4.2.2.4 Water

The Los Alamos potable water production system consists of 14 deep wells, 246 kilometers (153 miles) of main distribution lines, pump stations, storage tanks, and nine chlorination stations. On September 8, 1998, DOE transferred operation of the system from the LANL to Los Alamos County under a lease agreement. Under this agreement, LANL retained responsibility for operating the distribution system within its boundaries, whereas the county assumed full responsibility for operating the water system, including ensuring compliance with Federal and state drinking water regulations (LANL 2000f). The system supplies potable water to all of the county, LANL, and Bandelier National Monument. DOE's rights to withdraw an equivalent of about 6,830 million liters (1,806 million gallons) of water per year from the main aquifer and its right to purchase a water allocation from the San Juan-Chama Transmountain Diversion Project were included in the lease agreement. DOE plans to ultimately convey 70 percent of the water rights to the county (including the entire San Juan-Chama right) and lease the remainder to the county (LANL 2000e). Per the current lease agreement, LANL would retain the right to purchase the leased percentage with provision to purchase water in excess of the 30 percent (equivalent to about 2.05 billion liters [542 million gallons] annually) if available (DOE 1999h). Before transfer of the Los Alamos water supply system in October 1998, LANL's water use was estimated by subtracting the county's metered water use from total well production that resulted in counting other users such as Bandelier National Monument and system losses in the LANL water use total.

In 1999, LANL used approximately 1.71 billion liters (453 million gallons) of water (LANL 2000e) (see Table 4–2). Potable water is obtained from deep wells located in three well fields (Gauje, Otowi, and Pajarito). Nonpotable water is also supplied to the TA-16 steam plant from the Water Canyon Gallery. This system consists of about 1.6 kilometers (1 mile) of water line and a catchment basin improvement to a spring. TA-18 currently uses about 14.65 million liters (3.87 million gallons) of water annually.

4.2.3 Air Quality

Los Alamos has a semiarid, temperate mountain climate. This climate is characterized by seasonable, variable rainfall with precipitation ranging from 25 to 51 centimeters (10 to 20 inches) per year. The climate of the Los Alamos town site is not as dry (arid) as that part near the Rio Grande, which is arid continental. Meteorological conditions within Los Alamos are influenced by the elevation of the Pajarito Plateau. Climatological averages for atmospheric variables such as temperature, pressure, winds, and precipitation presented are based on observations made at the official Los Alamos meteorological weather station from 1961 to 1990. Normal (30-year mean) minimum and maximum temperatures for the community of Los Alamos range from a mean low of -8.1 °C (17.4 °F) in January to a mean high of 27 °C (80.6 °F) in July. Normal (30-year mean) minimum and maximum temperatures for the community of White Rock range from a mean low of -9.7 °C (14.6 °F) in January to a mean high of 29.8 °C (85.6 °F) in July. Temperatures in Los Alamos vary with altitude, averaging 3 °C (5 °F) higher in and near the Rio Grande Valley, which is 1,981 meters (6,500 feet) above sea level, and 3 to 5.5 °C (5 to 10 °F) lower in the Jemez Mountains, which are 2,600 to 3,050 meters (8,500 to 10,000 feet) above sea level. Los Alamos town site temperatures have dropped as low as -28 °C (-18 °F) and have reached as high as 35 °C (95 °F). The normal annual precipitation for Los Alamos is approximately 48 centimeters (19 inches). Annual precipitation rates within the county decline toward the Rio Grande Valley, with the normal precipitation for White Rock at approximately 34 centimeters (14 inches). The Jemez Mountains receive over 64 centimeters (25 inches) of precipitation annually. The lowest recorded annual precipitation in Los Alamos town site was 17 centimeters (7 inches) and the highest was 1 meter (39 inches).

Thirty-six percent of the annual precipitation for Los Alamos County and LANL results from thundershowers that occur in July and August. Winter precipitation falls primarily as snow. Average annual snowfall is approximately 150 centimeters (59 inches), but can vary considerably from year to year. Annual snowfall ranges from a minimum of 24 centimeters (9 inches) to a maximum of 389 centimeters (153 inches).

Los Alamos County winds average 3 meters per second (7 miles per hour). Wind speeds vary throughout the year, with the lowest wind speeds occurring in December and January. The highest winds occur in the spring (March through June), due to intense storms and cold fronts. The highest recorded wind in Los Alamos County was 34 meters per second (77 miles per hour). Surface winds often vary dramatically with the time of day, location, and elevation, due to Los Alamos' complex terrain.

In addition to seasonal changes in wind conditions, surface winds often vary with the time of day. An up-slope air flow often develops over the Pajarito Plateau in the morning hours. By noon, winds from the south usually prevail over the entire plateau. The prevalent nighttime flow ranges from the west-southwest to northwest over the western portion of the plateau. These nighttime winds result from cold air drainage off the Jemez Mountains and the Pajarito Plateau. Analyses of Los Alamos Canyon wind data indicate a difference between the atmospheric flow in the canyon and the atmospheric flow over the Pajarito Plateau. Cold air drainage flow is observed about 75 percent of the time during the night and continues for an hour or two after sunrise until an up-canyon flow forms. Wind conditions are discussed further in the *LANL SWEIS*.

Thunderstorms are common in Los Alamos County, with an average of 60 thunderstorms occurring in a year. Lightning can be frequent and intense. The average number of lightning-caused fires in the 1,104 hectares (2,727 acres) of Bandelier National Monument for the years 1990 through 1994 is 12 per year. There are no recorded instances of large-scale flooding in Los Alamos County. However, flash floods from heavy thunderstorms are possible in areas such as arroyos, canyons, and low-lying areas. No tornadoes are known to have touched the ground in the Los Alamos area.

4.2.3.1 Nonradiological Releases

LANL operations can result in the release of nonradiological air pollutants that may affect the air quality of the surrounding area. LANL is within the Upper Rio Grande Valley Intrastate Air Quality Control Region (#157). The area encompassing LANL and Los Alamos County is classified as an attainment area for all six criteria pollutants (i.e., carbon monoxide, nitrogen dioxide, lead, ozone, sulfur dioxide, and particulate matter) (40 CFR 81.332).

In addition to the National Ambient Air Quality Standards (NAAQS) established by the U.S. Environmental Protection Agency (EPA), the State of New Mexico has established ambient air quality standards for carbon monoxide, sulfur dioxide, nitrogen dioxide, total suspended particulates, hydrogen sulfide, and total reduced sulfur. Additionally, New Mexico established permitting requirements for new or modified sources of regulated air pollutants. Air quality permits have been obtained from the State Air Quality Bureau for beryllium operations, a rock crusher, and LANL's power plant that were modified or constructed after August 31, 1972. In accordance with Title V of the Clean Air Act, as amended, and New Mexico Administrative Code 202.72.402, the University of California and DOE submitted a sitewide operating permit application to New Mexico Environment Department in December 1995. The New Mexico Environment Department has reviewed this application and issued a Notice of Completeness, but has not yet issued an operating permit.

Criteria pollutants released from LANL operations are emitted primarily from combustion sources such as boilers, emergency generators, and motor vehicles. **Table 4–3** presents information regarding the primary existing sources. Toxic air pollutant emissions from LANL activities are released primarily from laboratory, maintenance, and waste management operations. Unlike a production facility with well-defined operational processes and schedules, LANL is a research and development facility with great fluctuations in both the types of chemicals emitted and their emission rates. DOE has a program to review new operations for their potential to emit air pollutants.

Table 4–3 Air Pollutant Emissions at LANL in 1999

Pollutant	LANL Sources Other Than TA-18 and TA-55 (metric tons per year) [a]	TA-18 Sources (metric tons per year)	TA-55 Sources (metric tons per year)
Carbon monoxide	24.6	(b)	4.44
Nitrogen dioxide	73.5	(b)	5.97
PM_{10}	3.66	(b)	0.402
Sulfur dioxide	0.474	(b)	0.021

PM_{10} = particulate matter less than or equal to 10 microns in aerodynamic diameter.

[a] Emissions from the following were included: TA-3 Steam Plant; TA-21 Steam Plant; TA-16 Boilers; TA-48 Boiler; TA-53 Boiler; TA-59 Boiler; paper shredder; TA-3 Asphalt Plant; and TA-54 Water Pump. The inventory did not include various small sources such as residential-size boilers and standby emergency generators.

[b] Emissions from small heating units which burn propane or natural gas are small and are not included in the inventory.

Sources: DOE 1999b, LANL 2000f.

Only a limited amount of monitoring of the ambient air has been performed for nonradiological air pollutants within the LANL region. The New Mexico Environment Department operated a DOE-owned ambient air quality monitoring station adjacent to Bandelier National Monument between 1990 and 1994 to record sulfur dioxide, nitrogen dioxide, ozone, and particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}) levels (see **Table 4–4**). LANL and the New Mexico Environment Department discontinued operation of this station in FY95 because recorded values were well below applicable standards. Beryllium monitoring performed in 1999 at 9 onsite stations, 10 perimeter stations, and 6 regional stations showed that beryllium levels were low. The New Mexico beryllium ambient standard has been repealed.

Table 4–4 Nonradiological Ambient Air Monitoring Results

Pollutant	Averaging Period	Most Stringent Standard [a] (micrograms per cubic meter)	Ambient Concentration [b] (micrograms per cubic meter)
Sulfur dioxide	Annual	41 [c]	2
	24 hours	205 [c]	18
	3 hours	1,030 [d]	Not applicable
Nitrogen dioxide	Annual	73.7 [c]	4
	24 hours	147 [c]	9
Ozone	1 hour	185 [d]	138
PM_{10}	Annual	50 [d]	8
	24 hours	150 [d]	29

PM_{10} = particulate matter less than or equal to 10 microns in aerodynamic diameter.

[a] The most stringent of the state and Federal standards are shown.

[b] 1994 ambient concentrations from monitoring site near Bandelier National Monument at TA-49.

[c] State standard.

[d] Federal standard (NAAQS).

Source: DOE 1999b.

Criteria pollutant concentrations attributable to existing LANL activities were estimated for the *LANL SWEIS* and are presented in **Table 4–5**. The concentrations presented are for the Expanded Operations Alternative, which are similar to the *LANL SWEIS* No Action Alternative.

For toxic air pollutants, a bounding analysis was performed for the *LANL SWEIS*, which indicated that the pollutants of concern for exceeding the guideline values at LANL were emissions from the High Explosives Firing Site operations and emissions that contributed to additive risk from all TAs on receptors near the Los Alamos Medical Center. These combined cancer risks were dominated by the chloroform emissions from the Health Research Laboratory. It was shown that pollutants released under the No Action Alternative in the *LANL SWEIS* are not expected to cause air quality impacts that would affect human health and the environment. Although various small quantities of toxic air pollutants are emitted from activities at TA-18, no toxic air pollutant emissions were identified from TA-18 that would be expected to have an adverse air quality impact (LANL 2001a).

Table 4–5 Modeled Ambient Air Concentrations from LANL Sources

Pollutant	*Averaging Period*	*Most Stringent Standard* [a] *(micrograms per cubic meter)*	*Maximum Estimated Concentration* [b] *(micrograms per cubic meter)*
Carbon monoxide	8 hours 1 hour	7,800 11,700	1,440 2,710
Lead	Calendar quarter	1.5	0.00007
Nitrogen dioxide	Annual 24 hours	73.7 147	9 90
PM_{10}	Annual 24 hours	50 150	1 9
Sulfur dioxide	Annual 24 hours 3 hours	41 205 1,030	18 130 254
Total suspended particulates	Annual 24 hours	60 150	2 18

a The more stringent of the Federal and state standards is presented if both exist for the averaging period. The National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50), other than those for ozone, particulate matter, lead, and those based on annual averages, are not to be exceeded more than once per year. The annual arithmetic PM_{10} mean standard is attained when the expected annual arithmetic mean concentration is less than or equal to the standard. Standards and monitored values for pollutants other than particulate matter are stated in parts per million (ppm). These values have been converted to micrograms per cubic meter ($\mu g/m^3$) with appropriate corrections for temperature (21 °C [70 °F]) and pressure (elevation 2,135 meters [7,005 feet), following New Mexico dispersion modeling guidelines (revised 1998) (NMAQB 1998).

b Based on the Expanded Operations Alternative in the *LANL SWEIS*. The annual concentrations were analyzed at locations to which the public has access–the site boundary or nearby sensitive areas. Short term concentrations were analyzed at the site boundary and at the fence line of certain technical areas to which the public has short access.

Source: DOE 1999b.

As reported in a special environmental analysis for the Cerro Grande Fire in 2000 (DOE 2000h), there may be some temporary increase in suspended particulate matter as a result of removal of vegetation cover, but air quality would be expected to be within the parameters analyzed in the *LANL SWEIS*.

In accordance with the Clean Air Act, as amended, and New Mexico regulations, the Bandelier National Monument and Wilderness Area have been designated as a Class I area (i.e., wilderness areas that exceed 4,047 hectares [10,000 acres]), where visibility is considered to be an important value (40 CFR 81 and 20 New Mexico Administrative Code 2.74) and requires protection. Visibility is measured according to a standard visual range, i.e., how far an image is transmitted through the atmosphere to an observer some distance away. Visibility has been officially monitored by the National Park Service at the Bandelier National Monument since 1988. The view distance at Bandelier National Monument has been recorded from approximately 77 to 166 kilometers (40 to 103 miles). The visual range has not deteriorated during the period for which data are available.

4.2.3.2 Radiological Releases

Radiological air emissions in 1999 from all LANL TAs are presented in **Table 4–6**. Radiological air emissions from TA-18 and TA-55 are also shown in the table. The airborne releases in 1999 were smaller than the annual projections given in the *LANL SWEIS*. Specifically, for TA-18, the 1999 release of argon-41 was 0.49 curies, compared with the maximum annual projection of 110 curies (see Section 3.2.1); and for

TA-55, the 1999 release of tritium was 1.8 curies, compared with the annual projection of 1,000 curies. The difference in the projected and actual releases are attributable to the fact that the facilities in the areas were operated well below their capacities in 1999.

Table 4–6 Radiological Airborne Releases to the Environment at LANL in 1999[a]

Emission Type	*Radionuclide*	*LANL (curies)*	*TA-18 (curies)*	*TA-55 (curies)*
Noble gases	Argon-41	14.2	0.49 [b]	—
Airborne particulates	Cobalt-60	3.97×10^{-6}	—	—
	Galluim-68	0.00173	—	—
	Germanium-68	0.00173	—	—
	Arsenic-73	1.83×10^{-5}	—	—
	Arsenic-74	4.49×10^{-5}	—	—
	Selenium-75	3.50×10^{-4}	—	—
	Mercury-197	0.00160	—	—
	Uranium-234/235/238	7.72×10^{-6}	—	7.1×10^{-8}
	Plutonium-238/239/240	2.11×10^{-5}	—	6.3×10^{-8}
	Americum-241	2.78×10^{-6}	—	5.4×10^{-8}
Halogens	Bromine-76	2.32×10^{-4}	—	—
	Bromine-77	1.15×10^{-5}	—	—
	Bromine-82	6.27×10^{-4}	—	—
Nitrogens and oxygens	Nitrogen-13	159	—	—
Tritium and carbons	Tritium (Hydrogen-3)	1,603	—	1.8
	Carbon-11	283 [b]	—	—

[a] Radionuclides with half-lives less than about 10 minutes are not included in the table (e.g., short-lived carbon, oxygen, and nitrogen isotopes). Also, not included are radionuclides for which less than 10^{-6} curies are released per year. Refer to LANL 2000f for the complete list of airborne releases.

[b] Includes nonpoint source emissions of activated air from the Los Alamos Neutron Science Center Facility and TA-18.

Note: Dashed lines indicate virtually no releases.

Source: LANL 2000f.

4.2.4 Noise

Existing LANL-related publicly detectable noise levels are generated by a variety of sources, including truck and automobile movements to and from the LANL TAs, high explosives testing, and security guards' firearms practice activities. Noise levels within Los Alamos County unrelated to LANL are generated predominately by traffic movements and, to a much lesser degree, other residential-, commercial-, and industrial-related activities within the county communities and the surrounding areas. Limited data currently exist on the levels of routine background ambient noise levels, air blasts, or ground vibrations produced by LANL operations that include explosives detonations.

Traffic noise contributes heavily to the background noise heard by humans over most of the county. Although some measurements of sound specifically targeting traffic-generated noise have been made at various county locations in recent studies, these sound levels are found to be highly dependent upon the exact measuring location, time of day, and meteorological conditions. There is, therefore, no single representative measurement of ambient traffic noise for the LANL site. Noise generated by traffic has been computer modeled to estimate the impact of incremental traffic for various studies, including recent NEPA analyses, without demonstrating meaningful change from current levels due to any new activities. While very few measurements of nonspecific background ambient noise in the LANL area have been made, two such measurements have been taken at a couple of locations near the LANL boundaries next to public roadways. Background noise levels were found to range from 31 to 35 decibels A-weighted (dBA) at the vicinity of the entrance to Bandelier National Monument and New Mexico Route 4 (NM 4). At White Rock, background noise levels range from 38 to 51 dBA (one-hour equivalent sound level); this is slightly higher than was found near Bandelier National Monument, probably due to higher levels of traffic and the presence of a residential neighborhood, as well as the different physical setting. The detonation of high explosives represents the peak noise level generated by LANL operations. The results of these detonations are air blasts and ground vibrations.

The primary source of these detonation activities is the high explosives experiments conducted at the LANL Pulsed High-Energy Radiation Machine Emitting X-Rays Facility and surrounding TAs with active firing sites. Within the foreseeable future, the Dual Axis Radiographic Hydrodynamic Test Facility will begin operation (followed by a corresponding reduction of Pulsed High-Energy Radiation Machine Emitting X-Rays Facility operations) and will become a source of high explosives testing. Explosives detonations were performed in March 1995 for the *Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement* (DOE 1995e) analysis, and measurements of air blasts and ground vibrations were obtained for representative Pulsed High-Energy Radiation Machine Emitting X-Rays Facility explosives tests.

Air blasts consist of higher-frequency, audible air pressure waves that accompany an explosives detonation. This noise can be heard by both workers and the area public. The lower-frequency air pressure waves are not audible, but may cause secondary and audible noises within a testing structure that may be heard by workers. Air blasts and most LANL-generated ground vibrations result from testing activities involving above-ground explosives research. The effects of vibration from existing activities at LANL are discussed further in the *LANL SWEIS*.

The forested condition of much of LANL (especially where explosives testing areas are located); the prevailing area atmospheric conditions; and the regional topography that consists of widely varied elevations and rock formations all influence how noise and vibrations can be both attenuated (lessened) and channeled away from receptors. These regional features are jointly responsible for there being little environmental noise pollution or ground vibration concerns to the area resulting from LANL operations. Sudden loud “booming” noises associated with explosives testing are similar to the sound of thunder and may occasionally startle members of the public and LANL workers alike.

Loss of large forest areas from the Cerro Grande Fire in 2000 has had an adverse effect on the ability of the surrounding environment to absorb noise. However, types of noise and noise levels associated with LANL and from activities in surrounding communities have not changed significantly as a result of the fire (DOE 2000h).

Noise generated by LANL operations, together with the audible portions of explosives air blasts, is regulated by county ordinance and worker protection standards. The standard unit used to report sound pressure levels is the decibel (dB); the A-weighted frequency scale (dBA) is an expression of adjusted pressure levels by frequency that accounts for human perception of loudness. Los Alamos County has promulgated a local noise ordinance that establishes noise level limits for residential land uses. Noise levels that affect residential receptors are limited to a maximum of 65 dBA during daytime hours (between 7 a.m. and 9 p.m.) and 53 dBA during nighttime hours (between 9 p.m. and 7 a.m). Between 7 a.m. and 9 p.m., the permissible noise level can be increased to 75 dBA in residential areas, provided the noise is limited to 10 minutes in any one hour. Activities that do not meet the noise ordinance limits require a permit.

The Los Alamos County Community Development Department has determined that LANL does not need a special permit under the Los Alamos County Code because noise related to explosives testing is not prolonged, nor is it considered unusual to the Los Alamos community.

Traffic noise from truck and automobile movements around the LANL TAs is excepted under Los Alamos County noise regulations, as is the traffic noise generated along public thoroughfares within the county.

The vigor and well being of area wildlife and sensitive, federally protected bird populations suggest that these environmental conditions are present at levels within an acceptable tolerance range for most wildlife species and sensitive nesting birds found along the Pajarito Plateau.

4.2.5 Geology and Soils

LANL is located on the Pajarito Plateau within the Southern Rocky Mountains Physiographic Province. The Pajarito Plateau lies between the Sierra de Los Valles and the Jemez Mountains to the west and the Rio Grande to the east. The surface of the Pajarito Plateau is divided into numerous narrow, finger-like mesas separated by deep east-to-west-oriented canyons that drain toward the Rio Grande. A primary geologic feature in the region is the Rio Grande Rift, which begins in northern Mexico, trends northward across central New Mexico, and ends in central Colorado. The rift is a complex system of north-trending basins that have formed by downfaulting of large blocks of the Earth's crust. In the Los Alamos area, the Rio Grande Rift is about 56 kilometers (35 miles) wide and encompasses the Española Basin. The Sangre de Cristo Mountains border the Rio Grande Rift on the east, and the Jemez Mountains lie over the western fault margin of the rift. The north-trending Pajarito Fault system is part of the Rio Grande Rift and consists of a group of interconnecting faults that are nearly parallel.

In summary, the rocks present in the LANL region were predominantly produced by volcanic and sedimentary processes. The Pajarito Plateau is capped by the Bandelier Tuff. This unit attains a thickness of more than 200 meters (700 feet) in the LANL region and consists of ash-flow deposits of rhyolitic tuff and pumice, erupted between about 1.2 and 1.6 million years ago during the early to middle Quaternary period (i.e., Pleistocene) from the Valles and Toledo calderas located in the Jemez Mountains volcanic field (located west of LANL). Older, underlying units include the Puye Formation, which is a sedimentary unit comprised from materials derived from the Jemez Mountains and the ancestral Rio Grande and intruded in places by Cerros del Rio basalt flows. Underlying it is the Tschicoma Formation which consists of volcanic vent deposits. The Santa Fe Group is the most extensive unit in the Rio Grande Rift and largely consists of sedimentary materials and rocks including evaporites derived from stream or deltaic deposits, but also contains volcanic tuff deposits and basalts. The Sante Fe Group sits atop Precambrian age (greater than 570 million years old) crystalline basement rock. Additional details about LANL site geology are presented in the *LANL SWEIS*.

There are no active mines, mills, pits, or quarries in Los Alamos County or on DOE land at LANL. However, rock and mineral resources including sand, gravel, and volcanic pumice are mined throughout the surrounding counties. Sand and gravel are primarily used in construction, including for road building, and pumice is used in textile laundries to soften material and as an abrasive, as well as for building blocks and in landscaping. The major sand and gravel deposit in the area is located in the lower member of the Puye Conglomerate. The welded and moderately welded units of the Bandelier Tuff are suitable as foundation rocks, structural and ornamental stone, or insulating material. Volcanic tuff has also been used successfully as aggregate in soil-cement subbases for roads.

The nearby north-trending Pajarito Fault system dominates the geologic structure of the LANL area. The Pajarito Fault system consists of three major faults and numerous secondary faults. The major faults in Los Alamos County are the Pajarito, Rendija Canyon, and Guaje Mountain (see **Figure 4–4**). Estimates of the most recent movements along the faults are based on trench studies where the faults are not buried. The estimates of movement range from as recent as 4,000 years ago for the Guaje Mountain Fault to 55,000 years ago for the Pajarito Fault, with estimated movement along the Rendija Canyon Fault occurring between 8,000

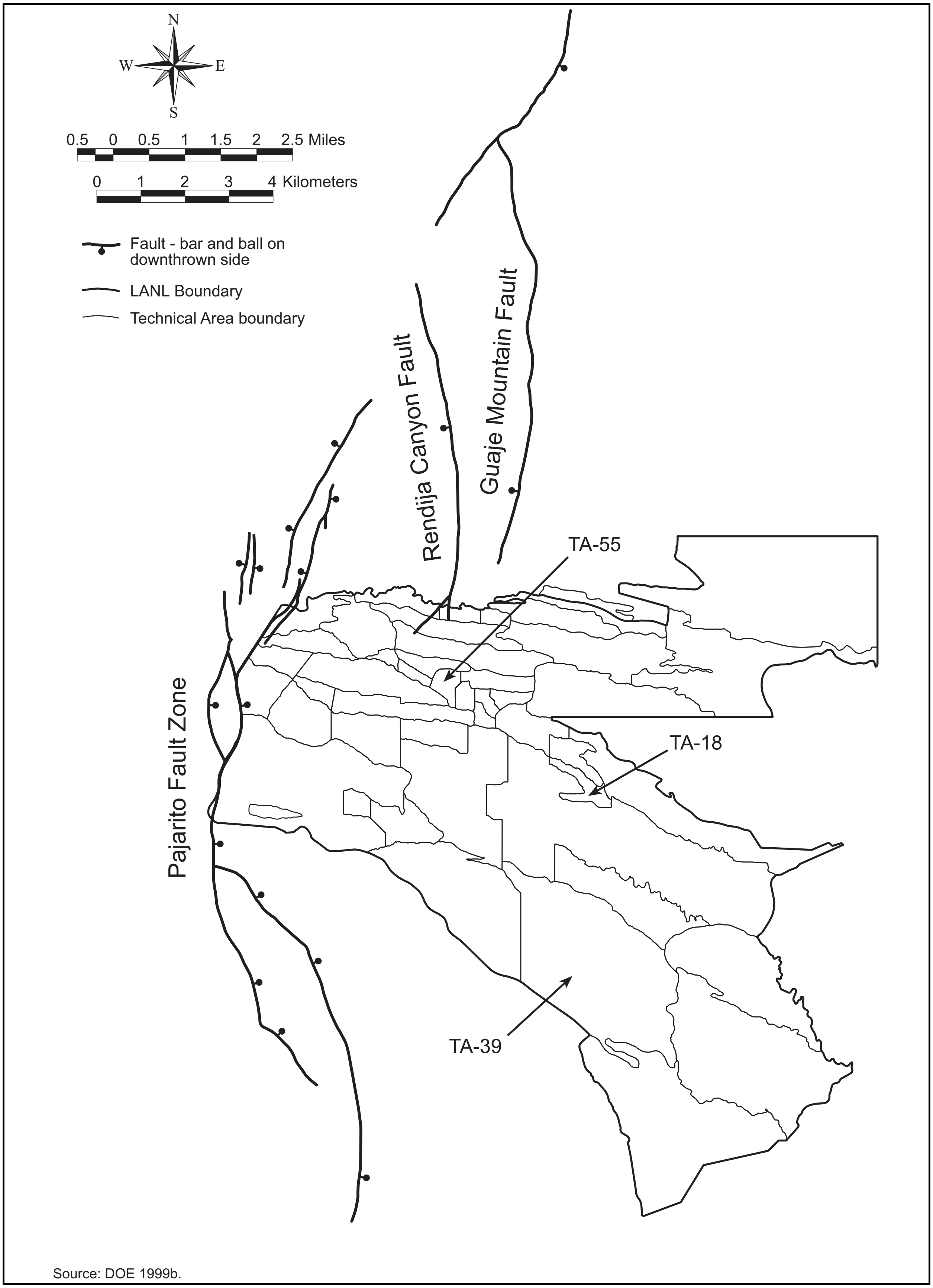

Figure 4–4 Major Faults at LANL

and 23,000 years ago. It is possible that the most recent movements along the faults are younger than those presented. Therefore, these faults should be considered active and capable per the U.S. Nuclear Regulatory Commission definition of the term as used for seismic safety. A capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years (10 CFR Part 100, Appendix A). Additional detail on ongoing seismic studies and their implications can be found in the *LANL SWEIS* and supplemental analyses that considered the seismic setting at TA-55.

LANL is located in a region of generally low to moderate seismicity overall. A historical catalog has been compiled of earthquakes that have occurred in the LANL area from 1873 to 1991. Only six of these have had estimated magnitudes of 5 or greater on the Richter scale. The May 1918 Cerrillos Earthquake was the most significant seismic event in this period. This earthquake had an estimated Richter magnitude of 5.5 and was centered approximately 31 miles (50 kilometers) southeast of LANL. This event had a reported Modified Mercalli Intensity of VII at its epicenter. Within a radius of 100 kilometers (62 miles) of central LANL, a total of five significant earthquakes (i.e., having a magnitude of at least 4.5 or a Modified Mercalli Intensity of VI or larger) have been documented, including the May 1918 event (USGS 2001b). Since 1973, six earthquakes have been recorded within 100 kilometers (62 miles) of central LANL ranging in magnitude from 1.6 to a magnitude 4.5 event in March 1973. This 1973 earthquake was the closest to LANL at 28 kilometers (16 miles) to the northeast. The most recent was a magnitude 2.8 earthquake that occurred in December 1998 at a distance of 86 kilometers (53 miles) (USGS 2001a).

Earthquake hazard results indicate that the Pajarito Fault system represents the greatest potential risk to LANL, with an estimated maximum earthquake magnitude of about 7. Although large uncertainties exist, an earthquake with a Richter magnitude greater than or equal to 6 is estimated to have an annual probability of occurrence of 1 in 4,000 (i.e., once every 4,000 years); an earthquake with a magnitude greater than or equal to 7 is estimated to have an annual probability of occurrence of 1 in 100,000 along the Pajarito Fault system. The hazard study of facilities in eight LANL TAs found that earthquakes having an annual probability of occurrence of 1 in 10,000 would cause a horizontal peak ground acceleration ranging from 0.53 to 0.57. Measures of peak (ground) acceleration indicate what an object on the ground would experience during an earthquake. This motion is customarily expressed in units of g (gravitational acceleration). Maintenance and refurbishment activities at LANL are specifically intended to upgrade the seismic performance of older structures. For reference, a comparison of Modified Mercalli Intensity (the observed effects of earthquakes) with measures of earthquake magnitude and ground acceleration is provided in Section F.5.2 (see Appendix F).

While peak acceleration is generally adequate to approximate what a short structure would experience in terms of horizontal force during an earthquake, it does not account for the range of energies experienced by a building during an earthquake, particularly for taller buildings. Thus, building design based on peak acceleration alone does not provide a uniform margin against collapse. However, the U.S. Geological Survey has developed new seismic hazard metrics and associated National Earthquake Hazard Reduction Program maps that are based on response spectral acceleration (spectral acceleration).

Spectral acceleration accounts for the natural period of vibration of structures (i.e., short buildings have short natural periods [up to 0.6 seconds] and taller buildings longer periods [0.7 seconds or longer]) (USGS 2001j). The National Earthquake Hazard Reduction Program maps have been adapted for use in the new *International Building Code* (ICC 2000), and depict maximum considered earthquake ground motion of 0.2- and 1-second spectral response acceleration, respectively, based on a 2 percent probability of exceedance in 50 years. This corresponds to an annual recurrence interval of about 1 in 2,500. The central portion of LANL (encompassing TA-18 and TA-55) is calculated to lie within the 0.57 g to 0.58 g mapping contours for a 0.2-second spectral response acceleration and the 0.18 g to 0.19 g contours for a 1-second spectral response acceleration. For comparison, the calculated peak ground acceleration for the given probability of exceedance is approximately 0.25 g (USGS 2001e).

Volcanism in the Jemez Mountains volcanic field, west of LANL, has a 13-million-year history. The Bandelier Tuff is the material upon which most LANL facilities are constructed. The Bandelier Tuff is generally thickest to the west of LANL near its source, and thins eastward across the Pajarito Plateau, due to increasing distance from the source and erosion. Volcanic eruptions continued up to about 520,000 years ago, followed by a 460,000-year period of dormancy. The most recent volcanic activity produced several rock units, including the El Cajete pumice, which is a minor unit in the LANL area that overlays the Bandelier Tuff. The El Cajete pumice dates at 50,000 to 60,000 years old. Recurrence intervals for future volcanism have not been established.

Facilities near a cliff edge or in a canyon bottom are potentially susceptible to slope instability and specifically are susceptible to the geologic hazards of rockfalls and landslides. Slope stability studies have been performed at these and other facilities where a hazard has been identified. As for other geologic hazards, the potential for land subsidence and soil liquefaction at LANL is considered low.

Several distinct soils have developed in Los Alamos County as a result of interactions between the bedrock, topography, and local climate. Most soils developed from acidic volcanic rock and range in texture from clay and clay loam to gravel. Rock outcrops are common occurring on greater than 50 percent of the surface (DOE 1996g). Soils that formed on mesa tops are well drained and range from very shallow (0 to 25 centimeters [0 to 10 inches]) to moderately deep (51 to 102 centimeters [20 to 40 inches]), with the greatest depth to the underlying Bandelier Tuff being 102 centimeters (40 inches). Soil erosion rates vary considerably on the mesa tops at LANL, with the highest rates occurring in drainage channels, where roads and structures concentrate runoff, and in areas of steep slopes and the lowest rates occurring on gently sloping portions of the mesa tops away from the channels. A recent study suggested that erosion rates are high across widespread portions of local pinyon-juniper woodlands, which are found on the eastern portion of LANL. High erosion rates appear to be relatively recent, most likely resulting from loss of vegetative cover, decreased precipitation, past logging practices, and past livestock grazing (DOE 1999b). Site soils are acceptable for standard construction techniques. No prime farmland soils have been designated in Los Alamos County (DOE 1996f).

The recent Cerro Grande Fire has increased the potential for soil erosion across areas burned at LANL due to the loss of vegetation and has also destabilized rocks close to the edges of mesas, mesa side slopes, and canyon bottoms. While the postburn assessment conducted by the U.S. Forest Service Burn Area Emergency Rehabilitation Team found that the Cerro Grande Fire created hydrophobic (water repellent) soil conditions, resulting in an increased runoff rate along rather appreciable tracts of land located just to the northwest of LANL, no significant areas of hydrophobic soils were found within LANL. These effects are expected to persist for some three to five years (DOE 2000h).

TA-18 is located approximately 5.3 kilometers (3.3 miles) southeast of the mapped terminating point of the Rendija Canyon Fault (see Figure 4–4). This fault is the nearest capable fault to TA-18. Typical subsurface stratigraphy at LANL and TA-18 consists of welded and poorly welded volcanic tuffs that comprise the Tshirege Member of the Bandelier Tuff Formation. The Tshirege Member attains a thickness of about 122 meters (400 feet) (DOE 1995e). Site-specific investigations in Pajarito Canyon near TA-18 have found the tuff to be highly weathered and unwelded, with the upper 3 to 4.5 meters (10 to 15 feet) of the material classified as clayey sand or sandy clay. However, surrounding cliff faces consist of welded tuff exhibiting vertical jointing. The canyon tuff is overlain by up to 4.5 meters (15 feet) of sandy and silty alluvium (URS 2000). Soils derived from these deposits are typically sandy loams (DOE 1995e). In general, sandy