November 2005), ID 091002.

ITSI 2005: Innovative Technical Solutions, Inc., "Work Plan for Corrective Action of SWMU 73-002 and Investigation of Consolidated Unit 73-002-99," prepared for U.S. Army Corps of Engineers and Los Alamos National Laboratory, ID 094312 (September 22, 2005).

LANL 1993: "RFI Work Plan for Operable Unit 1114," Los Alamos National Laboratory document LA-UR-93-1000, ID 020947 (July 1993).

LANL 1995: "RFI Work Plan for Operable Unit 1114, Addendum 1," Los Alamos National Laboratory document LA-UR-95-731, ID 057590 (July 1995).

LANL 1996: "RFI Report for PRSs 16-003(k) and 16-021(c) in TA-16 OU 1082," Los Alamos National Laboratory document LA-UR-96-3191, ID 055077 (September 1996).

LANL 1998a: "Hydrogeologic Workplan," Los Alamos National Laboratory document, ID 059599 (May 1998).

LANL 1998b: "RFI Report for Potential Release Site 16-021(c)," Los Alamos National Laboratory document LA-UR-98-4101, ID 059891 (September 1998).

LANL 2001: "Work Plan for the North Canyons," Los Alamos National Laboratory document LA-UR-01-1316, ID 071060 (September 2001).

LANL 2003: "Phase III RFI Report for Solid Waste Management Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-03-5248, ID 077965 (September 2003).

LANL 2004a: "Accelerated Corrective Action Work Plan for the Investigation and Remediation of Consolidated Solid Waste Management Unit 19-001-99," Los Alamos National Laboratory document LA-UR-04-0199, ID 085521 (January 2004).

LANL 2004b: "The Investigation Work Plan for Material Disposal Area T at TA-21, Solid Waste Management Unit 21-016(a)-99," Los Alamos National Laboratory document LA-UR-04-0559, ID 085641 (February 2004).

LANL 2004c: "Investigation Work Plan for the TA-16-340 Complex: SWMUs 13-003(a)-99, 16-003(n)-99, 16-003(o), 16-026(j2), and 16-029(f) at TA-16," Los Alamos National Laboratory document LA-UR-04-1466, ID 087345 (March 2004).

LANL 2004d: "Investigation Work Plan for Material Disposal Area U, Solid Waste Management Unit 21-017(a)-99, at Technical Area 21," Los Alamos National Laboratory document LA-UR-04-7268, ID 090801 (May 2004).

LANL 2004e: "Investigation Work Plan for Solid Waste Management Unit 21-018(a)-99, Material Disposal Area V, at Technical Area 21," Los Alamos National Laboratory document LA-UR-04-3699, ID 087358 (June 2004).

LANL 2004f: "Investigation Work Plan for Delta Prime Site Aggregate Area at Technical Area 21," Los Alamos National Laboratory document LA-UR-04-5009, ID 087461 (August 2004).

LANL 2005a: "Investigation Work Plan for Material Disposal Area A at TA-21, Solid Waste Management Unit 21-014," Los Alamos National Laboratory document LA-UR-05-0094, ID 088052 (January 2005).

LANL 2005b: "Investigation Work Plan for Consolidated Solid Waste Management Units 16-007(a)-99 (30s Line) and 16-007(a)-99 (90s Line) at Technical Area 16," Los Alamos National Laboratory document LA-UR-05-1694, ID 089331 (March 2005).

LANL 2005c: "Accelerated Corrective Action Work Plan for Solid Waste Management Unit 33-013, a Former Storage Area at Technical Area 33 (TA-33)," Los Alamos National Laboratory document LA-UR-05-1104, ID 088066 (March 2005).

LANL 2005d: "Investigation Work Plan for the Pueblo Canyon Aggregate Area," Los Alamos National Laboratory document LA-UR-05-2366, ID 090579 (May 2006).

LANL 2005e: "Response to the Notice of Disapproval (NOD) on the Work Plan for the North Canyons," Los Alamos National Laboratory document LA-UR-05-4495, ID 089412 (June 2005).

LANL 2005f: "Investigation Work Plan for Guaje/Barranca/Rendija Canyons Aggregate Area at Technical Area 00," Los Alamos National Laboratory document LA-UR-05-3869, ID 089657 (July 2005).

LANL 2005g: "Remedy Completion Report for the Investigation and Remediation of Consolidated Unit 19-001-99," Los Alamos National Laboratory document LA-UR-05-0975, ID 089660 (July 2005).

LANL 2005h: "Revisions to the Investigation Work Plan for Delta Prime Site Aggregate Area at Technical Area 21," Los Alamos National Laboratory document LA-UR-05-3218, ID 090225 (September 2005).

LANL 2005i: "Investigation Work Plan for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 2," Los Alamos National Laboratory document LA-UR-05-7363, ID 091547 (October 2005).

LANL 2005j: "Remedy Completion Report for the Investigation and Remediation of Area of Concern 03-001(i) and Solid Waste Management Units 03-029 and 61-002," Los Alamos National Laboratory document LA-UR-05-8863, ID 091150 (December 2005).

LANL 2006a: "Investigation Report for the TA-16-340 Complex Consolidated Units 13-003(a)-99 and 16-003(n)-99 and Solid Waste Management Units 16-003(o), 16-026(j2), and 16-029(f)," Los Alamos National Laboratory document LA-UR-06-0153, ID 091450 (January 2006).

LANL 2006b: "Accelerated Corrective Action Work Plan for Area of Concern 16-024(v) and Solid Waste Management Units 16-026(r) and 16-031(f) at Technical Area 16," Los Alamos National Laboratory document LA-UR-05-3979, ID 092087 (January 2006).

LANL 2006c: "Investigation Report for MDA U Consolidated Unit 21-017(a)-99 at TA-21," Los Alamos National Laboratory document LA-UR-05-9564, ID 092589 (February 2006).

LANL 2006d: "Remedy Completion Report for the Investigation and Remediation of Solid Waste Management Unit 33-013," Los Alamos National Laboratory document LA-UR-06-1218, ID 092080 (March 2006).

LANL 2006e: "Summary of Pajarito Canyon Phase 1 Sediment Investigation," Los Alamos National Laboratory document LA-UR-06-1545, ID 091812 (March 2006).

LANL 2006f: "Interim Measures Work Plan for Chromium Contamination in Groundwater," Los Alamos National Laboratory document LA-UR-06-1961, ID 091987 (March 2006).

LANL 2006g: "Investigation Work Plan for Material Disposal Area A at Technical Area 21, Solid Waste Management Unit 21-014, Revision 2," Los Alamos National Laboratory document LA-UR-06-3235, ID 095117 (April 2006).

LANL 2006h: "Accelerated Corrective Action Work Plan for the Investigation and Remediation of Solid Waste Management Unit 61-002," Los Alamos National Laboratory document LA-UR-06-2577, ID 092564 (April 2006).

LANL 2006i: "DP Site Aggregate Area Supplemental Work Plan at TA-21," Los Alamos National Laboratory document LA-UR-06-1508, ID 092079 (April 2006).

LANL 2006j: "Drilling Work Plan for Regional Monitoring Wells R-35a and R-35b," Los Alamos National Laboratory document LA-UR-06-3964, ID 093388 (June 2006).

LANL 2006k: "Interim Facility-Wide Groundwater Monitoring Plan, Revision 1.1," Los Alamos National Laboratory document LA-UR-06-4975, ID 094043 (June 2006).

LANL 2006l: "Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99," Los Alamos National Laboratory document LA-UR-06-5510, ID 093798 (August 2006).

LANL 2006m: "Investigation Report for MDA T, Consolidated Unit 21-016(a)-99, at TA-21," Los Alamos National Laboratory document LA-UR-06-6506, ID 094151 (September 2006).

LANL 2006n: "Response to Approval with Modifications for Investigation Work Plan for the North Canyons," Supplement to Los Alamos National Laboratory document LA-UR-01-1316, ID 093250 (September 2006).

LANL 2006o: "Investigation Report for Material Disposal Area U, Consolidated Unit 21-017(a)-99, at Technical Area 21, Revision 1," Los Alamos National Laboratory document LA-UR-06-6137, ID 094148 (September 2006).

LANL 2006q: "Mortandad Canyon Investigation Report," Los Alamos National Laboratory document LA-UR-06-6752, ID 094160 (October 2006).

LANL 2006r: "Investigation Report for Consolidated Unit 21-018(a)-99, Material Disposal Area V (MDA V), at Technical Area 21 (TA-21)," Los Alamos National Laboratory document LA-UR-06-6609, ID 094361 (October 2006).

LANL 2006s: "Investigation Report for Material Disposal Area A (MDA A), Solid Waste Management Unit (SWMU) 21-014 at Technical Area 21 (TA-21)," Los Alamos National Laboratory document LA-UR-06-7902, ID 095046 (November 2006).

LANL 2006t: "Interim Measures Investigation Report for Chromium Contamination in Groundwater," Los Alamos National Laboratory document LA-UR-06-8372, ID 094431 (November 2006).

LANL 2006u: "Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50," Los Alamos National Laboratory document LA-UR-06-8096, ID 094688 (December 2006).

LANL 2007: "Periodic Monitoring Report for Pajarito Watershed Sampled August 15-31, 2006," Los Alamos National Laboratory document LA-UR-07-1425, ID 095116 (March 2007)

NMED 2004a: "Approval of the Investigation Work Plan for the TA-16-340 Complex, Solid Waste Management Units 13-003(a)-99, 16-003(n)-99, 16-003(o), 16-026 (j2), and 16-029(f) at Technical Area 16, LANL," EPA ID# NM0890010515, HWB-LANL-04-004, ID 091143 (June 24, 2004).

NMED 2004b: "Approval as Modified, Accelerated Corrective Action Work Plan for the Investigation and Remediation of Consolidated SWMU 19-001-99 (Former TA-19/East Gate Laboratory), LANL," EPA ID# NM0890010515, HWB-LANL-04-001, ID 087285 (June 23, 2004).

NMED 2004c: "Approval with Modifications, IWP for SWMU 21-018(a)-99, Material Disposal Area V at TA-21, LANL," EPA ID# NM0890010515, HWB-LANL-04-008, ID 090174 (November 5, 2004).

NMED 2005a: "Approval with Modifications, Investigation Work Plan for Material Disposal Area U, Solid Waste Management Unit 21-017(a)-99, at Technical Area 21, Los Alamos National Laboratory," EPA ID# NM0890010515, HWB-LANL-04-015, ID 090611 (March 21, 2005).

NMED 2005b: "Approval with Modifications, Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50, Revision 1, LANL," EPA ID# NM0890010515, HWB-LANL-03-005, ID 090165 (April 6, 2005).

NMED 2005c: "Approval with Modifications for the Investigation Work Plan for Delta Prime Site Aggregate Area at Technical Area 21, LANL," EPA ID# NM0890010515, HWB-LANL-04-011 (April 13, 2005).

NMED 2005d: "Approval with Modifications, Accelerated Corrective Action Work Plan for SWMU 33-013, a Former Storage Area at TA-33, LANL," EPA ID# NM0890010515, HWB-LANL-05-003, ID 090159 (April 25, 2005).

NMED 2005e: "Approval with Modifications, Investigation Work Plan for material Disposal Area T, Solid Waste Management Unit 21-016(a)-99, LANL," EPA ID# NM0890010515, HWB-LANL-04-003, ID 091694 (May 19, 2005).

NMED 2005f: "Approval with Modifications, Investigation Work Plan for Material Disposal Area A at Technical Area 21, LANL," EPA ID# NM0890010515, HWB-LANL-05-002, ID 091660 (July 26, 2005).

NMED 2005g: "Approval of the Investigation Work Plan for Consolidated Solid Waste Management Units 16-007(a)-99, (30s Line) and 16-008(a)-99 (90s Line) at TA-16, LANL," EPA ID# NM0890010515, HWB-LANL-05-004, CT-05-072, ID 091672 (August 18, 2005).

NMED 2005h: "Approval with Modifications, Pueblo Canyon Aggregate Area Investigation Work Plan, LANL," EPA ID# NM0890010515, HWB-LANL-05-006, CT-05-006, ID 091388 (September 23, 2005).

NMED 2005i: "Approval of the Work Plan for Corrective Action of SWMU 73-002 and Investigation of Consolidated Unit 73-002-99," New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J. P. Bearzi (NMED HWB), ID 092180 (September 30, 2005).

NMED 2005j: "Approval with Modifications for the Investigation Work Plan for the North Canyons, September 2001, LANL," EPA ID# NM089001515, HWB-LANL-05-00, CT-05-061, ID 091653 (February 27, 2005).

NMED 2005k: "Material Disposal Area C Boreholes Required by Approval with Modifications Letter, Los Alamos National Laboratory," EPA ID# NM0890010515, HWB-LANL-03-005, ID 091695 (October 12, 2005).

NMED 2006a: "Approval with Modifications for the Investigation Work Plan for Guaje/Barrancas/Rendija Canyons Aggregate Area at TA-00, LANL," EPA ID# NM0890010515, HWB-LANL-05-018, ID 091532 (January 5, 2006).

NMED 2006b: "Approval, Accelerated Corrective Action Work Plan for Area of Concern 16-024(v) and Solid Waste Management Units 16-026(r) and 16-031(f) at Technical Area 16, LANL," EPA ID# NM0890010515, HWB-LANL-06-003, ID 091832 (March 20, 2006).

NMED 2006c: "Approval with Modifications for the Accelerated Corrective Action Work Plan for the Investigation and Remediation of Solid Waste Management Unit 61-002, LANL," EPA ID# NM0890010515, HWB-LANL-06-010, ID 092371 (May 2, 2006).

NMED 2006d: "Approval with Modifications for the Interim Measures Work Plan for Chromium in Groundwater, LANL," EPA ID # NM0890010515, HWB-LANL-06-009, ID 092543 (May 5, 2006).

NMED 2006e: "Approval and Certificates of Completion Remedy Completion Report for the Investigation and Remediation of Consolidated Unit 19-001-99 (Former Technical Area 19/East Gate Laboratory), LANL," EPA ID# NM0890010515, HWB-LANL-05-011 (June 27, 2006).

NMED 2006f: "Approval for the Drilling Work Plan for Regional Aquifer Wells R-35a and R-35b, LANL," EPA ID# NM0890010515, ID 093530 (July 24, 2006).

NMED 2006g: "Approval and Certificate of Completion Remedy Completion Report for the Investigation and Remediation of Solid Waste Management Unit 33-013, TA-33, LANL," EPA ID# NM0890010515, HWB-LANL-06-013, ID 093526 (August 30, 2006).

NMED 2006h: "Approval for the Investigation Report for Material Disposal Area U, Consolidated Unit 21-017(a)-99, at Technical Area 21, LANL," EPA ID# NM0890010515, HWB-LANL-06-006 (September 28, 2006).

NMED 2006i: "Notice of Approval with Direction, Investigation Report for Intermediate and Regional Groundwater, Consolidated Unit 16-021(c)-99, LANL," EPA ID# NM0890010515, HWB-LANL-06-016, ID 095026 (November 29, 2006).

NMED 2006j: D. Goering, "Pajarito Canyon Email Message," Los Alamos National Laboratory email to D. Katzman and NMED, ID 093027 (April 2006).

10. Environmental Risk and Hazard Reduction

10. Environmental Risk and Hazard Reduction

contributing authors:
Mike McNaughton, Rich Mirenda, and Terry Morgan

To Read About **Turn to Page**

Introduction *309*
Estimation of Risk *309*
Examples of Risk and Hazard Reduction *310*
Monitoring for Potential Exposures and Risks *313*
References *315*

A. INTRODUCTION

The Los Alamos National Laboratory (LANL or the Laboratory) is committed to evaluating and reducing hazards and risk or dose to humans and the environment from past and current Laboratory operations. These risks or doses (hereafter referred to as risk) may exist from the potential for unintentional releases, migration through the environment, or exposure of people to the hazard. Over the years, the Laboratory has decreased its release of materials into the environment and has reduced the amount of legacy contamination present. This is accomplished by assessing institutional processes, reducing sources, substituting chemicals in operations, recycling materials, and estimating the current, present-day risks as well as prospective risks, where appropriate. A few examples of these actions include the reduction in outfalls (from plant and process discharges) and air emissions, changes to effluent treatment processes at the Radioactive Liquid Waste Treatment Facility at Technical Area (TA) 50, the elimination of chromate in cooling towers, and the removal of contaminated material and waste at sites such as Material Disposal Area (MDA) P and Area G. These efforts throughout the Laboratory have significantly reduced or eliminated potential exposure and risk to workers, the public, and the environment.

This chapter describes how relative risks are estimated, some of the efforts the Laboratory is taking to reduce these risks, and how the environmental surveillance program monitors for new hazards. Detailed methods and results from the environmental surveillance program are discussed in the previous chapters of this report and specific examples of how monitoring has helped reduce risk are provided later in this chapter.

B. ESTIMATION OF RISK

Risk is evaluated either as current (present-day) risk or prospective risk (defined by the US Environmental Protection Agency [EPA] as "the future risks of a stressor not yet released into the environment or of future conditions resulting from an existing stressor"). The stressor (also known as a hazard) could be a radionuclide, a chemical, or a combination for which the potential risk is evaluated based on protective assumptions under a reasonable exposure scenario(s), safety analysis, or model.

The terminology used in describing the current risks is that a potential unacceptable risk is present or not. The "acceptable" nature is determined by target levels dictated by the regulatory authorities (NM Environment Department [NMED] or US Department of Energy [DOE]) and are equal to or less than 10^{-5} (1 in 100,000) probability of cancer, a hazard index equal to 1.0 or less for noncancer causing chemicals (indicates that no [noncancer] adverse human health effects are expected to occur), and a dose of 15 mrem/yr or less for radionuclides. In keeping with the policy of maintaining all dose and risk as low as reasonably achievable, the Laboratory strives to reduce risk/dose to below these target levels whenever possible. For the maximally

exposed individual (MEI) reported in Chapter 3 of this report, the calculated cancer risk from the estimated dose in 2006 is approximately 3×10^{-7} (3 in 10,000,000 chance of cancer).

To analyze current and prospective risk, LANL uses environmental data, computer evaluation tools, and computer models. A computer program called RACER (http://www.racteam.com/LANLRisk/RACERDatabase.htm or http://www.racteam.com/RACERatLANL.htm) is in development by the Risk Assessment Corporation (http://www.racteam.com/) in consultation with LANL and the NMED. The RACER tool will analyze collected environmental data to help estimate risk for a variety of exposure scenarios, such as recreational or residential uses. Models such as the residual radioactivity (RESRAD) model (http://web.ead.anl.gov/resrad/), Hotspot (http://www.llnl.gov/nhi/hotspot/), and CAP88 (http://www.epa.gov/radiation/assessment/CAP88/index.html) are used to evaluate risk based on material inventory buried or stored at a site or in transport (e.g., from the surface to the regional aquifer).

Prospective risk is also used to aid in the evaluation of remediation and corrective measure options. Probabilistic models account for physical system uncertainties within the context of the decisions under consideration. Prospective risk methods can identify the additional data needed to determine the optimal decision, thus guiding data collection operations.

C. EXAMPLES OF RISK AND HAZARD REDUCTION

The Laboratory is committed to reducing hazards and the associated risk to people and the environment. Current risk depends on the amount of hazardous material that actually reaches a receptor, whereas prospective risk depends on the amount of hazardous material and the probability of *exposure* in the future. It is often given as a range of concentrations and risks (expressed as a dose) rather than a single number or set of numbers due to the uncertainties associated with predicting future concentrations and exposures. Buried hazardous material buried may have little or no exposure under current conditions but may have an increased probability of exposure over time. In addition, if the material is brought to the surface either now or in the future, the potential for exposure and risk increases substantially.

The following are examples where current or past Laboratory operations have resulted in the storage of large quantities of wastes or the release of contaminants to the environment. These sites are being addressed by the Laboratory to reduce the potential and current hazards to humans and the environment.

1. TA-54 Area G and MDA G

The transuranic waste disposition program expedites the disposal of legacy transuranic waste to the Waste Isolation Pilot Plant (WIPP) in Carlsbad, NM, and ensures appropriate facilities and equipment are available to facilitate disposal of current and future transuranic wastes. Area G at TA-54 stores substantial amounts of radioactively contaminated waste and other contaminated materials in above-ground storage. MDA G at TA-54 is a subsurface disposal site containing potentially hazardous and radioactive wastes from operational activities and wastes from environmental restoration and demolition activities at the Laboratory. MDA G was also used for the retrievable storage of transuranic (TRU) waste. Most of the TRU waste will eventually be transported to permanent storage at WIPP.

As discussed in Chapter 3, the dose to the all-pathway MEI results from neutrons emitted from the TRU waste at Area G (1.1 mrem in 2006). The primary method to reduce both the current and prospective risk at Area G is to steadily reduce the inventory of transuranic waste by transporting drums of radioactive material to WIPP. During 2006, the shipping rate was more than five times that of previous years. Of the approximately 130,000 plutonium equivalent curies (PE-Ci) of radioactive materials in secure above-ground storage at Area G, the Laboratory shipped approximately 12,081 PE-Ci in 2,976 barrels to WIPP in 2006. Additionally, 294 drums

Laboratory shipped approximately 12,081 PE-Ci in 2,976 barrels to WIPP in 2006. Additionally, 294 drums of neutron sources, recovered by the Off-Site Source Recovery Program, were transported to WIPP. The shipping strategy in 2007 and 2008 will shift from an emphasis on shipping specific high-activity drums to maximize the PE-Ci of TRU waste shipped to WIPP and removed from LANL. Starting in 2009, TRU waste that was buried in retrievable forms in MDA G will be excavated and shipped to WIPP. All temporarily-stored radioactive wastes are scheduled to be removed by late 2013 (Figure 10-1).

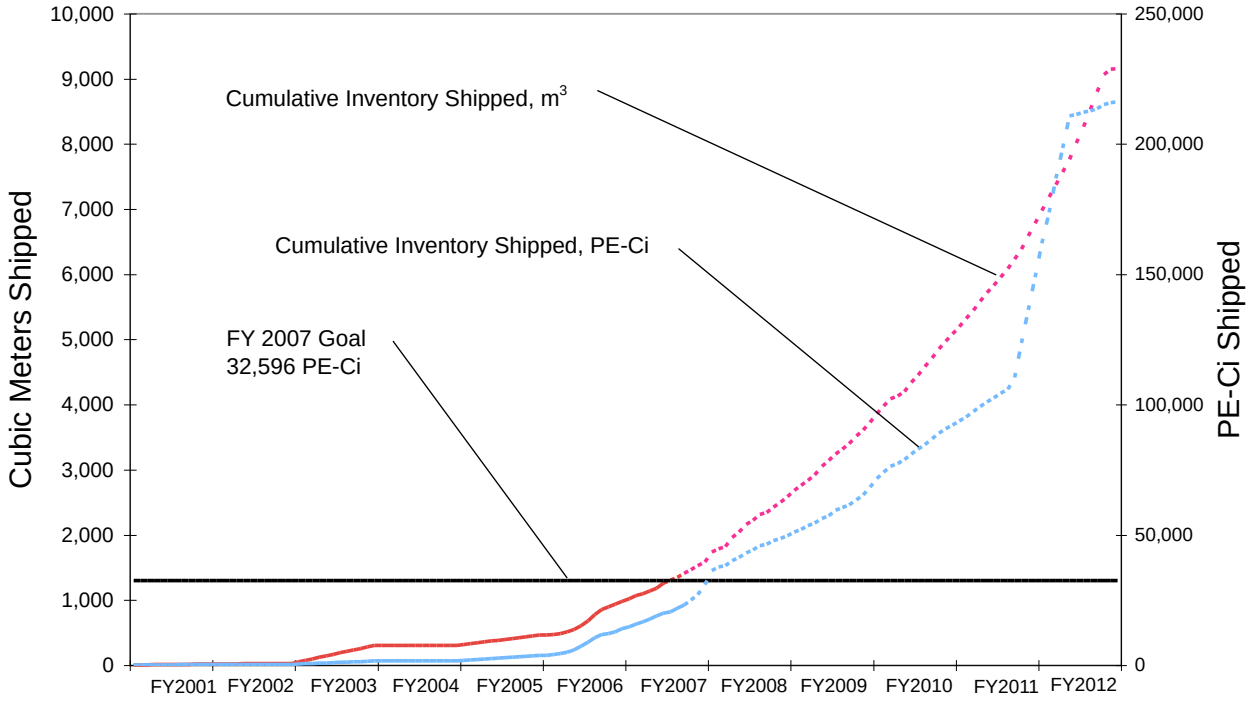


Figure 10-1. Graph showing goals for shipment of waste volume and activity at Area G.

2. TA-21

TA-21 is the site of the Laboratory's original plutonium processing facility, a tritium processing and handling facility, and several MDAs. This site has several MDAs and other solid waste management units (SWMUs) and areas of concern related to past operations. The inventories of hazardous and radioactive material at the MDAs are not well characterized because there are few records of waste disposal during the 1940s and the Manhattan Project. MDAs V and U have been remediated, MDAs A and T will undergo corrective measures evaluations to determine the appropriate corrective actions, and MDA B is scheduled to be remediated. In addition, the other sites at TA-21 are being characterized or remediated as part of the DP Site Aggregate Area investigation.

3. Groundwater

As discussed in detail in Chapter 5 (Groundwater Monitoring), Laboratory-derived impacts to groundwater have been found in some monitoring wells. At present, there is no measurable LANL-derived contamination in the supplied drinking water but there may be a prospective risk because of the potential for contamination to migrate to the drinking water supply wells in the future. Throughout 2006, efforts were under way to evaluate groundwater quality and augment the current monitoring network to ensure monitoring activities will detect contamination in groundwater before it can affect the drinking water.

4. LANSCE Emissions Reduction

Radioactive gases from the Los Alamos Neutron Science Center (LANSCE) at TA-53 have traditionally been the source of the highest radiation dose to the public from Laboratory facilities. As described in Chapter 4, emissions from LANSCE were substantially lower in 2006 than in 2005 and the lowest since 1999. Emissions in 2005 were abnormally high because of a cracked valve, but the replacement of the valve and the addition of more delay line (used to slow and allow decay of short-lived radionuclides) in 2005 resulted in greatly reduced emissions in 2006. Emissions are expected to remain low in 2007 and beyond.

5. Environmental Characterization and Restoration

The objective of the environmental investigation and cleanup activities at the Laboratory is to identify and characterize releases (the nature of the contamination), the location and extent of the contamination, whether it requires remediation (poses a potential unacceptable risk), and what type of remediation is appropriate. Over the past few years, the Laboratory has been conducting corrective action activities under the March 1, 2005 Compliance Order on Consent, which specifies requirements and goals to be met.

In the past several years, the Laboratory has determined where contamination is present and in many cases has reduced the legacy contamination. Where contamination is present, the risk is quantified to determine whether it is unacceptable with respect to human health and the environment. Table 9-3 lists the sites for which corrective actions were completed and approved in 2006.

Remediation has been completed at TA-73, which contained landfills, septic systems, an incinerator and surface disposal area, and other miscellaneous sites. This TA is currently part of or adjacent to the Los Alamos County Airport. The landfills and associated sites were addressed in 2006 as part of a corrective measure, which included the construction of an engineered cover. During the 1940s and early 1950s, ash and debris from incinerator operations were disposed of on the north-facing slope (known as the Airport Ashpile) of Pueblo Canyon. The disturbance of this site during the cleanup activities in 2006 contributed a portion of the calculated dose (0.47 mrem) at the adjacent airport terminal and resulted in this location becoming the site of the air pathway MEI for 2006 (see Chapter 3). The remediation of this site, which also included the removal of septic systems, drainlines, and outfalls in the vicinity of the ash pile, reduced the risk and dose to acceptable levels under a residential scenario.

Other major remediation activities were conducted in 2006 at MDA V at TA-21 where three absorption beds and other contaminated soil and tuff were excavated. In addition, other smaller sites around the Laboratory (individual SWMUs and areas of concern) were successfully investigated and, in some cases, remediated while other sites continue to be investigated. Investigations of groundwater contamination are continuing at several locations to determine the extent and potential for movement of contaminants.

Previous risk reduction successes include the cleanup of the MDA P landfill at TA-16; the removal of contaminated media from the 260 Outfall at TA-16; a voluntary corrective measure to remove contaminated material in DP Canyon at SWMU 21-011(k); and the removal of contaminated sludge, soil, and tuff from three lagoons at TA-53.

D. MONITORING FOR POTENTIAL EXPOSURES AND RISKS

LANL's environmental surveillance program identifies possible environmental hazards and impacts. Monitoring can detect and identify environmental impacts from hazardous and radioactive materials and data from monitoring can be used to help with mitigation of any impacts. To this end, each pathway by which an individual may be exposed is monitored. The sensitivity of environmental surveillance measurements allows for the detection of contaminants during cleanup or normal operations at near and remote locations. Additional monitoring may be conducted in places where there is an increased potential for environmental releases. In some cases, immediate actions are warranted because of monitoring results.

After sites have been remediated, long-term monitoring may be required as part of the chosen remediation solution. Such monitoring will eventually become part of the existing environmental surveillance programs and will fulfill requirements for a long-term environmental stewardship program as required by DOE.

The following subsections provide examples of findings by the environmental surveillance program that reduced or indicated the presence of LANL hazards.

1. Air Monitoring

As described in Chapter 2, LANL rigorously controls and monitors stack emissions, as required by the Clean Air Act. During 2006, the stack emissions were small and the measured concentrations and activities were less than 1% of the Clean Air Act standards.

In addition to stack emissions, other possible emissions are monitored using the AIRNET system (Chapter 4). During 2006, the AIRNET system detected several cases of emissions that were not from stacks, as described below.

- Area G is monitored by eight AIRNET stations. During 2006, as in previous years, the AIRNET data revealed plutonium emissions above background. LANL has taken steps to minimize these emissions, for example by wetting the surface at Area G when necessary and minimizing work during windy conditions.
- Unexpected elevated tritium concentrations were detected at three AIRNET stations at Area G, and the source of the tritium was traced to a tritium storage tank that had been removed during the decommissioning of the tritium facilities at TA-21. Although the emissions were not a health hazard, even for individuals close to the tank, the tank has been removed and buried in order to keep the dose as low as possible.
- An AIRNET station at TA-21 detected airborne plutonium-239 concentrations significantly greater than background during the remediation of MDA V. To monitor future work operations at TA-21, six additional AIRNET stations were installed approximately every 300 ft along DP Road and three additional stations were installed along State Road 502.
- The AIRNET station next to the Los Alamos Airport terminal measured elevated plutonium-239 concentrations near the airport during the cleanup operations at the adjacent ash pile within TA-73. These measurements were used to determine that the nearby airport terminal was the location of the air pathway MEI for 2006.
- Above-background plutonium has been detected for many years within the Los Alamos Townsite at AIRNET Station 66 near former TA-1. During the original Manhattan Project in the 1940s, the plutonium was discharged on the steep hillside of Los Alamos Canyon and is often resuspended by winds. An additional AIRNET station was installed nearby to collect more data before making a decision on future actions to keep the public dose as low as reasonably achievable.

2. Radiation Monitoring

Gamma and neutron radiation is monitored by the direct penetrating radiation monitoring network (DPRNET) described in Chapter 4.

The largest source of direct radiation is Area G at TA-54 and is monitored at 33 stations, all of which measure above-background intensities of neutron radiation. As discussed in Chapter 3, the all-pathway MEI is at the northern boundary of TA-54 and results primarily from neutrons. The neutron radiation is being reduced by removing the sources from Area G.

Though high radiation levels are not expected from TA-21 during the upcoming cleanup at that site, four new DPRNET stations have been installed along DP Road and State Road 502, between the potential sources at TA-21 and the public areas to the north and west.

NEWNET is a radiation monitor that displays radiation levels at 15-minute intervals in near real time. On December 12, 13, and 14, 2006, the NEWNET station at East Gate detected unexpected radiation, which was quickly traced to a source at LANSCE (traced to a flow condition of the target cooling water at the Isotope Production Facility). Prompt action by the LANSCE facility staff eliminated the emissions and kept the total dose to members of the public to a very low level (estimated at less than 0.03 mrem).

3. Soil, Foodstuff, and Biota Monitoring

Monitoring of soil, foodstuff, and non-foodstuff biota is an important indication of the health of the environment. Soil and sediment monitoring has established a baseline of known concentrations in selected areas on Laboratory property, in surrounding areas, and regionally. Comparison of known concentrations with future results may indicate movement of contaminants, for example in the flood retention structures that collect sediment transported downstream.

Collection and analysis of foodstuff (crops, game animals, fish, honey, milk, etc.) from the region provides confidence that no unexpected contamination has reached off-site locations. The program has identified since the 1990s that PCB and mercury levels in some types of fish both upstream and downstream in the Rio Grande are above EPA and NMED fish advisory levels.

Biota monitoring is a non-invasive method of detecting underground materials. The roots of some plants and trees penetrate into subsurface contamination and may bring contaminated material to the surface. For example, vegetation samples collected annually at MDA G demonstrate low concentrations of isotopic plutonium (approximately 1 pCi/g or less) in the soil toward the north and east of the area (Chapter 8). Tree samples indicate an area of underground tritium along the south fence of MDA G. At MDA B, tree samples from 2006 along the northern fence showed above-background plutonium-239 concentrations and cesium-137 concentrations which indicate radioactive materials are within reach of the roots. Also, measurements of chamisa within the fenced area of Bayo Canyon indicate underground concentrations on the order of 1,000 pCi/g near the southwest corner (Fresquez et al. 1995).

4. Water Monitoring

The Los Alamos County water supply system contains no detected LANL-derived contaminants so the current risk from contaminants in drinking water is less than 10^{-6}. At present, the major thrust of the water monitoring program, being developed in cooperation with the NMED, is directed toward estimating the prospective risk of contamination that may enter the drinking water in the future. One such activity is modeling to estimate the possibility of contaminants migrating from the surface through the vadose zone to the aquifer. Data show that plutonium, uranium, cesium, and strontium are tightly bound to the soil matrix and so will not migrate

in measurable amounts. Tritium is more mobile, but its migration is slower compared with its approximately 12-year radioactive half-life, so the concentrations of tritium in drinking water will remain far below drinking water standards. Thus, migration of radionuclides is not likely to be a problem, so attention is focused on migration of chemicals such as perchlorate, chromium, and high explosive residues.

Numerous additional monitoring wells have been drilled over the past several years and more are planned for 2007. These new wells will provide a better picture of the location and movement of contamination in the aquifer.

E. REFERENCES

DOE 1994: DOE-HDBK-3010-94 "Airborne Release Fractions/Rates, and Respirable Fractions for NonReactor Nuclear Facilities" (1994) (http://www.orau.gov/DDSC/dose/doehandbook.pdf)

DOE 2003: DOE/EH-412/0015/0802 rev. 1 "Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)," ISCORS Technical Report No. 1, (January 2003) (http://homer.ornl.gov/oepa/guidance/risk/iscors.pdf)

LANL 2003: "Emergency Planning Hazards Assessment," Los Alamos National Laboratory report LA-CP-03-0309 (2003)

LAHDRA 2007: "Interim Report of the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project," version 5 (March 2007) (http://www.lahdra.org/reports/LAHDRA%20Report%20v5%202007.pdf)

Fresquez et al 1995: Fresquez, P.R., T.S. Foxx, and L. Naranjo. "Strontium concentrations in chamisa (*Chrysothamnus nauseosus*) shrub plants growing in a former liquid waste disposal area in Bayo Canyon," Los Alamos National Laboratory report LA-13050-MS (1995)

Appendix A

STANDARDS FOR ENVIRONMENTAL CONTAMINANTS

Throughout this report, we compare concentrations of radioactive and chemical constituents in air and water samples with pertinent standards and guidelines in regulations of federal and state agencies. No comparable standards for soils, sediments, or foodstuffs are available. Los Alamos National Laboratory (LANL or the Laboratory) operations are conducted in accordance with directives for compliance with environmental standards. These directives are contained in Department of Energy (DOE) Orders 450.1, "Environmental Protection Program;" 5400.5, "Radiation Protection of the Public and the Environment;" and 231.1A, "Environmental Safety and Health Reporting."

Radiation Standards. DOE regulates radiation exposure to the public and the worker by limiting the radiation dose that can be received during routine Laboratory operations. Because some radionuclides remain in the body and result in exposure long after intake, DOE requires consideration of the dose commitment caused by inhalation, ingestion, or absorption of such radionuclides. This evaluation involves integrating the dose received from radionuclides over a standard period of time. For this report, 50-yr dose commitments were calculated using the EPA dose factors from Federal Guidance Report No. 13 (EPA 1999). The dose factors EPA adopted are based on the recommendations of Publication 30 of the International Commission on Radiological Protection (ICRP 1988).

In 1990, DOE issued Order 5400.5, which finalized the interim radiation protection standard for the public (NCRP 1987). Table A-1 lists currently applicable radiation protection standards, now referred to as public dose limits, for operations at the Laboratory. DOE's comprehensive public dose limit for radiation exposure limits the effective dose equivalent (EDE) that a member of the public can receive from DOE operations to 100 mrem per year. For one specific activity or pathway, DOE guidance specifies a "dose constraint" of 25 mrem per year (DOE 1999.) The public dose limits and the DOE occupational dose limits are based on recommendations in ICRP (1988) and the National Council on Radiation Protection and Measurements (NCRP 1987).

The EDE is the hypothetical whole-body dose that would result in the same risk of radiation-induced cancer or genetic disorder as a given exposure to an individual organ. It is the sum of the individual organ doses, weighted to account for the sensitivity of each organ to radiation-induced damage. The weighting factors are taken from the recommendations of the ICRP. The EDE includes doses from both internal and external exposure. External dose factors were obtained from Federal Guidance Report No. 12 (EPA 1993).

Radionuclide concentrations in water are compared with DOE's Derived Concentration Guides (DCGs) to evaluate potential impacts to members of the public. The DCGs for water are those concentrations in water that if consumed at a maximum rate of 730 liters per year, would give a dose of 100 mrem per year. Table A-2 shows the DCGs. For comparison with drinking-water systems, the DCGs are multiplied by 0.04 to correspond with the EPA limit of 4 mrem per year.

In addition to DOE standards, in 1985 and 1989, the EPA established the National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities, 40 CFR 61, Subpart H. This regulation states that emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr. DOE has adopted this dose limit (Table A-1). This dose is calculated at the location of a residence, school, business, or office. In addition, the regulation requires monitoring of all release points that can produce a dose of 0.1 mrem to a member of the public.

Table A-1
DOE Dose Limits for External and Internal Exposures

Exposure pathway	Dose Equivalent[a] at Point of Maximum Probable Exposure
Exposure of Any Member of the Public[b]	
All Pathways	100 mrem/yr[c]
One Specific Pathway (dose constraint)	25 mrem/yr[d]
Air Pathway Only[e]	10 mrem/yr
Drinking Water	4 mrem/yr
Occupational Exposure[b]	
Stochastic Effects	5 rem/yr (TEDE)[f]
Nonstochastic Effects	
Lens of eye	15 rem/yr
Extremity	50 rem/yr
Skin of the whole body	50 rem/yr
Skin of the whole body	50 rem/yr
Embryo/Fetus of Declared Pregnant Worker	0.5 rem/gestation period

[a] Refer to Glossary for definition.

[b] In keeping with DOE policy, exposures must be limited to as small a fraction of the respective annual dose limits as practicable. DOE's public dose limit applies to exposures from routine Laboratory operation, excluding contributions from cosmic, terrestrial, and global fallout; self-irradiation; and medical diagnostic sources of radiation. Routine operation means normal, planned operation and does not include actual or potential accidental or unplanned releases. Exposure limits for any member of the general public are taken from DOE Order 5400.5 (DOE 1990). Limits for occupational exposure are taken from 10 CFR 835, Occupational Radiation Protection.

[c] Under special circumstances and subject to approval by DOE, this limit on the EDE may be temporarily increased to 500 mrem/yr, provided the dose averaged over a lifetime does not exceed the principal limit of 100 mrem per year.

[d] Guidance (DOE 1999.)

[e] This level is from EPA's regulations issued under the Clean Air Act (40 CFR 61, Subpart H) (EPA 1989a).

[f] Refer to Glossary for definition.

Table A-2
DOE's Derived Concentration Guides for Water[a]

Nuclide	DCGs for Water Ingestion in Uncontrolled Areas (pCi/L)	DCGs for Drinking Water Systems (pCi/L)[b]
^{3}H	2,000,000	80,000
^{7}Be	1,000,000	40,000
^{89}Sr	20,000	800
^{90}Sr	1,000	40
^{137}Cs	3,000	120
^{234}U	500	20
^{235}U	600	24
^{238}U	600	24
^{238}Pu	40	1.6
^{239}Pu	30	1.2
^{240}Pu	30	1.2
^{241}Am	30	1.2

[a] Guides for uncontrolled areas are based on DOE's public dose limit for the general public (DOE 1990). Guides apply to concentrations in excess of those occurring naturally or that are due to worldwide fallout.

[b] Drinking water DCGs are 4% of the DCGs for non-drinking water.

Table A-3
National (40 CFR 50) and New Mexico (20.2.3 NMAC) Ambient Air Quality Standards

Pollutant	Averaging Time	Unit	New Mexico Standard	Federal Standards	
				Primary	Secondary
Sulfur dioxide	Annual	ppm	0.02	0.030	
	24 hours	ppm	0.10	0.14	
	3 hours	ppm			0.5
Hydrogen sulfide	1 hour	ppm	0.010		
Total reduced sulfur	1/2 hour	ppm	0.003		
Total Suspended Particulates	Annual	µg/m3	60		
	30 days	µg/m3	90		
	7 days	µg/m3	110		
	24 hours	µg/m3	150		
PM-10[a]	Annual	µg/m3		50	50
	24 hours	µg/m3		150	150
PM-2.5[b]	Annual	µg/m3		15	15
	24 hours	µg/m3		65	65
Carbon monoxide	8 hours	ppm	8.7	9	
	1 hour	ppm	13.1	35	
Ozone	1 hour	ppm		0.12	0.12
	8 hours	ppm		0.08	0.08
Nitrogen dioxide	Annual	ppm	0.05	0.053	0.053
	24 hours	ppm	0.10		
Lead and lead compounds	Calendar quarter	µg/m3		1.5	1.5

[a] Particles ≤10 μm in diameter.

[b] Particles ≤2.5 μm in diameter.

Nonradioactive Air Quality Standards. Table A-3 shows federal and state ambient air quality standards for nonradioactive pollutants.

National Pollutant Discharge Elimination System. The types of monitoring required under National Pollutant Discharge Elimination System (NPDES) and the limits established for sanitary and industrial outfalls can be found at *http://www.lanl.gov/environment/h2o/index.shtml*.

Drinking Water Standards. For chemical constituents in drinking water, regulations and standards are issued by the Environmental Protection Agency (EPA) and adopted by the New Mexico Environment Department (NMED) as part of the New Mexico Drinking Water Regulations (NMEIB 1995). To view the New Mexico Drinking Regulations go to *http://www.nmenv.state.nm.us/Common/regs_idx.html*. EPA's secondary drinking water standards, which are not included in the New Mexico Drinking Water Regulations and are not enforceable, relate to contaminants in drinking water that primarily affect aesthetic qualities associated with public acceptance of drinking water (EPA 1989b). There may be health effects associated with considerably higher concentrations of these contaminants.

Appendix A

Radioactivity in drinking water is regulated by EPA regulations contained in 40 CFR 141 (EPA 1989b) and New Mexico Drinking Water Regulations, Sections 206 and 207 (NMEIB 1995). These regulations provide that combined radium-226 and radium-228 may not exceed 5 pCi per liter. Gross alpha activity (including radium-226, but excluding radon and uranium) may not exceed 15 pCi per liter.

A screening level of 5 pCi per liter for gross alpha is established to determine when analysis specifically for radium isotopes is necessary. In this report, plutonium concentrations are compared with both the EPA gross alpha standard for drinking water and the DOE guides calculated for the DCGs applicable to drinking water (Table A-2).

For man-made beta- and photon-emitting radionuclides, EPA drinking water standards are limited to concentrations that would result in doses not exceeding 4 mrem per year, calculated according to a specified procedure. In addition, DOE Order 5400.5 requires that persons consuming water from DOE-operated public water supplies do not receive an EDE greater than 4 mrem per year. DCGs for drinking water systems based on this requirement are in Table A-2.

Surface Water Standards. Concentrations of radionuclides in surface water samples may be compared with either the DOE DCGs (Table A-2) or the New Mexico Water Quality Control Commission (NMWQCC) stream standard, which references the state's radiation protection regulations. However, New Mexico radiation levels are in general two orders of magnitude greater than DOE's DCGs for public dose, so only the DCGs will be discussed here. The concentrations of nonradioactive constituents may be compared with the NMWQCC Livestock Watering and Wildlife Habitat stream standards (NMWQCC 1995) (http://www.nmenv.state.nm.us/NMED_regs/swqb/20_6_4_nmac.pdf). The NMWQCC groundwater standards can also be applied in cases where discharges may affect groundwater.

Organic Analysis of Surface and Groundwaters: Methods and Analytes. Organic analyses of surface waters, groundwaters, and sediments are made using SW-846 methods. The specific compounds analyzed in each suite are listed in the supplemental tables for Chapters 5 and 6.

REFERENCES

DOE 2003a: US Department of Energy, "Environmental Protection Program," US Department of Energy Order 450.1 (January 15, 2003).

DOE 1990: US Department of Energy, "Radiation Protection of the Public and the Environment," US Department of Energy Order 5400.5 (February 8, 1990).

DOE 1999: US Department of Energy, "The Long-Term Control of Property: Overview of Requirements in Orders DOE 5400.1 & 5400.5," US Department of Energy Brief EH-412-0014/1099 (October 1999) http://www.hss.doe.gov/nuclearsafety/nsea/oepa/guidance/aea/doe5415b.pdf.

DOE 2003b: US Department of Energy, "Environment, Safety, and Health Reporting," US Department of Energy Order 231.1A (August 19, 2003).

EPA 1988: US Environmental Protection Agency, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors For Inhalation, Submersion And Ingestion, Federal Guidance Report No. 11," EPA-520/1-88-020 (September 1988).

EPA 1989a: US Environmental Protection Agency, "40CFR 61, National Emission Standards for Hazardous Air Pollutants, Radionuclides; Final Rule and Notice of Reconsideration," Federal Register 54, 51 653-51 715 (December 15, 1989).

EPA 1989b: US Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," Code of Federal Regulations, Title 40, Parts 141 and 142 (1989), and "National Secondary Drinking Water Regulations," Part 143 (1989).

EPA 1993: US Environmental Protection Agency, "External Exposure to Radionuclides in Air, Water, and Soil," Federal Guidance Report No. 12, EPA 402-R-93-081 (September 1993).

EPA 1999: US Environmental Protection Agency, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides," Federal Guidance Report No. 13, EPA 402-R-90-001 (September 1999).

ICRP 1988: International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers," ICRP Publication 30, Parts 1, 2, and 3, and their supplements, Annals of the ICRP 2(3/4) -8(4) (1979-1982), and Publication 30, Part 4, 19(4) (1988).

NCRP 1987: National Council on Radiation Protection and Measurements, "Recommendations on Limits for Exposure to Ionizing Radiation," NCRP report No. 91 (June 1987).

NMEIB 1995: New Mexico Environmental Improvement Board, "New Mexico Drinking Water Regulations," (as amended through January 1995).

NMWQCC 1995: New Mexico Water Quality Control Commission, "State of New Mexico Water Quality Standards for Interstate and Intrastate Streams," Section 3-101.K (as amended through January 23, 1995).

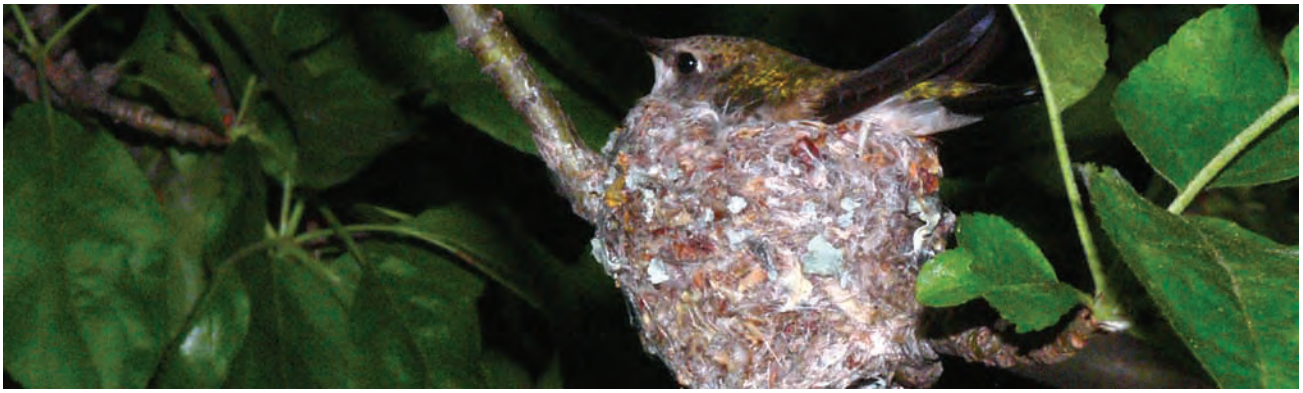
Appendix B

UNITS OF MEASUREMENT

Throughout this report the US Customary (English) system of measurement has generally been used because those are the units in which most data and measurements are collected or measured. For units of radiation activity, exposure, and dose, US Customary Units (that is, curie [Ci], roentgen [R], rad, and rem) are retained as the primary measurement because current standards are written in terms of these units. The equivalent SI units are the becquerel (Bq), coulomb per kilogram (C/kg), gray (Gy), and sievert (Sv), respectively. Table B-1 presents conversion factors for converting US Customary Units into SI units.

Table B-1
Approximate Conversion Factors for Selected US Customary Units

Multiply US Customary units	by	to Obtain SI (Metric) Unit
Fahrenheit (°F)	5/9 - 32	Celsius (°C)
inches (in.)	2.54	centimeters (cm)
cubic feet (ft^3)	0.028	cubic meters (m^3)
acres (ac)	.4047	hectares (ha)
ounces (oz)	28.3	grams (g)
pounds (lb)	0.453	kilograms (kg)
miles (mi)	1.61	kilometers (km)
gallons (gal.)	3.785	liters (L)
feet (ft)	0.305	meters (m)
parts per million (ppm)	1	micrograms per gram (μg/g)
parts per million (ppm)	1	milligrams per liter (mg/L)
square miles (mi^2)	2.59	square kilometers (km^2)
picocurie (pCi)	37	millibecquerel (mBq)
rad	0.01	gray (Gy)
millirem (mrem)	0.01	millisievert (mSv)



Appendix B

Table B-2 presents prefixes used in this report to define fractions or multiples of the base units of measurements. Scientific notation is used in this report to express very large or very small numbers. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2.0×10^{3}, the decimal point should be moved three numbers (insert zeros if no numbers are given) to the **right** of its present location. The number would then read 2,000. If the value given is 2.0×10^{-5}, the decimal point should be moved five numbers to the **left** of its present location. The result would be 0.00002.

Table B-2
Prefixes Used with SI (Metric) Units

Prefix	Factor	Symbol
mega	1 000 000 or 10^{6}	M
kilo	1 000 or 10^{3}	k
centi	0.01 or 10^{-2}	c
milli	0.001 or 10^{-3}	m
micro	0.000001 or 10^{-6}	μ
nano	0.000000001 or 10^{-9}	n
pico	0.000000000001 or 10^{-12}	p
femto	0.000000000000001 or 10^{-15}	f
atto	0.000000000000000001 or 10^{-18}	a

Table B-3 presents abbreviations for common measurements.

Table B-3
Common Measurement Abbreviations and Measurement Symbols

Symbol	Abbreviation
aCi	attocurie
Bq	becquerel
Btu	British thermal unit
Ci	curie
cm^3/s	cubic centimeters per second
cpm/L	counts per minute per liter
fCi/g	femtocurie per gram
ft	foot or feet
ft^3/min	cubic feet per minute
ft^3/s	cubic feet per second
kg	kilogram
kg/h	kilogram per hour
m^3/s	cubic meter per second
μCi/L	microcurie per liter
μCi/mL	microcurie per milliliter
μg/g	microgram per gram
$\mu g/m^3$	microgram per cubic meter
mL	milliliter
mm	millimeter
μm	micrometer
μmho/cm	micro mho per centimeter
mCi	millicurie
mg	milligram
mR	milliroentgen
mrad	millirad
mrem	millirem
mSv	millisievert
nCi	nanocurie
nCi/dry g	nanocurie per dry gram
nCi/L	nanocurie per liter
ng/m^3	nanogram per cubic meter
pCi/dry g	picocurie per dry gram
pCi/g	picocurie per gram
pCi/L	picocurie per liter
pCi/m^3	picocurie per cubic meter
pCi/mL	picocurie per milliliter
pg/g	picogram per gram
pg/m^3	picogram per cubic meter
PM_{10}	small particulate matter (less than 10 μm diameter)

Table B-3 (continued)

Symbol	Abbreviation
$PM_{2.5}$	small particulate matter (less than 2.5 μm diameter)
R	roentgen
s, SD, or σ	standard deviation
sq ft (ft^2)	square feet
>	greater than
<	less than
≥	greater than or equal to
≤	less than or equal to
±	plus or minus
~	approximately

Data Handling of Radiochemical Samples

Measurements of radiochemical samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique. Consequently, individual measurements can result in values of positive or negative numbers. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values are included in the population calculations (Gilbert 1975).

For individual measurements, uncertainties are reported as one standard deviation. The standard deviation is estimated from the propagated sources of analytical error.

Standard deviations for the station and group (off-site regional, off-site perimeter, and on-site) means are calculated using the standard equation:

$$s = (\Sigma (c_i - \bar{c})^2 / (N - 1))^{1/2}$$

where

c_i = sample i,

$\bar{c}$ = mean of samples from a given station or group, and

N = number of samples in the station or group.

This value is reported as one standard deviation (1*s*) for the station and group means.

REFERENCE

Gilbert 1975: R. O. Gilbert, "Recommendations Concerning the Computation and Reporting of Counting Statistics for the Nevada Applied Ecology Group," Battelle Pacific Northwest Laboratories report BNWL-B-368 (September 1975).

Appendix C

DESCRIPTION OF TECHNICAL AREAS AND THEIR ASSOCIATED PROGRAMS

Locations of the technical areas (TAs) operated by the Laboratory in Los Alamos County are shown in Figure 1-3. The main programs conducted at each of the areas are listed in this Appendix.

TA-0

The Laboratory has about 180,000 sq ft of leased space for training, support, architectural engineering design, and unclassified research and development in the Los Alamos town site and White Rock. The publicly accessible Community Reading Room and the Bradbury Science Museum are also located in the Los Alamos town site.

TA-2, Omega Site

Omega West Reactor, an 8-MW nuclear research reactor, was located here. It was placed into a safe shutdown condition in 1993 and was removed from the nuclear facilities list. The reactor was decontaminated and decommissioned in 2002.

TA-3, Core Area

The Administration Complex contains the Director's office, administrative offices, and support facilities. Laboratories for several divisions are in this main TA of the Laboratory. Other buildings house central computing facilities, chemistry and materials science laboratories, earth and space science laboratories, physics laboratories, technical shops, cryogenics laboratories, the main cafeteria, and the Study Center. TA-3 contains about 50% of the Laboratory's employees and floor space.

TA-5, Beta Site

This site contains some physical support facilities such as an electrical substation, test wells, several archaeological sites, and environmental monitoring and buffer areas.

TA-6, Twomile Mesa Site

The site is mostly undeveloped and contains gas cylinder staging and vacant buildings pending disposal.

TA-8, GT Site (or Anchor Site West)

This is a dynamic testing site operated as a service facility for the entire Laboratory. It maintains capability in all modern nondestructive testing techniques for ensuring quality of material, ranging from test weapons components to high-pressure dies and molds. Principal tools include radiographic techniques (x-ray machines with potentials up to 1,000,000 V and a 24-MeV betatron), radioisotope techniques, ultrasonic and penetrant testing, and electromagnetic test methods.

TA-9, Anchor Site East

At this site, fabrication feasibility and physical properties of explosives are explored. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied.

TA-11, K Site

Facilities are located here for testing explosives components and systems, including vibration testing and drop testing, under a variety of extreme physical environments. The facilities are arranged so that testing may be controlled and

observed remotely and so that devices containing explosives or radioactive materials, as well as those containing nonhazardous materials, may be tested.

TA-14, Q Site

This dynamic testing site is used for running various tests on relatively small explosive charges for fragment impact tests, explosives sensitivities, and thermal responses.

TA-15, R Site

This is the home of PHERMEX (the pulsed high-energy radiographic machine emitting x-rays), a multiple-cavity electron accelerator capable of producing a very large flux of x-rays for weapons development testing. It is also the site where DARHT (the dual-axis radiographic hydrotest facility) is located. This site is also used for the investigation of weapons functioning and systems behavior in nonnuclear tests, principally through electronic recordings.

TA-16, S Site

Investigations at this site include development, engineering design, prototype manufacture, and environmental testing of nuclear weapons warhead systems. TA-16 is the site of the Weapons Engineering Tritium Facility for tritium handled in gloveboxes. Development and testing of high explosives, plastics, and adhesives and research on process development for manufacture of items using these and other materials are accomplished in extensive facilities.

TA-18, Pajarito Laboratory Site

This is a nuclear facility that studied both static and dynamic behavior of multiplying assemblies of nuclear materials. Near-critical experiments were conducted by remote control using low-power reactors called critical assemblies. The special nuclear materials at this site have been relocated to the Nevada Test Site.

TA-21, DP Site

This site has two primary research areas: DP West and DP East. DP West has been in the D&D program since 1992, and six buildings have been demolished. The programs conducted at DP West, primarily in inorganic and biochemistry, were relocated during 1997, and the remainder of the site was scheduled for D&D in future years. DP East was a tritium research site.

TA-22, TD Site

This site is used in the development of special detonators to initiate high-explosive systems. Fundamental and applied research in support of this activity includes investigating phenomena associated with initiating high explosives and research in rapid shock-induced reactions.

TA-28, Magazine Area A

This is an explosives storage area.

TA-33, HP Site

An old, high-pressure, tritium-handling facility located here is being phased out. An intelligence technology group and the National Radio Astronomy Observatory's Very Large Baseline Array Telescope are located at this site.

TA-35, Ten Site

Work here includes nuclear safeguards research and development that are concerned with techniques for nondestructive detection, identification, and analysis of fissionable isotopes. Research is also done on reactor safety, laser fusion, optical sciences, pulsed-power systems, high-energy physics, tritium fabrication, metallurgy, ceramic technology, and chemical plating.

TA-36, Kappa Site

Phenomena of explosives, such as detonation velocity, are investigated at this dynamic testing site.

TA-37, Magazine Area C

This is an explosives storage area.

TA-39, Ancho Canyon Site

The behavior of nonnuclear weapons is studied here, primarily by photographic techniques. Investigations are also made into various phenomenological aspects of explosives, interactions of explosives, explosions involving other materials, shock wave physics, equation state measurements, and pulsed-power systems design.

TA-40, DF Site

This site is used in the development of special detonators to initiate high-explosive systems. Fundamental and applied research in support of this activity includes investigating phenomena associated with the physics of explosives.

TA-41, W Site

Personnel at this site engage primarily in engineering design and development of nuclear components, including fabrication and evaluation of test materials for weapons.

TA-43, Health Research Laboratory

This site is adjacent to the Los Alamos Medical Center in the town site. Research performed at this site includes structural, molecular, and cellular radiobiology, biophysics, mammalian radiobiology, mammalian metabolism, biochemistry, and genetics. The Department of Energy Los Alamos Area Office is also located within TA-43.

TA-46, WA Site

Activities include applied photochemistry research including the development of technology for laser isotope separation and laser enhancement of chemical processes. A new facility completed during 1996 houses research in inorganic and materials chemistry. The Sanitary Wastewater System Facility is located at the east end of this site. Environmental management operations are also located here.

TA-48, Radiochemistry Site

Laboratory scientists and technicians perform research and development activities at this site on a wide range of chemical processes including nuclear and radiochemistry, geochemistry, biochemistry, actinide chemistry, and separations chemistry. Hot cells are used to produce medical radioisotopes.

TA-49, Frijoles Mesa Site

This site is currently restricted to carefully selected functions because of its location near Bandelier National Monument and past use in high-explosive and radioactive materials experiments. The Hazardous Devices Team Training Facility is located here.

TA-50, Waste Management Site

This site is divided into two facility management units, which include managing the industrial liquid and radioactive liquid waste received from Laboratory technical areas and activities that are part of the waste treatment technology effort.

TA-51, Environmental Research Site

Research and experimental studies on the long-term impact of radioactive waste on the environment and types of waste storage and coverings are performed at this site.

TA-52, Reactor Development Site

A wide variety of theoretical and computational activities related to nuclear reactor performance and safety are done at this site.

TA-53, Los Alamos Neutron Science Center

The Los Alamos Neutron Science Center, including the linear proton accelerator, the Manuel Lujan Jr. Neutron Scattering Center, and a medical isotope production facility, is located at this TA. Also located at TA-53 are the

Accelerator Production of Tritium Project Office, including the Low-Energy Demonstration Accelerator, and research and development activities in accelerator technology and high-power microwaves.

TA-54, Waste Disposal Site
This site is divided into two facility management units for the radioactive solid and hazardous chemical waste management and disposal operations and activities that are part of the waste treatment technology effort; includes Area G.

TA-55, Plutonium Facility Site
Processing of plutonium and research on plutonium metallurgy are done at this site.

TA-57, Fenton Hill Site
This site is located about 28 miles west of Los Alamos on the southern edge of the Valles Caldera in the Jemez Mountains and was the location of the Laboratory's now decommissioned Hot Dry Rock geothermal project. The site is used for the testing and development of downhole well-logging instruments and other technologies of interest to the energy industry. The high elevation and remoteness of the site make Fenton Hill a choice location for astrophysics experiments. A gamma ray observatory is located at the site.

TA-58
This site is reserved for multiuse experimental sciences requiring close functional ties to programs currently located at TA-3.

TA-59, Occupational Health Site
Occupational health and safety and environmental management activities are conducted at this site. Emergency management offices are also located here.

TA-60, Sigma Mesa
This area contains physical support and infrastructure facilities, including the Test Fabrication Facility and Rack Assembly and the Alignment Complex.

TA-61, East Jemez Road
This site is used for physical support and infrastructure facilities, including the Los Alamos County sanitary landfill.

TA-62
This site is reserved for multiuse experimental science, public and corporate interface, and environmental research and buffer zones.

TA-63
This is a major growth area at the Laboratory with expanding environmental and waste management functions and facilities. This area contains physical support facilities operated by KSL Services.

TA-64
This is the site of the Central Guard Facility and headquarters for the Laboratory Hazardous Materials Response Team.

TA-66
This site is used for industrial partnership activities.

TA-67
This is a dynamic testing area that contains significant archeological sites.

TA-68
This is a dynamic testing area that contains archeological and environmental study areas.

TA-69
This undeveloped TA serves as an environmental buffer for the dynamic testing area.

TA-70
This undeveloped TA serves as an environmental buffer for the high-explosives test area.

TA-71
This undeveloped TA serves as an environmental buffer for the high-explosives test area.

TA-72
This is the site of the Protective Forces Training Facility.

TA-73
This area is the Los Alamos Airport.

TA-74, Otowi Tract
This large area, bordering the Pueblo de San Ildefonso on the east, is isolated from most of the Laboratory and contains significant concentrations of archeological sites and an endangered species breeding area. This site also contains Laboratory water wells and future well fields.

Appendix D

RELATED WEB SITES

For more information on environmental topics at Los Alamos National Laboratory, access the following Web sites:

http://www.lanl.gov/environment/all/esr.shtml	Environmental Surveillance reports and supplemental data tables
http://www.lanl.gov/	Los Alamos National Laboratory web site
http://www.doeal.gov/laso/default.aspx	DOE/NNSA Los Alamos Site Office web site
http://www.energy.gov/	Department of Energy web site
http://www.lanl.gov/environment/air/index.shtml	LANL's air quality pages
http://www.lanl.gov/environment/h2o/index.shtml	LANL's water quality pages
http://www.lanl.gov/environment/waste/index.shtml	LANL's waste pages
http://www.lanl.gov/environment/eco/index.shtml	LANL's ecology pages
http://www.lanl.gov/environment/risk/index.shtml	LANL's risk reduction pages
http://www.lanl.gov/environment/cleanup/index.shtml	LANL's clean-up pages

Glossary

activation products	Radioactive products generated as a result of neutrons and other subatomic particles interacting with materials such as air, construction materials, or impurities in cooling water. These activation products are usually distinguished, for reporting purposes, from fission products.
albedo dosimeters	Albedo dosimeters are used to measure neutrons. They use a neutron-sensitive polyethylene phantom to capture neutron backscatter to simulate the human body.
alpha particle	A positively charged particle (identical to the helium nucleus) composed of two protons and two neutrons that are emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.
ambient air	The surrounding atmosphere as it exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.
AOC	Area of concern.
aquifer	A saturated layer of rock or soil below the ground surface that can supply usable quantities of groundwater to wells and springs. Aquifers can be a source of water for domestic, agricultural, and industrial uses.
artesian well	A well in which the water rises above the top of the water-bearing bed.
background radiation	Ionizing radiation from sources other than the Laboratory. This radiation may include cosmic radiation; external radiation from naturally occurring radioactivity in the earth (terrestrial radiation), air, and water; internal radiation from naturally occurring radioactive elements in the human body; worldwide fallout; and radiation from medical diagnostic procedures.
beta particle	A negatively charged particle (identical to the electron) that is emitted during decay of certain radioactive atoms. Most beta particles are stopped by 0.6 cm of aluminum.
biota	The types of animal and plant life found in an area.
blank sample	A control sample that is identical, in principle, to the sample of interest, except that the substance being analyzed is absent. The measured value or signals in blanks for the analyte is believed to be caused by artifacts and should be subtracted from the measured value. This process yields a net amount of the substance in the sample.
blind sample	A control sample of known concentration in which the expected values of the constituent are unknown to the analyst.

CAA Clean Air Act. The federal law that authorizes the Environmental Protection Agency (EPA) to set air quality standards and to assist state and local governments to develop and execute air pollution prevention and control programs.

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Also known as Superfund, this law authorizes the federal government to respond directly to releases of hazardous substances that may endanger health or the environment. The EPA is responsible for managing Superfund.

CFR Code of Federal Regulations. A codification of all regulations developed and finalized by federal agencies in the *Federal Register*.

contamination (1) Substances introduced into the environment as a result of people's activities, regardless of whether the concentration is a threat to health (see pollution). (2) The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel.

controlled area Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and radioactive materials.

Ci Curie. Unit of radioactivity. One Ci equals 3.70×10^{10} nuclear transformations per second.

cosmic radiation High-energy particulate and electromagnetic radiations that originate outside the earth's atmosphere. Cosmic radiation is part of natural background radiation.

CWA Clean Water Act. The federal law that authorizes the EPA to set standards designed to restore and maintain the chemical, physical, and biological integrity of the nation's waters.

DOE US Department of Energy. The federal agency that sponsors energy research and regulates nuclear materials used for weapons production. Los Alamos National Laboratory is managed by the NNSA, an agency within the DOE.

dose A term denoting the quantity of radiation energy absorbed.

- ***absorbed dose*** The energy absorbed by matter from ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
- ***dose equivalent*** The product of absorbed dose in rad (or gray) in tissue, a quality factor, and other modifying factors. Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).

EDE Effective dose equivalent. The hypothetical whole-body dose that would give the same risk of cancer mortality and serious genetic disorder as a given exposure but that may be limited to a few organs. The effective dose equivalent is equal to the sum of individual organ doses, each weighted by degree of risk that the organ dose carries. For example, a 100-mrem dose to the lung, which has a weighting factor of 0.12, gives an effective dose that is equivalent to 100 × 0.12 = 12 mrem.

maximum individual dose The greatest dose commitment, considering all potential routes of exposure from a facility's operation, to an individual at or outside the Laboratory boundary where the highest dose rate occurs. It takes into account shielding and occupancy factors that would apply to a real individual.

population dose The sum of the radiation doses to individuals of a population. It is expressed in units of person-rem. See definitiion of person-rem.

whole body dose A radiation dose commitment that involves exposure of the entire body (as opposed to an organ dose that involves exposure to a single organ or set of organs).

EA Environmental Assessment. A report that identifies potentially significant environmental impacts from any federally approved or funded project that may change the physical environment. If an EA shows significant impact, an Environmental Impact Statement is required.

effluent A liquid waste discharged to the environment.

EIS Environmental Impact Statement. A detailed report, required by federal law, on the significant environmental impacts that a proposed major federal action would have on the environment. An EIS must be prepared by a government agency when a major federal action that will have significant environmental impacts is planned.

emission A gaseous waste discharged to the environment.

environmental compliance The documentation that the Laboratory complies with the multiple federal and state environmental statutes, regulations, and permits that are designed to ensure environmental protection. This documentation is based on the results of the Laboratory's environmental monitoring and surveillance programs.

environmental monitoring The sampling of contaminants in liquid effluents and gaseous emissions from Laboratory facilities, either by directly measuring or by collecting and analyzing samples in a laboratory.

environmental surveillance The sampling of contaminants in air, water, sediments, soils, foodstuffs, and plants and animals, either by directly measuring or by collecting and analyzing samples in a laboratory.

EPA Environmental Protection Agency. The federal agency responsible for enforcing environmental laws. Although state regulatory agencies may be authorized to administer some of this responsibility, EPA retains oversight authority to ensure protection of human health and the environment.

ephemeral A surface water that flows only in direct response to precipitation or snowmelt in the immediate locality.

exposure A measure of the ionization produced in air by x-ray or gamma ray radiation. (The unit of exposure is the roentgen.)

external radiation Radiation originating from a source outside the body.

gamma radiation Short-wavelength electromagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength (high energy), gamma radiation can cause ionization. Other electromagnetic radiation (such as microwaves, visible light, and radiowaves) has longer wavelengths (lower energy) and cannot cause ionization.

gross alpha The total amount of measured alpha activity without identification of specific radionuclides.

gross beta The total amount of measured beta activity without identification of specific radionuclides.

groundwater Water found beneath the surface of the ground. Groundwater usually refers to a zone of complete water saturation containing no air.

half-life, radioactive The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains (1/2 × 1/2), after three half-lives, one-eighth (1/2 × 1/2 × 1/2), and so on.

hazardous waste Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or yielding toxic constituents in a leaching test. In addition, EPA has listed as hazardous other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term generally refers to any waste that EPA believes could pose a threat to human health and the environment if managed improperly. Resource Conservation and Recovery Act (RCRA) regulations set strict controls on the management of hazardous wastes.

hazardous waste constituent The specific substance in a hazardous waste that makes it hazardous and therefore subject to regulation under Subtitle C of RCRA.

HSWA Hazardous and Solid Waste Amendments of 1984 to RCRA. These amendments to RCRA greatly expanded the scope of hazardous waste regulation. In HSWA, Congress directed EPA to take measures to further reduce the risks to human health and the environment caused by hazardous wastes.

hydrology The science dealing with the properties, distribution, and circulation of natural water systems.

internal radiation Radiation from a source within the body as a result of deposition of radionuclides in body tissues by processes such as ingestion, inhalation, or implantation. Potassium-40, a naturally occurring radionuclide, is a major source of internal radiation in living organisms. Also called self-irradiation.

ionizing radiation Radiation possessing enough energy to remove electrons from the substances through which it passes. The primary contributors to ionizing radiation are radon, cosmic and terrestrial sources, and medical sources such as x-rays and other diagnostic exposures.

isotopes Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons. Isotopes of an element have similar chemical behaviors but can have different nuclear behaviors.

- long-lived isotope - A radionuclide that decays at such a slow rate that a quantity of it will exist for an extended period (half-life is greater than three years).
- short-lived isotope - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (half-life is two days or less).

MCL Maximum contaminant level. Maximum permissible level of a contaminant in water that is delivered to the free-flowing outlet of the ultimate user of a public water system (see Appendix A and Table A-6). The MCLs are specified by the EPA.

MDA Material disposal area.

MEI Maximally exposed individual. The average exposure to the population in general will always be less than to one person or subset of persons because of where they live, what they do, and their individual habits. To try to estimate the dose to the MEI, one tries to find that population subgroup (and more specifically, the one individual) that potentially has the highest exposure, intake, etc. This becomes the MEI.

mixed waste Waste that contains a hazardous waste component regulated under Subtitle C of the RCRA and a radioactive component consisting of source, special nuclear, or byproduct material regulated under the federal Atomic Energy Act (AEA).

mrem Millirem. See definition of rem. The dose equivalent that is one-thousandth of a rem.

NEPA National Environmental Policy Act. This federal legislation, passed in 1969, requires federal agencies to evaluate the impacts of their proposed actions on the environment before decision making. One provision of NEPA requires the preparation of an EIS by federal agencies when major actions significantly affecting the quality of the human environment are proposed.

NESHAP National Emission Standards for Hazardous Air Pollutants. These standards are found in the CAA; they set limits for such pollutants as beryllium and radionuclides.

NNSA National Nuclear Security Agency. An agency within the DOE that is responsible for national security through the military application of nuclear energy.

nonhazardous waste Chemical waste regulated under the Solid Waste Act, Toxic Substances Control Act, and other regulations, including asbestos, PCB, infectious wastes, and other materials that are controlled for reasons of health, safety, and security.

NPDES National Pollutant Discharge Elimination System. This federal program, under the Clean Water Act, requires permits for discharges into surface waterways.

nuclide A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content—or alternately, by the atomic number, mass number, and atomic mass. To be a distinct nuclide, the atom must be capable of existing for a measurable length of time.

outfall The location where wastewater is released from a point source into a receiving body of water.

PCB Polychlorinated biphenyls. A family of organic compounds used since 1926 in electric transformers, lubricants, carbonless copy paper, adhesives, and caulking compounds. PCBs are extremely persistent in the environment because they do not break down into new and less harmful chemicals. PCBs are stored in the fatty tissues of humans and animals through the bioaccumulation process. EPA banned the use of PCBs, with limited exceptions, in 1976.

PDL Public Dose Limit. The new term for Radiation Protection Standards, a standard for external and internal exposure to radioactivity as defined in DOE Order 5400.5 (see Appendix A and Table A-1).

PE Curie Plutonium equivalent curie. One PE curie is the quantity of transuranic material that has the same radiation inhalation hazard as one curie of Pu-239. The PE curie is described in Appendix B of http://www.wipp.energy.gov/library/wac/CH-WAC.pdf.

perched groundwater A groundwater body above a slow-permeability rock or soil layer that is separated from an underlying main body of groundwater by a vadose zone.

perennial A surface water that flows continuously throughout the year.

person-rem A quantity used to describe the radiological dose to a population. Population doses are calculated according to sectors, and all people in a sector are assumed to get the same dose. The number of person-rem is calculated by summing the modeled dose to all receptors in all sectors. Therefore, person-rem is the sum of the number of people times the dose they receive. (For example, if 1,000 people each received a radiation dose of 1 rem, their population dose would be 1,000 person-rem.)

pH A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH less than 7, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.

piezometer A small diameter water well used to measure the hydraulic head (pressure) of groundwater in aquifers.

pollution Levels of contamination that may be objectionable (perhaps because of a threat to health [see contamination]).

point source An identifiable and confined discharge point for one or more water pollutants, such as a pipe, channel, vessel, or ditch.

ppb Parts per billion. A unit measure of concentration equivalent to the weight/volume ratio expressed as µg/L or ng/mL. Also used to express the weight/weight ratio as ng/g or µg/kg.

ppm Parts per million. A unit measure of concentration equivalent to the weight/volume ratio expressed as mg/L. Also used to express the weight/weight ratio as µg/g or mg/kg.

QA Quality assurance. Any action in environmental monitoring to ensure the reliability of monitoring and measurement data. Aspects of quality assurance include procedures, interlaboratory comparison studies, evaluations, and documentation.

QC Quality control. The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes. QC procedures include calibration of instruments, control charts, and analysis of replicate and duplicate samples.

rad Radiation absorbed dose. The rad is a unit for measuring energy absorbed in any material. Absorbed dose results from energy being deposited by the radiation. It is defined for any material. It applies to all types of radiation and does not take into account the potential effect that different types of radiation have on the body.
1 rad = 1,000 millirad (mrad)

radionuclide An unstable nuclide capable of spontaneous transformation into other nuclides through changes in its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

RESRAD A computer modeling code designed to model radionuclide transport in the environment.

RCRA Resource Conservation and Recovery Act of 1976. RCRA is an amendment to the first federal solid waste legislation, the Solid Waste Disposal Act of 1965. In RCRA, Congress established initial directives and guidelines for EPA to regulate hazardous wastes.

release Any discharge to the environment. Environment is broadly defined as water, land, or ambient air.

rem Roentgen equivalent man. The rem is a unit for measuring dose equivalence. It is the most commonly used unit and pertains only to people. The rem takes into account the energy absorbed (dose) and the biological effect on the body (quality factor) from the different types of radiation.

rem = rad × quality factor
1 rem = 1,000 millirem (mrem)

SAL Screening Action Limit. A defined contaminant level that if exceeded in a sample requires further action.

SARA Superfund Amendments and Reauthorization Act of 1986. This act modifies and reauthorizes CERCLA. Title III of this act is known as the Emergency Planning and Community Right-to-Know Act of 1986.

saturated zone Rock or soil where the pores are completely filled with water, and no air is present.

SWMU Solid waste management unit. Any discernible site at which solid wastes have been placed at any time, regardless of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at or around a facility at which solid wastes have been routinely and systematically released, such as waste tanks, septic tanks, firing sites, burn pits, sumps, landfills (material disposal areas), outfall areas, canyons around LANL, and contaminated areas resulting from leaking product storage tanks (including petroleum).

terrestrial radiation Radiation emitted by naturally occurring radionuclides such as internal radiation source; the natural decay chains of uranium-235, uranium-238, or thorium-232; or cosmic-ray-induced radionuclides in the soil.

TLD Thermoluminescent dosimeter. A material (the Laboratory uses lithium fluoride) that emits a light signal when heated to approximately 300°C. This light is proportional to the amount of radiation (dose) to which the dosimeter was exposed.

TRU Transuranic waste. Waste contaminated with long-lived transuranic elements in concentrations within a specified range established by DOE, EPA, and Nuclear Regulatory Agency. These are elements shown above uranium on the chemistry periodic table, such as plutonium, americium, and neptunium, that have activities greater than 100 nanocuries per gram.

TSCA Toxic Substances Control Act. TSCA is intended to provide protection from substances manufactured, processed, distributed, or used in the United States. A mechanism is required by the act for screening new substances before they enter the marketplace and for testing existing substances that are suspected of creating health hazards. Specific regulations may also be promulgated under this act for controlling substances found to be detrimental to human health or to the environment.

tuff Rock formed from compacted volcanic ash fragments.

unsaturated zone See vadose zone in this glossary.

UST Underground storage tank. A stationary device, constructed primarily of nonearthen material, designed to contain petroleum products or hazardous materials. In a UST, 10% or more of the volume of the tank system is below the surface of the ground.

vadose zone The partially saturated or unsaturated region above the water table that does not yield water for wells. Water in the vadose zone is held to rock or soil particles by capillary forces and much of the pore space is filled with air.

water table The water level surface below the ground at which the unsaturated zone ends and the saturated zone begins. It is the level to which a well that is screened in the unconfined aquifer would fill with water.

watershed The region draining into a river, a river system, or a body of water.

wetland A lowland area, such as a marsh or swamp, that is inundated or saturated by surface water or groundwater sufficient to support hydrophytic vegetation typically adapted for life in saturated soils.

wind rose A diagram that shows the frequency and intensity of wind from different directions at a particular place.

worldwide fallout Radioactive debris from atmospheric weapons tests that has been deposited on the earth's surface after being airborne and cycling around the earth.

Acronyms and Abbreviations

AIRNET	Ambient Air Monitoring Network
AOC	area of concern
AQA	Analytical Quality Associates
BCG	Biota Concentration Guides
BSRL	baseline statistical reference level
CFR	Code of Federal Regulations
CGP	Construction General Permit
CMR	Chemistry and Metallurgy Research (LANL building)
CWA	Clean Water Act
DAC	derived air concentration (DOE)
DARHT	Dual Axis Radiographic Hydrotest facility
DCG	Derived Concentration Guide (DOE)
DOE	Department of Energy
DRO	diesel-range organic compound
DU	depleted uranium
EDE	Effective Dose Equivalent
EIS	Environmental Impact Statement
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ES&H	environment, safety, & health
EU	enriched uranium
FY	fiscal year
GEL	General Engineering Laboratory
GMAP	gaseous mixed air activation products
HE	high-explosive
HMX	cyclotetramethylenetetranitramine
HSWA	Hazardous and Solid Waste Amendments
HT	elemental tritium
HTO	tritium oxide
ISM	Integrated Safety Management (LANL)
LANL	Los Alamos National Laboratory (or the Laboratory)
LANSCE	Los Alamos Neutron Science Center (TA-53)
LASO	Los Alamos Site Office (DOE)
LC/MS/MS	liquid chromatography/mass spectrometry/mass spectrometry
MAPEP	Mixed-Analyte Performance Evaluation Program
MCL	maximum contaminant level
MDA	material disposal area
MDL	method detection limit
MEI	maximally exposed individual
NCRP	National Council on Radiation Protection
NELAC	National Environmental Laboratory Accreditation Conference
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
P2	Pollution Prevention Program
PCB	polychlorinated biphenyls
PM	particulate matter
ppb	parts per billion
P/VAP	particulate/vapor activation products
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RDX	research department explosive (cyclonite) (also Royal Demolition Explosive)
RLWTF	Radioactive Liquid Waste Treatment Facility
RSRL	regional statistical reference level
SAL	screening action level
SL	screening level
SOW	statement of work
SPCC	Spill Prevention Control and Countermeasures
SR	State Road
SWEIS	Site-Wide Environmental Impact Statement
SWPP	Storm Water Prevention Plan
SWMU	solid waste management unit
TA	Technical Area
TCE	trichloroethylene
TLD	thermoluminescent dosimeter
TNT	trinitrotoluene
TSCA	Toxic Substances Control Act

Elemental and Chemical Nomenclature

Actinium	**Ac**
Aluminum	**Al**
Americium	**Am**
Argon	**Ar**
Antimony	**Sb**
Arsenic	**As**
Astatine	**At**
Barium	**Ba**
Berkelium	**Bk**
Beryllium	**Be**
Bicarbonate	**HCO_3**
Bismuth	**Bi**
Boron	**B**
Bromine	**Br**
Cadmium	**Cd**
Calcium	**Ca**
Californium	**Cf**
Carbon	**C**
Cerium	**Ce**
Cesium	**Cs**
Chlorine	**Cl**
Chromium	**Cr**
Cobalt	**Co**
Copper	**Cu**
Curium	**Cm**
Cyanide	**CN**
Carbonate	**CO_3**
Dysprosium	**Dy**
Einsteinium	**Es**
Erbium	**Er**
Europium	**Eu**
Fermium	**Fm**
Fluorine	**F**
Francium	**Fr**
Gadolinium	**Gd**
Gallium	**Ga**
Germanium	**Ge**
Gold	**Au**
Hafnium	**Hf**
Helium	**He**
Holmium	**Ho**
Hydrogen	**H**
Hydrogen oxide	**H_2O**
Indium	**In**
Iodine	**I**
Iridium	**Ir**
Iron	**Fe**
Krypton	**Kr**
Lanthanum	**La**
Lawrencium	**Lr (Lw)**
Lead	**Pb**
Lithium	**Li**
Lithium fluoride	**LiF**
Lutetium	**Lu**
Magnesium	**Mg**
Manganese	**Mn**
Mendelevium	**Md**
Mercury	**Hg**
Molybdenum	**Mo**
Neodymium	**Nd**
Neon	**Ne**
Neptunium	**Np**
Nickel	**Ni**
Niobium	**Nb**
Nitrate (as Nitrogen)	**NO_3-N**
Nitrite (as Nitrogen)	**NO_2-N**
Nitrogen	**N**
Nitrogen dioxide	**NO_2**
Nobelium	**No**
Osmium	**Os**
Oxygen	**O**
Palladium	**Pd**
Phosphorus	**P**
Phosphate (as Phosphorus)	**PO_4-P**
Platinum	**Pt**
Plutonium	**Pu**
Polonium	**Po**
Potassium	**K**
Praseodymium	**Pr**
Promethium	**Pm**
Protactinium	**Pa**
Radium	**Ra**
Radon	**Rn**
Rhenium	**Re**
Rhodium	**Rh**
Rubidium	**Rb**
Ruthenium	**Ru**
Samarium	**Sm**
Scandium	**Sc**
Selenium	**Se**
Silicon	**Si**
Silver	**Ag**
Sodium	**Na**
Strontium	**Sr**
Sulfate	**SO_4**
Sulfite	**SO_3**
Sulfur	**S**
Tantalum	**Ta**
Technetium	**Tc**
Tellurium	**Te**
Terbium	**Tb**
Thallium	**Tl**
Thorium	**Th**
Thulium	**Tm**
Tin	**Sn**
Titanium	**Ti**
Tritiated water	**HTO**
Tritium	**^3H**
Tungsten	**W**
Uranium	**U**
Vanadium	**V**
Xenon	**Xe**
Ytterbium	**Yb**
Yttrium	**Y**
Zinc	**Zn**
Zirconium	**Zr**

The following Los Alamos National Laboratory organizations perform environmental surveillance, ensure environmental compliance, and provide environmental data for this report:

Environment and Remediation Support Services Division (Terry Morgan and David B. Rogers, Coordinators)

Water Quality and RCRA Group (Luciana Vigil-Holterman and Robert Beers, Coordinators)

Air Quality and Ecology Group (Gil Gonzales and Jackie Little, Coordinators)

The beginning of each chapter credits the primary authors.

Previous reports in this series are LA-13633-ENV, LA-13775-ENV, LA-13861-ENV, LA-13979-ENV, LA-14085-ENV, LA-14162-ENV, LA-14239-ENV, and LA-14304-ENV.

Technical coordination
Terry Morgan, Group ERSS-GS

Cover Design
Shirley Veenis, Pro2Serve, Inc.

Editor
Caroline Spaeth, Group IRM-CAS

Composition
Teresa Hiteman, Pro2Serve, Inc.
Shirley Veenis, Pro2Serve, Inc.

An Affirmative Action/Equal Opportunity Employer

This report has been reproduced directly from the best available copy.

It is available electronically on the Web at http://www.lanl.gov/environment/air/reports.shtml

It is available to DOE and DOE contractors from
Office of Scientific and Technical Information,
P.O. Box 62
Oak Ridge, TN 37831
(423) 576-8401

It is available to the public from
National Technical Information Service
US Department of Commerce
5285 Port Royal Rd.
Springfield, VA 22616

Los Alamos
NATIONAL LABORATORY
EST.1943