An Assessment of Los Alamos National Laboratory Waste Disposal Inventory

Los Alamos, New Mexico

By

Jackie Travers, B.S., Ekaterina Alexandrova, B.A., and Marvin Resnikoff, Ph.D
Radioactive Waste Management Associates

November, 2009

Radioactive Waste Management Associates
526 West 26th Street
 # 517
New York, NY 10001

Table of Contents

Executive Summary

With Santa Fe County's plans to obtain additional drinking water from the Rio Grande River, there is renewed concern about the levels of radioactive and toxic chemical levels in the river. The project, called the Buckman Direct Diversion Project, would divert Rio Grande waters to complement underground wells and a reservoir presently in use. The contamination in the river arises from surface and ground waters from Los Alamos National Laboratory (LANL). The lab originated in 1943 as one of the Manhattan Project locations established for the development of the atomic bomb. Originally, the Laboratory consisted of an array of activities relating to plutonium work and weapon component fabrication, as well as weapon testing sites. Since World War II the Laboratory has continued to serve as a weapons development location, but has also been used for other nuclear work such as nuclear reactor research, biophysics, and radiobiology. Since the beginning of its operations LANL has disposed of millions of gallons of radioactive and hazardous waste throughout the laboratory grounds and in the canyons that surround the laboratory. This report summarizes the available information about the radioactive waste disposal history at LANL and assesses the waste inventories of various on- and off-site LANL disposal areas.

Local Geology

Los Alamos and its neighboring areas are located on the mesas and in the canyons of the Pajarito Plateau, which slopes east toward the Rio Grande. Some of the major canyons of concern, addressed in this paper because of their uses as waste release sites, include the Acid Canyon, Pueblo Canyon, Los Alamos Canyon, Sandia Canyon, Mortandad Canyon and Water Canyon (See Figure 1, p.1 and Section 5 p.49). In addition to their connection between the top of the plateau and the Rio Grande River, some of the canyons are covered with alluvial deposits, which are unsaturated and have the capacity to absorb large volumes of liquid to the subsurface water table. This geology allows the possibility that the waste released on top of the plateau has or will descend to the river through streams, subsurface water movement, and sediment erosion.

Disposal of Radionuclides

The waste discharge at LANL began in 1944 during the development of the atomic bomb. Due to time pressures, secrecy of the project, and general lack of knowledge at the time about the dangers of radioactive materials, the laboratory took poor precautions in its disposal of radioactive and other hazardous wastes during its early years of operations. Initially, the waste, in the form of liquids, drums and cardboard boxes, was released into the canyons or deposited into unlined pits completely untreated; poor records were maintained about the volumes and activities of these releases. By the 1960s, the waste disposal practices significantly improved and better records were kept.

In order to reconstruct the inventories of radionuclides present at Los Alamos, it is necessary to assess all potential contamination sources including officially designated waste disposal sites, canyons into which liquid waste was released, major accidents that

have occurred throughout the years, testing and firing sites, and air particulate releases from vents and stacks.

The Laboratory is divided into 74 sections, referred to as Technical Areas (Figure 2, p.2). Fairly complete information exists about the operations of each site, which allows for identifying the specific locations of firing sites and radioactive hazard buildings like waste treatment plants, plutonium processing labs, and nuclear reactors. Most of the waste disposed of at LANL is buried at 24 officially designated locations, Material Disposal Areas, situated at selected technical areas. These MDAs range in size, in the type and amount of radioactive waste deposited, and in their potential environmental hazard. Most MDAs hold solid waste, but some contain barrels with liquids and/or absorption beds, although LANL disposed of the majority of liquid waste into the aforementioned canyons. In the earlier years the waste disposal practices were crude. Liquid waste was not treated (Figure 36, p.57) and the solid waste was deposited into unlined pits and packaged in plastic bags or in cardboard boxes sealed with masking tape (Figure 27, p. 39). As practices improved, LANL began treating the liquid waste and sometimes solidifying it with cement. Likewise, some of the disposal shafts were lined with 12 inches of concrete (such as at MDA C) or covered with concrete caps (such as at MDA H). This report compiles the available information about the waste disposed of at each Material Disposal Area and into the three canyons, including any recent soil and water sampling results. Some of the sites with the highest deposits of radioactive contaminants include MDA's C, G, and H with respective inventories of up to 49,679 curies, 1,383,700 curies, and 391 curies. Routine sampling of soil and water is regularly performed and radionuclide contamination above background levels is often found at the burial sites (e.g. TA-21).

Little information is available regarding the airborne radionuclide releases from LANL, in the early days of LANL operation. Some of the point sources would include plutonium from Pu-processing buildings, gaseous fission products from reactors, and radioactive lanthanum tests. Much of the early equipment and plutonium-processing procedures were crude by modern-day standards. Hundreds of stacks throughout the laboratory released unfiltered gaseous waste directly from plutonium-processing hoods. The LAHDRA Project Team has developed a system of priority indices and determined that between 1944 and 1966, plutonium was the most significant contaminant released. LAHDRA estimated that the total amount of plutonium released by LANL throughout its history, even with the improved filtering systems in later years, exceeded 170 curies. Airborne radionuclides have the potential to settle on the ground, depending on meteorological conditions of the area and size of the particles, and can present similar dangers as disposed of solid and liquid waste. The LAHDRA team focused on airborne plutonium releases, and not releases that more directly affect groundwater.

Recommendations

We advise ChemRisk and AMEC to thoroughly identify the original and current contaminant inventories within the LANL site and the neighboring areas. It is essential to identify and model the geological/hydrological formations of the Pajarito Plateau and its surrounding canyons in order to most accurately assess LANL-origin contaminant movement and potential risks to the residents of Santa Fe County. Finally, we recommend designing an environmental monitoring schedule for the disposal areas to monitor future contaminant mobilization and migration, and developing criteria when emergency measures should be taken. Emergency measures should be specified.

1.0 Introduction

Through the Buckman Direct Diversion Project, the City of Santa Fe and the Santa Fe County plan to provide a regional sustainable water supply. Infrastructure will be created to access surface waters from the San Juan-Chama and the Rio Grande rivers and the water will be processed through a water treatment plant before distribution throughout the county. Due to this planned addition to regional aquifer sources, the concerns about radioactive contamination from Los Alamos National Laboratory have resurfaced. These concerns are rooted in the potential hazard of radioactive wastes from LANL's activities descending from the plateau into the surface water, consumed by the Santa Fe residents.

In 1943, the United States Department of Energy (DOE) developed the Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico as part of the Manhattan Project. The primary assignments given to LANL when it opened were to purify plutonium, reduce plutonium to its metallic state, determine plutonium's relevant and metallurgical properties, and develop the weapon component fabrication technologies. Plutonium (Pu) is a radioactive chemical element that most commonly appears in a silvery-white metallic form. Plutonium exists in several different forms, or isotopes, and the half-lives of plutonium isotopes range between 14 years (Pu-241) and 80 million years (Pu-244). LANL served as the primary site for US nuclear component fabrication until 1949, at which point it became a backup production facility and produced nuclear components for test devices. Among other tasks, the Laboratory has been used for thermonuclear weapon design, high explosives and ordnance development and testing, weapons safety, nuclear reactor research, waste disposal, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.

Since 1943, LANL has been staffed, managed, and operated by the University of California (UC). Between 1946 and 1985, the Zia Company operated as the principal subcontractor to the DOE at LANL and performed all construction and maintenance functions necessary at LANL facilities.

The LANL site and its neighboring communities are located on the Pajarito Plateau in New Mexico, approximately 25 miles northwest of Santa Fe. Below, Figures 1 illustrates the location of Acid Canyon, Pueblo Canyon, and Los Alamos Canyon in relation to the LANL site.

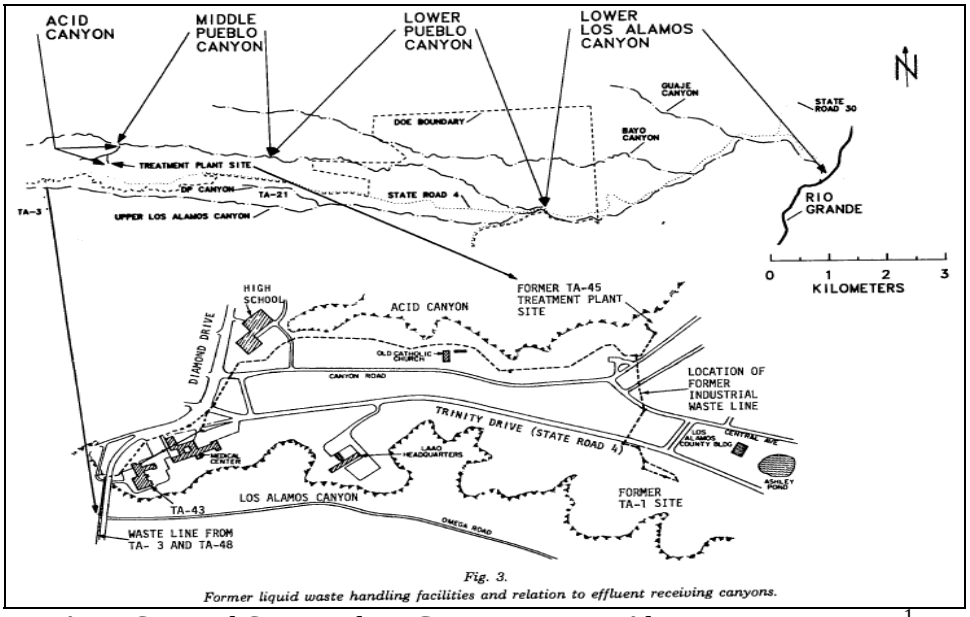


Figure 1. LANL Site and Surrounding Canyons in Los Alamos, New Mexico[1]

LANL constructed several nuclear reactors on site, processed plutonium in multiple buildings within the LANL property, and frequently manufactured and tested high explosive weapons. All LANL activities were carried out over several different land divisions known as technical areas (TA). LANL created and used 74 different technical areas throughout the history of its operations. Below, Figure 2 displays the various technical areas located at the LANL site.

[1] ChemRisk, et al., 2009

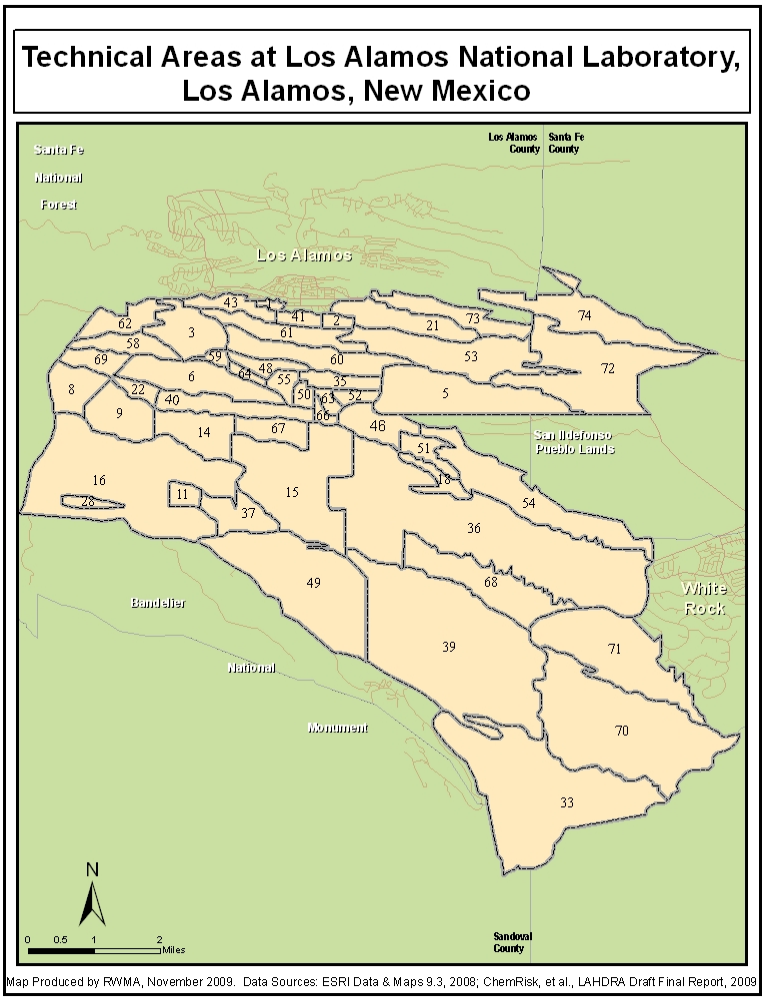


Figure 2. Technical Areas at LANL.

Throughout its operations, LANL has disposed of hundreds of thousands of gallons of radioactive and other hazardous wastes either on site or within the canyons that surround the facility. Most solid waste was buried or temporarily stored on site in one of LANL's technical areas, whereas liquid waste was most often discharged into the surrounding canyons. All liquid wastes discharged by LANL before 1951 was released untreated. In addition to the release of liquid radioactive wastes, LANL released unfiltered and unmonitored gaseous radioactive wastes directly into the atmosphere. Throughout LANL's operational history, airborne releases of radioactive materials were found to have reached several off-site residential areas that surround the laboratory[2].

[2] *Ibid*

Records of the quantities and types of waste disposed of by LANL prior to 1970 were not well kept. Waste disposals were not well inventoried or logged, mostly due to time and monetary pressures placed on LANL staff during wartime. A former LANL staff member stated that, "during the War years, partly because of ignorance and partly because of the stress of wartime conditions, operations with plutonium…were conducted with greater laxity than has ever been tolerated since"[3].

Due to a lack of specific information regarding the types and quantities of wastes that disposed of at LANL and in the surrounding canyons, researchers have worked to develop the Los Alamos Historic Document Retrieval and Assessment (LAHDRA) Project. The LAHDRA Project was created to identify and locate all available information pertaining to the releases of radionuclides and other hazardous materials from LANL. This project was started in 1999 and continues to be conducted by the Centers for Disease Control and Prevention (CDC). The main contractors to this project are ChemRisk Inc., Shonka Associates Inc., ENSR Corporation, and Advanced Technologies and Laboratories International, Inc.

2.0 Los Alamos Historical Document Retrieval and Assessment (LAHDRA)

The Los Alamos Historic Document Retrieval and Assessment Project was created to identify all available information pertaining to the releases of radionuclides and other hazardous materials throughout the history of LANL operations. Since 1999, researchers have worked to retrieve historical documents and records that pertain to waste releases from LANL buildings and former staff. Many of these documents are environmental assessment reports, LANL health division reports, notebooks, interoffice memorandums, and handwritten notes. The most relevant records and documents the LAHDRA Project team has uncovered have been converted to electronic document images and compiled in an online database with full search capabilities. Currently, there are over 8,400 documents in the LAHDRA online database.

Although many of the documents recovered by the LAHDRA Project team are incomplete or lacking in detail, they greatly aid in piecing together the types and quantities of waste disposed of by LANL. These documents are also useful as they assist researchers in estimating the types and quantities of waste that may still remain in or around the Los Alamos and Santa Fe areas and how likely these contaminants are of infiltrating local drinking, ground, and recreational water sources.

The main contractor to the LAHDRA Project is ChemRisk Incorporated (ChemRisk), lead by Project Director Tom Widner. On November 6, 2009 Tom Widner and his LAHDRA Project Team at ChemRisk were selected by the Buckman Direct Diversion

[3] *Ibid*

Project Board to provide a LANL-funded independent peer review of the potential exposure of residents living in Santa Fe County to LANL-origin contaminants that could possibly reach the Rio Grande. Since the primary focus of LAHDRA has been plutonium releases to the air, this new project for the Buckman Board will supplement the previous effort.

We have produced this report to bring attention to all of the waste sites utilized by LANL for radioactive and chemical waste disposal throughout its entire operating history. This will ensure that all potential health and environmental hazards that Santa Fe residents may face will be identified by ChemRisk's LAHDRA Project Team during their peer review of LANL-origin contaminants. The potential for LANL-origin contaminants to reach the Rio Grande River may vary, depending on the underground formations and the types of waste disposed of at each disposal site. The potential may be quite large, as the 2006 Santa Fe Water Quality Report stated a "qualified detection of plutonium-238"was detected in Santa Fe drinking water supplies[4]. The US DOE has also reported the detection of LANL radionuclides in Santa Fe drinking water since the late 1990s[5]. Plutonium is the main ingredient in the core or trigger of the nuclear weapons that were developed and produced at LANL, and approximately 423,776 cubic feet (ft^3) (12,000 cubic meters (m^3)) of plutonium contaminated waste is buried in unlined disposal pits, trenches, and shafts at the LANL site. This early detection of plutonium in Santa Fe drinking water may be an indicator of an approaching plutonium contamination plume in Santa Fe groundwater. And of course, plutonium is only one of many LANL-origin contaminants.

In producing this report, we reviewed documents from the LAHDRA Project online database and additional sources of information provided by LANL, US Department of Energy (DOE), the National Institute for Occupational Safety and Health (NIOSH), and several other research teams. All documents used in this report can be found in the references section, on page 84, of this report.

3.0 Background Radiation Levels in Neighboring Areas of the LANL Site

In order to properly evaluate whether LANL-origin contaminants are mobilized in underground formations and migrating towards Santa Fe drinking water sources, one must first know the background levels of radionuclides present in uncontaminated soils, sediments, and surface and subsurface water sources of the areas that surround the Laboratory.

[4] Lehrman, L., 2007
[5] *Ibid*

Most radionuclides are naturally occurring, and thus low concentrations of uranium, thorium and radium will be present in soil and water. Radionuclides may also be present in the environment due to nuclear fallout, or radioactive contamination due to the global and/or local testing of nuclear weapons.

In 1994, the annual effective dose equivalents due to background radiation in the Los Alamos and White Rock town sites were 348 and 336 mrem, respectively[6]. Naturally occurring radon accounted for approximately half of the total background levels, whereas the remaining background radiation came from cosmic and terrestrial radioactivity and self irradiation. Below, Tables 1, 2, and 3 lists measured background radionuclide levels and soils and water samples collected at off-site sampling stations located in the areas that surround the LANL site. Following Figure 3 displays the locations of each sampling station in relation to the LANL site.

Table 1. Background Radiation Measurements in Air Collected at Offsite Sampling Stations from LANL[7]

Radioactivity	Average (All Stations)
Gross Beta (pCi/L)	0.018
H-3 (pCi/L)	0.5
Uranium (µg/L)	1.14E-07
Pu-238 (pCi/L)	7.00E-07
Pu-239,240 (pCi/L)	9.00E-07
Am-241 (pCi/L)	2.90E-06

Table 2. Background Radiation Measurements in Soil Samples Collected at Offsite Sampling Stations from LANL[8]

Radioactivity	Chamita Station	Otowi Station	Frijoles Station
H-3 (nCi/L)	0.20	-0.30	0.30
Sr-90 (pCi/g)	-1.70	0.20	0.40
Cs-137 (pCi/g)	0.10	7.70	0.00
Uranium (µg/g)	1.00	1.50	2.00
Pu-238 (pCi/g)	0.00	0.00	0.01
Pu-239, 240 (pCi/g)	0.00	0.00	0.01
Am-241 (pCi/g)	2.00	0.00	3.00
Gross Gamma (pCi/g)	2.00	0.00	3.00

[6] LANL, 1996
[7] Hollis, D., et al., 1997
[8] *Ibid*

Table 3. Background Radiation Measurements in Surface Water Samples Collected at Offsite Sampling Stations from LANL[9]

Radioactivity	Embudo Station	Otowi Station	Cochitl Station
H-3 (nCi/L)	0.10	0.20	0.00
Sr-90 (pCi/L)	0.40	0.10	0.30
Cs-137 (pCi/L)	1.90	<0.6	1.90
Uranium (µg/L)	1.60	2.40	1.60
Pu-238 (pCi/L)	0.01	-0.01	-0.02
Pu-239, 240 (pCi/L)	0.03	0.04	-0.01
Am-241 (pCi/L)	0.00	N/A	0.02
Gross Gamma (cpm/L)	60	20	10

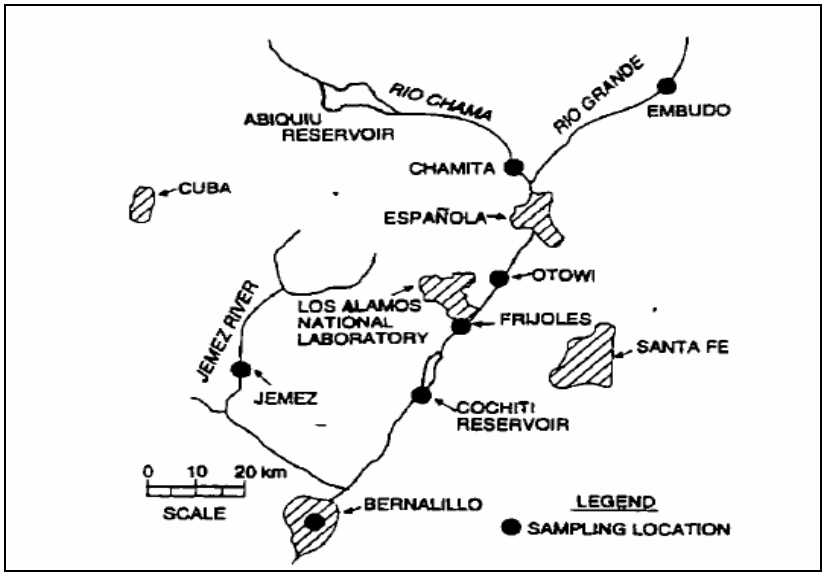


Figure 3. Locations of Sampling Stations Used to Determine Off-Site Background Radiation Levels[10]

The United States Environmental Protection Agency (US EPA)'s federal maximum concentration level (MCL) for all alpha emitting particles in drinking water is 15 pCi/L. Thus, concentrations of plutonium-238, plutonium-239, and americium-241 in drinking water may not exceed 15 pCi/L. The US EPA MCL for uranium is 30 µg/L and 20,000 pCi/L for tritium. Beta emitting particles, such as strontium-90 and cesium-137, are not to exceed concentrations that result in a dose rate greater than 4 millirems per year.[11] As

[9] *Ibid*
[10] *Ibid*
[11] US EPA, 2006

seen in Table 3, 1994 radionuclide concentrations measured in surface waters from the areas surrounding the LANL site did not exceed US EPA MCLs.

The following sections summarize the available information on the types and quantities of waste disposed of by LANL throughout the history of its operations, including any recent soil and water sampling results

4.0 On-Site Waste Disposal

LANL disposed of a great deal of its solid and liquid hazardous waste in several Material Disposal Areas (MDA), located throughout the various technical areas at the LANL site. In total, we have looked at 24 MDAs located within 13 different LANL technical areas. The following sections describe the types and quantities of wastes that were disposed of in these 13 technical areas. As previously discussed, information pertaining to the wastes disposed of by LANL is not always complete or fully available and so many of the types and quantities of waste disposed of at various LANL technical areas remain unknown.

4.1 Technical Area 6

Technical Area 6 (TA-6) is a 500 acre site, also known as the Two-Mile Mesa Site. Only one percent of the area is developed; it is occupied by the gas cylinder staging facility, vacant buildings waiting decommissioning, and a meteorological tower. The site served as a testing location for the "Fat Man" bomb and its current use includes High-Explosive Research and Development and Reserve. After the war, Material Disposal Area F was installed within TA-6 as a burial site for classified materials disposal.[12] Below, Figure 4 displays the locations of TA-6 and Material Disposal Area F.

4.1.1 Material Disposal Area F

Material Disposal Area F (MDA F) occupies only 0.18 acre north of Two-Mile Mesa Road and it received contaminated waste between 1946 and 1964. Run-off from site F drains north into the southwest fork of Two Mile Canyon, part of the Pajarito Canyon Watershed.[13]

Since the site was designated for classified waste, the pits and their inventories are not documented well and even when documentation is present, it does not always reflect the final pit construction and waste disposal. Work orders indicate that the site includes 5 disposal pits and several disposal shafts. [14] Some of the shafts supposedly contain spark gaps with cesium-137. In 1964, the total estimated amount of cesium-137 disposed of at MDA F was 30 microcuries. Other wastes buried in the pits may include contaminated

[12] NNSA, 2006
[13] *Ibid*
[14] Los Alamos Study Group 2009f

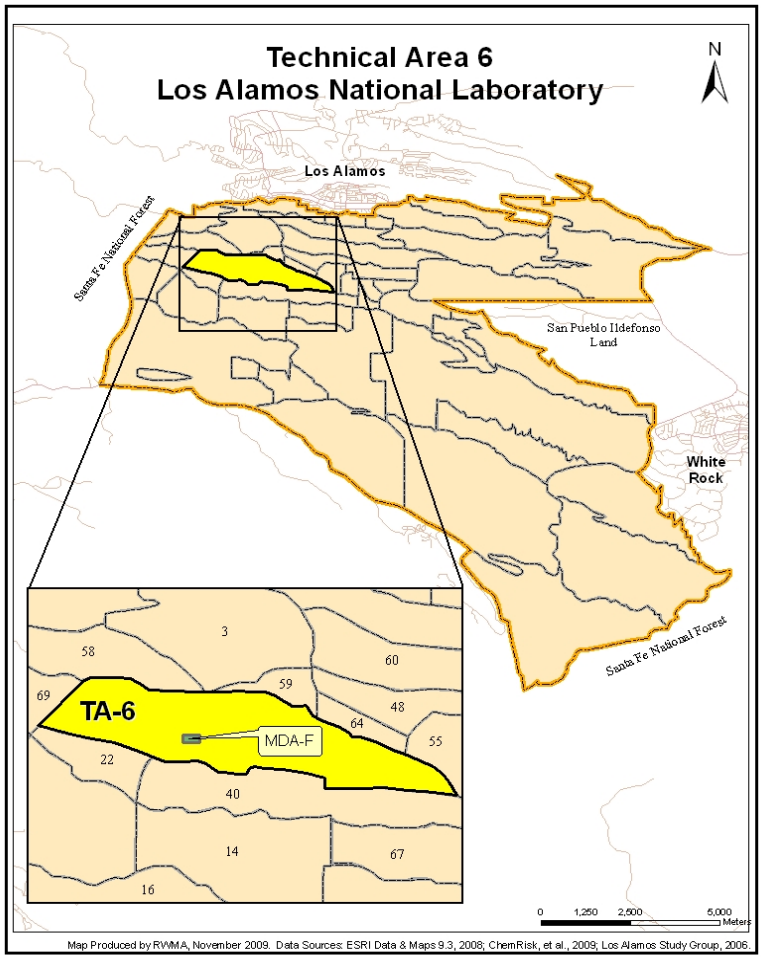


Figure 4. LANL's Technical Area 6 and Material Disposal Area F

squibs (electronic detonators), detonators, depleted uranium, and strontium-90, but evidence for these contaminants is available only through secondary sources such as scientists' accounts from the 1970s.[15] The area has been monitored for radioactivity since 1981, but no readings above background levels have been observed. [16] The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA F as an area with a low probability of contaminant movement and a low to moderate potential of contaminant release to groundwater.[17]

4.2 Technical Area 8

Technical Area 8 (TA-8), also known as the GT or Anchor Site West, was used by LANL as a gun firing site between 1943 to 1945, for explosive processing between 1945 and

[15] Rogers, M.A. 1977
[16] NNSA, 2006
[17] Los Alamos Study Group, 2006f

1950, and for nondestructive X-ray testing from 1950 to the present. In addition, it was used as a storage site for beryllium fluoride and beryllium oxide. TA-8 is located along the western edge of the LANL site, just east of West Jemez Road. Below, Figure 5 displays the locations of TA-8 and Material Disposal Area Q.

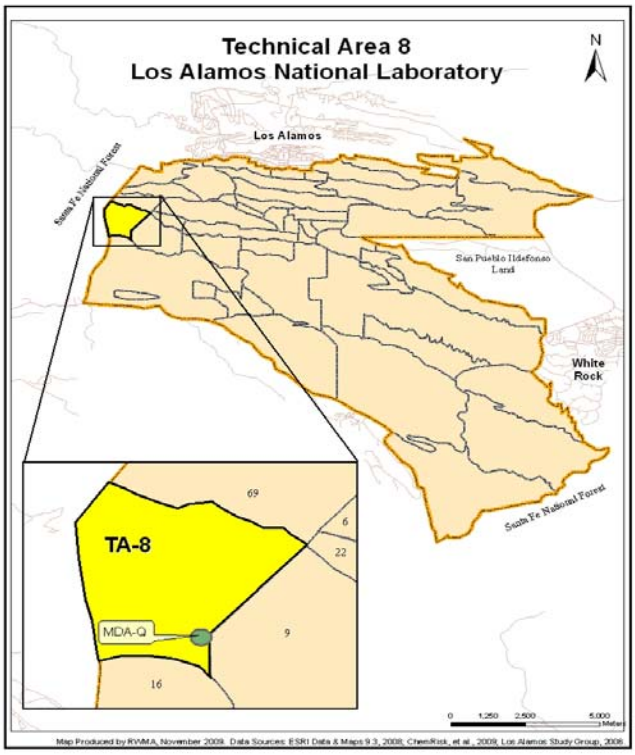


Figure 5. LANL's Technical Area 8 and Material Disposal Area Q

4.2.1 Material Disposal Area Q

Material Disposal Area Q (MDA Q) is approximately 0.2 acre in area and contains only 1 small plot disposal unit. It is located between the Canon de Valle and Pajarito Canyons. MDA Q was only used for 1 year in 1946 and is the only MDA located within TA-8. Based on background knowledge of LANL firing site activities, it is estimated that MDA Q contains high explosives, beryllium, uranium, copper, and lead. MDA Q formerly contained the naval guns used in the development of the Little Boy nuclear weapon, and thus wastes disposed of at MDA Q could possibly contain parts from Little Boy nuclear weapon tests[18]. Thus far, the quantities of each of the contaminants disposed of at MDA Q are unknown. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA Q as an area with a low probability of contaminant movement and a moderate potential of contaminant release to groundwater.[19]

[18] LANL, 2005
[19] Los Alamos Study Group, 2006o

A recent investigation into the soils of MDA Q found no radioactive contaminants in the soil of MDA Q, but concentrations of copper and lead were measured to be above background values for the area[20].

4.3 Technical Area 9

Technical Area 9 (TA-9), also known as the Anchor Site East or Anchor Ranch, is located on the western edge of the LANL site. It was used by LANL as a firing test site and for explosives research. Explosion research topics explored at TA-9 include fabrication feasibility and physical properties of explosives, new organic compounds to be used as explosives, and storage stability problems. TA-9 contains a beryllium fluoride fusion furnace and a gas boosting test facility. TA-9 contains only one Material Disposal Area, Material Disposal Area 3. Below, Figure 6 displays the locations of TA-9 and Material Disposal Area M.

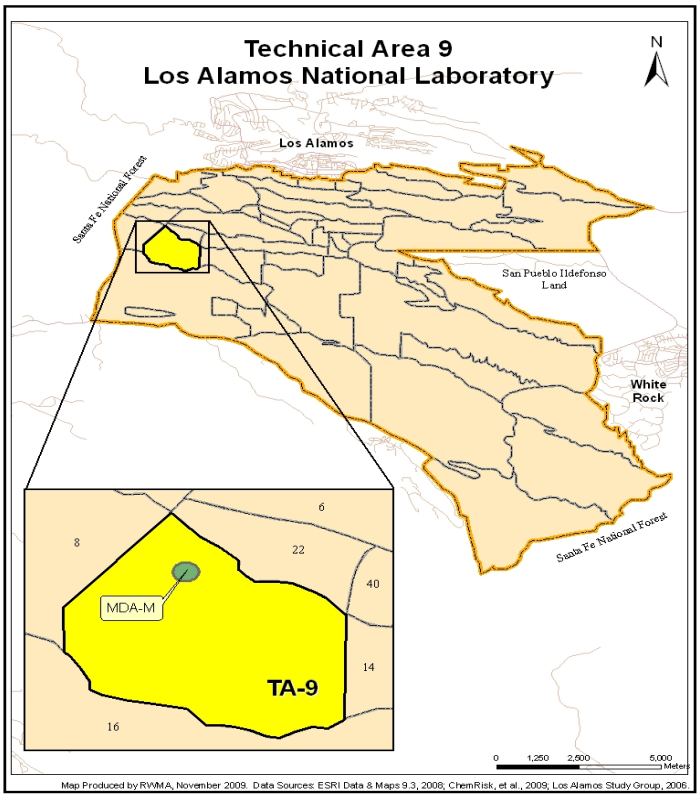


Figure 6. LANL's Technical Area 9 and Material Disposal Area M

4.3.1 Material Disposal Area M

Material Disposal Area M (MDA) M is located in TA-9, southwest of Pajarito Canyon. MDA M covers an area of approximately 3.2 acres and is circular in shape. It contains one small disposal area that was used between 1960 and 1965 for construction debris

[20] NNSA, 2006

produced at other sites.[21] The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau rank MDA M as an area with a high probability of contaminant movement and a moderate to high potential of contaminant release to groundwater[22].

The quantities of waste disposed of at MDA M are not known at this time. It is estimated that the site contains high explosives, tritium, uranium, PCBs, asbestos, VOCs, metals, pesticides, and organochlorine[23].

In 1996, all wastes disposed of at MDA M were removed from the site in preparation of a complete site survey. Documents we reviewed were unclear where this waste was taken. 26 soil samples were then collected from the area and analyzed for organic and inorganic chemicals, radionuclides, PCBs, and asbestos. All contaminants were either not detected or were found to be below recommended cleanup levels. As a result of the 1996 survey, the access road leading to MDA M was regraded and revegetated, and the MDA M was graded, tiered, and seeded to control soil erosion and movement in the area.[24]

4.4 Technical Area 11

Technical Area 11 (TA-11), also known as the K Site, was originally used by LANL for implosion studies and most recently for drop and vibration tests. TA-11 is located in the western portion of the LANL site, surrounded by TA-16 on its west, north, and south borders. TA-11 contains only one disposal area, Material Disposal Area S. Below, Figure 7 displays the locations of TA-11 and Material Disposal Area S.

4.4.1 Material Disposal Area S

Material Disposal Area S (MDA S) is a 100-square foot test plot located in TA-11. It began accepting waste in 1965 and is currently still active. Currently, MDA S is primarily used to investigate the effects of soil and weather on the decomposition of explosives.

[21] LANL, 2005
[22] Los Alamos Study Group, 2006l
[23] *Ibid*
[24] LANL, 2005

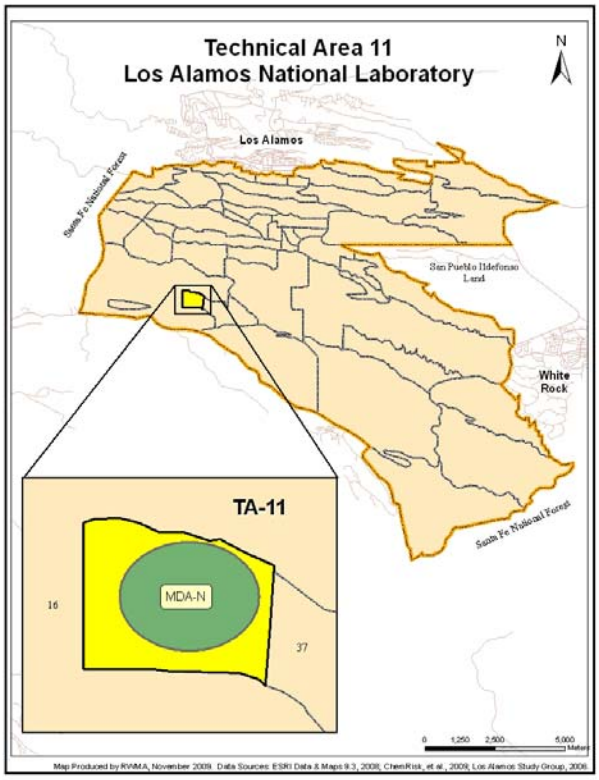


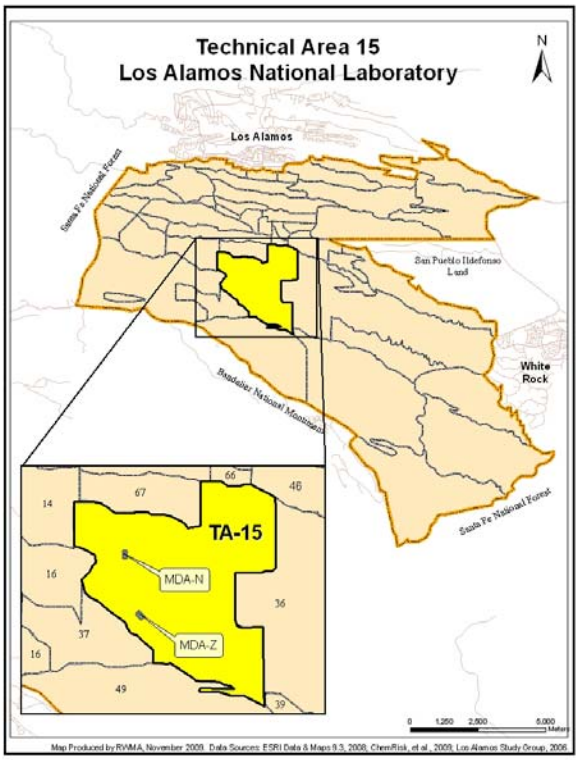
Figure 7. LANL's Technical Area 11 and Material Disposal Area S

According to LANL Environmental Restoration Workplans, MDA S contains 80 grams of high explosives. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau rank MDA S as an area with a high probability for contaminant mobilization and a low to moderate potential of contaminant release to groundwater.[25]

4.5 Technical Area 15

Technical Area 15 (TA-15) is located almost directly in the center of the LANL site. Most of TA-15 is located within the Ponderosa Pine Forest vegetation zone, but portions of it occupy the Pajarito Canyon, the Threemile Canyon, and the Water Canyon. The site is used primarily for high energy radiation tests and as the location of the Radiographic Hydrodynamic Facility and three firing sites. Material Disposal Areas N and Z contained within TA-15 are within the buffer zone of the Water Canyon-Cañon de Valle Areas of Environmental Interest.[26] Below, Figure 8 displays the locations of TA-15 and Material Disposal Areas N and Z.

[25] Los Alamos Study Group, 2006q
[26] Los Alamos Study Group, 2004



The Figure 8. LANL's Technical Area 15 and Material Disposal Areas N and Z

4.5.1 Material Disposal Area N

Material Disposal Area N (MDA N) is a small 0.1-acre site that contains 1 trench of unknown size which received demolished remnants of structures from R-site until 1965. The R Site buildings were most likely exposed to explosives and chemical contamination. The debris disposed of at MDA N is believed to be contaminated with unknown quantities of silver, thorium, uranium, VOCs, mercury, lead, and beryllium. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau rank MDA N as an area with a moderate probability for contaminant mobilization and a low to moderate potential of contaminant release to groundwater.[27]

4.5.2 Material Disposal Area Z

Material Disposal Area Z (MDA Z) is 0.46 acres in size and received waste from 1965 until 1981. The waste consisted of construction rubble and debris from testing at the Pulse High-Energy Radiation Machine Emitting X-rays (PHERMEX) site. The waste was placed in a natural depression on a sloped side of a mound; thus, part of the deposited pile remained exposed (15 ft high). The debris on the exposed face was probably bulldozed from PHERMEX site and consisted of metals from wire and blast mats, volatile/semi-volatile organic compounds, construction debris, and radioactive

[27] Los Alamos Study Group, 2006m

substances. One record cites that chunks of uranium were visible in the rubble; however, 1982 aerial radiological survey did not detect any contamination. A survey conducted in 1995-1996 found that beryllium, copper, lead, mercury, and silver appeared above background levels.[28] Additionally, uranium was found at a maximum concentration of 349 milligrams per kilogram.[29]

4.6 Technical Area 16

Technical Area 16 (TA-16), also known as the Sawmill Site or S Site for short, was named after a saw mill formerly located in the area. TA-16 was created in the 1950s and initially served as the site for explosives casting and machining operations. Later, TA-16 incorporated facilities that accommodated investigations into the development, engineering design, prototype manufacture, and environmental testing of nuclear weapons warhead systems. In addition, TA-16 contains a waste burning ground and the Weapons Engineering Tritium Facility which began operations in late 1989. As of 2001, this facility housed the largest tritium inventory at LANL[30]. An undated and un-authored LANL document estimates that 96,300 pounds of explosives were burned at TA-16 each year[31]. A 1981 memo from R.W. Ferensbaugh to H.S. Jordan stated that approximately 91,000 to 136,000 pounds of waste explosives were disposed of at TA-16 each year.

Many sites surrounding TA-16, such as the P, T, and V-Sites and TA-28, 29, and 37 have been absorbed into the TA-16 complex. TA-16 contains two disposal areas, Material Disposal Areas P and R. Below, Figure 9 displays the locations of TA-16 and Material Disposal Areas P and R.

4.6.1 Material Disposal Area P

Material Disposal Area P (MDA P) is located within TA-16. It is approximately 2 acres in size and operated between 1950 and 1984. MDA P contains a large, semi-elliptical landfill of unknown size, and wastes contained in the landfill are detonable high explosives, soil contaminated with residue from high explosives, barium, asbestos, uranium, lead, and cadmium. The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA P as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[32] A photograph of MDA P in TA-16 can be seen below in Figure 10.

[28] NNSA, 2006
[29] Los Alamos Study Group, 2006v
[30] ChemRisk, et al., 2009
[31] LAHDRA Repos. No. 0672
[32] Los Alamos Study Group, 2006n

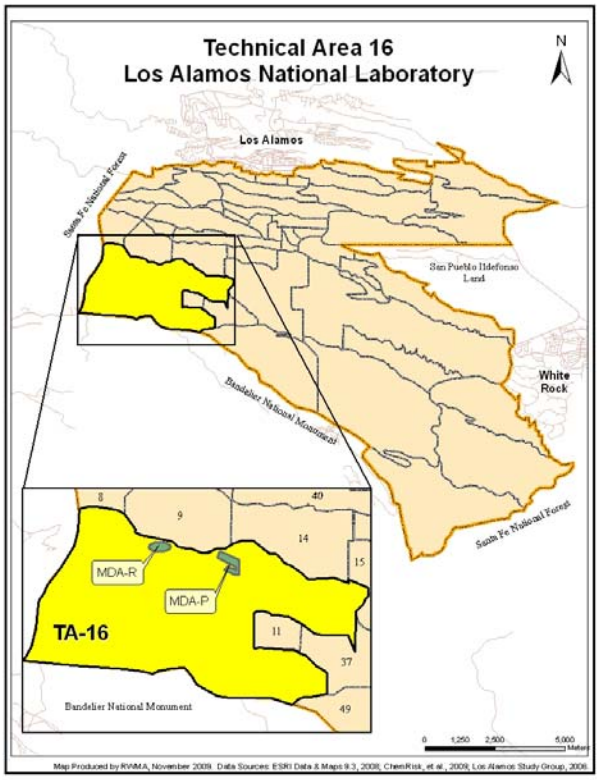


Figure 9. Technical Area 16 and Material Disposal Areas P and R

Figure 10. Photograph of MDA P in TA-16[33]

[33] *Ibid*

In 1997, LANL initiated the process to completely close MDA P, only to unexpectedly discover that high explosives ranging from the size of a fingernail to a softball were contained within the landfill. Excavation of the site was suspended until 1999, and later completed in 2000. 1,416,118 ft^3 (40,100 m^3) of soil and debris materials (including hazardous and industrial wastes), 387 pounds of detonable high explosives, 22,142 ft^3 (627 m^3) of hazardous waste with some form of radioactive contamination, 6,000 pounds of barium nitrate, 2,605 pounds of asbestos, 200 pounds of mixed waste, 237 ft^3 (6.7 m^3) of low-level radioactive waste (LLW), and 888 containers of unknown content were excavated from MDA P.[34] The recovered high explosives were subsequently burned.[35]

4.6.2 Material Disposal Area R

Material Disposal Area R (MDA R) is an inactive 11.5-acre site on the south side of Cañon de Valle that operated between 1948 and 1951. It contained a high explosive burning ground and a disposal pit. The size of MDA R is also cited as 2.27 acres, which possibly includes just the disposal pit area. It is believed that the MDA consist of three U-shaped pits, which contain soil and debris contaminated with high explosives, lead, asbestos, organic chemicals, and barium, as well as low levels of uranium, lead, and cadmium. The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA R as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[36,37] A photograph of MDA R in TA-16 can be seen below in Figure 11.

Figure 11. Photograph of MDA-R in TA-16[38]

[34] LANL, 2001b
[35] LANL, 2001c
[36] Los Alamos Study Group, 2006p
[37] NNSA, 2006
[38] Los Alamos Study Group, 2006p

4.7 Technical Area 21

Technical Area-21 (TA-21), also known as the Delta Prime Site, is divided into two sections, DP West and DP East. DP West was the site of a former plutonium operations facility, where chemical research for refining plutonium was performed between 1945 and 1978. DP East was designated for uranium and polonium operations and housed two buildings of interest, the Tritium Science and Fabrication Facility and the Tritium Systems Test Assembly. The Tritium Science and Fabrication Facility (Building 209) was used for tritium research, including tritium salt synthesis, and served as the site for physical preparation of the underground nuclear testing program. The Tritium Systems Test Assembly contained a large gas loop that simulates the proposed fuel cycle for a fusion facility (it is designed to handle up to ~360 moles/day of deuterium-tritium). In addition to hosting some of the major nuclear facilities, TA-21 contains five Material Disposal Areas, A, B, T, U, V. Environmental contamination from TA-21 can occur through run-off from the nuclear facilities and MDA's, which drains into the Los Alamos Canyon in the south and into the DP Canyon in the north.[39] Below, Figure 12 displays the locations of TA-21 and Material Disposal Areas A, B, T, U, and V.

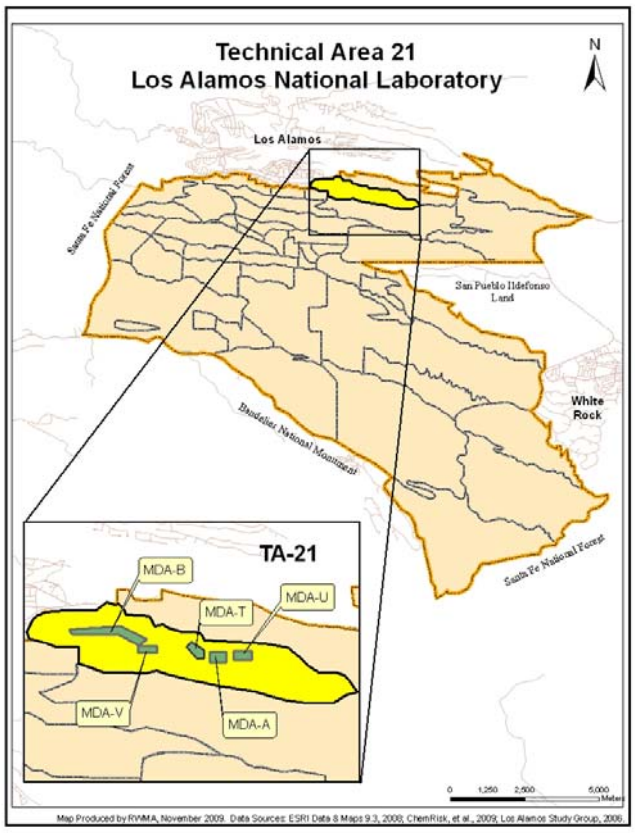


Figure 12. LANL's Technical Area 21 and Material Disposal Areas A, B, T, U, and V

[39] Los Alamos Study Group, 2004

4.7.1 Material Disposal Area A

Material Disposal Area A (MDA A) is an inactive 1.25-acre site that received contaminated waste between 1945-1949 and 1969-1977. Located approximately a quarter-mile east of the intersection of DP Road and TA-21's north perimeter road, the site contains two rectangular pits (Eastern Pits), two General's Tanks, and a large central pit (Figure 13).

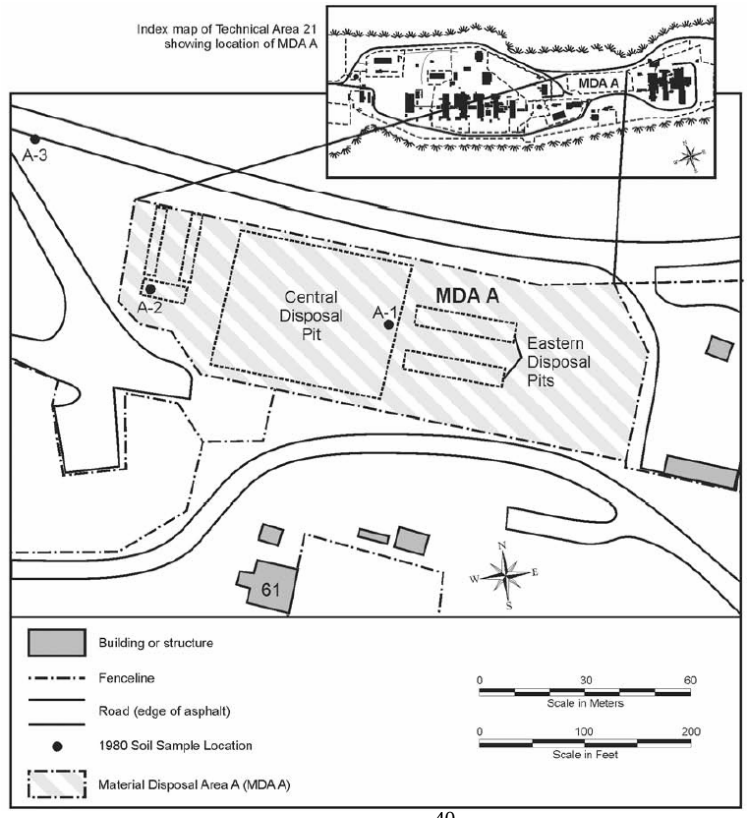


Figure 13. Material Disposal Area A[40]

The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA A as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater[41].

Eastern Pits. When its use as a disposal site first began in 1945, MDA A contained only two rectangular pits (15ft x 100ft. x 12ft) in its eastern section. The pits were quickly filled with waste, faster than LANL staff anticipated, and the pits were closed by July 1946[42]. The pits received radioactively contaminated equipment and chemicals primarily from Chemistry and Metallurgy Research operations.[43] The dominant contaminants are

[40] NNSA, 2006
[41] Los Alamos Study Group, 2006a
[42] Rogers, M.A., 1977
[43] Los Alamos Study Group, 2006a

assumed to be polonium, plutonium-239, and plutonium-240, but may have also included uranium, americium-241, and residues of iodine and sodium hydroxide. The radiological inventory has been estimated (and corrected for decay) to contain 19g of plutonium-239 (50th percentile) and 28g of plutonium-239 (90th percentile).[44] The estimated total volume of buried material in the eastern pits is 36,003 ft^3 (1,019.5 m^3)[45].

During the early 1950's several 55-gallon drums were also placed in the eastern section of MDA A, close to the pits. They stored sodium hydroxide and stable iodine solution, which contaminated the surface soil when the tanks corroded, releasing the liquid waste. The containers were eventually removed in 1960.[46]

General's Tanks. Also in 1945, two large "General's Tanks" were buried in the western section of MDA A. The tanks were named after General Leslie R. Groves, the primary military leader in charge of the Manhattan Project. Each tank had the capacity to store 50,000 gallons of liquid (12 ft in diameters and 63 ft in length) and was buried 12 ft under ground. The stored solutions contained sodium hydroxide in one tank and ammonium hydroxide in the other; both solutions were contaminated with plutonium-239 and plutonium-240. In 1950, the two tanks were sampled and it was discovered that they contained between 160 to 180 grams plutonium in each. In 1973, the amount of radioactivity in the tanks was found to be 230 grams of plutonium-239. It was estimated that only 0.7% of the radioactivity in the tanks was in solution, and thus the remaining radioactivity must have been in solid or sludge-like form.[47]

In 1975 these solutions were removed, solidified in cement, and moved to Pit#29 in MDA G for permanent storage. The tank openings were not sealed until 1985.[48] However, the sludge on the bottom of the tanks still remains and the post-effluent samples indicated that most of the inventory was left within the tanks. Information taken from laboratory notebooks has been reconstructed to indicate the current-day contaminants within the tanks (Table 4).[49]

Table 4. Reconstructed Present-day Inventories of General's Tanks at MDA A

Tank Contents	General Tank West	General Tank East
Contaminants	Pu, Am, Ca(NO3)2, Mg(NO3)2,I2, H2O2,KNO3, Al, Fe, Cr, Ni, Mg, and lanthanum	Pu, Am, NO3–, NH4 +, Mg, and Ca
pH	10	8

[44] LANL, 2008a
[45] Rogers, M.A., 1977
[46] NNSA, 2006
[47] Rogers, M.A., 1977
[48] NNSA, 2006
[49] LANL, 2008a

Current-day Radioactive Inventory	75 Ci	28 Ci

Central Pit. In 1969, one large central pit (150ft. x 40ft. x 22 ft deep) was built in the center of the MDA A, which was filled with demolition debris during the rehabilitation of TA-21. Most of the higher contaminated waste was sent to site G, so the central pit at site A received only foundations, soils, and some larger structures. The debris was contaminated with unknown quantities of plutonium-238, plutonium-239, plutonium-240, uranium-235, and depleted uranium.[50,51]

Additional Subsurface Structures in MDA A of interest include:

- 3-in. cast-iron radiological waste line – it is located north of MDA A along the North Perimeter Road and has been in service since 1970's. The line used to transport liquid waste from Tritium Science and Fabrication Facility and the Tritium Systems Test Assembly (TSTA) to Building 21-257 waste treatment facility located west of MDA A. There are two clean-out valves at the northeastern and northwestern corners of MDA A.
- A storm drain runs beneath North Perimeter Road near the northeastern corner of MDA A. It transports storm water from the roadways next to MDA A to DP Canyon.[52]

4.7.2 Material Disposal Area B

Material Disposal Area B (MDA B) is the largest disposal area in TA-21, approximately 6.03 acres in size, located on the southern side of the DP Road to the west of DP West. The area operated between 1945 and 1948 and received waste from the DP West and the DP East sites, including laboratory waste, debris, and some liquid waste.[53]

The area consisted of several *unlined* disposal trenches (15ft by 800-1000 ft by 12 ft deep). A 1998 geophysical survey suggested that one primary trench runs along the eastern leg of the site and one to three smaller trenches are located in the western section (Figure 14). The principal radioactive contaminants consist of plutonium, polonium, uranium, americium, curium, radioactive lanthanum, actinium, and waste products from the water boiler reactor. It is estimated that 90% of the waste consisted of contaminated debris such as paper, rags, paper gloves, glassware, and small metal apparatuses placed in cardboard boxes and sealed with masking tape. In addition, there is at least one truck buried at the site, contaminated with fission products from the Trinity test.[54] In 1948, the pit was closed after it had caught fire due to combustion of mixed chemicals. The

[50] NNSA, 2006
[51] Los Alamos Study Group, 2006a
[52] LANL, 2008a
[53] Los Alamos Study Group, 2006b
[54] LANL, 2004b

resulting craters were filled with non-contaminated debris and concrete from construction sites.[55]

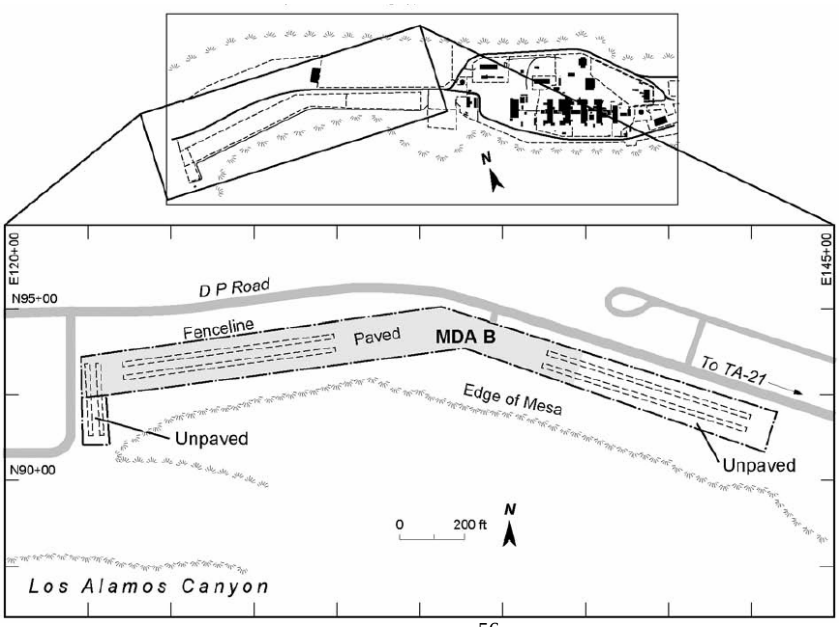


Figure 14. Material Disposal Area B[56]

The original volume of the pits is estimated to be 28,000 cubic yards, containing100 grams (6.13 curies) of Pu-239. [57] Recent site investigations indicated the presence of radionuclides and metals in concentrations greater than background values in surface soils along the perimeter of the site in areas not covered by asphalt. Additionally, a 1998 borehole testing showed elevated levels (above background) of tritium, plutonium-239, uranium, and lead in three of the seven drilled boreholes.[58]

The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA B as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater[59].

4.7.3 Material Disposal Area T

Material Disposal Area T (MDA T) is approximately 2.2 acres in size and is located in the northeastern corner of DP East. This waste storage site was designated primarily for liquid waste from DP West plutonium processing facilities. It consists of two wastewater treatment plants, four absorption beds (120 ft by 20 ft by 6ft deep), 62 disposal shafts (8 ft diameter; 65 ft height), and an area once used for solidified waste. The orientation of the four absorption beds is shown in Figure 15. A distribution box was located between

[55] NNSA, 2006
[56] LANL, 1991
[57] Rogers, M.A., 1977
[58] LANL, 2004b
[59] Los Alamos Study Group, 2006b

Beds 1 and 2, onto which effluent from the following buildings was piped: Buildings 2, 3, 4, and 5. Also, a direct drain connected effluent from Building 12 to Bed 1.[60] Due to the geology of the site, when the absorption beds became saturated they overflowed toward the DP Canyon.[61]

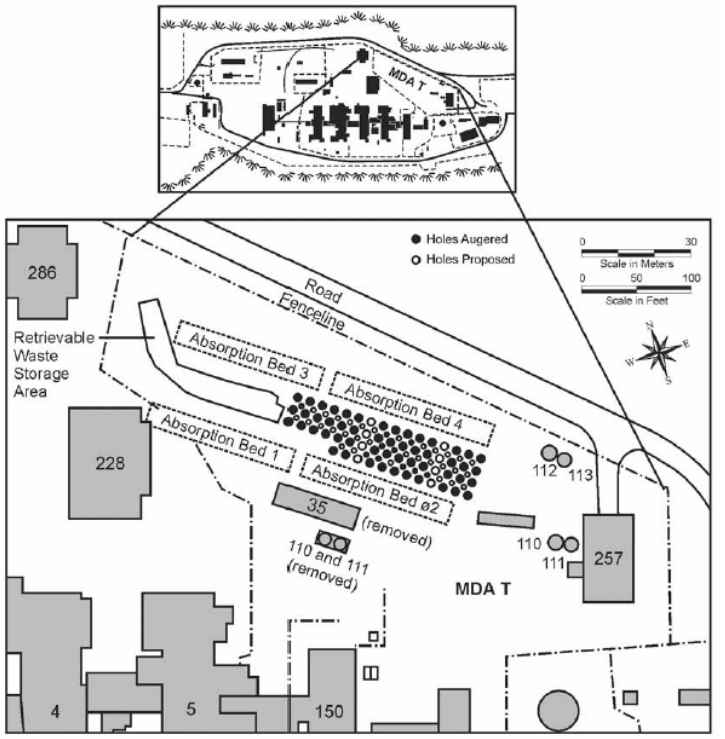


Figure 15. Waste Disposal Locations within Material Disposal Area T[62]

A total of 18.3 million gallons of wastewater were discharged at MDA T during the years 1945 to 1967. The absorption beds received untreated liquid waste from plutonium-processing labs between 1945 and 1952. Between 1952 and 1967 the beds continued to receive liquid discharge, but it was now treated before disposal. The disposal methods improved even more in the 1960s – between 1968 and 1983 not only was the liquid waste treated, but it was also mixed with cement before deposition into the cylindrical shafts.[63]

The absorption beds received the following amounts of liquid waste:

- 1945-1952: 14 million gallons of untreated wastewater contaminated with plutonium and fluoride
- 1951-1952: 10,450 gallons of ammonium citrate effluent containing plutonium and fluoride

[60] NNSA, 2006
[61] Rogers, M.A., 1977
[62] NNSA, 2006
[63] Los Alamos Study Group, 2006r

- 1953-1967: 4.3 million gallons of liquid waste

It is estimated that by 1973 the absorption beds had received 4 curies of tritium, 10 curies of Pu-239/Pu-240, as well as trace amounts of Pu-238, U-235, Am-241. The soil/sediment within the beds contained 10 curies of Pu-239. A follow-up investigation in 1976 showed the following contamination within the absorption beds: 7 curies U-233, 47 Ci of plutonium-238, 191 Ci of plutonium-239, 3,761 Ci of Am-241, and 3 Ci of mixed fission products.[64]

Although some of the shafts at MDA T temporarily held wastewater, most were used for storage of cement-stabilized waste and plant sludge; some of the shafts contained bathyspheres with Pu-239 and Pu-240. Below, Tables 5 and 6 summarizes the radioactive contaminant inventories (as of 2004) within each shaft at the site.[65]

Table 5. Plutonium-239 Disposed of in Material Disposal Area T Shaft Bathyspheres

Shaft Number	Plutonium-239 Bathysphere Inventory (grams)
3	290
17	342
18	134
19	245
20	210

Table 6. Radionuclide Inventories and Cement Paste Volume by Shaft

Shaft	Cement Paste (L)	Pu-239 (grams)	Pu-238 (grams)	Pu-240 (grams)	Am-241 (grams)	U-233 (grams)	U-235 (grams)
1	67,440	20.8	0.025	1.2	21	-	-
2	23,920	3.7	0.004	0.2	2.5	-	-
3	10,750	300.2	0.012	18	5.3	-	-
5	87,200	12	0.014	0.7	24.1	-	-
9	88,780	25	0.029	1.5	23.3	-	-
10	18,660	4	0.005	0.2	4.2	-	-
11	18,950	3.2	0.004	0.2	2.6	-	-
13	85,500	39.6	0.047	2.4	34.6	-	-
17	87,240	373.9	0.038	22.42	16.6	-	-
18	83,440	152.8	0.022	9.14	17.1	-	-
19	80,280	261.3	0.019	15.7	6.2	-	-
20	89,540	11.6	0.014	0.7	26.4	-	-
21	87,290	13.3	0.016	0.8	22.6	-	-
22	88,760	18.8	0.022	1.1	20	-	-
23	80,700	20.4	0.024	1.2	31.4	-	-

[64] NNSA, 2006
[65] LANL, 2004a

24	84,100	17.4	0.021	1	25	-	-
25	23,460	7.2	0.009	0.4	10	-	-
26	21,310	214.5	0.005	12.9	5.6	-	-
27	82,770	32.5	0.038	2	18.1	-	-
28	89,880	40.4	0.048	2.4	33.5	-	-
29	87,850	4.2	0.005	0.3	9.8	-	-
30	87,090	14	0.017	0.8	18.8	-	-
31	25,900	3	0.003	0.2	2.9	-	-
32	22,510	5.4	0.006	0.3	9.4	-	-
33	90,490	24.8	0.029	1.5	20.5	-	-
34	89,270	11.4	0.013	0.7	21.3	-	-
35	87,730	16	0.019	1	25.3	-	-
36	89,410	12.4	0.015	0.7	25.9	-	-
41	68,600	20.5	0.024	1.2	18.1	-	-
42	32,730	4.2	0.005	0.3	2.5	-	-
43	89,000	28.1	0.033	1.7	29.5	-	-
44	87,890	14.5	0.017	0.9	21.2	-	-
46	82,540	33	0.039	2	35.6	-	-
47	35,100	16.6	0.02	1	15.5	-	-
48	65,760	21.7	0.026	1.3	23.4	-	-
49	92,800	62.2	0.073	3.7	49.4	-	-
50	72,290	18.5	0.022	1.1	21.2	-	-
51	38,620	11.4	0.013	0.7	11.7	-	-
53	71,610	28.7	0.034	1.7	33.9	-	-
55	90,600	45.9	0.054	2.8	26.7	-	-
56	83,870	23.9	0.028	1.4	32.6	-	-
57	37,200	19.1	0.023	1.1	11.9	-	-
59	77,400	44.2	0.052	2.7	31.1	-	-
60	90,460	38.2	0.045	2.3	33	-	-
70	52,400	29.9	0.094	4.8	29.8	-	-
75	52,800	32.9	0.039	2	35.4	-	-
76	52,600	56.7	0.067	3.4	53.1	-	-
78	49,800	7.6	0.009	0.5	0.8	-	-
80	56,300	20	0.024	1.2	4	-	-
82		8.9	0.01	0.5	2.4	-	-
83	18,000	19.6	0.023	1.2	4.8	-	-
84	37,700	9.5	0.011	0.6	0.3	-	-
87		7.7	0.009	0.5	0.4	-	-
Complex B							
(52, 58)	64,690	34.2	0.04	2.1	20.1	713	-
Complex A							
(6, 8, 54, 90, 91, 92,94)	125,630	99.8	0.118	6	79.6	-	713
Total (grams)		2,471	1.5	148	1,112	713	713

Since one gram of Pu-239 is 0.067 Ci, the contents of the shafts alone is 166 Ci, a very large amount of radioactivity.

MDA T also contains several buildings that are considered to be potential release sites. Building 35 is an industrial liquid waste treatment plant that was in use between 1952 and 1967. When the building was decommissioned in 1967 the septic tank and leach fields were abandoned in place. Building 257 in TA-21 was also a treatment plant that prepared liquid wastes for disposal and had the following tanks associated with it: acid-holding tank, effluent-holding tanks, Pug Mill Tank, sodium hydroxide holding tank, and an americium raffinate storage tank. Building 257 had an outfall that discharged into the DP Canyon.[66]

Routine sampling has been performed at the site in 1992, 1994, 1995, 1996, and 1997, where surface soil samples and tuff from boreholes were collected. Radioactive contamination above background levels was found in the surface soil and shallow subsurfaces extending to the DP Canyon. The contaminants included americium-241, plutonium-238, and plutonium-239. Additionally, several metals including cadmium, copper, and nickel appeared at elevated levels in the surface near Building 35.[67]

The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA T as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater[68].

4.7.4 Material Disposal Area U

Material disposal Area U (MDA U) is a 0.2-acre inactive disposal area that was in use between 1948 and 1968. The area consists of two unlined absorption beds (80 ft by 20 ft by 6 ft) for the deposition of wastewater from the former laboratory and filter building and, until 1976 for the process-cooling water from Tritium Systems Test Assembly building (Figure 16). The total volume of the two absorption beds is 18,000 cubic ft and they are connected with lines to the distribution box.[69]

[66] NNSA, 2006
[67] LANL, 2004a
[68] Los Alamos Study Group, 2006r
[69] U.S. Department of Energy 2006

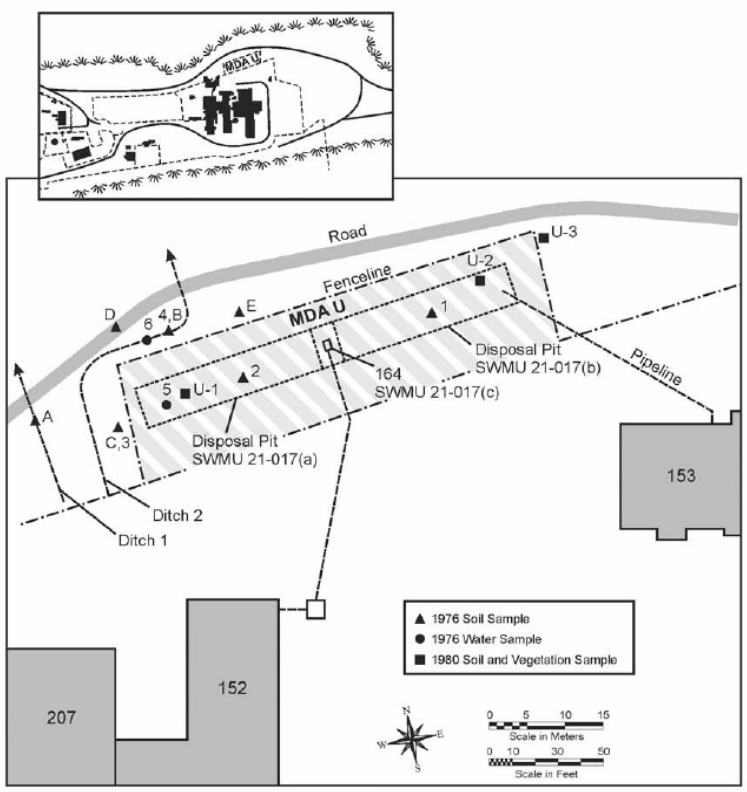


Figure 16. Material Disposal Area U[70]

During the years of operation, between 1948 and 1968, the two beds received 135,000 gallons of liquid waste, which contained primarily polonium-210, but also smaller amounts of actinium-227, plutonium, and tritium. In 1953, about 2.5 curies of actinium-227 were discharged from Building 21-153.

Run-off from MDA U drains into the DP Canyon and it is noted that at one point "liquid effluent [from the site] used to run down into the canyon and pond in a swampy area."[71]

Soil sampling has been conducted at site U in 1992, 1994, 1998, and 2001 and the following radionuclides and metals appeared above background levels: americium-241, plutonium-238, plutonium-239, tritium, chromium, lead, mercury, uranium, and zinc. In 1998 and 2001 the sampled fill from the beds displayed the following results:

- Tritium and uranium-234: above background levels.
- Tritium was found in eight boreholes in concentrations smaller than 1 picocurie per gram and at the bottoms of two boreholes, each 75 ft (23 m) below ground surface.

[70] Los Alamos Study Group, 2006s
[71] LANL, 1991

- Actinium-227 progeny (thorium-227, radon-219, and radium-223): found in the eastern beds and in one borehole within the east bed at 54 to 55 ft below ground surface.
- Uranium-234 and uranium-235: above background levels in two boreholes on the western side of MDA U.
- Subsurface samples: aluminum, arsenic, barium, beryllium, chromium, copper, lead, manganese, and mercury at levels above background.[72]

The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA U as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater[73].

4.7.5 Material Disposal Area V

Material Disposal Area V (MDA V) is approximately 0.88 acres in size and its run-off drains into the Los Alamos Canyon. It consists of 3 absorption beds that received wastewater from the laundry facility (used to wash clothing from plutonium refinement operations) and the sump in former Building 21-45 in TA-21. It also received wastewater from the Waste Studies Group from 1945 until 1961. The wastewater contains solvents and radioactive liquid waste including radionuclides such as strontium, barium, lanthanum, plutonium, tritium, and uranium.[74]

Most of the liquid waste disposed into the absorption beds at MDA V contained polonium-210, but also included actinium-227, plutonium, and tritium. Considering its short half-life, polonium-210 deposits have completely decayed to lead. 1998 and 2001 surveys of the disposal area showed that the soil and fill from the beds still contain radionuclides above background radiation. More specifically, the following findings were made:

- Tritium and uranium-234 (above background values) and Ac-227 progeny (thorium-227, radon-219, and radium-223) were found in the eastern beds.
- 1998 investigations found uranium-234 and uranium-235 above background values in two boreholes on the western side of MDA U.
- Actinium-227 progeny were found in one borehole within the east bed at 54 to 55 ft (16 to 17 m) below ground surface in a fractured interval.
- Tritium was found in eight boreholes in concentrations smaller than 1 picocurie per gram and at the bottoms of two boreholes, each 75 ft (ft) (23 m) below ground surface.

[72] LANL, 2004d
[73] Los Alamos Study Group, 2006s
[74] Los Alamos Study Group, 2006t

The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA V as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater[75].

4.8 Technical Area 33

Technical Area 33 (TA-33), also known as the Hot Point (HP) Site, operated as a shaft experiment site between 1948 and 1956 and as a high pressure tritium laboratory in the 1970s. Located at the southern-most tip of the LANL site and west of Bandelier National Monument, TA-33 houses Material Disposal Areas D, E, and K. The primary material involved in the activities carried out at TA-33 is tritium (H-3).

TA-33 was established in 1947 as the primary testing site for atomic bomb initiators[76]. Testing activities at TA-33 involved polonium and other materials and testing took place both under and above ground. Beginning in the early 1950s, facilities were built at TA-33 for the processing of tritium gas, and these high pressure tritium gas facilities were contained in Building HP-86 until late 1990[77]. HP-86 also contained several laboratory areas for conducting tritium gas system tests and material compatibility studies[78].

HP-86 is believed to be the largest source of atmospheric releases of tritium at LANL. Approximately 2,000 to 6,000 Ci of H-3 were released from HP-86 annually[79], and more than 60,000 Ci of H-3 gas had been released during ten separate incidents over the past 15 years in addition to routine annual releases[80]. It is believed these releases were due to evacuation of lines and vessels containing H-3 gas and leaks from the entire gas system.

Below, Figure 17 displays the locations of TA-33 and Material Disposal Areas D, E, and K.

---

[75] *Ibid*
[76] Garcia KLM, et al., 2004
[77] *Ibid*
[78] Tuggle, D.G., 1983
[79] Coffin, D.O., 1971
[80] ChemRisk, et al., 2009

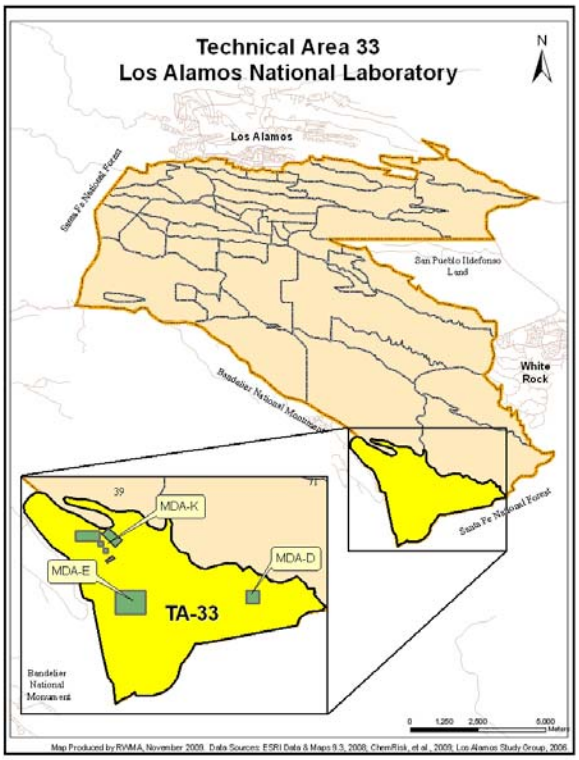


Figure 17. LANL's Technical Area 33 and Material Disposal Areas D, E, and K

4.8.1 Material Disposal Area D

Material Disposal Area (MDA) D is approximately 0.3 acres in size and is located in the south-southeast region of TA-33, approximately 800 ft above the bottom of Ancho Canyon and 1,000 ft above the bottom of White Rock Canyon. MDA D was operated between 1948 and 1952 and contains two underground chambers that were used for testing explosives and conducting polonium-210 experiments. Underground Chamber 1 (HP-4) had been used for an experiment before July 22, 1948, and an experiment in Underground Chamber 2 (HP-6) was conducted on December 23, 1948. The HP-6 chamber was octagon-shaped, 14.1 ft (4.3 m) wide with a 12.1 ft (3.7 m) ceiling. The shaft of HP-6 was approximately 5.9 ft (1.8 m) by 7.9 ft (2.4 m), with a depth of 45.9 ft (14 m). The exact shape of HP-4 is unknown, but it is assumed it is similar in construction to HP-6. The underground chambers are contaminated by unknown quantities of polonium, trace amounts of uranium, and possibly a trace amount of Co-60.[81] It is also assumed that tritium, barium, and beryllium are present at MDA D[82]. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA D as an area with a high probability of contaminant mobilization and a low to moderate potential of contaminant release to groundwater.[83]

[81] M.A. Rogers, 1977
[82] Los Alamos Study Group, 2006d
[83] *Ibid*

Below, Figure 18 displays an engineered drawing of MDA D in TA-33.

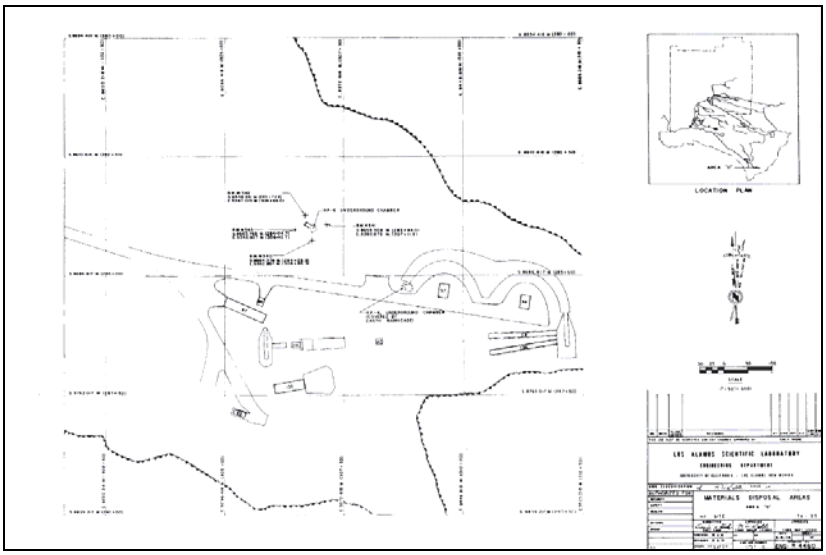


Figure 18. MDA D in TA-33

On July 22, 1948, the enclosed area directly over the elevator shaft to HP-4 and the area south of the fence at MDA D were monitored for the presence of radionuclides. All results were negative. On December 23, 1948, HP-6 was monitored using an alpha meter, and these results were found to be negative as well. In addition, the ground surrounding HP-6 was again found to be uncontaminated on April 7, 1952.[84]

On April 8th, 1952, the internal chamber of HP-6 was surveyed in preparation for the excavation of the chamber. A steel box on the south side of the chamber measured approximately 8,000 cpm, and radioactive contamination around the door frame of the chamber read approximately 15,000 cpm. The felt seal on the door read approximately 30,000 cpm. Later, on April 11, 1952, rubble from the experiment, which had been dispersed all over the room, gave readings greater than 200,000 cpm.[85]

On November 15, 1952, seven soil samples were collected from MDA D and analyzed for polonium. It is not certain whether these samples may have been centered over HP-6. The results of the seven soil samples are as follows: Sample A – 2,000 cpm/g; Sample B – no polonium; Sample C – 6 cpm/g; Sample D – 1 cpm/g; Sample E – 0.2 cpm/g; Sample F – 0.2 cpm/g; Sample G – no polonium. [86] The locations of each sample can be seen below in Figure 19.

[84] Rogers, M.A., 1977
[85] *Ibid*
[86] *Ibid*

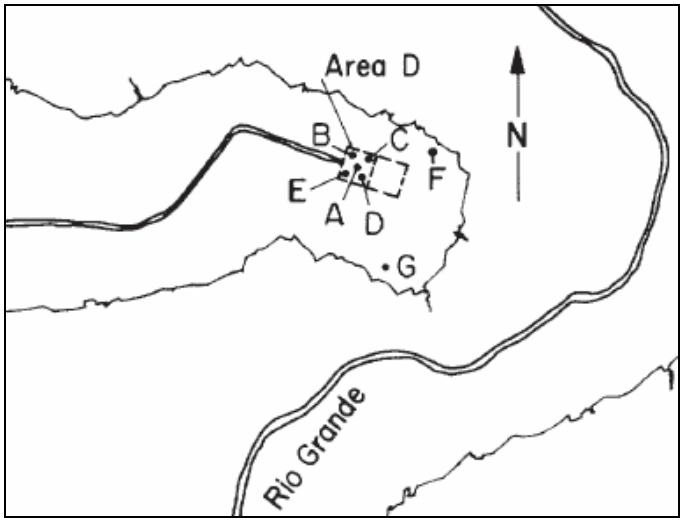


Figure 19. Map Indicating Soil Samples Collected at MDA D on November 15, 1952[87]

On August 24, 1953, the fenced-in area surrounding HP-6 was surveyed. The ground surface within the fenced in area showed no detectable alpha contamination, but some timbers in the area gave counts up to 500 cpm. Soil at a depth of 2 ft around the underground chamber gave a reading of 500 cpm.[88] The area around HP-6 was later bulldozed on October 21, 1953, and it was determined that the contamination in the area (soil and timber) had been buried within the remaining crater of HP-6 and covered under a heavy layer of dirt, thus reducing its radioactivity at the surface.[89]

4.8.2 Material Disposal Area E

Material Disposal Area (MDA) E is approximately 0.69 acres in size and his located near Chaquehui Canyon in the south-southwest region of TA-33. The area was used between 1949 and 1963. MDA E contains 6 waste pits that vary between 5.9 to 6.9 ft in depth, one underground chamber and two trenches. According to the USGS, Pit 1 is 16.4 ft wide by 75.5 ft long, Pit 2 is 16.4 ft wide by 45.9 ft long, Pit 3 is 4.9 ft in diameter, Pit 4 is 16.4 ft wide by 98.4 ft long, Pit 5 is 13.1 ft wide and 78.7 ft long, and Pit 6 is 13.1 ft wide and 62.3 ft long. Pits 5 and 6 intersect. [90]According to Engineering Drawing ENG-R-2457, the underground chamber at MDA E was destroyed in 1950, Pit 1 was closed in July 1951, and Pit 3 was closed in September 1951[91]. A map of MDA E is included below as Figure 20.

[87] *Ibid*
[88] *Ibid*
[89] *Ibid*
[90] Abrahams, J.H. Jr., 1963
[91] Rogers, M.A., 1977

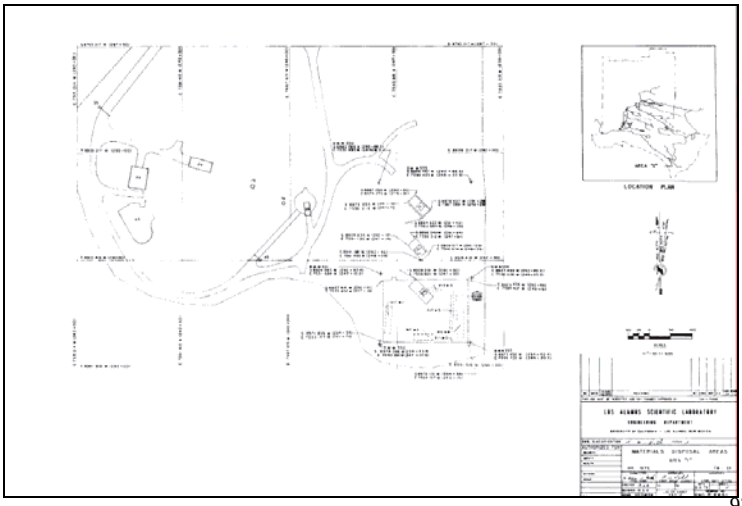


Figure 20. Map of Disposal Pits and Underground Chamber at MDA E[92]

MDA E was used for the storage and disposal of low level radioactive waste (LLW), most commonly in the form of contaminated equipment. It is assumed that MDA E contains unknown quantities of nickel, cadmium, lead, tungsten, polonium-210, tritium, cesium-137, beryllium, and several hundred kilograms of uranium-238. According to a 1977 study by M.A. Rogers, Pit 1 is known to contain miscellaneous polonium-beryllium fired targets with a total activity of 240 Ci, Pit 2 contains 60 Ci of Wally, Pit 3 contains a can of beryllium dust immersed in kerosene of unknown activity, and Pit 4 contains miscellaneous hot material of unknown activity. At the time of the study, there was no known information about the contents of Pits 5 and 6.[93] The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Bureau ranks MDA E as an area with a low probability of contaminant mobilization and a moderate potential of contaminant release to groundwater.[94]

4.8.3 Material Disposal Area K

Material Disposal Area (MDA) K is less than one acre in size and is located in the northwest corner of TA-33, near Ancho and Chaquehui Canyons. MDA K was operational between 1955 and 1961 and contains one septic system and two unlined sumps of unknown sizes. It is assumed that MDA K contains unknown quantities of tritium, the tritium facilities septic system, a leach field, contaminated sumps, and solvents. The contaminated sumps are assumed to be contaminated with ethanol, methanol, trichloroethene, benzene, and acetone. MDA K may also be contaminated with mercury and beryllium. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA K as an area with a high

[92] *Ibid*
[93] *Ibid*
[94] Los Alamos Study Group, 2006e

probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[95]

4.9 Technical Area 36

Technical Area 36 (TA-36), also known as the Kappa Site, is located in the southeastern portion of the LANL facility, northwest of White Rock in Santa Fe County, New Mexico. It was built in 1950 and replaced the activities that occurred in TA-9, TA-12, and TA-23. TA-36 contains four active firing sites, and it is believed that depleted uranium and beryllium was expended in substantial quantities at TA-36, due to firing site experiments. TA-36 contains only one disposal area, Material Disposal Area AA. Below, Figure 21 displays the locations of TA-36 and Material Disposal Area AA.

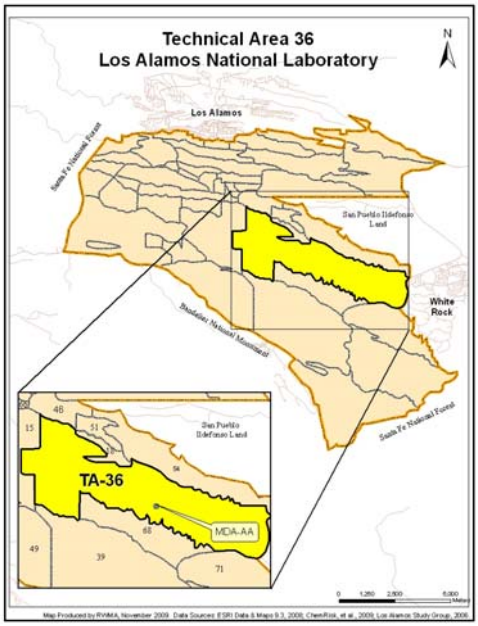


Figure 21. LANL's Technical Area 36 and Material Disposal Area AA

4.9.1 Material Disposal Area AA

Material Disposal Area AA (MDA AA) is located near the Portrillo Canyon, within TA-36, and is approximately 0.15 acres in size[96]. It is unclear the exact year in which MDA AA began accepting waste, but it is known that the area first accepted waste in the mid-1960s. The site operated as a waste disposal site until 1989 when it closed down in accordance with New Mexico State's solid waste regulations[97].

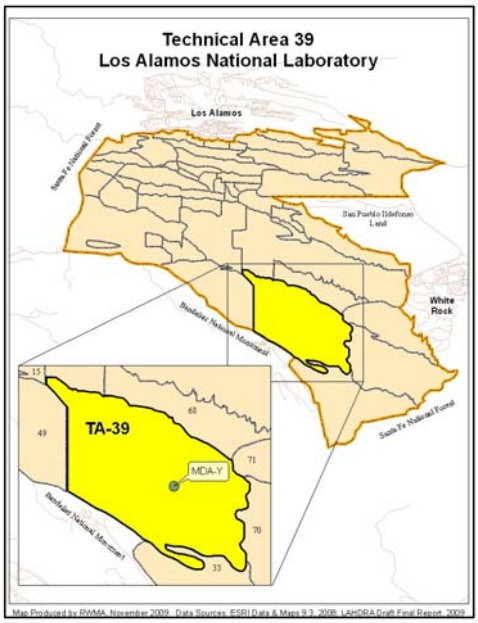
MDA AA contains 2 to 4 waste disposal trenches which are used to burn and dispose of waste associated with the firing activities that occurred at TA-36's firing sites. Two

[95] Los Alamos Study Group, 2006j
[96] Los Alamos Study Group, 2006w
[97] NNSA, 2006

trenches were identified during a Phase I RCRA Facility Investigation (RFI) conducted between 1993 and 1995. The northern trench was approximately 80 ft by 40 ft by 8 to 13 ft deep, and the southern trench was approximately 120 ft by 20 to 30 ft by 3 to 12 ft deep.[98] Based on the background knowledge of LANL firing activities, the trenches are thought to likely contain wood, nails, and sand and be contaminated with unknown quantities of barium, uranium, inorganic chemicals, plastics, and high explosives. The New Mexico Environment Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA AA as an area with a high probability of contaminant mobilization and a moderate potential of contaminant release to groundwater.[99]

4.10 Technical Area 39

Technical Area 39 (TA-39), also known as the Ancho Canyon Site, is located in the south-central section of the LANL facility, at the bottom of the Ancho Canyon. The Bandelier National Monument borders TA-39's southwestern edge. TA-39 contains 5 firing points and a waste incinerator and was used for a photographic study of the behavior of nonnuclear weapons. The firing sites were active from 1960 to 1975, suspended until 1988, and then again resumed until present time. TA-39 covers approximately 2,444 acres and was created when explosive work at TA-15, located directly to the northwest of TA-39, became too crowded. It is the second largest TA at LANL. The area remains largely forested with sporadic developed areas scattered throughout. [100] Material Disposal Area Y is the only disposal site located within TA-15. Below, Figure 22 displays the locations of TA-39 and Material Disposal Area Y.



[98] *Ibid*
[99] Los Alamos Study Group, 2006w
[100] NNSA, 2006

Figure 22. LANL's Technical Area 39 and Material Disposal Area Y

4.10.1 Material Disposal Area Y

Material Disposal Area Y (MDA Y) is located to the east of Ancho Road and is approximately 0.07 acres in size. MDA Y holds 3 waste disposal pits that contain debris produced as a result of the firing activities that occurred at TA-39. Other wastes disposed of in the pits include empty chemical containers and office waste. The first and second waste disposal pits in MDA Y are approximately 148 ft by 20 ft by 12 ft deep, and the third is approximately twice as long as the first and second, but possesses the same depth and width.[101] It is estimated that Pit 1 was dug in 1973, Pit 2 was used between 1976 and 1981, and Pit 3 was used between 1981 and 1989.[102]

Based on background knowledge of LANL firing site activities and additional operations that may have occurred at TA-39, it is assumed that unknown quantities of barium, beryllium, uranium-235, copper, mercury, iron, silver, cadmium, helium, plutonium, zinc, potassium-40, thorium-232, lead, solvent, and PCBs. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA Y as an area with a low probability of contaminant mobilization and a moderate potential of contaminant release to groundwater.[103]

4.11 Technical Area 49

Technical Area 49 (TA-49) was created at LANL in 1959. It was originally part of TA-15 which now sits directly north of TA-49. TA-49 is located on the southwestern edge of the LANL site and borders the Bandelier National Monument on its western and southern edges. Below, Figure 23 displays the locations of TA-49.

[101] *Ibid*
[102] LANL, 1993
[103] Los Alamos Study Group, 2006u

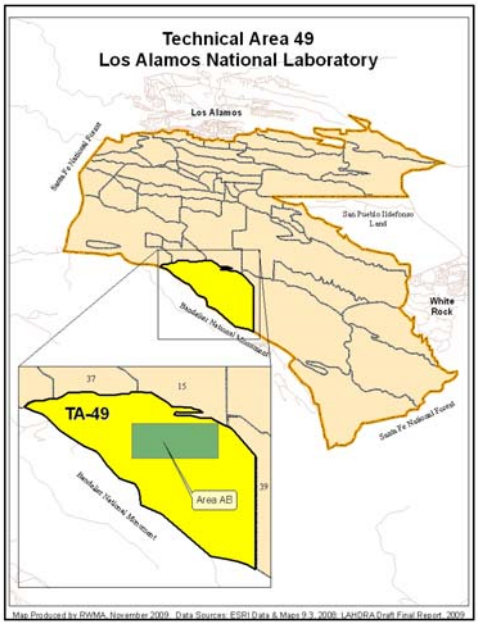


Figure 23. LANL's Technical Area 49 and Material Disposal Area AB

Between the fall of 1959 and August 1961, underground hydronuclear experiments were conducted at TA-49 in order to investigate the possibility of a nuclear yield from accidental detonation of a nuclear weapon's high explosive component. Experiments were conducted in six underground shafts (Experimental Areas 1, 2, 2A, 2B, 3, 4) that varied in depth from 31 to 142 ft. Between January 1960 and August 1961, 35 hydronuclear and 12 calibration and equation of state experiments were conducted within these shafts. In addition, at least 23 underground containment, equipment development, and mockup experiments were conducted using high explosives. Less commonly, experiments were conducted with small amounts of uranium-238 or a radioactive tracer. The experiments conducted in TA-49 caused the explosive dispersal of uranium-235, plutonium-239, lead, beryllium, and uranium-238 at the bottom of the shafts.[104]

4.11.1 Material Disposal Area AB

Material Disposal Area AB (MDA AB) is located in TA-49, between Ancho and Water Canyons. It is the only disposal area within TA-49 and it was utilized by LANL between 1959 and 1961. MDA AB encompasses the six shafts that were used for hydronuclear and high explosive testing, along with several other waste areas. Experimental holes in Areas 1, 2, 3, and 4 were spaced at 25-foot intervals on 100-foot square grid patterns. Areas 2A and 2B are irregular in shape and experimental holes were approximately 6 ft in diameter. Experimental configurations were usually placed in the bottom of the hole, cables that lead to the surface were installed, and the rest of the hole was backfilled in.

[104] NNSA, 2006

Metallic lead usually comprised a great deal of the down-hole equipment. Only holes that were known to contain special nuclear material were capped with concrete.

The shafts were backfilled and therefore almost all of the contamination is contained underground. It is assumed that most of the contamination is within a maximum radius of 10 to 15 ft from each detonation point.[105] Below, Table 7 displays the amount of plutonium, uranium-235, and uranium-238 that is confined within the 6 disposal shafts located within MDA AB, as of 1992.

Table 7. 1992 Principle Radionuclide Inventories at MDA AB[106]

MDA AB Area	Plutonium[a] (kg)	Uranium-235 (kg)	Uranium-238 (kg)
Area 1	1.06	0.00	62.30
Area 2	12.62	47.40	52.50
Area 2A	3.75	9.80	10.60
Area2B	5.67	6.40	14.70
Area 3	0.00	0.01	0.03
Area 4	17.04	29.40	29.00
Total	**40.14**	**93.01**	**169.13**

[a]: Plutonium isotopic composition in weight-percent: Pu-239 (93.5-94.2%); Pu-240 (5.3-6.1%); Pu-241 (0.458-0.563%).

The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA AB as an area with a low probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[107]

4.12 Technical Area 50

Technical Area-50 was a designated location for 33 waste management structures, including office trailers, tanks, storage sheds, and four buildings. The facilities treated radioactive liquid waste, decontaminated respirators, equipment, instruments, vehicles, and waste items, reduced the size of transuranic wastes, and characterized transuranic wastes. These facilities processed a range of wastes including low-level radioactive waste (LLW), low-level mixed waste, transuranic (TRU) waste, and hazardous waste. One notable building is the Radioactive Liquid Waste Treatment Facility (RLWTF)**,** which concentrates radioactive components and partially removes them from the liquid waste. Pipelines throughout the Laboratory connect facilities to the RLWTF. Two major waste treatment operations occur within the RLWTF: a standard treatment operation and a pretreatment operation specifically for acid and caustic radioactive liquid wastes piped from TA-55 (the Plutonium Facility). The acid and caustic wastes generated at TA-55 generally have much higher americium and plutonium content than other wastes

[105] *Ibid*
[106] LANL, 1992
[107] Los Alamos Study Group, 2006x

processed at RLWTF. An underground, reinforced-concrete vault (Building 66) contains two tanks that hold untreated acid and caustic wastes from TA-55. Sludge from the RLWTF is dewatered, drummed, and transported to TA-54 for disposal, while the treated waste is discharged into the Mortandad Canyon.[108]

TA-50 is also the site of Material Disposal Area C. Figure 24 below displays the locations of TA-50 and Material Disposal Area C.

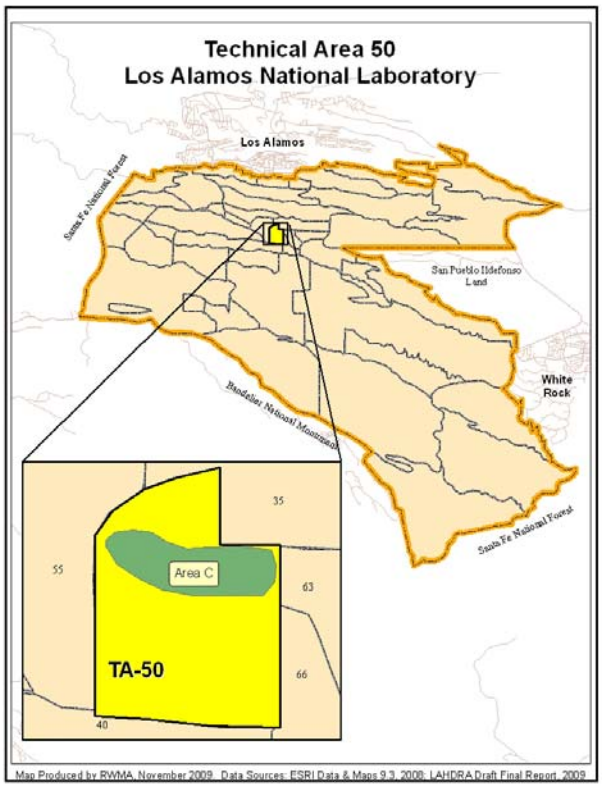


Figure 24. LANL's Technical Area 50 and Material Disposal Area C

4.12.1 Material Disposal Area C

Material Disposal Area C (MDA C) is an 11.8-acre inactive disposal area that received waste between 1968 and 1974 (it replaced MDA B at TA-21). The area is located north of Pajarito Road at the head of Ten Site Canyon. It consists of 7 pits, including 1 for non-radioactive waste (10-25 ft below original surface), and 108 shafts (3 ft diameter, 15ft deep). Ten shafts (#98-107) are lined with 12 inches of concrete, but the rest of the pits and shafts are unlined.[109] Below, Figure 25 displays a map depicting the various waste disposal pits and shafts in MDA C.

[108] Los Alamos Study Group, 2004
[109] LANL, 2009c

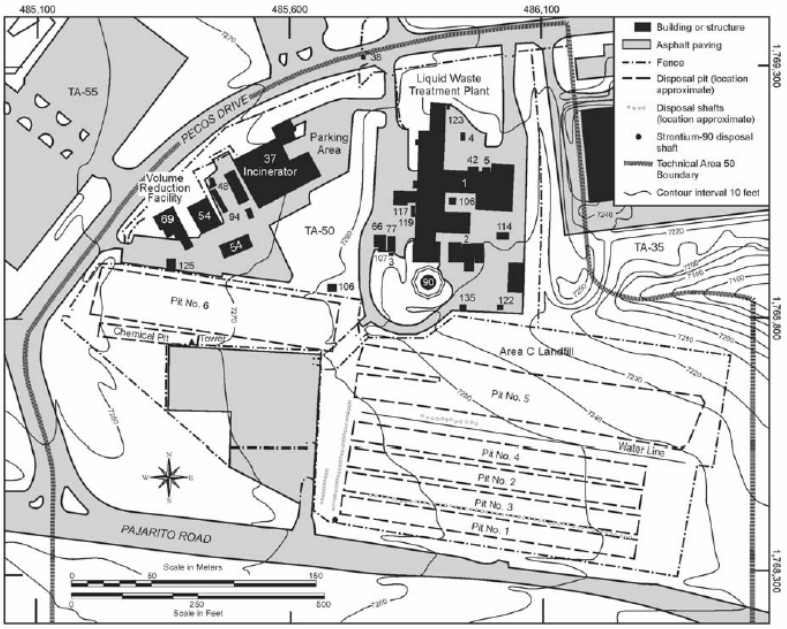


Figure 25. Map of Material Disposal Area C [110]

The wastes disposed of at the MDA C consisted of liquids, solids, and containerized gases. The waste filling the pits was packaged in a variety of containers. Routine radioactive trash generated in chemical labs was packaged in cardboard boxes and 5-ml plastic bags, and 55-gallon barrels were used to contain sludge from the waste treatement plants at Building 35, DP West, and TA-45. Non-routine waste included demolition debris of the Bayo Site and TA-1, classified materials, and uranium alloy chips. In addition to radioactive waste, hazardous constituents and uncontaminated classified material were often deposited in the pits as well. Radioactive, hazardous chemicals, and uncontaminated classified materials were all buried together in the pits. "Beta-gamma waste," mostly from the Chemical Metallurgy Research Building at TA-3 was buried in the shafts.[111] Below, Figures 26 and 27 display photographs of the carefree methods in which radioactive materials were containerized and disposed of at MDA C.

[110] NNSA, 2006
[111] Rogers, M.A., 1977

Figure 26. Dump Truck Dumping Radioactive Waste into Pit 6 at MDA C in TA-3 in 1958[112]

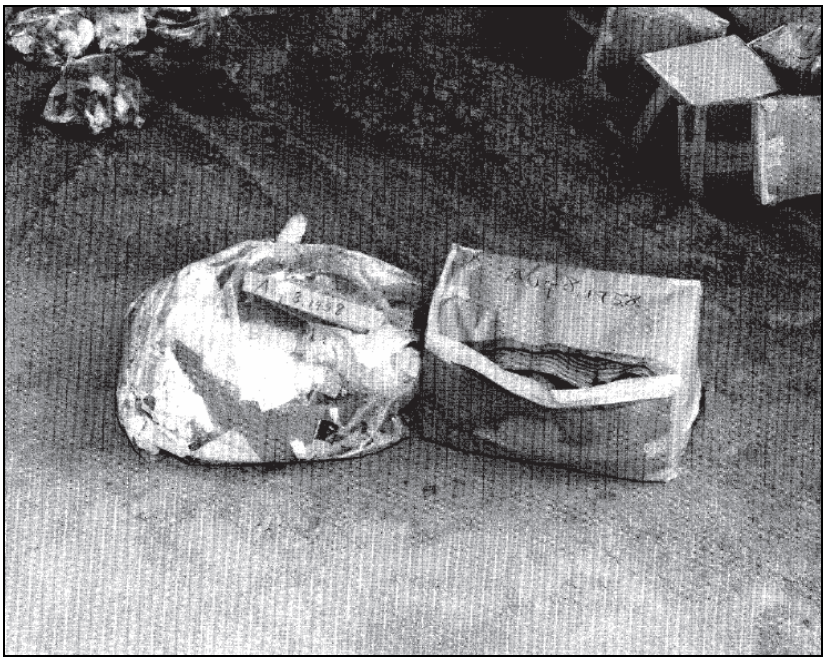


Figure 27. Bags and Cardboard Boxes used to Package Radioactive Materials Disposed of at MDA C in TA-3. (Each container in this photograph had been weathered for 3 months.)

[112] Rogers, M.A., 1977

Table 8, below, displays the radionuclide concentrations (decay corrected) present in MDA C pits and shafts as of January 1, 1973.

Table 8. Estimated Radionuclide Inventories in MDA C Pits and Shafts, Decay Corrected as of 1973[113]

Disposal Unit	Radionuclide	Activity (curies)
Pits	Uranium-234, -235, -236, -238	25
	Plutonium-239	26
	Americium-241	145
	Total	**196**
Shafts	Tritium	49,136
	Sodium-22	40
	Cobalt-60	20
	Strontium-90/Yttrium-90	31
	Radium-226	1
	Uranium-233	5
	Uranium-234, -235, -236, -238	<0.1
	Fission products*	50
	Activation products*	200
	Total	**49,483**

* Uncorrected because exact compositions are unknown

Fires have occurred at MDA C as a result of chemical waste spills, which could have contributed to contaminant transport from some of the open pits. The present-day radionuclide inventories at MDA C are estimated to be 5,600 Ci in surface-contaminated waste, where plutonium isotopes make up about 90% of the activity; 320 Ci in concrete and sludge (also mostly plutonium isotopes); and 0.75 Ci in soil, where mostly uranium isotopes are encountered.[114]

Other releases had additional effects upon the total deposition of radionuclides at the site. An area north of Pit 5 had suffered two accidental operational releases in 1974 that contained untreated radioactive waste and unknown chemicals. The area was partially remediated in 1981. Certain buildings at TA-50 released radionuclides through exhaust stacks; these contaminants were potentially deposited onto the ground surface.[115]

The 2008-2009 sampling at MDA C indicated the presence of the following radionuclides in tuff samples: americium-241, cesium-134, cesium-137, cobalt-60, europium-152, plutonium-238, plutonium-239/240, ruthenium-106, sodium-22, strontium-90, tritium, uranium-234, uranium-235/236, and uranium-238. [116]

[113] Rogers, M.A., 1977
[114] LANL, 2009c
[115] *Ibid*
[116] *Ibid*

In addition, MDA C is located on the Medita del Buey mesa, where water flows only as storm water and snowmelt runoff. Data suggests that runoff from MDA C had an effect primarily on the Ten Site Canyon. However, sheet erosion occurs around the east and northeast portions of the site and the eroded surface soil from MDA C (and from other solid waste management units) may have been deposited in the canyon bottom and stream banks of the Mortandad Canyon.[117]

The direction of groundwater under MDA C flows east/southeast toward Rio Grande, and the velocity of groundwater ranges from 20-250 ft per year. Since MDA C is located on a mesa top, no shallow alluvial groundwater is present in the vicinity.

4.13 Technical Area 54

Technical Area 54 (TA-54) is located in the east-central section of the LANL facility, northwest of White Rock, New Mexico in Santa Fe County. In the 1950s, TA-54 was selected as LANL's solid waste disposal site and holds Material Disposal Areas G, H, J, and L. Below, Figure 28 displays the location of TA-54 and its Material Disposal Areas.

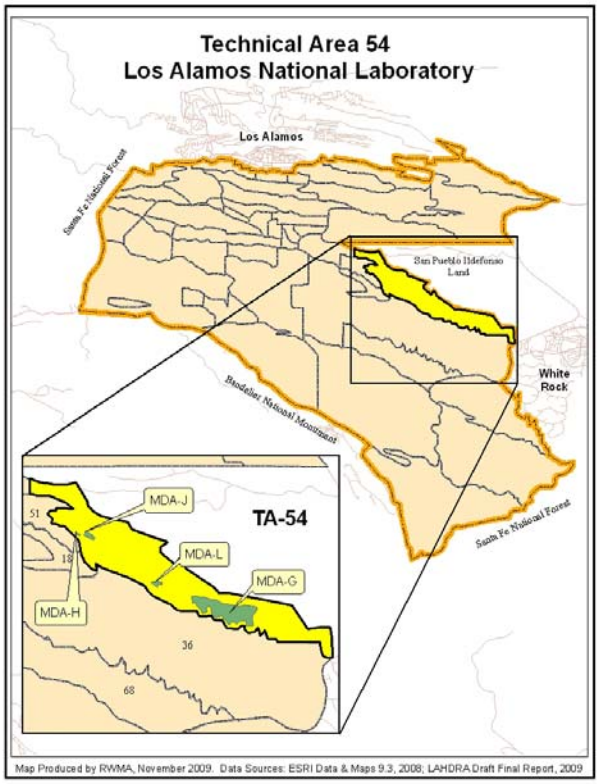


Figure 28. LANL's Technical Area 54 and Material Disposal Areas G, H, J, and L

[117] LANL, 2009c

4.13.1 Material Disposal Area G

Material Disposal Area (MDA) G is approximately 63 acres in size and is located in the southern portion of TA-54, near Pajarito and Canada del Buey Canyons. MDA G began operating in 1957 and still accepts waste today. It contains 32 waste pits, 194 shafts, and 4 trenches. The pits and trenches in MDA G range between 8 and 61 ft (2.4-18.6 m) in depth and the shafts range between 25 to 65 ft (7.6-19.8 m) in depth and 1 to 8 ft (0.3-2.4 m) in diameter.[118] It is estimated that a total of 10,800,000 ft^3 (305,821 m^3) of waste containing various radionuclides is buried at this disposal site. Most of the waste comes from weapons development and nuclear technology. Asbestos-contaminated material and polychlorinated biphenyls (PCBs) are also deposited at this site. Most of the disposed wastes are in the form of contaminated equipment, paper, plastic, clothing, structural wastes from the demolition of LANL facilities, and process wastes[119]. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA G as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[120] Below, Figure 29 displays the locations of the waste disposal pits, shafts, and trenches in MDA G. An aerial photograph of the MDA G is presented in the following Figure 30.

.

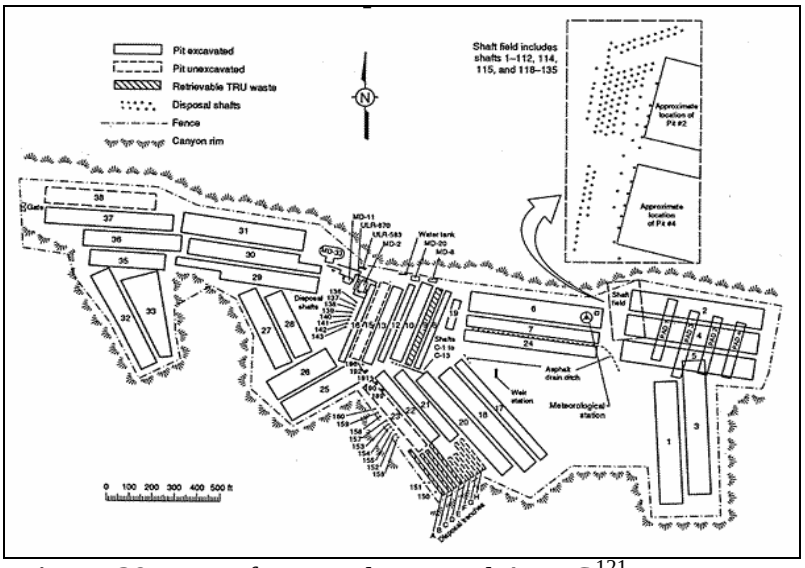


Figure 29. Map of Material Disposal Area G[121]

[118] LANL, 2009a
[119] Mayfield, D., and W.R. Hansen, 1983
[120] Los Alamos Study Group, 2006g
[121] *Ibid*

Figure 30. Image of Material Disposal Area G[122]

The quantification of radioactive and other hazardous waste types deposited at MDA G was not always kept in complete, well-documented records. In fact, detailed records describing the types and quantities of MDA G wastes between 1957 and 1970 are not at all available. It is known that early wastes contained large amounts of low level radioactive waste (LLW), some transuranic waste (TRU), and mixed low level radioactive waste (MLLW). Before 1971, TRU waste was not separated from LLW prior to disposal, and MLLW was not separated from LLW until the mid-1980s. Because no records exist regarding the types and quantities of wastes disposed of at MDA G, researchers have estimated these parameters based on the records that are available beginning in 1971.

A 1997 study[123], performed by Diana Hollis, et al., used annual volumes and activities of LLW and TRU waste disposed of at MDA G during and after 1971 in order to determine the most probable waste characteristics between 1957 and 1970. In this study, the characteristics of waste disposed between 1957 and 1970 were extrapolated from data pertaining to waste disposed between 1971 and 1977. Average annual disposal quantities of the pre-1971 waste inventory at MDA G were estimated, and the averages were multiplied by the number of operational years at MDA G from 1957 to 1970. Pits received routine waste for 12 years between 1957 and 1970, but the shafts only began accepting waste in 1966. Routine waste included cardboard boxes (13'x13'x24'), 5 mil plastic bags, and 55 gallon barrels of sludge from waste treatment plants at Building 35 of DP-West, TA-45, and TA-50.

All waste that was unique to post-1971 (those that would not have been disposed from 1957 to 1970) was identified by interviewing individuals who were familiar with LANL's

[122] *Ibid*
[123] Hollis, D., et al., 1997

waste generating and waste management programs during the times of interest. Waste that was disposed of only after 1971 was removed from the data, which would be used for extrapolation. Waste that was disposed of between 1957 and 1970 (but not after 1970) was estimated and added to the 1957 to 1970 inventory using the extrapolation approach.

Below, Table 9 displays the extrapolated volumes and radioactivities for each inventory category disposed of at MDA G between 1957 and 1970.

Table 9. Extrapolated Volumes and Activities for Each Inventory Category disposed of at MDA G from 1957 through 1970[124]

Inventory Category and Disposal Unit	LLW		TRU Waste		Total	
	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)	Volume (m^3)	Activity (Ci)
Pit Waste						
Surface Contaminated	4.00E+04	7.40E+02	1.70E+03	1.50E+04	4.20E+04	1.60E+04
Soil	6.00E+03	1.90E+01	1.10E+01	3.70E+01	6.10E+03	3.90E+01
Concrete/Sludge	4.50E+03	4.10E+02	3.00E+03	2.40E+03	7.50E+03	2.80E+03
Bulk Contaminated	1.10E+01	7.80E-02	0.00E+00	0.00E+00	1.10E+01	7.80E-02
Shaft Waste						
Surface Contaminated	1.40E+02	3.80E+04	1.20E+00	8.30E+02	1.50E+02	3.60E+04
Soil	2.10E-01	0.00E+00	0.00E+00	0.00E+00	2.10E-01	0.00E+00
Concrete/Sludge	4.40E-01	0.00E+00	0.00E+00	0.00E+00	4.40E-01	0.00E+00
Bulk Contaminated	5.30E-01	5.51E+00	0.00E+00	0.00E+00	5.30E-01	5.50E+01

As seen in Table 9, the total estimated waste disposed of in pits at MDA G between 1957 and 1970 is 1,963,496 ft^3 (55,600 m^3) with an activity of 18,800 Ci. The total waste disposed of in MDA G shafts between 1957 and 1970 is approximately 5,333 ft^3 (151 m^3) with an activity of 36,055 Ci. Thus, the total amount of waste is 1,970,559 ft^3 (55,800 m^3) with an activity of 54,900 Ci.

The pit waste activity is dominated by several TRU radionuclides; several plutonium isotopes and americium-241 are present at activities ranging from 44 to 8,100 Ci in one or more waste forms. Shaft waste is primarily dominated by tritium, accounting for approximately 99-percent of the total shaft waste activity.[125] Specific radionuclide inventories of the MDA G pits and shafts are provided as a sub-document to the D. Hollis, et al., 1997 report, titled, *Radioactive Waste Inventory for the TA-54, Area G Performance Assessment and Composite Analysis.* This sub-document is not readily available to the public.

[124] *Ibid*
[125] *Ibid*

An additional report published in December 1970 based on all available LANL Health Division Group 1 (H-1) documents stated that, as of 1970, MDA G contained 9,034 grams of uranium-235, 1,084 grams of plutonium-239, 0.204 grams of plutonium-238, and less than 10 grams of tritium[126].

In the 1997 study conducted by D. Hollis et al., waste inventories at MDA G between 1971 and September 25, 1988 were estimated using disposal data in the LANL LLW disposal database and the TRU waste database. The TRU waste database was designed to keep record of the TRU waste generated at LANL and stored at MDA G prior to shipment to the Waste Isolation Pilot Plant (WIPP) for permanent disposal[127]. Thus, most TRU waste at MDA G was stored retrievably in order to be removed at a later date for permanent disposal at an alternative location. The TRU waste that was non-retrievable was added to the LLW inventory to estimate the total inventory for the period[128].

Based on LANL's LLW and TRU waste databases, it was found that the annual disposal volumes of LLW and non-retrievable TRU wastes in the disposal pits ranged between 70, 629 and 388, 461 ft^3 (2,000 and 11,000 m^3), averaging about 176,573 ft^3 (5,000 m^3) per year. Annual disposal volumes of LLW and non-retrievable TRU waste in shafts ranged from 353 to 4,944 ft^3 (10 to 140 m^3), with the highest waste disposal volumes occurring between 1981 and 1988. Approximately 4,520,278 ft^3 (128,000 m^3) of LLW and TRU waste were deposited at MDA G between 1971 and September 25, 1988.[129]

The total waste deposited at MDA G between 1971 and September 25, 1988 totaled approximately 870,000 Ci and was buried 23 pits and almost 100 shafts that were active during the time period. Approximately 830,000 Ci of the total waste was disposed of in the shafts. Annual disposal activities in the pits ranged between 4 and 35,000 Ci, whereas shaft annual disposal activities ranged between 250 and 350,000 Ci. Four pits at MDA G, Pits 10, 18, 28, and 29, accounted for 98-percent of the total activity accrued in the pits between 1971 and September 25, 1988.[130]

The total volume of non-retrievable TRU waste disposed of at MDA G during this time was 2,507 ft^3 (71 m^3) in four pits and 155 ft^3 (4.4 m^3) in shafts, totaling approximately 3,400 Ci. (Since this waste is non-retrievable, it was included in the previously discussed totals).

Between 1971 and September 25, 1988, the major radionuclides disposed of at MDA G pits were tritium, cobalt-60, strontium-90, and cesium-137. The most abundant radionuclide was tritium, contributing an activity of approximately 800,000 Ci. Other

---

[126] Rogers, M.A., 1977
[127] Christensen, D.V., et al., 1997
[128] Hollis, D., et al., 1997
[129] *Ibid*
[130] *Ibid*

radionuclides reported in shaft waste at MDA G were cobalt-60, krypton-85, strontium-90, barium-133, cesium-137, and plutonium-239, each contributing 100 to 3,000 Ci to the total shaft activity. Again, the specific inventories of all shafts and pits during this time period are provided as a sub-document to the D. Hollis, et al., 1997 report, titled, *Radioactive Waste Inventory for the TA-54, Area G Performance Assessment and Composite Analysis*. This sub-document is not readily available to the public.

Beginning on September 26, 1988, the recording and documenting of all chemical, physical, and radiological characteristics of MDA G waste was done in accordance with the new requirements of DOE Order 5820.2A. Between September 26, 1988 through 1995, approximately 1,059, 440 ft^3 (30,000 m^3) of LLW and TRU waste with an activity of 440,000 Ci was deposited at MDA G. The average annual volumes and activities of waste disposed of in pits were approximately 141,259 ft^3 (4,000 m^3) and 20 Ci. Predominant radionuclides disposed of in the pits were tritium, cobalt-60, and uranium-238. The activities of these radionuclides ranged between 5 and 16 Ci. Average annual volumes and activities of waste disposed of in shafts were approximately 1,413 ft^3 (40 m^3) and 40,000 Ci. Nearly all of the waste disposed of in shafts was tritium. Other radionuclides disposed of in shafts were tritium, cobalt-60, and cesium-137, which ranged in activities from 83 to 430,000 Ci.[131]

A 1980 surface reconnaissance study[132] at MDA G describes the inventories of several selected radionuclides stored and disposed of at MDA G between 1957 and 1978. These numbers were retrieved from the 1979 US DOE Final Environmental Impact Statement (FEIS) conducted at the Los Alamos National Laboratory Site[133]. Below, Table 10. displays the inventory of radionuclides stored and disposed of at MDA G between 1957 and 1978, according to the MDA G reconnaissance study.

Table 10. Radionuclide Inventory Stored or Disposed of at MDA G between 1957 and 1978[134].

Radionuclide	1957-1977[a,b] (Ci)	1977[c] (Ci)	1978[c] (Ci)
H-3	123,853	40,910	58,440
U-233	46	N/A	N/A
U-234,235,236,238	56	2	1
Pu-238	56,001	14	9
Pu-239	1,407	10,572	13,193
Am-241	2,086	6,355	3,338
Fission Products	3,936	1,389	1,226
Activation Products	573	8	76

[A]: All values have been corrected for decay.
[b]: Data are known to be incomplete due to the lack of early laboratory

[131] *Ibid*
[132] Mayfield, D., and W.R. Hansen, 1983
[133] US DOE, 1979
[134] *Ibid*

disposal records. No pre-1960 tritium disposal records are available. Some post-1960 disposals were not well recorded.
[c]: All values are reported as at time of disposal or storage.

An additional study performed by M.A. Rogers in 1977[135] reports the radionuclide inventory of disposal pits and shafts up until January, 1976. These types and quantities of wastes can be seen below in Table 11.

Table 11. Radionuclide Inventory in Disposal Pits and Shafts at MDA G between 1957 and 1975[136]

Radionuclide	Pits 1957-1975 (Ci)	Shafts 1965-1975 (Ci)
H-3	N/A	91,973
Na-22	N/A	20
Co-60	N/A	154
Sr-90/Y-90	2,750	284
Cs-137	N/A	6
U-233	N/A	5
U-234, 235, 236, 238	54	<1
Pu-238	44	4
Pu-239	368	46
Am-241	2,064	N/A
Fission Products	N/A	196
Induced Activity	N/A	662

According to this study, the minor nuclides found in Area G Disposal Shafts include Na-24, P-32, Cr-51, Co-57, Fe-59, Zn-65, Kr-85, Y-91, Ag-105, In-114, I-131, Xe-133, Ba-140, Ce-144, Pm-147, Eu-152, Ta-182, Au-191, Po-210, Ac-227, Th-232, Pu-240, Pu-242, Cm-244, and Cf-252[137].

As can be seen through a comparison between the studies conducted in 1997 by D. Hollis, et al., the US DOE in 1979, and M.A. Rogers in 1977, available data on the quantities and concentrations of waste types disposed at MDA G is conflicting. However, it can be agreed that MDA G contains an extremely large quantity of radioactive waste with a high potential for contaminant mobilization within the underground formation.

[135] Rogers, M.A., 1977
[136] *Ibid*
[137] *Ibid*

Thus, it is imperative that the Chem-Risk thoroughly reviews all available documentation to properly assess the contamination present in MDA G.

Groundwater occurs in three modes beneath the site: water found in shallow alluvium in the canyons, perched water that is discontinuous, and the main aquifer.[138] The main aquifer serves as the only source of municipal water for the cities of Los Alamos and White Rock. Located within the Tesuque Formation, the depths of the aquifer range from 600 feet to 1200 feet beneath the soil.[139] The aquifer partially discharges into the Rio Grande through springs in White Rock Canyon,[140] located 130 to 200 feet above the Rio Grande river. The discharge are has an 11.5 mile reach between Ottowi Bridge and the mouth of Rito de los Friholes. Approximately 4300 – 5500 acre-feet are discharged annually from the aquifer.[141] The thickness of the Tesuque Formation is estimated to be approximately 3,900 feet.[142] Until as recently as five years ago, LANL used to protect the "myth" that the volcanic tuft overlying the deep groundwater was impermeable, therefore groundwater contamination was impossible. More recent data completely dispels this myth. According to the LA Times, perchlorate and fission products have been found in White Rock Canyon seeps.[143]

4.13.2 Material Disposal Area H

Material Disposal Area (MDA) H is approximately 0.3 acres in size and is located north of Pajarito Road in TA-54, adjacent from MDA J and near Pajarito and Canada del Buey Canyons. MDA H operated as LANL's primary disposal area for classified, solid-form waste between May 1960 and August 1986. It contains 9 cylindrical disposal shafts; each 6 ft in diameter and 60 ft deep. The locations of the 9 shafts in MDA H are shown below in Figure 31.

It is estimated that a total of 15,885 cubic ft (119,000 gallons) of waste containing unknown quantities of solid-form radioactive waste, depleted uranium, tritium, magnesium, lithium, beryllium, motor oil, metals, and high explosives is buried at this disposal site. Recording media (film, slides, computer tapes, and paper documents) and graphite were also largely disposed of at MDA H. The shafts are filled to a depth of 6 ft below the ground surface. The waste in shafts 1 through 8 are covered by a 3-foot layer of crushed tuff, topped with a 3-foot layer of concrete, whereas the waste in shaft 9 is

---

[138] US DOE. "Environmental Surveillance at Los Alamos during 1998", <http://lib-www.lanl.gov/la-pubs/la-13633.pdf> : 3.
[139] US DOE. "Environmental Survey Preliminary Report", January 1988: 2-6.
[140] US DOE. "Environmental Surveillance at Los Alamos during 1998", <http://lib-www.lanl.gov/la-pubs/la-13633.pdf> : 3, 145.
[141] LANL, Interim Facility-Wide Groundwater Monitoring Plan, Rev. 1. April 2006. ER2006-0195
[142] US DOE. "Baseline Compliance Assessments (Tiger Team) Database: LANL", DOE/EH-0204, November 1, 1991: 1.4.
[143] Clifford, F., "Toxic Waste Trickles Toward New Mexico's Water Sources," LA Times, November 1, 2009.

covered by a 6-foot layer of concrete. All shafts are located at least 50 ft from the rim of the Pajarito Canyon. LANL believes the waste is at least 900 ft above the regional

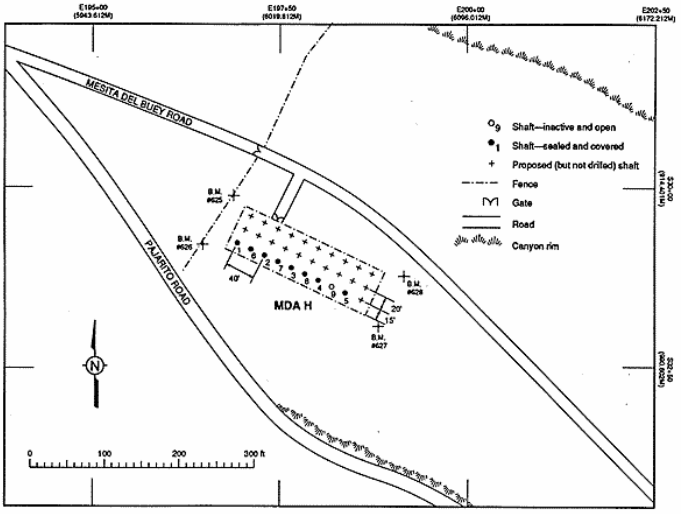


Figure 31. Map of Material Disposal Area H[144]

aquifer.[145] (The regional aquifer at MDA H is estimated to sit at an average depth of 1,040 ft below the ground surface.[146]) The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA H as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[147]

In 1990, MDA H was the first of ten mesa-top Material Disposal Areas to undergo a corrective measures study under LANL's Environmental Restoration (ER) Project initiated in 1989. The corrective measures study was conducted in order to evaluate different alternatives for the future management of the disposal site. MDA H was chosen as the first site to undergo a corrective measures study as the waste disposal conditions at MDA H were thought to present a future risk to humans and the environment. RCRA facility investigations at MDA H began in 1994 and were completed in 2001. The study found that water vapor-form tritium and vapor-phase volatile organic compounds (VOCs) were being released from the subsurface shafts.[148]

Before conducting the corrective measures study at MDA H, LANL first had to properly estimate the waste inventory disposed of at MDA H between 1960 and 1986. LANL found that approximately 391,229 pounds of waste had been disposed of at LANL, and the largest portion of the waste, approximately 57-percent, consisted of both radioactive

---

[144] *Ibid*
[145] LANL, 2001a
[146] LANL, 2007
[147] Los Alamos Study Group, 2006h
[148] LANL, 2001a

(24-percent) and non-radioactive (33-percent) metals[149]. The radioactive metals are depleted uranium. The remaining portion of waste disposed of at MDA H consists of 1-percent potentially reactive materials (such as lithium compounds), 9-percent graphite, 24-percent additional radioactive materials other than depleted uranium, 9-percent plastic materials, 1-percent paper, and 1-percent high explosives. Thus, 48%, or 187,790 pounds of the waste disposed of at MDA H is radioactive. Radionuclides known to be present at MDA H are tritium, uranium-234, uranium-235, uranium-236, uranium-238, plutonium-238, plutonium-239, plutonium-240, plutonium-241, and plutonium-242. It is assumed, due to background knowledge of LANL processes, that barium, cadmium, chromium, lead, mercury, and silver are additionally present at MDA H, as these materials were used for shielding, solders, parts, or coatings. [150]

Table 12, below, lists the quantities and activities of radioactive and other hazardous materials that are known, or estimated, to be disposed of at MDA H. Estimated amounts of materials are based on logbook entries kept by LANL workers, interviews with LANL site workers, and information on material excavated from the Classified Waste Landfill at SNL/NM. For metals, LANL logbooks do not list the actual quantities of each type of metal disposed of at MDA H and thus metal wastes recovered from the Classified Waste Landfill at SNL/NM were analyzed to estimate the quantities of aluminum, beryllium, cadmium, chromium, copper, lead, mercury, silver, and steel disposed of at MDA H[151]. Estimates of quantities of high explosives were based solely on logbook entries kept by LANL workers. Plutonium contamination was estimated to exist in the form of plutonium oxide and quantities were retrieved from three logbook entries, tritium quantities were estimated based on analytical data for tritium gathered during FRI activities (since logbook entries on tritium were insufficient), and uranium estimates were based on sporadic logbook entries and background knowledge of past disposal practices and LANL processes.[152]

Table 12. Quantities and Activities (if applies) of Materials Known to be Disposed of at MDA H between 1960 and 1986.

Material	Mass Reported in Logbook (lb)	Estimated Total Mass Disposed of at MDA H (lb)	Estimated Activity Disposed of at MDA H (Ci)	Form
Aluminum	N/A	N/A		N/A
Barium	N/A	5,300		Estimated to be 40% of mock/inert high explosives.
Beryllium	238	6,534		Solid-part of shapes and weapon components.

[149] LANL, 2003
[150] *Ibid*
[151] Galloway, R.B., 2001
[152] LANL, 2003

Cadmium	Not Reported	20		Solid-part of shapes and weapon components.
Chromium	Not Reported	1,960		Solid-in chrome plated parts.
Copper	230	2,350		Solid-part of shapes and weapon components.
Graphite	47,162	47,162		N/A
High Explosives	51,958	1,275		Assumed to be RDX.
High Explosives (mock/inert)	13,260	13,260		Cyanuric acid (40%).
Lead	Not Reported	78,250		Solid-part of shapes and weapon components.
Lithium	75	75		Solid and potentially reactive/toxic.
Lithium hydride	466	466		Solid and potentially reactive/toxic.
Lithium fluoride	4,408	3,790		Solid and potentially reactive/toxic.
Lithium boride	10	10		Solid and potentially reactive/toxic.
Mercury	Not Reported	1,300		Part of electrical components.
Paper	755	755		N/A
Plastics (film)	42,346	41,036		N/A
Plastics (magnetic media)	4,337	4,337		N/A
Plastics (non-specific)	6,555	6,555		N/A
Plutonium*	300	300	0.014	Surface Contamination
Shapes and Parts w/o Material Description	134,295	N/A	N/A	N/A
Slides	1,223	1,223		N/A
Silver (in developed film)	Listed Under Plastic.	1,310		Film.

Silver (non-film)	Not Reported	39		Plating of electrical parts.
Steels	Listed as one of many materials	156,490		Solid-part of shapes and weapon components.
Tritium	80		3.5-106	Residual radioactivity in stainless steel canisters.
Tungsten	11,500	11,500		N/A
Uranium*	67,055	265,300(104,800)[a]	284.5(94.2)[a]	depleted uranium, enriched uranium, fuel elements.
Totals	**391,229**	**709,297(548,797)[a]**	**288-391(98-200)[a]**	

[a]: The first number represents the maximum (upper-bound) amount of material present in the waste. The number in parenthesis is the best-estimate of material present in the shafts.

4.13.3 Material Disposal Area J

Material Disposal Area (MDA) J is approximately 2.65 acres in size and is located in the center of TA-54, adjacent from MDA H, near Pajarito and Canada del Buey Canyons (Figure 32). MDA J was used by LANL between October 1961 and 1987 and contains 4 waste pits of unknown size, 2 to 4 shafts ranging between 6 ft in diameter by 197 ft (60 m) deep, and 6 disposal cells of unknown size. Currently, 3 disposal cells and two shafts are still used for controlled industrial solid wastes, and asbestos waste is stored at these locations until it can be shipped off-site for proper disposal. It is estimated that unknown quantities of scrap metal, construction debris, and classified materials are buried at this disposal site, due to LANL operations. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA J as an area with a low probability of contaminant mobilization and a low to moderate potential of contaminant release to groundwater.[153]

[153] Los Alamos Study Group, 2006i

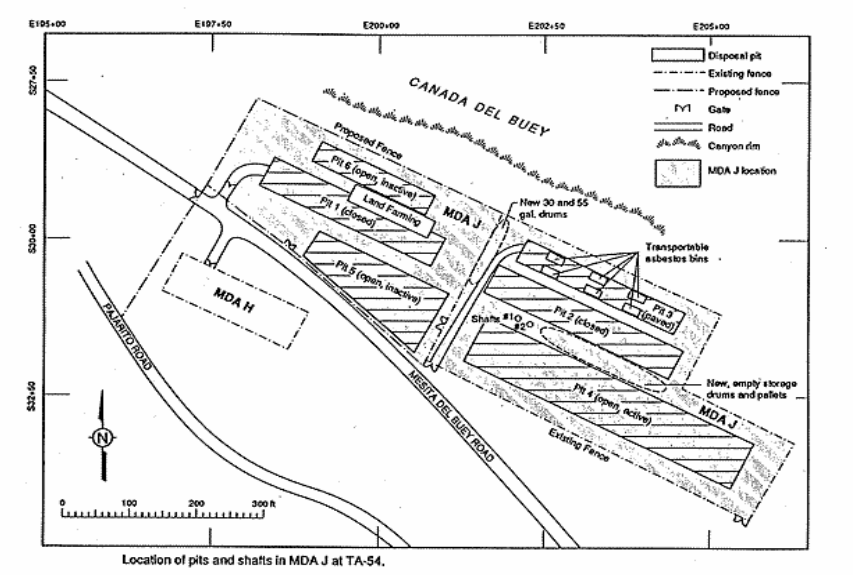


Figure 32. Map of Material Disposal Area J[154]

4.13.4 Material Disposal Area L

Material Disposal Area (MDA) L is approximately 2.65 acres in size and is located in the lower half of TA-54, near Pajarito and Canada del Buey Canyons (Figure 33). It is unclear the date that LANL began using MDA L, sometime in the early 1960s, but it was used continuously through 1985. MDA L was used for the disposal of nonradiological liquid wastes, including both containerized and uncontainerized liquid wastes. It contains 1 waste pit of unknown size, 3 surface impoundments of unknown sizes, and 34 shafts that range between 3 and 8 ft in diameter and 15 to 65 ft in depth. All disposal structures are unlined.[155]

The disposal pit at MDA L consists of 3 near-vertical walls on the west, north, and south sides of the pit, and an entrance ramp on the east side of the pit. The bottom of the pit is flat. The pit was decommissioned after the waste inside of the pit reached a height of 3 ft from the ground surface. After decommissioning, the pit was covered with crushed, consolidated tuff. The three surface impoundments at MDA L have near-vertical walls on their west and east sides, and entrance ramps exist on their north and south sides. All three pits have additionally been decommissioned and covered with consolidated tuff. The 34 disposal shafts at MDA L have been filled with 3 ft of crushed tuff at the bottom of each shaft, to fill cracks and joints in the underground formation. Each shaft was topped with 3 ft of concrete once the waste within the shaft reached a height that came within 3 ft from the ground surface. In 1986, after all disposal units at MDA H had been

[154] *Ibid*
[155] LANL, 2008a

decommissioned, the entire surface was paved with asphalt.[156] Below, Figure 33 displays a map of the subsurface disposal units contained at MDA L.

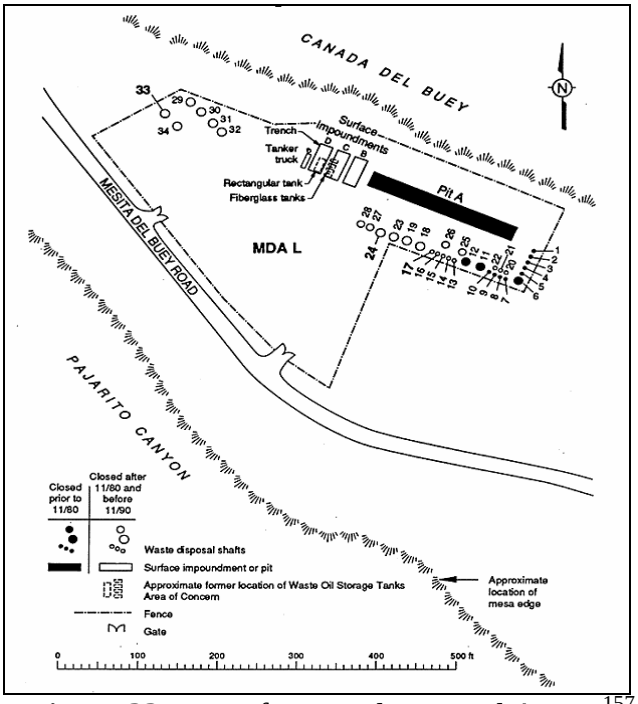


Figure 33. Map of Material Disposal Area L[157]

MDA L is now used for the storage and treatment of RCRA hazardous waste and mixed wastes under interim status. Hazardous waste and mixed low-level wastes (MLLW) are stored at MDA L in container storage units in preparation for off-site disposal. Storage units are located on the paved area of MDA L, above the decommissioned subsurface disposal units. The New Mexico Environmental Department's (NMED) Hazardous and Radioactive Material Bureau ranks MDA J as an area with a high probability of contaminant mobilization and a moderate to high potential of contaminant release to groundwater.[158] Below, Figure 34 displays an aerial photograph of MDA L's above surface storage units.

[156] LANL, 2008a
[157] Los Alamos Study Group, 2006k
[158] *Ibid*

Figure 34. Image of MDA L[159]

Logbooks were used to keep record of the type and volume of wastes disposed of at the MDA L subsurface disposal units. Each log book also documented the date and location of each waste disposal activity. However, logbooks kept before 1974 are incomplete, and many of the logbooks, both before and after 1974, do not contain full detailed entries, only brief descriptions of the disposed waste. As a result, two databases were constructed to determine the types and volumes of waste disposed at MDA L. These two databases, the Source Term Database and the Batch Waste Database, contain information about untreated wastes and wastes that underwent batch treatment before disposal, respectively. Each database contains information reported in logbook entries and estimates of wastes determined from the original information included in the logbooks. According to the Source Term Database and the Batch Waste Database, an approximate total of 71,540 ft^3 (2,026 m^3) of chemical waste were disposed of at this site.[160]

Two investigations were conducted at MDA L in order to determine if contaminants buried at MDA L posed a potential risk to current or future environmental and/or human health. The first study, Phase I of the RCRA facility investigation, conducted between 1993 and 1995, sampled sediment in 8 locations within the outfall to Canada del Buey Canyon. Each sample ranged between 0 inches to 4 inches, or 4 inches to 8 inches in depth and was tested for gross alpha, beta, and gamma radiation. Additional off-site laboratory analysis was performed on selected samples as well. At the time of this investigation, no inorganic chemicals were detected above background values. Plutonium was detected at levels above the background value or fallout value for the area. The highest detected concentration of plutonium was 0.011 pCi/g, which exceeded the fallout value of 0.006 pCi/g for the area. The pesticide methoxychlor[4,4'-] was also detected in 2 samples at concentrations of 0.028 mg/kg and 0.063 mg/kg, approximately 1 to 3 times over the estimated limit of 0.02 mg/kg. [161]

---

[159] *Ibid*
[160] *Ibid*
[161] *Ibid*

In addition, 7 vertical boreholes and 11 angled boreholes were drilled at MDA L in the vicinity of the subsurface waste disposal units. A total of 184 core soil samples were collected and 8 samples were submitted for inorganic chemical analysis. It was found that concentrations of aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, uranium, vanadium, and zinc in the soil samples were all above background levels. Tritium was also identified in 5 out of 7 samples submitted for analysis, whereas americium-241 and cesium-137 were not.

Nineteen different volatile organic compounds (VOCs) were detected as present in samples from 8 boreholes drilled near the disposal shafts and pits. Tritium and VOC surface fluxes were additionally measured at MDA L, and 20 VOCs and tritium were detected in all air samples. The detected VOCs contained acetone, benzene, bromobenzene, carbon tetrachloride, toluene, Freon 113, among many other hazardous chemicals.

Between 2004 and 2005, a second field study was conducted at MDA L. 7 shallow and 1 deep boreholes were drilled at various locations within MDA L. Rock, soil, and pore-gas samples were subsequently collected. During this time, no radionuclide or inorganic chemicals were detected in soil samples at levels above the acceptable background levels for the area. Rock and pore-gas samples provided results that were consistent with the findings of VOCs in the 1993-1995 field study, and only one radionuclide was detected above background levels (U-235 = 0.144 pCi/g; Background Value = 0.14 pCi/g).

5.0 Off-Site Waste Disposal

Throughout the history of LANL operations, specifically in its earlier years, liquid radioactive wastes were released from LANL into the surrounding canyons in Los Alamos. These canyons include, but are not limited to, Acid/Pueblo Canyon, Los Alamos Canyon, and Mortandad Canyon. All liquid wastes discharged prior to 1951 were released without treatment, and the majority of these wastes were disposed of in Acid Canyon. The volume of effluent discharged to Acid and Los Alamos Canyons was so immense at several portions of LANL's operating history that surface flows in the canyons were maintained for distances as great as 1.5 kilometers[162]. Figure 35 below displays a photograph of a potentially contaminated stream in Acid Canyon.

[162] ChemRisk, et al., 2009

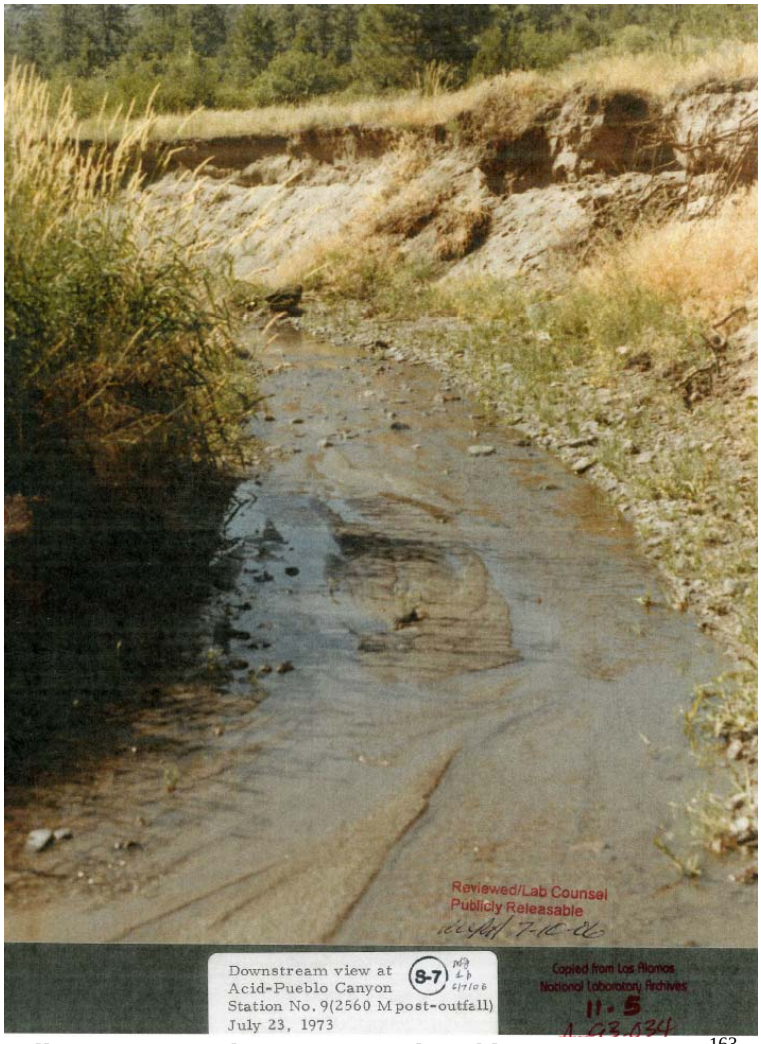


Figure 35. Potentially Contaminated Stream in Acid-Pueblo Canyon in 1973[163]

The following sections describe the types and quantities of wastes that were released into Acid-Pueblo, Los Alamos, and Mortandad Canyons during LANL operations.

5.1 Acid-Pueblo Canyon

Acid Canyon is a small tributary of the larger Pueblo Canyon, and is therefore largely referred to as Acid-Pueblo Canyon throughout the literature. Acid-Pueblo Canyon merges with Los Alamos Canyon east of the LANL site and eventually empties into the Rio Grande River.

From 1943 to 1951, untreated waste from Technical Area 1 (TA-1) was discharged via a weir box directly into the South Fork of Acid-Pueblo Canyon (Figure 36).[164] Between

[163] LANL, 2006A

1943 and 1945, TA-1 was used as the major plutonium processing and storage site at LANL. After 1945, the majority of plutonium operations were transferred to Building 12 at DP West in TA-21, but TA-1 continued to process plutonium until 1965. One chemical line connected all of the laboratories in TA-1 draining the laboratory floors, sinks and operations and emptied directly into Acid Canyon with no dilution. The untreated liquid wastes discharged into Acid Canyon contained strontium, cesium, uranium, plutonium, americium, and tritium[165]. The liquid wastes were discharged untreated until the first liquid waste treatment plant in TA-45 was completed at LANL in 1951.

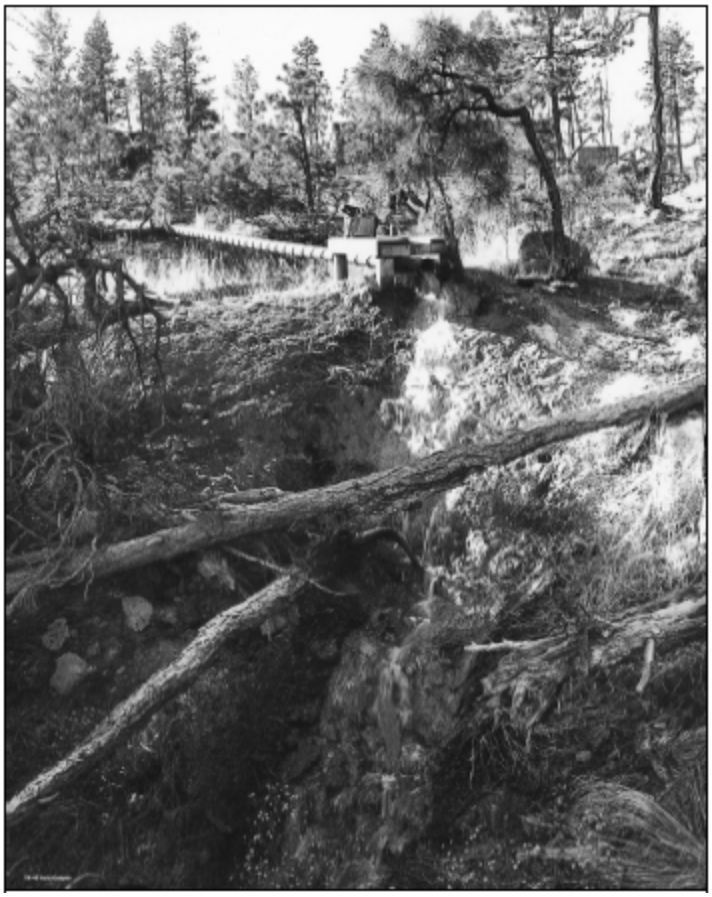


Figure 36. Liquid Radioactive Waste Discharged by LANL into Acid Canyon in the mid-1940s[166]

In mid-1951, LANL opened a liquid waste treatment plant in TA-45. Liquid wastes from TA-1 were then treated at TA-45 before being discharged to Acid Canyon. In June 1953, liquid radioactive wastes from TA-3, a new laboratory complex south of Los

[164] LANL, 1967
[165] Graf WL, 1993
[166] *Ibid*

Alamos Canyon, were added to the plant. As of December 1953, approximately 30% of TA-3 waste was released to Acid Canyon untreated because it was measured to be lower than the administrated level for effluent of 330 disintegrations per minute per liter (dpm/liter) of waste water[167]. A dpm is a measure of radioactivity, indicating the number of atoms in a given quantity of radioactive material that decay in one minute. A simple conversion between dpm and picocuries (pCi) is to multiple dpm by 0.45.

In 1953, liquid wastes from the Health Research Laboratory at TA-43 were added to the liquid waste treatment plant. In 1958, liquid wastes from a radiochemistry facility in TA-48 were additionally added to the treatment plant. The waste products from this site were primarily fission products.

In 1963, a new treatment plant in TA-50, south of Los Alamos Canyon, began accepting liquid wastes from all research facilities south of the canyon. At this time, wastes from TA-3 and TA-48 were redirected to the new plant at TA-50, and wastes from TA-43 were redirected to a sanitary sewer due to the small quantities of low concentration wastes that were generated at that time. From this point on, only liquid wastes from TA-1 were processed at the original liquid waste treatment plant from that point on until the plant was shut down in May 1964. This was the last time when effluents are reported to have been released into Acid-Pueblo Canyon, although three sanitary waste treatment plants release effluents thought to be non-radioactive into Acid-Pueblo Canyon.[168]

Very little information is available concerning radionuclide concentrations in air, soil, sediment, or water in Acid-Pueblo Canyon during this time period. Limited data was collected beginning in 1943, although much of this data is not publicly available and sampling was limited to specific radionuclides. As previously discussed, LANL kept poor records of its liquid radionuclide wastes released in Acid-Pueblo Canyon, and there is evidence that items were at times dumped directly into the canyon without much (or any) paper trail. A handwritten note on one paper states "Tanks dumped in Acid Canyon 10/28/66,"[169] without any mention of the type or quantity of waste contained in the tanks. It is quite possible that other wastes were dumped directly into the canyon without record, particularly during the first several decades of LANL's operation.

The following sections describe the radionuclide concentrations found in the air, soil, sediment, and water of Acid-Pueblo Canyon during different periods of time throughout the operational history of LANL.

According to a 1992 LANL document, the average plutonium concentrations released in untreated liquid effluent between 1943 and 1951 were estimated to be 1,000 picocuries per liter (pCi/L) with maximum concentrations of 10,000 pCi/L. During the same time

[167] LANL, 1992a
[168] *Ibid*
[169] LANL, 1966

period, 18.25 Ci of tritium, 0.25 Ci of strontium-89, and 0.094 Ci of strontium-90 were also released to Acid-Pueblo Canyon[170].

A 1974 Correspondence from W.D. Purtymun of the Health Division H-8 monitoring group to LaMar J. Johnson, the H-8 Group Leader, discuss the estimated amounts of plutonium, cesium, americium, strontium, and uranium discharged into Acid-Pueblo Canyon between 1943 and 1974. According to LANL, the estimated amount of plutonium released from TA-1 and TA-45 into the Acid-Pueblo Canyon from 1944 through 1964 was 170 mCi, with 143 mCi being released before the installation of the treatment plant in 1951.[171]

Stream water samples collected in 1945 from the section of Pueblo Creek that runs north-northwest over TA-1 contained 1,400-38,000 dpm of plutonium per liter of water (dpm/L). This is equivalent to 630.6 to 12,612.6 pCi/L. Polonium was measured at levels ranging from 660 to 1,000 dpm/L (297.3-450.5 pCi/L)[172]. Samples collected in July and September 1946 from sanitary waste sewers emptying into Pueblo Canyon ranged from 1.2 to 180 dpm/L (0.5-81.1 pCi/L) of plutonium and 1.2 to 274 dpm/L (0.5-123.3 pCi/L) of polonium. Samples collected from chemical waste sewers discharging into Pueblo Canyon ranged from 124 to 1,900 dpm/L (55.9-855.9 pCi/L) of plutonium and 248 to 5,720 dpm/L (111.7-2,576.6 pCi/L) polonium. On September 27, 1946, it was decided that Pueblo Canyon should be restricted from public access due to contamination of the Pueblo Creek.[173]

A 1946 memorandum between J.F. Tribby and Dr. E.R. Jette regarding the disposal of contaminated sewage show that sewer outfalls in Acid-Pueblo Canyon were measured to be 100 dpm (45 pCi) near the special engineering detachment area, 105 dpm (47.3 pCi) by the #2 sewer, 23,800 dpm (10,710 pCi) by the #3 sewer, 5,000 dpm (2,250) by #s 5&6 sewers, and 3,000 dpm (1,350 pCi) by #s 6&7 sewers.[174]

Several soil samples collected in Acid-Pueblo Canyon in the late 1940s found that the soil surfaces near the bottom of the canyon measured as high as 20,000 dpm/g (9,000 pCi/g) in gross alpha radioactivity. Soil samples were collected from the canyon walls and along the canyon bed. Plutonium in soil samples collected from the Acid-Pueblo Canyon seepage pits was detected at levels as high as 5,000 dpm/100 g (50 dpm/g, or 22.5 pCi/g), and polonium was detected as high as 300,000 dpm/100 g (3,000 dpm/g, or 1,350 pCi/g).[175]

---

[170] LANL, 1992a
[171] Purtymun, W.D., and T.E. Hakonson, 1974
[172] Hempelmann, L.H., 1945
[173] Hempelmann, L.H., 1946
[174] Tribby, J.F., 1946
[175] Tribby, J.F., 1948

Stagnant water samples measured in the same study were found to be as high as 5,000 dpm/L (2,250 pCi/L) in plutonium. In another location, polonium was detected at 140,000 dpm/L (63,000 pCi/L). In ponds within the canyon, plutonium levels as high as 500 dpm/L (225 pCi/L) were detected.[176]

Samples collected from Pueblo Canyon in 1947 detected polonium levels ranging from 0 to 28 dpm/L (0-12.6 pCi/L) in stream water and 0 to 12 dpm/100 g (0-0.12 dpm/g, or 0-0.05 pCi/g) in soil. Plutonium was detected within the range of 18 to 352 dpm/L (8.1-158 pCi/L) in stream water and 96 to 211 dpm/100 g (0.96-2.11 dpm/g, or 0.43-0.95 pCi/g) in soil[177].

On December 1, 1948, a mercury spill was reported at the plutonium fast reactor, also known as the Clementine site, and took a "prolonged period" to clean up. Another mercury coolant spill was reported at the Clementine site in early 1951. In late 1950 it was discovered that a plutonium rod had ruptured and contaminated the mercury coolant. Clementine was decommissioned following the spill and other process abnormalities. It is unknown where the mercury coolant was disposed of.

Estimates of the amounts of plutonium introduced into the alluvium on Acid and Pueblo Canyon floors between 1943 and 1950 when no treatment plant was on site are presented in the literature by Dr. Stoker and Dr. Lane, industrial hygienists at LANL. Stoker[178] and associates estimate that 150 mCi (0.00015 Ci) plutonium were released to Acid and Pueblo Canyons between 1943 and 1950, whereas Lane[179] and his co-workers estimate that 300-900 mCi (0.0003-0.0009 Ci) plutonium were released to Acid and Pueblo Canyons between 1943 and 1950. Lane's estimate was determined based on samples collected from Acid-Pueblo Canyon in the late 1970s, and thus his estimate is based on the plutonium that remained after some of the canyon's alluvium had been removed in 1966. (A more detailed discussion on the decontamination and decommissioning of Acid-Pueblo Canyon can be found in Section 3.1.2.5 of this report.) Accounting for the plutonium that may have been removed from Acid-Pueblo Canyon before the time of Lane's sampling, Lane estimates that releases during 1943-1950 may have actually been as high as 3,000 mCi (0.003 Ci).

It is estimated that only 0.0233 additional Ci of plutonium were released into Acid Canyon from 1954 through the end of effluent releases in 1964. It is estimated that 31.2 more Ci of tritium and 0.0563 Ci of unidentified alpha were released during this time period.

---

[176] *Ibid*
[177] Schnap, B. and J.F. Tribby, 1947
[178] Stoker et al., 1981
[179] Lane et al., 1985

A 1982 US Department of Energy (DOE) report[180] presented plutonium, tritium, gross alpha, and gross beta measurements in Acid Canyon between the years 1951 and 1964 when the liquid waste treatment plant operated in TA-45. Measurements collected between 1951 and 1964 are presented below in Table 13. According to the report, the unidentified alpha radionuclides are assumed to be predominantly plutonium and uranium.

Table 13. Estimated Activity (in Curies) of Radionuclides Released via Effluent into Acid Canyon: 1951-1964[181]

Year	Unidentified Gross Alpha	Unidentified Gross Beta	Tritium	Plutonium
1951	0.0024	--	3	0.0013
1952	0.0041	--	3	0.0011
1953	0.0038	--	3	0.0012
1954	0.0044	--	3	0.0022
1955	0.0041	--	3	0.0022
1956	0.006	--	3	0.0011
1957	0.0087	--	3	0.0009
1958	0.0038	--	3	0.0009
1959	0.0018	--	3	0.0012
1960	0.0035	1.251	3	0.0026
1961	0.0093	0.505	3	0.0053
1962	0.0074	1.222	3	0.0039
1963	0.0072	0.804	3	0.003
1964	0.0001	0.0001	1.2	0.00004
Totals	**0.0666**	**3.78**	**40.2**	**0.0269**
Activity Decayed to December 1977	[a]	[a]	**13.1**	**0.0269**

a: No estimate of decay made because data on isotopic mixtures are not available.

The effluent from the treatment plant which began operation in 1951 ranged from 20-150 pCi/L during its operation. It is thought that the plant removed 98-99% of plutonium prior to its release, which would result in approximately 0.34 grams of plutonium being directly released from the plan during its 14 years of operation. It is estimated that 1.9 grams of Pu-239 were released prior to operation of the plant over the initial eight years[182].

[180] US DOE, 1982
[181] *Ibid*
[182] ChemRisk, et al., 2009

In the spring 1952, plutonium was detected at levels ranging from 3.0 to 172 dpm/g (1.4-77 pCi/g) in soil in Pueblo Canyon, whereas uranium was detected at 0.03 to 0.27 dpm/g (0.01-0.12 pCi/g). In the fall of 1953, plutonium in Pueblo Canyon was detected at levels of 4 to 320 dpm/g (1.8-144 pCi/g) in soil and 4.4 to 2,300 dpm/g (2.0-1,035 pCi/g) in grass. Uranium was detected at levels from 0.024 to 2.3 µg/g of soil and 0.053 to 2.4 µg/g grass.[183]

Soil and grass samples were collected in 1953 and 1954 from Pueblo Canyon. Uranium was detected in almost every soil and grass sample at levels of 0.05-0.5 µg/g, while higher samples were detected inside the fenced area in Acid Canyon. The maximum detected level was 100 µg/g for soil[184].

In the summer 1954, gross alpha in Pueblo Canyon was detected at 6-7,736 dpm/g (2.7-3,481 pCi/g) in the soil to a depth of one foot, and 4-9,660 dpm/g (1.8-4,482 pCi/g) to a depth of two ft. Uranium was detected at a one foot depth from 0.09-16 µg/g in the soil. In the fall of the same year, plutonium was detected at concentrations of 1.6 to 576 dpm/g (0.7-259 pCi/g) in soil while uranium in soil was detected at levels of 0.08 to 81.2 µg/g.[185]

Soil samples collected by the Health Division in Acid-Pueblo Canyon on July 19, 1954 documents ranged from 10 to 60 cpm/g at the canyon surface, 8 to 38 cpm/g 12 inches below ground, and 6 to 40 cpm/g 24 inches below ground. On September 6, 1956, gross alpha readings in Acid-Pueblo Canyon ranged between 0.2 and 0.3 cpm/g for dry soil, whereas gross beta readings increased from 0 cpm/g to 7.2 cpm/g to 76 cpm/g as depth increased from the surface, to 12 inches below ground, to 24 inches below ground. Gross gamma readings spanned from 0 cpm/g to 6 cpm/g to 4 cpm/g on the surface of the canyon floor, 12 inches below ground, and 24 inches below ground, respectively. [186]

In 1957, samples were collected by the USGS from the Rio Grande River and analyzed for gross alpha, gross beta, plutonium, and uranium. The amount of plutonium in surface water samples from Acid-Pueblo Canyon averaged 20 pCi/L during this period, while a concentration of 27 pCi/g of plutonium was found in the soil of lower Acid Canyon. Water samples from groundwater, water supplies, and springs in the Los Alamos area were sampled by the USGS. The samples were analyzed for pH, gross alpha, gross beta, plutonium, uranium, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO_3, and conductivity.[187]

Surface water samples collected in Acid Canyon in 1958 and 1959 ranged from 15 to 40 µg/L uranium and 10 to 30 dpm/L plutonium. Surface water samples collected in Pueblo

[183] Dodd AO, 1956
[184] *Ibid*
[185] *Ibid*
[186] Burke, J.E., 1954
[187] Abrahams, J.H., 1958

Canyon ranged from 0 to 5 µg/L uranium and 0-10 dpm/L plutonium. Gross beta measured in Acid canyon read 500 to 3,000 dpm/L (225-1,350 pCi/L) and gross beta measured in Pueblo Canyon read 0 to 1,000 dpm/L (0-450 pCi/L).[188]
Further complicating information on the early years of waste disposal at LANL, the reporting of spills and accidents was primarily confined to indoor spills and exposures. There is evidence that waste from the liquid waste treatment plant at TA-45 was not always treated properly prior to accidental release. For example, in 1958, pockets of sludge were found along the Acid Canyon floor and it is thought that they were discharged directly through a floor drain as opposed to being drained into a sump pump. No samples were collected for this incident[189].

Soil samples collected after a radioactive spill in Acid Canyon in November and December 1958, ranged from 19 to 3,968 cpm/g for gross alpha, 200-11,370 cpm/g for gross beta, and 0-3,480 cpm/g for gross gamma. Gross beta measurements in surface water samples collected from Acid Canyon on July 14, 1959 ranged from 1,200 to 1,500 dpm/L (540-675 pCi/L).[190]

In June 1965 soil samples collected from Acid Canyon had uranium concentrations at the surface of the canyon floor ranging from 0.5 to 5.0 µg/g, while plutonium was detected at the surface floor of the canyon at levels of 0.4 to 452 dpm/g (0.2-203 pCi/g)[191].

On August 31, 1965, numerous dry rocks within Acid Canyon produced gross alpha readings between 2,000 and 3,000 counts per minute and a reading of 0.2 mr/hr for gross beta. These rocks were found between TA-45 outfall No. 3 and 2,000 ft down the canyon. During the same day, every dry spot along Acid Canyon stream produced a count, and this condition continued until Acid Canyon merged with Pueblo Canyon. At approximately 200 yards beyond the merging of the canyons, gross alpha readings measured 500-800 counts per minute and gross beta levels were detected at 0.05 mrem/hr on rocks.[192]

The first annual environmental monitoring report was published by LANL in 1970. These annual reports contained monitoring data from direct radiation readings, thermoluminescent dosimeters, surface water, groundwater, particulate and gaseous air, soil and sediment, food sources, and biota[193]. A site-wide Environmental Impact Statement (EIS) was published in 1979.

Surface water samples taken in 1970 detected concentrations in the Acid-Pueblo weir of gross alpha; 2.7 pCi/L, gross beta; 105 to 346 pCi/L, plutonium; 0.03 pCi/L, strontium;

[188] Valentine, A.M. and J.C. Dummer, 1979
[189] LANL, 1958
[190] Buckland, C., 1965
[191] Barnett, C.H., 1965
[192] Buckland, C., 1965
[193] ChemRisk, et al., 2009

0.07 to 0.48 pCi/L, tritium; 3,000 pCi/L, and uranium; 0.7 µg/L. Samples in surface water throughout the Pueblo Canyon found gross beta levels at 10.3 to 24.8 pCi/L, plutonium-239 levels at 0.04 to 0.08 pCi/L, and uranium levels at 0.5-1.3 µg/L. The Hamilton Bend spring contained gross alpha readings of 1.3 to 1.8 pCi/L, gross beta readings of 4.4 to 7.7 pCi/L, plutonium-239 readings of 0.05 pCi/L, and uranium readings of 0.5 µg/L.[194]

In 1973 plutonium concentrations in filtered surface water in Acid-Pueblo Canyon had an average of 20 pCi/L. The suspended material had a concentration twice as high. In 1970 alluvium samples from the Acid-Pueblo Canyon had a concentration of 27 pCi/g with a concentration of 4.6 pCi/g one mile below Acid Canyon[195].

Samples were collected in the 1976 and 1977 and were reported in a 1982 report[196] prior to further remediation near the contaminated areas closest to the treatment plant. These data are shown in Table 14 below. These data demonstrate that high levels of radionuclides accumulated within the drainage areas in Acid Canyon, particularly those closest to the treatment plant outfalls.

Table 14. Average Radionuclide Concentrations (1976) in Soil in Acid Canyon Areas of Cleanup

Clean Up Location	Sr-90 (pCi/g)	Cs-137 (pCi/g)	Pu-239 (pCi/g)	Pu-238 (pCi/g)	Pu-241 (pCi/g)	Am-241 (pCi/g)	Ra-226 (pCi/g)	Total U (mg/g)	Th-232 (mg/g)
2	0.9	1.85	63.9	0.26	--	0.93	1.2	4.7	13
3	0.3	2.19	61.4	0.08	--	1.46	1.28	5.5	9.7
12	1	10.7	86,500	326	7,970	55	1.2	79	71
9	8.9	1.13	163,000	696	14,900	1,200	0	122	93
8	2.4	2.26	16,300	70.4	1,620	126	2	20	--
6	5.1	36	3,690	26.4	--	106	1.8	600	75
7	1.8	25.1	433	2.72	--	10	1.24	105	20
16	229	176	41.9	0.26	--	--	0.87	126	11.7
15	1.5	1.82	0.61	0	--	--	0.94	4.4	12.9
45-2	0.52	0.29	43.9	0.25	--	--	0.68	1.5	19.2
45-3	0.24	0.13	259	1.14	--	--	0.56	3.5	12.1
C-1	0.61	0.31	34	0.32	--	--	0.94	2.4	13.7
B-1	183	77.6	35.2	0.25	--	--	0.75	110	12.1
Mean	**33**	**26**	**20,805**	**86**	**8,163**	**214**	**1.04**	**91**	**30**
St Dev	**77**	**50**	**48,908**	**204**	**6,642**	**438**	**0.52**	**161**	**30**

Liquid wastes discharged to Acid-Pueblo Canyon were not limited to those of a radioactive nature. High explosives were reported to have been used in the 1940s. A total of 824,111 pounds of barium nitrate, Composition B, Composition B-1, Composition B-

[194] Kennedy, W.R., 1971
[195] Hanson, W.C., 1973
[196] US DOE, 1982

2, TNT, aluminum-TNT 60/40, Torpex, Saltex, Pentolite, Cyclotol 70/30, PTX, and RDX were reported to have been used at LANL between August 1944 and December 1945.[197] Metals including aluminum, beryllium, cadmium, lead, and uranium were released in test shots since the 1940s. It is reported that between 75,000 and 95,000 kilograms of uranium have been released via experimental shots from 1949 through 1970[198]. Un-depleted uranium was used until 1954, at which point the use of depleted uranium began. The reports do not say where the uranium was dispersed. According to a report from 1952, approximately 300 pounds of uranium and 200 pounds of barium were used each month[199]. Currently, contaminants including lead, mercury, selenium, silver, perchlorate, PCBs, and PAHs are of concern in Acid Canyon.

5.2 Los Alamos Canyon

Beginning in the early 1940s, radioactive liquid wastes from the DP Site at TA-21 were discharged into Los Alamos Canyon during early LANL operations. Los Alamos Canyon is a large canyon that runs south of LANL's original technical area (TA-1). Los Alamos Canyon also served as the location of the three types of nuclear reactors built at LANL between 1943 and 1992. In addition, runoff from Acid Canyon empties into Los Alamos Canyon through the intermediary canyon, Pueblo Canyon.

In 1945, LANL completed the construction of Building 12 at the DP West site in TA-21. With the completion of Building 12, DP West became the technical area in which the majority of LANL plutonium operations took place. In 1945, the majority of plutonium operations were transferred to Building 12 at DP West. Wastes from DP West were discharged into DP Canyons which ultimately drained into Los Alamos Canyon. Los Alamos Canyon drains into the Rio Grande River east of the LANL site.

Similar to Acid-Pueblo Canyon, very little information is available concerning radionuclide concentrations in air, soil, sediment, or water in Los Alamos Canyon. Limited data was collected beginning in 1945, although much of this data is not publicly available.

The primary suspected radioisotopes of interest discharged to Los Alamos Canyon include tritium, strontium, cesium, uranium, plutonium, and americium. Detailed analysis is not available on what was released into the disposal canyon. Unfortunately, the majority of monitoring prior to the 1970s was only for specific radionuclides (most often plutonium, polonium, and uranium), and did not include other toxic contaminants which were also of disposed of in the canyon.

Stream water samples collected in 1945 from the section of Los Alamos Creek that runs beside the Omega Site (TA-2, contains 3 nuclear reactors) contained 48 dpm/L of

[197] ChemRisk, et al., 2009
[198] *Ibid*
[199] English, S.G., 1952

polonium (21.6 pCi/L). Areas of the stream located southwest of TA-1 were found to contain 84 dpm/L (37.8 pCi/L) of plutonium and 2,300 dpm/L (1,036.0 pCi/L) of polonium. Stream measurements taken near the TA-1 laundry ditch in Los Alamos canyon ranged as high as 62,000-144,000 dpm/L (27,927.9-64,864.9 pCi/L) plutonium and 48,000-114,000 dpm/L (21,621.6-51,351.4 pCi/L) polonium. Measurements taken from Los Alamos Creek near the TA-1 laundry drain exit ran between 200,000 and 800,000 dpm (90,090.9-360,360.4 pCi) plutonium and 2,000 and 13,000 dpm (900.9-5,855.9 pCi) polonium per liter of water. Measurements taken in Los Alamos Canyon, further downstream from the laundry drain exit, were lower, ranging from 100-3,000 dpm/L (45-1,350 pCi/L) plutonium and 300 -20,000 dpm/L (135.0-9,009.0 pCi/L) polonium. At the time, the safe limit for plutonium and polonium in drinking water was not known, but 20 dpm per liter of water was considered to be unsafe. [200]

Samples collected in July and September 1946 from sanitary waste sewers emptying into Los Alamos Canyon ranged from 0-540 dpm/L (0.0-243.2 pCi/L) plutonium and 4-20,560 dpm/L (8.9-9,261.3 pCi/L) polonium. Samples collected from chemical waste sewers discharging into Pueblo Canyon ranged from 62-6,700 dpm/L (27.9-3,018.0 pCi/L) plutonium and 22-46,640 dpm/L (9.9-21,009.0 pCi/L) polonium.[201]

Surface water samples collected from Los Alamos Canyon in 1947 ranged from 4 to 6 dpm/L (1.8-2.7 pCi/L) of polonium and 13 to 106 dpm/L (5.85-47.7 pCi/L) of plutonium. Levels of plutonium in soil samples collected at Los Alamos Canyon were also found to range from 134 to 614 dpm/g (60.3-276.3 pCi/g).[202] However, an assay performed by JF Tribby in 1947 found water in stagnant pools in Pueblo Canyon to be 0.02 mCi/L (20,000 pCi/L)[203].

In the Spring of 1953, plutonium was measured in the soils of Los Alamos Canyon at levels of 1.5 to 2.8 dpm/g (0.68-1.26 pCi/g). Uranium was not measured at this time. In the Fall of 1953, plutonium in Los Alamos Canyon was measured at levels ranging from 0.7 to 2.6 dpm/g (0.32-1.17 pCi/g) and uranium was measured at levels ranging from 0.08 to 0.17 µg/g. In the Fall of 1954, plutonium in Los Alamos Canyon was measured at levels ranging from 0.8 to 2.2 dpm/g (0.36-0.99 pCi/g) and gross alpha radioactivity was measured at levels ranging from 2.8 to 17.2 dpm/g (1.26-7.74 pCi/g).[204]

The United States Geological Survey (USGS) collected water samples in two locations of Los Alamos Canyon in September of 1956. The samples collected ranged from 40-54 dpm/L (18-24.3 pCi/L) for gross alpha, 1.8-7.4 dpm/L (0.81-3.33 pCi/L) for plutonium, and 30 dpm/L (13.5 pCi/L) for uranium[205].

---

[200] Hempelmann, L.H., 1945
[201] *Ibid*
[202] Schnap, B. and J.F. Tribby, 1947
[203] Hemplemann, L.H., 1947
[204] Dodd, A.O., 1956
[205] LANL, 1956

Samples collected in October 1957 in Los Alamos Canyon at the Well #6 outfall measured 130 µg/L of uranium. Samples collected in December of the same year measured 23 µg/L of uranium. In February of 1958, samples collected at the same location in Los Alamos Canyon measured 17.5 µg/L of uranium after the well had been pumped for 5 minutes, and 22.0 µg/L of uranium after the well had been pumped for 9 minutes.[206]

There is little information available regarding radionuclide concentrations measured in Los Alamos Canyon in the 1960s and 1970s. As of yet, we have only been able to locate two sources of information pertaining to these concentrations.

Water samples collected by the USGS in December of 1960 detected plutonium levels ranging from 4 to 7 cpm/L and gross alpha radioactivity levels of 0-47 cpm/L[207]. Samples collected at Los Alamos Canyon measured 2.1-2.9 pCi/L for gross alpha, 3.2-107 pCi/L for gross beta, 0.03-0.11 pCi/L plutonium-238, 0.03-0.20 plutonium-239, 6-190 pCi/L tritium, and 0.7-1.6 pCi/L uranium[208].

In summary, it was estimated that 32.1 mCi of plutonium were discharged from TA-21 to Los Alamos Canyon between 1952 and 1974.[209]

5.3 Mortandad Canyon

LANL began disposing liquid wastes into Mortandad Canyon in 1955. At the time, liquid waste was treated at TA-35 (Ten Site) and TA-45 plants through a 5-cubic-ft cation exchange column before being released into the Mortandad Canyon. The waste at the TA-35 facility was retained in storage for up to 6 months in order to reduce radioactivity by decay. It was then pumped to the ion exchange columns and the effluent was discharged or recirculated. After each run, the radioactive material remaining in the columns was removed using nitric acid and contained as sludge.[210] LANL documents do not indicate where the sludge was disposed. The disposal of waste from TA-35 and TA-45 continued until 1963; however, the treatment methods slightly improved through the years. After 1957 TA-35 waste was treated through *two* cation exchange columns and after 1960 the waste underwent additional physical/chemical treatment before a series of cycles in the cation exchange column.[211]

The waste from TA-35 mainly contained Ba-140, La-140, Sr-89, Sr-90, Y-90, and traces of Ru-106 and Cs-137. The presence of these fission products indicate the processing of irradiated nuclear fuel at Los Alamos. In 1957, a total of 465,850 gallons were treated in

[206] Dodd, A.O., 1956
[207] Fowler, E.B., 1961
[208] Smith B. and A. Amonette, 2006
[209] Purymun, W.D. and T.E. Hakonson, 1974
[210] Shipman, T.L., 1958
[211] LASL, 1967

the ion exchange units, which represents about 32 curies of beta activity (including 2.5 curies of radiostrontium). Although the waste was treated, removing approximately 93% of radioactivity, Sr-90 concentrations in the effluent were still above NBS Handbook 52 tolerance levels for drinking water.[212] In addition, some releases that exceeded the contaminant limits occurred nonetheless. A report from 1952 discussed releases of up to 50,000 gallons of radioactive waste containing 1.5 mCi/L of activity from Ba-140, La-140, trace amounts of Sr-89, Sr-90.[213]

In 1963 a new waste treatment plant in Technical Area 50 replaced the two plants at TA-45 and TA-35. The new plant treated the waste through a 146-cubic-ft resin cation exchange column at 250 gallons per minute. [214] After 1963 essentially all liquid waste disposed into Mortandad Canyon came from the TA-50 plant.

Few records are available on exact radionuclide content of the disposed liquid until the mid-1970s (with the exception of plutonium). The plutonium inventory has been reconstructed for the time period 1963-1973 using the data for gross alpha activity. These input estimates are calculated in "Pu-239 equivalents" because the gross alpha activity was assumed to be Pu-239 (in reality, Pu-238 made up a significant percentage of plutonium). From 1964 until 1973 approximately 50 mCi of plutonium were released into the Mortandad Canyon (Table 15). [215]

Table 15. Plutonium Concentrations in Effluent Released into Mortandad Canyon

Year	mCi of Plutonium in Effluent
1963	1.5
1964	2.0
1965	3.5
1966	1.7
1967	4.2
1968	2.6
1969	6.8
1970	5.1
1971	6.0
1972	8.1
1973	8.8

The input of plutonium into Mortandad Canyon increased with the opening of the new Plutonium Research Facility in 1978. As of 2004, about 60,000 gallons per month of liquid effluent containing americium, plutonium, nitrate, perchlorate and fluoride at

[212] Shipman, T.L., 1958
[213] Aeby, J.W., 1952
[214] LASL, 1967
[215] Purtuman, W.D. and T.E. Hakonson, 1974

levels considered to be below regulatory concern were discharged into the upper reaches Mortandad Canyon.[216]

Unfortunately, cesium-137 amounts released into the canyon cannot be accurately estimated due to a lack of records. However, the earliest sampling of the radionuclide concentrations in the Canyon (in 1972), when the canyon was sampled at 10 monitoring stations, showed the presence of 319 mCi of cesium-137. Still, it is known that in 1973 293 mCi of cesium-137 were disposed into the Mortandad Canyon. Thus, if the same amount of cesium was released annually from 1963 until 1972, then the 319 mCi estimate accounts for only 10% of the actual inventory. The unaccounted cesium could have deposited into the deeper alluvium in the lower canyon at Mortandad or it could have been taken away by overflowed stream channels. The lower reaches of Mortandad Canyon are covered with alluvial deposits, in some places down to 82 ft (25 m). This alluvium is unsaturated and has the capacity to absorb large volumes of water.[217] In fact, about 90% of water movement in the canyon is in the subsurface. Tritium oxide tracer experiments have indicated that 85% of the water released from the liquid waste treatment plants is lost through evapo-transpiration. The total transit time from the outfall of the canyon to a monitoring well 11,122 ft (3,390 m) away is about one year. Sampling of monitoring wells throughout the canyon also reveals that plutonium and americium are found in groundwater 11,155 ft (3,400 m) from the outfall.[218]

In the 1970's LANL began sampling and testing ground and surface waters that are affected by disposed wastes. The following tables (Tables 16 and 17) summarize the radiochemical inventories in Mortandad Canyon in 1970.[219]

Table 16. Radionuclide Inventory in Surface Water

Radionuclide	Total pCi/L (unless other unit indicated)
Cs-137	1,420-32,330
Americium	0.09-17.6
Pu-238	0.34-50.7
Pu-239	0.19-18.48
Sr-90	67.4-1,260
Uranium	1.7 µg/L
Gross Alpha	2.3-74.2
Gross Beta	353-19,280

[216] CCNS, 2004
[217] Purtyman, W.D. and T.E. Hakonson, 1974
[218] Rail, C.D., 2000
[219] Kennedy, W.R., 1971

Table 17. Radionuclide Inventory in Wells

Radionuclide	Total pCi/L (unless other unit indicated)
Cs-137	1,420-32,330
Americium	0.2
Pu-238	0.06-1.29
Pu-239	0.03-0.68
Sr-90	54.4-191
Uranium	0.6-2.3 µg/L
Gross Alpha	1.8-6.3
Gross Beta	8.1-975

In 1979 samples of water and sediment were taken at 100 meter intervals downstream of the outfall of TA-50 waste treatment facility in Mortandad Canyon. The average tritium concentrations in sediment were 4.75 pCi/L and in water 4.72pCi/L.[220]

Tritium studies in 1998 indicated significantly higher concentration of tritium in surface waters that ranged from 60,000 to 3,500,000 pCi/L.[221] It should be noted that the Safe Drinking Water Standard for tritium is 20,000 pCi/L[222]; thus, the highest concentration of tritium is 175 times greater than the SDWA limit.

Several technical areas operated along the Mortandad Canyon. The activities at these sites provided different pathways, other than the liquid waste disposal, for radionuclide contamination.

TA-3: The Upper Mortandad Canyon Aggregate Area includes only a part of TA-3. Operations with radioactive contaminants took place at the CMR Building and at the Sigma Complex. The contamination from this site could have been released through drainages, outfalls, firing sites, liquid spills, leaks, or operational releases. [223] The waste contained mainly plutonium-238 and smaller amounts of cesium-137, plutonium-239, strontium-89, and strontium-90.[224]

In addition to the above radionuclides, hexavalent chromium was detected in the regional aquifer in 2004. It is hypothesized that the contaminant was released from the power plant at Technical Area 3, where it was used to prevent corrosion of the plant's cooling towers. Between 1956 and 1972 approximately 200,000–300,000 pounds of chromium

[220] Ferenbaugh, R.W. and E.S. Gladney, 1979
[221] Franke, B., undated
[222] NRC, 2006
[223] LANL, 2009b
[224] LANL, 2006b

were released. Daniel Katzman, program manager at LANL, testified that the wetland created by lab operations is probably contaminated and that even White Rock Canyon Springs might show some chromium contamination in the future.[225] Since 2006 a number of monitoring wells have been installed to check the contaminant levels and their spread. Sampling in 2004 showed chromium concentrations of 270ppb in the regional aquifer beneath Mortandad Canyon; by 2006, the concentrations had increased up to 405ppb.[226] The most recent sampling in 2008 detected concentrations in two regional aquifer wells in Mortandad Canyon that were 16 times above the NM groundwater standard (50ppb). In addition, a well in the intermediate zone of the Sandia Canyon contained concentrations of chromium that were 11.2 times above the standard. This confirms LANL's model for the path of chromium contaminants, which move from Sandia Canyon downward and southward into the regional aquifer below Mortandad Canyon. [227]

TA-35: Solid Waste Management Unit 35-016 is an active outfall that historically handled reverse osmosis discharge and now handles cooling tower blowdown.[228] Unknown quantities of tritium were disposed from 1953 to 1974 and the drainline is still suspected to contain tritium. It is estimated that from 1951 until 1963 the total activity discharged was 20 curies gross beta activity (Ba-140, La-140, Sr-89, Sr-90, and trace amounts of Cs-137, Ru-106, plutonium, technetium-99, and uranium) and 1.4 Curies of Sr-89 and Sr-90.[229]

TA-42: In 1951, an incinerator was built for volume reduction of low-level plutonium-contaminated wastes. It was never fully operational and was shut down in 1952, but some liquid waste and ash was deposited into Mortandad Canyon during that year. When the incinerator was decommissioned in 1952, its debris was deposited to Area G. No documented accidental releases have occurred at the site, but radionuclides were likely released through airborne emissions.

TA-48: The Radiochemistry Site was established in 1957 to test bombs, but eventually was used to for other research related to geochemistry and radiochemistry. Originally, outfalls from cooling water were released into the canyon. Other releases may have occurred from ventilation stacks, a septic system, drain lines and outfalls, industrial waste lines, container storage areas, sumps and tanks, a disposal shaft, and soil contamination.[230] Sampling was performed at the site in 1993, 1995, and/or1997 and showed the presence of the following radionuclides: americium-241, cobalt-60, cesium-

[225] LANL, 2006c
[226] LANL, 2006d
[227] LANL, 2008b
[228] LANL, 2009b
[229] LANL, 2006b
[230] LANL, 2009b

137, sodium-22, plutonium isotopes, ruthinium-106, and strontium-90 and uranium isotopes.[231]

TA-50: This site contains a waste treatment plant, incinerator complex (built in 1975), volume-reduction facility (built in 1983), and MDA C (operated 1948-1974). As already discussed, the liquid waste from the treatment plant has always been released into Mortandad Canyon. Currently, most of the liquid wastes from the incinerator and the volume-reduction facilities are transferred by drainlines to the liquid waste treatment plant, where they are treated as radioactive industrial waste. In addition, liquid TRU wastes are transferred to the special TRU-treatment facilities. The three facilities monitor and filter particulate contaminants in hoods and stacks. Contamination may have been released to surface soil during the peak use of MDA C and after fires, which occasionally occurred on site.

The discharge record indicates that from 1963 until 2004 a minimum of 0.156 Ci of americium-241, more than 2 Ci of cesium-137, more than 0.10 Ci of plutonium-238, 0.2 Ci of plutonium-239,240, 1.5 Ci of strontium-89,90, and 823 Ci of tritium were discharged. Most of these radionuclides were released between 1972 and 1983, but the records are incomplete before 1973. Cs-137, Sr-90, and tritium have been largely lost due to decay, but other radionuclides remain in the watershed.[232]

Soil samples were taken at the outfalls of the former drain lines and the following radionuclides were identified: americium-241, cobalt-60, cesium-137, potassium-40, plutonium-238, plutonium-239,240, Ra-226, strontium-90, and thorium-232. [233]

TA-55: The Plutonium Processing Facility was built in the 1970s and produces liquid waste and air particulate waste. The liquid wastes are primarily from the plutonium scrap recovery/purification operations and from the sanitary waste systems. However, some radioactive liquid wastes are also produced in glove box cooling water. These liquid wastes are piped to TA-50 RLWTF for processing. The exhaust waste from glove boxes and facility rooms is filtered through banks of HEPA filters and continuously monitored before being discharged to the atmosphere.

In addition to the routine disposal of wastes into Mortandad Canyon, accidents have occurred throughout the years. It is likely that many of the events will remain unknown, but the records show that at least the following release accidents have occurred. The list below contains accidents that occurred from 1952 onwards; clearly accidents would have occurred in the early days, and not just accidents involving contaminated water, but also contaminants to the air:

---

[231] LANL, 2006b
[232] *Ibid*
[233] *Ibid*

- 1952: 2,000-3,000 gallons of "hot water" from waste storage tanks located at the TA-35 Liquid Waste Treatment Plant were accidentally released into the canyon. Radiation dose readings ranged from 0.5 mR/hr at a distance of 3 miles to 300 mR/hr at the TA-35 perimeter fence.[234]
- 1956: a line broke on a full tank of waste releasing 1 Curie of Strontium.
- 1956: a pipe carrying water near Ten Site developed a leak released 35,000 gallons of contaminated water into Mortandad Canyon.[235]
- 1974: Two accidental releases from a radioactive liquid-waste line (near the CMR building at TA-3).
- 1974: Two unplanned releases of untreated waste occurred because of overflow of a sump in TA-50. When the drain lines were later excavated in 1982 radionuclides were encountered in the surrounding soil: cesium-137, plutonium-239, ruthenium-106, strontium-89, strontium-90, and yitrium-90.[236]
- Before 1975: Six unplanned releases of cooling water from the new Sigma Building; but no information is available regarding possible contaminants.
- 1981: liquid from an industrial waste line serving TA-48 was inadvertently pumped into Mortandad Canyon.
- 1982: A section of piping carrying fission products from hot cells at TA-48 was found leaking. Only a limited area on TA-48 site was affected and the contaminated soil was removed down to bedrock up to the end of Mortandad Canyon, and replaced with clean soil.[237]

6.0 LANL Airborne Waste Releases

So far as we have been able to determine, there is little available documentation regarding the airborne releases of radionuclides throughout the history of LANL operations. There has been no comprehensive compilation or accounting of historical airborne radionuclide releases prepared by LANL, and the most complete compilation of airborne radionuclide effluent data was assembled by LANL in the 1970s during the preparation of a 1979 Final Environmental Impact Statement.

In an effort to determine the most hazardous airborne releases of radionuclides throughout different periods of the history of LANL operations, the LAHDRA team developed a system of priority indices for each radionuclide known to be released by LANL. Priority Indices (PI) were computed by calculating the air volume required to dilute the annual activity released to be equal to the maximum effluent concentration (MEC) regulations listed in 10CFR20 Appendix B Table 9.2. Airborne effluent releases of plutonium for years prior to 1979 were therefore prioritized based on the limited amount of documented values compiled for the 1979 FEIS.

---

[234] Aeby, J.W., 1952
[235] ChemRisk, et al., 2009
[236] LANL, 2006b
[237] ChemRisk, et al., 2009

Based on available historical information, the LAHDRA team determined that between 1944 and 1966, plutonium was the radionuclide with the highest priority index, and thus the radionuclide released in the greatest quantities during this time period. Plutonium was released into the atmosphere from several different locations within LANL. These locations include: D Building stacks at TA-1, DP West Building 12 stacks at TA-21, DP West and East Building Vents at TA-21, the Chemistry and Metallurgical Research (CMR) Building exhausts (beginning in 1953) at TA-3, accidents and incidents, burial ground fires, and waste disposal sites. Of these locations, there are no documented airborne release data from the stacks at D Building for the entire time it was in operation (1944-1953) or from the DP Site between 1945 and 1947. During these times, LANL was the United State's sole manufacturer of plutonium cores for atomic weapons.

In its 1979 FEIS, LANL indicated that between 1943 and 1972, approximately 1.2 curies of plutonium had been released into the atmosphere from LANL site activities. As previously discussed, this estimate does not include any plutonium releases from D Building throughout its entirety of operations or DP West prior to 1948. Furthermore, a 1975 document attributed the 1.2 curies released between 1943 and 1972 solely to the stacks of DP West Building 12, not all of LANL activities[238].

Plutonium releases from DP West Building 12 stacks were documented beginning in 1948. In 1955, a team of LANL industrial hygienists led by E.C. Hyatt conducted a study in which improved, isokinetic stack sampling systems were operated next to the original sampling systems installed by LANL. After six months of data collection, the results of the original and improved sampling systems were compared and correction factors were derived for all documented released prior to 1956. All air samples collected with the improved stack sampling systems after 1956 were not corrected. After applying the correction factors derived from this study, it was determined that approximately 227 g, or 14 curies of plutonium, were released from DP West Building 12 stacks between 1948 and 1955.

In addition, the LAHDRA team has upwardly adjusted these values roughly by a factor of 20. These values have been adjusted by a sample line loss correction factor of 5 for the years 1948-1958 and a correction factor of 2 for the years 1959-1975. The correction factor was reduced in 1959 because LANL added a single stage of HEPA filters to the exhaust system at DP West Building 12 in 1959[239]. A filter burial correction factor of 2.33 was also applied to the release values, based on the findings of recent LANL staff[240]. With the application of the line loss and filter burial correction factors, the total amount of plutonium released just from DP West Building 12 stacks between 1948 and 1955 was

[238] Maraman, W.J., et al., 1975
[239] *Ibid*
[240] Fuehne, D.P., 2008

170 curies. This is more than 100 times greater than the original 1.2 curies reported in the 1979 FEIS for all LANL operations between 1943 and 1972.

If plutonium releases from all LANL operations were compiled, the total amount of plutonium released by all of LANL for all years of operation would most definitely surpass 170 curies. Reconstructed releases from Rocky Flats, Hanford, and Savannah River, additional DOE plants that processed plutonium, total to approximately 39 curies for all three facilities combined[241]. If the airborne plutonium releases from DP West Building 12 stacks between 1948 and 1955 were as high as the 1956 reports by the Lab's industrial hygiene staff indicate, plutonium releases from LANL easily exceeds the independently reconstructed airborne plutonium release totals from these three DOE production plants, even without the other sources and other years of LANL operations included.

Annual plutonium releases from DP West Building 12 stacks (adjusted by the LAHDRA team) for a period between 1948 and 1960 can be seen below in Table 18.

Table 18. Adjusted Annual Plutonium Releases from DP West Building 12 Stacks between 1948 and 1960

Year	Annual Releases (g)	Annual Releases (Ci)
1948	17.91	13.15
1949	86.60	63.56
1950	61.74	45.31
1951	10.43	7.66
1952	16.71	12.26
1953	8.41	6.17
1954	5.01	3.68
1955	19.82	14.55
1956	1.23	0.90
1957	1.19	0.87
1958	1.32	0.97
1959	2.97	2.18
1960	0.60	0.44

In order to estimate airborne plutonium releases from D Building and DP West between 1945 and 1947, the LAHDRA team used several different approaches to determine the most probable releases of plutonium from these sites. Their approaches included:

- Evaluation of historical measurements of plutonium in soil samples collected around Los Alamos to "back calculate" how much plutonium would have been released to match current environmental levels of plutonium remaining in soils.

[241] ChemRisk, et al., 2009

- Examination of a rarely available dataset of measurements of plutonium in human tissue samples collected at autopsy from 236 people who lived in Los Alamos.
- Estimation of releases of plutonium from the chemical processing performed in D Building, as release fractions derived from relevant research have been assigned to each identified release mechanism of plutonium processing.
- Analysis of measurements of airborne radioactivity inside D Building to estimate, with knowledge of the ventilation system within the building, the quantities that could have been released to the environment.

According to historical documents, approximately 85 rooftop stacks atop D Building (Figure 37) discharged airborne radionuclide effluent into the atmosphere. D Building emissions were not filtered or monitored before discharge into the environment. Many of these exhaust vents were directly attached to laboratory hoods and other confinement devices used to conduct plutonium experiments.[242]

Figure 37. Rooftop Vents on top of D Building. Approximately 85 of these vents released unfiltered and unmonitored exhausts into the air until 1953 (photograph taken in 1940s)[243]

The equipment and plutonium-processing procedures used by scientists and engineers in D Building are considered extremely crude by modern-day standards, and plutonium operations in D Building were "conducted with greater laxity than has ever been tolerated since." [244] A former LANL plutonium worker wrote that "D Building was known to be hotter than a firecracker."[245]

[242] *Ibid*
[243] *Ibid*
[244] Coffinberry, 1961
[245] *Ibid*

It is important to note that the LAHDRA team focused on airborne plutonium releases, but based on water measurements, it is likely that fission products were also present in the air

Several other point sources within LANL were found to have released plutonium and additional radionuclides into the atmosphere. Documents show that the discharge of gaseous fission products from the water boiler reactors at TA-2 were most unsatisfactory and posed a serious health and environmental hazard[246]. A flexible tubing line was run up the wall of Los Alamos Canyon and tied to a tree atop South Mesa to serve as the release point for gases released from the reactors. Gases released from this tubing were essentially at the same elevation as the trailer park residents who resided just next to the canyon. Dose rates greater than 50 r/hr were frequently measured near the water boiler reactors' discharge point[247].

In 1947, it was found that the water boiler reactor's off-gas line had been shattered due to high winds at about 100 ft prior to the discharge point. The shattered line was located in the top of a pine tree over the mesa just south of Los Alamos Canyon.

Before 1968, a 150 foot tall stack on the mesa just south of the Los Alamos Canyon (the same mesa that contained the discharge point for the Water Boiler reactor's off-gas line) was used to ventilate the OWR thermal column region and experiment. Argon-41 was discharged from this stack at a rate of 880 cubic ft per minute, and approximately 600 curies of Ar-41 were discharged from the stack per year[248]. A charcoal filter was not added to the vent line until 1968.

Historical LANL documents indicate that LANL did perform some air monitoring in the 1940s and 1950s. During this time, LANL was most concerned with monitoring radioactive global fallout from the RaLa firing area in Bayo Canyon (TA-10). After RaLa test shots were fired, LANL would often close the road that spanned from TA-1 to the East Gate to allow time for the removal and decay of radioactive contamination to levels deemed acceptable for public access on the road, as the plumes from RaLa test shots often reached the Los Alamos town site. A plume from a 1949 RaLa test shot was found to spread contamination as far as 10 miles east of the test site[249].

In addition to documented releases of airborne radionuclides, several accidents and incidents that occurred at LANL may have contributed to releases of radionuclides into the air. In 1955 it was reported that alpha activity leaked from DP West Stacks due to poorly installed CWS-6 filters that allowed contaminated air to leak around the edges of the filters[250]. Fires at the DP West Site were reported in numerous LANL reports, and improper and unsatisfactory media and methods for sampling airborne waste streams for

[246] LAMD-155-1, 1947
[247] ChemRisk, et al., 2009
[248] LANL, 1973
[249] LASL, 1949
[250] Shipman, T.L., 1955

radioactive iodine were reported at the CMR Building, the Omega Site that housed all three LANL nuclear reactors, and the DP West Site that housed the majority of LANL plutonium processing operations. Stacks of airborne effluent located at TA-35, where the RaLa Program was conducted, were not properly monitored because LANL's monitoring instrumentation could not gauge the excessive radioactivity released at this site[251]. In January 1953, LANL scientists discovered that a polonium-beryllium source had ruptured and contamination had spread to nearby Los Alamos residential areas[252]. Dust and demolition from D Building and other facilities that processed plutonium at TA-1 was burned at the contamination dump site[253].

Based on the numerous accidents and incidents that occurred at LANL and the unreliability of much of their filtering and monitoring equipment, it is very likely that the radionuclides release from LANL via airborne effluent is much greater than has been estimated.

7.0 Conclusion

Based on a review of available primary LANL documents and secondary research that has been conducted on LANL waste disposal and contaminant releases, we conclude the following:

Throughout the history of its operations, LANL produced a great deal of radioactive and other hazardous chemical wastes in both solid and liquid forms. It is estimated that millions of cubic feet of solid and liquid waste have been disposed of at LANL Material Disposal Areas, and more than 11.5 million gallons of radioactively contaminated liquid waste was generated by LANL in 1957 alone[254]. Initially, LANL did not follow strict precautions while disposing of this waste; early radioactive solid waste was contained in cardboard boxes sealed with masking tape, and until 1951 all radioactive and other hazardous liquid wastes discharged by LANL were released without treatment. It was not until 1951 that LANL began treating its liquid waste before disposal.

There are several unlined solid waste disposal pits, shafts, and trenches located throughout the LANL site. These unlined waste disposal units are particularly located in Material Disposal Areas B and U in Technical Area 21, Material Disposal Area K in Technical Area 33, Material Disposal Area C in Technical Area 50, and Material Disposal Area L in Technical Area 54. Waste disposal units accepted both radioactive and non-radioactive hazardous wastes, and, reportedly, there is approximately 423,776 ft^3 (12,000 m^3) of waste containing plutonium in these unlined units[255]. The New Mexico Environmental Department's Hazardous and Radioactive Waste Bureau ranks all five of

[251] ChemRisk, et al., 2009
[252] Shipman, T.L., 1953
[253] ChemRisk, et al., 2009
[254] *Ibid*
[255] Lehrman, L., 2007

the aforementioned Material Disposal Areas as areas with high probabilities of contaminant movement and moderate to high potentials for contaminant releases to groundwater.

Accurate records of the types and quantities of wastes LANL disposed of prior to 1970 do not exist. Thus, complete inventories of wastes at various locations throughout the LANL site may never be known. It is important that the LAHDRA Project Team continues to identify and locate all primary LANL documents pertaining to the types and quantities of LANL disposed wastes, as much information still remains missing. Based on current available information, Material Disposal Areas C, G, and H contain the greatest volumes of radioactive and other hazardous waste forms with respective inventories of up to 49,483 curies, 1,383,700 curies, and 391 curies.

In addition to scheduled and/or recorded waste disposal events, there were several incidents and accidents that occurred throughout the history of LANL operations that may have contributed a great deal of untreated radioactive or other hazardous chemical waste to LANL's waste disposal units or its neighboring canyons. For example, just one incident that occurred in 1952 released 2,000 to 3,000 gallons of "hot water" from waste storage tanks located at the liquid waste treatment plant in TA-35 to Mortandad Canyon. Significant concentrations of radionuclides were measured several miles downstream.[256] There may be several hundred incidents and accidents that were never properly attended to, or even reported, by LANL.

Plutonium contamination originating from the LANL site has been detected in Santa Fe drinking water since the early 1990s. However, all contamination detections thus far were below federal and state drinking water quality limits.[257] Small quantities of plutonium in Santa Fe drinking water may be an indicator of an underground contamination plume migrating from the LANL site towards Santa Fe drinking water sources. Thus, it is imperative to carry out a thorough and effective review of all LANL waste sites.

The LAHDRA team has focused on plutonium in the air and has neglected fission products in the air, such as cesium, strontium and iodine. In addition, accidents that released radioactive materials to the air, particularly in the early years, prior to 1952, are notably missing.

[256] ChemRisk, et al., 2009
[257] Lehrman, L., 2007

8.0 Recommendations to the ChemRisk Inc. LAHDRA Project Team

We recommend the following actions to be carried out by the ChemRisk Incorporated LAHDRA Project Team during their peer-review of LANL-origin contaminants that could possibly reach the Rio Grande River:

- Continue to identify and locate all existing LANL log books, notebooks, memorandums, and any other documentation useful in identifying original inventories of LANL wastes disposed of both on- and off-site.

- Thoroughly review all existing LANL primary documents, as well as all reports that resulted in thorough investigations of the LANL Technical Areas, Material Disposal Areas, and canyons that surround the LANL site. Such documents may include, but are not limited to, Corrective Measure Study Reports, Health Division Reports, Environmental Impact Statements, Environmental Surveillance Reports, and Technical Area Remediation Work Plans.

- Identify the hydrological and geological properties of the formations that underlie all identified waste disposal areas within the LANL site and its surrounding area.

- Identify all original and current contaminants disposed of at the LANL site and its surrounding off-site areas. A comparison should be made between original and current waste inventories to determine if contaminants have become mobilized in surface subsurface waters. If original data are not available, estimates should be made based on all available literature and knowledge of specific LANL practices and operations.

- Prioritize all identified waste disposal sites based on their potential risks of contaminant mobilization and migration towards the Rio Grande River. In addition, waste disposal sites should be prioritized in accordance with the types and quantities of wastes identified at the site, as certain contaminants pose substantially greater risks to human health if ingested through drinking water.

- Use 3-Dimensional GIS modeling software to spatially and temporally model all potential underground contaminant plumes and migration pathways that may reach the County of Santa Fe's groundwater and Rio Grande drinking water sources.

- Identify any and all disposal areas that may pose a threat to the drinking water of current and future residents of the county of Santa Fe. Recommend remedial

actions that must be taken in order to protect the environmental integrity of the county of Santa Fe.

- Design an environmental monitoring schedule for each waste disposal area in order to monitor potential contaminant mobilization and migration.

9.0 References

Aeby, J.W., 1952. *Monitoring in Mortandad Canyon,* Memorandum to D.D. Meyer, 28 October 1952. LAHDRA Repos. No. 0277.

Abrahams, J.H., Jr., 1958. *Quarterly Progress Report on Work at Los Alamos, New Mexico*, United States Geological Survey, January-March, 1958. LAHDRA Repos. No. 0768.

Abrahams, J.H. Jr., 1963. *Geologic and Hydrologic Environment of Radioactive Waste-Disposal Sites at Los Alamos, New Mexico,* United States Geological Survey, 1963.

Barnett, C.R., 1965. *Alpha Contamination in Pueblo Canyon*, Inter-Office Memorandum to W.R. Kennedy, Group Leader, H-6, 16 August, 1965. LAHDRA Repos. No. 1965.

Buckland, C., 1965. *Radioactive Contamination Survey of Acid Canyon (Upper Southwest Finger of Pueblo Canyon)*, Memorandum to D. Meyer, 1 September 1965. LAHDRA Repos. No. 0233.

Burke, J.E., 1945. *Scheduled Operations at DP Site*, May 9, 1945. LAHDRA Repos. No. 0542.

ChemRisk, et al., 2009. *Draft Final Report of the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project*, Prepared for the Centers of Disease Control and Prevention (CDC), June 2009.

Christensen, D.V., 1997. *Los Alamos National Laboratory Transuranic Database Analysis*, Los Alamos National Laboratory LA-UR-96-4051, 2 March 1997.

Coffin, D.O., 1971. *Environmental Impact of HP-86 Operations*, Memorandum to J.E. Dougherty, Los Alamos National Laboratory W-3-71-4619, 2 June 1971. LAHDRA Repos. No. 6860.

Coffinberry, A.S., 1961. *Later Plutonium Metallurgical Research at Los Alamos*. The Metal Plutonium, 1961.

Concerned Citizens for Nuclear Safety (CCNS), 2004. *The Rio Grande Watershed Initiative*, August, 2004. Accessed November 11, 2009, Web URL: http://www.nuclearactive.org/docs/RGWIindex.html

Dodd, A.O., 1956. *A Survey of Some Los Alamos County Canyons for Radioactive Contamination*, Spring 1953 to Spring 1955, LAMS-2038, April 1956. LAHDRA Repos. No. 2248.

English, S.G., 1952. *Project Crave: Survey of the U.S. Atomic Energy Commission Operations and Facilities*, Brookhaven National Laboratory, Brookhaven, New York, BNL-157, 1952. LAHDRA Repos. No. 0611.

Ferenbaugh, R.W. and E.S. Gladney, 1979. *Mortandad Canyon: Elemental Concentrations in Vegetation, Streambank Soils, and Stream Sediments – 1979.* LA-13325-MS, June,1979.

Fowler, E.B., 1961. *USGS Water Samples Received by H-7 For Analysis*, 1961. LAHDRA Repos. No. 0769.

Franke, Bernd, undated. *Tritium in Water and Bioaccumulation of Cesium and Strontium*, Institut für Energie und Unweltforschung, Heidelberg, Germany, Undated.

Fuehne, D.P., 2008. *Correction Factors for Sample Line Loss Depth-of-Burial,* Personal Communication with David P. Fuehne of LANL Meteorology & Air Quality Group, Electronic Correspondence Summarized by LANL Staff, 3 November 2008. LAHDRA Repos. No. 7875.

Galloway, R.B., 2001. *RCRA Waste Constituents*, e-mail correspondence from R.B. Galloway to B. Meyers, Albuquerque, New Mexico, 3 October 2001.

Garcia, K.L.M., et al., 2004. Garcia, K.L.M., McGehee, E.D., Ronquillo J., and J. Isaacson, *Upgrades to TA-33-87, -88, and -8,* Los Alamos National Laboratory, LA-UR-04-6061, 2004. LAHDRA Repos. No. 7846.

Graf, W.L., 1993. *Summary of Wastes and Effluents: Omega Site, TA-2*, 1993. LAHDRA Repos. No. 2325.

Hanson, W.C., 1973. *Plutonium-239 Concentrations in Acid-Pueblo Canyon*, Memorandum to G. Voelz, Health Division Leader, H8-73-207. LAHDRA Repos. No. 0577.

Hempelmann, L.H., 1945. *Report on the Contamination of Creek Water (continued)*, Inter-Office Memorandum to W.H. Hinch, 15 October 1945. LAHDRA Repos. No. 0132.

Hempelmann, L.H., 1946. *Contaminated Areas in Pueblo Canyon and Los Alamos Canyon below Omega*, Inter-Office Memorandum to J.F. Tribby, 30 September 1946. LAHDRA Repos. No. 0539.

Hempelmann, L.H., 1947. *Contaminated Streams*, Memorandum to Dr. ER Jette, 1947. LAHDRA Repos. No. 0540.

Hollis, D., et al., 1997. *Performance Assessment and Composite Analysis for Los Alamos National Laboratory Material Disposal Area G*, Los Alamos National Laboratory LA-UR-97-85, Report 54G-013,R.2, 1997. LAHDRA Repos. No. 7720.

Kennedy, W.R., 1971. *Radiochemical and Chemical Analysis of Water Samples from Disposal Canyons*, Letter to William E. Hale, District Chief of United States Geological Survey, 11 May 1971. LAHDRA Repos. No. 0764.

LAMD-155-I, 1947. *Manhattan District History: Supplement to Book VIII LA Project Y*, October 15, 1947. LAHDRA Repos. No. 4816.

Lehrman, L., 2007. *LANL Plutonium Reported in Santa Fe Drinking Water*, Article presented on rense.com, 11 July, 2007. Accessed on November 10, 2009, Website URL: http://rense.com/general77/santa.htm

Los Alamos National Laboratory (LANL), 1956. Correspondence between CD Conever, USGS and CW Christenson, H-7 Group Leader. LAHDRA Repos. No. 6908

LANL, 1958. *H-Division Progress Report*, 11/20/58-12/20/58.

LANL, 1966. *Results of Pu and U Analyses at TA-45*. LAHDRA Repos. No. 0782.

LANL, 1967. *History of Management of Liquid Radioactive Wastes at LASL*. LAHDRA Repos. No. 112.

LANL, 1973. *Summary of Wastes and Effluents: Omega Site, TA-2*. LAHDRA Repos. No. 645.

LANL, 1991. *Environmental Restoration, TA-21 Operable Unit Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Workplan*, LA-UR-91-962, May 1991.

LANL, 1992a. Ferenbaugh RW, Buhl TE, Stoker AK, and WR Hansen, *Environmental Analysis of Acid/Middle Pueblo Canyon*, Los Alamos, New Mexico, 1992. LAHDRA Repos. No. 0377.

LANL, 1992b. *RFI Work Plan for Operable Unit 1144*, LA-UR-92-900, Los Alamos, New Mexico, May 1992.

LANL, 1993. *RFI Work Plan for Operable Unit 1132 (TA-39)*, LA-UR-93-768, Los Alamos, New Mexico, June 1993.

LANL, 1996. *Environmental Surveillance at Los Alamos during 1994,* Los Alamos National Laboratory LA-13047-ENV, 1996.

LANL, 2001a. *Information Sheet: Material Disposal Area H,* Los Alamos National Laboratory, LA-LP-01-131, ER2001-0470, 2001.

LANL, 2001b. Information *Sheet: Material Disposal Area P*, Los Alamos National Laboratory, LA-UR-01-6778, ER2001-1002, 2001.

LANL, 2001c. *MDA-P: Not the First but the Biggest,* Bass, J., Los Alamos News Letter, 2(17): p. 5, 23 August 2001.

LANL, 2003. *Corrective Measures Study Report for Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54,* Los Alamos National Laboratory, LA-UR-03-3354, ER2003-0121, May 2003.

LANL, 2004a. *Investigation Work Plan for Material Disposal Area T at Technical Area 21, Solid Waste Management Unit 21-016(a)-99,* LA-UR-04-0559, Los Alamos, New Mexico, February 2004.

LANL, 2004b, *Investigation Work Plan for Material Disposal Area B at Technical Area 21, Solid Waste Management Unit 21-015,* LA-UR-04-3713, Los Alamos, New Mexico, June 2004.

LANL, 2004c. *Documented Safety Analysis for Surveillance and Maintenance of Nuclear Environmental Sites at Los Alamos National Laboratory.* LA-UR-04-7505, ER2004-0606, November 2004.

LANL, 2004d. *Historical Investigation Report for Material Disposal Area U, Solid Waste Management Unit 21-017(a)-99,* at Technical Area 21, LA-UR-04-7267, Los Alamos, New Mexico, November 2004.

LANL, 2005. *PRS Data Base for LANL*, Unpublished, Word file, 24 January 2005.

LANL, 2006a. Photographs Copied from Los Alamos National Laboratory Archives. LAHDRA Repos. No. 5951, 2006.

LANL, 2006b. *Mortandad Canyon Investigation Report.* LA-UR-06-6752, October 2006.

LANL, 2006c. *Minutes of the Los Alamos National Laboratory Oversight Committee and the Radioactive and Hazardous Materials Committee.* August 9, 2006. Conference Room Los Alamos Research Park.

LANL, 2006d. *Interim Measures Work Plan for Chromium Contamination in Groundwater,* LA-UR-06-1961. ER2006-0214. March 2006.

LANL, 2007. *Periodic Monitoring Report for Vapor-Sampling Activities at Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54, Fiscal Year 2007,* Los Alamos National Laboratory LA-UR-07-7803, EP2007-0716, November 2007.

LANL, 2008a. *Corrective Measures Evaluation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54,* Los Alamos National Laboratory, LA-UR-08-0050, EP2007-0356. January 2008.

LANL, 2008b. *Environmental Surveillance at Los Alamos in 2008: Executive Summary*. <http://www.lanl.gov/environment/all/docs/reports/2008ESR_Summary.pdf>.

LANL, 2009a. *Material Disposal Areas at LANL: Material Disposal Area (MDA) G,* 2009. Accessed on November 4, 2009, Website URL: http://www.lanl.gov/environment/cleanup/mda.shtml

LANL, 2009b. *Investigation Report for Upper Mortandad Canyon Aggregate Area.* LA-UR-09-6081, September, 2009.

LANL, 2009c. *Phase II Investigation Report for Material Disposal Area C, Solid Waste Management Unit 50-009, at Technical Area 50,* May 2009.

Los Alamos Scientific Laboratory (LASL), 1949. *H Division Monthly Progress Report,* LAMS 889, HSPT-REL-94-260, 20 March 1949. LAHDRA Repos. No. 2263

LASL, 1953. *Radiation Survey of Old Hot Point, TA-33,* Internal Memo from Charles D. Blackwell, Alt. Leader General Monitoring Section H-1 to Henry Petrzikla, W-3, 28 October 1953.

LASL, 1967. *History of Management of Liquid Radioactive Wastes at LASL.* LAHDRA Repos. No. 112, 1967.

Los Alamos Study Group, 2004. *Technical Areas at Los Alamos National Laboratory,* 2004. Accessed on October, 30, 2009. Website URL: http://www.lasg.org/maps/pages/contents/TAmainmap.htm

Los Alamos Study Group, 2006a. *Material Disposal Area A,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab1.htm

Los Alamos Study Group, 2006b. *Material Disposal Area B,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab2.htm

Los Alamos Study Group, 2006c. *Material Disposal Area C,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab3.htm

Los Alamos Study Group, 2006d. *Material Disposal Area D,* 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab4.htm

Los Alamos Study Group, 2006e. *Material Disposal Area E,* 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab5.htm

Los Alamos Study Group, 2006f. *Material Disposal Area F*, 2006 Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab6.htm

Los Alamos Study Group, 2006g. *Material Disposal Area G*, 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab7.htm#GN_1_

Los Alamos Study Group, 2006h. *Material Disposal Area H*, 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab8.htm

Los Alamos Study Group, 2006i. *Material Disposal Area J*, 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab9.htm

Los Alamos Study Group, 2006j. *Material Disposal Area K*, 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab10.htm

Los Alamos Study Group, 2006k. *Material Disposal Area L*, 2006, Accessed on November 4, 2009, Website URL: http://www.lasg.org/waste/mdab11.htm

Los Alamos Study Group, 2006l. *Material Disposal Area M,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab12.htm

Los Alamos Study Group, 2006m. *Material Disposal Area N,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab13.htm

Los Alamos Study Group, 2006n. *Material Disposal Area P,* 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab14.htm

Los Alamos Study Group, 2006o. *Material Disposal Area Q*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab15.htm

Los Alamos Study Group, 2006p. *Material Disposal Area R*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab16.htm

Los Alamos Study Group, 2006q. *Material Disposal Area S*, 2006. Accessed on

November 3, 2009, Website URL: http://www.lasg.org/waste/mdab17.htm

Los Alamos Study Group, 2006r. *Material Disposal Area T*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab18.htm

Los Alamos Study Group, 2006s. *Material Disposal Area U*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab19.htm

Los Alamos Study Group, 2006t. *Material Disposal Area V*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab20.htm

Los Alamos Study Group, 2006u. *Material Disposal Area Y*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab21.htm

Los Alamos Study Group, 2009v. *Material Disposal Area Z*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab22.htm

Los Alamos Study Group, 2006w. *Material Disposal Area AA*, 2006, Accessed on November 10, 2009, Website URL: http://www.lasg.org/waste/mdab23.htm

Los Alamos Study Group, 2009x. *Material Disposal Area AB*, 2006. Accessed on November 3, 2009, Website URL: http://www.lasg.org/waste/mdab24.htm

Maraman, W.J., et al., 1975. Maraman WJ, McNeese WD, and RG Stafford, *Plutonium – Health Implications for Man: Confinement Facilities for Handling Plutonium*, Health Physics, 29, pp: 469-480, 1975.

Mayfield, D. and W.R. Hansen, 1983. *Surface Reconnaissance Through 1980 for Radioactivity at Radioactive Waste Disposal Area G at the Los Alamos National Laboratory*, Los Alamos National Laboratory LA-9656-MS, March 1983.

National Nuclear Security Administration (NNSA), 2006. *Draft Site-Wide EIS for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico*, United States Department of Energy, Los Alamos, New Mexico, DOE/EIS-0380D2006, June 2006.

Nuclear Regulatory Commission (NRC), 2006. *Fact Sheet on Tritium, Radiation Protection Limits, and Drinking Water Standards*, July 2006. Accessed November 12, 2009, Website URL: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html

Purtymun, W.D. and T.E. Hakonson, 1974. *Inventory and Movement of Plutonium in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyon*, Office Memorandum to LaMar J. Johnson, 3 December 1974. LAHDRA Repos. No. 0976.

Rail, C.D., 2000. *Groundwater Contamination: Management, Containment, Risk Assessment & Legal Issues*, Volume 2, CRC Press, 2000.

Rogers, M.A., 1977. *History and Environmental Settings of LASL Near Surface and Disposal Facilities for Radioactive Wastes (Areas A, B, C, D, E, F, G, and T); A Source Document,* Los Alamos Scientific Laboratory Report, LA-6848, Volume 1, June 1977.

Schnap, B. and J.F. Tribby, 1947. *Radioassay and Spectrochemical Analysis of Water and Soil Samples Collected from Los Alamos, and Pueblo Canyons and Analyses of Water Samples from Tech Area, DP Site, and Laundry Drains*, 1947. LAHDRA Repos. No. 2945.

Shipman, T.L., 1953. *H Division Monthly Progress Report*, December 20, 1952 – January 20, 1953. LAHDRA Repos. No. 2276.

Shipman, T.L., 1955. *H Division Monthly Progress Report, H-219*, September 20, 1955-October 20, 1955. LAHDRA Repos. No. 2379.

Shipman, T.L., 1958. *Annual Report, Health Division 1957*, HSPT-REL-94-451, LA-2216, LAHDRA Repos. No. 2392, 1958.

Smith, B. and A. Amonette, 2006. *The Environmental Transport of Radium and Plutonium: A Review,* Institute for Energy and Environmental Research (IEER), 23 June 2006.

Tribby, J.F., 1946. *Disposal of Contaminated Sewage*, Memorandum to Dr. ER Jette, October 28, 1946. LAHDRA Repos. No. 0605.

Tribby, J.F., 1948. *The Canyon Problem at Los Alamos*, 1948. LAHDRA Repos. No. 0273.

Tuggle, D.G., 1983. *Weapons Subsystems Laboratory*, Construction Proposal from LANL Archives Collection, Los Alamos National Laboratory (A-2007-002-668-1), 1983.

United States Department of Energy (US DOE), 1979. *Los Alamos Scientific Laboratory Site,* Final Environmental Impact Statement, DOE/EIS-0018, December 1979.

United States Environmental Protection Agency (US EPA), 2006. *Basic Information about Radionuclides in Drinking Water,* 16 September 2006. Accessed on November 13, 2009, Website URL: http://www.epa.gov/safewater/radionuclides/basicinformation.html

Unknown Author and Date. *Disposal of Hazardous Materials by Burning*, Central Records Center, LAHDRA Repos. No. 0672.

Valentine, A.M. and J.C. Dummer, 1979. *Monthly Progress Reports Area Health Physics*, August 1979. LAHDRA Repos. No. 0548.