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PREFACE

In October 1994, the Los Alamos National Laboratory (LANL) established a project office to provide support to the Department of Energy (DOE) and its contractor for the preparation of a site-wide environmental impact statement (SWEIS). The role of the SWEIS Project Office was to provide background information and to respond to requests for information. DOE and its contractor prepared the SWEIS.

Because of the institution's size and the diversity of its ongoing projects, summary information on the LANL's organization, programs, ecological setting, infrastructure, and operations did not readily exist in a consolidated form at the time the SWEIS Project Office was established. Thus, it was necessary to obtain and integrate data from many organizations and sources to provide all this information in a concise presentation. A number of individuals contributed to the process, and the project office served as the focal point for integration. Information was gathered between 1995 and 1997, and information was updated to the extent feasible. Changes in the organizational structure introduced by the new Laboratory director, appointed in November 1997, have not been incorporated.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION TO LOS ALAMOS NATIONAL LABORATORY

Los Alamos National Laboratory (LANL or the Laboratory) and the associated residential areas of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico, approximately 60 mi (100 km) north-northeast of Albuquerque and 25 mi (40 km) northwest of Santa Fe (Figure 1-1). The 43-mi^2 (111-km^2) Laboratory site is situated on the Pajarito Plateau, which consists of a series of fingerlike mesas separated by deep east-to-west-oriented canyons cut by intermittent streams. Mesa tops range in elevation from approximately 7,800 ft (2,400 m) on the flanks of the Jemez Mountains to about 6,200 ft (1,900 m) at their eastern termination above the Rio Grande Canyon. Plant communities on these mesa tops range from ponderosa pine forests on the flanks of the Jemez Mountains to pinyon-juniper woodlands near the Rio Grande. The climate is moderate with relatively mild winters and summers (LANL 1996a).

Most Laboratory and community developments are confined to mesa tops. The surrounding land is largely undeveloped, and large tracts of land north, west, and south of LANL are held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, General Services Administration, and Los Alamos County. The Pueblo of San Ildefonso borders the Laboratory to the east (LANL 1996a).

The Laboratory is divided into technical areas (TAs) that are used for building sites, experimental areas, waste disposal locations, etc. (Figure 1-2). However, these uses account for only a small part of the total land area. Over one-half of the total acreage has slopes whose grade exceeds 20%, making development impossible. In addition, much of the area that could be developed is needed for security and safety buffers because of the work being performed. Therefore, of the 43 mi^2 (111 km^2), less than 25% is developed (LANL 1990).

The Department of Energy (DOE) controls the area occupied by LANL and has the option to completely restrict access. The public is allowed limited access to certain areas of LANL. An area north of Ancho Canyon between the Rio Grande and State Road 4 is open to hikers, rafters, and hunters, but wood cutting and vehicles are prohibited. Portions of Mortandad, Los Alamos, and Pueblo canyons are also open to the public. Archaeological sites in Bayo Canyon, in the area northwest of State Road 502 near White Rock, and in Mortandad Canyon are open to the public, subject to restrictions protecting cultural resources (LANL 1996a).

The operating cost for LANL during fiscal year (FY) 1995 (the Laboratory's fiscal year runs from October 1 through September 30) was $1,084 million, with an additional $65 million for equipment, $25 million for construction, and $11 million for general plant projects. In FY95, $951 million of the operating cost was spent on DOE programs, including $440 million on defense programs, $210 million on environmental restoration and waste management, $93 million on energy research, and $85 million on nonproliferation and international security. Approximately $133 million was spent on work for others (clients other than DOE), including $71 million on Department of Defense (DoD) projects (LANL 1996b).

In 1995, LANL employed approximately 7,000 people in permanent positions; approximately 39% of these employees were technical staff members, 7% were managers, 12% were support staff members, 26% were technicians, and 16% were office worker or general support workers. LANL also employed about 3,000 other people in special programs such as work/study programs, graduate research positions, and limited-term positions. In addition, approximately 2,500 people were employed by contractors, providing support services, protective force services, and specialized scientific and technical services.

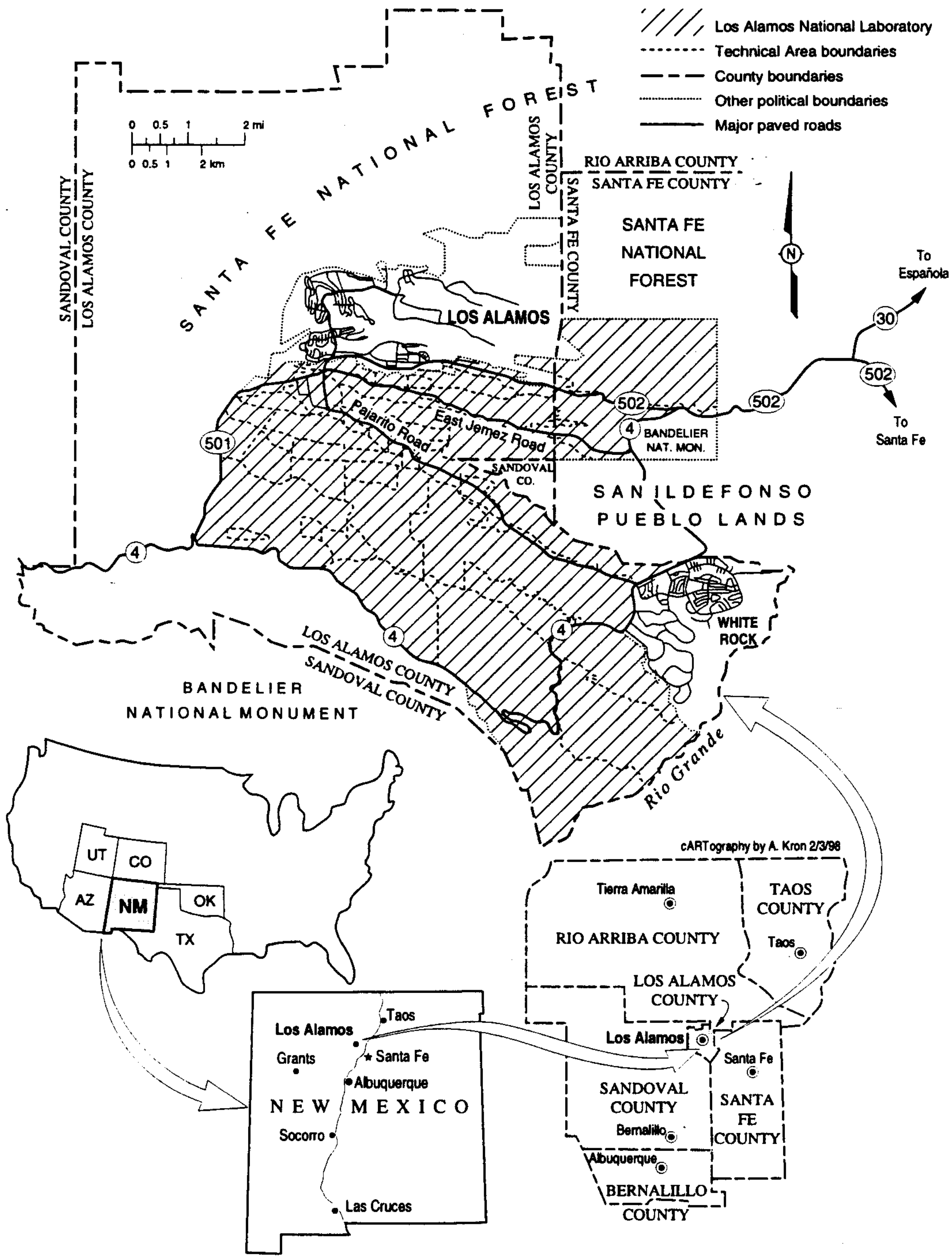

Figure 1-1. Location map for Los Alamos National Laboratory.

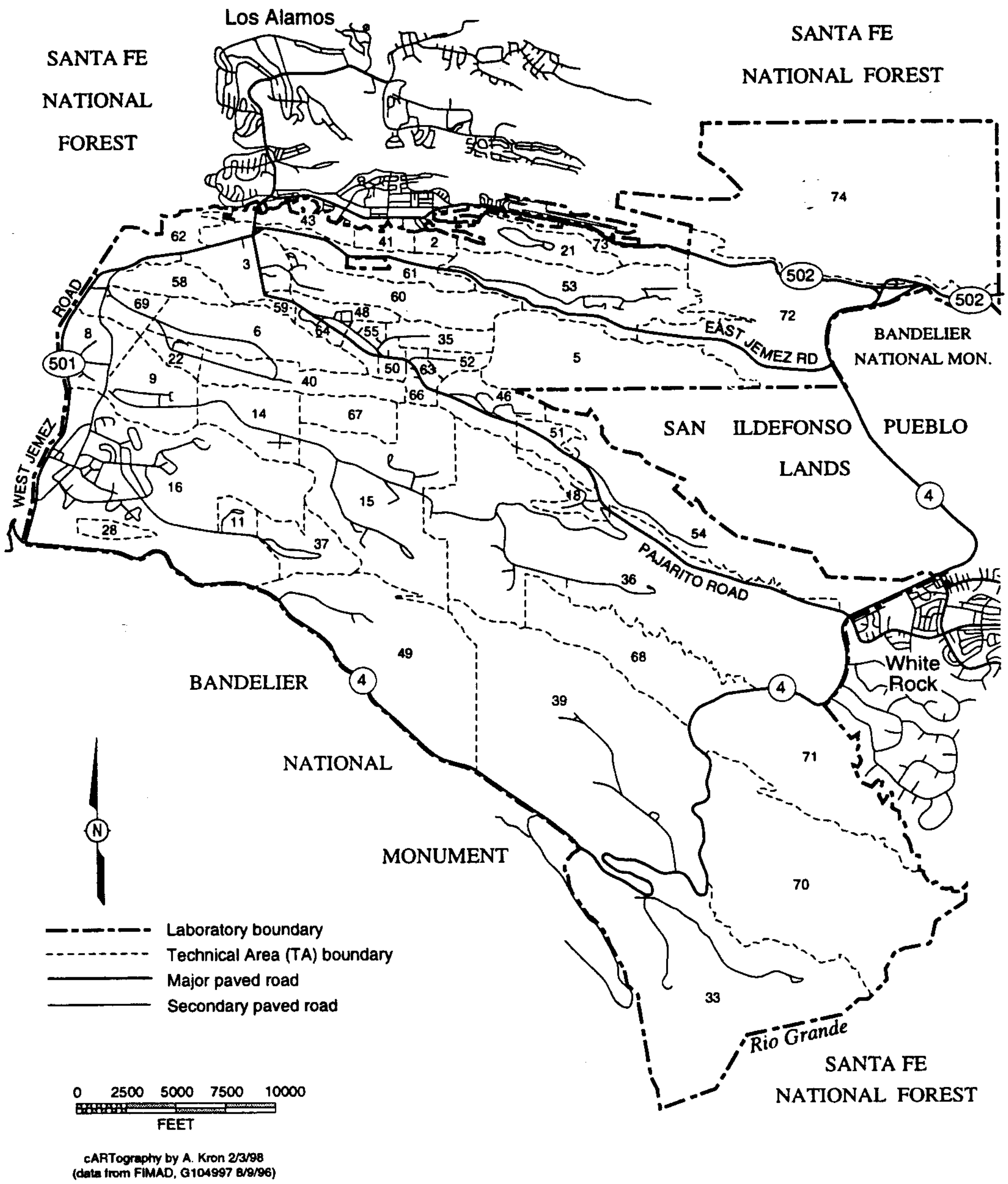

Figure 1-2. Map of LANL technical areas and roads.

LANL is administered under a contract between the University of California (UC) and the DOE through DOE's Los Alamos Area Office (LAAO) and Albuquerque Operations Office (DOE-AL). This contract is reviewed once every five years. As a nonprofit organization managed by UC, LANL functions more like a major university than a business in private industry. The Laboratory's director is ultimately responsible for all LANL activities as prescribed by this contract. However, technical and administrative responsibility and authority have been delegated to directorates and technical and support offices. The director is supported by a deputy director; both the director and the deputy director are supported by special assistants. In 1995, the Laboratory's management structure consisted of 17 division offices, 10 program offices, and 6 institutional offices. The directors of all programs and divisions form the Laboratory Leadership Council (LANL 1996b).

1.1 History

A basic understanding of LANL's history requires not only a knowledge of its physical development but also a knowledge of the congressional actions that resulted in its establishment. This section presents an overview of both topics, following the Laboratory's development from its start during World War II, moving into postwar development, and ending with its modern configuration.

1.1.1 Physical Development

A variety of good source documents provide information on the Laboratory's development; three of these should be mentioned because of their unique attributes: One, "Los Alamos: The First Forty Years" (Lyon and Evans 1984), is a unique collection of newspaper clippings and articles that present the cross section of public information made available as LANL grew. Another, "Project Y: The Los Alamos Story" (Hawkins et al. 1983), is a good presentation of the scientific advances made to produce nuclear weapons at the embryonic laboratory. The last is a series of articles produced by LANL, authored by Robert Seidel, in celebration of its 50th anniversary, which is available on the Internet at http://bang.lanl.gov/video/history/lanl50th. The following section has been extracted from these and other source documents.

1.1.1.1 The War Years (1942–1946)

During World War II, Los Alamos was the site selected for developing a weapon based on advanced concepts and new discoveries in physics. Scientists in Nazi Germany had discovered nuclear fission in late 1938, and refugee scientists were convinced that Germany was pursuing development of a weapon based on this concept. They persuaded Albert Einstein, America's most famous physicist, to warn President Franklin Roosevelt of this danger. In response to this warning, Roosevelt ordered increased research in nuclear physics.

The National Bureau of Standards started a small research program in 1939 at the Naval Research Laboratory in Washington, DC, to explore uranium isotope separation. A separate study was established at Columbia University, where prototype nuclear reactors were built based on various configurations of graphite and uranium. Then, in 1941, British scientists announced that very small amounts of the fissionable isotope of uranium (^{235}U) could produce an explosion equivalent to several thousand tons of TNT. This announcement prompted the National Academy of Sciences to propose an all-out effort to build nuclear weapons. No sooner had this decision been made than the Japanese bombed Pearl Harbor.

During 1942, the War Department established sites at Oak Ridge, Tennessee, and Richland, Washington—one site for uranium and plutonium refinement and enrichment, the other for metal production. In addition, the War Department contracted with many private-sector companies to produce necessary equipment and parts. This was the start of the nuclear weapons complex.

In December 1942, General Leslie Groves, Commander of the Manhattan Engineer District, and J. Robert Oppenheimer, the UC physicist whom Groves had asked to head the new nuclear weapons design laboratory, selected the Los Alamos Ranch School as the preferred construction site. Undersecretary of War, Robert Patterson, approved the acquisition on November 25, 1942. The War Department informed the school's director, A. J. Connell, in a letter dated December 1, 1942, that the property would be condemned pursuant to purchase for military purposes and that the ranch school would have to be vacated on February 8, 1943.

Ninety percent of the land surrounding the Los Alamos Ranch School, 54,000 acres (21,854 ha) of semiarid forest and grazing land, was already controlled by the federal government and was easily transferred to the Manhattan Project. The remaining 8,900 acres (3,600 ha) of private holdings were purchased in five separate actions.

1.1.1.1.1 Townsite

When the school closed, digging and trenching for laboratory buildings had already begun. The existing 54 Ranch School buildings were immediately converted to new uses, and additional buildings were built as needed. The Ranch School buildings were converted as follows: the Big House was divided into bachelor quarters, recreation room, and library; a five-car garage was converted to a fire station; the arts and crafts building became a nursery school and two bachelor quarters; and other ranch homes were converted to housing. To the existing buildings were added soldiers' barracks, a mess hall, officers' quarters, an administration building, a theater, and an infirmary, as well as apartments, a bachelor dormitory, laboratory technical buildings, and utilities for civilian scientists.

The US government owned all facilities and restricted access to the entire site. Site personnel paid rent for their houses, and everyone, including housewives and children of school age, received a badge allowing entrance to the site.

1.1.1.1.2 Operations Areas

The Main Technical Area (TA-1), which consisted of technical, administrative, and warehousing facilities, was constructed on about 25 acres (10 ha) around Ashley Pond and along the south side of the present Trinity Drive out to the edge of Los Alamos Canyon. By 1945, approximately 100 structures were in use. Although some were small or were being used for storage, the area was a large complex that combined features of both experimental laboratory research and industrial operations. Between 1943 and 1945, much of the theoretical, experimental, and production work involving the development of the atomic bomb took place in TA-1 (Figure 1-3). The structures indicated by dashed lines represent the original TA-1, and the shaded structures show the townsite as it is today.

Some of the work being done was considered too dangerous to be performed at TA-1, so these operations were placed at remote locations. For example, the Omega Site (TA-2) was built to house experiments on integral assemblies. This work involved experiments to determine critical masses of fissionable material. In 1946, this work moved to TA-18. Alpha Site at TA-4, abandoned

in the late 1940s, was used as a firing site to test high explosives (HE). It was originally used to fire several charges per day of up to 100 lb (45.4 kg) and was then converted to accommodate studies of small equation-of-state tests that used only a few pounds of HE per shot. Beta Site at TA-5 was used extensively in 1945 as a firing site for the pin or electric method of studying implosions. Larger charges could be safely used at TA-5, and shots of several hundred pounds were used. S-Site at TA-16 was developed for production of HE to be used in the various tests.

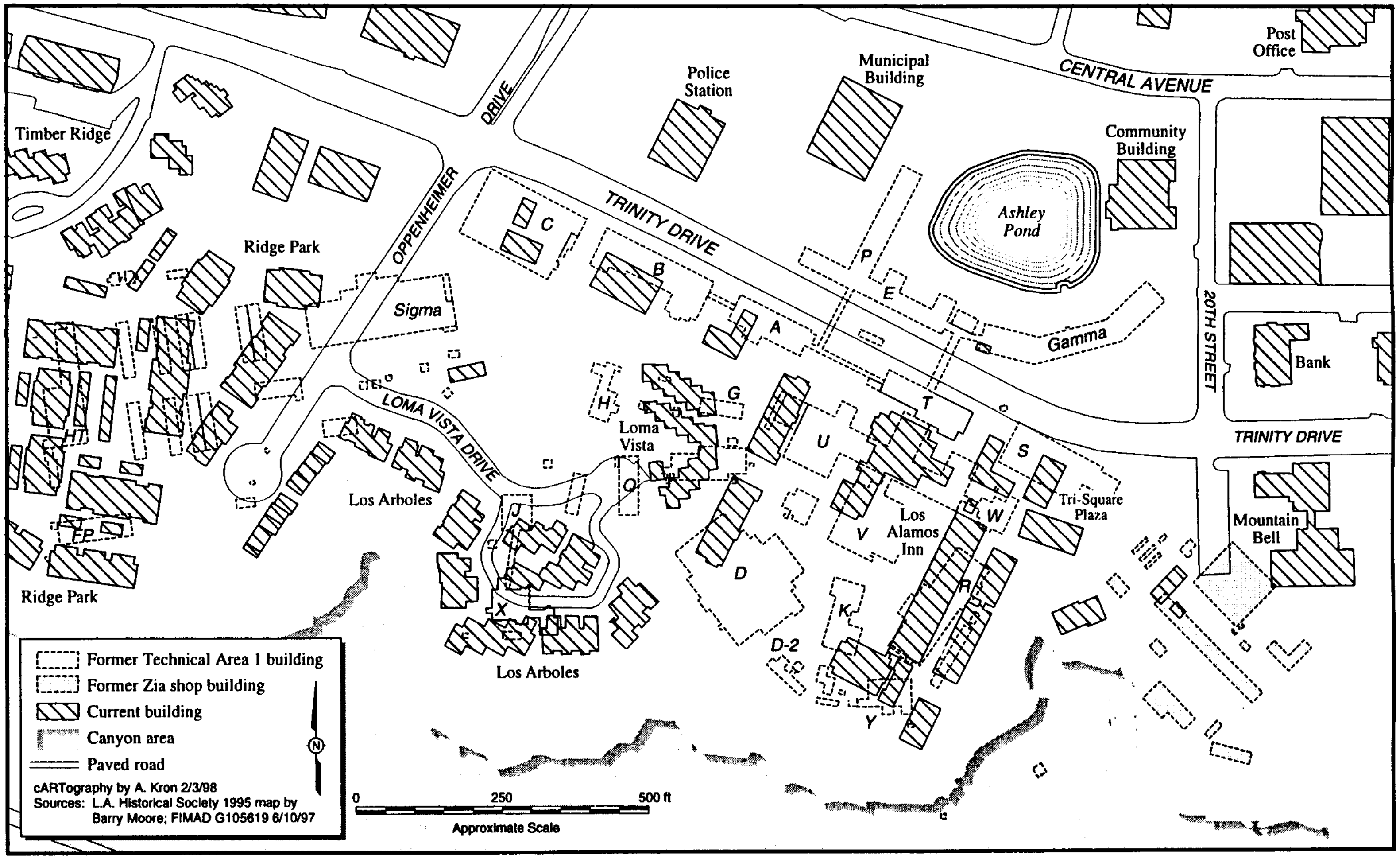

Figure 1-3. Map of TA-1.

Many other sites developed during the war years were used for a variety of purposes. Within LANL boundaries, many experiments were conducted that released or had the potential to release contaminants to the environment. LANL has compiled detailed information on these sites under the auspices of the Environmental Restoration Program and is in the process of cleaning them up. At some of the sites are buildings over 50 years in age that have historical significance. Many of these historic facilities contain residues of hazardous substances and have deteriorated. Information regarding these sites can be found in "Comprehensive Environmental Assessment and Response Program, Phase 1: Installation Assessment, Los Alamos National Laboratory" (DOE 1986), and the subsequent "Installation Work Plan for Environmental Restoration" (LANL 1992).

1.1.1.1.3 Waste Areas

The work at TA-1 involved a variety of radioactive and hazardous materials that required appropriate disposal. Radioactive materials handled included tritium (H^3), curium (^{242}Cm and ^{244}Cm), uranium (^{238}U), phosphorus (^{285}P), polonium (^{210}Po), thorium (^{232}Th), radium (^{226}Ra), cesium (^{137}Cs), strontium (^{90}Sr), and americium (^{241}Am). Hazardous materials handled included lithium hydride, beryllium, mercury, iodine, trisodium phosphate, ammonium sulfate, various acids (such as hydrochloric, nitric, perchloric, hydrofluoride, and orthophosphoric), and various types of organics. In addition, nonhazardous waste was generated by regular office activities, routine nonhazardous operations, and the townsite.

Two major dump areas were established to accept these wastes. Nonhazardous waste was disposed in an area located adjacent to and under portions of the existing airport. This dump consisted of a burning area and landfill. Hazardous and radioactive wastes were disposed in separate disposal areas at or adjacent to TA-21.

Other waste areas were established adjacent to remotely located facilities. In addition, testing conventional ammunitions resulted in impact areas that contained unexploded ordnance. These areas, which contain what is termed "legacy" contamination, are being evaluated for potential risk to human health and the environment, and, when appropriate, are being cleaned up by the Environmental Restoration Program under the oversight of the Environmental Protection Agency (EPA) and New Mexico Environment Department (NMED).

1.1.1.2 Postwar Development (1947–1960)

As originally planned, the Laboratory's sole purpose was to develop the atomic bomb, and the War Department planned to dismantle it upon completion of the project. However, at the end of the war, distrust of the Soviet Union and the US government's perceived need for developing and maintaining a nuclear arsenal resulted in the establishment of a permanent nuclear weapons research and design entity at Los Alamos. The facility was soon named Los Alamos Scientific Laboratory, a name that lasted until the early 1980s, when it changed to Los Alamos National Laboratory. Immediately following the war, work concentrated on refining the design of fission weapons.

1.1.1.2.1 Townsite

During the late 1940s and early 1950s, the Town of Los Alamos expanded to the rim of Pueblo Canyon. Los Alamos High School and Mesa Elementary School were constructed, along with the first permanent single-family dwellings. One set of dwellings, named for its location west of the high school, was called the "Western Area." These dwellings were of standard construction. The other set of dwellings, located north of the high school, was called the "Denver steels." These houses were composite construction consisting of regular foundations, subfloors, and floors;

however, they had steel wall supports, sides, and roofs. The steel components were made in Denver.

In 1948, as a result of an extreme housing shortage in Los Alamos, the government established a construction camp (trailer park and temporary government housing) at the location of what is now White Rock. By 1952, occupancy of this camp started a steady decline, and it was closed on September 30, 1957.

In early 1957, Los Alamos became an open town. The guard gates strategically located around the Laboratory site were removed, and, for the first time, visitors could simply drive into town. The government allowed residents to purchase their homes, and Los Alamos became more like a normal town. One year later, the government sold Barranca Mesa for development of private housing. Complete transfer of the townsite to private ownership occurred over several years because special legislation was necessary to allow the government to construct support facilities and transfer ownership to county government.

This special legislation also permitted the development of White Rock by allowing 250 acres (100 ha) of the former construction camp site to be sold to private developers for housing. It also allowed the rehabilitation of the White Rock sewage system and construction of a water distribution system for the new development.

1.1.1.2.2 Operations Area

During the late 1940s and early 1950s, concomitant with the growth of the townsite, Laboratory operations in TA-1 were slowly moved to South Mesa across Los Alamos Canyon from the townsite. TA-3, the new home for most of these operations, became one of the largest and most complex of the technical areas in the Laboratory. Easy access to TA-3 from the townsite was provided in late 1951 by the open-spandrel, steel-arch bridge that spans Los Alamos Canyon (Figure 1-4).

The first new facility built at TA-3 was the van de Graaff Laboratory complex, which included a vertical machine for accelerating particles (and later a horizontal machine), followed by construction of the Chemistry and Metallurgical Research (CMR) Building. CMR was designed to be the major laboratory for investigating plutonium chemistry and metallurgy and the properties of other materials, such as uranium, tritium, and other radionuclides. The next facilities built were warehouses (Buildings 30 and 31). Thereafter, a flurry of building activity occurred during which the administration building, the cryogenics complex, the shops/fabrication building, and the Physics Building were constructed. By the mid-1950s, construction started on the Sigma Complex, and most operations had been moved from TA-1 to TA-3. TA-1, however, lingered on for a number of years as operations continued in some of the buildings—in some cases, into the early 1960s.

In 1957, Area G (TA-54) was opened to replace the trenches used at TA-21 for radioactive waste disposal. Burial and storage units at Area G include pits, shafts, trenches, and pads of varying dimensions. Area G remains in operation today. Also located at TA-54 are Area H, built between 1959 and 1963 for disposal of uncontaminated classified material; Area J, used for disposal of equipment wastes that require administrative control (i.e., may have minute quantities of high-explosive contamination); and Area L, used for chemical disposal from 1964 to 1975.

During the spring and summer of 1945, TA-21 was conceived and built for chemical and metallurgical work. This site, as developed and used over the years, can be divided into two main sections: DP West and DP East. DP West was built to replace D Building at TA-1. D Building could not safely handle large quantities of plutonium. DP East was built to process polonium and to produce initiators. Plutonium work continued at TA-21 until late 1977 or early 1978, when these operations

Figure 1-4. Bridge over Los Alamos Canyon.

moved to TA-55. TA-21 is mentioned here because it was one of the few operations that did not move south of Los Alamos Canyon during the 1950s and 1960s.

1.1.1.3 Modern Configuration (1961–Present)

LANL continued to evolve as an active research and development institution; however, the construction of new facilities started to decline in 1961, and most of the new construction was confined to remodeling existing structures to accommodate new applications. A major exception was the construction of a new technical area, TA-55, during the 1970s and the creation of a consolidated "plutonium corridor" in the central portion of LANL along Pajarito Road. Other new buildings of interest include the Plutonium-Processing Facility at TA-55, the accelerator physics building at TA-53, the Weapons Engineer Test Facility (WETF) at TA-16, and the Materials Science Laboratory at TA-3.

1.1.1.3.1 Townsite

The communities of White Rock and Los Alamos continued to expand until nearly all available building space had been occupied. Contaminated areas existing in Los Alamos were cleaned up, the land was transferred to the county or to private ownership for development, and housing was built throughout these areas. Today, there is no remaining space into which either community can conveniently expand without transferring additional government lands for development purposes.

1.1.1.3.2 Operations Area

Because LANL's mission continued to expand into areas other than nuclear weapons research, by the late 1980s considerable thought was being given to land use planning. By 1990, the Laboratory had developed a planning model that proposed building on and strengthening existing development patterns to achieve effective functional working relationships between major programs, taking into account the compatibility of land uses. In this planning model, TA-3 and its immediate environs remain the administrative and functional center of LANL. Emanating from this area are three main development corridors, each with its own major programmatic emphasis.

The East Jemez Corridor consists of the Los Alamos Meson Physics Facility (LAMPF)—now the Los Alamos Neutron Scattering Center (LANSCE)—Sigma Mesa, and East Jemez Road. LANSCE is devoted primarily to accelerator-related experimental science; Sigma Mesa is proposed for administrative, technical, and physical support functions; and East Jemez Road is reserved for physical support functions and primary access to LANL. The Pajarito Corridor is used primarily for nuclear materials research and development, fusion and laser research and development, waste management, and other multipurpose experimental science. The West Jemez Corridor is used for weapons engineering and dynamic testing.

Satellite support and service areas for Laboratory administrative and technical support functions are planned for each of the three main development corridors. Satellite sites may also be used for physical support functions. Facilities providing cafeterias, wellness centers, and other employee services may also be located in these areas. All such satellites require expansion areas to permit the phased, planned growth of facilities as funding permits.

The Laboratory currently consists of approximately 2,043 structures. Of these, 1,835 are buildings, which contain 7.3 million square feet (2.225 million square meters). The other structures consist of meteorological towers, water tanks, manholes, small storage sheds, electrical transformers, etc. Overall, LANL facilities are very old: 80% are more than 20 years old, 50% are more than 30 years old, and 30% are more than 40 years old.

1.1.2 Congressional Actions

LANL exists because of specific congressional actions, including establishing and approving the actions of the War Department and passing the Atomic Energy Act, the Energy Research and Development Administration Act, and the Department of Energy Organization Act. The prime sponsor for LANL changed under the four major pieces of legislation. A short discussion of this legislation is presented below. Enough history is included to connect the four pieces.

1.1.2.1 War Department Action

In the summer of 1942, Colonel Leslie Groves was appointed to take charge of the atomic weapons project. The first thing he did was rechristen the project "The Manhattan District," also known as "The Manhattan Engineer District." At the same time, Groves was promoted to brigadier general, which gave him the rank thought necessary to deal with senior scientists in the project and to provide easy access to materials and funds through the War Department.

The Manhattan Engineer District immediately took charge and accelerated construction of the necessary metal production facilities (to provide the nuclear material), which consisted of the Y-12 Plant at Oak Ridge, Tennessee, and the Hanford Site at Richland, Washington. In early October 1942, Groves learned that a new research and development laboratory was needed to collocate the theoretical and experimental efforts involved in designing a nuclear weapon. By mid-October, the formal decision was made to create a nuclear weapons design laboratory.

A letter dated January 23, 1943, laid out a rudimentary agreement calling for the Office of Scientific Research and Development to contract with UC for "certain investigations to be directed by Dr. J. R. Oppenheimer" (DOE 1994). UC President, Robert Gordon Sproul, accepted the letter of intent on February 10, 1943. The contract was signed on April 20, 1943, making UC the manage- and operations (M&O) contractor for LANL, a function that UC still performs today.

To ensure UC control and to protect the secrecy of Los Alamos, material for the Laboratory was routed through UC's purchasing office in Los Angeles, which shipped it on to Los Alamos. UC was kept largely ignorant of the nature of the project at Los Alamos until after the war. In 1947, UC entered into a new operating agreement with the Manhattan Engineer District's successor, the Atomic Energy Commission (AEC).

1.1.2.2 Atomic Energy Act and Atomic Energy Community Act

By the Atomic Energy Act of 1946, Congress established the AEC to assume responsibility for nuclear research, including the nation's nuclear defense research program, thereby removing control of nuclear weapons design, development, and production from the War Department. The tradition of having civilian control of the nuclear weapons complex still exists today.

Executive Order 9816 (The White House 1946) said, in part:

> ". . . transferred to the Atomic Energy Commission all interests owned by the United States or any Government Agency in the following property: All fissionable material, all atomic weapons and parts thereof, all facilities, equipment and material for the processing, production or utilization of fissionable material or atomic energy; all processes and technical information of any kind, and the source thereof (including data, drawings, specifications, patents, patent applications and other sources) related to the processing, production and utilization of fissionable material or atomic energy, and all contracts, agreements, leases, patents, applications for patents, inventions and discoveries (whether patented or unpatented), and other right of any kind concerning any such item."

"There are also transferred to the Atomic Energy Commission all properties, real or personal, tangible or intangible, including records owned by or in the possession, custody or control of the Manhattan Engineer District, War Department, in addition to the properties described in paragraph 1 above."

By this executive order, LANL became the property of the AEC and, as such, was essentially self-regulated in handling nuclear materials and radioactive hazardous wastes for and on behalf of the AEC. Most of the work at LANL had military application, although some work had direct applicability to the budding industry of using nuclear power for peacetime purposes.

In 1954, Congress revamped the Atomic Energy Act to separate the use of nuclear energy for weapons and commercial applications (USC, Title 42, Chapter 23, Development and Control of Atomic Energy). This act defined—and set apart for AEC regulation—control of the plutonium and uranium used in weapons [special nuclear material (SNM)], the original or raw material from which the special nuclear material was produced (source material), and any wastes generated by processing these materials into weapons (by-product materials), while allowing the federal government and private industry to promote nuclear power in partnership. This act solidified the civilian control of nuclear weapons, and LANL continued to work for and on behalf of the AEC under contract with UC.

Congress also enacted the Atomic Energy Communities Act (USC, Title 42, Chapter 24, Disposal of Atomic Energy Communities) to (1) facilitate the establishment of local self-government; (2) provide for the orderly transfer of municipal functions, municipal installations, and utilities to these local government entities; and (3) provide for the orderly sale to private purchasers of property in those communities with a minimum of dislocation. This act established the policy for transferring excess land to the local government rather than transferring the land back to its original owners.

The act was promulgated to make the townsites at the national laboratories into "real cities" and to provide the scientists working at these laboratories an opportunity to invest in a home. As stated in the congressional findings: "The continued morale of project-connected persons is essential to the common defense and security of the United States" (DOE 1994).

1.1.2.3 Energy Research and Development Administration

The US government played a limited role in formulating national energy policy before the 1973 energy crisis. The government left the task of long-range planning and energy utilization to private industry or state, local, and regional authorities for whom the private sector filled most of the nation's energy needs. Through the early 1970s, energy programs were scattered throughout the federal departments and agencies, reflecting the government's decentralized approach to energy management. The energy crisis of 1973 forced recognition that the US government needed a coordinated national energy policy and that the various energy programs needed to be consolidated in one agency.

Even as the energy crisis eased, the nation's dependence on foreign oil imports increased. Because of this dependence on foreign oil, the energy crisis, and the need for a national energy policy, Congress started to consolidate government efforts in energy research. On January 19, 1975, as a result of the Energy Reorganization Act of 1974, the AEC was replaced by the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA).

ERDA inherited the largest portion of its budget and personnel from the AEC, including AEC's network of field offices and national laboratories. ERDA also incorporated all energy research and development functions from the Department of the Interior's Office of Coal Research and all Bureau of Mines energy research centers. The National Science Foundation (NSF) relinquished its offices involved in solar and geothermal energy development, and the EPA transferred its functions related to research, development, and demonstration of innovative automotive systems.

The Energy Reorganization Act of 1974 required the ERDA administrator to collaborate with the Secretary of Defense to decide whether the nuclear weapons programs should be transferred to the DoD or be retained under civilian control. As recommended in its report submitted to the President on January 16, 1976, ERDA retained oversight of the military application program. Thus, this act maintained civilian control of nuclear weapons but split control and regulation of radioactive material by assigning weapons applications to ERDA and peacetime applications to NRC. LANL's operating contract with the UC was transferred from the AEC to ERDA.

1.1.2.4 Department of Energy

Natural gas supplies in New England fell critically short during the winter of 1976-1977. On February 2, 1977, President Carter proclaimed a national emergency, as defined in the Emergency Natural Gas Act of 1977, and, on March 1, the President presented Congress with proposed energy reorganization legislation to create the DOE. This legislation also created a unified energy policy framework that placed much greater emphasis on reducing energy consumption and developing alternative energy technologies. Congressional action on the Department of Energy Organization Act was completed by August 3 and was signed into law (Public Law 95-91) on August 4. DOE officially replaced ERDA on October 1, 1977.

By law, DOE would be led by three principal officers: the secretary, deputy secretary, and undersecretary. Energy technologies would not be divided by fuel type, such as fossil, nuclear, or solar, but would be grouped under the assistant secretaries according to the stage of evolution of the fuel's development—from research and development through application and commercialization. This approach formulated a comprehensive energy policy rather than simply a fuel management system.

The DOE inherited about 40 regional and field offices, research centers, university programs, and laboratories from its predecessor agencies. These varied from the 10 regional regulatory offices of the Federal Energy Administration to the Bureau of Mines research laboratories at Bartlesville, California; Morgantown, Pennsylvania; Pittsburgh, Pennsylvania; and Laramie, Wyoming. The bulk of the department's inherited facilities came from ERDA. These included 8 operations offices and various production and weapons facilities. Again LANL's operating contract with UC was transferred, and LANL started operating for and on behalf of the DOE.

During the 1980s, President Reagan advocated abolishing the DOE. However, the question of what to do with DOE's Nuclear Weapons Program became a major obstacle to all plans. Suggestions to place the nuclear program in DoD met with strong congressional opposition. The Nuclear Weapons Program had been under civilian control since the Atomic Energy Act of 1946, and Congress wanted it to stay that way. Placing the Nuclear Weapons Program in the Department of Commerce or Interior did not receive widespread support, nor was there congressional support for creating an independent nuclear weapons agency.

During the late 1980s, environmental and safety concerns with DOE's aging nuclear weapons complex became a matter of concern. In mid-1987, DOE conducted a year-long study detailing environmental conditions at all federal nuclear facilities. The study focused on 17 sites and examined efforts to clean up environmental contamination and to ensure compliance with environmental, safety, and health (ES&H) standards. The study estimated cleanup and compliance costs of $66 billion through fiscal year 2025 (DOE 1994).

In December 1988, DOE released another study known as the 2010 Report (DOE 1994). This study estimated that operating and maintaining the weapons complex would cost $244 billion over the next 20 years. These costs included new production plants, waste facilities, and environmental and safety corrective actions and compliance. The 2010 Report recommended ending all materials production at Hanford and closing down the Rocky Flats and Fernald facilities, as well as the Mound nuclear material plant.

By the fall of 1991, the Cold War was over, the Soviet Union had dissolved, and the Strategic Arms Reduction Treaty had been signed. This treaty promised to reduce the US nuclear weapons stockpile to 6,000 accountable warheads (each warhead is numbered and tracked from creation to disposal). Then, the US government announced major additional cuts in the nuclear weapons arsenal. Because tritium requirements had been greatly reduced as a result of the treaty, DOE announced a two-year delay in selecting the technology and location for tritium production. In addition, DOE announced its intent to accelerate downsizing the nuclear weapons complex. Nonnuclear component manufacturing operations would be consolidated at the Kansas City Plant, and facilities at Pinellas and Mound would be closed. The nation's nuclear weapons complex would start downsizing.

A complete discussion of the history of DOE is found on the internet at http://www.doe.gov/html/doe/about/history.

1.2 LANL as Part of the DOE Complex

For over 50 years, LANL has served the nation as one of two nuclear weapons design laboratories (Lawrence Livermore National Laboratory is the other) during which it designed about 80% of the nation's nuclear weapons stockpile. LANL's missions have evolved over time in response to national needs; however, the primary role of serving as a national resource of scientific, technical, and technical engineering excellence, with a special focus on national security, has remained (Chapter 2 contains a discussion of the Laboratory's current mission and assignments).

LANL is, and has always been, only a small part of the nuclear weapons complex. To produce a nuclear weapon, a variety of materials and systems had to be designed and fabricated. Nuclear material suitable for a weapon had to be produced, which required mining operations, enrichment plants, reactors, special foundries, and the development of new technologies for casting and molding these materials. Electrical systems (fusing and firing) and explosive systems (shaped charges to produce an implosion) also had to be developed and tested. Finally, all these components and systems had to be brought together into a workable unit.

Although the two weapons used in World War II (Little Boy and Fat Man) were assembled at LANL, shortly following the war weapons assembly moved to assembly plants specifically designed for that purpose, and LANL continued its role in research and development (R&D). For each weapon developed at LANL, this role has included design, testing, and certification. Like everything else, nuclear weapons deteriorate as they age. Certification is the process whereby an aging weapon is determined to be safe (that is, it will detonate only on demand) and reliable (it will produce the expected yield). This process used to involve periodic detonation of a weapon from the stockpile (i.e., atmospheric testing in the 1950s and underground testing up until the early 1990s). When the moratorium on underground testing was adopted in 1992, computer modeling and other techniques replaced underground testing as means of determining safety and reliability. This topic is discussed in greater detail in the Stockpile Stewardship and Management Programmatic Environmental Impact Statement (DOE 1996a).

Thus, LANL has responsibility for its nuclear weapons from conception through development and placement in the national stockpile to retirement from the stockpile when a weapon is replaced by a new weapon. This concept of ownership from cradle to grave has resulted in a very reliable national stockpile, where there has never been an accidental nuclear detonation.

As shown in Figure 1-5, during the height of the Cold War, the nuclear weapons complex consisted of the following:

- weapons research and design laboratories (LANL and Lawrence Livermore National Laboratory);
- a weapons engineering laboratory (Sandia National Laboratories);
- production plants (Pinellas, Florida—neutron generators; Rocky Flats, Colorado—warhead triggers; Kansas City, Missouri—electronic, mechanical, and plastic components; Mound, Ohio—actuators, ignitors, and detonators; and Pantex, Texas—high-explosives fabrication and final warhead assembly and disassembly);
- uranium enrichment plants (Paducah, Kentucky, and Portsmouth, Iowa);
- uranium refinery and metal foundry plants (Weldon Spring, Missouri, and Fernald, Ohio);
- chemical separation facilities (Idaho National Engineering Laboratory);
- fuel and component fabrication facilities (Hanford, Washington);
- component fabrication facilities using highly enriched uranium, depleted uranium, and lithium deuteride (Oak Ridge National Laboratory, Tennessee);
- fuel and target fabrication facilities plus tritium production facilities (Savannah River, South Carolina); and
- weapons testing facilities (Nevada Test Site) (DOE 1995).

Since the end of the Cold War, the need for nuclear weapons has decreased, the stockpile has been reduced, and the nuclear weapons complex has been downsized. Several of the production plants have been closed, production of nuclear metal has ceased, and operations have been consolidated. These changes in the nuclear weapons complex have resulted in new roles for LANL.

In recent years, with ever-tightening federal budgets, DOE has started a process to improve the mission focus, governance, and cost-effectiveness of the national laboratories. An in-depth review of DOE's strategic focus for the national laboratories, including LANL, is presented in "Strategic Laboratory Missions Plan—Phase I, July 1996" (DOE 1996b).

1.2.1 The Contractor-Operator

The arrangement by which LANL works for the DOE under contract with the UC is called a GoCo (government-owned, contractor-operated) operation. The land, facilities, and intellectual property belong to the government, and the installation is run by the contractor. Under the GoCo, UC is called the M&O contractor. This concept dates back to World War II, when the government needed assistance in managing large businesses for the war effort. Many large private companies such as DOW Chemical and the Chrysler Corporation, as well as major universities, accepted this challenge and provided these services as a national service for essentially no charge.

UC has always been the M&O contractor for LANL. The contract is bid every five years, and negotiations now include performance measures negotiated between UC and DOE. Thus, LANL man-

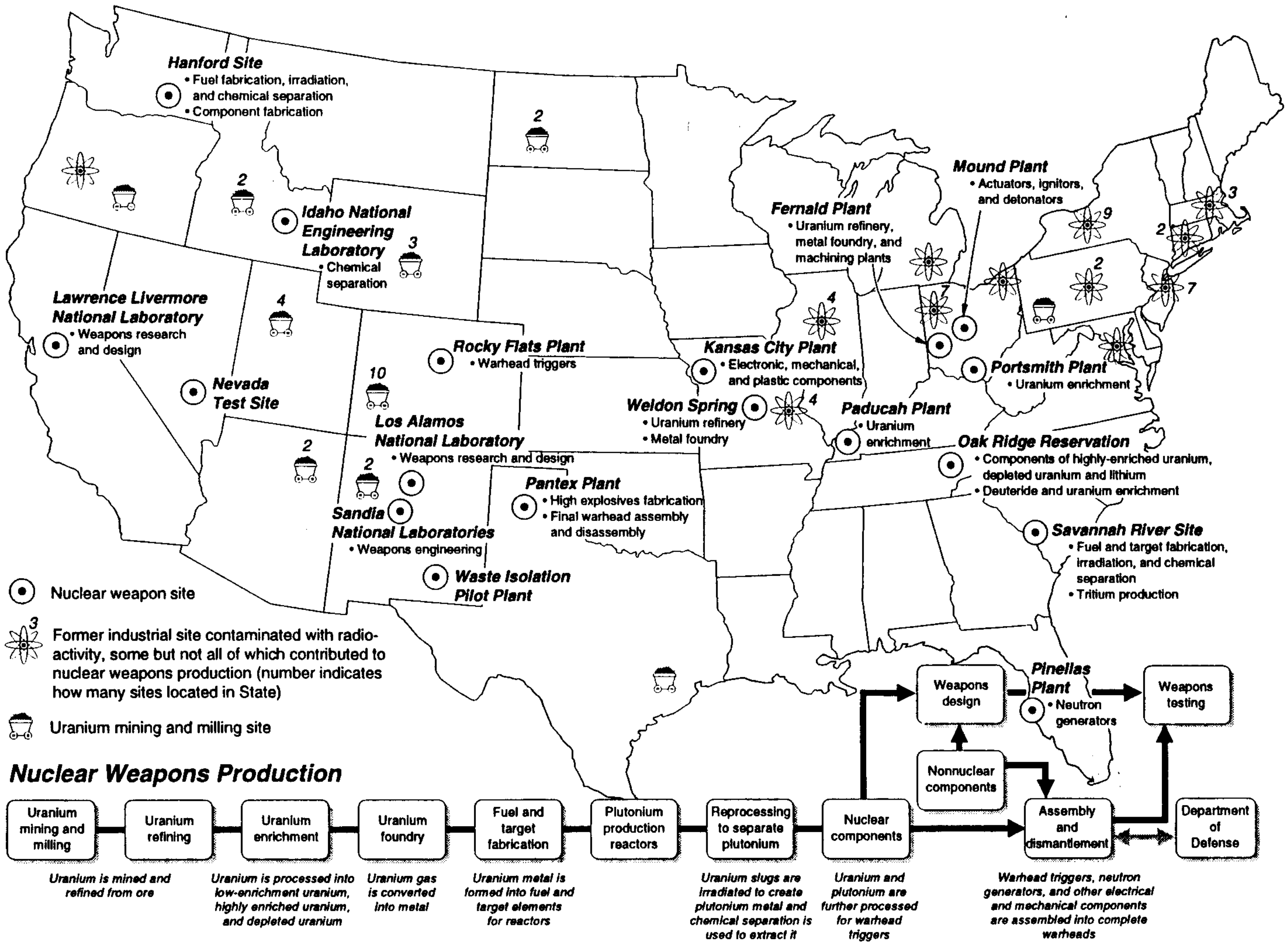

Figure 1-5. Nuclear weapons complex.

agement has to answer to UC's board of regents for the way LANL is operated and to DOE for the way work is performed.

1.2.2 Complex 2000 and LANL's Role

The nuclear weapons complex is being downsized; missions are being consolidated, and installations are being closed or reconfigured. LANL is undergoing reconfiguration to assume a limited production role and to maintain capability for conducting underground nuclear detonations, should there be a need to resume testing. LANL will also accept the role of reprocessing and managing materials (such as sealed sources) for the NRC that NRC does not have the capability to handle. More important, however, is LANL's core mission of reducing global nuclear danger and solving national problems while being responsive to the dynamic and unpredictable nature of international politics, the global economy, and US society.

Together with the other national laboratories, LANL has embarked on a science-based approach to stockpile stewardship and management. This approach focuses on modeling and simulation, as well as on developing a more fundamental understanding of the science, materials, and engineering required for stewardship of the stockpile. This approach is consistent with the presidential decision to pursue a zero-yield comprehensive test ban and to continue the current ban on underground testing.

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2.0 LOS ALAMOS NATIONAL LABORATORY: ITS MISSION, ORGANIZATION, CORE COMPETENCIES, AND PROGRAMS

This chapter provides an overview of LANL's missions, programs, organizations, and operations. For more detail, the reader is referred to the Laboratory's Institutional Plan (e.g., LANL 1997a), which is updated annually.

2.1 Mission

LANL's central mission is reducing global nuclear danger to ensure a more secure future (LANL 1995, 1996a, 1996b, 1996c, and 1997a). From its original mission of designing, developing, and testing the first atomic bombs, LANL's mission has evolved to reducing global nuclear danger by maintaining and safeguarding the nuclear stockpile without performing underground tests and by providing technologies for counterproliferation and assisting with material control and accountability for nonproliferation. Its vision is to use science to enhance global security, to preserve the earth, and to improve the quality of life (LANL 1996d).

Because LANL is a national resource, its areas of investigation change in response to federal administrative policy and congressional actions. LANL is typically asked to solve problems that

- are large in scale of time, space, size, or complexity;
- require a strong science base;
- require engineering, teamwork, and special facilities;
- benefit from a multidisciplinary approach and continuity of effort; and
- have a public service orientation.

Although LANL's central mission is defense, it is engaged in a number of nondefense programs such as advanced computing, nuclear and non-nuclear energy, atmospheric science, space and geosciences, bioscience and biotechnology, and environmental stewardship (Figure 2-1). This figure illustrates the relationships among major programs, core competencies, and the various missions at LANL. The center of the figure represents the Laboratory's prime mission—reducing the nuclear danger. Surrounding this central mission are the missions relating to nuclear weapons and environmental stewardship. These missions interface with each other, and they are supported by the core technical competencies shown surrounding the central circle. Not only are there direct and indirect interactions between the core competencies, there are also direct and indirect interactions between the core competencies and the various missions. The outer wheel of the diagram represents the national interface of the Laboratory in conventional defense, in assisting with civilian needs, and in technology transfer through industrial partnerships. Again, there are both direct and indirect interactions between the core competencies and these non-nuclear interfaces.

2.2 Organization

UC has managed LANL for DOE since the Laboratory's creation during World War II, and the M&O contract between DOE and UC has been renegotiated numerous times. A new 5-year contract became effective on October 1, 1997. At that time, the Laboratory had 18 divisions (line organizations) and 10 major programs (multiorganizational participation) (Figure 2-2). Changes in this structure are published annually in the Institutional Plan. These two systems (line and program management) function together to identify and accomplish work. The leaders of both systems report to the Laboratory director, who has overall responsibility for Laboratory operations.

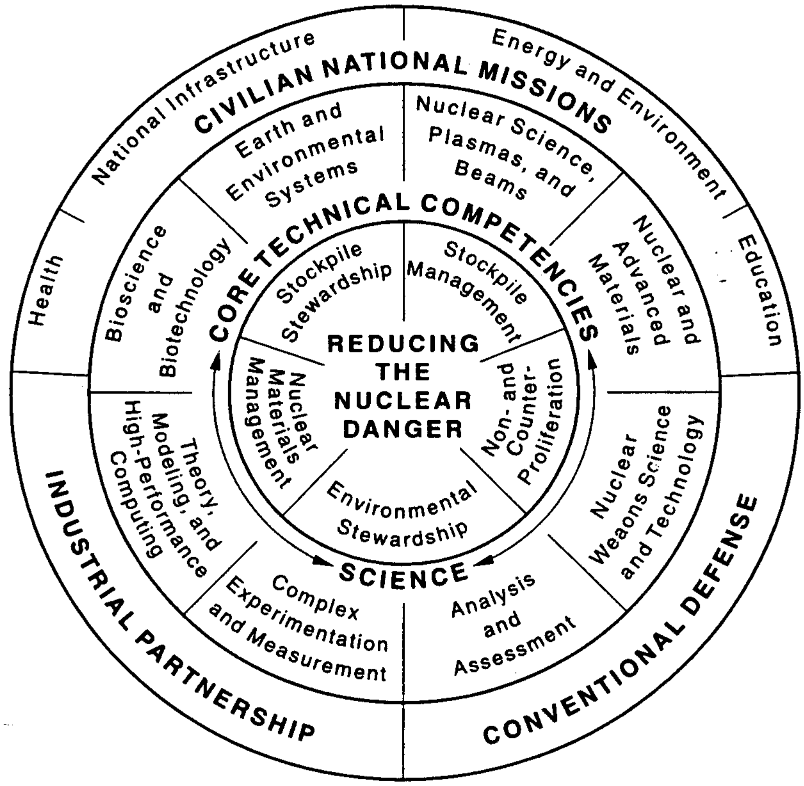

Figure 2-1. The Laboratory's national missions and core technical competencies.

2.2.1 Line Management

Each division provides a major segment of LANL's capabilities in a broad technical or professional area (LANL 1995) or provides institutional support to the various operations. Divisions are further divided into groups and offices according to the types of work performed. Group and office organizations are dynamic, evolving in both name and function in response to changing needs. Most of LANL's personnel are members of a group or office staff. Individual staff members may be reassigned to other groups or offices on either a permanent or temporary basis, as work requirements dictate.

2.2.1.1 Roles

The divisions provide for LANL's strategic planning and development and implement policies for managing personnel, equipment, and facilities. Each division is a collection of groups; each group administers a collection of capabilities made up of people and equipment that provide technical and/or operational support. The LANL director selects division directors (LANL 1996e), and the division directors select group leaders in a competitive process.

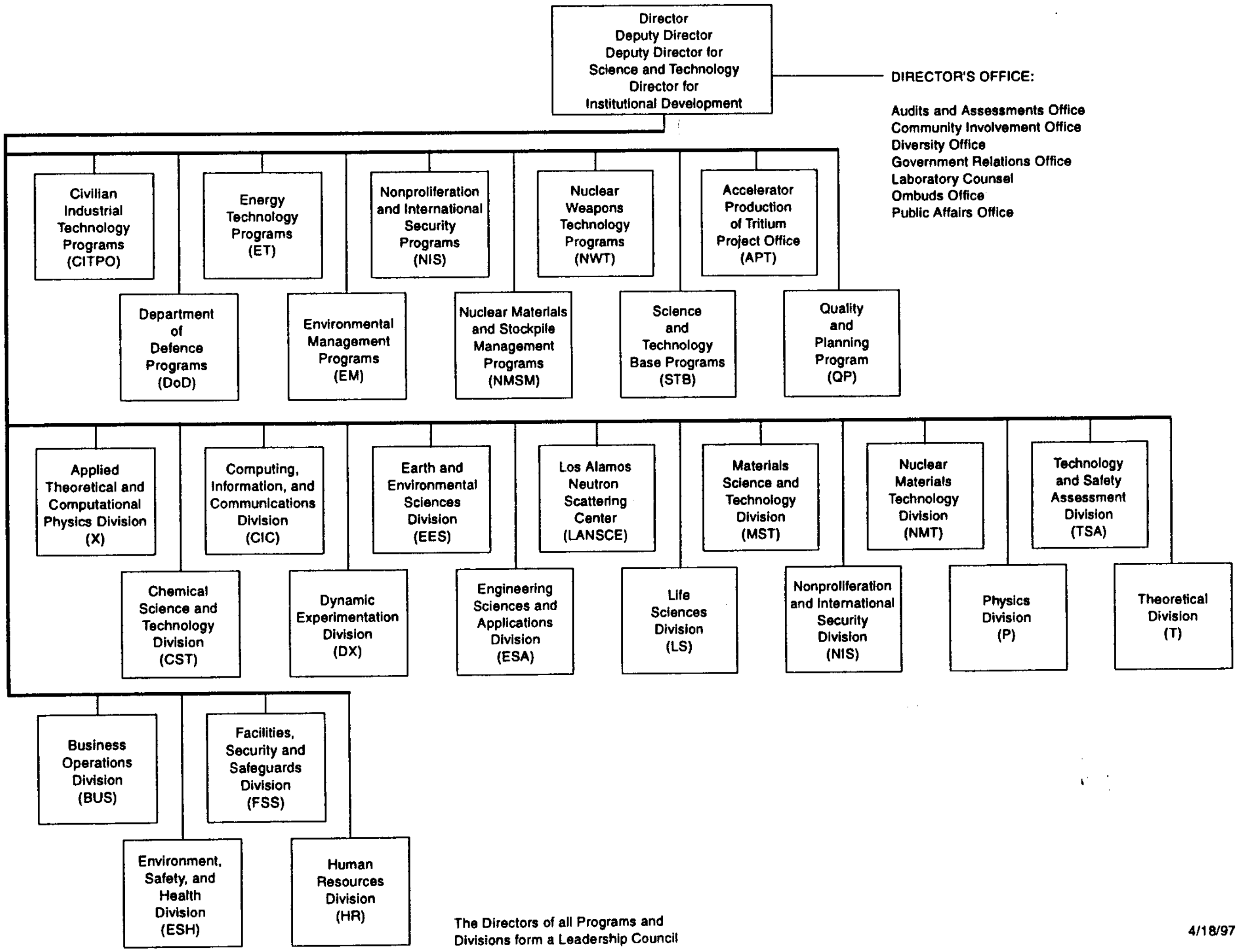

Figure 2-2. Laboratory organization chart.

Offices are organizations that perform specialized functions in divisions and program offices. These functions can include operating a remote installation (e.g., Fenton Hill), overseeing a Laboratory-wide activity (e.g., Public Affairs), and providing specialized interfaces with outside organizations that do not directly sponsor work at LANL (e.g., Community Involvement and Outreach). Office leaders are selected in a competitive process by a division or program directors (LANL 1996e).

2.2.1.2 Responsibilities

Division directors are responsible for providing their divisions' capabilities to support Laboratory programs and for managing their divisions. They

- make commitments and provide technical expertise for completing projects that fall within their division's capabilities,
- manage their division's budgets,
- accept funds from program managers to implement projects,
- are responsible for conducting operations in their facilities and for delivering the required products on schedule and within planned budgets,
- are responsible for the safety of all division employees and for minimizing the environmental impacts of their operations, and
- authorize all hiring and approve all terminations of personnel.

At present, division directors are responsible for managing facilities through the facility management system (Section 3.1 and LANL 1996e).

Group leaders, who report to division directors,

- are responsible for achieving and maintaining technical and professional excellence in their organizations;

- act as proponents for their groups' capabilities and are expected to maintain or expand their groups' work;

- are responsible for managing group resources, which includes hiring individuals to meet Laboratory program requirements and negotiating budgets and funding allocations with the division directors and program managers;

- conduct performance appraisals, manage salaries, oversee the conduct of operations in their facilities, ensure a safe work place, and minimize environmental impacts; and

- are responsible for delivering quality products and services (LANL 1996e).

Office leaders are responsible to their division or program directors for managing the office's resources, championing the office's functions, and delivering quality products and services. Their responsibilities are much the same as those of group leaders (LANL 1996e).

2.2.2 Program and Project Management

Programs are business centers at LANL whose objective is to develop and apply a technology or a set of technologies to satisfy the requirements of a sponsor or group of sponsors. Programs typically last several years, and their annual budgets are often funded at the multimillion-dollar level. The 13 major externally funded programs, through which most funds enter LANL, are

- five DOE weapons technology and energy programs:
  - Nuclear Weapons Technology,
  - Nuclear Material and Stockpile Management,
  - Nonproliferation and International Security,
  - Energy Research, and
  - Energy Technology;
- five DOE environmental management programs:
  - Waste Management,
  - Environmental Restoration and Decommissioning,
  - Environmental Stewardship,
  - Independent Technical Assessments,
  - Field Programs; and
- work-for-others programs:
  - Department of Defense and
  - Science and Technology Basic Research.

In addition, LANL maintains 12 internally funded programs:

- Human Resources;
- Ombuds Office;
- Laboratory-Directed Research and Development;
- Environment, Safety, and Health;
- Legal Counsel;
- Audits and Assessments;
- Information and Material Security;
- Business Management;
- Property Management;
- Information and Records Management;
- Public Relations; and
- Collaborations and Partnerships.

Each program is implemented through a series of projects that are typically of short duration (lasting from periods of months to 1-3 years) and that involve one or more millions of dollars in annual funding. The projects have clearly defined budgets, schedules, objectives (deliverables), and costs as negotiated between the division director and the sponsor. Projects are usually carried out at the group level (LANL 1996e).

2.2.2.1 Roles

Each program has a single program director and one or more program managers. The program director is in charge of marketing, typically provides a single point of contact with sponsors (customers), and provides policy and guidance for allocating funds. Program directors are selected by and report to the LANL director (LANL 1996e).

Program managers, who are selected by the program directors, help develop business opportunities and work with customers to ensure their satisfaction. They oversee program execution and appoint project leaders for the duration of a project (LANL 1996e).

Project leaders provide the technical and professional leadership required to carry out a project. They plan the project, assemble the project team, assign tasks, provide guidance, monitor progress, and manage the project's budget (LANL 1996e).

2.2.2.2 Responsibilities

Program directors have overall responsibility for interacting with LANL's sponsors, developing business opportunities, and securing funds. They are held accountable for overall customer satisfaction, and they lead strategic planning to develop and market capabilities that fulfill sponsor needs (LANL 1996e).

Program managers assist the program director with developing programs, developing project proposals, and executing programs and projects. They work with other project managers to determine the feasibility of projects and with group leaders and division directors to match customer programs with Laboratory capabilities (LANL 1996e).

Project leaders assist program managers with developing proposals for new projects. Once funding has been received, they are responsible for carrying out the project, producing the deliverable, and controlling project schedules and budgets. They negotiate staffing and resources with group management and are accountable to program managers for executing projects and satisfying customers (LANL 1996e).

2.2.3 Subcontractors

LANL has, at present, two major subcontractors: one to take care of general infrastructure and support and one to provide security. In addition, LANL has a large group of subcontractors who supply various goods and services. Each subcontract is negotiated and administered according to federal requirements. Support subcontracts have fixed terms, are regularly recompeted, and depend on the nature of the goods or services required.

2.2.3.1 General Infrastructure Support

Johnson Controls, Inc., of Northern New Mexico (JCINNM, usually referred to as JCI) currently has the general infrastructure support contract for LANL. The contract includes repairing and maintaining facilities and equipment, operating the motor vehicle pool, maintaining Laboratory grounds and roads (including snow removal and trash collection), and operating LANL's recycling and salvage operations. JCI personnel also operate the gas, water, and electricity distribution systems for LANL. This service includes operating the potable water well fields and the water supply and distribution system that serve all of Los Alamos County, Bandelier National Monument, and the Laboratory. JCI also operated the airport at Los Alamos until 1996, when this function was transferred to Los Alamos County. Infrastructure activities are addressed more fully in Section 3.

2.2.3.2 Security and Protection

Protection Technologies of Los Alamos (PTLA) currently holds the security and protection contract for LANL. This service was privatized in the 1980s under the initiative to turn government services over to private industry.

2.2.3.3 Goods and Services

LANL has a large number of subcontracts to obtain goods and services from firms located in northern New Mexico. In recent years, DOE and LANL have shifted much of the support work that had been done by UC employees to subcontractors. For instance, whereas once all office, clerical, and cafeteria personnel were UC employees, most are now supplied by local firms. In addition, LANL has increasingly turned to specialized support contractors to supply trained personnel, such as health physicists, engineers for short-term needs, and writer/editors.

One recent innovation in buying supplies was establishment of a "Just In Time" purchasing system. Firms contract to supply steady-demand items, such as standard computer equipment and office supplies, in a very short time. This approach relieves LANL of maintaining an extensive inventory, reduces warehouse space, and maximizes the dollars spent for supplies (e.g., purchases are limited to an as-needed basis).

Major construction at LANL is also performed under subcontracts. Construction projects are discussed in some detail in Section 3.3.

2.3 Core Competencies

The concept of core competencies is used to describe an aggregation of existing skills used to respond to a diverse set of customers. These core competencies evolve as needs dictate and change in both name and composition through time. Currently, LANL has eight core competencies, which are described in the Institutional Plan (LANL 1997a). The relationship of the core competencies to LANL's central mission is shown in Figure 2-1.

2.3.1 Theory, Modeling, and High-Performance Computing

LANL's high-performance computing research center is one of two such centers designated by DOE to facilitate the solution of complex problems in science, industry, and defense. High-performance computing involves applying unique simulation and advanced computational resources to problems previously beyond the capability of existing computer systems (LANL 1995). The competency combines fundamental theory and numerical solution methods with the power of high-performance computing to model a broad range of physical, chemical, and biological processes. It complements ongoing experiment programs with numerical approaches to solving complex, nonlinear problems, and it also supports the other core competencies.

2.3.2 Complex Experimentation and Measurements

Complex experimentation and measurements involve experiments that use energy sources such as accelerators, high-power lasers, high explosives, and pulsed-power systems. It includes the capability of taking measurements from these experiments using multidisciplinary diagnostics or one-of-a-kind measurement systems across a wide range of physical conditions. It also includes LANL's special research and development facilities for handling radioactive, explosive, and hazardous materials capabilities that are not easily duplicated by other institutions.

2.3.3 Analysis and Assessment

The analysis and assessment competency integrates basic theory and experimental data from many disciplines in realistic simulation models; validates the models through comparison with data obtained through experiments and other information; and converts the models into computer programs for assessing complex systems. Examples of the latter include weapons performance and surety, energy systems, military systems, transportation, atmosphere and ocean environments, manufacturing and materials processes, nuclear facility performance and safety, and health system analysis (LANL 1996f).

2.3.4 Nuclear and Advanced Materials

The nuclear and advanced materials competency includes synthesizing and processing both nuclear and advanced materials and using these materials in existing or future applications. The capabilities include the ability to cast, forge, extrude, draw, form, and machine many types of materials—such as metals, ceramics, and polymers—in both bulk and thin-film forms into complex shapes over a range of sizes from microscopic to massive. The types of materials used include (LANL 1996f)

- radioactive materials (e.g., transuranics, tritium, and man-made radioactive species);
- energetic materials (e.g., high explosives, polymers, binders, and detonators);
- hazardous materials (e.g., beryllium and toxic organics); and
- structural materials (e.g., metals and metal alloys, intermetallic compounds, ceramics, and organic materials such as plastics and polymers).

2.3.5 Nuclear Weapons Science and Technology

Nuclear weapons science and technology comprise LANL's scientific and engineering skills in nuclear weapons design and assessment. Design includes the range of activities from preliminary engineering to full integration of weapons components in a working system. Assessment includes the experimental testing and instrumentation needed to evaluate weapons systems and to perform research in weapons science. It also includes surveillance and fabrication of nuclear weapons components and research in nuclear weapon materials science and technology, with special emphasis on energetic, nuclear, and specialized organic and inorganic materials (LANL 1996f).

2.3.6 Earth and Environmental Systems

The earth and environmental systems competency integrates earth and environmental sciences with physics and engineering disciplines. It provides unique capabilities in biosensors, remote sensing, and space instrumentation and assists basic research in chemical, biological, physical, and engineering sciences by supplying skills in theory, modeling, and measurement. It includes all life and geological sciences on Earth, as well as space science.

2.3.7 Bioscience and Biotechnology

The bioscience and biotechnology competency integrates LANL's capabilities in genomic, molecular, and cellular biology; cytology; structural biology; theoretical and computational biology; spectroscopy; biochemistry; biophysics; and biomedical engineering for studying life processes and systems. These capabilities are being applied to problems in environmental remediation and environmental challenges to human health (e.g., radiation, pollution, and biological and chemical threats) (LANL 1996f).

2.3.8 Nuclear Science, Plasmas, and Beams

This competency integrates the capabilities of beam physics, starting from the origin of the beam to its end use. This range of functions includes developing particle accelerators based on knowledge of the underlying beam physics, understanding how the beam interacts with various fields and matter, and finally answering questions in basic nuclear and plasma sciences based on these interactions. Laboratory research encompasses nuclear, particle, and plasma physics; astrophysics; nuclear chemistry; accelerator technology; laser science; and beam physics. It has a wide range of applications such as neutron scattering, transmutation, plasma processing, radiography, microlithography, and inertial fusion. It is also used in national defense projects (LANL 1996f).

2.4 Programs

LANL has two types of programs: directly funded programs (i.e., those funded by external sponsors) and indirectly funded programs (i.e., those funded through a burden placed on the directly funded programs). Indirectly funded programs include institutional support (e.g., business operations, facilities and utilities, human resources, and regulatory compliance). At present, the burden required for indirect programs is about 50% of incoming dollars. Although these indirect costs seem high, they are required to do business with radioactive and other hazardous materials in a highly regulated environment.

2.4.1 Directly Funded Programs

LANL receives its authority to implement directly funded programs by way of budget classifications (cost codes), as defined by federal budget allocations. These codes, called budget and reporting (B&R) codes, are used to allocate funds for specific types of work on an agency-by-agency basis. For work assigned to LANL, each B&R code is further defined by program codes assigned to the work packages. These program codes specify what work may be done and what funds may be spent. As work is accomplished and paid for, the costs are tallied by B&R code designation. Monies cannot be transferred between B&R codes without DOE or congressional approval.

Programs funded by DOE contribute about 75% to 80% of LANL's direct funds. The additional 20% comes from sources other than DOE. These sources include DoD and other federal agencies, universities, private companies, and some foreign governments. Projects from the non-DOE sector are proposed to LANL and approved by DOE. DOE must be certain that LANL will recover full costs and will not compete with private industry. In addition, LANL must be able to perform the work using its existing experimental capability, and the work must be achievable within current safety and environmental protection requirements. In addition, DOE must also be satisfied that LANL's ability to do DOE's work will not be compromised. If these conditions are met, DOE accepts the proposed work and funds and passes the funded activity to LANL through one of the B&R codes. LANL's major directly funded programs are described below.

2.4.1.1 DOE Weapons Technology and Energy Programs

Most directly funded work at LANL is performed for the five major DOE programs in weapons technology and energy.

2.4.1.1.1 Nuclear Weapons Technology

The Nuclear Weapons Technology Program focuses on providing a nuclear deterrent through proven technical capabilities and weapons science. It includes

- stockpile stewardship activities;
- surety assessment to minimize risk under credible accident conditions and to minimize risk of unauthorized access to weapons;
- weapons science to develop the capabilities needed to accurately understand the details of weapons operation and to predict the effects of aging without the tool of underground nuclear testing;
- developing ways to extend the usable lifetime of weapons remaining in the stockpile while improving their safety and operating reliability;
- research and development of new materials, processes, and components that are more reliable, faster, cheaper, less wasteful, and/or more environmentally benign; and
- maintaining readiness for resumption of nuclear testing at the Nevada Test Site.

2.4.1.1.2 Nuclear Material and Stockpile Management Program

The Nuclear Material and Stockpile Management Program, formerly called the Nuclear Materials and Reconfiguration Technology Program, ensures that the materials used in the nuclear weapons remaining in the stockpile are available, if needed, and are stored or disposed safely, if unneeded. The program includes

- LANL's capabilities for dealing with nuclear materials, such as developing and implementing fabrication methods, reducing waste, controlling and accounting for these materials, preparing certified "standard" materials, and studying the effects of these materials on the environment.

- developing technology to reduce environmental impacts, quantities of waste, and exposure of workers to radiation.

- stabilization technologies to improve capabilities for safely packaging, storing, and monitoring a variety of nuclear materials for extended time periods.

2.4.1.1.3 Nonproliferation and International Security

The goal of nonproliferation and international security is to deter, detect, assess, and respond to threats to domestic or international security when those threats relate to nuclear, biological, or chemical weapons of mass destruction. Programmatic work includes

- developing methods for verifying compliance with treaties, for closely tracking nuclear materials, and for guarding against their diversion;

- identifying and controlling critical knowledge for designing and making such weapons;

- developing instrumentation to detect use of such weapons by foreign entities or terrorists (e.g., onsite, ground-based, airborne, and spaceborne detection systems); and

- creating secure computer networks for high-speed information exchange and computation to assist with analyzing possible or imminent threats, analyzing traditional and new response options, and providing linkage to all relevant Laboratory resources in response to a threat.

2.4.1.1.4 Energy Research

Energy research programs cover an assortment of tasks related either to use of LANSCE or to historical energy-related problems. LANSCE is a proton linear accelerator that "shoots" (accelerates) certain atomic particles down a half-mile-long channel into selected materials (targets). The reactions of these targets provide a detailed basic understanding of the materials and their properties.

Health research funded under this program addresses basic understanding of biological systems, including studies on the human genome, the physical structure (shape) of biological molecules, factors and mechanisms that cause and allow repair of dioxyribonucleic acid damage, computer simulation and computations of biological systems, new medical radioisotopes, and magnetoencephalography (a tool for noninvasive examination of the brain). Environmental research at LANL includes computer modeling of global climate change, airflow over and around features of rough terrain, predictions of the movement of radioactive materials and liquids through soils, and biological methods for removing contaminants from soil and water.

2.4.1.1.5 Energy Technology

Research on energy technology focuses on integrating chemical and material processing. The methods brought together include process engineering, chemistry, computer simulation of processes and process control, and economic and systems analyses. Work activities include modeling internal combustion engines to improve engine design, developing technology to reduce energy use and creation of waste in industry, developing high-temperature superconductors, producing medical radioisotopes, and developing technologies for coal utilization in the US. It also includes projects directly associated with energy supplies and the environment. Studies include increasing US production of oil and natural gas, advanced drilling methods, characterizing Yucca Mountain in Nevada as a repository for high-level radioactive waste, and urban air quality. Finally, it includes transportation and infrastructure. These studies include developing fuel cells, solving technical problems associated with transportation and New Mexico's environment, and performing computer simulation and analysis of large-scale urban transportation systems.

2.4.1.2 DOE Environmental Management Programs

DOE directly funds an extensive program of environmental restoration, pollution prevention, and waste management at LANL.

2.4.1.2.1 Waste Management

Section 3.5 provides detailed information on waste management.

2.4.1.2.2 Environmental Restoration

The Environmental Restoration Program is cleaning up contaminated sites created by the Laboratory's 50+ years of operations (initially over 2,000 sites). Activities include assessing sites, establishing cleanup priorities, obtaining regulatory agency approval of cleanup plans, cleaning up sites, and disposing of the wastes.

2.4.1.2.3 Decontamination and Decommissioning

Some contaminated facilities require decontamination to free space for nonradiological work and/or renovation to meet new requirements. Facilities that cannot reasonably be cleaned up or renovated are removed.

2.4.1.2.4 Environmental Stewardship

The Environmental Stewardship Program is responsible for changing operations to make them more environmentally benign and for keeping LANL employees and managers aware of changing regulatory requirements. The three main thrusts of environmental stewardship are waste minimization, pollution prevention, and material substitution.

2.4.1.2.5 Independent Technical Assessments

This program provides for an independent review of Laboratory operations on an as-needed basis. It supplies "red teams" to perform technical assessments of facilities and processes for DOE. The goal of the reviews is to formulate policy choices that involve fewer environmental impacts.

2.4.1.2.6 Environmental Technology

The Environmental Technology Program is responsible for improving and developing new technologies to solve local, regional, and global environmental problems. Areas of technology development include pollution prevention, waste characterization, waste treatment, site cleanup, automation and robotics, and underground storage tanks.

2.4.1.2.7 Field Programs

LANL assists in solving environmental problems at DOE sites around the country. The Laboratory's larger contributions to date include developing methods for treating high-level radioactive wastes stored in underground tanks at Hanford, methods to stabilize old plutonium wastes, and methods to stabilize and deactivate old surplus equipment and facilities.

2.4.1.3 Work-for-Others Programs

LANL also performs some work for federal agencies other than DOE and the private sector. The DOE calls these activities "work for others." Non-DOE government agencies currently sponsoring research and development at LANL include, but are not limited to, the DoD, National Aeronautics and Space Administration (NASA), National Institutes of Health, the Social Security Administration, the EPA, the US Postal Service, Department of Transportation (DOT), the Internal Revenue Service, the Federal Bureau of Investigation, and the NSF.

2.4.1.3.1 Department of Defense

LANL's DoD Programs Office applies LANL's capabilities in defense science and technology work, which ranges from conducting basic research to providing systems ready for military use. Many of DoD's areas of interest complement DOE projects. Such work includes conventional weapons technology, modeling and simulation, defense beams and sensors, advanced concepts for national security applications, high-performance computing, and biological and environmental technologies.

2.4.1.3.2 Basic Research in Science and Technology

Laboratory research staff receive grants for a wide spectrum of basic and applied research projects from the agencies listed in Section 2.4.1.3. Typically, grants are given for a single year; however, productive research efforts often receive follow-on grants. Outstanding research includes developments in cytometry, biotechnology and biophysics, mapping the human genome, and developing superconducting films and ribbons.

2.4.2 Indirectly Funded Programs

Like any large company, LANL requires support services to operate. These services are paid for by overhead charges on directly funded programs. The rates (or percentages) of these charges, called general and administrative costs, are set annually and must be approved by DOE.

2.4.2.1 Human Resources

The Human Resources Division provides in-house training, ensures that development opportunities exist, and assists with problems in human interactions. The division also manages compensation and fringe benefits and assists personnel with administrative problems.

2.4.2.2 Ombuds Office

The Ombuds Office was established to provide an independent entity at LANL to assist personnel in resolving work-related concerns that are not addressed under the auspices of some other Laboratory office (e.g., the Mediation Center). The services of the ombudsman do not replace these other channels of problem resolution; rather, these services are designed to complement each other (LANL 1997b). The Ombuds Office maintains an informal and confidential atmosphere.

2.4.2.3 Laboratory-Directed Research and Development

The Laboratory-Directed Research and Development (LDRD) Program encourages in-house research that augments LANL's base in science and technology. As the title implies, projects are funded to conduct preliminary investigations into promising research areas and to develop these new research areas into funded projects. Funds for LDRD are set aside as a percentage of each year's total Laboratory operating funds. The percentage of funds set aside and appropriate uses for them must comply with many controls, including public laws, the prime contract between UC and DOE, and DOE regulations and orders.

2.4.2.4 Environment, Safety, and Health

LANL provides ES&H subject matter experts to ensure that operations are performed safely and in compliance with regulations designed to protect human health and the environment. These experts prepare permits; conduct monitoring and reporting functions; offer required guidance, training, and oversight; and establish general institutional standards. Major areas covered by these professionals include environmental protection, health physics, safety and health protection, integrated safety management, and emergency management.

2.4.2.5 Legal Counsel

The Laboratory's Legal Counsel Office is an adjunct of the Director's Office. The principal legal officer advises senior managers on legal matters. Other legal staff provide general counsel and interpretations of the laws and regulations that apply to Laboratory operations and counsel on business matters such as the operating contract between DOE and UC and LANL's subcontracts. They counsel employees on employment and labor law, litigation matters, and workman's compensation issues. They also provide advice and representation on intellectual property rights, including patents and copyrights. Finally, the legal staff represents LANL in lawsuits and other legal matters.

2.4.2.6 Audits and Assessments

LANL's Audits and Assessments Office is the point of contact for all external audits. LANL also performs internal assessments of organizations, facilities, and programs. The assessment process identifies significant potential problems and causative factors, suggests improvements, and tracks the results of process modifications. Information from these assessments is provided to managers to assist in improving overall operations.

At the request of senior management, these staff investigate allegations of any improper activity placing LANL at risk, including allegations of fraud, waste, and abuse. The office also serves as LANL's whistle-blower office, receiving allegations of improper activity from Laboratory managers and employees.

2.4.2.7 Information and Material Security

LANL handles information and materials that require protection because of national security interests. Within the DOE Complex, access authorizations are identified by the terms L- and Q-clearances. These clearances permit holders access based on job requirements to selected classified matter. Table 2-1 shows the differences in access requirements (LANL 1997c). Information about salaries, performance evaluations, and medical conditions, including radiation exposures, is also protected. Section 3.9 provides details on information and material security.

TABLE 2-1

CLASSES OF INFORMATION AND CLEARANCES AT LOS ALAMOS NATIONAL LABORATORY

	Category		
Level	Restricted Data	Formerly Restricted Data	National Security Information
Top Secret	Q[a]	Q	Q
Secret	Q	Q/L[b]	Q/L
Confidential	Q/L	Q/L	Q/L

a. Q-Clearance—Provides access up to top-secret restricted data on a need-to-know basis.
b. L-Clearance—Provides access to limited amounts of classified information, again on a need-to-know basis.

2.4.2.8 Business Operations

LANL's Business Operations (BUS) has responsibility for all financial actions, procurement, and shipping and receiving. Major financial activities include tracking funds, negotiating contracts, compensating personnel, and keeping records. Procurement operations provide small-ticket items from qualified just-in-time suppliers and large-ticket items through competitive bids. LANL's shipping and receiving facility keeps track of all unclassified deliveries and shipments, including chemicals. Chemical orders are tracked using the Automated Chemical Inventory System database. Certain classified items and SNM are delivered directly to the LANL facility that has the proper handling and storage systems. These records are kept separately.

2.4.2.9 Property Management

Following federal property management guidelines, LANL bar-codes property and then assigns this property to an individual who is responsible for its whereabouts and condition. Before an item can be removed from the Laboratory, a record of its interim destination and valid use must be generated and approved. Items of property may be transferred from one individual to another. When items are no longer usable, they are removed from the property inventory system and disposed (LANL 1997d). Being able to account for each item of assigned property is one element of each individual's annual performance appraisal.

2.4.2.10 Information and Records Management

Information and records management includes (1) telecommunications and scientific and administrative computing resources and software; (2) printing and publications, library services, photography, and writing and editing; and (3) records management and document control (LANL 1995). A variety of activities support these functions, including LANL's desire to provide reliable, efficient, state-of-the-art computing and communications resources and information services.

LANL has become a leader in applications of high-performance computing and in business applications of advanced computing, communications, and networking. The goal is to provide LANL staff with an improved capability to handle information more quickly and effectively. Ongoing studies include technological issues surrounding information management, infrastructure services, and application development [e.g., gathering, storing, processing, sharing, and protecting information (LANL 1995)].

LANL maintains a library that contains physical copies of reports, journals, books, magazines, and other items. However, given the large quantity of information generated annually and the need to rapidly access information, LANL has started to develop a virtual library. The virtual library delivers information from digital library resources to researchers' desktop computers wherever and whenever that information is needed. The long-term goal is to create a network of knowledge systems and machines capable of facilitating synergistic collaborations between people (LANL 1995).

To meet this long-term goal, LANL is performing research in a number of areas such as a national information infrastructure that links enabling technologies. These technologies include asynchronous transfer mode networking, object-oriented distributed computing, graphical and multimedia user interfaces, security and privacy capabilities, and data-mining capabilities for specific applications. This research also includes electronic-information-sharing systems that use commercial software components to form an integrated electronic publishing capability with powerful search and retrieval technology.

2.4.2.11 Public Affairs

LANL maintains a public affairs staff to provide accurate information about Laboratory activities and to arrange for visits by government officials and scientists from other countries. The staff also prepare news releases and draft responses to queries from the news media and public interest groups. In addition, they spearhead the community involvement program by listening to and responding to the concerns of the surrounding communities. These concerns include use of local merchants for procurements, availability of jobs to the local workforce, monitoring local environs, and educational opportunities for youth.

2.4.2.12 Collaborations and Partnerships

Through the Civilian and Industrial Technologies Office, LANL connects its scientific and technical capabilities with the needs of universities, industry, and government. This office is the point of contact for making industrial agreements, for developing industrial partnerships, and for participating in the technology transfer program. It uses technologies developed by LANL to assist US industries in the global marketplace, and to improve LANL's research and business operations by using industry's best practices. The work includes transferring to private industry certain technologies related to weapons products and processes and providing technological knowledge to small and often new businesses in New Mexico.

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3.0 SUPPORT SERVICES AND INFRASTRUCTURE

This chapter, which addresses the general support services and infrastructure required to operate LANL, includes descriptions of

- facility management,
- maintenance and refurbishment,
- construction,
- utilities,
- waste management,
- roads and grounds,
- packaging and transportation,
- communications,
- safeguards and security,
- emergency management and response, and
- fire protection.

The Laboratory has about 8 million square feet of structural space. Approximately 7.3 million square feet exist in 1,835 buildings, and about 0.7 million square feet exist in 208 other structures, such as meteorological towers, manhole covers, and small storage sheds. The buildings house more than 9,000 Laboratory employees (including full-time, part-time, visiting, and casual-status employees) and over 4,000 additional contract employees, vendors, and members of the protective guard force.

According to the Laboratory's Institutional Plan for FY97-02 (LANL 1996b), administrative functions occupy 25% of the Laboratory's space, and storage and services, including power facilities, occupy approximately 23%. Thus, central services and infrastructure account for almost half of the Laboratory's structural space. These activities and structures include

- administrative/technical services—facilities used for support functions, including the Director's Office; BUS; Human Resources Division; Facilities, Security and Safeguards Division (FSS); Environment, Safety and Health Division (ESH); and the Computing, Information, and Communications (CIC) Division .

- public/corporate interface—facilities, both restricted and unrestricted, that allow public and corporate access and use. These facilities include the J. Robert Oppenheimer Study Center, Bradbury Science Museum, and special research centers.

- physical support and infrastructure—facilities used for physical support of other Laboratory facilities, including warehouses, general storage, utilities, and wastewater treatment.

The other 52% of LANL space is occupied by a wide variety of laboratories, fabrication facilities, production and testing facilities, and other structures dedicated to research and development.

3.1 Facility Management Program

It is LANL's policy to manage, organize, and conduct its operations in a manner that ensures appropriate levels of safety and complies with environmental laws and regulations. LANL has established a facility management program to integrate operations; engineering; maintenance; health and safety; environmental compliance; and Laboratory policies, procedures, and standards. The Facility Management (FM) Program, when fully implemented, will

- ensure that facility operations are performed correctly and consistently;
- ensure that facility operations are performed in compliance with applicable requirements, laws, regulations, orders, standards, policies, and procedures; and
- provide consistent, cost-effective, and responsive facility capabilities.

As part of the FM Program, LANL has developed general awareness training for conducting operations. Facility managers and line managers lead this training to ensure that Laboratory employees understand facility-specific safety procedures and conduct of operations. Small teams consisting of ES&H and operations personnel assist facility managers with these activities. The goal is to provide operating capabilities that meet programmatic requirements in a timely and cost-effective manner by reducing controllable costs while achieving operational effectiveness. Responsibility for and implementation of the program rests with the various division directors who have landlord responsibilities for various structures and facilities.

3.1.1 Program Development

Historically, LANL facilities did not have designated owners or direct linkage to major programs; therefore, funding was not readily available for needed upgrades and repairs. To solve this problem, in late 1991, LANL chartered a Facilities Management Task Force as part of a reengineering study to determine alternative processes and methods for facilities management and to provide direction and guidelines for program implementation.

The starting point for this work was the "apartment model," wherein the "landlord" (division director) of the facility supports the customers or tenants by providing the design and operational integrity of the facility's ES&H envelope, including maintenance management. The final study was consistent with the original model and provided a blueprint for flexible and accountable facility management by fostering a team approach. The approach focused on the roles, responsibilities, and authorities of division directors, facility managers, and facility management support teams, which form the facility management partnership.

3.1.2 Program Implementation

Facility managers implement the FM Program through facility management units (FMUs), which are defined as

> "A group of structures, systems, and equipment that are related by function or activity or are located contiguously and that serve a particular purpose, capability, or mission need. Facilities include the utility supply and distribution systems and other support infrastructures within the boundary or other identified interfaces" (LANL 1996a).

The FM Program applies to all FMUs and to anyone performing work under LANL's contract with UC, including UC personnel, contractors, and subcontractors. Criteria for defining facility boundaries include

- Nuclear or Nonnuclear Status—The DOE requires that each nuclear facility be a separate entity, especially major facilities, such as the Plutonium-Processing Facility and CMR.

- Hazard Level—It takes more time for a facility manager to oversee high- and medium-hazard areas than low-hazard areas. A single facility manager is able to handle a larger number of office buildings than laboratories.

- Overall Complexity—Because a facility manager is required to know about activities and operations in the facility, more complex areas require more time and effort.

- Contiguity and Geography—Difficulties associated with security, access, and transportation are addressed by considering contiguity and geography. Contiguity is sometimes subordinate to similarity of purpose.

- Similarity of Mission or Purpose—Grouping technical work that is related by type of technology and worker skills allows accountability, flexibility, and responsibility for operations. Similarity is sometimes subordinate to contiguity.

3.1.2.1 Integrated Safety Management

The Integrated Safety Management (ISM) Program is a major program that encompasses the entire Laboratory. Under ISM, the FM Program is required to integrate safety management and work practices, where safety is defined as including ES&H.

3.1.2.1.1 Framework

Safety expectations include standards, policies, requirements, laws and regulations, procedures, engineered and administrative controls, and personal responsibilities that apply to the performance of work. A five-step process used throughout DOE helps establish, implement, and ensure these safety expectations. The five-step process is

- define the scope of work,
- analyze hazards,
- develop and implement controls,
- perform work, and
- ensure performance.

At LANL, a graded approach is used to implement this process. It integrates safety management and applies safety functions at three levels:

- activity level—applies to discrete work activities performed by individuals in the workplace (e.g., the level of application is directly related to the risk involved in the operation being performed).

- facility level—applies collectively, as appropriate, to the activities conducted in a specific facility (e.g., CMR) or, more broadly, to an FMU.

- institution level—focuses on and applies collectively, as appropriate, to the activities conducted at LANL as a whole.

LANL's ES&H commitment establishes unambiguous roles, responsibilities, and authorities, of which the most important are

- line managers, who are responsible for safety;

- program managers, who are responsible for providing funding and are held accountable for expenditures;

- ESH Division, which is responsible for providing safety expertise and services and a process for establishing unambiguous institutional expectations.

UC's president delegates the authority to manage all activities at LANL to LANL's director. The director retains ultimate responsibility.

3.1.2.1.2 Roles and Authorities

Under the ISM system, safe conduct of work requires that each individual fulfill assigned safety roles and be accountable for various safety responsibilities associated with the assigned role. Working safely is every worker's responsibility and is a condition for employment at LANL. The work force ensures that all hazardous work is covered by approved procedures and is done by trained personnel. The work force has authority to perform and will be held accountable for performing work that is covered by safe work practices requirements. Any employee has the authority and responsibility to stop work deemed to be unsafe (i.e., work that presents a clear and present danger). Nonsupervisors are authorized to prepare but not approve activity-level procedures and practices needed for conducting work safely in accordance with institutional and facility expectations.

Under the ISM system, group leaders, facility managers, program managers, and office leaders are authorized to conduct readiness reviews of their operations and to require activity-level safety procedures and practices. They are authorized to approve corrective actions and are expected to participate in developing activity, facility, and institutional safety goals that apply to their organization's work. It is their responsibility to define safety envelopes for facilities.

In addition, programmatic-, facility-, and institutional-level roles are assigned to facility managers and institutional support organizations. The institutional support organizations, which provide an oversight role, include the

- Laboratory Director's Office,
- Legal Counsel,
- Laboratory Leadership Council,
- Operations Working Group,
- Resource Working Group,
- ESH Division,
- FSS Division,
- BUS Division,
- Quality and Planning Office,
- Audits and Assessments Office, and
- Laboratory safety committees.

Working with facility and program management, the institutional support organizations have the authority and responsibility for establishing safety expectations for LANL and the authority to review and provide feedback throughout LANL regarding the effectiveness of safety operations. LANL is ultimately responsible for the safety of all onsite subcontractor organizations. However, safety activities may be assigned to subcontractors by contract. In such cases, LANL exercises due diligence to ensure that subcontractors meet contractual safety obligations.

3.1.2.1.3 Process

Each FMU has a facility management team that provides the infrastructure, processes, and resources required to effectively support safe work practices. The facility management team works with tenant organizations to establish facility-specific safety expectations. Facility expectations define the operational limits and boundaries of facility processes to ensure that the current safety capabilities of the facility (commonly referred to as "facility operating limits" or "safety envelope") are not exceeded. They also establish the requirements for interfaces among tenants, the facility management team, and support organizations.

A facility safety plan is prepared to help facility managers establish, document, and integrate facility-level expectations. Establishing and documenting the facility safety plan is the responsibility of the landlord and is usually delegated, along with other facility management responsibilities, to the facility manager. Development of the facility safety plan begins with a basic understanding of the work and its hazards. Its development includes input from the people doing the work, subject matter experts, and appropriate stakeholders. The plan is tailored to the work, incorporates applicable external standards, and complies with applicable statutory requirements.

The facility safety plan contains a definition of the facility's safety envelope and a description of the facility's administrative and engineering controls. It includes, and is consistent with, institutional expectations (i.e., Laboratory performance requirements, implementation requirements, and guidelines); Laboratory permits; and other institutional requirements. The level of detail of the work description, the rigor of hazard analyses, and the evaluation of facility processes and controls are consistent with Laboratory criteria and are matched to the magnitude of the hazards associated with the facility. For nuclear or hazardous facilities, the facility safety plan may include DOE-prescribed requirements, such as final safety analysis reports, technical safety requirements, safety analysis documents, and unreviewed determinations of safety questions. DOE requires that these reports provide for evaluation of all potential hazards and mitigation measures necessary to protect both workers and the general public. Alternatively, facilities having only low-hazard activities may have short facility safety plans that consist mainly of references to institutional programs or a few facility-specific documents, such as emergency evacuation plans.

3.1.2.2 Facility Manager Assignments

Division directors are ultimately responsible for conducting operations, establishing safety limits, and overseeing operations that occur in their FMUs. The key individuals assisting the division directors are the facility managers. Table 3-1 presents the names of the FMUs, their locations, and the divisions responsible for their operations.

Facility managers, who are appointed by division directors, have the responsibility for operational integrity and the authority to control operations at assigned facilities. At complex facilities, the facility manager may delegate authority to members of the facility management support team, which is chosen by the facility manager. Depending on cost-effectiveness and availability, the facility manager draws members from support divisions at LANL or from outside contractors. To ensure consistent application of regulatory requirements, team members are trained by support organizations, and, when feasible, team members are expected to reside at the facility.

3.1.2.3 Funding

LANL funds the FM Program by making maintenance costs the responsibility of programs. Direct funding of facility maintenance from programmatic budgets ensures that the actual cost of doing work is charged back to the client. User fees are negotiated between facility managers and users based on equitable "rent" payments for space, facility equipment, utilities, supplies, and maintenance costs.

Facility operating budgets include both fixed and variable costs. The fixed costs are general and administrative and include minimum resource requirements for "keeping the doors open." Variable costs represent resource use during operations per unit of operating time and include routine maintenance related to use. Total operating budgets are the sum of the fixed costs and variable costs multiplied by the total expected operating time.

Capital budgets are developed for refurbishing old buildings and equipment and for increasing capacities to meet customer expectations. Once budgets are approved and funded, financial performance is monitored by comparing actual revenues and expenses with projections. The facility manager is expected to identify trends and determine corrective actions.

TABLE 3-1

FACILITY MANAGEMENT ASSIGNMENTS

Facility Management Unit	Facility Name	Location	Owner Division[a]
61	LANSCE	TA-53	LANSCE
62	Business Complex	TA-3 Warehouse, TA-3-170 Gas Plant	BUS
63	CIC	TA-3 CIC Complex	CIC
64	Waste Disposal Facility	TA-54	EM
65	CMR	TA-3-29	CST
66	Radiochemistry Facility	TA-2, TA-48, TA-35 (part), TA-21 (part), TA-46 (part)	CST
67	Explosives and Dynamic Testing	TA-6, TA-8-21, TA-9, TA-14, TA-15, TA-22, TA-35 (part) TA-36, TA-39, TA-40, TA-60, TA-67, TA-69	DX
68	EES Facilities	TA-57, TA-21 West	EES
70	Engineering Complex	TA-21 East, TA-41, TA-33-86, TA-3-39, TA-8 (part) TA-11, TA-16, TA-28, TA-37, TA-46 (part)	ESA
71	ES&H Support Facility	TA-59, TA-3 (part)	ESH
72	Life Sciences Facility	TA-43, TA-54-1001 through 1003	LS
73	Materials Science Complex	TA-3 Sigma Complex, TA-35 (part)	MST
74	Critical Assemblies Facility	TA-18, TA-36-1	NIS
75	NIS Complex	TA-35 East, TA-33 (part)	NIS
76	Plutonium Facility	TA-55	NMT
77	Physics Complex	TA-3-40, TA-3-16	P
78	RD Site	TA-52	TSA
79	Radiation Exposure Facility	TA-51	EES
80	Utilities and Infrastructure	Utility systems, airport[b], roads, and grounds	FSS
81	Unclaimed Facilities	TA-3 administrative facilities, TA-49	FSS
84	Radioactive Liquid Waste Treatment	TA-50	EM

a. Full division names are provided in the acronym list at the end of this document.
b. The airport has been transferred to Los Alamos County and is no longer the responsibility of LANL or DOE.

3.2 Maintenance and Refurbishment

Existing structures and facilities require periodic maintenance, refurbishment, and upgrades. LANL manages maintenance and refurbishment by using resources on an "as-needed" basis. Conducted in compliance with applicable requirements, these activities do not produce uncontrolled releases of hazardous substances, nor do they have adverse effects on environmentally sensitive resources. JCI, LANL's support services subcontractor, has primary responsibility for maintenance and refurbishment. LANL's waste management system readily manages wastes produced by these activities.

Typically, maintenance and refurbishment occur in and around existing buildings, in developed areas, and along existing roadways. Examples include

- maintaining and extending onsite roads and parking areas;
- replacing apparatus and components, such as pumps and filters, to retain and improve facility performance or to extend the useful life of buildings and equipment;
- cleaning, painting, repairing, and servicing buildings, utility lines, equipment, and vehicles;
- decontaminating equipment and facilities;
- erecting, operating, and demolishing support structures to facilitate ongoing operations;
- relocating and consolidating equipment and operations from one location to another at which similar activities are being performed; and
- placing facilities in a safe-shutdown condition when they are not needed.

3.2.1 Condition of Physical Plant

Most LANL facilities have reached the age at which major building systems begin to fail and maintenance and operating costs increase. About 80% of LANL's facilities are more than 20 years old, 50% are more than 30 years old, and 30% are more than 40 years old.

LANL conducts a condition assessment survey to inspect all real property (buildings and installed equipment) at predetermined intervals to ensure that facilities are maintained in a condition consistent with assigned missions and long-range planning. The condition assessment survey identifies the condition of architectural, structural, mechanical, electrical, communications, and safety and security systems and provides estimated budget costs to correct identified deficiencies. The results of the condition assessment survey are shown in Table 3-2.

TABLE 3-2

GROSS SPACE BY PHYSICAL CONDITION

Condition	Percent
Fair	44
Adequate	37
Excellent	1
Good	8
Poor	9
Fail	1
TOTAL	100

3.2.2 Routine Maintenance

Routine maintenance operations (preventive or predictive) are based on an evaluation of probability of failure and magnitude of consequence in the event of failure. The evaluation categorizes both real property and installed equipment in order of importance. These categories are

- Category M1—The failure of the structure, system, or component may cause
  - death or serious injury or illness to a member of the public,
  - severe damage to the environment beyond the boundaries of LANL, or
  - major environmental cleanup.
- Category M2—The failure of a structure, system, or component may cause
  - minor injury, illness, irritation, or annoyance to a member of the public;
  - death or serious (disabling) injury or illness of a Laboratory worker;
  - damage to the environment inside LANL's boundaries that would require limited cleanup;
  - potential loss or theft of Category I quantities of SNM or national security information;
  - total loss of the use of a facility or major process; or
  - severe mission or economic impacts.
- Category M3—The failure of the structure, system, or component would cause
  - no impact on the public but might cause minor injury or illness of a Laboratory worker;
  - damage to the local environment immediately adjacent to the facility that would require minimal cleanup;
  - potential loss or theft of Category II or III quantities of SNM or classified information;
  - damage to a facility or process; or
  - serious impact on the capability of facilities and equipment to meet the quality, schedule, and budget expectations of its users.
- Category M4—The failure of the structure, system, or component would cause
  - no probable impact on the public, Laboratory workers, or the environment;
  - no safeguard or security concerns but might cause minor damage to a facility or process that would interrupt the mission or cause inconvenience.

The goal of scheduled maintenance is to enhance the reliability of systems or components for either safety or economic benefits. The assignment of equipment to one of the four categories shown above provides a starting point for evaluating the basis for scheduled maintenance. Facilities with high risk receive more frequent attention than facilities with low risk. For example, facilities and equipment in Categories M1 and M2 have potential safety implications for both the public and workers; therefore, the benefits derived from routine maintenance are high compared with the potential consequences of untimely equipment failure.

Facility managers are responsible for routine maintenance of real property and installed equipment. Real property and installed equipment include land; improvements such as buildings, roads, fences, bridges, and utility systems; and equipment installed as part of the normal functioning of a building (such as plumbing, electrical, and mechanical systems).

Line management is responsible for routine maintenance of personal property and programmatic equipment. This equipment (reactors, accelerators, chemical-processing lines, lasers, computers, etc.) is used only for programmatic purposes; therefore, costs of maintaining this equipment are directly linked to the users.

In FY95, the total allocation for maintenance and refurbishment at LANL was $54.6 million. This total includes custodial services, snow and waste removal, and landscaping provided by JCI.

3.2.3 Renovations and Upgrades

When approved by DOE and funded by Congress, LANL may undertake major renovations or upgrades to extend the life and usefulness of existing facilities. Typically, these actions are required to meet health, safety, and structural requirements, which have become more stringent over the years. Major upgrades are also undertaken to enable an existing facility to house new research programs or to save the costs of demolishing an old facility and building a new one.

To ensure that LANL can meet its assigned missions over the next 20 years, an increasing percentage of Laboratory facilities will need to be renovated and upgraded as time goes on. Planning and budget processes for these projects are described in Chapter 2; the construction process is described below.

3.3 Construction

Four major DOE programs—Defense Programs, Energy Research, Environmental Management, and Civilian Radioactive Waste Management—describe the minimum project management requirements for implementing DOE Order 430.1, Life Cycle Asset Management (DOE 1995a). This directive applies to all projects, defined as

- strategic systems,
- line item projects,
- operating-expense-funded projects, and
- general plant projects and capital equipment.

3.3.1 Construction Process (Titles I, II, and III)

The planning process described in Chapter 2 is followed by preconceptual design to identify the proposed action, document the mission, and estimate total project cost. Total project cost is composed of the total estimated costs for design, construction, acceptance testing, and operating expense. DOE participates in critical decisions at significant milestones during project development and authorizes the next set of activities. Critical decisions include

- CD1—approval of mission need: expense funds authorized;
- CD2—approval of baseline (plans, estimate, and schedule): capital funds authorized;
- CD3—start construction: funds obligated; and
- CD4—completion of facility and start of operations.

DOE manages the project baselines, including scope, budget cost and schedule, and authorization to expend capital funds. Architect-engineer (A-E) design subcontractors are hired to provide technical support and design documents in sufficient detail to ensure project success. LANL uses the federal acquisition regulations (FARs) to acquire the services of outside A-E firms for larger projects.

CD-2 results in an authorization from DOE to proceed with a Title I (conceptual design) summary report prepared by an A-E firm for additional review and approval by DOE before beginning Title II (design). JCI provides these services for appropriate smaller projects, including expense-funded projects. Completion of the detailed design, plans, cost estimate, and project schedule allows obligation of funds and start of construction (CD-3).

Typically, construction contractors are hired to perform the actual construction and installation of equipment [Title III (construction)]. LANL prepares the construction contracts in compliance with federal acquisition regulations. Engineering interfaces among LANL, DOE, and the construction contractors are maintained during Title III to ensure adequate controls and customer coordination.

Completion of Title III includes conducting final inspections, correcting deficiencies, and, after DOE has conducted a preoccupancy safety inspection (CD-4), transferring the facility to the owner division and facility manager. Facility startup includes installing personal property and programmatic equipment. Project closeout consists of final reconciliation of project costs (e.g., all project costs have been identified, all costs have been charged to the appropriate cost accounts, all invoices have been paid, and all accounts have been formally closed). LANL prepares a final closing statement for DOE's review and approval.

3.3.2 Near-Term Projects

Near-term projects involve design, construction, or acceptance testing. These projects have received authorization and funding from (1) Laboratory management for expense projects, (2) DOE for general plant projects, or (3) Congress for line item projects. Information on the justification, estimated costs, schedule, and funding profile for each near-term project can be found in the Capital Assets Management Plan Report (LANL 1995a).

3.3.3 Out-Year Projects

Out-year projects are in the preconceptual planning stage and have not been authorized by DOE or Congress. These projects arise when LANL personnel evaluate anticipated DOE-directed work and facility requirements against existing facility capabilities. These projects are in a state of flux, being rescoped and refined continually as LANL management and DOE come into agreement on future assignments. Out-year projects are included in the Capital Assets Management Project Report; however, their listing does not imply decisions by Congress, DOE, or LANL about a project's scope, viability, cost, or location.

3.4 Utilities

Ownership and distribution of utility services are split between DOE and Los Alamos County. DOE owns and distributes all utility services to LANL facilities, and the county provides these services to the communities of White Rock and Los Alamos. DOE also owns and maintains several main lines for electrical, natural gas, and water distribution located throughout the town's residential areas. The county's Department of Public Utilities taps into these main lines at a number of locations and owns and maintains the final distribution systems.

Utility systems at LANL include electrical service, natural gas, steam, water, sanitary wastewater, and refuse. Electrical service includes operating and maintaining the complete power system, including retrofilling or replacing polychlorinated biphenyl (PCB) transformers, coordination with the County Resource Pool, generation as needed at the TA-3 power plant, and distribution to the input side of low-voltage transformers at Laboratory facilities. The natural gas system includes a DOE-owned high-pressure main and distribution system to Los Alamos County and pressure-reducing stations at Laboratory buildings. Steam systems include production and distribution at TA-3, TA-16, and TA-21. The water system includes supply wells, water chlorination, pumping stations, storage tanks, and distribution systems. Sanitary wastewater systems include septic tanks, a new, centralized sanitary wastewater collection system, and a treatment plant. JCI collects refuse, which is combined with refuse from Los Alamos County and disposed in a landfill owned by DOE and managed by Los Alamos County. Under special agreement, this landfill also takes refuse from the City of Española.

3.4.1 Gas

Los Alamos County currently purchases natural gas from Meridian Oil Company in the San Juan Basin of northwestern New Mexico. The DOE independently purchases gas from Duke Solutions' Energy Office in Salt Lake City, Utah, through a DOE/DoD Federal Defense Fuels Procurement. The DOE and Public Service Company of New Mexico (PNM) own portions of the main gas supply line coming into and crossing Los Alamos County. This line is also used to provide gas to customers in the Española, Taos, and Red River areas. The DOE has agreed to sell its share of this line to PNM in the near future. Figure 3-1 shows the gas distribution system at LANL.

The county and LANL both have delivery points at which gas is monitored and measured. In 1994, the county used approximately 946,000 decatherms (DTH) of gas, compared with the 1,682,000 DTH used by LANL. About 80% of the gas used by LANL was used for heating (both steam and hot air). The remainder was used for electrical generation to fill the difference between peak loads and the electric distribution system's capacity. If the demand for natural gas increases, the existing gas distribution system, portions of which are 47 years old, will require modification and/or replacement.

As shown in Table 3-3, LANL burns natural gas to produce steam to heat buildings at three technical areas (TA-3, TA-16, and TA-21). The use of gas to produce steam remained relatively constant over the five years from 1991 to 1995. Peak use occurred in 1993 when the TA-3 steam/power plant used about 775,000 DTH of gas to produce steam and about 412,000 DTH to generate electricity. The low-pressure steam is supplied to the TA-3 district heating system and the electricity is routed into the power grid. The TA-3 steam distribution system has about 5.3 mi (8.5 km) of steam supply lines and an additional 5.3 mi (8.5 km) of condensate return lines. Most of the condensate return lines are old and corroded, resulting in the loss of up to 10-20 million gallons per year of treated condensate. In addition, operation and maintenance costs for the district heating system (which supplies steam heat) are 3 to 4 times that of natural gas at about $5 million per year. Without upgrades, these costs will increase dramatically.

Gas use at the TA-16 and TA-21 steam plants is small compared with use at the TA-3 power plant. In addition, under a shared savings contract, JCI has replaced the TA-16 district heating with small, natural-gas-fired, distributed heaters and boilers. Based on 1993 data, gas consumption at the old TA-16 steam plant was 336,543 DTH, and gas consumption at the TA-21 steam plant was 81,510 DTH.

3.4.2 Electricity

In 1985, the DOE and Los Alamos County formally agreed to pool their electrical generating and transmission resources and to share bulk power costs based on usage. The Electric Resource Pool currently provides bulk electricity to LANL and customers in the communities of White Rock and Los Alamos, as well as in Bandelier National Monument. Pool resources currently provide from 99 MW in winter to 117 MW in summer (Hinrichs and Lundberg 1997) from a number of hydroelectric, coal, and natural gas power generators throughout the western US, including hydroelectric generators owned by Los Alamos County. The pool sells excess power to other area power utilities. Power delivered to the Electric Resource Pool is limited by the two existing regional 115-kV transmission lines, one owned by PNM and the other by DOE. The two 115-kV electric power transmission lines come from the Bernalillo-Algodones substation near Albuquerque and the Norton Substation near White Rock. Many northern New Mexico communities, including Santa Fe and Española, also receive power from these substations. Onsite electric generating capacity for the pool is limited to the existing TA-3 steam/power plant, which has a design capacity of 20 MW.

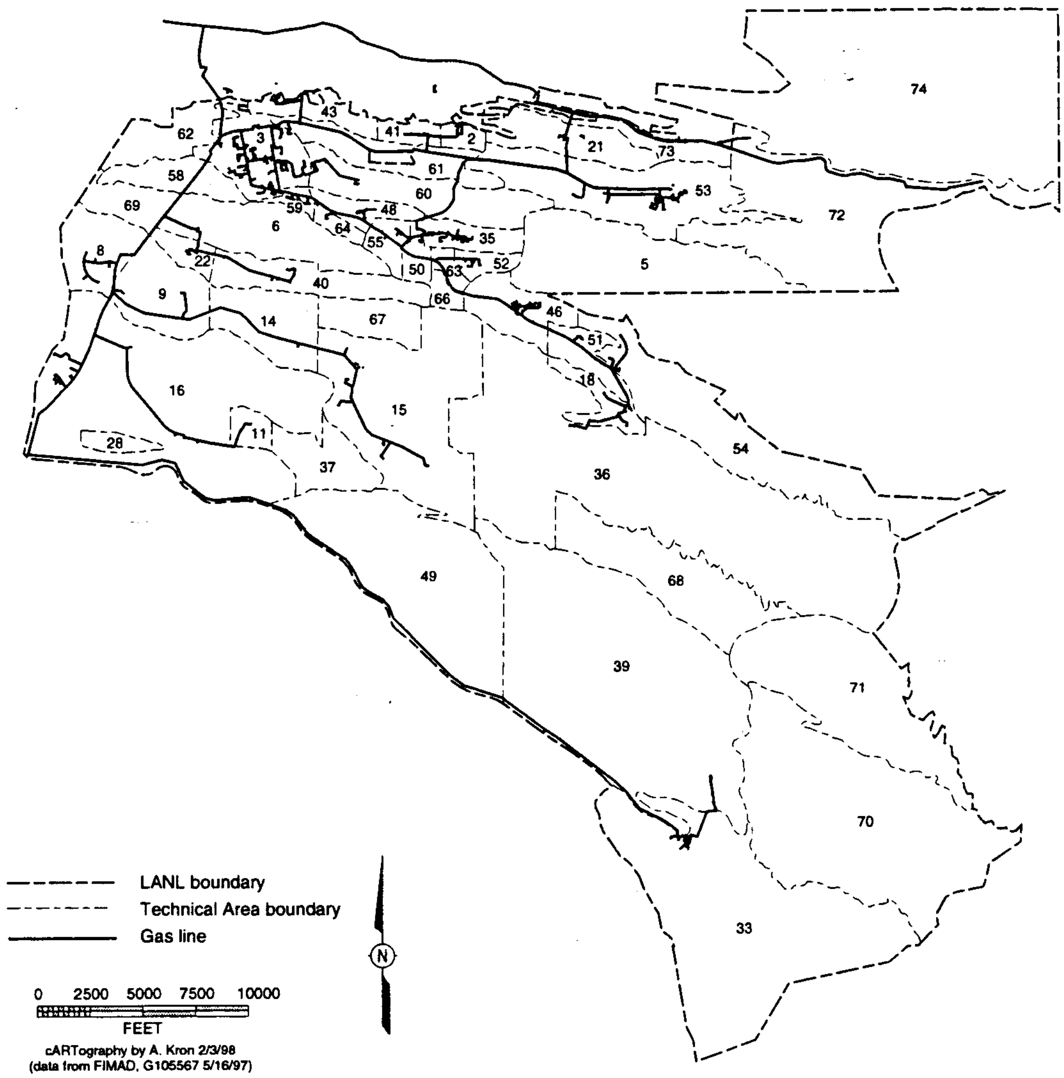

Figure 3-1. Gas distribution system at the Laboratory.

TABLE 3-3

GAS CONSUMPTION (DTH) AT LANL FY91–FY95

	FY91	FY92	FY93	FY94	FY95
Total LANL Consumption	1,480,789	1,833,318	1,843,936	1,682,180	1,520,358
Total Used for Electricity Production	64,891	447,427	411,822	242,792	111,908
Total Used for Heat Production	1,415,898	1,385,891	1,432,113	1,439,388	1,408,450
TA-3 Steam Production	471,631	387,421	774,750	719,769	583,229
TA-16 Steam Production	252,916	282,206	336,543	314,430	328,332
TA-21 Steam Production	78,261	74,673	81,510	60,613	65,026
Total Steam Production	803,168	744,300	1,192,803	1,094,812	976,587

Source: Gonzales 1997.

Tables 3-4 and 3-5 show peak demand and annual use of electricity for FY91 to FY95. LANL's usage ranged from about 352,000 MWh in FY94 to about 382,000 MWh in FY92. Most of this fluctuation was a result of power consumption by LANSCE. Peak demand declined from about 76,000 kW in FY91 to about 66,000 kW in FY95. Again, this reduction is attributable to the decline in power demand at LANSCE.

TABLE 3-4

ELECTRIC PEAK COINCIDENTAL DEMAND (kW) FOR DOE'S FISCAL YEARS 1991 TO 1995*

	LANL Base	LANSCE	LANL Total	City Total	Pool Total
FY91	43,452	32,325	75,777	11,471	87,248
FY92	39,637	33,707	73,344	12,426	85,770
FY93	40,845	26,689	67,534	12,836	80,370
FY94	38,354	27,617	65,971	11,381	77,352
FY95	41,736	24,066	65,802	14,122	79,924

*The total pool is a coincidental peak or the highest peak hour of a given month or year. The subsets are components that make up the load during the peak hour.

Source: Hinrichs 1997.

Historically, offsite power system failures have disrupted operations in LANL facilities; therefore, all facilities that require safe shutdown capability during power outages are equipped with emergency generators to ensure that safe shutdown can occur. The emergency generators serve

TABLE 3-5

ELECTRIC CONSUMPTION (MWh) FOR DOE'S FISCAL YEARS 1991 TO 1995

	LANL Base	LANSCE	LANL Total	City Total	Pool Total
1991	282,994	89,219	372,213	86,873	459,086
1992	279,208	102,579	381,787	87,709	469,496
1993	277,005	89,889	366,894	89,826	456,720
1994	272,518	79,950	352,468	92,065	444,533
1995	276,292	95,853	372,145	93,546	465,691

Source: Hinrichs 1997.

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such nuclear facilities as TA-55 and CMR, which require uninterrupted power for critical ventilation, control systems, and lighting.

The TA-3 steam/power plant currently provides the additional electric power needed to meet peak load demands when demand exceeds contract import rights (71 MW). When electric power generation is required, steam production is increased (additional gas is burned), and the extra steam is routed to three steam turbines. Typically, peaking power is needed for only a few months out of the year when LANSCE is fully operational. Loss of power from the regional electric transmission system results in cutting off the power supply to Los Alamos. The TA-3 steam/power plant is the only local source of sufficient capacity to prevent a total blackout. The TA-3 steam/power plant, which is over 40 years old, needs various upgrades of the steam turbine generators, battery banks, circuit breakers, metering, and power generation controls. In addition, though the steam/power plant has a design capacity of 20 MW, the existing cooling system (composed of low-pressure steam condensers, pumps, valves, and piping) limits the generating capacity to 12 MW in summer and 15 MW in winter (Hinrichs and Lundberg 1997).

A retrofit of the existing TA-3 steam boilers to increase electric power generation capacity and reliable electric power for LANL could be accomplished by replacing the turbine generators with natural-gas-fired, low-emission, combined-cycle turbine generators backed up by oil fuel and boilers that recover exhaust heat. During construction, the TA-3 plant will still be able to supply steam for the TA-3 district heating system. Increased demand for natural gas for electric power generation would require additional natural gas capacity unless an alternate fuel were made available during peak demand periods. Oil backup is available at TA-3.

Another approach would be to install a new 10-mi- (17-km-) long 345-kV transmission line from PNM's Norton Substation to the new 345-/115-kV South Technical Substation at TA-70 near White Rock, which would increase capacity and reliability and enable the Laboratory to keep pace with projected growth in its power requirements, including those for the low-energy-demonstration accelerator. This option might require acquisition of a right-of-way.

Most of the Laboratory's 120-mi (200-km) 115-/13.8-kV overhead electrical distribution system—including transformers, switchgear, and other components—is past or nearing the end of its design life. As a result, the likelihood of component failure is increasing, and many of the components are no longer replaceable. When additional power is supplied through the system to meet projected power demands, most of the Laboratory's 480-/277-V and 208-/120-V systems will fall below industry reliability standards. Thus, backup and replacement transformers and their ancillary equipment are needed to increase system reliability. The Laboratory's electrical distribution system is shown in Figure 3-2.

3.4.3 Water

DOE currently supplies potable water to all of Los Alamos County, LANL, and Bandelier National Monument and supplies some nonpotable water to LANL for industrial use. The DOE has rights to withdraw 5,541.3 acre-feet [about 1,806 million gallons (6,836 million liters)] of water per year from the main aquifer. In addition, DOE obtained the right to purchase 1,200 acre-feet [about 391 million gallons (1,480 million liters)] of water per year from the San Juan-Chama Transmountain Diversion Project in 1976. Although these San Juan-Chama water rights exist, no delivery system is in place.

Potable water is obtained from deep wells located in three well fields (Guaje, Otowi, and Pajarito). This water is pumped into production lines, and booster pump stations lift the water to reservoir storage tanks for distribution. The entire water supply is disinfected with chlorine before distribution. DOE's potable water production system consists of 14 deep wells, 153 mi (246 km) of main distribution lines, pump stations, storage tanks, and 9 chlorination stations. DOE and Los Alamos County are currently negotiating a possible transfer of most of this system to county ownership. Los Alamos County already owns and maintains the distribution system for the communities of Los Alamos and White Rock.

Portions of the Laboratory's water system—including pressure-reducing valves, block valves, hydrants, and 8,400 ft (2,600 m) of transite asbestos fiber piping—have been in place for about 50 years. In addition, another 30 mi (48 km) of distribution piping is near the end of its useful life and needs replacement. The Laboratory's water distribution system is shown in Figure 3-3.

During FY94, DOE withdrew about 1,430 million gallons (5,490 million liters) from the aquifer (Table 3-6). Of this total, the county used about 64% [about 922 million gallons (3,440 million liters)]; the National Park Service used about 5 million gallons (19 million liters) for Bandelier, Tsankawi, and Ponderosa Camp Grounds; and the Laboratory used the remainder, approximately 487 million gallons (1,843 million liters).

The projected annual water demand is expected to increase to about 87% of the main aquifer water right or 1,571 million gallons (5,946 million liters) (DOE 1996a). To meet this projected demand, LANL and Los Alamos County may need to institute additional water conservation and recycling and/or install a delivery system for the San Juan-Chama water.

The Water Canyon Gallery used to supply nonpotable water to the TA-16 steam plant (Table 3-7). This system consists of about 1 mi (1.6 km) of water line and a catchment basin improvement at a spring. In 1994, this gallery produced about 12 million gallons (45 million liters) of water. The TA-16 steam plan is now shut down; thus, this water is no longer needed.

3.5 Waste Management

Most wastes produced at LANL are similar to those of a small town; they include office trash, cafeteria waste, sewage, construction debris, and drain waters from sinks and cooling towers. LANL produces smaller amounts of other wastes, including administratively controlled industrial solid wastes, toxic wastes, hazardous wastes (including chemicals and explosives), low-level radioactive wastes (LLW), transuranic (TRU) wastes, and mixtures of the above.

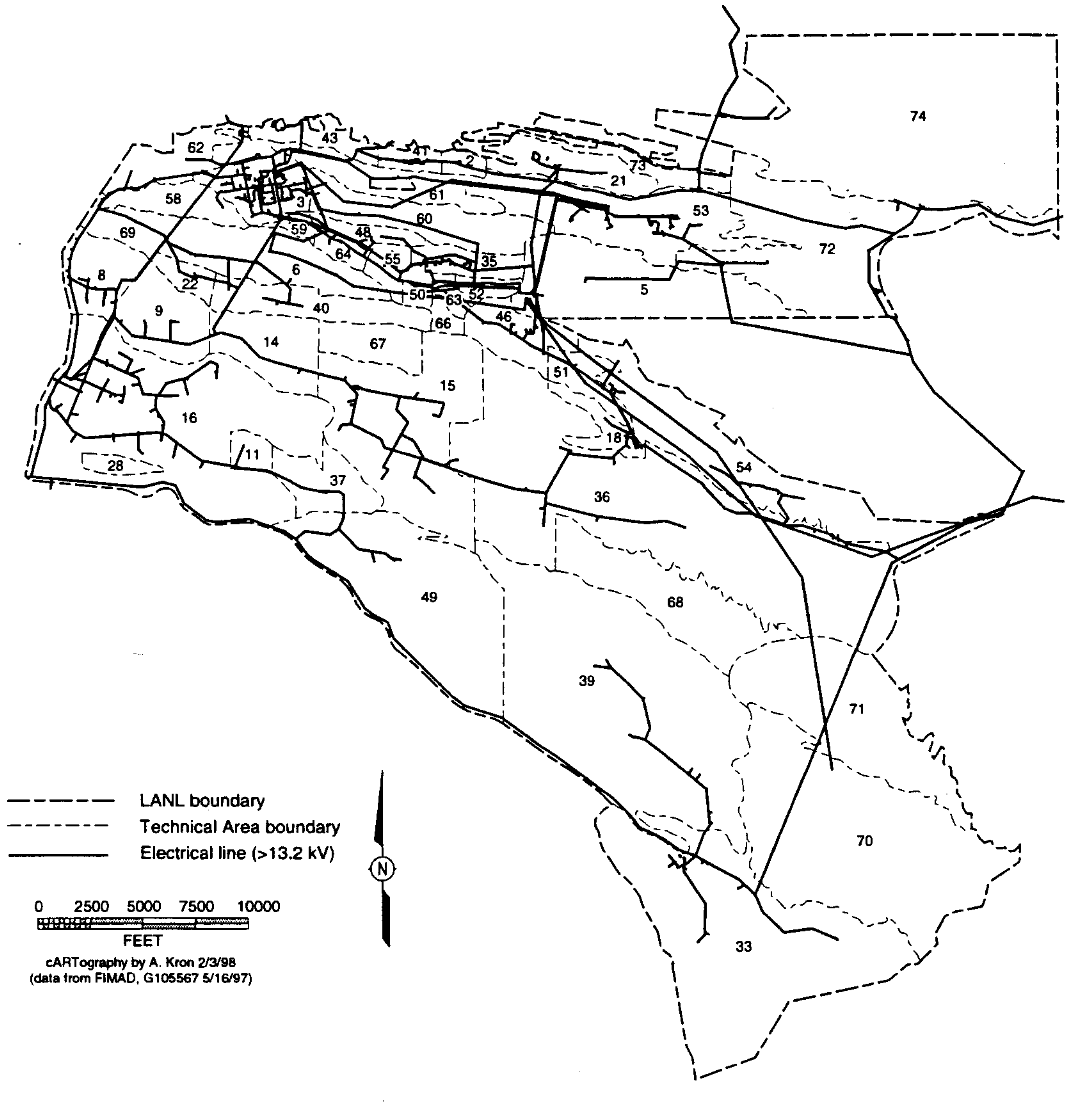

Figure 3-2. Electrical distribution system at the Laboratory.

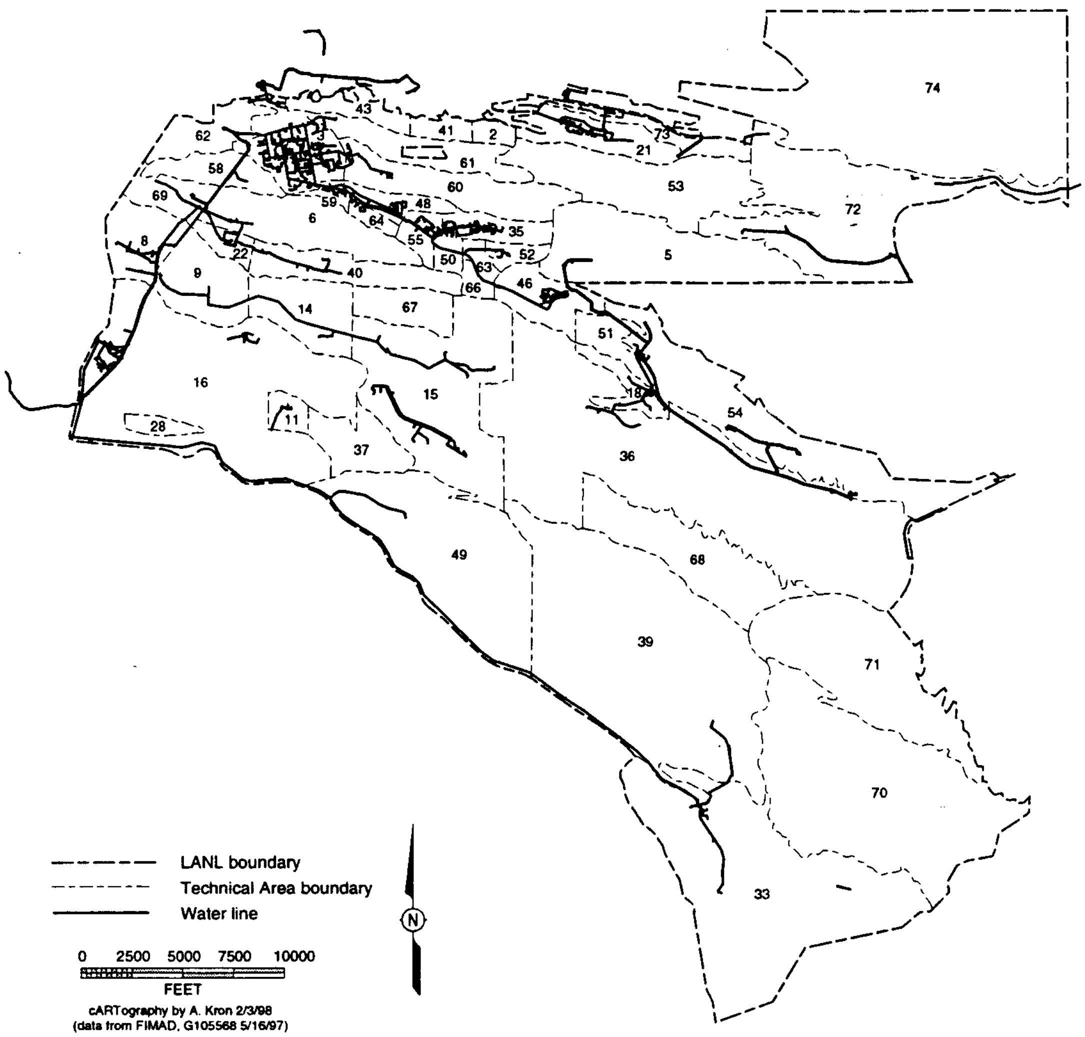

Figure 3-3. Water distribution system at the Laboratory.

TABLE 3-6

POTABLE WATER PRODUCTION AND ESTIMATED USE (MILLION GALLONS)

	1991	1992	1993	1994	1995
LA Field	125	13	0	0	0
Guaje Field	502	472	298	179	230
Pajarito Field	820	1,044	876	1,042	1,126
Otowi Field	0	0	284	206	0
Water Canyon Gallery	0	0	0	0	0
Total	1,447	1,529	1,458	1,427	1,356
LANL Use	500	500	500	500	500
LA County and National Park Service	947	1,029	958	927	856

Sources: Purtymun et al. 1994, Purtymun et al. 1995a, Purtymun et al. 1995b, McLin et al. 1996, and McLin et al. 1997.

TABLE 3-7

NONPOTABLE WATER PRODUCTION* (MILLION GALLONS)

	1991	1992	1993	1994	1995
Water Canyon Gallery	12	0.1	6.4	11.6	1.6
Guaje Canyon Reservoir	1.5	0.0	0.0	0.0	0.0
Los Alamos Canyon Reservoir	2.4	0.0	0.5	0.0	1.6
Total	15.9	0.1	6.9	11.6	3.2

*Nonpotable water is used for makeup water at the steam plants. The large reduction in use from 1994 to 1995 reflects the changes made at the TA-16 steam plant.

Sources: Purtymun et al. 1994, Purtymun et al. 1995a, Purtymun et al. 1995b, McLin et al. 1996, and McLin et al. 1997.

Wastes can be described as either "mission wastes" or "legacy wastes." Mission wastes are generated by current and anticipated operations, and a management path has been established for these wastes from generation to disposal. The term legacy waste, as used here, encompasses three types of wastes encountered at LANL: (1) orphan wastes (wastes that cannot be traced to a specific program or operation), which are occasionally found on Laboratory lands, (2) wastes that were created by past operations and now require proper disposal (i.e., much of the material resulting from site cleanup activities being performed by the Environmental Restoration Program), and (3) regulatory wastes (i.e., wastes that are defined as mixed or TRU wastes under RCRA and NMED regulations) in storage pending development and availability of technologies for safe treatment and disposal. LANL's goal is to reduce (and eliminate by 2002) the amount of legacy wastes stored onsite.

Waste management activities encompass the several ways in which both mission and legacy wastes are collected, transported, stored, treated, and disposed. The infrastructure support subcontractor, currently JCI, manages trash, including recycle and salvage operations. Hazardous wastes are collected at TA-54 to be turned over to commercial waste management firms. Low-level solid radioactive wastes are buried in designated locations at TA-54, Area G. Mixed and transuranic wastes are collected and stored at Area G pending shipment offsite. Aqueous radioactive wastes are collected at the Radioactive Liquid Waste Treatment Facility (RLWTF) at TA-50, where the contaminants are removed by chemical coagulation, flocculation, and sedimentation. (This process will soon be changed to ultrafiltration, followed by reverse osmosis coupled with biodegradation of nitrates). The resulting liquids discharged to the land surface and the sludges are collected in drums, solidified, and managed as TRU wastes.

Characterization—the identification of waste composition and properties—involves knowledge of the processes that produced the waste, sampling and analysis, radiological testing, or combinations of these techniques. Characterization ensures that the generator and waste management personnel recognize the inherent hazards associated with the wastes and their containers, consider the range of treatment and disposal options that can be applied to the waste, and understand the relevant regulatory requirements. Services provided by waste management personnel center on four activities:

- transport involving proper packaging and transportation;
- storage occurring before or after transport and before or after treatment;
- treatment involving methods, techniques, and processes to reduce waste volumes; to change the physical, chemical, or biological characteristics of the waste; or to change the composition of the wastes to render them nonhazardous or less hazardous; and
- disposal in a permanent location in a manner that provides isolation from the biosphere and requires substantial effort for retrieval.

The main storage and disposal facilities at LANL are

- Los Alamos County Landfill—a DOE-owned landfill on East Jemez Road operated under a special-use permit by Los Alamos County; the landfill accepts office and cafeteria trash, county trash from the Laboratory, and trash from Española.
- TA-54, Area J—a disposal site for nonhazardous solid wastes, including administratively controlled industrial solid wastes and oil-contaminated soils.
- TA-54, Area L—a storage site for liquid chemical wastes, solid and liquid PCB wastes, used gas cylinders, small quantities of hazardous wastes in 5-gal. (19-L) lab packs that are separated if incompatible and stored, and drums of liquid low-level mixed waste.
- TA-54, Area G—a site for disposal of most LLW and storage of TRU waste. Some low-level mixed waste is also currently stored in one part of Area G but may be relocated to Area L as the backlog of mixed wastes is shipped offsite over the next 10 years for treatment and disposal. Pyrophoric uranium chips are stored outdoors in drums of oil. Radioactively contaminated PCB liquid wastes and asbestos wastes (asbestos suspected of being contaminated with radioactive material) continue to be disposed at a monofill disposal cell (a cell that receives only one type of waste). The Area G facility is located on Mesita del Buey Road at the east end of TA-54 and has been a disposal site since 1957.

3.5.1 Nonhazardous Wastes

Nonhazardous liquid and solid wastes are produced, collected, and disposed at LANL.

3.5.1.1 Nonhazardous Liquid Waste

Sanitary liquid wastes are delivered by dedicated pipelines to the Sanitary Wastewater Systems Consolidation (SWSC) plant at TA-46. The plant has a design capacity of 600,000 gal. (2.27 million liters) per day and in 1995 processed a maximum of about 400,000 gal. (1.5 million liters) per day. Some septic tank pumpings are delivered periodically to the plant for treatment via tanker truck. Sanitary waste is treated by an aerobic digestion process. Liquid effluent is treated and recycled to the TA-3 power plant as makeup water for the cooling towers or is discharged to Sandia Canyon adjacent to the power plant under an National Pollutant Discharge Elimination System (NPDES) Permit NM0028355 and groundwater discharge plan (LANL 1996c). Solids are dried in beds at the SWSC plant and are landfilled in dedicated space with limited public access. These dried solids are used as soil amendments for erosion control in specified areas of LANL where construction has occurred.

According to the LANL Utilities and Infrastructure Group, the TA-3 sewer lines between Pajarito Road and Diamond Drive and between Diamond Drive and the SWSC connection are 40 years old and are flowing at 58% to 68% of capacity as the result of deterioration and infiltration. These lines will need to be refurbished or replaced if new construction results in significantly increased loads.

Some industrial effluent at LANL is discharged into the local environs via NPDES-permitted outfalls. To comply with new regulatory requirements and the discharge limitations specified in LANL's NPDES permit, DOE has decided to eliminate 27 of the 88 industrial effluent outfalls associated with wetlands. The action includes modifying plumbing to reroute effluent from 14 outfalls into the sanitary sewage system, replacing parts of the cooling water system to recycle once-through cooling water, and changing operations to eliminate discharges from 13 outfalls. When the industrial effluent discharge has been eliminated, these outfalls will be removed from the NPDES permit. The existing piping from the effluent source to the discharge point will be removed or plugged. The reader is referred to DOE's environmental assessment for effluent reduction (DOE 1996b) for a detailed description of the activities being undertaken and an evaluation of consequences.

3.5.1.2 Nonhazardous Solid Waste

Office and cafeteria trash are collected by compactor trucks and delivered to the Los Alamos County landfill. LANL contributed 22% [2,649 tons (2,402,643 kg)] of the total quantity of trash disposed at the landfill during calendar year (CY) 1995; the remainder came from the county and the City of Española. LANL also sent 5,689 tons (5,160,000 kg) of concrete/rubble, 776 tons (704,000 kg) of construction and demolition debris, 82 tons (74,000 kg) of brush for composting, and 45 tons (41,000 kg) of metal for recycling to the landfill construction and demolition area during CY95. Table 3-8 presents a summary of the materials collected by JCI at LANL's salvage yard during FY95 and sold to area dealers in recycled materials.

Administratively controlled nonhazardous and nonradioactive wastes are disposed in Area J, a controlled location at TA-54. These wastes include, but are not limited to, classified waste, sensitive waste, special wastes defined by the State of New Mexico, and empty containers whose capacity is greater than 30 gal. (113 L). New Mexico special wastes include treated, formerly characteristic (before treatment) hazardous wastes (Section 3.5.2). Classified waste is any classified mate-

TABLE 3-8

QUANTITIES OF WASTE RECYCLED BY JCI IN FY95

Waste Material	Pounds	Kilograms
Paper	759,720	345,327
Photographic film	2,200	1,000
Lead w/steel	53,533	24,333
Lead acid batteries	25,365	11,530
Electric cable	16,091	7,314
Aluminum shavings	2,210	1,005
Scrap steel/tin/iron	681,310	309,969
Aluminum solid	71,800	32,636
Copper	1,604	729
Stainless steel	3,590	1,632
Brass	110	50
Tires	16,400	7,455
Waste oil	214,345	97,430
Flammable liquids	115,837	52,653
Chemicals	35,257	16,026
Mercury light bulbs	3,164	1,438
Gas cylinders	2,770	1,259
Phone books	12,200	5,545

rial that has been determined to be waste. In CY95, the landfill at Area J received and disposed of 128 yd^3 (~98 m^3) of solid, administratively controlled wastes.

Regulations for use or disposal of sewage (EPA 1996) establish numerical, management, and operational standards for using sewage as fertilizer or for surface disposal. Under these regulations, LANL is required to collect representative samples of sewage sludge to demonstrate that it is not a hazardous waste and that it meets LANL's administrative requirements (LANL 1995b). During 1995, the Sanitary Waste System Consolidation Plant generated approximately 38 dry tons (34,500 kg) of sewage sludge. Analytical monitoring demonstrated 100% compliance with minimum federal and Laboratory standards for land application. In June 1995, the Groundwater Protection and Remediation Bureau of the NMED approved LANL's groundwater discharge plan application to apply dried sanitary sludge from the TA-46 Sanitary Waste System Consolidation Plant for a period of five years. The sewage sludge landfill is operated by the county.

3.5.2 Hazardous Wastes

Hazardous wastes at LANL include gases, liquids, and solids such as compressed-gas cylinders containing combustible gases; acids, bases, and solvents; out-of-date laboratory chemicals; and lead bricks. At present, no disposal facility for hazardous chemical waste exists at LANL. Hazardous wastes are shipped offsite for further treatment and disposal to facilities designated in accordance with the Resource Conservation and Recovery Act (RCRA). The Laboratory managed approximately 2,554,359 lb (1,158,638 kg) of RCRA hazardous waste in CY95.

3.5.2.1 Hazardous Liquid Wastes

Incompatible drums of liquid chemical wastes are segregated, temporarily stored (accumulated) at Area L in TA-54, and sent offsite for treatment and disposal. For example, during 1995, the last 7 high-concentration (>500 ppm) PCB transformers were replaced with non-PCB transformers. The liquid from the old transformers was stored at Area L until it could be shipped for treatment and disposal. During 1995, LANL shipped 10 loads of PCB waste, totaling about 3.1 million pounds (1.4 million kilograms).

LANL also generates wastewater contaminated with HE. DOE has decided to filter and recycle this HE wastewater and is currently installing the necessary filtering and recycling equipment. In addition to installing new equipment, water-sealed vacuum pumps and wet HE collection systems are being replaced by equipment that does not use water. These actions will reduce the amount of water used in HE processing [about 131 thousand gallons (494 thousand liters) per year] by approximately 99%. This decision was made to improve management of wastewater from high explosives R&D and to meet current and future regulatory standards for wastewater discharge.

To process HE wastewater, solvents will be extracted at the processing facility at TA-16. Then, the HE wastewater will be transferred for filtering and recycling to the new treatment facility adjacent to the existing treatment facility. HE wastewater will be trucked, as needed, to the new facility. For a detailed description of the wastewater treatment system upgrade and impacts associated with its installation and use, the reader is referred to DOE's environmental assessment for the HE wastewater treatment facility at Los Alamos (DOE 1995b). Sources of non-HE industrial wastewater are being eliminated from HE-processing areas. HE is currently being removed from outfall piping, and storm water will be allowed to discharge through the decontaminated pipes.

3.5.2.2 Hazardous Solid Wastes

Most hazardous solid waste, including asbestos, gas cylinders, solid PCB wastes, and small-quantity [5-gal. (19-L)] waste lab packs, is shipped offsite for treatment and disposal. A transfer station for asbestos wastes is located at Area J pursuant to NMED regulations. Oil-contaminated soils are land-farmed at Area J under an interim permit from NMED.

LANL also generates solid HE wastes. These wastes are collected, packaged, and transported to locations on Laboratory property for open burning. New Mexico regulations allow DOE and LANL to burn waste explosives. In 1995, LANL had five open-burning permits: one for burning jet fuel and wood used in ordnance testing at K Site (TA-11); one each for burning explosive-contaminated materials at TAs-14, -16, and -39; and one for burning explosive-contaminated wood at TA-36.

3.5.3 Radioactive Wastes

Radioactive wastes are divided into three main waste types: LLW, TRU waste, and high-level waste (HLW).

- LLW is defined as waste that contains radioactive material that is not classified as high-level, TRU waste, spent nuclear fuel, tailings from milling uranium or thorium ore, or by-product material (DOE 1988). Test specimens of fissionable material that have been irradiated for R&D may be classified as LLW, provided that the concentration of TRU elements is less than 100 nCi/g of waste at the time of assay (DOE 1988). Fissionable material generated during the production of power or plutonium does not qualify as LLW.

- TRU is defined as radioactive waste that contains alpha-emitting radionuclides with an atomic number (number of neutrons) greater than uranium (i.e., transuranic), half-lives greater than 20 years, and concentrations greater than 100 nCi/g of waste. The major radioactive contaminants in TRU wastes at LANL are plutonium and americium.

- HLW is defined as radioactive waste generated by chemically reprocessing spent nuclear reactor fuels. HLW includes liquid waste produced directly from reprocessing and solid wastes derived from the liquid. It contains a combination of transuranic and fission product nuclides in quantities that require permanent isolation. No HLW currently exists at LANL. When the Omega West Reactor was decommissioned, the fuel elements were removed and shipped to the Idaho National Engineering Laboratory for reprocessing and storage.

3.5.3.1 Low-Level Waste

LLW is further categorized by its physical and chemical characteristics. The various waste types are distinguished by waste codes and include plastics, cellulosics (such as paper and rags), nitrate salts, evaporator bottoms, combustible trash, waste metals, contaminated process instrumentation, radiation protection clothing, demolition debris from decommissioning activities, and contaminated soils and debris from environmental cleanup activities. Approximately 60 types of LLW are generated, which are grouped into larger treatability groups whose physical or chemical attributes affect treatment and disposal strategies. Less than 1% of LLW requires special handling and shielding to protect workers and the public (e.g., LLW and TRU wastes require remote handling only when the external exposure rate at the surface of the waste container exceeds 200 mrem/hr).

LLW at LANL includes

- solid waste contaminated with radioactive materials, including plutonium, americium, uranium, or tritium from weapons design and test work;
- waste tracers and medical isotopes from scientific studies;
- mixed fission materials from nuclear energy work; and
- activation products from physics experiments. (Activation products are formed when a substance is struck by protons or neutrons and the atoms of the original substance are converted to other unstable radioactive elements.)

In CY95, approximately 107,072 ft^3 (3,032 m^3) of LLW were managed at LANL.

3.5.3.2 Transuranic Waste

About 95% of the TRU waste at LANL is mixed TRU waste. Because both TRU and mixed TRU waste are managed together, they are collectively referred to as TRU waste. Distinctions are made between the two only when necessary.

TRU waste at LANL consists of rags, equipment, solidified wastewater treatment sludge, paper, and protective clothing. Facility and program managers are responsible for minimizing the amount of TRU waste they generate and for characterizing those wastes generated. Waste Management Operations accepts responsibility for these wastes once they have been characterized. The characterization of wastes already in storage is the responsibility of waste management personnel. In 1995, less than 3,353 ft^3 (95 m^3) of newly generated TRU waste required management by LANL.

TRU wastes at LANL that require management are

- TRU wastes generated from operations and research activities (primarily from TA-55 and CMR);
- TRU wastes generated by cleanup efforts of the Environmental Restoration Program;
- TRU wastes currently stored in domes at TA-54; and
- legacy TRU wastes stored under earthen cover on Pads 1, 2, and 4 at TA-54.

The management scheme for TRU waste is to store it at TA-54 pending shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. At present, approximately 13,000 containers are stored in fabric-covered domes, and another 17,000 containers are stored under earthen cover on Pads 1, 2, and 4 at Area G. Under the Transuranic Waste Inspectable Storage Project, the latter will be retrieved, repackaged if necessary, cleaned, characterized, and placed in new storage domes to await shipment to the Waste Isolation Pilot Plant.

3.5.3.3 Radioactive Liquid Wastes

Radioactive liquid waste, either LLW or TRU, is generated by a variety of chemical and production activities conducted at 17 different facilities. Generators of radioactive liquid waste are responsible for minimizing the amounts of waste that they generate and for characterizing those wastes. Most of this waste is transferred by direct pipeline from the generator to the treatment equipment in the RLWTF at TA-50. The remaining radioactive liquid waste is transferred to the RLWTF via truck. Limited quantities of radioactive liquid waste from buildings located at TA-21 are treated at TA-21 on an as-needed basis.

To comply with current and future regulatory requirements, DOE is actively pursuing a long-term strategy for maintaining a radioactive liquid waste treatment capability at LANL. This strategy involves (1) a series of upgrades and modifications of the existing process and (2) use of new "state-of-the-art" process equipment. Currently under discussion is a new process building at TA-50 adjacent to RLWTF that will house the newer treatment technologies (ultrafiltration and reverse osmosis). This approach eliminates most chemicals released by the existing process and will comply with NMED's discharge limits for nitrates.

3.5.3.4 Radioactive Solid Wastes

Sludge from the RLWTF chemical treatment process is managed as either LLW or TRU waste. The sludge is dewatered, drummed, and sent to TA-54 for disposal. Radioactive asbestos and asbestos suspected of being contaminated with radioactive material continue to be disposed at a monofill disposal cell at Area G. Contaminated lead bricks are subjected to a grit blast and subsequent water wash at TA-50 to remove radioactive contamination. The bricks are then reused, and spent grit is packaged as solid LLW or TRU waste. Wash solutions are drummed, sampled, and transported to the RLWTF for treatment. Bulky metallic TRU wastes, such as large gloveboxes, are sectioned and repackaged in a ventilated enclosure at the Waste Characterization, Reduction, and Repackaging Facility at TA-50.

3.5.4 Mixed Wastes

When a radioactive waste (LLW, TRU, or HLW) contains a hazardous substance as defined by RCRA, the waste is referred to as "mixed." Mixed wastes make up the smallest volumes of wastes managed at LANL. These wastes take the physical form of solids, liquids, and compressed gases (such as hydrogen with a tracer radioactive isotope). The gases are contained in cylinders. Examples of low-level mixed wastes include tritiated mercury, radioactively contaminated lead shielding, and solid chemicals that react violently with water. Other mixed wastes generated at LANL include radioactive asbestos wastes and radioactive PCB wastes. All mixed wastes are characterized by the generator, then collected by waste management personnel and transported to Area L for sorting and packaging. Wastes are segregated by type and are stored in roofed facilities.

3.5.4.1 Liquid Mixed Wastes

Liquid mixed wastes generated at LANL include contaminated solvents, oils, and spent solutions from electroplating operations. Liquid mixed wastes are collected at the generating facilities and are transported to Area L for storage pending the availability of offsite commercial treatment or development of technologies to treat those wastes that cannot be treated by the commercial sector. During 1995, LANL disposed of 35 lb (16 kg) of mixed liquid LLW—a liquid LLW with PCB contamination—that required special handling.

3.5.4.2 Solid Mixed Wastes

TRU mixed wastes at LANL are solids. The major hazardous component is solvents or toxic heavy metals such as cadmium or lead. Solid low-level mixed waste generated at LANL is collected at the generating facilities, packaged, and transported for storage in one part of Area G. These wastes may be relocated to Area L as the backlog of mixed wastes is shipped offsite over the next 10 years after offsite commercial treatment or development of technologies to treat those wastes that cannot be treated by the commercial sector become available. Radioactive asbestos wastes and solid radioactive PCB wastes are disposed in shafts at Area G instead of at Area L.

3.6 Roads and Grounds

DOE, either directly or through LANL, has built and maintains its own roads and associated infrastructure. DOE has taken this approach because access must be controlled when nuclear materials are being moved and the county tax base does not support the additional work that would be required if these roads were given to the county.

3.6.1 Road Maintenance and Construction

LANL's general contractor, JCI, is responsible for maintaining Laboratory roads and grounds, including paving, signage, striping, traffic signals, landscaping, and parking lots. The contractor is also charged with removing snow and sanding after major storms. The general scope of road maintenance covers inspecting and maintaining

- 85 mi (140 km) of asphalt- and concrete-paved roadway with a surface area of about 1.5 million yd^2 (1.2 million m^2);
- 12 million square yards (10 million square meters) of asphalt- and concrete-paved parking areas;
- 68,000 linear feet (20,700 m) of concrete and asphalt sidewalk;
- 83,000 linear feet (25,300 m) of guard rail;
- 1,800 traffic signs, 30 signs indicating technical areas, and 10,000 "No Trespassing" signs; and
- 8 traffic signals.

Road maintenance is based on a five-year plan of preventive maintenance and on springtime road condition surveys. Roads and parking areas within LANL boundaries are constructed and maintained by JCI and other contractors. Roads outside LANL boundaries are constructed and maintained by the State Highway and Transportation Department and the Forest Service. Roads and parking areas proposed for construction (inside LANL boundaries) are surveyed for right-of-way, archaeological resources, and potentially contaminated areas. After these surveys have been completed and the appropriate mitigation measures have been taken, engineering designs and excavation permits for clearing and grading the right-of-way are prepared. LANL then issues a start-work order to JCI for construction. Adequate road base and paving materials are installed and compacted, followed by surface treatment, if necessary, in accordance with New Mexico State Highway and Transportation Department specifications.

Occasionally, traffic safety upgrades are needed to bring an existing road into compliance with current DOE traffic design standards. These upgrades may include widening traffic lanes; adding turning, deceleration, and acceleration lanes; establishing carpool turnouts; and adding base course to roadway shoulders. These improvements and ongoing maintenance improve traffic safety, thereby reducing the opportunity for accidents involving nuclear materials.

3.6.2 Ground Keeping

Ground-keeping activities are required for open areas (lawns, areas between buildings, shoulders of roadways, fire breaks, etc.). JCI provides these services, which include maintaining and operating sprinkler systems, applying fertilizer, mowing, weeding, controlling pests, installing industrial fencing, and managing storm water to control erosion. In accordance with the Federal Insecticide, Fungicide, and Rodenticide Act, JCI maintains a state-certified control officer, who oversees the storage, use, and disposal of pest and weed control chemicals in accordance with Department of Agriculture regulations.

JCI, in association with the Centers for Disease Control, also provides a state-certified wildlife officer to oversee capture of problem animals for testing (for example, deer mice to be tested for hantavirus). The wildlife officer also oversees retrieval and disposal of dead animals from Laboratory facilities, roads, and grounds.

Because of the threat from wildfire, DOE requires interagency cooperation among LANL, the Forest Service, and Bureau of Indian Affairs. Through this process, firebreaks are established and maintained to protect LANL facilities. JCI provides the equipment and manpower to cut and maintain these firebreaks.

3.6.3 Batch Plant

JCI maintains an asphalt batch plant for smaller road construction projects and repairs. The batch plant is equipped with a wet scrubbing system to minimize air emissions. Asphalt is prepared in accordance with New Mexico State Highway and Transportation Department specifications and is delivered by truck to each job site as needed. For larger projects, LANL also purchases asphalt hot mix from a local supplier.

3.6.4 Heavy-Equipment Shops

JCI's heavy-equipment shops contain all equipment necessary for new road construction, grounds and road maintenance, and snow removal. These shops also maintain and repair all heavy equipment.

3.7 Packaging and Transportation

Packaging and transportation both on and off the Laboratory site take place in accordance with applicable regulatory requirements of the DOT; DOE; EPA; International Civil Aviation Organization; International Air Transport Association; NRC; and state, local, and tribal laws. To meet these requirements, LANL maintains the appropriate documentation (shipping manifests, bills of lading, etc.), defines emergency response procedures, establishes packaging requirements, conducts training, determines driver qualifications, arranges for vehicle placarding, and provides for occurrence reporting and assessment. In addition, all packages are certified according to test performance criteria defined by the DOT and NRC to meet containment requirements based on the types, activity, form, and consistency of hazardous material. Special provisions for packaging or transportation require DOE approval.

3.7.1 Onsite Shipments

Vehicles owned by the General Services Administration and DOE are used for onsite shipments. Vehicle and driver requirements, including the requirements for maintaining and inspecting commercial motor vehicles, conform with Federal Motor Carrier Safety regulations. Drivers are required to have commercial licenses for specific types of vehicles and materials, must undergo random alcohol and drug testing, and must participate in periodic training. LANL maintains driver qualification files that document this training and testing.

3.7.2 Offsite Shipments

In December 1995, DOT became the regulatory agency primarily responsible for offsite hazardous materials shipments, as defined in the Code of Federal Regulations, Title 49 (DOT 1996). DOE orders on transportation generally require compliance with DOT requirements for offsite transportation, including shipments made by air or water. LANL uses "best available mode of transportation" for all offsite shipments; this requirement addresses package selection, marking, labeling, loading, and tie-down requirements; cost; vehicle and driver requirements; and includes other special provisions. When shipping radioactive materials, LANL also provides for monitoring.

3.8 Communications

Laboratory communications systems include mail service, telephone service, and electronic communications service via computer networks.

3.8.1 Mail Service

LANL maintains its own post office with a dedicated zip code (87545). This post office collects, sorts, and delivers Laboratory mail to the entire site. The mail includes all letters, packages, and items shipped to LANL by any mail carrier (e.g., the US Postal Service, United Parcel Service, common courier). Incoming mail is sorted and routed to internal mail stops via 14 mail routes. Mail delivery is coordinated with deliveries of small purchased items. When no mail stops are identified, the mailroom searches LANL's work force database to locate addressees. Typical mail volumes are shown in Table 3-9.

TABLE 3-9

MAIL VOLUMES AND CARRIERS

Pieces Handled	**Volumes**
Outgoing Mail	42,000–61,000 pieces per month
Incoming Mail	650,000–990,000 per month
Carriers	**Percents**
USPS First Class	48
USPS Bulk	25
DHL* First Class	17
Other	10

*DHL is the corporate name of a private mail carrier used for international mail.

All classified mail is transported in locked bags and handled separately in a dedicated sorting area. Outgoing mail is sorted and posted in accordance with postal regulations. Outgoing certified, registered, postal express, foreign express, and insured mail is logged. Postage costs about $400,000 annually.

3.8.2 Phone System

In October 1992, LANL contracted with US West Communications Federal Services to design, implement, and operate the Los Alamos Integrated Communications System. The system includes

- integrated voice and data telephone services for the entire Laboratory,
- fiber-optic infrastructure for Laboratory-wide, high-speed data communications,
- teleservices such as an on-line electronic directory and voice mail, and
- modernization and reinforcement work order processing for faster service.

The foundation of this communications system is a Laboratory-wide fiber-optic transmission system placed in service in May 1994. The system is arrayed in a star topology, the center of which is the Laboratory Data Communications Center (LDCC) at TA-3. The LDCC node serves users in TA-3, the townsite, and White Rock. The rest of LANL is served by remote nodes located at

- TA-16 (serving the areas between S Site and TA-39 in Ancho Canyon),
- TA-50 (serving users along Pajarito Road), and
- TA-53 LANSCE.

The remote nodes are connected to the LDCC by single-mode, fiber-optic cables. Each cable has 144 fibers, and each fiber is capable of transmission rates in excess of 1.5 gigabits per second. A total of over 9 mi (14.5 km) of fiber cables are installed in an underground concrete-encased duct.

Layered on the transmission system is an AT&T-distributed telephone-switching system. All 16,800 Laboratory telephone subscribers receive service from the switch. Laboratory users are able to place simultaneous voice and data calls through a common telephone instrument over common wires. Voice mail was installed with basic "answering-machine" and "message-store-and-forward" features. Networking with similar voice mail systems at other DOE sites is being investigated.

The AT&T switch is connected to the outside world through 360 local US West trunks and 120 long-distance (Federal Telecommunications System) trunks, of which 24 are dedicated to incoming 800 calls. Other teleservices provided by the integrated communications system include an online directory service, an enhanced 911 emergency service call-routing system, and a comprehensive telemanagement system.

3.8.3 Computer Network

The integrated computing network (ICN) is LANL's primary computer network. It provides controlled access to and support for a wide variety of computing resources. The ICN has two major partitions: the open partition for processing unclassified information (available to the general public) and the closed partition for processing classified information (restricted access). The World-Wide Web provides access to the open partition. The electronic front door to LANL is LANL's home page (http:// www.lanl.gov).

Three major realms of network computing occur at LANL:

- The "Internet-only" realm, which handles E-mail, local computer programs, electronic databases, and other electronic information that LANL makes available to workers and the general public. This realm is supported by computers (servers) dedicated to unclassified work.

- The "administrative" realm in which dedicated administrative computers (servers) provide access to institutional data. This realm includes the Laboratory's data warehouse, protected databases (property and employee information, financial information, etc.), and all of the Labwide functions (e.g., time-and-effort reporting and financial reporting). A smart card and an ICN password are generally required for access.

- The "computer server" realm focuses on providing access to large mainframe machines, supercomputers, and work station clusters. An ICN password is required for access.

All computer users at LANL are trained in computer security. All Laboratory computers, computing systems, and their associated communication systems are used only for official business and are protected in accordance with property protection and security rules. Software must be legally procured, and records of ownership and proof of license must be maintained. Duplication of copyrighted or proprietary software must be authorized.

3.9 Safeguards and Security

LANL conducts safeguards and security operations to protect national security interests, proprietary information, personnel, property, and the general public. Items needing physical protection include SNM; vital equipment; and sensitive information, property, and facilities. Physical protection strategies are based on a graded approach involving threat analysis, risk assessments, and cost/benefit analysis.

At LANL, special nuclear materials (the nuclear materials used in weapons and referred to as SNM) are rigorously controlled and accounted for to ensure proper management and adequate safeguards. DOE Orders 5632 (1994a) and 5633.3B (DOE 1994b) require LANL to have a stringent materials control and accountability system that deters, prevents, detects, and responds to unauthorized use, possession, or sabotage of these materials. SNM is tracked by the inventory and storage system from the time it enters LANL until it leaves. To protect SNM, LANL uses perimeter security fences and access control stations that limit access to those individuals who have the proper level of security clearance (DOE Q) and a work assignment requiring access. In addition, LANL's protective force guards and others are trained to respond to threats and emergencies.

Six materials access areas have been designated when the quantities and uses of SNM dictate that special precautions be taken. Special protective areas called vaults are available to store these materials when they are not in use. These vaults are shielded to protect personnel from radiation and are locked to prevent unauthorized access. In addition, they are constructed to retain their integrity in case of external impacts such as fire and earthquake.

Organizations at LANL that have and use SNM or other nuclear materials appoint a nuclear materials custodian. This person is responsible for maintaining records on quantities and locations of nuclear materials and for providing safe storage locations. A computer-based accountability, control, and management system operates across LANL to provide

- near real-time tracking of nuclear material,
- an internal database for tracking inventories,
- early detection of inventory inconsistencies,
- a measurement control database,
- materials management features,
- access to reports, and
- inventory and transaction audit trails.

Besides the computer-based inventory, a physical inventory program requires physical verification of the records on a scheduled basis.

SNM transfers between facilities at LANL and external to LANL are tracked through the Material Control and Accountability System. As needed, protective force personnel and armored vehicles provide protection from external theft and sabotage during onsite transfer operations.

The overall safeguards and security system was designed to protect against credible threats, which include compromise, loss, theft, diversion, espionage, sabotage, and other malevolent or inadvertent acts that may cause unacceptable risks to national security, employee or public health and safety, and/or the environment. LANL provides these services by maintaining comprehensive programs in physical security and property protection (including guard forces and use of DOE identification badges with clearance levels and special-access authorizations), nuclear material control and accountability, personnel security assurance, computing and communications security, and personnel/information security.

Protection strategies are based on the following:

- vulnerability of assembled or partially assembled nuclear weapons or test devices to malevolent acts;
- vulnerability of SNM, vital equipment or facilities, or sensitive matter to malevolent acts;
- importance of facilities to overall DOE missions and costs of replacement, the classification level of the matter, and the impact of its loss or compromise on national security;
- potential effects of a malevolent act on the health and safety of employees, the environment, or the public;
- the need for compartmentalization of safeguards and security interests; and
- the need for efficient and cost-effective methods for protecting the safeguards and security interests, based on DOE orders and performance tests.

Physical security is maintained by a comprehensive program that uses physical barriers and guard forces coupled with electronic systems. For example, the material control and accountability system tracks nuclear material from its entry into LANL, through its movement within, and shipment from LANL. Physical barriers and guards restrict access to these materials.

LANL works with DOE through jointly sponsored initiatives (e.g., working groups, task forces, and self-assessments) to update and improve its safeguards and security operations. Based on these interactions, the Laboratory has initiated and is committed to the following improvements in safeguards and security:

- quality management practices that provide innovative, creative, and credible safeguards and security;
- consolidation (and, where practical, reduction) of safeguards and security interests;
- increased use of technologies (such as automated access and automated validation systems) that promote more cost-effective, efficient, and reliable safeguards and security operations;
- standardized protection systems, including physical restraints, guard force weapons, alarm systems, and computer hardware; and
- training that provides a well-qualified and knowledgeable guard force.

3.9.1 Information Security

Some information produced or received at LANL is classified and requires protection because of national security interests. LANL reviews this information to determine the proper level of classification, restrictions on use, and/or the extent to which the information may be disseminated or must be protected. Safes and vaults are used to protect sensitive, classified, and proprietary information. Persons wishing to use this information must have the appropriate level of DOE security clearance and a legitimate need to know. Information about salaries, performance evaluations, and medical conditions, including radiation exposures, is also protected.

3.9.2 Guard Force

LANL maintains an onsite security force, currently through the services of PTLA, which provides trained personnel to man security checkpoints that restrict admission to properly qualified individuals. PTLA also provides armed guards in special vehicles to escort certain nuclear materials being moved over public roads within LANL boundaries, as well as armed guards to monitor vehicles entering secure areas and to respond to unauthorized activities and/or other situations that place SNM at risk.

Training and fitness requirements for the PTLA guard force include a mandatory exercise and fitness program and a mandatory marksmanship program for which the Laboratory provides a small-arms practice range. PTLA personnel are also trained in emergency response, including antiterrorist tactics. In cooperation with the Los Alamos County Police Force, the local hospital, and other organizations, PTLA stages one or more simulated emergency exercises, such as vehicle accidents with multiple injuries and/or release of radioactive or hazardous material release.

LANL controls PTLA's budget and prioritizes its tasks and activities based on requirements derived from operational and programmatic needs; DOE orders; and safety, health, and environmental requirements. PTLA provides the necessary managerial, technical, professional staff, and guard force to provide quality, cost-effective services and to create and foster a safe work environment.

PTLA operates under established policies and procedures. Its duties include monitoring alarms, dispatching response, validating actions and conditions, and transferring 911 calls to other agencies as appropriate. Following a response, LANL conducts an inquiry to determine whether evidence indicates that a theft or vandalism has occurred. If it has, LANL contacts the appropriate law enforcement agency (in most cases, the Los Alamos Police Department). When appropriate, LANL also notifies the Federal Bureau of Investigation and DOE's Inspector General. Most incidents are administratively resolved through supervisors and the Laboratory's Human Resources Division.

3.9.3 Police Force

The Los Alamos Police Department handles general law enforcement at LANL. The department responds to LANL needs by investigating criminal activity, issuing citations, arresting suspects, and forwarding cases to the Los Alamos County legal system for prosecution.

3.10 Emergency Management and Response

In accordance with federal regulations, LANL has an institutional emergency planning, preparedness, and response program. Personnel are available on a 24-h/day basis for emergencies, and they provide a 24-h/day notification service for all Laboratory employees and their families, anywhere in the world, should assistance be needed. The Emergency Management and Response (EM&R) Program equips and trains both a Crisis Negotiations Team and a Hazardous Devices Team. The EM&R Program provides for an Emergency Operations Center 24 h/day to coordinate emergency responses and maintains an alternate emergency operations center as required by DOE. To effectively operate during an emergency, EM&R personnel have established memoranda of understanding among DOE, Los Alamos County, and the State of New Mexico to provide mutual assistance during emergencies and to provide open access to medical facilities. In addition, the program supports development and deployment of a DOE-directed, complex-wide data-handling and display system.

To assist emergency responders, the EM&R Program maintains a database with facility-specific information such as building managers, phone numbers, building locations, and chemicals of concern. In addition, the EM&R Program has an emergency management plan that contains all procedures for mitigating emergencies and collecting response data.

LANL has its own fully trained Hazardous Materials (HAZMAT) Team of approximately 18 members, which is fully equipped to handle large spills and events. The HAZMAT Team responds to emergencies at LANL through the EM&R Office and to emergencies offsite through mutual-aid agreements with DOE and the State of New Mexico. The HAZMAT Team maintains a staff of fully trained personnel to call as auxiliary members, should they be needed.

LANL also has a Spill Prevention Control and Countermeasures Plan to meet the regulatory requirements of the EPA and NMED that pertain to pollution from oil and hazardous chemical spills. The plan ensures that adequate prevention and response measures are provided to prevent oil and chemical spills from reaching a water course. In addition to requiring secondary containment for all aboveground storage tanks, the plan provides for spill control at drum and container storage, transfer, and loading/unloading areas. Either the HAZMAT Team or the Health Physics Operations Group responds to chemical spills and mixed (radioactive and hazardous) spills.

3.11 Fire Protection

LANL's fire protection program ensures that personnel and property are adequately protected against fire and related incidents. The program is directed at all aspects of traditional fire protection, wildland fire prevention, and life safety as detailed in the National Fire Protection Association code.

This program is carried out in five areas:

- fire protection engineering, such as loss prevention assessments;
- fire protection document review to ensure that proposed facilities and workers are protected against any life safety or fire hazards;
- fire protection system maintenance oversight to ensure that protection systems, once installed, are properly maintained so that they operate correctly in an emergency;
- fire protection inspection program to monitor installed safety systems for changes in conditions that affect readiness; and
- fire department oversight to ensure that LANL receives necessary and adequate services from the DOE-funded fire department.

DOE contracts with Los Alamos County under a government-owned, county-operated prime contract for fire department services, which covers a geographic fire services area that includes the county, the townsite, and the Laboratory. All equipment and facilities are government-owned, although fire department personnel are county employees. The Los Alamos Fire Department provides fire suppression, medical/rescue, wildland fire suppression, and fire prevention services to the fire services area. Five continuously manned fire stations are located on government property, including two at LANL, and a training facility at the fire department headquarters. An additional reserve station and training facility on DP Road, not continuously manned, may dispatch firefighters when it is occupied. DOE-LAAO and the Laboratory provide contract administration and technical oversight.

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4.0 LOS ALAMOS NATIONAL LABORATORY'S TECHNICAL AREAS AND FACILITIES

The concept of technical areas (TAs) was implemented during the first five years of the Laboratory's existence; however, the early TA designations did not cover all lands inside the Laboratory's boundary, and, in the early 1980s, LANL revamped the TA-numbering system to provide complete coverage. Because all TAs received new numbers, a correlation between the historic system and the new numbering system does not exist. In addition, in the new system, some numbers were reserved for future TAs.

LANL has both active TAs (places where work is performed) and inactive TAs (areas that are no longer in use and from which the buildings have been removed). Some active TAs contain inactive buildings and/or sites with residual contamination (chemical, radioactive, or both) from past operations. The Environmental Restoration Program is addressing the contamination present at inactive TAs and inactive portions of active TAs as legacy contamination. Sites with legacy contamination are typically referred to as solid waste management units (LANL 1992).

The land controlled by LANL is divided into 49 separate TAs (Figure 1-2), two of which do not belong to DOE. TA-0, the townsite, belongs to Los County, and TA-57 is the Fenton Hill site, which belongs to the US Forest Service. Together, these TAs compose the basic geographic configuration of the Laboratory. TA-3, located on South Mesa, is the main technical area, where approximately one-half the total LANL workforce is located. TA-3 serves as the central technical, administrative, and physical support facility for LANL. The remaining TAs contain research and development facilities or production facilities. However, most of the land in many of these TAs is undeveloped to provide a buffer for security, safety, and possible expansion. The Fenton Hill Site, which is located ~28 mi (~45 km) west of Los Alamos), is the Laboratory's only remotely located site.

4.1 Background

TAs were set up to facilitate administration of related functions, enhance security, provide safe distances between dynamic experiments, and isolate various program elements. For example, some TAs (such as the firing sites) require a great deal of space to protect people from shrapnel and other energetic releases, and some TAs (such as locations where nuclear-weapon-like assemblies are made) require isolation from public view for security purposes. Other TAs require ready access to neighboring TAs in which related activities are conducted (e.g., to minimize movement of hazardous materials).

Because all TAs have operations that pose some risk either to the workers, public, and/or local environs, LANL uses a risk-based system to categorize its facilities. Non-nuclear facilities are rated as low-, moderate-, or high-risk, and nuclear facilities are rated as Category 1, 2, or 3. These classifications limit the type of work that can be performed in a given building or facility.

Not all activities fit well into this system. For example, some work is done outside buildings at specialized facilities (firing sites, burning grounds, etc.), and DOE's nuclear facilities categories do not include all radioactive material. In addition, the definition of a facility tends to be site-specific and varies somewhat within LANL. Typically, a facility is a group of structures, systems, and equipment that are related by function, activity, or location and that serve a particular purpose, capability, or mission. Facilities include the utility supply and distribution systems and other support infrastructures.

Many of LANL's technical areas and facilities are vital to the continued implementation of assigned operations. Some facilities support the national security mission of stockpile stewardship and management and disposition of weapons-usable fissile materials. Others support high-energy physics, waste management, and R&D such as materials research, radiochemistry, and health research. These facilities also have the greatest potential for affecting the environment and generating public interest. In addition, LANL contains several facilities with unique characteristics (one of a kind or not easily duplicated). These facilities include the TA-55 Plutonium Facility, the LDCC, LANSCE, CMR, the Material Science Laboratory, and the Health Research Laboratory.

As explained in Chapter 2, Laboratory staff knowledge is combined with facility capacities and characteristics (buildings or aggregations of buildings that house equipment) to perform research and development work. When a new project or activity is proposed for the Laboratory, facility managers and environment, safety, and health professionals evaluate the anticipated operations, processes, and types of materials (e.g., hazardous, radioactive) to be used. The proposed location of the new project or activity is also evaluated to determine whether the location(s) are suitable. Suitability is based on many factors, including the safety envelope of the facility, which limits the type of work and hazards that can be supported. An individual project or technical task may be located in one facility or, more likely, involve activities at more than one TA, facility, or building.

4.2 Hazard Classifications of Facilities

All LANL facilities, whether proposed, under construction, preoperational, operational, or idle, DOE-owned or leased, temporary or permanent, occupied or unoccupied have been categorized according to hazards inherent to their actual operations or planned use. If the operations do not fall into one or more of the nuclear or non-nuclear hazard classifications, the facility is categorized as "no hazard."

The first step taken in categorizing a facility is segregating the facility by function. A screening methodology is used to sort the various facilities based on work processes or operations performed. Using this system, the Laboratory has first categorized facilities as follows:

Administrative/Technical—facilities used for Laboratory support functions, which include the Director's Office, Comptroller, Human Resources, BUS, FSS, ESH, and communications.

Public/Corporate Access—facilities, both restricted and unrestricted, that allow public and corporate access and use, including such facilities as the R. J. Oppenheimer Study Center, Bradbury Science Museum, and special research centers.

Theoretical/Computational—facilities such as computer centers used for theoretical and computational functions for both classified and unclassified work.

Experimental Science—facilities used for such experimental functions as accelerator, fusion, and laser R&D and testing and multiuse experiments.

Waste Management—facilities used for WM activities such as storage, treatment, and/or disposal of low-level, transuranic, hazardous, and mixed wastes.

Special Nuclear Materials—facilities used for SNM functions, including storage and R&D involving SNM. For the purposes of this document, the term SNM also covers nonspecial nuclear materials such as tritium.

High Explosives—facilities used for HE functions, including storage and R&D.

Physical Support—facilities such as warehouses, general storage buildings, utilities, and wastewater treatment.

Vacant/Unoccupied—facilities currently vacant or unoccupied that could be rendered suitable for certain operations.

Decontamination and Decommissioning—facilities that are currently in or are scheduled for decontamination and/or decommissioning.

Abandoned/Closed—facilities that are unoccupied and have been abandoned or closed and will not be occupied in the future.

Environmental Restoration—facilities or areas that are being restored under RCRA, including landfills and burn pits.

Facilities that do not involve unusual hazards (i.e., hazards not routinely encountered by the general public) are eliminated from further screening. These facilities include facilities categorized as entirely administrative/technical, public/corporate access, theoretical/computational, vacant/unoccupied, and abandoned/closed. Then, in accordance with DOE guidance, LANL divides the facilities with potential sources of danger (e.g., a hazard with the potential to cause illness, injury, or death to personnel; damage to a facility; and/or negative affects on the environment) into nuclear or non-nuclear categories. Having been defined as nuclear or non-nuclear, the facility is further evaluated based on the consequences of an unmitigated accident or release.

Once the hazard potential is known, the process of controlling the perceived risk is implemented to ensure comprehensive, integrated, and balanced risk management of all safety and environmental hazards posed by these facilities and operations. This task is accomplished by providing engineering controls, administrative controls, and skilled workers. When possible, potentially unacceptable risks are eliminated by modifying processes, substituting materials, or modifying engineering designs.

4.2.1 Nuclear Facility Hazard Categories

Nuclear hazards are categorized by DOE Order 5480.23 (DOE 1992) as Category 1, 2, or 3. The order defines these categories as follows:

Category 1 Hazard. The hazard analysis shows the potential for significant offsite consequences.

Based on total curie content, potential material forms, and maximum energy available for dispersion, only one class of DOE facilities has this hazard potential: DOE Class A Nuclear Reactors as defined by DOE Order 5480.6 (DOE 1986). By this definition, Category 1 nuclear facilities or operations do not exist at LANL.

Category 2 Hazard. The hazard analysis shows the potential for significant onsite consequences.

DOE constructed the Category 2 hazard definition from existing regulations that define minimum thresholds for many radionuclides based on consequences from these hazards in the immediate vicinity of a facility. Table A.1 in DOE-STD 1027-92 (DOE 1992) provides the resulting threshold quantities for radioactive materials that define a Category 2 facility. Such an approach is consistent with the intent of DOE Order 5480.23 to categorize at Level 2 those facilities with the potential for significant onsite consequences.

Category 3 Hazard. The hazard analysis shows the potential for only significant localized consequences.

Category 3 is designed to capture those facilities that use nuclear materials in quantities below Category 2 levels but above Level 3 thresholds and that are considered to represent a low hazard. At LANL, these facilities typically include laboratory operations, low-level-waste-handling facilities, and research machines. DOE-STD-1027-92 states that facilities should be categorized as Level 3 if there is only the potential for "significant localized consequences" (DOE 1992). Essentially, all industrial facilities have a potential for significant localized consequences because the potential for worker injuries from typical industrial accidents is always present. However, Category 3 facilities pose additional hazards because of the presence of radionuclides. Table A.1 in DOE-STD 1027-92 provides the Category 3 thresholds for radionuclides.

Radiological Facilities. Facilities that use nuclear materials in quantities below the Category 3 threshold are considered to be radiological facilities. Administrative controls are in place at these facilities to ensure that minimum threshold values are not exceeded through the introduction of new radiological materials. Radiological facilities are considered "no hazard" unless operations warrant categorization under non-nuclear facility hazard criteria.

All nuclear facilities at LANL are either Category 2, Category 3, or radiological. As previously stated, LANL does not have any Category 1 nuclear facilities (DOE Class A Nuclear Reactors). LANL had a research reactor, the Omega West Reactor; however, this reactor did not generate enough steady-state power (>20 MW) to qualify as a Category 1 hazard. The reactor was decommissioned, the fuel rods were removed, and the site is slated for cleanup under the Environmental Restoration Program.

Nuclear facilities at LANL are typically buildings whose operations involve radioactive and/or fissionable materials in such form and quantity that a significant nuclear hazard *potentially* exists to the worker, general public, or the environment. Activities performed include those that

- produce, process, or store radioactive liquid or solid waste, fissionable materials, or tritium;
- conduct separations operations;
- conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations;
- conduct fuel enrichment operations; and/or
- perform environmental remediation or waste management activities involving radioactive materials.

4.2.2 Non-Nuclear Facility Hazard Categories

DOE Order 5481.1B (DOE 1988) categorizes non-nuclear hazards as low (L), moderate (M), or high (H). The order defines these categories as follows:

- low hazards are those hazards that present minor onsite and negligible offsite impacts on people or the environment;
- moderate hazards are those hazards that present considerable potential onsite impacts on people or the environment but, at most, result in only minor offsite impacts; and
- high hazards are those hazards that have the potential for onsite or offsite impacts on large numbers of persons or major impacts on the environment.

The Laboratory has further grouped non-nuclear hazards as hazardous energy sources (ENS), hazardous chemical sources (CHEM), hazardous radiation sources (RAD), and hazardous environmental sources (ENV). A fourth grouping, identified as "no hazard," identifies activities that involve only hazards normally encountered by the public in day-to-day activities.

4.2.2.1 Hazardous Energy Sources

The following hazardous energy sources are found at the Laboratory:

- High Explosives—Any facility that processes, handles, or stores more than 2.2 lb (10 g) of HE is categorized as a low-hazard facility because of the localized consequences of detonation events. This source includes all HE for which a credible direct or sympathetic detonation could be postulated. Low-order detonation or deflagration of HE (deflagration is a partial detonation of HE in which some of the HE detonates, scattering the remainder) or insensitive high explosives are evaluated on a case-by-case basis.

- Lasers—Facilities containing lasers that have the capability of causing harm beyond a distance similar to the normal warning area specified by American National Standards Institute (ANSI) standards for Class IV lasers (LANL 1997; ANSI, current version) have been categorized as being a low hazard. Lasers in other ANSI classes are considered to be in the no-hazard category.

- Other Energy Sources—A facility containing electrical, motion, gravity-mass, pressure, chemical, heat/fire, cold, or radiant energy sources capable of causing irreversible health effects to more than two operating personnel or causing any injury to onsite personnel outside the facility, or any injury to a person offsite is categorized as low hazard.

4.2.2.2 Hazardous Chemical and Biological Sources

Facilities that store, process, or handle significant quantities of nonradiological hazardous materials are categorized according to criteria developed by the Laboratory that use guidance outlined in several DOE documents and professional guides, including DOE Order 6430.1A (DOE 1989) and the American Industrial Hygiene Association's emergency response planning guides (AIHA 1997). These materials include toxic chemicals, harmful biological agents, carcinogens, or other materials that might expose workers, members of the public, or the environment to an unusual hazard if released from primary confinement by a credible means.

4.2.2.3 Hazardous Radiological Sources

Facilities that process, handle, and/or store radioactive materials in quantities less than Category 3 threshold levels are categorized as hazardous radiological sources. Operations include work with powders, metal shavings, solid or liquid waste samples, small x-ray, and monitoring equipment.

4.2.2.4 Hazardous Environmental Sources

Those facilities that house hazardous material and that have a potential to release hazardous material to the environment through credible postulated events are categorized as hazardous environmental sources. These events could include, but would not be limited to, leakage from transformer oil storage tanks or damage to DOE Type B containers, during either storage or transport.

4.3 Facilities at Los Alamos Categorized as Potentially Hazardous

Of the total 2,043 structures at Los Alamos, 411 carry hazard classifications. Two of these buildings (Building 125 at TA-35 and Building 2 at TA-39) carry both L/ENS and L/RAD designations and have been counted twice. Table 4-1 shows the total number of structures under each hazard category and the percentages of the total structures that fall in each hazard category.

TABLE 4-1

NUMBERS AND PERCENTAGES OF LABORATORY STRUCTURES HAVING HAZARD CATEGORY DESIGNATIONS

Nuclear Facilities	Number	Percent of Total Structures with Hazard Designation	Percent of Total Structures
Category 2	38	8	2
Category 3	10	2	<1
Total Nuclear Facilities	48	11	2
Non-Nuclear Facilities			
M/RAD	1	<1	<1
M/CHEM	13	3	1
L/RAD	54	13	3
L/ENS	255	63	12
L/CHEM	39	10	2
L/ENV	1	<1	<1
Total Non-Nuclear Facilities	363	~89	18

Table 4-2 lists the facilities at the Laboratory that have the highest potential for hazards—and thus attract the most public interest—and describes the functions conducted at each. Table 4-3 provides a summary of all the structures at the Laboratory that have a hazard classification. More detailed descriptions of these facilities, including those with low-hazard classifications, are provided in "A Guide to Technical Areas and Facilities at Los Alamos National Laboratory" (LANL 1998).

TABLE 4-2

SUMMARY OF FUNCTIONS AT BUILDINGS IN NUCLEAR HAZARD CATEGORIES AND IN MODERATELY HAZARDOUS NON-NUCLEAR CATEGORIES

Nuclear Facilities Hazard Category, Name, and Building Number	Functions
Category 2	
TA-3-29, Chemistry and Metallurgy Research Building	Nuclear materials analytical chemistry, nuclear materials science, waste characterization, environmental remediation.
TA-3-65, Sealed Source Building	Research and measurement using encapsulated radioactive materials and SNM.
TA-8-22-24, -70	Radiographic facilities used for performing nondestructive evaluation of parts of components. These facilities occasionally house nuclear materials in sufficient quantities to qualify them as Category 2 nuclear facilities. Based on safety analyses, the necessary controls are in place when nuclear materials are being handled. For all other operations, these facilities are considered non-nuclear.
TA-16-411	Facility used to combine HE components with metal components and to house the completed assembly until is is moved as part of normal operations. This facility occasionally houses nuclear materials in sufficient quantities to qualify it as a Category 2 nuclear facility. Based on safety analyses, the necessary controls are in place when nuclear materials are being handled. For all other operations, these facilities are considered non-nuclear.
TA-16-205/205A, Weapons Engineering Tritium Facility, plus addition	Supports high-pressure tritium gas fills and processing, gas boost system testing and development, diffusion and membrane tritium purification research and development, thin-film loading of tritium on target materials, solid material and container storage, tritium analysis, and calorimetry.
TA-18, Pajarito Laboratory TA-18-23, Critical Assembly Building, Kiva 1 TA-18-26, Hillside Vault TA-18-32, Critical Assembly Building, Kiva 2 TA-18-116, Critical Assembly Building, Kiva 3	Used for nuclear criticality experimentation research and development; criticality safety training, studies, and research; radiation detector and instrumentation development; radiation scattering and spectral experimentation; and radiation effects on materials.
TA-21-155, Tritium Systems Test Assembly	Used to develop, demonstrate, and integrate tritium-processing technologies related to the deuterium-tritium fuel cycle for large-scale fusion reactor systems. Supports other tritium processing, research, and development studies.

Category 2 (Continued)	
TA-21-209, Tritium Science and Fabrication Facility	Supports thin-film loading of tritium on target materials, diffusion and membrane tritium purification research and development, solid material and container storage, metallurgical and material research on tritium effects and properties, tritium analysis, and calorimetry.
TA-50-1, Radioactive Liquid Waste Treatment Facility	Treatment and disposal of most of the industrial liquid and radioactive liquid waste generated at LANL.
TA-50-69, Waste Characterization, Reduction, and Repackaging Facility	Waste characterization, reduction, and repaekaging.
TA-54, Area G: Buildings 33, 48, 49, 144, 145, 146, 153, 177, 226, 229, 230, 231, 232, 281, 283, Pad 2, Pad 3, Pad 4	Management and disposal of radioactive solid and hazardous chemical waste.
TA-54-38 (Area G West)	Waste package characterization, including verification assay and radiographic examination of unopened containers and radioactive and mixed waste.
TA-55-4, Plutonium Facility TA-55-41, Nuclear Materials Storage Facility	Plutonium chemical processing (synthesis, reprocessing, stabilization); plutonium physical processing (casting, forming, fabricating, measuring); actinide chemistry; radioactive waste research; nuclear fuels research; NASA fuel development. The Nuclear Materials Storage Facility is not operational and is being renovated to bring it up to current nuclear facility standards.
Category 3	
TA-3-40, Physics Building	Calibration and evaluation of all types of radiation detection instrumentation used throughout the Laboratory.
TA-3-66, Sigma Building	Materials science (synthesis, processing, characterization, fabrication); nuclear materials stabilization; materials deposition research; surface reactions, including materials joining; material-aging research; uranium process development.
TA-3-130, Calibration Building	Radiation evaluation studies using sealed radiation sources for calibrating instruments used to evaluate the response of various detectors to x-ray, gamma, beta, and neutron emissions.
TA-3-159, Thorium Storage Building	Stores thorium in ingot and oxide forms.
TA-21-146, Exhaust Building	Decontaminated building awaiting declassification as a hazardous facility.
TA-33-86, High-Pressure Tritium Facility	Preparing and packaging tritium-containing gas mixtures to meet precise experimental specifications.
TA-35-2, -27, Nuclear Safeguards Research	Nuclear safeguards, research, development, and training; a 7-in. launcher is used to determine responses of various fuels and other materials to different kinds of impacts.

Category 3 (continued)	
TA-48-1, Radiochemistry Laboratory	Radiochemistry research, development of waste management technologies, radionuclide transport, inorganic chemistry, structural analysis, medical radioisotope research.
TA-53-3-M, Los Alamos Neutron Science Center	Subatomic, particle, and atomic physics; subatomic chemistry; radioisotope production; materials science studies; proton and neutron radiography of HE and actinides; neutron irradiation techniques for waste; fusion research; condensed matter research; advanced accelerator concepts; advanced free-electron lasers.
Non-Nuclear Facilities	
M/RAD	
TA-41-4, Laboratory	Past operations included handling and storing materials such as uranium, tritium, deuterium, and liquid nitrogen. All nuclear materials were removed from this facility in 1995. The building is currently used for nonradiological work related to weapons engineering.
M/CHEM	
TA-0-1009, TA-0-1110, TA-0-1113, TA-0-1114, Chlorination stations	Chlorination.
TA-3-170, Liquid and Compressed Gas Facility	Receiving and distribution point for bulk quantities of specialized gases used in R&D.
TA-16-560, Chlorination Station	Chlorination.
TA-21-3, -4, Laboratories	Radiochemistry operations (being decommissioned).
TA-35-213, Target Fabrication Building	Polymer science, ceramic technology, specialized physical processing (machining, fabrication, electroplating).
TA-46-340, Sanitary Wastewater Treatment Facility	Disinfecting plant effluent before release to holding ponds; uses chlorine gas for this purpose.
TA-54-1008, Chlorination Station	Chlorination.
TA-72-3, Chlorination Station	Chlorination.
TA-73-9, Chlorination Station	Chlorination.

TABLE 4-3

SUMMARY OF FACILITIES CATEGORIZED AS HAZARDOUS AT LOS ALAMOS NATIONAL LABORATORY

TA	Nuclear Facilities		Nonnuclear Facilities					
	Cat. 2	Cat. 3	M/RAD	M/CHEM	L/RAD	L/ENS	L/CHEM	L/ENV
TA-0				1109, 1110, 1113, 1114				
TA-2					1, 4, 44, 50			
TA-3	29, 65	40, 66, 130, 159		170	16, 35, 102, 316	216	24, 30, 31, 32, 34, 39, 141, 1698	
TA-8	22, 23, 24, 70[a]					1, 2, 3, 31, 32		
TA-9						21, 22, 23, 24, 25, 26, 27, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 204, 208	29, 31	
TA-11						0, 25, 30, 36		
TA-14						5, 6, 22, 23, 24, 34, 39		
TA-15					184, 203, 312[b], 313	41, 42, 43, 183, 241, 242, 243, 263, 285, 306, 314		
TA-16	205/205A, 411			560		58, 220, 221, 223, 224, 225, 226, 236, 260, 261, 263, 265, 280, 281, 282, 283, 284, 285, 287, 288, 301, 302, 303, 307, 308, 313, 340, 341, 342, 343, 345, 350, 351, 352, 353, 354, 360, 380, 388, 389, 399, 401, 406, 410, 413, 415, 416, 418, 419, 430, 435, 437, 442, 443, 444, 460, 461, 462, 463, 477, 478	88, 339, 344	
TA-18	23, 26, 32, 116				127, 129, 227, 247, 249			
TA-21	155, 209	146		3, 4	5, 150, 257, 324		30, 212	

TA-22						1, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 34, 35, 69, 91, 93, 96	95	
TA-28						1, 2, 3, 4, 5		
TA-33		86				19, 95, 114		
TA-35		2, 27		213	7, 125-1	86, 124, 125-2, 128, 189, 207, 294, 301		85
TA-36					86	3, 4, 5, 7, 9, 10, 11, 12, 55, 82, 83		
TA-37						3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26		
TA-39					2, 138	2, 3, 4, 5, 6, 7, 54, 56, 57, 69, 77, 89, 95, 111		
TA-40						2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 23, 36, 37, 38, 39, 40, 41, 72		
TA-41			4		1		7	
TA-43						20	1, 47	
TA-46				340	161, 208	24, 30, 31, 41, 76, 154, 158, 200, 250	324	
TA-48		1						
TA-49						0, 128, 130		
TA-50	1, 69				37			
TA-53		3-M			1, 3, 7, 8, 10, 14, 17, 18, 29, 30, 34, 315, 364, 369, 370, 371, 372, 374, 382, 541, 616, 823	19, 365, 633, 761, 1031		
TA-54								
Area G	33, 48, 49, 144, 145, 146, 153, 177, 226, 229, 230, 231, 232, 281, 283, Pad 2, Pad 3, Pad 4				2			
Area G West	38							

Area L							31, 32, 35, 36, 39, 46, 50, 55, 58, 62, 68, 69, 70, 82, 174, 215, 216	
Other TA-54 Buildings				1008	1009			
TA-55	4, 41[c]					7	3, 5	
TA-72				3		Pistol Range 3, Rifle Range 4		
TA-73				9				

a. These facilities occasionally house nuclear materials in sufficient quantities to qualify them as Category 2 nuclear facilities. Based on safety analyses, the necessary controls are in place when nuclear materials are being handled. For all other operations, these facilities are considered non-nuclear.
b. The DAHRT Facility is not yet operational.
c. The Nuclear Materials Storage Facility is not operational and is being renovated to bring it up to current nuclear facility standards.

References for Chapter 4

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5.0 ENVIRONMENTAL SETTING

This chapter has four major topics of discussion. It starts with the physical setting of LANL, which includes the geological, seismological, hydrological, and climatological components of the regional environs. This discussion is followed by a description of the ecological setting, which includes threatened, endangered and sensitive species; unique and sensitive habitats; and floodplains and wetlands. Because of the rich history of the Pajarito Plateau from an Indian settlement standpoint and the historic buildings and structures dating to the Manhattan Project, a section is included on cultural resources, which includes an overview of the prehistoric, historic, and traditional cultural properties. The chapter closes with a presentation of the socioeconomic setting, which identifies the regional context of these data, the types of data routinely collected and their limitations, the ethnic and geographic location of the workforce, and the Laboratory's contribution to the region's economy.

5.1 Physical Setting

Los Alamos is located on the eastern flank of an inactive volcano in the mountains of the desert Southwest. This region has a rich geological history; a very complex and not completely understood hydrology; some seismic activity; and a system of canyons, mesas, and mountains that generate a complex-terrain climatology. The following four sections explain what is known about each of these physical systems. Much of the information presented is based on the Laboratory's Installation Work Plan (IWP) for Environmental Restoration, Revision 4 (LANL 1995), prepared by the Environmental Restoration Program.

5.1.1 Geology

The Laboratory has been collecting data on the soil, seismic, and geologic characteristics of the Laboratory since the 1950s in an effort to better understand (1) water supply and the potential for hydrologic transport of contaminants, (2) seismological stability, particularly as it affects nuclear facilities, and (3) local ecosystems and the effects of Laboratory activities on those ecosystems. Currently, geohydrologic characterization data are collected primarily by the Environmental Surveillance and Monitoring Program, and special studies are conducted by various Laboratory groups, by the Environmental Restoration Program, and by a number of interested groups outside the Laboratory.

The Laboratory is situated on the Pajarito Plateau, which extends eastward from the base of the Jemez Mountains to the western edge of the Rio Grande rift, a major tectonic feature of the western United States (Figure 5-1). The plateau occupies the western part of the Española basin portion of the rift; the basin lacks distinct major faults on its eastern margin, but faults of major vertical offset may exist within the Precambrian rocks of the Sangre de Cristo uplift (Vernon and Riecker 1989, Biehler et al. 1991). The western margin of the Española basin is characterized by a zone of prominent major faults that cuts through Miocene to Quaternary rocks of the Jemez volcanic field (Smith et al. 1980, Gardner and Goff 1984, Goff et al. 1990). These border faults strongly influenced the location and development of the volcanic field (Gardner and Goff 1984; Gardner et al. 1986).

The Jemez volcanic field consists of some 432 mi^3 (1,800 km^3) of volcanic rock erupted from numerous vents, including a giant, multistage caldera (Gardner et al. 1986). It lies at the intersection of the Jemez lineament, a northeast-trending alignment of volcanic fields, and the north-trending zone of extensional tectonics that is the Rio Grande rift (Aldrich 1986). The Jemez Mountains are part of the Jemez volcanic field.

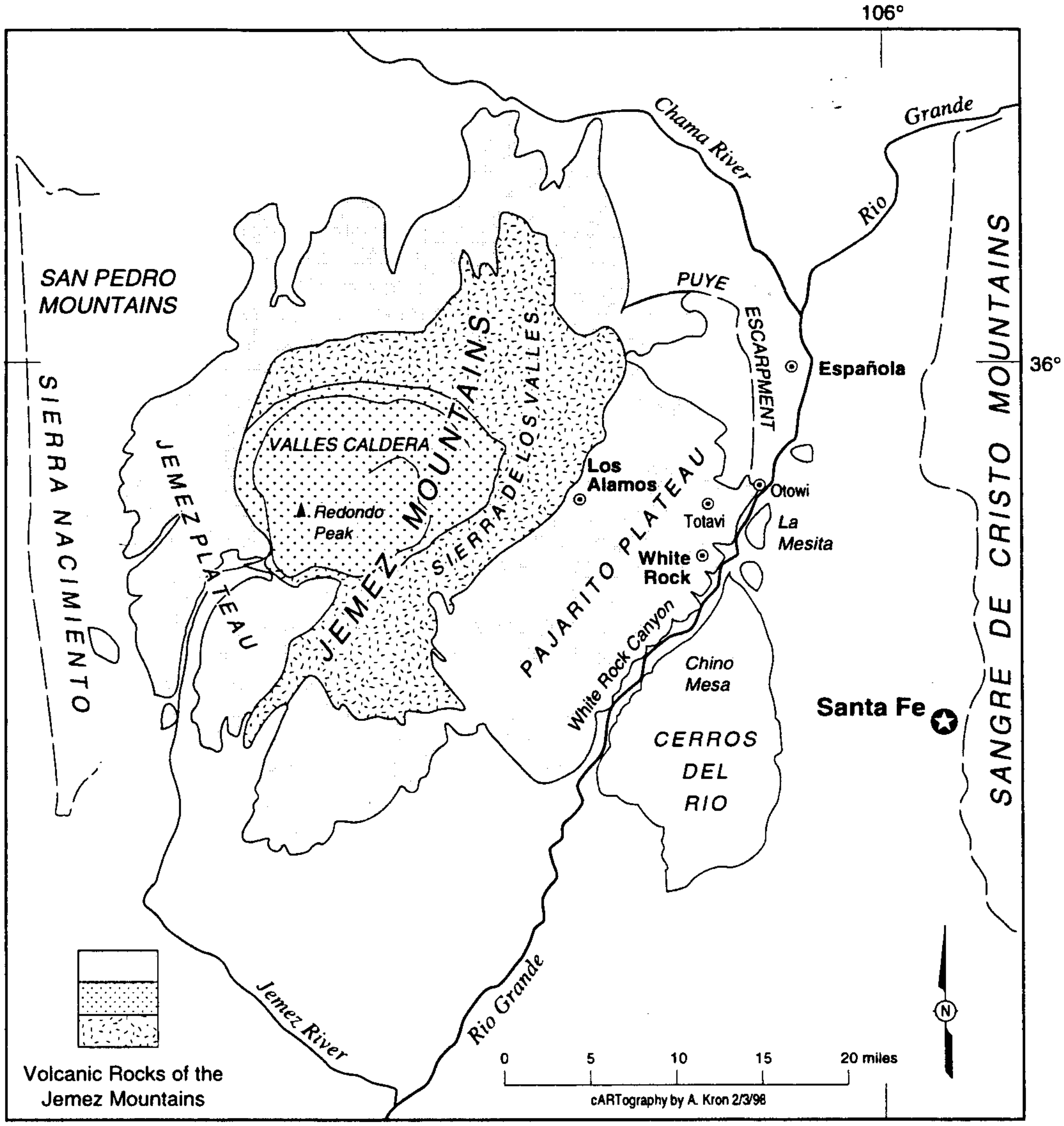


Figure 5-1. Regional map and generalized geology surrounding the Laboratory.

Rocks formed before the rift developed underlie and are exposed around the margins of the Española basin. These rocks consist of Mississippian to Permian marine limestones, sandstones, and shales; Mesozoic marine and terrestrial sandstones and shales; and Eocene sandstones, shales, and freshwater limestones. Precambrian rocks—predominantly quartzite, granitic gneiss and schist, and greenstone—are exposed in the cores of the Sangre de Cristo, Nacimiento, and Brazos uplifts that flank the basin (Kelley 1978). The earliest sediments deposited in the Tertiary Española basin are those of the Abiquiu, Picurís, and Los Piños formations, which consist of tuffaceous sandstones and volcaniclastic conglomerates derived largely from volcanic highlands to the north and northeast. These units range in age from about 28 to 17 million years old (Baldridge et al. 1980, May 1994, Ingersoll et al. 1990).

The Rio Grande rift began to form over 20 million years ago as a result of local downfaulting, which was followed by accumulations of rocks of the Santa Fe Group as fill in the depression. The andesitic rocks of the Paliza Canyon Formation represent effusions of numerous coalesced composite volcanoes in the southwestern portion of Los Alamos County, dating to some 9.1 to 8.5 million years ago. The next sequence of volcanic activity in the county took place along faults at or near the western boundary of the Rio Grande rift, when the flow rocks of the Jemez Mountains volcanic pile were erupted from volcanic feeders. These rocks subsequently eroded and were deposited as an alluvial fan, the Puye Formation. Subsequently, the basaltic lavas of Chino Mesa erupted from volcanic centers in the Cerros del Rio area and flowed northwest into what is now the White Rock-Pajarito Acres area.

In mid-Pleistocene times, local volcanism climaxed in two gigantic pyroclastic outbursts, one about 1.5 million years ago and the second about 1.13 million years ago; these events created the Otowi and Tshirege members of the Bandelier Tuff, which together comprise nearly 100 mi^3 (418 km^3) of deposited rhyolite ash and pumice (Smith and Bailey 1966, Spell et al. 1990).

The first of these volcanic events was precipitated by the upward movement of rhyolite magma. Once exposed to the atmosphere, the magma was ejected, forming first the Guaje pumice and then the Otowi Member of the Bandelier Tuff as great volumes of magma swept down the flanks of the volcanic pile in the form of granular pumice. The eruptions caused the crater to collapse, creating the Toledo Caldera; a portion of the viscous, volatile-poor magma was extruded to form the Cerro Toledo rhyolite domes and, subsequently, the Cerro Rubio quartz lattice and latite domes.

The second eruption of rhyolite magma resulted in the formation of the Tsankawi pumice, followed in rapid succession by several ash flows that produced the Tshirege Member of the Bandelier Tuff. With this eruption, the collapse of the crater resulted in the Valles Caldera. A few minor eruptions followed the Tshirege flows and deposited a small amount of ashfall pumice on top of the Bandelier Tuff. After formation of the calderas, volcanism continued with the extrusion of domes along ring fractures.

The latest eruption in the Jemez Mountains occurred about 60,000 years ago, producing the El Cajete pumice and Banco Bonito rhyolite flow (Wolff and Gardner 1995, Gardner et al. 1986, Self et al. 1988). Vestiges of volcanic activity continue today, as evidenced by solfataric and hot-spring activity both inside and outside of the Valles Caldera (Goff et al. 1989). Studies of P-wave arrival time delays suggest the presence of partially molten rock beneath the Valles Caldera, possibly the remnants of the cooling Bandelier magma chamber (Roberts et al. 1991).

5.1.1.1 Geologic Structure

As mentioned earlier, the Laboratory is situated on the Pajarito Plateau, which lies at the western margin of the Española basin of the Rio Grande rift, a major tectonic feature of the North American continent. The Pajarito fault system forms the western margin of the Española basin and exhibits

Holocene movement and historical seismicity (Gardner and House 1987, Gardner et al. 1990, Gardner and House 1994). The fault system is made up of over 65 mi (105 km) of mapped fault traces and connects with regional structures that extend at least as far as Cochiti to the south and Taos to the northeast (Gardner and House 1987).

Within Los Alamos County, the Pajarito fault system consists of three unconnected fault segments that are active or potentially active: the Frijoles Canyon, Rendija Canyon, and Guaje Mountain segments. The Frijoles Canyon fault segment is a zone of faulting more than 0.25 mi (0.4 km) wide, whose major scarp forms the western boundary of the Laboratory. This scarp is over 410 ft (125 m) high near the southwestern corner of the Laboratory and is composed of rocks about 1 million years old. Movement on this fault segment is normal-oblique, and the fault's eastern side is relatively downdropped. The Rendija Canyon and Guaje Mountain segments, exposed north of Los Alamos Canyon, are characterized by zones of gouge and breccia, generally 100 to 150 ft (30 to 46 m) wide. Both fault segments produce visible offsets of stratigraphic horizons and are dominantly normal-oblique faults whose west sides are downdropped. There are some indications of strike-slip movements on the Guaje Mountain fault segment (Wachs et al. 1988, Aldrich and Dethier 1990, Gardner et al. 1990). The youngest movements on the Guaje Mountain segment have been constrained to between roughly 4,000 and 6,000 years ago (Gardner et al. 1990).

Displacement on the Guaje Mountain and Rendija Canyon faults apparently decreases south of Los Alamos Canyon, and narrow zones of faulting are replaced by wide [over 300 ft (90 m)] zones of intense brecciation and fracturing superimposed on the network of cooling joints in the Bandelier Tuff (Vaniman and Wohletz 1990). In contrast to cooling joints, these tectonic fractures cross flow-unit and lithologic unit boundaries; thus, tectonic fractures may provide more continuous and more deeply penetrating flow paths for groundwater migration than do cooling joints.

Dransfield and Gardner (1985) integrated a variety of data to produce structure contour and paleogeologic maps of the pre-Bandelier-Tuff surface beneath the Pajarito Plateau. Their maps reveal that subsurface rock units are cut by a series of down-to-the-west normal faults; the overlying Bandelier Tuff is not obviously displaced by these buried faults. However, where detailed fracture studies have been done on the plateau, they show that fractures and apertures are more abundant in the Bandelier Tuff over fault projections, which indicates the occurrence of tectonic fracturing, as mentioned earlier (Vaniman and Wohletz 1990). In addition, small-scale offsets along fractures have been observed in various parts of the Laboratory, including Area G at TA-54 (Rogers 1977), which suggests additional unmapped fault zones. Detailed studies of fractures on the Pajarito Plateau are few.

5.1.1.2 Stratigraphic Units

The mesas of the Pajarito Plateau are formed of Bandelier Tuff of Pleistocene age, which is overlain by a veneer of soils and alluvial deposits. The tuff is exposed in the canyon walls and is penetrated by numerous drill holes. Beneath the Bandelier Tuff is a sequence of interstratified sedimentary and volcanic rocks of Miocene to Pleistocene age, which have been penetrated by water supply wells and have been studied where they are exposed in canyons on the margins of the Pajarito Plateau. These rock units include volcanic rocks of the Paliza Canyon Formation, the Tschicoma Formation, and the Cerros del Rio volcanic field, as well as sedimentary deposits of the Puye Formation, the Totavi Formation, the Cochiti Formation, and the Santa Fe Group. Figure 5-2 is a generalized cross section, from west to east, of the geology in the vicinity of the Laboratory.

5.1.1.2.1 Santa Fe Group

The Santa Fe Group is of Miocene and early Pliocene age (formed 28 to 4.5 million years ago) and consists of a thick series of terrestrial conglomerates, sandstones, and mudstones, with minor limestones, evaporites, volcanic tuffs, and intercalated basalts. These rocks are the most exten-

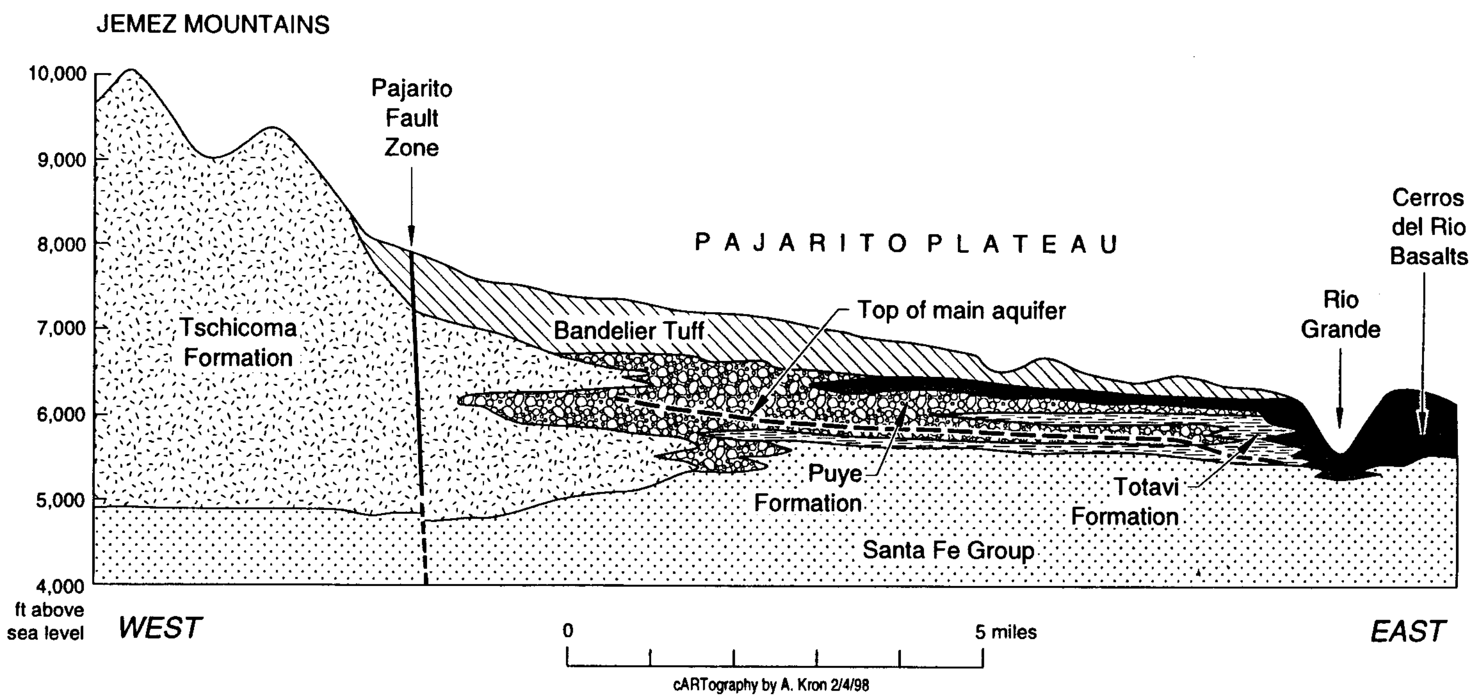


Figure 5-2. West-east vertical cross section showing the generalized geology in the vicinity of the Laboratory.

sive units filling the Rio Grande rift, and most production from water wells at Los Alamos is from the Santa Fe Group (Griggs and Hem 1964, Purtymun et al. 1984). Sedimentary rocks usually dominate the Santa Fe Group, although basalts constitute up to 45% of the section penetrated by water supply wells at the Laboratory (Purtymun et al. 1984). In the Española basin and below the northern part of Los Alamos County, the Santa Fe Group is subdivided into two formations (the Tesuque and the Chamita) and into several members, which reflects the diversity of the coalesced alluvial fans deposited in the Española basin (Galusha and Blick 1971, Ingersoll et al. 1990). Early investigators inferred that all Santa Fe Group rocks exposed around the flanks of the Pajarito Plateau and intersected by water wells beneath the plateau belonged to the Tesuque Formation (Griggs and Hem 1964, Cooper et al. 1965). However, more recent investigations suggest that some of the upper Santa Fe Group in the vicinity of Los Alamos is Chamita Formation (Turbeville et al. 1989).

5.1.1.2.2 Keres Group

Two formations of the Keres Group (Bailey et al. 1969, Gardner et al. 1986) may be important in the pre-Bandelier-Tuff subsurface in the southern parts of the Laboratory. These are the Paliza Canyon and Cochiti formations, both about 13 million to 6 or 7 million years old. The St. Peter's Dome area, about 3 mi (4.8 km) from the southern boundary of the Laboratory, was a major center of Keres Group volcanism (Goff et al. 1990). Large volumes of Paliza Canyon andesite were erupted from the St. Peter's dome center, whence they spread to the east and north. It appears that some of the volcanic units encountered in wells at TA-49 (Weir and Purtymun 1962) may be Paliza Canyon lavas that had been misidentified as Tschicoma and Cerros del Rio units, as discussed below.

Beneath the southern Pajarito Plateau, sedimentary deposits of the Cochiti Formation compose the Miocene basin fill and are therefore laterally equivalent to the sedimentary rocks of part of the Santa Fe Group—and, possibly, also to those of the Puye Formation (Section 5.1.1.2.4) to the north (Gardner et al. 1986). The Cochiti Formation consists predominantly of basin fill gravels derived from the volcanic centers of the southern and central Jemez Mountains volcanic field. Transitions between the Cochiti, Santa Fe, and Puye formations probably exist somewhere beneath Los Alamos County; however, they are very poorly defined.

5.1.1.2.3 Tschicoma Formation

The Tschicoma Formation consists of a sequence of dacitic domes and lavas that were erupted from vents in the central to northeastern Jemez Mountains between about 7 and 3 million years ago (Gardner et al. 1986). These volcanic rocks outcrop extensively in the mountains immediately west of the Laboratory and have been observed in the subsurface beneath the western and southern part of the Laboratory (Weir and Purtymun 1962, Griggs and Hem 1964, Dransfield and Gardner 1985).

5.1.1.2.4 Puye Formation

The Puye Formation consists of a Pliocene-to-Pleistocene fanglomerate that was shed eastward from Tschicoma volcanic centers in the northeastern Jemez volcanic field between about 4 and 1.7 million years ago. Earlier workers (e.g., Griggs and Hem 1964) included the Totavi Lentil—now considered a separate formation (Section 5.1.1.2.5)—in the Puye Formation. Most of the Puye conglomerates contain cobbles of dacitic to andesitic composition in a matrix of volcanic sand. The beds include streamflow deposits, debris, volcanic deposits, and ash-fall and pumice-fall deposits (Waresback and Turbeville 1990). The Puye Formation is best exposed north of the Laboratory, but lithologically similar rocks have been penetrated by drill holes as far south as Frijoles Mesa (Weir and Purtymun 1962, Dransfield and Gardner 1985). Under parts of the Laboratory, the Puye

Formation is interstratified with basalts of the Cerros del Rio volcanic field. In Los Alamos water supply wells, the top of the main aquifer is usually within the Puye Formation.

5.1.1.2.5 Totavi Formation

Immediately beneath the fanglomerates of the Puye Formation is a section of poorly consolidated fluvial gravels that unconformably overlie the Santa Fe Group; Griggs and Hem (1964) originally named these gravels the Totavi Lentil of the Puye Formation. However, the gravels contain clasts that differ lithologically from those in the Puye, including abundant well-rounded cobbles and boulders of quartzite, granite, and pegmatite that testify to a source area distant from the Jemez Mountains. This unit probably consists of axial channel gravels of an ancestral Rio Grande. Recently, Waresback and Turbeville (1990) redefined the unit as a separate formation; their Totavi Formation also includes lacustrine sediments that are complexly interstratified with the upper Puye Formation ("old alluvium" of Griggs and Hem). In some water supply wells beneath the Laboratory, the Totavi Formation was reportedly observed between the Santa Fe and the Puye formations at lower elevations in the eastern wells (Cooper et al. 1965, Purtymun et al. 1983, Purtymun et al. 1984). The presence of the Totavi at these levels suggests that Rio Grande river gravels were deposited on erosional surfaces, conditions analogous to those that created the Quaternary terraces of the Rio Grande in the Española basin before deposition of the Puye fans, which unconformably overlie older formations (Dethier et al. 1988).

5.1.1.2.6 Cerros del Rio Basalts

Basaltic flows, breccias, and scoria of the Cerros del Rio occur in the subsurface beneath much of the Pajarito Plateau (Dransfield and Gardner 1985) and outcrop in the east and southeast parts of Los Alamos County (Griggs and Hem, 1964). These volcanic rocks are associated with the Pliocene-to-Pleistocene Cerros del Rio basalt field east of the Rio Grande, rocks from which have been dated at 4.6 to 2.0 million years old (Gardner et al. 1986). The youngest lava flows in this area occurred between the two Bandelier Tuff eruptions 1.5 and 1.13 million years ago ("basaltic andesite of Tank Nineteen" described by Smith et al. 1980). Part of this volcanic field is also known as basaltic rocks of Chino Mesa (Griggs and Hem 1964). The top of the main aquifer beneath the Laboratory is locally within this section of basaltic rocks.

5.1.1.2.7 Otowi Member, Bandelier Tuff

The Otowi Member of the Bandelier Tuff underlies the Tshirege Member beneath much of the Pajarito Plateau and outcrops in many of the canyons (Griggs and Hem 1964). The Otowi Member is mostly a nonwelded ash-flow tuff (ignimbrite) that was erupted from the Jemez Mountains 1.5 million years ago (Spell et al. 1990). It is highly porous and poorly indurated and is composed of multiple flow units. Where it outcrops, cooling joints are typically absent because of relatively low emplacement temperatures and the lack of induration. The Guaje Pumice Bed, which is composed of sorted pumice fragments averaging 0.8 to 1.6 in. (2 to 4 cm), is generally found at the base of the Otowi Member (Crowe et al. 1978).

5.1.1.2.8 Cerro Toledo Rhyolite and Interbedded Sediments

An interbedded sequence of rhyolitic tuffs and sediments commonly occurs between the Otowi and Tshirege members of the Bandelier Tuff. The rhyolitic tuffs were erupted between 1.5 and 1.2 million years ago, predominantly from the Cerro Toledo domes in the northeastern Jemez Mountains (Heiken et al. 1986). The interbedded sediments are epiclastic sands and sandy gravels that lithologically resemble Puye Formation fanglomerates. At the Laboratory, deposits belonging to this interval have sometimes been referred to as "Tsankawi pumice" or "Tsankawi member." These units may play an important role in the migration of water through the subsurface beneath the Laboratory (Stoker et al. 1991).

5.1.1.2.9 Tshirege Member, Bandelier Tuff

The most widespread rock unit on the Pajarito Plateau is the Tshirege Member of the Bandelier Tuff (Griggs and Hem 1964), which was erupted from what is now the Valles Caldera in the Jemez Mountains about 1.13 million years ago (Spell et al. 1990). The Tshirege Member is composed of multiple flow units of crystal-rich, ash-flow tuff (ignimbrite) and displays significant variations in welding and alteration, both in a single stratigraphic section and with varying distance from the caldera. Individual units tend to be more welded and thicker to the west. Flow units are locally separated by volcanic surge deposits of well-sorted, fine-grained, cross-bedded crystal and pumice fragments. Vapor-phase alteration, caused by postemplacement cooling and migration of entrained magmatic gases, occurs in much of this unit. The base of the Tshirege Member is often marked by 1.5 to 10 ft (0.5 to 3 m) of bedded, unconsolidated, pumice-rich ash-fall tuff of the Tsankawi Pumice Bed (Bailey et al. 1969, Crowe et al. 1978). The Tsankawi Pumice Bed is generally poorly recognized in drill-bit cuttings because the soft pumice is often ground to dust by a rotary drill.

The Tshirege Member has been subdivided into a sequence of mappable units, based on either erosional characteristics (Weir and Purtymun 1962, Baltz et al. 1963, Purtymun and Kennedy 1971) or on primary cooling units. These units have been correlated over large distances on the Pajarito Plateau. However, the boundaries between them are not always distinct in the field and can be difficult to recognize in drill holes, with the result that different investigators make different judgments concerning the locations of these boundaries. Furthermore, in the absence of geologic mapping in the intervening areas, the validity of the correlations is uncertain.

Stratigraphic features in the tuff, such as volcanic surge deposits, may locally provide preferential migration pathways for moisture and contaminants in the subsurface (Purtymun 1973b, Crowe et al. 1978). Purtymun (1973a) noted increased rates of vapor-phase migration of tritium away from storage shafts at TA-54 along a stratigraphic boundary that includes surge layers. Individual flow units in the Tshirege Member contain vertical cooling joints that may or may not cross flow unit boundaries. In ash-flow tuffs, the spacing of cooling joints varies primarily with the thickness of the unit, the emplacement temperature, the substrate temperature, and topography. Joint density tends to be greatest in welded tuff and least in nonwelded tuff. Hydraulic conductivities are generally greatest in the fractured, welded parts of ash-flow tuffs and least in the nonwelded parts (Crowe et al. 1978).

5.1.1.2.10 Post-Bandelier-Tuff Units

Stratigraphically overlying the Bandelier Tuff are discontinuous Quaternary alluvial units that occur as thin deposits [typically measuring less than 15 ft (4.6 m)] on mesa tops and in canyons. These post-Bandelier-Tuff alluvial units represent a range of ages, from 1.1 million years ago to the present. Alluvial fans, consisting mostly of dacite debris, are being shed over the Bandelier Tuff at the western boundary of the Laboratory. Well-sorted to poorly sorted sandy and gravelly alluvium, ranging up to 70 ft (21 m) thick in some drill holes (Baltz et al. 1963), is found in the major drainages of the Pajarito Plateau. Older alluvium occurs on stream terraces in canyon bottoms, where it is often buried by colluvial deposits from the canyon walls. Generally, alluvial units on the surface of the mesas are probably oldest, having been formed before the cutting of the plateau by multiple parallel drainages. The distribution of alluvial deposits on the mesa tops has not been mapped, but these deposits are most widespread in the western part of the plateau. Those units lowest in the drainages grade into the active alluvium along canyon bottoms.

The alluvial sediments in the canyon bottoms probably record a complex history of erosion and deposition, in part related to regional climatic changes. In Cabra Canyon, immediately north of Los Alamos, several cycles of erosion and deposition of sediment have occurred over the last 6,000 years, during which most of the previously stored sediment was eroded (Gardner et al. 1990).

Similar cycles of erosion and deposition have been documented in many parts of the southwestern United States, and the older alluvial units in the vicinity of Los Alamos may also record the effects of regional climatic changes (Dethier et al. 1988).

The mesas of the Pajarito Plateau are also covered in part by deposits of El Cajete pumice, erupted from the El Cajete crater in the Jemez Mountains. These deposits have not been mapped, but in the area of the Laboratory they appear to be most common to the south, and the axis of the volcanic dispersal plume is south of Los Alamos County. Available data suggest that the El Cajete pumice is 60,000 years old (Wolff and Gardner 1995).

5.1.1.3 Geomorphic Processes

Significant geomorphic processes active on the Pajarito Plateau include (1) erosion of mesa-top soils by runoff, (2) retreat of canyon walls as the result of rockfalls and landslides, (3) colluvial transport along sloping portions of canyon walls, and (4) erosion and deposition of sediments by streams in the canyon bottoms. Little information exists on the rates of erosion and landscape change caused by these different processes on the Pajarito Plateau. The rates at which vertical erosion of mesas takes place over the long term have been estimated by calculating the rates at which overlying units are stripped off (Purtymun and Kennedy 1971), but these estimates may be of limited value because the resistant cliff-forming units may be eroded primarily by lateral cliff retreat rather than by vertical erosion. Erosion rates of mesas vary considerably; the highest rates occur in and near drainage channels and in areas of locally steeper slope, and the lowest rates occur in the more gently sloping areas farthest from channels. Areas in which runoff is concentrated because of the presence of roads and other development are especially prone to accelerated erosion.

The rates and processes of erosion may differ significantly between the north and south slopes of canyons. Under current vegetation and climate conditions, the south-facing slopes are drier and less vegetated and exhibit more extensive exposures of bedrock than the north-facing slopes, suggesting that erosion of fine-grained materials, mainly by runoff, is higher on the south-facing sides of canyons; these fine materials are largely retained on the north-facing slopes. However, no studies have been conducted to quantify the rates and processes of erosion on canyon sides.

Cliff faces retreat primarily through dislodgment of blocks bounded by joints and, to a lesser extent, by large-scale landsliding, including the formation of huge toreva blocks in White Rock Canyon. At present, the rates of cliff retreat have not been documented. Neither is it known to what extent rates of cliff retreat may vary with climatic changes, with evolution of the canyons, or with proximity to side drainages.

The rates of deposition, erosion, and transport of sediments through canyons are also largely unknown, owing principally to the paucity of data on the thicknesses and ages of alluvium in canyon bottoms and the lack of detailed stratigraphies. The studies that have been done on the alluvial stratigraphy of the Pajarito Plateau reveal multiple cycles of extensive erosion of sediment, followed by renewed deposition, over the past 6,000 years (Gardner et al. 1990). At Cabra Canyon, north of Los Alamos, the last few hundred years has seen a net accumulation of sediment in the canyon bottom (Gardner et al. 1990); however, such accumulations of sediment can at any time be mobilized and transported downcanyon by flood waters. It is possible that erosion-deposition cycles are climatically driven and are regional in extent, but more extensive data from additional canyons are needed before any conclusions can be drawn. On a longer time scale, evidence from the adjacent Española basin does suggest strong climatic control on periods of alluviation and canyon incision over the last million years (Dethier et al. 1988).

5.1.1.4 Soils

On the Pajarito Plateau, the nature of the underlying bedrock, slope characteristics, and climate have combined to produce a wide variety of soils (Nyhan et al. 1978). The principal parent materials of about 95% of Los Alamos County soils are Bandelier Tuff, volcanic rocks of the Tschicoma and Puye formations, basaltic rocks of Chino Mesa, and remnants of the El Cajete pumice. The remaining 5% formed from colluvium, alluvium, and andesitic rocks of the Paliza Canyon Formation, from Cerro Rubio quartz latites, and from tuffs and associated sediments of Cerro Toledo rhyolite. Alluvium derived from the Pajarito Plateau and from the east side of the Jemez Mountains contributes to soils in the canyons and also to those on some of the mesa tops. Layers of pumice derived from El Cajete in the Jemez Mountains and windblown sediment derived from other parts of New Mexico are also significant components of many soils on the Pajarito Plateau.

5.1.1.4.1 Classification of Soils

The current system of soil classification has six categories. From broadest to narrowest, these are order, suborder, great group, subgroup, family, and series. The criteria on which this classification is based are soil properties that are observable and measurable; these properties are chosen so that soils of similar origin are grouped together. Of the ten recognized soil orders, only five exist in the Los Alamos area: alfisols, aridisols, entisols, inceptisols, and mollisols. About 80% of the county's soils can be grouped in the alfisol, entisol, and inceptisol soil orders.

Soils formed on the tops of mesas on the Pajarito Plateau include the Carjo, Frijoles, Hackroy, Nyjack, Pogna, Prieta, Seaby, and Tocal series. These soils typically have loam or sandy loam surface horizons and clay or clay loam subsurface horizons. Some, including the Frijoles, Hackroy, and Seaby soils, contain abundant pumice. Others, including the Prieta soils, contain abundant wind-deposited sediment. Soils on the mesas can vary widely in depth and typically become more shallow toward the edges of the mesas, where the bedrock is often exposed. Soils formed from alluvial and colluvial deposits include the Potrillo, Puye, and Totavi series, which are generally loose and sandy. Many of the slopes between mesa tops and canyon bottoms consist of steep rock outcrops and patches of shallow, undeveloped colluvial soils. Typically, the south-facing canyon walls are steep and have little or no soil material or vegetation, whereas the north-facing walls have areas of very shallow, dark-colored soils and are more heavily vegetated (Nyhan et al. 1978).

Soil-forming processes extend into fractures in the bedrock, where coatings of clay and calcium carbonate record the transport of water to significant depths in the tuff. For example, at TA-54, Area G, calcium carbonate has been observed as deep as 39 ft (12 m) and clay coatings as deep as 46 ft (14 m) below the ground surface (Purtymun et al. 1978). Roots have also been observed in coreholes and pits at similar depths along fractures, suggesting that these soil-forming processes continue at depth today.

5.1.1.4.2 Soil Profiles: Major Horizons

According to Nyhan et al. (1978), most Los Alamos soils have three major horizons. These are designated with the letters A, B, and C, from the surface downward. Some soils, such as certain very steep soils, do not have B horizons; soils that have been severely eroded may have lost the entire A horizon and occasionally the B horizon as well.

The A horizon, commonly referred to as the surface soil, is the most active biologically. Plant roots, bacteria, fungi, insects, and small burrowing animals are most commonly found in the A horizon. Plant roots, such as the extensive root systems of the native prairie grasses and trees, are important sources of organic matter for many Los Alamos soils. The depths of A horizon soils in the Los

Alamos area vary widely [from 2 to 30 in. (5 to 76 cm)], but those in the 5- to 12-in. (13- to 30-cm) range are most common.

The B horizon, commonly called the subsoil, is found immediately below the A horizon. It is lower in biological activity than the A horizon and thus is lower in organic matter. For this reason, and as a result of the accumulation of clays leached from the A horizon, the B horizon is usually harder when dry and stickier when wet than the A horizon. The B horizon can be absent entirely or can be as thick as 59 in. (150 cm), perhaps more; most local soils have B horizons between 6 and 21 in. (14 and 53 cm) thick.

The C horizon occurs below the B horizon (though it may be missing in some shallow soils). Biological activity is low. The C horizon may be the parent material from which the A and B horizons developed or may be of a different geologic material. The C horizons of local soils usually include the top 7.5 to 23 in. (19 to 59 cm) below the A and B horizons and usually do not have a distinct lower boundary.

5.1.1.4.3 Physical and Chemical Composition

Soils on the Pajarito Plateau are extremely variable in physical and chemical properties, such as particle size distribution, percent calcium carbonate, clay mineralogy, percent iron oxides, and trace element chemistry. Variations in background concentrations of soil elements are related to climate, topography, parent material, soil age, surficial processes, and vegetation. Parent materials consist of alluvial fans, sheetwash material, colluvium, El Cajete pumice, and, in some instances, the Bandelier Tuff. Analysis of samples from various deposits reveals ages ranging from several thousand years to perhaps as old as 1 million years).

Soil profiles range from poorly developed to well developed, depending on location. In lower Los Alamos Canyon, soil profiles are poorly developed, consisting only of A, C, and 2Cb horizons. These profiles exhibit some clay enrichment, with clay-size materials varying from 2.4% to 7.4% by weight. Concentrations of nitric-acid-digested beryllium and arsenic range from 0.31 to 0.42 ppm and from 0.7 to 0.9 ppm, respectively. In contrast, soils on the mesas near Ancho Canyon are well developed and contain several horizons: A1, A2, Bt, Bwkb, Btkb, and K. These soil profiles contain a significant amount of clay and calcium carbonate enrichment; clay-size materials range from 11.6% to 53.6% by weight. Concentrations of nitric-acid-digested beryllium and arsenic range from 3.0 to 11.2 ppm and from 0.8 to 4.0 ppm, respectively (Longmire et al. 1996).

The well-developed soils are richer in trace elements than the weakly developed soils, and the B horizons are richer in trace elements than the A and C horizons. Trace element enrichment in the B horizons is controlled by the abundances of clay minerals and iron oxides, which are characterized by relatively large surface areas. Compared with Bandelier Tuff, the soils are higher in aluminum, arsenic, barium, calcium, cesium, cobalt, chromium, and iron; however, the Bandelier Tuff is higher in beryllium, lead, sodium, potassium, thorium, and uranium.

Trace elements are distributed in background soils through the following processes:

- chemical weathering, by which trace elements (e.g., arsenic) are concentrated through adsorption on the surfaces of soil particles (clay minerals, iron oxides, solid organic matter, and calcium carbonate);

- coprecipitation, by which trace elements (e.g., barium, thorium, and uranium) are concentrated in soil-particle matrices that consist of primary minerals (silicates) and glass; and

- a combination of the first two processes (affected trace elements include beryllium, chromium, lead, and vanadium).

Barium, thorium, and uranium tend to show lesser amounts of leaching from primary silicate minerals and glass relative to arsenic and beryllium, which have become concentrated on surfaces of soil particles through chemical weathering, leading to element remobilization. Uranium (Valence State IV) is probably the dominant valence state in primary phases present in soil, as evidenced by the significant differences observed between the total element and the nitric-acid-digested fractions (these differences suggest some leaching of uranium in poorly developed soils in the Los Alamos area).

Because of the limited number of samples of Bandelier Tuff and of soils collected, this data set may not be fully representative of the tuff and soils of the area and may not include the full range of natural concentrations of the various elements. The data do, however, provide insight into many of the geochemical interactions that take place in Pajarito Plateau soils and serve as a basis for interpreting analytical results from potentially contaminated sites. By comparing the geomorphic settings and soil profile characteristics of sites of concern with those of "background" sites, better site-specific constraints on geochemical and natural backgrounds are possible.

5.1.2 Seismology

North-central New Mexico is a geologically complex region that has a long and rich history of volcanic and tectonic activity. The Rio Grande rift divides the region from north to south; the Great Plains and the southern Rocky Mountains lie to the east and the Colorado Plateau to the west. Figure 5-3 shows seismic features and representative seismic stations in north-central New Mexico.

Volcanism in the Jemez Mountains volcanic field began more than 13 million years ago and continued without significant hiatus until about 60,000 years ago (Gardner et al. 1986, Wolff and Gardner 1995). Reports of unknown reliability describe what were apparently phreatic explosions and, possibly, associated earthquakes within the volcanic field about 115 years ago (Santa Fe *Daily New Mexican* 1882). Regardless, given the long history of spatially focused, geologically continuous volcanic activity, future volcanism can be expected. The likelihood of future volcanic activity directly affecting the Laboratory is probably small, but currently available data are neither sufficient for quantifying the probabilities nor for predicting the nature of future volcanism.

Direct effects of future seismicity at the Laboratory are likely, although quantification of probabilities is not possible at present. Since late 1973, the Los Alamos Seismograph Network operated by the Laboratory has been recording data on earthquakes in north-central New Mexico. Between 1973 and 1984, the network comprised 10 or more stations covering an area of about 124 by 124 mi (200 by 200 km). [Since 1984, because of funding shortfalls, the network has been reduced to only 7 stations, covering Los Alamos and its immediate vicinity—an area of about 9 by 12 mi (15 by 20 km)]. Studies such as those of Cash and Wolff (1984) have shown that seismicity in northern New Mexico is fairly diffuse, with a few regions of distinct concentration that collectively form an elongated-horseshoe-shaped zone of relatively inactive seismicity around the Valles Caldera and the Jemez Mountains (Figure 5-4). The tectonics of this region would be better understood with additional information, such as data on the focal mechanisms of the earthquakes.

Near the Nacimiento Fault zone are two prominent clusters: one just south of 35° 48', near a bend in the San Ysidro-Jemez Fault zone, and the other just northeast of Cuba. Both clusters are mainshock-aftershock sequences (i.e., a main earthquake followed by one or more notably smaller earthquakes). Farther north, earthquakes are scattered along the Gallina-Archuleta arch.

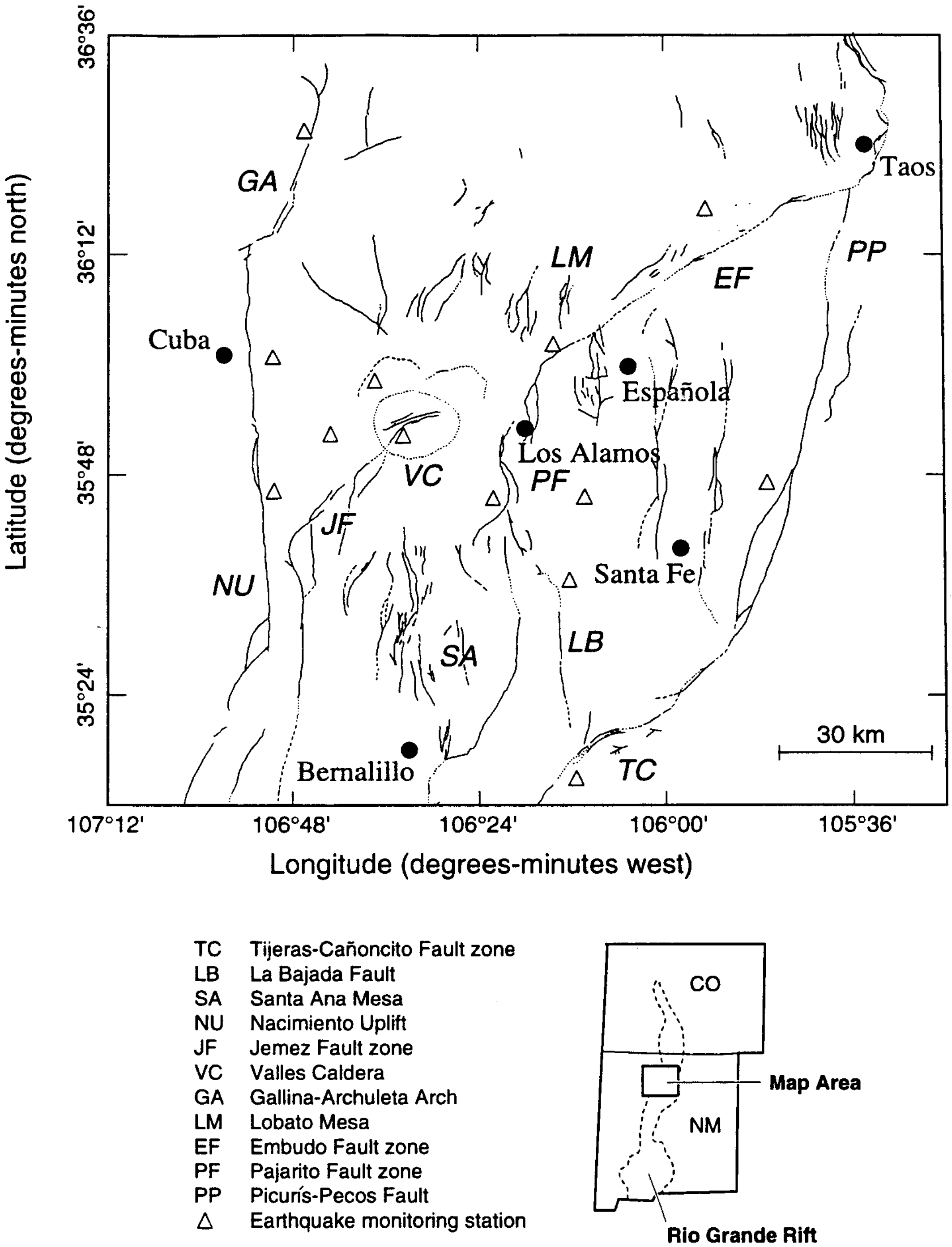
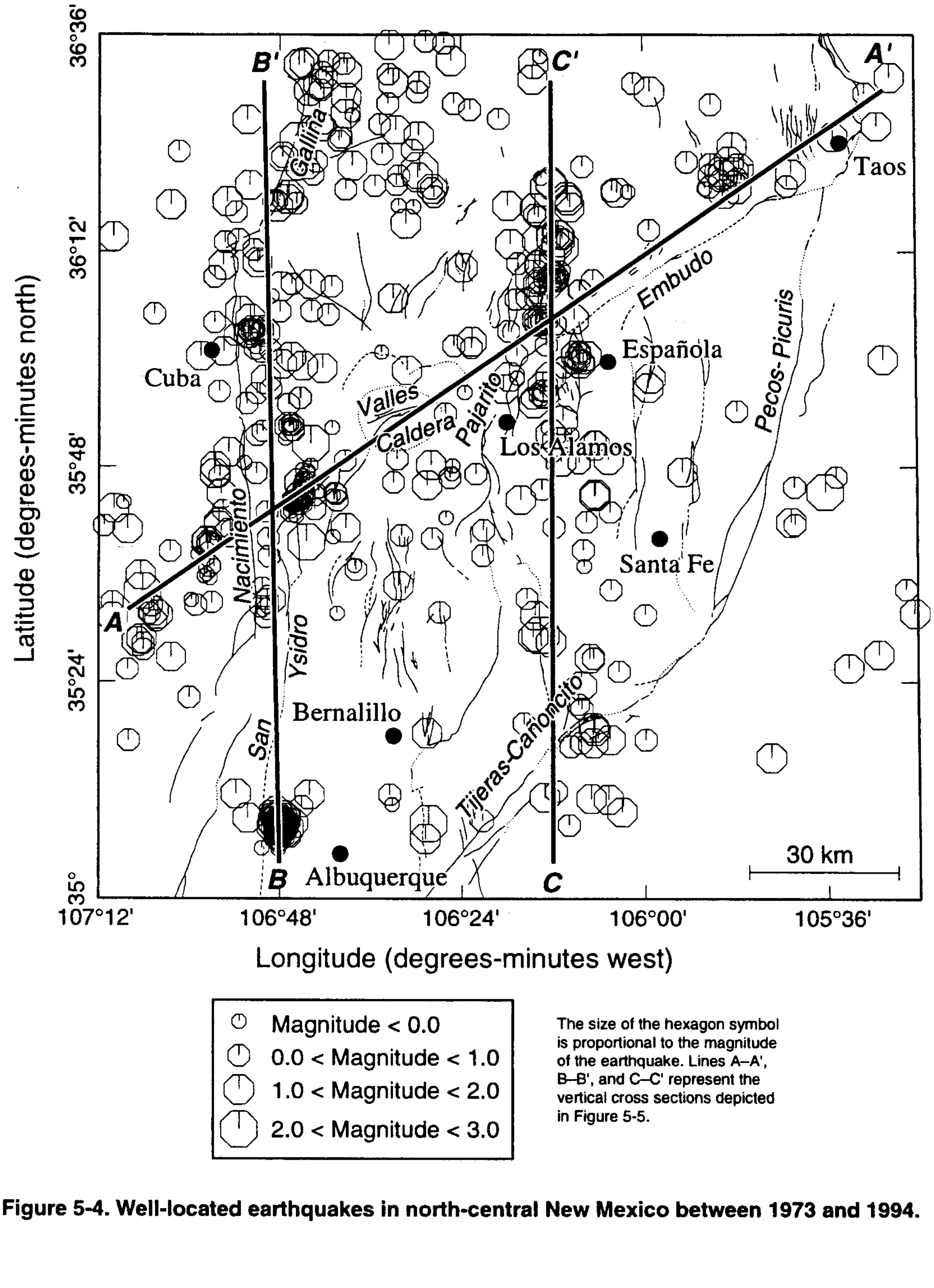


Figure 5-3. Location map and identification of majoy structural and tectonic elements in north-central New Mexico.



The size of the hexagon symbol is proportional to the magnitude of the earthquake. Lines A–A', B–B', and C–C' represent the vertical cross sections depicted in Figure 5-5.

Figure 5-4. Well-located earthquakes in north-central New Mexico between 1973 and 1994.

Epicenters to the east of the arch are almost entirely north of the Rio Chama and extend to the southeast about as far as Abiquiu Reservoir (36° 12' N and 106° 24' W).

To the south and east of Abiquiu Reservoir is a fairly intense cluster of epicenters that trends roughly north-south. The earthquakes having epicenters south of the Rio Chama coincide with several relatively short, north-south-trending faults on Lobato Mesa and occurred as a series of swarms (earthquakes of similar magnitude that occur within a distinct time interval). The Lobato Mesa area is at the western edge of a 6- to 9-mi- (10- to 15-km-) wide zone of subsidence identified from leveling surveys.

Earthquake epicenters just to the west of Española trend northeast to southwest, clustering in the northeast toward the northern end of the Puye Fault zone (a series of short, generally north-south-trending faults). A diffuse zone of north-south-trending seismicity passes east of Los Alamos and extends as far south as the cluster near a bend in Tijeras-Cañoncito Fault zone.

About 12-19 mi (20-30 km) west-southwest of Taos is a cluster of isolated epicenters. These represent several earthquakes that are neither related with respect to time of occurrence nor associated with the nearby Embudo Fault zone.

The lack of seismicity along the Embudo, Pajarito, Tijeras-Cañoncito, and Pecos-Picurís fault zones contrasts strongly with the abundant seismicity along the trends of the Nacimiento Fault zone and the Gallina-Archuleta arch. That lack of seismicity does not reflect lack of monitoring in these areas, which were included in the Los Alamos Seismic Network (LASN) between 1973 and 1984.

5.1.2.1 Fault Behavior

The differing seismicities of the prominent fault zones may indicate different slip behaviors. Those fault zones with little seismicity may be inactive, may slip aseismically, or may slip only episodically after long periods of little or no slip. From the seismicity data alone, it is difficult to distinguish between these possible behaviors, but each has very different implications with respect to the potential for occurrence of earthquakes and seismic hazards. Except for the Valles Caldera area, where high heat flow may suppress brittle slip (Cash and Wolff 1984), it is unlikely that fault slip occurs aseismically. It seems more likely that the lack of earthquakes along the major fault zones indicates episodic activity. Other earthquake data (for example, on focal mechanisms) would provide additional insight into fault behavior.

5.1.2.2 Monitoring Earthquakes in the Los Alamos Area

Numerous small earthquakes are recorded in the Los Alamos area and northern New Mexico each year (Sanford et al. 1979, Cash and Wolff 1984, Gardner and House 1987). Since the Laboratory was established, several earthquakes of Richter magnitude 3 to 4 have shaken Los Alamos (Gardner and House 1987). Recent work has shown that three fault segments in Los Alamos County are seismically active and that they are capable of generating large earthquakes (measuring at least 7 on the Richter scale) (Gardner and House 1987, House and Cash 1988, Gardner et al. 1990, Gardner and House 1994). Unknown at this time is how frequently such large earthquakes occur and what their potential is for generating surface rupture and mass wasting (occurrences such as rockfalls and landslides not caused primarily by the movement of water) within the confines of the Laboratory.

As part of a study of seismic hazards within an area of about 99 by 99 mi (160 by 160 km) centered on Los Alamos (House and Hartse 1995), data on well-recorded earthquakes that occurred between 1989 and 1994 were analyzed by LANL scientists using new techniques, and data from older earthquakes (1973-1988) were reanalyzed on the same basis. The reanalysis involved selecting 104 of the best-recorded earthquakes and picking P and S arrival times for these from the original seismograms; the arrival times were then inverted to create a layered velocity structure and to make station corrections. This newly determined velocity structure has provided information on the locations of earthquake epicenters that is more accurate and more detailed than any previously available. Given the complex geology of the area studied, the use of a single velocity structure for the entire area would undoubtedly oversimplify the results. Yet, the data available are not adequate to determine a more complicated structure.

This new information, based on 581 events, shows that earthquake locations are generally widely scattered, although some occur in clusters and some are associated with mapped fault zones. Several studies, such as those reported by Olsen et al. (1979) and Spence and Gross (1990), have determined the velocity structure for smaller areas of northern New Mexico.

A total of 672 earthquakes were recorded by the LASN between 1973 and 1994, of which 617 are well located, having computed epicentral errors of 3 mi (5 km) or less. Of the 672 recorded events, 581 events were within the 99- by 99-mi (160- by 160-km) study area centered on Los Alamos. In Figure 5-4, the epicenters of the 581 earthquakes in the study area are plotted. The largest earthquakes in the study area were about Magnitude 3.

To help judge whether the new velocity structure has improved the accuracy of locating earthquake epicenters, House and Hartse (1995) compared LASN data on earthquakes in the Albuquerque volcanoes swarm with data on the same earthquakes obtained from a detailed study by Jaksha et al. (1981). The comparison revealed that the epicenters originally calculated for the swarm were mislocated by about 5 mi (8 km), whereas the reanalyzed epicenters were within 1.2 mi (2 km).

For the earthquakes that occurred between 1973 and 1984, the locations identified as epicenters are probably accurate to within a few kilometers. Owing to the much smaller area covered by the LASN after 1984, the epicenters identified for earthquakes occurring after that time are probably less accurate. Relatively small errors in the arrival times used in the calculations for locating individual earthquakes can drastically change the estimations of their epicenters.

5.1.2.3 Determination of Earthquake Depths

The number and distribution of monitoring stations, even before 1984, is generally not adequate for reliable determination of the depths of earthquakes. The depth of seismogenesis in north-central New Mexico can be determined by means of vertical cross sections. Figure 5-4 shows the locations of three cross sections, represented by the lines A-A', B-B', and C-C', which parallel three major tectonic and fault trends. Two of these, the Jemez Lineament-Embudo Fault zone (cross section A-A') and the Pajarito Fault zone (cross section B-B'), are discussed below.

Each vertical cross section shows earthquake depths along a 19-mi- (30-km-) deep zone (Figure 5-5). Cross section A-A' shows that most earthquakes occur at depths of less than 9 mi (15 km). From southwest (A) to northeast (A'), earthquake depths show

- scattered seismicity associated with the Mt. Taylor volcanic field from about 0 to 25 mi (0 to 40 km) horizontal distance on the cross section;
- a nearly vertical distribution of seismicity that includes a mainshock-aftershock sequence along the Jemez Fault zone at about 30 mi (50 km);
- a low level of activity between about 37 and 56 mi (60 and 90 km) in the vicinity of the Valles Caldera;
- intense clusters of activity between about 62 and 75 mi (100 and 120 km) (near Española);

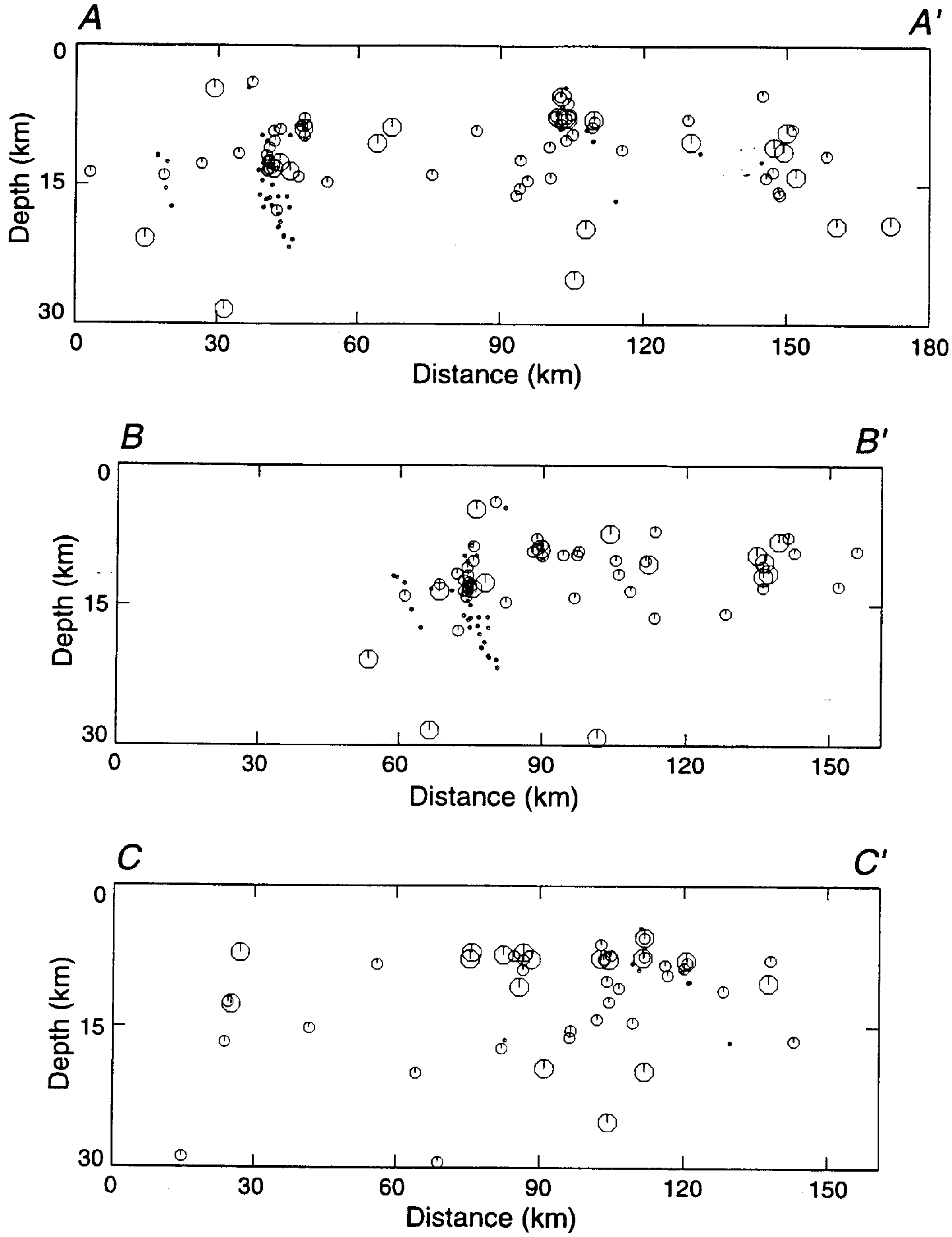


Figure 5-5. Vertical cross-sections along lines A–A', B–B', and C–C'.

- a zone entirely devoid of activity between about 81 and 93 mi (130 and 150 km) (the western portion of the Embudo Fault zone); and
- a relatively deep cluster of events near 99 mi (160 km), all of which apparently occurred below a depth of about 6 mi (10 km).

Cross section B-B', which parallels the north-south Pajarito Fault system near Los Alamos (Figure 5-5), shows most seismicity at depths of about 6 mi (10 km) or less. Earthquakes located farther than 75 mi (120 km) to the north are generally considered too far from a monitoring station for depth determinations to be accurate; in such cases, the trial depth of 10 km was used as a default. A seismicity cluster is located at about the 62-mi (100-km) position at quite shallow depths. Given its proximity to a monitoring station (Station CLP), these depths should be reasonably well constrained. Because this cluster coincides with faults mapped at the surface, these events may provide information about the deformation now occurring along those faults.

Several events at the 43- to 50-mi (70- to 80-km) distance are estimated to have occurred at depths of 9 to 12 mi (15 to 20 km). The accuracy of depth estimates at these distances should be fairly good. The epicenters of these events coincide with a series of faults mapped to the southwest of Española; therefore, seismic analysis may also provide information about deformation along those faults.

Earthquakes at the 30- to 43-mi (50- to 70-km) distance are estimated to have occurred between the very near surface and about 7 mi (12 km). Because recording stations are nearby, those events deeper than about 3 mi (5 km) should be well located. These earthquakes are all of approximately Magnitude 1 and for the most part are located beneath the White Rock Canyon of the Rio Grande, which is a well-defined topographic feature. In contrast, little seismicity can be directly associated with a similar topographic feature, the Rio Grande Gorge just west of Taos.

5.1.3 Hydrology

In northern New Mexico, water movement is the major mechanism by which contaminants are transported and redistributed. For this reason, collection of hydrologic data is essential for understanding the potential for contamination of local water supplies (and those of nearby areas—particularly the Rio Grande and adjacent pueblos), as well as for preventing and mitigating contamination. Such data are also essential for determining the potential effects of contaminant migration on natural resources and the environment. Most of the hydrological studies currently under way are carried out under the auspices of the Laboratory's Environmental Surveillance and Monitoring Program and of the Environmental Restoration Program.

This summary of the hydrogeologic environment of the Laboratory and northern New Mexico is taken mainly from the Laboratory's Installation Work Plan for Environmental Restoration (LANL 1995). It describes the major hydrologic and hydrogeologic characteristics of the area and their conceptual interrelationships, and it addresses how those characteristics and interrelationships affect the generation and movement of surface water and groundwater. It also addresses the interactions of surface water and groundwater as they relate to the potential for contaminant transport.

5.1.3.1 Surface Water

The Rio Grande is the major watercourse of north-central New Mexico. All the drainage from the Pajarito Plateau, both surface water and groundwater, is ultimately discharged into the Rio Grande. The drainage area of the Rio Grande to the north of Otowi (just east of Los Alamos) is estimated to encompass a 14,300-mi^2 (37,037-km^2) region of northern New Mexico and southern Colorado. Since record keeping began, the discharge rate has ranged from a minimum (in 1902) of 60 cubic feet per second (cfs) (1.7 m^3/s) to a maximum (in 1920) of 24,400 cfs (691 m^3/s). The river carries about 1 million tons (907,183 metric tons) of suspended sediments past Otowi annually.

Essentially all of the water flowing downstream of the Laboratory via the Rio Grande passes through Cochiti Reservoir. This reservoir was created in 1976 as a means of flood control and sediment retention: floodwaters are stored here temporarily until they can be released at safe rates. The dam is designed to trap at least 90% of the sediments carried by the Rio Grande. The reservoir also provides an area for recreation and fishery development.

Figure 5-6 shows the locations of the major surface water drainages in the Los Alamos area. These drainages are primarily ephemeral streams (streams that flow only periodically, in response to local storms or snowmelt) in canyons. Other streams are intermittent, that is, their flow aboveground is not continuous but is interspersed with dry stretches. Intermittent streams are sustained by groundwater that attains the surface in places (especially during times of the year when snowmelt is actively recharging perched alluvial groundwater bodies). Intermittent streamflow is generally more sustained than ephemeral flow.

Only four of the canyons contain perennial reaches inside Laboratory boundaries: Pajarito, Water, Ancho, and Chaquehui canyons. Of these, only Pajarito Canyon has a perennial reach that extends upstream (west) of any Laboratory facilities or effluent discharge points. Perennial reaches are found outside Laboratory boundaries in several canyons: Guaje, Los Alamos, Sandia, Pajarito, Water, Cañon de Valle (a tributary of Water Canyon), Ancho, and Chaquehui. The lower part of DP Canyon, a branch of Los Alamos Canyon, also contains a short perennial reach sustained by discharge from DP Spring. At present, it is unknown whether the origin of the spring flow is natural or artificial.

In the lower portions of Ancho and Chaquehui canyons, perennial flow extends to the Rio Grande, whereas in lower Water Canyon the perennial reach is very short and does not extend to the Rio Grande. In Pajarito Canyon, about 1 mi (1.6 km) east of State Road 501, a spring (sometimes called Homestead Spring) feeds a perennial reach a few hundred yards long. Farther east, the flow becomes intermittent for distances that vary, depending on climate conditions.

Springs between elevations of 7,900 and 8,900 ft (2,407 and 2,713 m) on the flanks of the Jemez Mountains supply base flow throughout the year to the upper reaches of Cañon de Valle and Guaje, Los Alamos, Pajarito, and Water canyons (Purtymun 1975). These springs discharge water perched in the Bandelier Tuff and Tschicoma Formation at rates of 2 to 135 gal./min (8 to 511 L/min) (Abeele et al. 1981), which is insufficient to maintain surface flow in more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium.

Eleven drainage areas, totaling about 82 mi^2 (212 km^2), intersect the Laboratory's eastern boundary. Those of Los Alamos, Pajarito, and Water canyons are greater than 10 mi^2 (26 km^2), that of Pueblo Canyon is 8 mi^2 (21 km^2), and those of the other canyons are less than 5 mi^2 (13 km^2). Some of these drainages carry runoff from heavy thunderstorms and the melting of large snow packs as far as the Rio Grande several times a year. Theoretical maximum flood peaks range from 24 cfs (1 m^3/s) at a 2-year frequency to 686 cfs (19 m^3/s) at a 50-year frequency (McLin 1992). There is almost no risk of flooding of community or Laboratory buildings because nearly all the buildings are on the mesa tops, from which runoff drains rapidly into the deep canyons. Further discussion of natural surface flow drainage may be found in the IWP, Revision 3 (LANL 1993).

Contaminants are carried into the surface water drainages by natural surface runoff, by liquid discharges from Laboratory facilities, and occasionally by air deposition (Becker et al. 1985, Becker 1986). Contaminants transported by natural runoff are largely bound to sediments; their rate of downstream travel is governed by the scouring and carrying power of successive runoff events

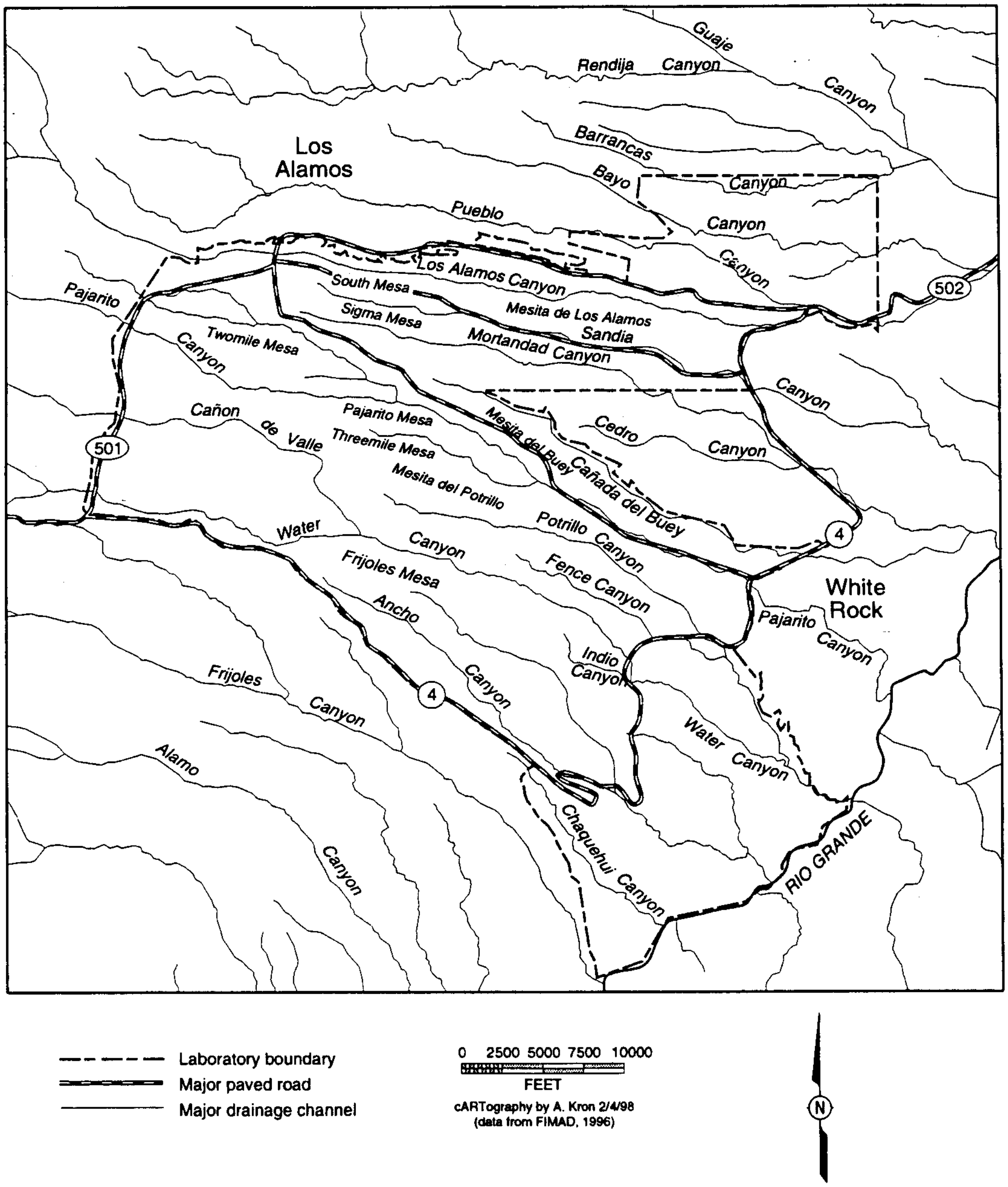


Figure 5-6. Locations of the major surface water drainages in the Los alamos area.

(Lane et al. 1985). Given sufficient time, these sediments and contaminants will be transported beyond Laboratory boundaries.

Most of the surface water drainages have received liquid industrial or sanitary discharges from the Laboratory. In some drainages, nearly all of the water flow is produced by these discharges. As the water travels downstream, most of the effluent-derived metals and radionuclides become sediment-bound and remain near the surface of the stream channel; other contaminants, such as nitrates, are lost by evaporation or move downward into the alluvium. Detailed field investigations in Mortandad Canyon, for example, demonstrate that generally more than 99% of the total inventory of transuranic radionuclides discharged in treatment plant effluents is associated with sediments in or immediately adjacent to the stream channel (Stoker et al. 1991).

In canyons that have received treated, low-level radioactive effluents (Acid-Pueblo, DP-Los Alamos, and Mortandad), concentrations of radioactivity in the alluvium are generally highest near the treated effluent outfall and decrease downstream as the sediments and radionuclides are dispersed by other treated industrial effluents, sanitary effluents, and surface runoff.

A study of the transport of plutonium by snowmelt runoff in Los Alamos and Pueblo canyons (Purtymun et al. 1990) shows that most of the plutonium that reached the Rio Grande via runoff in these canyons was bound to sediments—about 57% to suspended sediments and 40% to bed sediments. A total of about 600 mCi of plutonium was carried to the Rio Grande by five snowmelt runoff events studied between 1975 and 1986.

A regional plutonium analysis for the Rio Grande upstream of Elephant Butte Reservoir shows that fallout contributes about 90% of the total plutonium moving through the drainage system in any given year (Graf 1993). The remaining 10% is from releases at Los Alamos and is associated with relatively coarse sediments, which often behave as bedload in the Rio Grande (Graf 1993).

Environmental monitoring for chemical and radiochemical quality in surface water began with US Geological Survey (USGS) investigations (Purtymun 1964, 1975; Purtymun and Kunkler 1967; Purtymun 1967) and has been continued by the Laboratory (Environmental Protection Group 1993).

5.1.3.2 General Groundwater Conditions

In the Los Alamos area, groundwater is found in three modes: (1) as perched alluvial groundwater in the bottoms of some of the larger canyons; (2) as perched water in the Tschicoma volcanics, in the Bandelier Tuff (especially the Guaje Pumice Bed), and in the underlying basalts and conglomerates; and (3) as groundwater in the main aquifer.

5.1.3.2.1 Perched Alluvial Groundwater

Intermittent and ephemeral streams in the canyons of the Pajarito Plateau have deposited alluvium that in places is as thick as 100 ft (30 m). In canyons that originate in the Jemez Mountains, the alluvium is generally composed of sands, gravels, cobbles, and boulders derived from the Tschicoma Formation and the Bandelier Tuff on the mountain flanks. The alluvium in canyons that originate on the plateau is more fine-grained, consisting of clays, silts, sands, and gravels derived from the Bandelier Tuff. The saturated hydraulic conductivity of the alluvium typically ranges from 4×10^{-3} ft/s (1.2×10^{-1} cm/s) for a sand to 4×10^{-5} ft/s (1.2×10^{-3} cm/s) for a silty sand (Abeele et al. 1981).

In contrast to the underlying volcanic tuff and sediments, the alluvium is quite permeable. Ephemeral runoff in some canyons infiltrates the alluvium until downward movement is impeded by the less permeable tuff and sediments, resulting in the buildup of a shallow alluvial groundwater body. The vertical and lateral extent of such groundwater bodies is restricted because some of the water is depleted through evapotranspiration and some through movement into the underlying rocks (Purtymun et al. 1977), which precludes the use of alluvial groundwater as a municipal and/or industrial water supply. Lateral flow of the alluvial perched groundwaters is to the east. In Mortandad Canyon, tracer studies have shown that stream velocities range from about 60 ft (18 m)/day in the upper reach to about 7 ft (2 m)/day in the lower reach (Purtymun 1974).

The quality of the water in perched alluvial groundwater bodies varies, depending on whether and to what extent the groundwater contains discharged Laboratory effluent. In Mortandad Canyon, for example, plutonium concentrations fluctuate with variations in the quantities of effluent discharged from the TA-50 treatment plant and of storm runoff. Similarly, tritium concentrations in the canyon's alluvial groundwater have fluctuated in close correspondence with the average annual concentration of tritium in the effluent, with a lag time of about 1 year (Environmental Protection Group 1992).

Further information on alluvial perched groundwaters by drainage area may be found in reports by Purtymun (1973b and 1975). The results of an extensive monitoring study of the alluvial perched groundwater in Mortandad Canyon are presented by Abrahams et al. (1962), Baltz et al. (1963), Purtymun (1973b, 1974), Purtymun et al. (1977, 1983b), and Stoker et al. (1991).

5.1.3.2.2 Perched Water in Volcanics, Sediments, and Basalts

Some perched water occurs in volcanics on the flanks of the Jemez Mountains to the west of the Laboratory. This water discharges in several springs (including American and Armstead springs) and supplies the gallery in Water Canyon. The gallery has contributed to the Los Alamos water supply for 41 years, producing 23 to 96 million gal. (87,055,000 to 363,360,000 L) annually.

In recent years, numerous additional springs have been discovered in the western part of the Pajarito Plateau below the Jemez Mountains. Many of these springs are located in Cañon de Valle, Pajarito, and Three Mile canyons and could originate from perched water in the Tshirege Member, which composes the mesas. Both the source(s) of these springs and the volumes of water they produce are undocumented. For some springs, such as those in Cañon de Valle, the source—at least in part—could be industrial outfalls.

Perched water bodies also occur in the conglomerates and basalts that underlie the alluvium and the Bandelier Tuff in the middle and lower reaches of Pueblo and Los Alamos canyons and in the lower reach of Sandia Canyon. Depth to perched water ranges from about 90 ft (27 m) in the middle reach of Pueblo Canyon to about 450 ft (137 m) in lower Sandia Canyon. In the Guaje pumice at the base of the Bandelier Tuff beneath Los Alamos Canyon, perched water has been observed at a depth of 325 ft (199 m). The lower reaches of Pueblo and Los Alamos canyons are the only areas in which perched water has been studied in some detail. The vertical and lateral extent of perched groundwaters in the area, the nature and extent of perching units, and the potential for migration of perched water to the main aquifer are not yet fully understood.

Patterns of chemical concentrations and water level measurements indicate that the intermediate perched groundwater [between 90 ft (27 m) and 450 ft (137 m)] in Pueblo Canyon is hydrologically connected to the stream in Pueblo Canyon (Abrahams and Purtymun 1966). Discharges from this perched groundwater body emerge at the base of the basalt at Basalt Spring in lower Los Alamos Canyon, which is on San Ildefonso Pueblo land. The rate of movement of the perched groundwater in this vicinity has been estimated at about 60 ft (18 m)/day, which translates to about 6 mo from recharge to discharge (Abrahams and Purtymun 1966).

It is unknown whether and to what extent the perched water systems of the area may be hydrologically interconnected. Available data suggest that most are of limited extent: during testing of the perched system in mid Pueblo Canyon, for example, the water was depleted after about an hour's pumping at 2 to 3 gal./min (7.6 to 11.4 L/min) (Weir et al. 1963). Whereas perched water was encountered in mid Los Alamos Canyon during the drilling of the Otowi 4 supply well (Stoker et al. 1992), it was not reported in an adjacent well (Test Well 3) located 300 ft (91 m) to the east (it should be noted that Test Well 3 was drilled in 1947, by means of a cable tool rig, and perched water could have been present but not observed—or not reported—by the driller). In upper Los Alamos Canyon, perched water was found in three boreholes (H-19, LADP-3, and LAOI-1.1) drilled into the Guaje Pumice Bed. These wells span a distance of about 2.5 mi (4 km) from the Omega Bridge to near TA-21.

Tritium has been found in intermediate-depth groundwater at four locations in Pueblo and Los Alamos canyons. Measurements of samples from Test Well 2A in Pueblo Canyon have yielded tritium levels of between 2,000 and 3,000 pCi/L for several years. Low-detection-limit measurements (taken since 1991) of samples from Test Well 1A, in lower Pueblo Canyon near its confluence with Los Alamos Canyon, and from Basalt Spring, in Los Alamos Canyon just downstream from its confluence with Pueblo Canyon, have consistently revealed tritium at levels of about 150 pCi/L. These results are consistent with what has been known since the USGS began measuring tritium in the 1950s and 1960s: that the intermediate-depth perched groundwater is affected by effluents discharged into Pueblo Canyon (Abrahams et al. 1961). Further, the results demonstrate that recharge to those depths has taken place during the last several decades (the levels of tritium in these groundwater bodies are high enough that their source can be identified as effluent or other releases from Laboratory operations).

The fourth location is Well LADP-3, in the middle reach of Los Alamos Canyon about 1 mi (1.6 km) downgradient of TA-2 (the Omega reactor site). The most recent observation of tritium in intermediate-depth groundwater was made in this well, which was completed in 1993 by the ER Program (Broxton and Eller 1995). Perched water was encountered at a depth of about 320 ft (98 m) to 330 ft (100 m) at the contact of the Otowi Tuff and the Puye Conglomerate. Samples of water from that well contained about 6,000 pCi/L of tritium.

5.1.3.2.3 Main Aquifer

The main aquifer of the Los Alamos area is the only groundwater source sufficient for municipal water supply (Purtymun 1984). In 1994, water for the Laboratory, the communities of Los Alamos and White Rock, and Bandelier National Monument was supplied from 12 deep wells in 3 well fields and from the Water Canyon gallery. The wells are located on the Pajarito Plateau and in Los Alamos and Guaje canyons east of the plateau. Municipal and industrial water supply during 1994 was 1.438 billion gal. (5.443 billion L). In 1992, individual well yields ranged from about 175 gal. (1,400 L) to 662 gal. (5,300 L) (Stoker et al. 1992). The hydraulic characteristics of the aquifer, determined through tests or on the basis of production data from supply wells and test holes, are summarized by Purtymun (1984).

The surface of the main aquifer rises westward from within the Santa Fe Group near the Rio Grande to the lower part of the Puye Conglomerate beneath the central and western part of the Pajarito Plateau. The depths to water from the mesa tops range from about 1,200 ft (366 m) along the western margin of the plateau to about 600 ft (185 m) at the eastern margin. The main aquifer is separated from perched groundwater in the alluvium and in the volcanics and sediments by 350 ft (107 m) to 620 ft (189 m) of unsaturated tuff and volcanic sediments (Environmental Protection Group 1993). In its eastern portions along the Rio Grande, the aquifer exhibits artesian conditions (Purtymun 1984). Water level data, continuously collected from test wells since the fall of 1992, indicate that throughout the plateau the main aquifer responds to barometric and earth tide effects in the manner typical of confined aquifers.

The exact source of recharge to the main aquifer is unknown. Cushman (1965) suggested three sources of recharge: infiltration of runoff in canyons, underflow from the Valles Caldera through the Tschicoma Formation, and infiltration through mesa tops. It is inferred that recharge takes place primarily from the west, because the piezometric surface slopes downward to the east. However, a considerable body of hydrologic, structural, and geochemical data indicate that the caldera may not serve as an appreciable source of recharge to the main aquifer (Conover et al. 1963, Griggs and Hem 1964, Goff 1991). Furthermore, natural recharge from the mesa tops through undisturbed Bandelier Tuff is believed to be insignificant (Purtymun and Kennedy 1971, Kearl et al. 1986). With respect to canyon runoff, the data needed to evaluate the importance of this potential source are lacking. Water level data suggest that groundwater flows from the Jemez Mountains east and east-southeast toward the Rio Grande, where a part is discharged into the river through seeps and springs (Purtymun et al. 1980). Springs fed by the main aquifer discharge an estimated 4,300 to 5,000 acre-feet of water annually into White Rock Canyon along an 11-mi (18-km) reach between Otowi Bridge at State Road 502 and the mouth of Rito de Frijoles (Cushman 1965).

The hydraulic gradient of the aquifer averages 60–80 ft/mi (5.3×10^6 to 6.2×10^6 m^3) within the Puye Conglomerate but increases to 80–100 ft/mi (15–19 m/km) along the eastern edge of the plateau as the aquifer waters enter the less permeable sediments of the Santa Fe Group. The rate of movement of water in the upper section of the aquifer varies, depending on the nature of the materials in which the water is stored. Tests indicate that the movement ranges from 20 ft/yr (6 m/yr) in the Tesuque Formation to 345 ft/yr (105 m/yr) in the more permeable Puye Conglomerate (Purtymun 1984).

To better understand the nature of recharge of the main aquifer in the Los Alamos area, Laboratory and DOE researchers have initiated a study in which a range of geochemical and geochronological techniques (such as isotopic tagging) are being used to identify potential sources and ages of water in the main aquifer. At present, a number of ^{14}C and low-level-tritium measurements are available that permit some preliminary estimates of the age of the water at various locations in the main aquifer. (Carbon-14 is a radioisotope that comes mainly from natural sources. Tritium comes from natural sources, from fallout from atmospheric nuclear weapons testing, and, in the Los Alamos area, from Laboratory operations.)

"Age of water" means the time elapsed since the water, as precipitation, entered the ground and became isolated from the atmosphere. The water is assumed to have contained atmospheric equilibrium amounts of both tritium and ^{14}C at the time of its entry into the ground. Preliminary interpretation of the results of seven ^{14}C analyses indicate that the age of water in the main aquifer increases with distance eastward, ranging from a minimum of about 1,000 years under the western portion of the Pajarito Plateau to about 30,000 years near the Rio Grande. These values are consistent with what is known about the aquifer from physical and geological observations, which indicate flow from west to east and major recharge from the west.

Tritium has been measured in samples of water from five wells near Los Alamos that draw from the main aquifer. Three of these wells are in Los Alamos Canyon near its confluence with the Rio Grande; they are LA-1A (an observation well), LA-2 (an old water supply well), and a domestic well. The tritium measurements, which are based on extremely-low-detection-limit analytical methods, appear to show the presence of some recent recharge (within the last four decades). Samples from another 30 wells, on the other hand, show no clear evidence of recent recharge to the main aquifer.

The fourth well is Test Well 1, located in Pueblo Canyon near its confluence with Los Alamos Canyon. Although sampling consistently showed tritium to be present, the migration pathways are not yet understood. For several years, this well has been suspected, based on other types of data

(Abrahams et al. 1961), of having a well-bore leakage or other communication from the surface. One possible migration pathway is down the outside of the ungrouted steel casing (cable-tool drilling does not include an annular seal). Another possible pathway is through the rock beneath the canyon.

The fifth well is Test Well 8 in Mortandad Canyon, which was sampled at the end of 1993 as part of the Environmental Surveillance Program. This well, completed to a depth of 1,065 ft (325 m) in 1960, is located about 1 mi (1.6 m) downstream of the outfall for the Laboratory's radioactive liquid waste treatment plant at TA-50. The upper section of the well penetrates shallow alluvial perched groundwater in which residual contaminants discharged by the TA-50 treatment plant have been found. Sampling of the alluvial groundwater in the vicinity of Test Well 8 showed tritium levels ranging from as much as 1,000,000 pCi/L in the mid-1970s to about 100,000 pCi/L in the last few years.

None of the wells used to supply water to Los Alamos contained tritium at levels exceeding background: measured levels ranged from less than 1% to less than 1/100th of a percent of current drinking water standards. They were also below the levels that could be detected by the EPA-specified analytical methods normally used to determine compliance with drinking water regulations.

In Mortandad Canyon, at least three pathways exist by which tritium could move toward the main aquifer: (1) via the wellbore outside the steel casing, (2) via saturated flow through fractures or faults, and (3) via unsaturated flow through the vadose zone (the zone between the land surface and the main aquifer). Analysis of samples from cores collected to a depth of 100–200 ft (30–61 m) at locations farther west demonstrates that tritium is migrating downward through the unsaturated zone beneath the alluvial perched groundwater in Mortandad Canyon (Stoker et al. 1991).

5.1.3.3 Hydrogeology

In the central area of the Laboratory, the main aquifer lies beneath an unsaturated zone consisting of more than 1,000 ft (305 m) of Bandelier Tuff, Puye Conglomerate sediments, and basaltic rocks of Chino Mesa.

Since the 1950s, numerous investigations focusing on hydrogeologic characterization of the upper 100 ft (30 m) of the Bandelier Tuff have been conducted in the Los Alamos area (including investigations by Abrahams et al. 1961, Weir and Purtymun 1962, Abrahams 1963, Purtymun and Koopman 1965, Purtymun and Kennedy 1971, Purtymun et al. 1978, Abeele et al. 1981, Kearl et al. 1986, Purtymun et al. 1989, Stoker et al. 1991). Below about 100 ft (30 m), the unsaturated (vadose) zone has generally not been adequately characterized. Data on hydrogeologic properties, including moisture content, saturated hydraulic conductivity, and bulk density, are available for about 160 undisturbed mesa-top and canyon-bottom core samples from 21 wells (Rogers and Gallaher 1995). The relationship between moisture content and soil-water potential has been obtained for 82 of these core samples (Rogers and Gallaher 1995).

Until about the mid-1980s, most of the samples analyzed to determine the hydrogeologic properties of the Bandelier Tuff consisted of crushed or disturbed tuff. Those used more recently have consisted largely of undisturbed cores (e.g., Kearl et al. 1986, Stoker et al. 1991). The hydraulic properties measured in undisturbed cores are summarized in Table 5-1. The table includes measured values for bulk density, porosity, saturated hydraulic conductivity, and residual saturation. [The α and N residual saturation parameters are from van Genuchten's formulation of the moisture characteristic curve (van Genuchten 1980)]:

<u>TABLE 5-1</u>

SUMMARY OF HYDRAULIC PROPERTIES DATA FOR BANDELIER TUFF OBTAINED SINCE 1984[a]

				van Genuchten Parameters		
	Bulk Density (g/cm³)	Porosity (%)	Ksat (cm/sec)	Residual Saturation (%)[b]	α	N
Tshirege Member						
Minimum	0.94	34.6	5.6×10^{-6}	0.0	0.0011	1.152
Median	1.18	48.8	1.1×10^{-4}	2.3	0.0056	1.696
Harmonic Mean			5.8×10^{-5}			
Maximum	1.49	7.42	3.9×10^{-3}	7.9	0.2312	2.877
Number of Observations	43	63	85	32	32	32
Tsankawi Pumice						
Minimum	0.90	36.7	4.7×10^{-5}	0.0	0.0005	1.106
Median	1.25	46.0	6.8×10^{-4}	0.23	0.0187	1.481
Harmonic Mean			1.7×10^{-4}			
Maximum	1.60	65.6	4.3×10^{-3}	7.28	0.0513	1.890
Number of Observations	18	12	9	9	9	9
Otowi Member						
Minimum	0.98	40.3	1.1×10^{-5}	0.0	0.0039	1.388
Median	1.18	44.0	2.7×10^{-4}	2.5	0.0060	1.653
Harmonic Mean			1.3×10^{-4}			
Maximum	1.49	59.0	7.8×10^{-3}	12.1	0.0185	2.307
Number of Observations	31	25	25	21	21	21

a. Samples represent a compilation by Rogers and Gallaher (1995) of available hydraulic property determinations on undistributed core samples taken between 1984 and 1992. Field and laboratory data from USGS work in the 1950s and 1960s and air/water injection tests conducted by Bendix Corporation in the mid-1980s (Kearl et al. 1986) are not included in the compilation because of concerns relating to the comparability of different measurement techniques.

b. Most cores with θ >10 are omitted because of the absence of thermocouple psychrometer measurements at high matric suctions.

$$\tilde{\theta} = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \frac{1}{\left[1 + |\alpha h|^N\right]^M} ,$$

where

$\tilde{\theta}$ = effective saturation,
θ = volumetric moisture content,
θ_s = saturated moisture content,
θ_r = residual moisture content,
h = suction,
α, N = van Genuchten fitting parameters, and
M = 1-1/N.

5.1.3.3.1 Effects of Physical Characteristics

The degree of welding of the tuff determines a number of physical characteristics: the more welding, the higher the density of the rock matrix and the lower the porosity and hydraulic conductivity (Purtymun and Koopman 1965). These characteristics, which vary markedly within and between tuff units, influence the nature and variability of hydrogeologic properties. At the same time, the degree of welding appears to affect fracturing: welded tuff tends to be more highly fractured (jointed) than nonwelded tuff; thus, whole-rock permeability can be locally greater in the case of welded tuff (Crowe et al. 1978).

5.1.3.3.1.1 Porosity

Porosity measurements by Abrahams (1963) range from 20% to 60% by volume, generally decreasing as the degree of welding increases. Measurements reported by IT Corporation (1987) are higher, from approximately 39% to 74%. Tuff samples that contain fragments of pumice exhibited the highest porosities—in some cases comparable to those of the upper ranges found in fine clays. Such high porosities, however, are unusual for indurated materials. Extreme changes in porosity over a short vertical distance have been observed (Abrahams 1963).

5.1.3.3.1.2 Moisture Content

A number of hydraulic properties of the Bandelier Tuff vary with changing moisture content. The tuff is only partially saturated throughout the Laboratory, even beneath stream channels containing alluvial perched groundwater systems. The natural moisture content of the tuff forming the mesas is relatively high in the near surface, which is the zone affected by seasonal inputs of moisture and evapotranspiration. It then decreases rapidly with depth to less than 5% by volume below the top 30 ft (9 m). Moisture content is lower beneath undisturbed soils than beneath disturbed soils (Abrahams 1963). Weir and Purtymun (1962) attributed the low moisture content to the protective cap of clay soil formed by weathering of the tuff near the surface, low rainfall, and high evapotranspiration. Further evidence of low moisture content is the absence of weathering below about 33 ft (10 m) (Wheeler et al. 1977) and the absence of perched water at potential perching horizons in the tuff.

The tuff beneath the canyon bottoms has considerably higher moisture content than that beneath the mesa tops, typically ranging from 20% to 50% by volume and generally decreasing with depth (Weir and Purtymun 1962, Stoker et al. 1991). Field studies in Mortandad, Sandia, and Potrillo canyons show that moisture content varies greatly with depth, depending on texture (Stoker et al. 1991, Environmental Protection Group 1993).

5.1.3.3.1.3 Moisture Characteristic Curves

The relationship between moisture content and soil-water potential has been obtained from more than 60 undisturbed mesa-top and canyon-bottom cores at TA-54 (Rogers and Gallaher 1995).

The data indicate a residual moisture content of 0% to 4%. Purtymun and Stoker (1987) found that at TA-49 residual moisture content ranged from 11% to 27%. Detailed analyses in Mortandad Canyon show that moisture retention characteristics vary significantly between and within formational units (Stoker et al. 1991). Abrahams (1963) determined the relationship between energy and moisture content of a moderately welded tuff having a saturated moisture content of about 41% by volume. When moisture content is below about 4%, there is no movement of water; from about 4% to 8%, moisture is redistributed by diffusion; from about 8% to 23%, distribution is governed by gravity and capillarity; and above 23%, movement is controlled by gravity only (Abrahams 1963).

5.1.3.3.1.4 Hydraulic Conductivity

Hydraulic conductivity is the parameter that describes the rate of flow of fluid through a porous medium in response to a hydraulic gradient; it is a function of both the fluid and the medium. Saturated hydraulic conductivities have been measured for tuff many times, under laboratory as well as under field conditions; the values range from 0.054 to 65 ft/day (1.9×10^{-5} to 2.3×10^{-2} cm/s), comparable to those of silty sand. In general, nonwelded tuff has greater saturated conductivity than welded tuff, and horizontal conductivities are greater than vertical conductivities (Abrahams 1963). Unsaturated hydraulic conductivities may be many orders of magnitude lower, typically ranging from 2.8×10^{-3} to 2.8×10^{-8} ft/day (10^{-6} to 10^{-11} cm/s) (Stoker et al. 1991, Rogers and Gallaher 1995), depending on in-situ moisture contents.

5.1.3.3.1.5 Joints

Typically, the tuff has the appearance of irregular blocks delineated by the numerous joints and fractures that formed as the ash flows cooled or that were produced subsequently by faulting. The major joint sets are vertical or nearly vertical, having dips greater than 70°; joint frequency increases with the degree of welding and with proximity to faults (Vaniman and Wohletz 1990). Joints and fractures in moderately welded tuffs generally terminate when they reach areas of nonwelded tuff (Baltz et al. 1963). The joints are often limited to the depth of a single ash-flow or ash-fall unit (Purtymun and Kennedy 1971). Joint widths range from essentially 0 (closed) to as wide as 6 in. (15 cm). The joints are commonly filled with caliche near the surface, grading into clay with depth, and may be open to depths exceeding 30 ft (9 m) (Purtymun et al. 1978, Abeele et al. 1981). Examination of cores obtained from horizontal drilling beneath a waste disposal site at TA-54 showed that about 80% of the joints were filled or plated with clay or secondary mineralization (Purtymun et al. 1978). Joint apertures at TA-54 are typically small, having median values of about 10 ft (3 m); median joint spacing is 1.9–4.0 ft (0.6–1.2 m). There is a general absence of clay illuviation in any joints at depths greater than 20 ft (6 m) within an excavated pit at TA-54.

5.1.3.3.2 Movement of Moisture in the Bandelier Tuff

The movement of moisture in the Bandelier Tuff is governed by a complex interaction of many factors. Climatic and site-specific land use factors control the supply of moisture available for infiltration, and hydrogeologic characteristics control the redistribution of moisture in the tuff. Perhaps the most significant aspect of the tuff is its ability to absorb water. Most of the pore spaces in the tuff are of capillary size and have a strong tendency to hold water against gravity by surface tension forces. As a result, water entering the dry tuff moves very slowly if at all.

Water moves through the tuff in two ways: (1) through the pores of the tuff, as liquid or as vapor, and (2) through open, interconnected joints (Abrahams 1963). When moisture content is low, movement in the vapor phase dominates, and liquid movement through the rock matrix is extremely slow. However, when water enters open, interconnected joints, it can move downward quite rapidly. The walls of some fractures are coated with low-permeability materials that facilitate flow; however, fractures with uncoated walls absorb water, necessitating large and continuous volumes of water to sustain flow (Thoma et al. 1992). If the joints do not traverse contacts between subunits of the tuff, water could become perched above the contact and tend to move laterally, potentially exiting through the walls of canyons.

5.1.3.3.3 Transport of Contaminants Through Mesa Tops

Numerous studies suggest that little moisture moves through mesa tops capped with undisturbed soil and plant cover. However, in areas such as landfills, where the natural soil and plant cover have been removed or altered, the moisture content of the underlying tuff is significantly higher than at undisturbed locations. It appears that surface modifications alter the delicate combination of evapotranspiration and surface runoff that otherwise reduce natural infiltration levels on mesa tops.

Kearl et al. (1986) concluded that at TA-54, vapor-phase water movement is the predominant mechanism for potential transport of contaminants in the subsurface. They also conclude that there is neither an interconnection nor a fracture network that would allow movement of liquid water in the portion of tuff studied [upper 100 ft (30 m) of the Tshirege Member]. Other laboratory analyses on cores of moderately welded tuff support the likelihood of vapor phase dominance at most mesa-top locations (Abrahams 1963).

From a waste containment perspective, the likelihood of vapor-phase dominance is significant; in extremely dry rock, vapor-phase transport can affect only contaminants existing in a gaseous state, such as tritium or volatile organic solvents. Other radionuclides and metals can be transported only under wetter conditions, which allow the uninterrupted movement of liquid water (i.e., capillarity). Because of chemical interactions between the rock and dissolved constituents during vapor-phase transport, the rate of constituent movement may be lower than during water transport.

Few definitive field measurement techniques exist by which natural recharge through mesa tops can be quantified. One very promising technique is the use of natural tracer profiles. Recharge rates are inferred by comparing the natural tracer profiles with profiles generated by analytical solute transport solutions. Another technique is based on the supposition that the flux of liquid water through the rock matrix that could eventually become recharge is approximately equal to the unsaturated hydraulic conductivity (assuming that flow is downward and at steady state).

Rogers and Gallaher (1995) computed unsaturated hydraulic conductivities (fluxes) in situ for tuff at TA-54, Material Disposal Area (MDA) L. Laboratory analysis of five undisturbed Bandelier Tuff cores obtained from three separate coreholes yielded hydraulic conductivities ranging from 3.7×10^{-5} to 1.9×10^{-1} ft/yr (3.6×10^{-11} to 1.8×10^{-7} cm/s). Given that flow through media having spatially varying hydraulic conductivities will not be uniform, an average hydraulic conductivity can be assumed to lie between the harmonic and arithmetic mean hydraulic conductivities (de Marsily 1986). The arithmetic and harmonic mean hydraulic conductivities for this set of cores are 5.8×10^{-2} and 1.1×10^{-4} ft/yr (5.6×10^{-8} and 1.1×10^{-10} cm/s), respectively. Based on the moisture conditions and calculated unsaturated hydraulic conductivities at MDA L, the rates of water movement in the upper part of the mesa are estimated to be between 1.2 and 0.002 ft/yr (0.4 and 6.1×10^{-4} m/yr) (assuming that there are no "fast paths" of water movement, such as fracture flow, to significant depths). These calculated rates, which are relatively low, imply that there is very little movement of moisture from the mesa tops to the main aquifer under natural conditions, which probably would apply to an isolated liquid waste spill at the land surface as well.

The greatest concern about migration of moisture through mesa tops to the subsurface is the potential for ongoing release of large volumes of contaminants to zones in which there are open and interconnected joint/fracture networks. If such networks existed beneath a surface impoundment or a leaky chemical storage tank, the protective effect of water movement only through pores in the tuff would be lost (Abrahams 1963).

When fractures are filled with clays or other material, the movement of moisture through them is impeded. Open fractures are effective barriers to moisture flow under unsaturated conditions; however, under saturated or near-saturated conditions, they can provide preferential flow paths for either vapor-phase transport or water (Abeele et al. 1981). In some joints, roots have been found to depths exceeding 42 ft (13 m) (Weir and Purtymun 1962), which suggests that joints are important local pathways for infiltration of moisture. At TA-54, the moisture content of several fracture zones is higher than that of adjacent porous media (Kearl et al. 1986).

Although fractures clearly affect infiltration in the upper portions of the mesas, it is less clear to what depth they play a role for three reasons. First, water passing through a fracture system has a tendency to be "wicked" into the adjacent rock matrix by capillary suction forces in the tuff, provided the fracture wall is not sealed with material of low permeability (Thoma et al. 1992). Analytical and numerical modeling at TA-54 indicates that transient infiltration pulses in fractures probably affect only the very near surface because the moisture is absorbed into the adjacent tuff at still-shallow depths (Rosenberg et al. 1993).

Second, most of the open fractures occur in the moderately welded to welded Tshirege (upper) Member of the Bandelier Tuff; the underlying nonwelded Otowi Member is significantly less fractured (Baltz et al. 1963) and is therefore far more likely to be dominated by the relatively slow process of capillarity.

Third, although fractures may initially provide a pathway for movement of water into the mesas, they may later enhance the removal of water (as water vapor). Barometric and air pressure variations along the canyon walls can cause an exchange of gas and water vapor between the atmosphere and the mesas. When barometric pressure is low, air transfers from the tuff to the atmosphere, especially via interconnected fractures and joints, which are highly permeable to air. Although studies of this phenomenon at TA-54 have been inconclusive (Abeele et al. 1981, Kearl et al. 1986), such air transfer has been documented in boreholes penetrating the tuff at TA-49 (Purtymun et al. 1974) and has been observed elsewhere on the plateau.

In summary, the combination of the Bandelier Tuff's low moisture content, its associated hydraulic characteristics, and its thickness provides a substantial degree of protection to the main aquifer from infiltration through the mesa tops. Risks to the main aquifer from waste sites that have not received contaminated liquids are quite low, and for most such sites detailed characterization of the subsurface probably is not warranted. (Site-specific conditions must always be considered, however, before deciding not to characterize a site.) For waste sites at which contaminated liquids or materials have been disposed—especially highly contaminated liquids released over long periods—phased subsurface investigations should be conducted to verify that the waste is sufficiently contained.

Open fractures may be a key factor in whether contaminants migrate to deeper sections of the tuff or travel laterally and are eventually released into canyons through the mesa walls. All subsurface investigations should initially focus on the upper 100 to 200 ft (30 to 60 m) of the vadose zone.

5.1.3.3.4 Transport of Contaminants Beneath Canyon Bottoms

The canyons in which perched alluvial groundwater bodies exist are presumed to be more conducive to the downward movement of moisture (and, hence, contaminants) than are the mesa tops. These canyon bottoms have a constant (or often replenished) water source, so that the moisture content of the tuff below the saturated alluvium is significantly higher than that of the tuff beneath the mesa top. Further, because the depth to the main aquifer from the canyon bottom is several hundred feet less than from the mesa top, the possibility of migration of constituents to the aquifer is higher in the case of the canyons.

Moisture content in the Bandelier Tuff beneath the canyon bottoms can be highly variable. Stoker et al. (1991) evaluated the moisture content of tuff beneath the alluvial perched groundwater in Mortandad Canyon. Most values for gravimetric moisture content in the Tshirege Member ranged from 10% to 30%, corresponding to 20% to 60% saturation. Several peak values approached 90% saturation (near the contact with or in the Tsankawi tuff and fluvial Cerro Toledo rhyolite deposits overlying the Otowi Member at depths of around 100 ft (30 m). In the Otowi Member, the gravimetric moisture content decreased and leveled off at 12%–18%, which corresponds to 20%–40% saturation. Similar patterns were observed in a corehole farther downstream in Mortandad Canyon, beyond the zone of alluvial perched groundwater (Stoker et al. 1991), as well as in Sandia and Potrillo canyons (Environmental Protection Group 1993). These data suggest that there are complex variations in hydrologic properties in the layers from the base of the Tshirege through the top of the Otowi Member that significantly affect the movement of moisture in the unsaturated zone (Rogers and Gallaher 1995). They also suggest that moisture conditions in the Otowi tuff vary only moderately, depending on the extent of saturation of overlying layers (Environmental Protection Group 1993).

Recent investigations provide some important information on the movement of moisture and contaminants in the unsaturated tuff beneath canyon bottoms. The best field evidence comes from corehole data collected by Stoker et al. (1991) in Mortandad Canyon. Treated liquid effluents containing radioactive constituents have been discharged to this canyon from the TA-50 treatment plant for some 30 years, and these constituents serve as accurate tracers for fluid and contaminant migration. The basic conclusions of the Mortandad study are that (1) soluble and particulate radioactive constituents have moved at most about 10 ft (3 m) into the unsaturated zone beneath the alluvial perched groundwater, and (2) tritium, as tritiated water, has moved at least 150 ft (46 m) below the alluvial perched groundwater [tritium concentrations in Corehole MCM-5.9—the deepest corehole drilled so far in the canyon—decrease by a factor of about 100 between 150 (46 m) and 195 ft (59 m), suggesting that tritium has not moved much deeper than 195 ft (59 m) over the 30 years (Stoker et al. 1991)]. These results suggest a downward rate of movement of at least 6 ft/yr (1.8 m/yr); however, data from additional, deeper coreholes will be needed to confirm this estimate.

In Los Alamos Canyon, Characterization Well LADP-3 has yielded evidence that Laboratory-derived tritium has migrated to depths of at least 330 ft (101 m) beneath the canyon bottom (Broxton and Eller 1995). In the case of this canyon, the history of tritium releases is not well documented, making calculation of the downward rate of contaminant movement difficult.

Additional field data and theoretical interpretation will be required to confirm the patterns and quantify the rates of water movement.

5.1.4 Climatology

Since 1943, the Laboratory has maintained a weather station. Its original purpose was to provide meteorological information for test shots and for operation of the airport. As Laboratory operations increased in complexity and became more dispersed throughout the Laboratory site and as air quality regulations became more stringent, the need for a network of weather stations became clear. Currently, the Laboratory gathers data from eight stations; these data are collected at a central location and are archived for subsequent reference and analysis.

For the most part, early weather data were collected on strip charts and in other paper records that have been archived; however, they are difficult to retrieve. More recent data have been archived in electronic form and are available on the World-Wide Web (http://weather.lanl.gov).

Bowen (1990) published a comprehensive report on the climatology of the Los Alamos area, which is based on observations from several meteorological stations within Laboratory boundaries. This report was followed by a summary document (Bowen 1992) that used more recent observations.

This section summarizes some of Bowen's analyses, supplemented with recent observations of wind patterns in Los Alamos Canyon and a discussion of evapotranspiration. The topics covered are (1) the state of the atmosphere (its temperature, pressure, and moisture), (2) precipitation, (3) wind conditions, and (4) the exchange of energy at the surface. Normal values are based on observations taken between 1961 and 1990 at the official Los Alamos meteorological station. Extremes are based on the entire record. Although the location of the "official" station has changed several times over the years (the current location, since 1990, is at TA-6), the various locations are all within 100 ft (30 m) of one another in elevation and within 3 mi (5 km) in distance.

In general terms, the Pajarito Plateau, at an elevation of about 7,400 ft (2,256 m) above sea level, has a temperate mountain climate with four distinct seasons. Spring tends to be windy and dry. Summer begins with warm, often dry, conditions in June, followed by a two-month rainy season. Autumn brings a return to drier—as well as cooler and calmer—weather, and in winter midlatitude storms drop far enough south to keep the ground covered with snow for about two months.

5.1.4.1 Atmospheric State

In July, the warmest month of the year, the temperature ranges from an average daytime high of 81°F (27.2°C) to an average nighttime low of 55°F (12.8°C). The highest recorded daytime temperature is 95°F (35°C). In January, the coldest month, temperatures range from an average daytime high of 40°F (4.4°C) to a nighttime low of 17°F (-8.3°C). The lowest recorded temperature is -18°F (-27.8°C). The wide range in temperature results from the area's relatively dry, clear atmosphere, which allows strong solar heating during the daytime and rapid radiative cooling at night.

Average atmospheric pressure at the official meteorological station is 22.92 in. (58.22 cm) of mercury (776 mb), which is 76% of standard sea-level pressure. Average near-surface air density, calculated on the basis of the mean pressure and temperature at the TA-6 station, is 0.06 lb/ft^3 (0.958 kg/m^3).

Although relative humidity can vary considerably over 24 h, monthly average values vary little during the year. Relative humidity ranges from a low of 39% in June to a high of 56% in December, averaging 51% over the entire year. Absolute humidity, measured as the amount of water per volume of air, is a better indicator of atmospheric moisture content. It ranges from a low of 1.5×10^{-4} lb/ft^3 (2.4 g/m^3) in Januray to a high of 5.4×10^{-4} lb/ft^3 (8.7 g/m^3) in July and August. Fog is very rare in Los Alamos, occurring on average less than five times a year.

5.1.4.2 Precipitation

Average annual precipitation (rainfall plus the water equivalent of frozen precipitation) for the region is 18.7 in. (47.6 cm). However, the annual total fluctuates considerably from year to year; the standard deviation of these fluctuations is 4.8 in. (12.2 cm). The lowest recorded annual precipitation is 6.8 in. (17.3 cm), and the highest is 30.3 in. (77.1 cm). Maximum precipitation records are 3.5 in. (8.8 cm) for a 24-h period and 0.9 in. (2.3 cm) for a 15-min period. Because of the eastward slope of the terrain, there is a significant east-to-west increase in precipitation across the plateau. White Rock, on the eastern edge, often receives 5.1 in. (13 cm) less annual precipitation than does the official meteorological station, whereas the flanks of the Jemez Mountains, on the western edge, often receive 5.1 in. (13 cm) more.

About 36% of the annual precipitation comes from convective storms during July and August. Most of these storms are of the single-cell type (local conditions do not support the development of supercells and the severe weather associated with them). This period of maximum precipitation is often referred to as the "monsoon" season, even though it lacks the signature of true monsoon circulation—namely, large and persistent changes in wind direction. A more accurate characterization would probably be "rainy season."

Lightning is very frequent in Los Alamos, where an average year sees 61 thunderstorm days (days on which thunder is heard or a thunderstorm occurs)—about twice the national average. Only in the southeastern part of the country is this frequency exceeded. In addition to lightning, hail often accompanies these summertime convective storms. Hailstones of 0.25 in. (0.6 cm) are common, but stones of 1 in. (2.54 cm) have been reported. Hail can cause significant damage to property and vegetation, and localized accumulations of 3 in. (7.6 cm) have been observed.

Winter precipitation occurs mostly as snow; freezing rain is rare. The snow is generally dry (on average, 20 units of snow is equivalent to 1 unit of water). Annual snowfall averages 59 in. (150 cm), but amounts can vary significantly from year to year. The standard deviation of fluctuations in the annual value is 28 in. (71 cm). The highest recorded snowfall for one season is 153 in. (389 cm) and that for a 24-h period is 22 in. (56 cm). In a typical winter season, snowfalls equal to or exceeding 1 in. (2.6 cm) occur on 15 days, and snowfalls equal to or exceeding 4 in. (10.2 cm) occur on 5 days. The highest recorded snowfall for a single storm is 48 in. (122 cm).

5.1.4.3 Wind Conditions

Los Alamos winds are generally light, having an annual average speed of 5.5 mi/h (2.5 m/s) at the TA-6 station. The period from mid-March to early June is generally the windiest: daytime wind speeds exceed 8.8 mi/h (4 m/s) 20% of the time, and daily maximum wind gusts exceed 31 mi/h (14 m/s) 20% of the time. The highest recorded wind gust is 77 mi/h (34.4 m/s). High winds are associated with passing fronts, thunderstorms, and midlatitude storm systems. No tornadoes are known to have touched ground in the Los Alamos area; however, funnel clouds have been observed in Los Alamos and Santa Fe counties.

Whenever a weather system, such as a thunderstorm or large midlatitude storm, passes through the region, the local winds reflect the wind pattern associated with that system. Wind direction, however, is often significantly modified by the presence of the Jemez Mountains. Whenever the region is not affected by such systems, winds develop in response to the local pressure patterns created by differential heating and cooling of the atmosphere near the ground.

On the Pajarito Plateau, these locally generated winds exhibit considerable spatial variability because of the complex topography, and their temporal behavior follows the daily heating-cooling cycle. During sunny, light-wind days, an upslope flow often develops over the plateau in the morning hours as the east-facing mountainsides heat up. This flow is more pronounced along the western edge of the plateau, where it is typically 650 to 1,650 ft (198 to 503 m) deep. By noon, the prevailing flow over the entire plateau usually shifts to southerly—possibly attributable to the development of an upvalley flow in the Rio Grande valley (at present, data are insufficient to confirm this explanation).

Shortly after sunset, winds along the western edge of the plateau shift to west-southwesterly to north-northwesterly as cooled air begins to drain off the more elevated terrain to the west. The drainage layer is typically 165 ft (50 m) deep in the vicinity of TA-6, and the air moves with an average speed of 4.4 mi/h (2 m/s). If the sky is clear and the winds aloft are weak, these drainage winds persist until sunrise. Often, however, the drainage is disrupted by the winds aloft; in fact, only 25% of nighttime winds have the signature of a drainage wind.

Observations made at TA-41 in Los Alamos Canyon show that the wind pattern in the larger canyons is very different from that over the plateau. During the night, cold-air-drainage flow is observed more frequently—about 75% of the time—and is more steady than on the plateau. This drainage usually persists for an hour or two after sunrise, then ceases abruptly. An unsteady upcanyon flow develops and lasts for a couple of hours or until the plateau wind shifts to its normal daytime southerly direction. If the cross-canyon wind component is strong enough, the upcanyon wind is disrupted by the formation of a "rotor" (a large, turbulent eddy whose axis is parallel to that of the canyon). If winds over the plateau are southwesterly (or southeasterly), the wind in the canyon bottom will be northwesterly (or northeasterly); that is, the atmosphere in the canyon rotates and spirals downcanyon or upcanyon, depending on the along-canyon component of the plateau wind. Shortly after sunset, the rotor is replaced by the cold-air-drainage wind. Canyon geometry appears to be an important factor in rotor formation; whereas they are frequent in Los Alamos Canyon, there is little evidence of rotors in Pajarito Canyon, which has a larger width-to-depth ratio.

Turbulence intensity—when expressed as the standard deviation of fluctuations in the horizontal wind direction—has a median value of 22° during the day. Other things being equal, this value is larger than would be observed over flatter, smoother sites. At night, when the atmosphere is stable, the median value of the standard deviation of wind direction fluctuations drops to 15°.

It is standard practice to use the magnitude of the fluctuations in wind direction to determine an atmospheric stability parameter, which in turn is used to calculate the rate of atmospheric dispersion of pollutants. This parameter ranges in value from A (in very unstable conditions—good mixing) to D (neutral conditions) to F (very stable conditions—poor mixing). When this stability parameter is based on site-wide measurements of wind direction fluctuations, the frequency of occurrence of unstable, neutral, and stable conditions is 24%, 42%, and 34%, respectively.

5.1.4.4 Energy Exchange at the Surface

Solar irradiance measurements show that Los Alamos receives more than 75% of possible sunshine annually. (Possible sunshine is defined as the total amount that would be received if the sky were cloud-free all year.) During most of the year, when there is no snow on the ground, about 80% of this incoming solar energy is absorbed at the surface; about half of that absorbed short-wave energy is offset by a net loss of long-wave radiation to space. The remainder of the radiant energy, called "net all-wave radiation," is dissipated as it heats the soil, heats the lower layer of the atmosphere, and evaporates water from the soil and from plants (evapotranspiration). Preliminary analyses suggest that monthly total evapotranspiration is highest in July, when it reaches about 2.5 in. (6.4 cm). Monthly totals during the winter months are less than 0.25 in. (0.6 cm). Total annual evapotranspiration, measured at TA-6, varies little from year to year and is equal to approximately 90% of the average annual precipitation.

5.2 Ecological Setting

This section focuses on plants and animals within their regional ecological context. In addition, information has been included on floodplains and wetlands because of their importance in the semi-arid setting of Los Alamos.

5.2.1 Regional Description

The environment of New Mexico is largely semiarid and is characterized by plant communities ranging from Chihuahuan desert scrub to alpine tundra (Brown 1982). The Laboratory, which is located in the north-central part of the state, has a variety of vegetative complexes dictated by a wide range of elevational zones.

5.2.1.1 Flora

Two climatic zones are found in the higher-elevation (nonriparian) mountainous areas of north-central New Mexico. These zones comprise three upland plant communities: the Rocky Mountain Subalpine Conifer Forest and Woodland, the Rocky Mountain Montane Conifer Forest, and the Great Basin Conifer Woodland (Brown 1982). At the lower elevations, two grassland climatic zones contain at least three different upland communities: the Plains Grassland, the Great Basin Shrub Grassland, and the Rocky Mountain Montane Grassland.

Numerous wetland (riparian) plant communities occur in association with most of the upland plant communities. These wetland communities are located in five different climatic zones: the Cold Temperate Swamp and Riparian Forest, the Arctic-Boreal Swamp-Scrub, the Arctic-Boreal Marshland, the Arctic-Boreal Strand (streams and lakes), and the Cold Temperate Strand (streams and lakes).

Table 5-2 lists climatic zones and communities found in north-central New Mexico and typical plant species of each. Many of these plant communities are found over the eastern slopes of the Jemez Mountains and the Pajarito Plateau (which extends eastward from the Jemez Mountains) and thus occur in Los Alamos County or relatively close to the county borders.

The lowest-elevation land in or near Los Alamos County is the Rio Grande floodplain, which is characterized by a Plains and Great Basin Riparian-Deciduous Forest in which cottonwood and willow predominate. Nonnative species, such as salt cedar and Russian olive, are also present. At elevations just above the floodplain, ranging from about 5,600–6,200 ft (1,707–1,890 m), juniper becomes a typical upland overstory species, intermixed with lesser amounts of pinyon pine; both species are typical of the Great Basin Conifer Woodland. Pinyon pine and juniper are common at higher elevations [6,200–6,900 ft (1,890–2,103 m)] and cover a large portion of the mesa tops. This woodland community eventually intergrades with the more common plant communities of the western portion of Los Alamos County, where overstory species of the Rocky Mountain Montane Conifer Forest are found. Ponderosa pine is a common species at about 6,900–7,500 ft (2,103–2,286 m) on the higher mesa tops and along many of the north-facing canyon slopes. Species of the Rocky Mountain Subalpine Conifer Forest and Woodland—fir intermixed with ponderosa pine, often referred to as a mixed-conifer community—occur along the higher north-facing slopes and at the extreme western edge of the county, especially the higher elevations of the nearby Jemez Mountains.

Because most of the watercourses in the canyons in and adjacent to Los Alamos County are ephemeral (flowing during periods of precipitation), these canyon bottoms are not considered wetlands. However, springs and some Laboratory facility outfalls produce a small number of permanent or near-permanent stream flows in short stretches of certain canyons. Many of these streams and other wetlands are characterized by vegetation of the Rocky Mountain Riparian Deciduous Forest and the Plains Interior Marshland.

A general vegetation map of north-central New Mexico is shown in Figure 5-7, and a more complete checklist of species found within the plant communities of Los Alamos County and lands bordering the county is given by Foxx and Tierney (1985).

5.2.1.2 Fauna

The wide range of plant communities contains an equally wide range of micro- and macrohabitats in the Los Alamos County area. This diversity of habitats results in a relatively large diversity of wildlife species, including both invertebrates and v ertebrates, with a variety of species interactions.

TABLE 5-2

CLIMATIC ZONES AND PLANT COMMUNITIES OF NORTH-CENTRAL NEW MEXICO

Climatic Zone	Plant Community	Typical Plant Species[a]
Upland		
Boreal Forests and Woodlands	Rocky Mountain Subalpine Conifer Forest and Woodland	Englemann spruce Corkbark fir
Cold Temperate Forests and Woodlands	Rocky Mountain Montane Conifer Forest	Colorado spruce White fir Douglas fir Gambel oak Ponderosa pine
	Great Basin Conifer Woodland	Pinyon pine One-seed juniper Gambel oak Ponderosa pine
Arctic-Boreal Grassland	Rocky Mountain Alpine and Subalpine Grassland	Sedge/forb mixture
Cold Temperate Grassland	Plains Grassland Community	Blue grama Western wheatgrass Galleta
	Great Basin Shrub Grassland	Wheatgrass Galleta Sagebrush Saltbush
	Rocky Mountain Montane Grassland	Thurber fescue Arizona fescue Mountain muhly Sedge
Wetland		
Cold Temperate Swamp and Riparian Forest	Plains and Great Basin Riparian-Deciduous Forest	Fremont cottonwood Willow
	Rocky Mountain Riparian-Deciduous Forest	Narrowleaf cottonwood Willow Boxelder
Arctic-Boreal Swamp-Scrub	Rocky Mountain Alpine and Sub-alpine Swamp and Riparian Scrub	Narrowleaf alder Sandbar willow Scoulere willow
	Plains and Great Basin Riparian Scrub	Willow Salt cedar
Arctic-Boreal Marshland	Rocky Mountain Alpine and Subalpine Marshland	Rush
	Plains Interior Marshland	Cattail Bulrush
	Rocky Mountain Montane Marshland	Rush
Arctic-Boreal Strand	Rocky Mountain Alpine and Sub-alpine Stream and Lake Strand	[b]
Cold Temperate Strand	Rocky Mountain Montane Stream and Lake Strand	[b]

a. Plant species listed are intended as generally representative of a community; they are not necessarily present in all such communities.
b. These zones are open water; no plant species are associated with them.

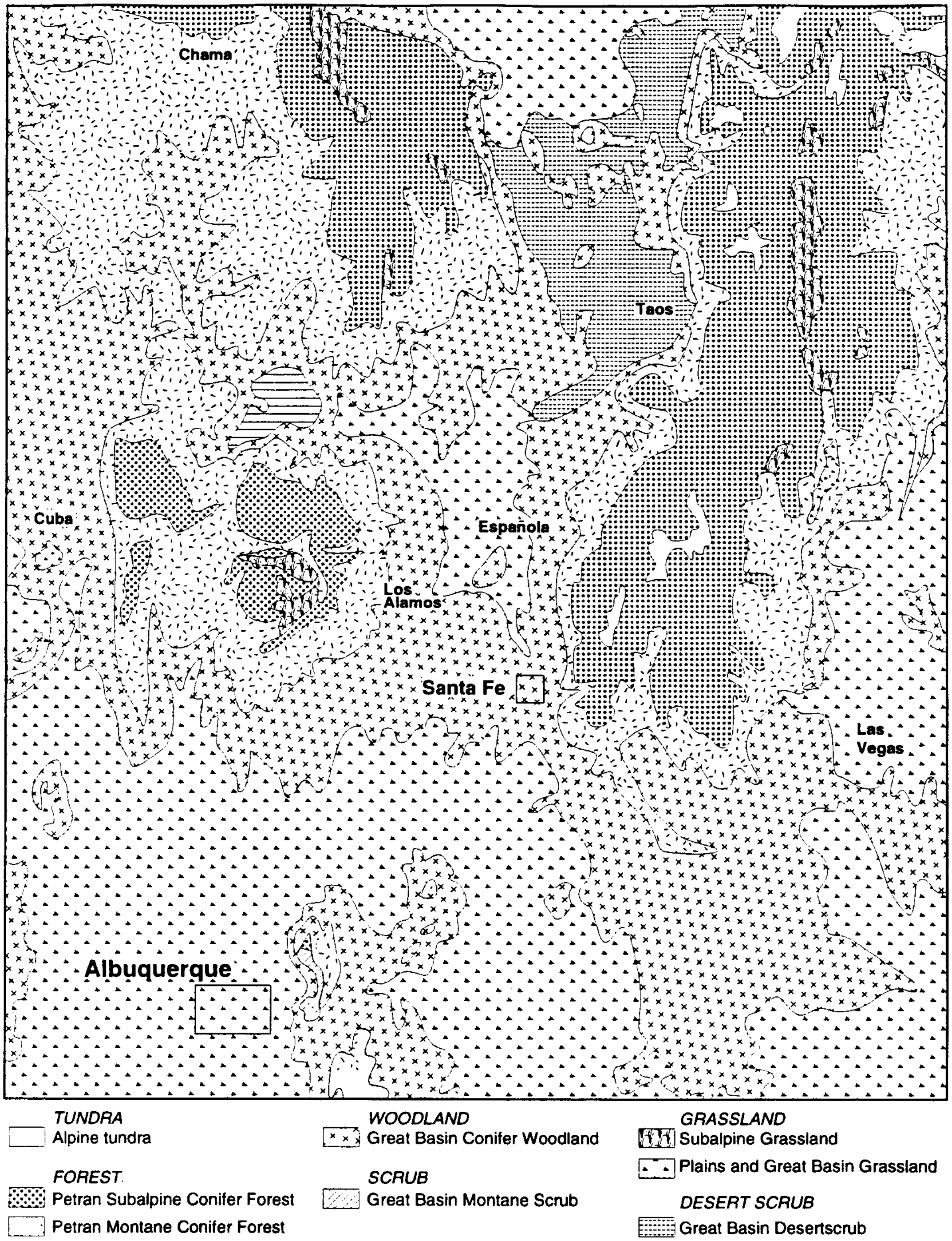


Figure 5-7. General vegetation map of north-central New Mexico.

Table 5-3 gives an example of a possible food web that includes several layers of plant and animal species in the area. This table is intended only as a general representation, not as a complete and accurate description.

TABLE 5-3

A POSSIBLE GENERAL FOOD WEB OF THE COMMON BIOLOGICAL RESOURCES OF THE LOS ALAMOS COUNTY REGION*

Group	Juniper Grassland	Pinyon-Juniper	Riparian Canyons	Ponderosa Pine	Mixed Conifer
Producers	Juniper	Pinyon pine	Cottonwood	Ponderosa pine	Douglas fir
	Saltbush	Juniper	Currant	Gambel oak	Ponderosa pine
	Ponderosa pine	Rabbitbrush	Hoptree	Skunkbush	Aspen
	Prickly pear	Apache plume	Box elder	Mountain muhly	White fir
	Feathergrass	Mountain mahogany	Sedge		
	Dropseed	Blue grama	Bluegrass		
	Three-awn		Little bluestem		
Consumers	Deer mouse	Deer mouse	Harvest mouse	Deer mouse	Pocket gopher
	Pinyon mouse	Pinyon mouse	Meadow vole	Chipmunk	Montane vole
	Cottontail	Cottontail	Cottontail	Squirrel	Chipmunk
	Woodrat	Woodrat	Chipmunk	Woodrat	Woodrat
		Mule deer	Mule deer	Mule deer	Mule deer
			Elk	Elk	Elk
					Bluebird
					Junco
Secondary Consumers	Coyote	Coyote	Coyote	Mountain lion	Mountain lion
	Gray fox	Gray fox	Raccoon	Black bear	Black bear
	Bobcat	Bobcat	Bobcat	Bobcat	Green-tailed towhee
	Scrub jay	Steller's jay	Steller's jay	Pygmy nuthatch	Clark's nutcracker
	Pinyon jay	Pinyon jay	Common raven	Common flicker	Hairy woodpecker
	Rattlesnake	Spiny lizard	Kestrel	Pygmy nuthatch	
			Golden eagle	Common raven	
			Gopher snake		

*Source: DOE 1979.

5.2.1.2.1 Invertebrates

Surveys for terrestrial and aquatic invertebrates have been conducted on Laboratory and Bandelier National Monument property. However, because these surveys were restricted to localized areas, the applicability of the results to the region as a whole is limited. The information provided below includes the most recent studies and surveys conducted at the Laboratory. In addition, an extensive study has been conducted at Bandelier National Monument; some of the results of that study are discussed here as well.

Studies of terrestrial arthropods have been conducted since the 1970s, and since 1990 they have been conducted on a yearly basis. These studies have been done at various locations within the Laboratory, as well as at control sites outside the Laboratory. To date, 164 families of terrestrial arthropods have been identified on Laboratory property, many down to genus or species. Eighteen species of terrestrial mollusks from 11 families have also been found at LANL.

The Laboratory has conducted and continues to conduct numerous studies of aquatic invertebrates in Los Alamos County and its surrounding watersheds. At present, LANL is monitoring aquatic stations at springs along the Rio Grande and on Laboratory property, in the lower canyon confluences with the Rio Grande, and at various Laboratory outfalls. The aquatic communities of Sandia, Guaje, Los Alamos, and Pajarito canyons are also being investigated.

Three species of aquatic snails and two species of freshwater clams have been found on LANL property. Segmented worms, water mites, horsehair worms, scuds, water fleas, copepods, roundworms, and flatworms have also been collected. To date, 8 families of stoneflies, 6 families of mayflies, 5 families of dragonflies, 4 families of damselflies, 5 families of true bugs, 13 families of caddisflies, 1 family of nerve-wing, 2 families of butterflies and moths, 10 families of beetles, and 16 families of true flies have been recorded living in the waters of Los Alamos County and its surrounding watersheds. These aquatic insects belong to 178 genera, and LANL studies have found several taxa in Los Alamos County not previously reported by the State of New Mexico.

5.2.1.2.2 Reptiles and Amphibians

A variety of reptiles are common throughout much of the county and include at least 14 species of skinks, lizards, and snakes. The presence of wetlands adds additional habitat for water-associated species. At least 7 species of amphibians are found in the county.

5.2.1.2.3 Mammals

At least 29 species of small mammals (e.g., mice, woodrats, voles, squirrels, chipmunks) occur in the area, some of which are specific to certain elevations. Deer mice, woodrats, and least chipmunks inhabit most areas of the region. Pinyon mice are found primarily in pinyon-juniper woodlands, the red-backed vole is found in the higher elevations, and the western harvest mouse and long-tailed voles are found in the moister canyon bottoms. Shrews are found near flowing water. Another group of small mammals—at least 13 different species of bats—are also present within Laboratory boundaries.

Mule deer and elk are the best known of the larger mammals of the region, although their populations and distributions are constantly changing. These species generally winter in the lower elevations of the Pajarito Plateau, including many of the mesas and canyons along the central and eastern portions of the county and surrounding areas, and spend their summers at the higher elevations of the Jemez Mountains. However, recent surveys in the Los Alamos County area indicate growing population numbers of these species residing year-round at lower elevations. Little is known about other large- and medium-size mammals of the area, but observations and current studies indicate that at least 12 species of carnivores are present, including bear, mountain lion, bobcat, fox, and coyote.

5.2.1.2.4 Birds

Birds are the most diverse group of wildlife found in the area, because of both the wide range of habitats and the mobility of the species. Birds observed locally include a variety of nesting and migrating raptors that occupy some of the less disturbed areas and the steeper canyon walls. Over 200 bird species have been reported in the county, which includes at least 112 species of breeding birds (Travis 1992). Of the breeding birds, at least 39 are resident species and 59 are migratory summer resident species.

5.2.2 Threatened and Endangered Species

Judging from the presence of preferred habitats, a total of 14 species of plants and animals listed by the state and/or federal government as threatened or endangered are known to occur or could occur in Los Alamos County. Potential occurrence is also based on whether a species has been observed at locations adjacent to the county (e.g., in Bandelier National Monument or in the Jemez Mountains). Table 5-4 lists threatened and endangered plant and wildlife species known to occur or to potentially occur in the county, along with their listing status and preferred habitat.

5.2.3 Unique and Sensitive Habitats

5.2.3.1 Travel Corridors

The Laboratory is located in a transitional area for wintering elk and deer. Herds of these animals move down onto Laboratory property during the winter as snow accumulates at higher elevations (Eberhardt and White 1979, White 1981). A wider distribution and additional travel corridors on Laboratory property are suspected.

5.2.3.2 Breeding and Nesting Areas

Some herds of elk and deer are now residing year-round on Laboratory property, and more widely distributed fawning and calving grounds than in the past are expected for these species. Additional intensive studies will be necessary to identify these areas.

A survey of breeding birds of Los Alamos County indicates locations of birds breeding in the area (Travis 1992). Many of the less disturbed mesas and canyons support breeding birds, as do some of the more disturbed areas. The combination of steep canyons and coniferous forests provides suitable nesting sites for a variety of bird species.

5.2.3.3 Foraging and Hunting Areas

Those habitats supporting relatively higher diversities and densities of prey species, such as wetlands, can be expected to harbor greater diversities and densities of predator species. For example, where elk and deer are more numerous, predators that feed on these animals are also more numerous. Since the studies of elk and deer were completed (Eberhardt and White 1979; White 1981), the number and distribution of deer have probably remained static; the number of elk, however, has continued to increase in the county, and they have become more widely distributed and use a broader range of habitats. Additional intensive studies will be necessary to more accurately identify sensitive foraging and hunting areas for all groups of wildlife species in the area.

5.2.3.4 Water Sources

Surface water in the Los Alamos area occurs primarily as ephemeral streams in canyons cut into the Pajarito Plateau. Within Laboratory boundaries, only four of the canyons contain perennial streams: Pajarito, Water, Ancho, and Chaquehui canyons. Other perennial watercourses are found outside Laboratory lands, in Guaje, Los Alamos, Sandia, Pajarito, Water (and its tributary Cañon de Valle), Ancho, and Chaquehui canyons. Portions of some of the canyons on Laboratory property are fed by Laboratory facility outfalls and/or other artificial sources. These sources produce small areas with free-flowing water that are used to a relatively high degree by a variety of species. During certain times of the year, areas receiving intermittent flow also provide important sources of water for species such as amphibians and migratory wildlife.

TABLE 5-4

FEDERAL AND STATE THREATENED AND ENDANGERED FLORA AND FAUNA OCCURRING OR POTENTIALLY OCCURRING IN LOS ALAMOS COUNTY

Species	Status	General Habitat/ Elevation	Confirmed in Los Alamos County
Flora			
Grama grass cactus (*Toumeya papyracantha*)	State Endangered	Pinyon-juniper 5,000–7,300 ft (1,524–2,225 m)	Yes
Wood lily (*Lilium philadelphicum var. andinum*)	State Endangered	Mixed conifer 7,500–10,000 ft (2,285–3,0480 m)	Yes
Yellow lady's slipper (*Cypripedium calceolus var. pubescens*)	State Endangered	Riparian, mixed conifer 6,000–10,000 ft (1,830–3,050 m)	Yes
Fauna			
Jemez Mountains salamander (*Plethodon neomexicanus*)	State Endangered Group 2	Mixed conifer 7,225–9,250 ft (2,200–2,819 m)	Yes
Bald eagle (*Haliaeetus leucocephalus*)	State Endangered Group 2, Federal Threatened	Riparian zones	Yes
Arctic peregrine falcon (*Falco peregrinus tundrius*)	Federal Threatened	Mixed conifer, riparian, and grassland	No
Grey vireo (*Vireo vicinior*)	State Endangered, Group 2	Juniper, savanna, and pinyon-juniper	Yes
Peregrine falcon (*Falco peregrinus var. anatum*)	State Endangered Group 1, Federal Endangered	Ponderosa, pinyon	Yes
Mexican spotted owl (*Strix occidentalis lucida*)	Federal Threatened	Mixed conifer	Yes
Southwestern willow flycatcher (*Empidonax trailii extimus*)	State Endangered Group 1, Federal Endangered	Riparian zones	Yes
Whooping crane (*Grus americana*)	State Endangered Group 1, Federal Endangered	Rivers, streams	Yes
Spotted bat (*Euderma maculatum*)	State Endangered Group 2	Varies, usually near water	Yes
Meadow jumping mouse (*Zapus hudsonius luteus*)	State Endangered Group 2	Wetland	Yes
Black-footed ferret (*Mustela nigripes*)	Federal Endangered	Prairie	No

5.2.4 Floodplains and Wetlands

All of the major canyon systems within Laboratory boundaries contain floodplains in the canyon bottoms, produced by localized precipitation events. Wetlands in Los Alamos County and adjacent areas fall into two categories, as designated in the National Wetlands Inventory maps (US Department of the Interior 1990): riverine and palustrine.

A riverine system is contained in a channel. Most of the Laboratory's wetlands are of this type and are man-induced (resulting from effluent outfalls). Just outside county boundaries, Frijoles Canyon is considered to contain a riverine system along the banks of its perennial stream. Palustrine systems are defined as nontidal wetlands that are dominated by trees, shrubs, emergents, and/or other aquatic vegetation; are less than 20 acres (8 ha) in size; are less than 6.5 ft (2 m) deep; and contain no active wave-forming shoreline features. Examples are ponds, marshes, and bogs. The lower portion of Pajarito Canyon, near its intersection with State Road 4, is classified as palustrine.

5.3 Cultural Resources

Cultural resources are defined as archaeological sites; prehistoric or historic districts, sites, buildings, structures; traditional use areas, or object included in, or eligible for inclusion in, the National Register of Historic Places. Artifacts, records, and remains related to and located within such properties are also considered cultural resources.

5.3.1 Prehistoric

Approximately 70% of the DOE lands occupied by LANL have been surveyed for archaeological sites, and approximately 1,400 sites have been identified. Most of these sites (about 1,300) were occupied in the prehistoric period and represent the material remains of pueblos and camps that were used from 6,000 BC to the mid-1500s AD. These sites have been categorized, and 17 distinct types are known to exist. However, about 80% of these sites fall into 1 of only 4 categories: single-room block pueblos (about 350 sites), 1-3 room structures (about 300 sites), artifact scatters (about 200 sites), and cavate pueblos (about 200 sites).

Several of the larger sites underwent partial excavation during the early 1900s, and all sites were accessible to the public up to Army occupation of these lands in the mid-1940s. Since then, the public has been excluded from these lands, and most of these sites remain undisturbed. The only sites disturbed by the Laboratory are those impacted by past or present facility construction activities.

5.3.2 Historic

Approximately 100 sites that qualify as historic cultural properties have been identified within Laboratory boundaries. These properties fall into two categories: (1) those related to homesteading and the ranch school and (2) those related to World War II and post-World-War-II activities.

5.3.2.1 Farming, Ranching, and School

Approximately 70% of the historic sites are related to farming, ranching, or school activities. During the late 1800s and early 1900s, several small ranches for raising beans and other seasonal crops existed on the plateau. In addition, cattle were grazed on these lands as part of small cow-calf operations. Several of these homesteads have been located, along with other remains such as wagon roads, implements, and other items of historic interest. Most of the remains of the Boys School are on land now owned by Los Alamos County and are no longer a responsibility of DOE or the Laboratory.

5.3.2.2 World War II and Post-World-War-II Historic Sites

Approximately 30 of the historic sites are related to more modern-day activities. The assembly areas for Fat Man and Little Boy, along with some of the original high-explosive-assembly buildings, are in this category. This list is expected to grow, however, because not all Laboratory structures meeting the 50-year-age requirement for inclusion on the National Register of Historic Places have been evaluated for significance.

5.3.3 Traditional Cultural Properties

Traditional cultural properties include shrines, springs, plants, soils, ruins, and/or other objects of religious or special significance to contemporary Native Americans. These properties have special significance in the practice of traditional religions. Properties of this nature exist within the Laboratory boundaries, and DOE holds regular meetings with tribal representatives from the pueblos of San Ildefonso, Cochiti, Santa Clara, and Jemez to review Laboratory undertakings that have the potential to affect cultural sites.

5.4 Socioeconomic Setting

This discussion is limited to north-central New Mexico, and the three primary counties of Los Alamos, Santa Fe, and Rio Arriba. Most of the workforce is drawn from these three counties, and most of the economic impact of the Laboratory occurs in these three counties.

5.4.1 Regional

North-central New Mexico was originally settled by various Native American tribes, some of whom established pueblos along the Rio Grande. In the mid-sixteenth century, the region was conquered by the Spanish. As a result, a strong Hispanic culture flourished as the Native Americans were subjugated. The Anglo influence is a fairly recent phenomenon dating from the 1850s, when Anglo-Americans began to settle the territory taken from Mexico as a result of the Mexican/American War. This influence accelerated in the mid-twentieth century when the Manhattan Project established at Los Alamos in 1943 created a new influx of Anglo workers into this region. Today, the region is an interesting mixture of these three distinct cultures.

5.4.2 Understanding Socioeconomic Data at Los Alamos

At any institution as large as LANL, human resource data are collected for a variety of purposes, and a basic understanding of those data is essential to their proper use. A misunderstanding of the limitations of these data can result in indiscriminate use and misinterpretations of impacts.

5.4.2.1 Limitations of Socioeconomic Data

Use of human resource data from Laboratory databases requires a basic understanding of two concepts. The first concept is that Los Alamos has a dynamic workforce that changes daily, and the databases used to track this information are constantly updated to reflect these changes. Therefore, any given query of these databases reflects these variations through time. A request for information made on Monday may or may not result in a response identical to a similar request made on Tuesday. The Laboratory does, however, maintain end-of-month snapshots for historical and query purposes.

The second concept is that human resource data are kept by head count for some purposes and by full-time equivalent (FTE) for others. No one-to-one relationship between FTEs and head counts exists. In some cases, one FTE may represent portions of several different people. For example, two half-time employees would equal one FTE; however, both half-time employees would show up in the head count.

5.4.2.2 Standard Employee Groupings

When discussing employees at Los Alamos, four basic groups are routinely used in the discussions:

- total Laboratory-related work force. This group, which numbered approximately 12,700 people at the end of October 1996, includes
  - LANL (all UC employees, including special-program employees and students),
  - LANL consultants (affiliates and student guests), and
  - LANL contract employees.
- total Laboratory work force. This group numbered approximately 9,200 people at the end of October 1996. The group includes
  - LANL (all UC employees, including special-program employees and students) and
  - LANL contract employees.
- total Laboratory UC employees. This group numbered approximately 8,200 people at the end of October 1996. It consists of all UC employees, including special-program employees and students.
- full-time/part-time regular Laboratory employees. This group, which numbered approximately 6,100 people at the end of October 1996, includes LANL career employees but does not include any student or special-program employees. It does include a few employees involved in the Advanced Study Program and on professional renewal and teaching leave.

The only employees over which LANL has total control in the human resources databases are the total Laboratory UC employees and the full-time/part-time regular Laboratory employees. Obtaining data on the remaining workforce requires input from external organizations such as JCI and PTLA.

5.4.2.3 Discussion

A review of human resources data reveals several interesting phenomena. Head count significantly increases during the spring, remains elevated but somewhat constant over the summer, and then sharply drops in the fall. The spring influx is represented by students, affiliates, and student guests coming to Los Alamos from April through June. Most of these individuals are here by June, work through the summer, and return to school in October. In addition, many of these affiliates and students remain "on the books" throughout the year, which creates a major variance between head count and FTEs. The FTE count also shows fluctuation; however, shifts in FTEs are more gradual and reflect hiring practices that depend on long-term funding projections and guidance from funding agencies.

Neither head count nor FTE count tracks accrued costs closely on a month-by-month basis. Costs tend to reflect the nature of LANL's research and development activities, whose charges per staff member and how those charges are accrued are project-dependent. Monthly costs also reflect the use of a 4-week, 4-week, 5-week quarter. This accounting practice causes every third month to show significant increases in cost.

LANL is a complicated organization from a business standpoint; the data kept on employment, salaries, and costs have many idiosyncrasies that require the end user to have a good understanding of what the data represent. This understanding is especially important when the data are used to project future employment and costs.

5.4.3 Ethnic/Geographic Composition of the Workforce

Head count data show that over 90% of regular Laboratory employees live in one of three counties: Los Alamos, Santa Fe, and Rio Arriba (Table 5-5). Of these employees, about 25% are Hispanic and about 63% are white. The remainder are mostly Native American or Asian.

<u>TABLE 5-5</u>

PERCENT DISTRIBUTION OF REGULAR LABORATORY EMPLOYEES BASED ON HEAD COUNT (NOVEMBER 1996)

	Not Stated	Native American	Asian	Black	Hispanic	White	Total
Los Alamos	0.9	0.6	2.9	0.2	4.9	50.1	59.5
Santa Fe	0.1	0.4	0.3	0.1	7.1	10.8	18.9
Rio Arriba	0.0	0.5	0.0	0.0	12.5	2.4	15.5
All Others	0.1	0.1	0.2	0.1	0.9	4.7	6.1
Total	1.1	1.6	3.4	0.4	25.5	68.0	100.0

5.4.4 Regional Economic Contribution

For several years, DOE-AL and New Mexico State University have maintained an interindustry input-output model that is capable of assessing the effect on an economy of developments initiated outside the economy. This model has been used to evaluate the impacts of federal (LANL) moneys that flow into New Mexico, and the following information has been extracted from the report covering FY95 (Lansford 1996).

5.4.4.1 Funding

Total LANL funding (operating and capital budget) in north-central New Mexico in FY95 was $1.2 billion. LANL's regional (Los Alamos, Santa Fe, and Rio Arriba counties) expenditures were $704 million for salaries and wages, trade and services, capital equipment, and construction. Of the $704 million, UC operating expenditures accounted for 86%, JCI for 10%, and PTLA for 4%.

The economic sectors accounting for most of LANL's regional expenditure for FY95 were households ($573 million), other business services ($28 million), engineering services ($23 million), wholesale trade ($17 million), and retail trade ($13 million). These sectors combined accounted for about 93% of total regional expenditures. By far the largest regional expenditure was labor, which accounted for about 81% of the total.

5.4.4.2 Employment

In FY95, LANL had approximately 8,113 employees in the 3-county region (Los Alamos, Santa Fe, and Rio Arriba). JCI had about 1,524 employees, and PTLA had about 439 employees. Thus, the total number of region-wide jobs (all types of personnel) funded by the Laboratory or by contracts directly associated with the Laboratory averaged about 10,000. In addition, about 2,000 more jobs were indirectly funded by the Laboratory through subcontractors.

5.4.4.3 Economic Impact

An economic model that incorporates buying and selling linkages among regional industries was used to analyze the Laboratory's economic impact on north-central New Mexico. This modeling technique produces three multipliers (one for general economic activity, the second for income, and the third for employment). The activity multiplier identifies the extent to which an activity, such as LANL's operations, relies directly and indirectly on the regional economy to provide it with the materials, services, and labor it requires to conduct its activities and the extent to which respending by businesses and industries occurs in the region. The income and employment multipliers make it possible to identify not only the direct impacts of the activity on income and jobs but also the indirect (business) and induced (household) effects of the activity.

LANL's initial spending generates substantial first-round impacts on households (net) and businesses ($503 million and $121 million, respectively, for FY95) in the three-county north-central region. This initial spending provides government $11 million in new revenues (mainly in state and local government taxes and fees). Respending by regional businesses and purchases by households and state and local government eventually bring the total private business impact to about $965 million. Also, respending activity will continue to add to personal income and government revenues so that total personal income will increase to $1.04 million, and state and local government tax revenues and government fees will expand $140 million as a result of direct, indirect, and induced effects.

5.4.4.4 Overall Impact

The economic activity multiplier for LANL for FY95 was 2.89, which means that for every $1.00 spent by LANL and its major onsite contractors, another $1.89 was generated, for a total impact of $2.89. Based on LANL's funding for FY95—$1.2 billion—the estimated increase in economic activity was about $3.4 billion. This $3.4 billion represents about 30% of the estimated $11.35 billion total economic activity in the region.

The income multiplier for LANL for FY95 was 1.95. Applying this multiplier to the direct net personal income figure of $503 million (the total of gross labor, net wages and salaries, and indirect and induced income) yields a total impact of $1.03 billion. In FY95, total personal income in north-central New Mexico was estimated at $3.56 billion, indicating that LANL contributed about 29% to regional personal income.

Besides this dollars-and-cents impact, LANL affects regionwide employment. In addition to the average of 10,076 mainly full-time jobs created by LANL in FY95, other jobs are supported by the resulting needs for goods and services. The regional employment multiplier for LANL was estimated to be 2.71, indicating that for every 100 jobs created by LANL, another 171 jobs were supported, translating to a total impact of 27,282 jobs. These jobs accounted for about 32% of the total employment in the region.

In summary, LANL's operations in north-central New Mexico have a significant and positive influence on the regional economy. LANL's funding of about $1.2 billion yielded a total economic impact of over $3.4 billion or about 30% of the total regional economic activity in FY95. Total personal income impact was $1.03 billion or about 29% of the personal income derived in the 3 counties. The 10,076 jobs directly supported by LANL resulted in a total of 27,282 jobs or nearly 1 of every 3 jobs in the region. Approximately 78% of the indirectly created jobs occurred in the trade and services sectors.

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6.0 ENVIRONMENTAL REGULATORY OVERSIGHT

The Laboratory's operations are subject to a multitude of federal and state environmental statutes, regulations, and permits. These directives address handling, transport, release, and disposal of contaminants, pollutants, and wastes, as well as protection of ecological, archaeological, historic, atmospheric, and aquatic resources. Table 6-1 presents a list of the major environmental laws that affect LANL and the agencies responsible for regulatory oversight. This chapter is an overview of these laws as they apply to LANL. The principal agencies responsible for administering the environmental regulations are the EPA, DOE, and NMED.

6.1 Regulatory History

As mentioned in Chapter 1, the AEC was established by the Atomic Energy Act of 1946 to assume from the War Department responsibility for atomic and nuclear research, including the nation's nuclear defense research program. The Atomic Energy Act of 1946 charged the AEC with directing the development and utilization of atomic energy toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace. In the late 1940s and early 1950s, limited stocks of uranium precluded the rapid development of peaceful uses, including civilian power reactors.

Over the next eight years, atomic energy was developed primarily for defense purposes. However, in 1953, President Eisenhower proposed establishing an international pool of fissionable nuclear material to be used for developing peaceful uses of the atom, especially for nuclear power reactors. From this genesis emerged not only the agreement to create the International Atomic Energy Agency and other bilateral and multilateral agreements but also a budding domestic nuclear power industry. However, the AEC's monopoly of nuclear sciences, including reactor technology, required amending the Atomic Energy Act to include private industry. The result was the Atomic Energy Act of 1954, USC, Title 42, Chapter 23, Development and Control of Atomic Energy. This act defined—and set apart for AEC regulation—control of the plutonium and uranium used in weapons (special nuclear material), the original or raw nuclear material (source material), and any wastes generated by processing these materials into weapons (by-product materials), while allowing the federal government and private industry to promote nuclear power in partnership. However, the amendment did not address tritium or its use by the nuclear weapons industry. LANL continued to be "self-regulated" in the handling of nuclear materials and radioactive hazardous wastes for and on behalf of the AEC.

The 1960s witnessed phenomenal growth and development in the nuclear power industry. At the same time, the growing environmental movement began scrutinizing the AEC and its "self-regulating" activities. AEC regulations held the AEC responsible only for potential radiological hazards to public health and safety. Critics charged that this policy was inconsistent with NEPA and asserted that the AEC should also consider thermal pollution and other environmental issues in licensing reactors.

As the environmental movement continued to gain momentum in the early 1970s, the US began to experience sporadic energy shortages. This energy crisis resulted in the development of a single national energy policy and program. On January 19, 1975, as a result of the Energy Reorganization Act of 1974, the AEC was replaced by the NRC and ERDA. The intent of Congress was (1) to focus the federal government's energy research and development activities in a unified agency whose major function would be to promote the speedy development of various energy technologies and (2) to separate nuclear licensing and regulatory functions from the development and

TABLE 6-1

MAJOR ENVIRONMENTAL AND SAFETY STATUTES, REGULATIONS, AND ORDERS UNDER WHICH THE LABORATORY OPERATES

Resource Category	Legislation	Federal Regulatory Citation	Responsible Agency*	Related Legislation and Regulations
Air	Clean Air Act	42 USC§§7401 et seq. 40 CFR 50-99	EPA NMED NMEIB	National Ambient Air Quality Standards/State Implementation Plans (42 USC§§7409 et seq.). Standards of Performance for New Stationary Sources (42 USC§§7412). National Emission Standards for Hazardous Air Pollutants for Radionuclides (40 CFR 61, Subpart H) requires emission reporting, monitoring, and quality assurance and establishes a yearly public emission standard. Asbestos (40 CFR 61, Subpart M) requires abatement and rate procedures. Beryllium (40 CFR 61 Subpart C) requires notification, emission limits, and stack performance testing. Unleaded fuel (40 CFR 80, Subpart B) requires labeling and other gas pump controls. Refrigerants (40 CFR 82) requires controls on recovery and recycling refrigerants. Ambient Air Quality Standards (40 CFR 50). Prevention of Significant Deterioration (42 USC§§7470 et seq.). Executive Order 12843: Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances (April 21, 1993). NM Air Quality Control Act (NM Statute Title 74, Article 2). New Mexico Air Quality Standards and Regulations (NM Air Quality Control Regulations §100).
Acoustic	Noise Control Act of 1972	42 USC§§4901 et seq.	EPA	

Water	Clean Water Act	33 USC§§1251 et seq. 40 CFR 121-136 40 CFR 400-424 40 CFR 503	EPA NMED NMWQCC	NPDES. EPA Standards for the Use or Disposal of Sewage Sludge. NM Water Quality Act (NM Statute Title 76, Article 6). NM Water Quality Control Regulations (NM Water Regulations). NM Liquid Waste Disposal Regulations. Water Quality Standards for Interstate and Intrastate Streams.
Water	Safe Drinking Water Act	42 USC§§300f et seq. 40 CFR 141-148	EPA NMED	NM Drinking Water Regulations.
Soil	RCRA	42 USC§§6901 et seq./PL 98-616 40 CFR 257, 258, 260-268, 270-272, 280, and 281	EPA NMED	Hazardous and Solid Waste Amendments. Federal Facilities Compliance Act Amendments. Solid Waste Disposal Act (PL 89-272). Nuclear Waste Policy Act of 1982 (42 USC§§10101 et seq.). Low-Level Radioactive Waste Policy Act (42 USC§§2021b-2021d). NM Hazardous Waste Act. NM Hazardous Waste Management Regulations. NM Solid Waste Act (NM Statute Chapter 74, Article 8). NM Solid Waste Regulations. NM Groundwater Protection Act. NM Underground Storage Tank Regulations.
Soil	CERCLA	42 USC§§9601 et seq./PL 99-499 40 CFR 300-311	EPA	Superfund Amendments and Reauthorization Act. Community Environmental Response Facilitation Act. Designation, Reportable Quantities, and Notification. Emergency Planning and Community Right-to-Know Act (42 USC§§11001 et seq., 40 CFR 350-373). Executive Order 12856: Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements (August 3, 1993). NM Emergency Management Act.

Biotic	Endangered Species Act	16 USC§§1531 et seq. 50 CFR 402	USFWS NMGF	Fish and Wildlife Coordination Act. Bald and Golden Eagle Protection Act (16 USC§§668 et seq.). Migratory Bird Treaty Act (16 USC§§703 et seq.). NM Wildlife Conservation Act (New Mexico Game and Fish Regulations). NM Endangered Plant Species Act.
Biotic	Federal Insecticide, Fungicide, and Rodenticide Act	40 CFR 150-189	EPA NMDA	NM Pest Control Act.
Cultural	National Historic Preservation Act	16 USC§§470 et seq. 36 CFR 800	NACHP SHPO DOI	Archeological and Historical Preservation Act of 1974 (16 USC§§469 et seq.). Archaeological Resources Protection Act of 1979 (ARPA) (16 USC§§470aa et seq., 43 CFR 7). American Indian Religious Freedom Act (AIRFA) of 1978 (42 USC§§1996). Native American Graves Protection and Repatriation Act of 1990 (42 USC§§3001). Executive Order 11593: Protection and Enhancement of the Cultural Environment (3 CFR 154, 1971-1975 Comp. p. 559). NM Cultural Properties Act.
Worker Health and Safety	Occupational Safety and Health Act	5 USC§§5108	OSHA	Hazard Communication Standard (29 CFR 1910.1200).
Transportation	Hazardous Materials Transportation Act	49 USC§§1801 et seq.	DOT	Hazardous Materials Transportation Uniform Safety Act of 1990 (49 USC§§1801).
Other	Atomic Energy Act of 1954, as amended.	42 USC§2011	DOE NRC	

Other	NEPA	42 USC§§4321 et seq. 40 CFR 1500-1508 10 CFR 1021 10 CFR 1022	CEQ DOE WRC FEMA COE FWS	Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (February 11, 1994). Executive Order 11514: Protection and Enhancement of Environmental Quality (3CFR, 1955-1970 Comp., p. 906) Executive Order 11988: Floodplain Management (3 CFR, 1977 Comp. p. 117). Compliance with Floodplain/Wetlands Environmental Review Requirements (10 CFR 1022). Clean Water Act, Section 404, Rivers and Harbors Act (33 USC§§1251 et seq.).
Other	TSCA	15 USC§§2601 et seq. 40 CFR 700-766	EPA	
Other	Pollution Prevention Act of 1990	42 USC 11001-11050	EPA	Executive Order 12088: Federal Compliance with Pollution Control Standards (3 CFR, 1978 Comp., p. 243). Executive Order 12873: Federal Acquisition, Recycling, and Waste Prevention (February 11, 1994).

*CEQ—Council on Environmental Quality
CFR—Code of Federal Regulations
COE— (Army) Corps of Engineers
DOI—Department of the Interior
EPA—Environmental Protection Agency
FEMA—Federal Emergency Management Agency
NACHP—National Advisory Council on Historic Preservation
NMDA—New Mexico Department of Agriculture
NMED—New Mexico Environment Department
NMEIB—New Mexico Environmental Improvement Board
NMGF—New Mexico Game and Fish Department
NMWQCC—New Mexico Water Quality Control Commission
NRC—Nuclear Regulatory Commission
OSHA—Occupational Safety and Health Administration
SHPO—State Historic Preservation Officer
FWS—Fish and Wildlife Service
WRC—Water Resources Council

production of nuclear power and weapons, thus splitting the control and regulation of radioactive material into weapons applications (ERDA) and peacetime applications (NRC).

This arrangement created an interesting problem by mandating two different management systems for similar isotopes. For example, ^{238}Pu, generated by a commercial reactor (peacetime use), was managed by NRC, whereas, ^{238}Pu (source material) from a reactor at the Hanford Site (a weapons metal production reactor) was managed and controlled by ERDA. ERDA was still self-regulated in its management of nuclear materials and radioactive hazardous wastes under the provisions of the Atomic Energy Act of 1954.

In 1977, President Carter signed energy reorganization legislation (Public Law 95-91), thereby creating the DOE. DOE continued the "self-regulation" policy of its predecessors under the Atomic Energy Act of 1954 and the supposition that DOE orders carried the same authority as regulations imposed by sister federal agencies on private industry. Therefore, unless an act specifically waived sovereign immunity, such as the Clean Air Act, DOE considered itself the regulating agency.

DOE was not the only federal agency facing increased congressional action as a result of the growing environmental movement. For example, in 1977, Congress amended the Clean Air Act to require federal agencies to comply with both the substantive and procedural requirements of state programs. Previously, federal agencies had interpreted this federal compliance section of the Clean Air Act to mean that they were subject only to the substantive portions and that they were not required to comply with the permitting, record-keeping, monitoring, and reporting requirements of state plans. In addition, Congress wrote similar language into the Clean Water Act.

From 1975 to 1990, the number of environmental regulations increased dramatically. The general public wanted a clean, healthy environment and demanded that Congress take action. It was during the middle of this growing environmental movement that DOE lost a landmark lawsuit. In 1984, in the matter of LEAF v. Hodel, a federal court found that the "exclusive regulation" theory was incorrect, that the RCRA applied to the hazardous, nonradioactive component of mixed waste, and that the Atomic Energy Act applied only to the radioactive component. Thus, EPA assumed control of nonradioactive contaminants of waste at DOE installations.

In 1992, Congress approved and the President signed the Federal Facilities Compliance Act (FCCA), which amended RCRA. This amendment did not contain a blanket waiver of sovereign immunity with respect to other environmental statutes. Nonetheless, the FFCA did represent a major change from existing law. The act has the following significant provisions:

- contains a waiver of sovereign immunity with respect to federal, state, interstate, and local substantive and procedural requirements, including all administrative orders and all civil and administrative penalties and fines;

- waives sovereign immunity with respect to payment of reasonable service charges, including inspection charges;

- provides that the EPA administrator "may commence" an administrative enforcement action against federal agencies pursuant to the enforcement authorities contained in RCRA;

- defines "person" as including any department, agency, or instrumentality of the US;

- requires the EPA administrator to undertake annual inspections of federal facilities and requires federal agencies to reimburse EPA for the costs of the inspection; and

- authorizes state inspections to enforce state programs at federal facilities where the state has primacy.

As a result of this act, both the states and the EPA are now able to charge fees, including inspection fees, for a wide range of activities and to assess penalties against federal agencies. The President's signing statement also made it clear that the source of funds for payment of penalties is the agency's appropriations. A special fund was not established to pay these penalties.

Thus, by the early 1990s, the era of self-regulation was ended. DOE and its facilities, like LANL, are now subject to review by multiple state and federal regulatory agencies. However, the regulation and control of nuclear materials for weapons (source material, by-product material, and SNM) still resides with DOE.

6.2 Major Regulations

It is LANL's policy that all its operations be performed in a manner that protects the environment and complies with applicable federal and state environmental laws and regulations. These laws and regulations were written to protect human health first and were then expanded to protect the local environs. These regulations are mostly risk-based but are very conservative in their application (e.g., they regulate emissions at levels far below the thresholds required to produce measurable biological effects). This section presents the major environmental regulations, organized by the resource category affected, that govern operations at LANL and identifies how these regulations apply to LANL. Details on monitoring and compliance with these regulations are presented in LANL's annual environmental surveillance reports.

A basic understanding of the roles of the regulatory agencies is essential to an understanding of how the various laws, rules, and regulations interact with each other. The EPA has the power to enforce the requirements of the RCRA through the FFCA. The EPA also enforces the requirements of the Clean Air Act and the Clean Water Act by means of federal facilities compliance agreements and administrative orders through which deficiencies are identified, corrective actions are determined, and schedules for implementation are stipulated. NMED enforces the RCRA requirements for which it is responsible under New Mexico's Hazardous Waste Act by means of compliance orders, which provide a mechanism for correcting deficiencies and/or assessing penalties. (The NMED regulations were written to be as stringent or more stringent than those written by the EPA and became effective when EPA delegated authority to the state.)

The Environmental Oversight and Monitoring Agreement (known as the "Agreement in Principle") between DOE and the State of New Mexico provides for technical and financial support by DOE for state activities in environmental oversight, monitoring, access, and emergency response. The agreement, which was signed in October 1990, covers Los Alamos and Sandia national laboratories, the Waste Isolation Pilot Project, and the Inhalation Toxicology Research Institute. Under the agreement, NMED is the lead state agency. On October 2, 1995, DOE and NMED extended the Agreement in Principle for an additional 5 years.

6.2.1 Air Resources

The federal government and the various state governments have been aggressive in passing legislation to protect air resources from pollution by requiring industry to meet certain standards and to obtain permits when releasing materials to the atmosphere.

6.2.1.1 Clean Air Act

The federal government's involvement in solving the air pollution problem started with the Air Pollution Control Act of 1955 (Public Law No 84-159, 69 Statute 322). This act treated air pollution as a strictly local problem to be handled and resolved by the states. To assist the states, the 1955 act authorized federal research programs for air pollution control. The federal program was designed to develop and recommend control techniques to assist states in setting up their own programs for the regulation of sources of air pollution (Skillern 1981).

By the early 1960s, it became clear that this problem was national in scope and that a coordinated federal program was required. The federal government commenced its regulatory program under the Clean Air Act of 1963, which provided that the federal government could, upon request, investigate local or state air pollution conditions and, on its own initiative, interstate situations. This act introduced the conference procedure as the method for enforcing and abating air pollution. It also authorized the federal government to develop air quality criteria that reflect scientific knowledge about the effects of concentrations of pollutants. In addition, the act expanded financial grants to states to help them develop control programs and train personnel in air pollution problems (Skillern 1981).

The next major piece of federal legislation was the Air Quality Act of 1967 (Public Law No 90-148, 81 Statute 485). Although this act has been largely amended or repealed by subsequent statutes, its provisions laid the foundation for the Clean Air Act Amendments of 1970 (42 USC § 1857 et seq.) and the current federal air pollution program. This act began a regional and intergovernmental approach to preventing and controlling air pollution. It required the federal government to establish air quality control regions, to develop criteria, and to report on control techniques for air pollutants and concentrations of pollutants within these regions (Skillern 1981).

The Clean Air Act Amendments of 1970 brought a dramatic change in the federal approach to and involvement in the air pollution problem. The act still acknowledged that the primary responsibility for regulating and controlling air pollution remained with the states; however, federal involvement became direct and significant. The 1970 legislation inaugurated a system of cooperative federalism that Congress subsequently has used in several other programs. The basic approach to improve ambient air under the 1970 amendments was to have the federal government, through the EPA, establish national ambient air quality standards (NAAQS). These standards were promulgated for pollutants for which air quality criteria had been developed under prior acts. Two sets of standards were established: primary NAAQS were established based on air quality criteria to protect human health, and secondary NAAQS were established to protect public welfare from known adverse effects from the particular pollutants (42 USC § 7409). By basing the NAAQS on health and welfare considerations and excluding technology and economics, Congress forced industry to develop necessary control techniques (Skillern 1981).

The Clean Air Act was recodified by the Clean Air Act Amendments of 1977. These amendments resulted in a number of federal air quality regulations applicable to LANL. However, all of these, except for national emission standards for hazardous air pollutants (NESHAP) (EPA 1973a) and provisions for stratospheric ozone protection (EPA 1995) have been adopted by the State of New Mexico as part of the state implementation plan (New Mexico Air Quality Bureau 1994). Therefore, all of these regulations, except the radionuclide NESHAP and the provisions for stratospheric ozone protection, are covered under the New Mexico Air Quality Control Act.

Under 40 CFR 61, Subpart H (EPA 1992), the EPA limits to 10 mrem/yr the effective dose equivalent to any member of the public from radioactive airborne releases from DOE facilities.

Effective July 1, 1992, Section 608 (National Emission Reduction Program) of the Clean Air Act Amendments of 1990 prohibits individuals from knowingly venting ozone-depleting substances used as refrigerants into the atmosphere while maintaining, servicing, repairing, or disposing of air-conditioning and refrigeration equipment. JCI, the Laboratory's support services contractor, recovers and recycles all ozone-depleting substances when servicing and repairing refrigeration equipment at LANL and does not vent ozone-depleting substances to the atmosphere.

Section 609 (Servicing of Motor Vehicle Air Conditioners) of the Clean Air Act Amendments of 1990 established standards and requirements related to recycling equipment used in servicing motor vehicle air conditioners and training and certifying technicians who provide such services. JCI provides all servicing and maintenance relating to automotive air-conditioning equipment at LANL in full compliance with these regulations.

Section 611 of the Clean Air Act Amendments of 1990 established requirements that no container containing Class I or II ozone-depleting substances nor any product containing Class I ozone-depleting substances may be shipped across state lines unless it bears an appropriate warning label. This regulation went into effect on November 11, 1993. Laboratory groups that ship ozone-depleting substances and ozone-depleting substances containing waste offsite are currently working to ensure that labeling requirements are met.

In addition to the existing federal programs, the Clean Air Act Amendments of 1990 mandate new programs that may affect LANL. These programs require technology for controlling hazardous air pollutants, preventing accidental releases, and replacing chlorofluorocarbons. LANL will continue to track new regulations written to implement the act to determine their effects on LANL operations and to implement programs as needed.

6.2.1.2 New Mexico Air Quality Control Act

The New Mexico Environmental Improvement Board, as provided by the New Mexico Air Quality Control Act, regulates air quality through a series of air quality control regulations in the New Mexico Administrative Code (NMAC). These regulations are administered by the NMED. The NMACs (formerly called air quality control regulations) relevant to LANL operations are discussed below.

6.2.1.2.1 Open Burning

Regulation 20 NMAC 2.60 (NM 1995) regulates open burning. Under this regulation, DOE and LANL are permitted to burn waste explosives materials when it might be dangerous to transport them to other facilities. Research projects or experiments that involve burning high explosives potentially resulting in releases to the atmosphere also require open burning permits.

6.2.1.2.2 Smoke and Visible Emissions

Regulation 20 NMAC 2.61 (NM 1995) limits the visible emissions allowed from LANL boilers to less than 20% opacity. Opacity is the degree to which emissions reduce the transmission of light and obscure the view of a background object. Because LANL's boilers are fueled by clean-burning natural gas, it is unlikely that this standard is exceeded during routine operations; however, it may be exceeded for a short time when oil is used to start the boilers, which is done periodically (though infrequently) to ensure that the backup system is operating properly.

6.2.1.2.3 Asphalt Process Equipment

Provisions of 20 NMAC 2.11 (NM 1995) set emission standards according to process rate and require the control of emissions from asphalt-processing equipment. The asphalt concrete plant operated by JCI is subject to this regulation. The plant, which has a 75-ton (68,162-kg)/hr capacity, is required to meet an emission limit for particulate matter of 33 lb (15 kg)/hr.

6.2.1.2.4 Oil-Burning Equipment: Particulate Matter

The regulation governing particulate matter from oil-burning equipment (20 NMAC 2.18, NM 1995) applies to any oil-burning unit having a rated heat capacity greater than 250 million Btu/hr. Oil-burning equipment of this capacity must emit less than 0.03 lb (0.0136 kg) of particulate per million Btu. Although LANL's boilers use oil as a backup fuel, all have maximum-rated heat capacities below this level; consequently, this regulation does not apply.

6.2.1.2.5 Gas-Burning Equipment: Nitrogen Dioxide

Provisions of 20 NMAC 2.33 (NM 1995) require gas-burning equipment built before January 10, 1972, to meet an emission standard of 0.3 lb (0.0136 kg) of NO_2 per million Btu when natural gas consumption exceeds 10^{12} Btu/yr/unit. The TA-3 power plant, the only LANL facility having the capacity to operate at this level, meets the emission standard.

6.2.1.2.6 Oil-Burning Equipment: Sulfur Dioxide

The regulation governing sulfur dioxide emissions from oil-burning equipment (20 NMAC 2.31, NM 1995) applies to equipment that has a heat input of greater than 1×10^{12} Btu/yr. Although LANL uses oil as a backup fuel, it has no oil-fired equipment that exceeds this threshold heat input rate. Should such equipment operate above the heat input limit, emissions of sulfur dioxide would be required to be less than 0.34 lb (0.15422 kg) per million Btu.

6.2.1.2.7 Oil-Burning Equipment: Nitrogen Dioxide

This regulation (20 NMAC 2.34, NM 1995) applies to oil-burning equipment that has a heat input of greater than 1×10^{12} Btu/yr. Although LANL uses oil as a backup fuel, no oil-fired equipment exceeds this threshold heat input rate. Should such equipment operate above the heat input limit, emissions of nitrogen dioxide would be required to be less than 0.3 lb (0.0136 kg) per million Btu.

6.2.1.2.8 Permits

Provisions of 20 NMAC 2.72 (NM 1995) require permits for any new or modified source of potentially harmful emissions if they exceed threshold emission rates. More than 500 toxic air pollutants are regulated, and each chemical's threshold hourly rate is based on its toxicity. LANL reviews each new and modified source and makes conservative estimates of maximum hourly chemical use and emissions. These estimates are compared with the applicable 20 NMAC 2.72 limits to determine whether additional permits are required.

6.2.1.2.9 Prevention of Significant Deterioration

This regulation (20 NMAC 2.74, NM 1995) has stringent requirements that must be addressed before construction of any new, large stationary source can begin. Under 20 NMAC 2.74, wilderness areas, national parks, and national monuments receive special protection; thus, the proximity of Bandelier National Monument's wilderness area could have an impact on construction at LANL. However, all of the new or modified sources at LANL have been reviewed for compliance with the requirements of 20 NMAC 2.74, and, to date, none has exhibited emission increases considered "significant."

6.2.1.2.10 Emission Standards for Hazardous Air Pollutants

In its regulation governing emission standards for hazardous air pollutants (20 NMAC 2.78, NM 1995), NMED adopts by reference all of the federal NESHAP provisions, except those for radionuclides and residential wood heaters. The only two NESHAP provisions applicable to LANL are those for asbestos and beryllium.

Under the NESHAP for asbestos, LANL is required to notify NMED of asbestos removal operations and disposal quantities and to ensure that these operations produce no visible emissions. Asbestos removal activities involving less than 160 ft^2 (15 m^2) are covered by an annual small-job notification to NMED. Projects involving greater amounts of asbestos require separate advance notification to NMED.

Quantities of asbestos wastes for both small and large jobs are reported to NMED on a quarterly basis. These reports include any asbestos contaminated, or potentially contaminated, with radionuclides. Radioactively contaminated material is disposed in a designated radioactive asbestos burial area. Nonradioactive asbestos is transported offsite to designated commercial asbestos disposal areas.

The NESHAP for beryllium includes requirements for preconstruction and preoperation approval of beryllium-machining operations and for startup testing of stack emissions from these operations. Before the NESHAP for beryllium became applicable for DOE operations in the mid-1980s, the NMED, the DOE, and LANL agreed to follow the NMED new-source preconstruction/preoperation approval process for large existing beryllium-machining operations at LANL. Since then, several very small beryllium-machining operations that were already in existence have been registered with NMED.

Exhaust air from each of the permitted beryllium operations passes through air pollution control equipment before exiting a stack. A fabric filter controls emissions from TA-3-39 (tech shops). The other buildings that house beryllium operations use high-efficiency particulate air (HEPA) filters, whose efficiency is 99.95%, to control emissions. Source tests for existing operations have demonstrated that all beryllium operations meet the permitted emission limits set by NMED and have a negligible impact on ambient air quality.

6.2.1.2.11 Operating Permits

EPA approved the NMED's Operating Permit Program established under 20 NMAC 2.70 (NM 1995) in December 1994. It requires that all major producers of air pollution obtain an operating permit from NMED. Because of LANL's potential to emit large quantities of regulated air pollutants (NO_x and CO_2, primarily from steam plants), LANL is considered a major source. LANL submitted its permit application to NMED in December 1995. Once LANL receives the permit, New Mexico will begin to charge yearly fees based on the amounts of air pollutants described in the permit.

6.2.1.2.12 Excess Emissions During Malfunction, Startup, Shutdown, and Scheduled Maintenance

The provisions of this regulation (20 NMAC 2.07, NM 1995) allow for excess emissions from process equipment during malfunction, startup, shutdown, and scheduled maintenance, provided that the operator verbally notifies the NMED either before or within 24 h of the occurrence, followed by written notification within 10 days of the occurrence.

6.2.2 Acoustic Resources

As a result of the environmental movement of the 1960s and early 1970s, US citizens have become increasingly aware of the adverse impacts of uncontrolled noise upon public health and welfare. Congressional action in this arena resulted in the Noise Control Act of 1972. By this act, Congress directed all federal agencies to carry out the programs under their control to promote an environment free from noise that jeopardizes public health or welfare. Furthermore, it requires any federal agency engaged in any activity resulting, or which may result, in the emission of noise to comply with federal, state, interstate, and local requirements pertaining to control and abatement of environmental noise to the same extent that any person is subject to such requirements. Levels of occupational exposures to noise at LANL are governed by standards based on the US Air Force Regulation 161-35.

6.2.3 Water Resources

Protection of water resources in the desert Southwest is paramount. With increasing human population and expansion of urban areas, demand for water is exceeding local water supplies. As a major user of water in the north-central portion of New Mexico, DOE's water usage is carefully monitored and regulated.

6.2.3.1 Clean Water Act

The primary goal of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters.

6.2.3.1.1 National Pollutant Discharge Elimination System

The Clean Water Act established the NPDES, which requires that point-source effluent discharges to the nation's waters meet specific chemical, physical, and biological criteria before the effluent is discharged. Although most of LANL's nonradioactive effluent is discharged to normally dry arroyos, LANL is required to meet effluent limitations under the NPDES permit program.

In 1995, LANL had 10 NPDES permits: 1 covered the effluent discharges at LANL, 1 covered the hot dry rock geothermal facility located 30 mi (50 km) west of LANL at Fenton Hill (currently shut down), and 8 covered storm water discharges. The UC and DOE are co-owners of the permits covering LANL. The permits are issued and enforced by EPA Region 6 in Dallas, Texas. However, NMED performs some compliance evaluation inspections and monitoring for EPA through a water quality grant issued under Section 106 of the act.

6.2.3.1.2 Waste Stream Characterization

LANL conducts a waste stream characterization program to verify that liquid waste streams discharged to the environment are correctly characterized and permitted under the proper outfall category specified in LANL's NPDES permit. This program includes dye testing, interviews with user groups, and coordination between LANL organizations to ensure that waste streams are properly treated with respect to the sources, concentrations, and volumes of pollutants they contain and that they are discharged correctly to the environment. NMED controls the nonradioactive components of waste streams; however, DOE controls most of the radioactive components under the Atomic Energy Act of 1954, as amended.

6.2.3.1.3 Storm Water Discharges

On November 16, 1990, the EPA promulgated the final rule for NPDES regulations for storm water discharges, which modified 40 CFR 122, 123, and 124. This rule was required to implement Section 402(p) of the Clean Water Act (added by Section 405 of the Water Quality Act of 1987).

To comply with NPDES storm water regulations, LANL operates under an NPDES general permit for storm water discharges associated with industrial activity. Storm water discharges associated with a construction site at LANL are covered by a special NPDES permit until the facility is operational; at that time, the discharges become covered by the NPDES general permit. As a condition of the NPDES general permit, the facility manager for each LANL facility covered by the permit had to prepare a storm water pollution prevention plan. The plan identified potential sources of pollution that could affect the quality of storm water discharge. In addition, the plan described practices that would be used to reduce the pollutants in storm water discharge at each facility and to ensure compliance with the terms and conditions of the general permit. Solid waste management units (designated under RCRA) located on the facility site were also addressed because under the storm water regulations they are considered to be installations associated with industrial activities.

6.2.3.1.4 Spill Prevention Control and Countermeasures Program

LANL has a spill control and countermeasures plan, as required by 40 CFR 112 (EPA 1973b) under the Clean Water Act. This plan requires that secondary containment be provided for all aboveground storage tanks. The plan also provides for spill control at drum and container storage, transfer, and loading/unloading areas.

6.2.3.1.5 Sanitary Sewage Sludge Management Program

In February 1993, the EPA promulgated 40 CFR 503, the Standards for Use or Disposal of Sewage Sludge (EPA 1993). The purpose of these regulations is to establish numerical, management, and operational standards for the beneficial use or disposal of sewage sludge through land application or surface disposal. Under the Part 503 regulations, LANL is required to collect representative samples of sewage sludge to demonstrate that it is not a hazardous waste and that it meets the minimum federal standards for pollutant concentrations.

6.2.3.2 Safe Drinking Water Act

To implement the Safe Drinking Water Act, the EPA established maximum contaminant levels for microbiological organisms, organic and inorganic constituents, and radioactivity in drinking water. These standards have been adopted by New Mexico and are included in the Drinking Water Regulations (NM 1995). EPA has given NMED authority to administer and enforce federal drinking water regulations and standards in New Mexico.

To ensure compliance with these regulations, LANL has implemented a program to sample water from various points in the single drinking water distribution system that serves the Laboratory, Los Alamos County, and Bandelier National Monument. Samples are analyzed for organic and inorganic constituents and for radioactivity at the New Mexico Health Department's Scientific Laboratory Division in Albuquerque, which reports the analytical results directly to NMED. JCI's environmental laboratory also collects samples from all three locations for microbiological testing. Programs conducted to protect the water supply system include the following:

6.2.3.2.1 Wellhead Inspection Program

JCI Utilities inspects wells daily to maintain pumping equipment and to identify any problems that might lead to potential health hazards.

6.2.3.2.2 Disinfection Program

Whenever new construction or repair work is required on the distribution or supply system, the pipe must be disinfected before it is put in service. The piping is flushed, then a high-strength chlorine solution is pumped through the system. During a second flushing to remove the chlorinated water, JCI's environmental laboratory samples the water and analyzes it for the presence of coliform bacteria.

6.2.3.2.3 Cross-Connection Survey

In 1992, LANL began a comprehensive building-by-building survey of interior plumbing systems to identify and correct cross-connections. The surveyors visually inspected buildings for actual or potential cross-connections between potable water systems and nonpotable water supplies, such as those used for industrial processes, fire-fighting, and cooling. They also checked for the presence of adequate backflow prevention devices and labeled piping and outlets as needed. Any potential cross-connections identified were corrected.

6.2.3.3 Groundwater Protection

Groundwater monitoring and protection efforts at LANL have evolved from the early programs initiated by the USGS to present efforts. The major regulations, orders, and policies pertaining to groundwater are included in DOE Order 5400.1, General Environmental Protection Program (DOE 1988a). The order requires LANL to prepare a groundwater protection management program plan and to implement the program outlined by that plan. The groundwater protection management program plan also fulfills the requirements of Chapter IV, Section 9, of DOE Order 5400.1. This section requires development of a groundwater-monitoring plan. The groundwater-monitoring plan identifies all DOE requirements and regulations applicable to groundwater protection and includes strategies for sampling, analysis, and data management.

Section 9c of Chapter IV of the DOE Order 5400.1 requires that groundwater-monitoring needs be determined by site-specific characteristics and, where appropriate, that groundwater-monitoring programs be designed and implemented in accordance with 40 CFR 264 (EPA 1980a), Subpart F, or 40 CFR Part 265, Subpart F (EPA 1980b). The section also requires that monitoring for radionuclides comply with DOE orders in the 5400 series dealing with radiation protection of the public and the environment.

In addition to DOE Order 5400.1, Module VIII of the RCRA permit [i.e., the HSWA (Hazardous and Solid Waste Amendments of 1984) Module, Task III (EPA 1990)] requires LANL to collect information to supplement and verify existing information on the environmental setting at the facility and collect analytical data on groundwater contamination. Under Task III, Section A.1, LANL is required to conduct a program to evaluate hydrogeological conditions. Under Task III, Section C.1, LANL is required to conduct a groundwater investigation to characterize any plumes of contamination at the facility.

Historically, the groundwater-monitoring requirements of RCRA (40 CFR 264, Subpart F) have not been applied to LANL's regulated units [treatment, storage, and disposal (TSD)] because DOE and LANL had submitted demonstrations for a groundwater-monitoring waiver based on the depth to groundwater and lack of physical evidence of contaminant migration to these depths. However, NMED denied the requested waiver as of May 30, 1995, and requested DOE/LANL to provide a groundwater-monitoring program plan to bring the Laboratory into compliance with RCRA. In the denial letter, NMED recommended that the plan addresses both site-specific and LANL-wide groundwater-monitoring objectives.

The State of New Mexico also protects groundwater via the New Mexico Water Quality Control Commission regulations (NM 1995), which control liquid discharges onto or below ground surface to protect all groundwater of the State of New Mexico. Under these regulations, a groundwater discharge plan must be submitted by the facility and must be approved by NMED or, for energy/mineral extraction activities, by the Oil Conservation Division. Subsequent discharges must be consistent with the terms and conditions of the plan.

In 1995, New Mexico Water Quality Control Commission regulations were significantly expanded by the adoption of comprehensive abatement regulations. The purpose of these regulations is to abate both surface and subsurface contamination for designated or future uses. Of particular importance to DOE/LANL is the contamination that may be present in alluvial groundwater.

6.2.4 Soil Resources

Public concern over the disposal of wastes and releases of contaminants into the environment resulted in two pieces of landmark legislation: RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

6.2.4.1 Resource Conservation and Recovery Act

LANL produces a wide variety of hazardous wastes. RCRA, as amended by HSWA, sets forth a comprehensive program to regulate hazardous solid wastes. The hazardous waste management provisions of RCRA, as enacted in 1976, govern the day-to-day operations of hazardous waste TSD facilities. Sections 3004(u) and (v) of RCRA established a permitting system and set standards for hazardous waste management operations at TSD facilities. Under this law, LANL qualifies as a treatment and storage facility and must have a permit to operate.

In 1984, Congress amended RCRA by passing HSWA. HSWA emphasizes reducing the volume and toxicity of hazardous waste and requires treatment of hazardous waste before land disposal. Sections 201, 202, 203, 206, 207, 212, 215, and 224 of HSWA modified the permitting sections of RCRA (Sections 3004 and 3005). In accordance with these provisions, LANL's permit to operate includes a section (the HSWA Module) that prescribes a specific corrective action program for LANL, the primary focus of which is the investigation and cleanup, if required, of inactive sites called solid waste management units.

The HSWA Module specifies a three-step corrective action process, which is being implemented at LANL by the Environmental Restoration Program.

- The RCRA facility investigation—This investigation is conducted to identify the extent of contamination in the environment and the pathways along which these contaminants could travel to human and environmental receptors. To control costs, the investigation limits contaminant characterization to the level of detail necessary to determine what corrective measures, if any, need to be taken.

- Corrective measures study—If the RCRA facility investigation indicates that corrective measures are needed, a corrective measures study is performed to evaluate alternative remedies. These remedies are evaluated for their projected efficacy in reducing risks to human and environmental health and safety in a cost-effective manner.

- Corrective measures implementation—The remedy chosen by the regulatory authority is implemented, its effectiveness is verified, and ongoing control and monitoring requirements are established.

Original jurisdiction for implementing RCRA lay with the EPA; however, RCRA authorizes EPA to turn this responsibility over to individual states as they develop satisfactory implementation programs. The EPA granted base RCRA authorization to New Mexico on January 25, 1985, transferring regulatory control of hazardous wastes under RCRA to the NMED. State authority for hazardous waste regulation is set forth in the New Mexico Hazardous Waste Act and Hazardous Waste Management Regulations (20 NMAC 4.1, NM 1995), which adopted, with a few minor exceptions, all of the federal codification for regulations in effect on July 1, 1993, concerning the generation and management of hazardous waste. On July 25, 1995, EPA authorized the State of New Mexico's Hazardous Waste Program to regulate mixed waste in lieu of the federal program.

Under the RCRA permitting process, a TSD facility submits a RCRA Part A permit application that identifies the facility's location, the owner and operator, the hazardous waste or mixed waste (mixture of hazardous and radioactive wastes) to be managed and the methods selected to manage the waste. The facility is then allowed to manage hazardous or mixed wastes under transitional regulations known as interim status requirements, pending the submittal of, and determination on, a RCRA Part B application to NMED. The Part B permit application consists of a detailed narrative description of all facilities and procedures related to hazardous or mixed-waste management. Approval of the Part B application results in the issuance of a permit.

On November 8, 1989, the DOE and UC, as co-operators of LANL, were granted a RCRA Part B permit to manage hazardous wastes. An additional Part B application for mixed-waste storage and treatment units throughout LANL was submitted on January 25, 1991. Those units are currently managed under the interim status requirements. Permit modifications and additional Part A applications have been submitted since 1991; all units mentioned in those documents are operating pending permit notification.

6.2.4.1.1 Closure

Several solid waste management units listed in the HSWA Module are subject to both the corrective action and closure provisions of RCRA. NMED is the lead regulatory agency for closure of these sites. To satisfy both sets of regulations and to avoid duplication of effort, the closure process takes place concurrently with the corrective action process.

6.2.4.1.2 Solid Waste Disposal

LANL maintains an industrial solid waste landfill at Area J of TA-54 (on Mesita del Buey), which complies with New Mexico's solid waste management regulations. The landfill is used as a disposal site for solid wastes (such as classified wastes, other nonhazardous waste materials, and "special solid waste" as defined by the State of New Mexico) and as a staging area for nonradioactive asbestos waste, which is later shipped offsite to an approved commercial disposal facility. Radioactive asbestos waste and asbestos waste suspected of being contaminated with radioactive material are disposed in a dedicated cell constructed at TA-54, Area G. A more detailed discussion of these facilities is presented in Section 3.5, Waste Management.

LANL disposes of sanitary solid waste and rubble at Los Alamos County's landfill on East Jemez Road. This landfill lies on DOE property and is operated by Los Alamos County under a special-use permit (an agreement between DOE-LAAO, and the county specifies the types of wastes LANL may dispose in the landfill). As the operator, Los Alamos County is responsible for obtaining the necessary permits from the state.

Under Subtitle D, LANL salvages or recycles materials through JCI rather than placing them in the county landfill. Materials recycled by JCI include rubble and debris that can be used for road fill. This program complements LANL's waste minimization program under RCRA Subtitle A, discussed below.

6.2.4.1.3 Other RCRA Sites

From 1964 to 1985, Area L at TA-54 was used for disposal of hazardous wastes. At present, it is used for storing hazardous and mixed wastes, as well as other regulated wastes. Although small amounts of RCRA waste have been placed in Area G at TA-54, this area was never intended to accept such waste. Area G is currently being used for storing mixed wastes. The vadose zone (the subsurface above the main aquifer) is being monitored on a quarterly basis throughout Areas L and G for organic vapors (indicators of possible releases from the disposal units).

6.2.4.1.4 Waste Minimization

Subtitle A of RCRA states that generation of hazardous waste must be reduced or eliminated to minimize the present and future threat to human health and the environment. RCRA requires recovery, recycling, and treatment as alternatives to land disposal of hazardous wastes. Since RCRA was enacted, LANL has adopted a program to reduce its generation of hazardous and mixed wastes and will continue to search for new methodologies to significantly reduce waste streams.

6.2.4.2 Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA (also called "Superfund"), as amended by the Superfund Amendments and Reauthorization Act of 1986, addresses liability, compensation, cleanup, and emergency response relating to the release of hazardous substances into the environment and cleanup of inactive hazardous waste disposal sites. Under the provisions of the National Contingency Plan, a plan prepared by the EPA under CERCLA, the EPA ranks facilities throughout the nation according to their potential hazard to human and environmental health and safety. LANL has been ranked and did not score high enough to be placed on the National Priority List. Therefore, all legacy contamination found in the environment at LANL is being cleaned up under RCRA.

Even though LANL is designated as a RCRA facility and is not on the National Priority List, DOE Order 5400.4 (DOE 1989) specifies that LANL conform to CERCLA requirements to the extent possible. DOE guidance resulting from Executive Order 12580, Superfund Implementation (DOE 1993), leads to the following interpretation:

- CERCLA applies if hazardous substances are released into the environment or if a substantial threat of release exists.
- CERCLA specifies that the remediation requirement apply equally to federal and nonfederal entities.

Hazardous materials generated during the decommissioning process are regulated both by RCRA and by CERCLA, and radioactive materials are regulated under the Atomic Energy Act and/or CERCLA. The hazardous constituents of mixed waste are also subject to RCRA. New Mexico's authority in the assessment and remediation process for hazardous waste is as authorized by the EPA under RCRA. DOE Order 5400.1 (DOE 1988a) establishes the environmental protection program requirements, authorities, and responsibilities for DOE operations to ensure compliance with applicable federal, state, and local environmental protection laws, regulations, and executive orders.

6.2.4.3 Emergency Planning and Community Right-to-Know Act

As part of CERCLA, Congress passed the Emergency Planning and Community Right-to-Know Act. Title III, Section 313, of this act requires facilities that meet certain standard industrial classification code criteria to submit an annual toxic chemical release inventory report. A report describing the use of and emissions from Section 313 chemicals must be submitted to EPA and the New Mexico Emergency Management Bureau every July for the preceding calendar year.

LANL does not meet standard industrial classification code criteria for reporting but has voluntarily submitted annual toxic chemical release inventory reports since 1987. All research operations are exempt under the provisions of the regulation, and only pilot plants, production, or manufacturing operations at LANL are reported.

On August 3, 1993, the President issued Executive Order 12856 requiring all federal facilities, regardless of standard industrial classification code, to report under Title III, Section 313. Research operations remain exempt.

In accordance with DOE orders in the 5500 series, it is LANL's policy to develop and maintain an emergency management system that includes emergency planning, emergency preparedness, and effective response capabilities for responding to and mitigating the consequences of an emergency. LANL's Emergency Management Plan is a document that describes the entire process of planning, responding to, and mitigating the potential consequences of an emergency (Section 3.10, Emergency Management and Response).

6.2.5 Biotic Resources

LANL has habitat that supports both migratory and permanent species protected under the various endangered, threatened, or protected species laws. In addition, use of pesticides (both plant- and animal-specific) is strictly controlled to protect the local environs.

6.2.5.1 Endangered, Threatened, and Protected Species

The DOE and LANL must comply with the Endangered Species Act, New Mexico Wildlife Conservation Act, and the New Mexico Endangered Plant Species Act. To ensure compliance, LANL has established a Biological Resource Evaluation Team to evaluate the amount of previous development or disturbance at a proposed construction site and to determine the presence of any surface water or floodplains in the site area. This review also determines whether the appropriate habitat types and habitat parameters are present to support any threatened or endangered species. If such habitat exists, an intensive survey is designed to determine the presence or absence of a threatened or endangered species at the project site. In addition, LANL adheres to the protocols and permit requirements of the New Mexico Game and Fish Department.

6.2.5.2 Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act regulates the manufacture of pesticides, imposing requirements on registration, labeling, packaging, record keeping, distribution, worker protection, certification, experimental use, and tolerances in foods and feeds. The sections of this act that are applicable to LANL include recommended procedures for storing and disposing of pesticides and requirements for certifying personnel working with pesticides.

LANL is also regulated by the New Mexico Pest Control Act, administered by the New Mexico Department of Agriculture, which regulates pesticide use, storage, and certification. The department conducts annual inspections to determine JCI's compliance with the act. Application, storage, disposal, and certification of chemicals are conducted in accordance with these regulations. In 1984, LANL prepared a pest management plan, which includes programs for controlling vegetation, insects, and small animals. This plan has been revised as necessary by the Pest Control Oversight Committee, which includes personnel from the Water Quality and Hydrology Group, the Utilities and Infrastructure Group, and JCI. This committee reviews and recommends policy changes in LANL's pest management program.

6.2.6 Cultural Resources

LANL occupies land that is rich in archaeological ruins and historic cultural properties that require protection. As required by Section 106 of the National Historic Preservation Act, proposed LANL activities are evaluated in consultation with the State Historic Preservation Officer for possible effects on cultural resources. Most surveys are conducted on DOE property; however, when appropriate, surveys are conducted on land owned by other federal agencies, on state-owned land, on tribal lands, or on other private holdings, and LANL holds discussions, as appropriate, with various Indian tribes to determine how new LANL activities might affect cultural resources. The tribes are also requested to provide input on what mitigation measures they want implemented before LANL begins an activity.

As required by the National American Graves Protection and Repatriation Act, the Laboratory has completed a summary list of cultural items excavated in the past from archaeological sites on Laboratory property. Copies of this summary were sent to local pueblos having ancestral ties to the Pajarito Plateau. This summary provides a basis for future repatriation of cultural items to tribal governments.

In accordance with the American Indian Religious Freedom Act, LANL activities are planned so that they do not adversely affect the practice of traditional religions. Tribal groups are notified of projected construction activities and are requested to inform the DOE if any activity will affect a traditional cultural property.

Four federally recognized Indian tribes—the pueblos of Cochiti, Jemez, Santa Clara, and San Ildefonso—have special relationships with the land now occupied by LANL. Federal laws and executive orders guarantee tribal members access to religious sites and recognize tribal rights to cultural properties, burial materials, and other articles of antiquity. Yet, Congress has assigned responsibilities to DOE that preclude open access to LANL land. Thus, some of the parties' interests in and uses for LANL land are difficult to reconcile.

To achieve mutual goals of improved understanding and cooperation, the four pueblos and DOE are now recognized as sovereign entities that will interact with one another on a government-to-government basis. DOE and each of these four pueblos have executed formal accord documents setting forth these relationships. The governor of each pueblo has signed an accord in behalf of his pueblo. Each accord has also been signed by the Assistant Secretary for Defense Programs on behalf of DOE and has been approved as to form by the Area Director of the Bureau of Indian Affairs, US Department of the Interior. The last of the accords was signed in December 1996. The accords are consistent with Public Law 95-91 and other applicable laws.

The accords provide a framework for government-to-government relationships between each of the pueblos and DOE. Further, the accords identify general procedures by which the sovereign entities will interact. By signing the accords, DOE has made a commitment to provide information and involve the pueblos in long-range planning and decisions. Initially, a team of individuals representing the accord pueblos and DOE, called the Los Alamos-Pueblo Project, held discussions and negotiations on primary concerns, including the pueblos' request for funds to implement their monitoring and oversight projects. The accords state DOE's commitment to working with its contractors and subcontractors and with other federal, state, and local agencies to clarify those roles and responsibilities of these entities that appear to conflict or overlap as they relate to the pueblos.

The mechanisms by which the accords will be implemented are still being established. The Los Alamos-Pueblo Project, similarly, is in the formative stage. The roles and responsibilities of LANL personnel with regard to consultations have not been clarified with regard to participation, beyond acting as technical and support staff for DOE.

6.2.7 Worker Health and Safety

Like all federal agencies, DOE is subject to all applicable worker safety and health legislation. As the operating contractor for DOE, LANL is not subject to these regulations, but it does follow a program of voluntary compliance.

The Occupational Safety and Health Act requires federal agencies to provide workers with a safe and healthy work environment and to prepare, or have available, Material Safety Data Sheets for all chemicals used in the workplace. In addition, the Hazard Communication Standard (29 CFR 1910.12) (DOL 1971) requires that workers be informed of, and trained to handle, all chemical hazards in the workplace.

6.2.8 Transportation

LANL routinely ships and receives hazardous and radioactive materials. The methods by which these materials are packaged and shipped are strictly controlled by federal legislation.

The Hazardous Materials Transportation Act (49 USC§§1801 et seq.) authorizes the Secretary of Transportation to establish criteria for handling hazardous materials and requires all federal agencies to comply with the requirements governing hazardous materials and waste transportation. Shippers of highway-route-controlled quantities of radioactive materials are required to use permitted carriers, and DOT must certify the radioactive materials shipping container. The implementing requirements also determine what type of container may be used for specific materials and the quantity of material that may be placed in any one container.

In addition to these requirements, as the agency in control of special nuclear material, source material, and by-product material, DOE has also codified regulations on packaging and transportation (Section 3.7, Packaging and Transportation).

6.2.9 Other

In addition to the regulations discussed above, LANL is subject to a set of regulations that either have wide applicability or are not otherwise easily placed into a restrictive category.

6.2.9.1 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) (15 U.S.C. 2601-2692) is administered by the EPA. Unlike other statutes that regulate chemicals and their risk after they have been introduced into the environment, TSCA is intended to require testing and risk assessment before a chemical is introduced into commerce. TSCA also establishes record-keeping and reporting requirements for new information regarding adverse health and environmental effects of chemicals; governs the manufacture, use, storage, handling, and disposal of PCBs; and sets standards for cleaning up PCB spills.

Specifically, TSCA gives EPA authority to (1) conduct premanufacture reviews of new chemicals before their introduction into the marketplace; (2) require testing of chemicals that may present a significant risk to humans and the environment; (3) establish record-keeping and reporting requirements for new information regarding adverse health and environmental effects associated with chemicals; (4) govern the manufacture, use, storage, handling, and disposal of PCB equipment; and (5) set standards for cleaning up PCB spills.

Because LANL's research and development activities are not related to the manufacture of new chemicals, the PCB regulations (40 CFR 761, EPA 1996) are LANL's main concern under TSCA. Activities at LANL that are governed by the PCB regulations include, but are not limited to, management and use of authorized PCB-containing equipment, such as transformers and capacitors; management and disposal of substances containing PCBs (dielectric fluids, contaminated solvents, oils, waste oils, heat transfer fluids, hydraulic fluids, paints, slurries, dredge spoils, and soils); and management and disposal of materials or equipment contaminated with PCBs as a result of spills.

TSCA regulates PCB items and materials having concentrations exceeding 50 ppm. The regulations contain an antidilution clause that requires waste to be managed based on the PCB concentration of the source (transformer, capacitor, PCB equipment, etc.), regardless of the actual concentration in the waste. If the concentration at the source is unknown, the waste must be managed as though it were a spill of mineral oil with an assumed PCB concentration of 50–500 ppm. At LANL, PCB-contaminated wastes are transported offsite for treatment and disposal unless they also have a radioactive component. Solid wastes containing both radionuclides and PCBs are disposed at Area G (TA-54), which has been approved by the EPA for such disposal (provided that strict requirements are met with respect to notification, reporting, record keeping, operating conditions, environmental monitoring, packaging, and types of wastes disposed).

LANL currently has no treatment or disposal facilities for liquid wastes that contain both radionuclides and PCBs. Such wastes have been stored at Area L at TA-54 for longer than one year (in violation of TSCA regulations, which stipulate a maximum of one year for "storage for disposal" of PCBs). However, commercial facilities do not exist to accept these wastes because of the radionuclides. In August 1996, the EPA and the DOE signed a federal facilities compliance agreement allowing long-term storage of these radioactive liquid wastes containing PCBs at Area L. The agreement includes provisions for

- tracking inventories of solid and liquid wastes contaminated with both radionuclides and PCBs or radionuclides and other RCRA components;
- reporting annually on the status of these wastes;
- identifying near- and long-term treatment and disposal options; and
- ensuring that DOE facilities actively pursue those options as a means of reducing inventories of stored wastes.

6.2.9.2 National Environmental Policy Act

NEPA regulations mandate that federal agencies consider the environmental impact of their actions before making a final decision on whether to proceed with those actions. NEPA establishes the national policy of creating and maintaining conditions under which man and nature can exist in productive and enjoyable harmony and provide for the social, economic, and other needs of present and future generations. Proposed actions are evaluated to determine whether they have the potential to affect the environment.

The sponsoring agency (DOE for LANL actions) is responsible for preparing implementing regulations and documents required by NEPA, which include the following: (1) a categorical exclusion, which applies to specific types of actions that DOE has determined to have no significant environmental impacts and for which no additional NEPA documentation is required; (2) an environmental assessment, which evaluates environmental impacts, leading either to a finding of no significant impact—if the impacts are indeed found to be not significant—or to an environmental impact statement if the impacts are significant; and (3) an environmental impact statement in which the impacts of a proposed action and of alternative actions (including no action) are evaluated, mitigation measures for the preferred action are proposed, and a decision on proceeding with the preferred action (or no action) is presented by the agency in a record of decision.

NEPA provides specific protection to areas defined as unique resources (sensitive areas). Under NEPA review, proposed actions are evaluated for possible effects on cultural resources (archaeological sites or historic buildings) in accordance with the National Historic Preservation Act of 1966. In addition, proposed actions are evaluated for their potential impact on threatened, endangered, or sensitive species in accordance with the Endangered Species Act and on floodplains and wetlands in accordance with relevant executive orders. A proposed action otherwise eligible for a categorical exclusion cannot be approved as such if it is determined that sensitive areas would be adversely affected.

LANL initiates NEPA reviews for DOE by completing ES&H questionnaires, which form the basis of DOE environmental checklists (DECs) submitted to DOE/LAAO. LAAO uses DECs to assist DOE's Albuquerque office in determining the appropriate levels of NEPA documentation (categorical exclusions, environmental assessments, or environmental impact statements) for LANL's actions. LANL also prepares broad-scope DECs ("umbrellas") to cover a range of similar actions, such as routine maintenance and instrument calibration. When DOE determines that the actions are categorically excluded from further NEPA review, these categorical exclusions serve as prior NEPA documentation to facilitate DOE review.

6.2.9.3 Floodplain and Wetland Protection

DOE must comply with Executive Order 11988, Floodplain Management, and Executive Order 11990, Protection of Wetlands (The White House 1977a and b). Therefore, before initiating any new construction and/or activity that may adversely affect the local environs, LANL performs a floodplains and wetlands review. In compliance with 10 CFR 1022 (DOE 1979), a Floodplain and Wetland Notice of Involvement and Statement of Findings are submitted to the DOE for publication in the Federal Register when a potential impact to either a floodplain or wetland is identified.

6.2.9.4 Applicable DOE Orders Governing Environmental Protection

The 1977 act that established DOE and the Atomic Energy Act of 1954, as amended, provide for, among other things, the protection of the environment and the health and safety of workers and the public in the conduct of the department's programs. To execute its responsibilities under these two acts, DOE has adopted implementing orders that establish policies, guidelines, and minimum requirements by which DOE and its contractors operate. From an environmental standpoint, the following three DOE Orders have significant impact on LANL operations.

6.2.9.4.1 DOE Order 5400.1

DOE Order 5400.1, General Environmental Protection Program, establishes the environmental protection program requirements, authorities, and responsibilities for DOE operations for ensuring compliance with applicable federal, state, and local environmental protection laws and regulations, executive orders, and internal DOE policies. The provisions of this order apply to all DOE elements and contractors performing work for the DOE, as provided by law and/or contract and as implemented by the appropriate contracting officer.

Specifically, this order provides for environmental protection standards, notification of and reports on discharges and unplanned releases, environmental protection and program plans, and environmental monitoring requirements. It establishes formal recognition that DOE's environmental management activities are extensively, but not entirely, regulated by EPA, state, and local environmental agencies, and it provides requirements for satisfying these externally imposed regulations. In addition, its establishes requirements for those environmental protection programs that are not externally regulated.

6.2.9.4.2 DOE Order 5400.5

DOE Order 5400.5 (DOE 1990), Radiation Protection of the Public and Environment, establishes standards and requirements for operations of DOE and DOE contractors with respect to protecting members of the public and the environment against undue risk from radiation. Specifically, this order states that it is DOE's policy "to implement legally applicable radiation protection standards and to consider and adopt, as appropriate, recommendations by authoritative organizations, e.g., the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection. It is also the policy of DOE to adopt and implement standards generally consistent with those of the NRC for DOE facilities and activities not subject to licensing authority."

This order provides for general standards; requirements for radiation protection of the public and the environment; derived concentration guides for air and water; and guidelines, limits, and control of residual radioactive materials. The order also establishes DOE's objective to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established by this order and radioactive contamination is controlled through the management of DOE's real and personal property. It establishes DOE's objective to keep potential exposures of members of the public as far below the established limits as is reasonably achievable and establishes DOE's objective that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and nonroutine releases and to assess doses to members of the public. It also establishes DOE's objective to protect the environment from radioactive contamination to the extent practical.

6.2.9.4.3 DOE Order 5820.2A

DOE Order 5820.2A (DOE 1988b), Radioactive Waste Management, establishes the policies, guidelines, and minimum requirements by which DOE manages its radioactive waste, mixed waste, and contaminated facilities.Specifically, this order establishes DOE policy that radioactive and mixed wastes be managed in a manner that ensures protection of the health and safety of the public, DOE, contractor employees, and the environment. In addition, the generation, treatment, storage, transportation, and/or disposal of radioactive wastes, and the other pollutants or hazardous substances they contain, must be accomplished in a manner that minimizes the generation of such wastes across program office functions and complies with all applicable federal, state, and local environmental, safety, and health laws and regulations and DOE requirements.

This order provides for management of high-level waste, transuranic waste, low-level waste, and waste containing naturally occurring and accelerator-produced radioactive material. It also addresses decommissioning of radioactively contaminated facilities and provides a generalized outline for facility waste management plans.

References for Chapter 6

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ACRONYMS AND ABBREVIATIONS

A-E	Architect-engineer
AEC	Atomic Energy Commission
AL	Albuquerque Operations Office (of DOE)
ANSI	American National Standards Institute
B&R	Budget and reporting
BUS	Business Operations (Division)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIC	Computing, Information, and Communications (Division)
CMR	Chemistry and metallurgy research
CST	Chemical Science and Technology (Division)
CY	Calendar year
DARHT	Dual-Axis Radiographic Hydrodynamic Test (Facility)
DEC	DOE environmental checklist
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DTH	Decatherm
DX	Dynamic Experimentation (Division)
EES	Earth and Environmental Science (Division)
EM	Environmental Management (Division)
EM&R	Emergency Management and Response (Program)
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESA	Engineering Sciences and Applications (Division)
ES&H	Environment, safety, and health
ESH	Environment, Safety, and Health (Division)
FFCA	Federal Facilities Compliance Act (or Agreement)
FM	Facility management
FMU	Facility management unit
FSS	Facilities, Security, and Safeguards (Division)
FTE	Full-time equivalent
FY	Fiscal year
HAZMAT	Hazardous Materials (Team)
HE	High explosive(s)
HEPA	High-efficiency air particulate
HLW	High-level waste
HRL	Health Research Laboratory
HSWA	Hazardous and Solid Waste Amendments
ICN	Integrated computing network
ISM	Integrated safety management
IWP	Installation Work Plan
JCI	Johnson Controls, Inc.
JCINNM	Johnson Controls, Inc., of Northern New Mexico
LAAO	Los Alamos Area Office (of the DOE)
LAMPF	Los Alamos Meson Physics Facility
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LASN	Los Alamos Science Network
LDCC	Laboratory Data Communications Center
LDRD	Laboratory-directed research and development
LLW	Low-level waste

LS	Life Sciences (Division)
MDA	Materials disposal area
M&O	Management and operations
MST	Materials Science and Technology (Division)
NAAQS	National ambient air quality standards
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standard for Hazardous Air Pollution
NIS	Nonproliferation and International Security (Division)
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMT	Nuclear Materials Technology (Division)
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
P	Physics (Division)
PCB	Polychlorinated biphenyl
PNM	Public Service Company of New Mexico
PTLA	Protection Technologies of Los Alamos
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RLWTF	Radioactive Liquid Waste Treatment Facility
SNM	Special nuclear material
SSM	Stockpile stewardship and management
SWSC	Sanitary Waste System Consolidation (Plant)
TA	Technical area
TRU	Transuranic waste
TSA	Technology and Safety Assessment (Division)
TSCA	Toxic Substances Control Act
TSD	Treatment, storage, and disposal
UC	University of California
US	United States
USC	US Code
USGS	US Geological Survey
WETF	Weapons Engineering Tritium Facility