

## APPENDIX A ACRONYMS, GLOSSARY, AND METRIC CONVERSION TABLES

### A-1.0 ACRONYMS

ACOLR	colorimetric analysis
AOC	area of concern
B&K	Bruel & Kjaer
BMP	best management practice
BV	background value
CLP	contract laboratory program
CMS	corrective measures study
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CVAA	cold vapor atomic absorption
DCF	dose conversion factor
DL	detection limit
DOE	US Department of Energy
EDL	estimated detection limit
EPA	US Environmental Protection Agency
EQL	estimated quantitation limit
ER	Environmental restoration
ESL	ecological screening level
FIMAD	Facility for Information Management, Analysis, and Display
FV	fallout value
GFAA	graphite furnace atomic absorption
GPC	gel permeation chromatography
HE	high explosive
HQ	hazard quotient
HSWA	Hazardous and Solid Waste Amendments of 1984
HWB	Hazardous Waste Bureau
IA	interim action
ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectroscopy
ID	identification
IDL	instrument detection limit
Laboratory	Los Alamos National Laboratory
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory (LANL before January 1, 1981)
LCS	laboratory check sample
MDA	Material disposal area

NMED	New Mexico Environment Department (New Mexico Environmental Improvement Division before 1991)
NOD	notice of deficiency
OU	operable unit
PCB	polychlorinated biphenyl
PBX	plastic-bonded explosives
PCE	perchloroethane
PRS	potential release site
QA	Quality assurance
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RDX	1,3,5-trinitro-1,3,5-triazacyclohexane
RFI	RCRA facility investigation
RPD	relative percent difference
RRF	relative response factor
RSD	risk-specific dose
SAL	screening action level
SWMU	solid waste management unit
SOP	standard operating procedure
SOW	statement of work
SVOC	semivolatile organic compound
T&E	threatened and endangered
TA	technical area
TAL	target analyte list (EPA)
TCA	trichloroethane
TCE	trichloroethylene
TIC	tentatively identified compound
TPU	total propagated uncertainty
TRU	transuranic
UCL	upper confidence level
UTL	upper tolerance limit
VOC	volatile organic compound

## A-2.0 GLOSSARY

**Administrative authority (AA).** The Director of the New Mexico Environment Department, or his/her designee, or the U.S. Environmental Protection Agency.

**Alluvial.** Relating to geologic deposits or features formed by running water.

**Area of concern (AOC).** An area at the Laboratory known or suspected to be contaminated with radionuclides but not contaminated by hazardous chemicals or hazardous waste.

**Background value (BV).** The upper tolerance limits (UTLs) of background sample results, calculated as the upper 95% confidence limit for the 95th percentile. When a UTL cannot be calculated, either the detection limit or the maximum reported value is used as a BV; BVs are used as simple threshold numbers to identify potentially contaminated site sample results that are greater than background levels in that geological sample medium (or group of media). All inorganic chemicals and radionuclides have BVs.

**Baseline risk assessment (also known as risk assessment).** A site-specific analysis of the potential adverse effects of hazardous substances that are released from a site in the absence of any control or mitigation actions. A baseline risk assessment consists of four steps: data collection and analysis, exposure assessment, toxicity assessment, and risk characterization.

**Best management practice.** For facilities that manufacture, use, store, or discharge toxic or hazardous pollutants as defined by the 1977 Clean Water Act, a required program to control the potential spill or release of those materials to surface waters. (The Facts on File Dictionary of Environmental Science, edited by L. Harold Stevenson and Bruce Wyman)

**Chemical of potential concern (COPC).** Chemical, detected at a site, that has the potential to adversely affect human and/or ecological receptors due to its concentration, distribution, and mechanism of toxicity. A COPC remains a concern until exposure pathways and receptors are evaluated in a site-specific risk assessment.

**Chemical of potential ecological concern (COPEC).** A chemical, detected at a site, that has the potential to adversely affect ecological receptors due to its concentration, distribution, and mechanism of toxicity.

**Cold vapor atomic absorption (CVAA).** An analytical technique used for measuring mercury; it is described in EPA Methods 7470A (Mercury in Liquid Waste) and 7471A (Mercury in Solid or Semisolid Waste). The technique is based on the absorption of radiation at 253.7-nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration.

**Corrective measures study (CMS).** A study to assess risks (from a release) to human health, the environment, costs, and other factors (such as disposal methods) in a given area. If a RCRA facility investigation indicates further action is required, a CMS is performed to identify and evaluate cleanup alternatives.

**Data validation.** Systematic process that applies a defined set of performance-based criteria to a body of data; may result in qualification of the data. The data validation process is performed independently of the analytical laboratory that generates the data set and occurs before conclusions are drawn from the data. The process may comprise a standardized data review (routine data validation) and/or a problem-specific data review (focused data validation).

**Department of Energy (DOE).** Federal agency that sponsors energy research and regulates nuclear materials for weapons production.

**Detection limit.** Minimum concentration that can be determined by a single measurement by an instrument; implies a specified statistical confidence that the analytical concentration is greater than zero.

**Dose.** Quantity of radiation that is absorbed, per unit of mass, by the body or by any portion of the body.

**Ecological screening level (ESL).** An organism's exposure-response threshold for a given chemical constituent. The concentration of a substance in a particular medium corresponds to a hazard quotient (HQ) of 1.0 for a given organism below which no risk is indicated.

**Environmental Protection Agency (EPA).** Federal agency responsible for enforcing environmental laws. While state regulatory agencies may be authorized to administer some of this responsibility, the EPA retains oversight authority to ensure protection of human health and the environment.

**Estimated detection limit (EDL).** The detection limit required by the Laboratory statement of work (SOW) for analytical services (RFP No. 9-XS1-Q4257). The Laboratory value reflect the contract-required detection limits (CRDLs) of the Contract Laboratory Program (CLP) methods.

**Estimated quantitation limit.** The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine analytical-laboratory operating conditions. Sample estimated quantitation limits are highly matrix-dependent, and the specified estimated quantitation limits might not always be achievable.

**Evapotranspiration.** The combined discharge of water from the earth's surface to the atmosphere by evaporation from lakes, streams, and soil surfaces, and by transpiration from plants.

**Exposure pathway.** Mode by which a receptor may be exposed to contaminants in environmental media (e.g., drinking water, ingesting food, or inhaling dust).

**External standard.** External standard calibration involves comparison of instrument responses from the sample to the responses from the target compounds in the calibration standards. Sample peak areas (or peak heights) are compared to peak areas (or heights) of the standards.

**Fallout radionuclides.** Radionuclides that are present at globally elevated levels in the environment as a result of the fallout from atomic weapons tests. The Laboratory background data sets consist of Environmental Surveillance samples taken from marginal and regional locations for the following radionuclides associated with fallout: tritium, cesium-137, americium-241, plutonium-238, plutonium-239/240, and strontium-90. Samples were collected from regional and marginal locations in the vicinity of the Laboratory that are (1) representative of geological media found within Laboratory boundaries and (2) were not impacted by Laboratory operations.

**Fault.** A fracture, or zone of fractures, in rock along which there has been vertical or horizontal movement; adjacent rock surfaces are displaced.

**Field blank (also known as field reagent blank).** A blank sample either prepared in the field or carried to the sampling site, exposed to sampling conditions (e.g., bottle caps removed, preservatives added), and returned to a laboratory for analysis in the same manner in which environmental samples are analyzed. Used to identify the presence of contamination potentially added during the sampling and analysis process.

**Field duplicate.** A second sample collected as near as possible to the original sample.

**Gamma radiation.** A form of electromagnetic, high-energy radiation emitted from a nucleus. Gamma rays are essentially the same as x-rays and require heavy shielding, such as concrete or steel, to be blocked.

**Hazard quotient (HQ).** The ratio of a calculated exposure (E) to or dose (D) from a given contaminant (I) to a given receptor (j) over a reference value (TRV) for contaminant (I) determined to be protective of receptor (j), i.e.,  $HQ_{ij} = E_{ij}$  [or  $D_{ij}$ ]TRV<sub>ij</sub>.

**Hazardous and Solid Waste Amendments (HSWA).** The Hazardous and Solid Waste Amendments of 1984 (Public Law No. 98-616, 98 Stat. 3221), which amended the Resource Conservation and Recovery Act of 1976, 42 U.S.C. § 6901 et seq.

**HSWA module.** A portion of the Laboratory's permit to operate under RCRA that contains requirements specific to Los Alamos National Laboratory. It is this portion of the permit that contains the list of solid waste management units that must be cleaned up in accordance with RCRA procedures.

**Hydrogeology.** The science that applies geologic methods to the understanding of hydrologic phenomena.

**Inductively coupled plasma emission spectroscopy (ICPES).** ICPES determines trace elements, including metals, in solutions. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized, and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by a radio-frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices are used to monitor the intensities of the emission lines.

**Inductively coupled plasma mass spectroscopy (ICPMS).** ICPMS is applicable to the determination of sub- $\mu\text{g/l}$  concentrations of a large number of elements in water samples and in waste extracts or digests. When dissolved constituents are required, samples must be filtered and acid preserved before analysis. No digestion is required before analysis for dissolved elements in water samples. The method measures ions produced by a radio-frequency inductively coupled plasma. Analyte species originating in a liquid are nebulized, and the resulting aerosol transported by argon gas into the plasma torch. The ions produced are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier.

**Instrument detection limit (IDL).** The IDL is defined to be three times the average of the standard deviations obtained on three nonconsecutive days from the analysis of a standard solution, with seven consecutive measurements of that solution per day. The standard solution must be prepared at a concentration of three to five times the instrument manufacturer's estimated IDL. This is a measure of instrument sensitivity without any consideration for contributions to signal from reagents.

**Internal standards.** Compounds added to the sample after sample preparation for qualitative and quantitative instrument analysis—the compounds serve as a standard of retention time and response, which is invariant from run to run with the instruments. (Handbook of Environmental Analysis, by Roy-Keith Smith, 3rd ed.)

**Laboratory control sample (LCS).** A known matrix that has been spiked with compound(s) representative of the target analytes. The LCS is used to document laboratory performance. The acceptance criteria for LCSs are method specific.

**Laboratory qualifier (or laboratory flag).** Codes applied to the data by the contract analytical laboratory to indicate, on a gross scale, a verifiable or potential data deficiency. These flags are applied using the Environmental protection Agency (EPA) contract laboratory program (CLP) guidelines.

**Matrix spike.** An aliquot of sample spiked with a known concentration of target analyte(s). Matrix spike samples are used to measure the ability to recover prescribed analytes from a native sample matrix. The spiking typically occurs before sample preparation and analysis.

**Matrix spike duplicate.** An intralaboratory duplicate sample spiked with a known amount of target analyte(s). Spiking occurs before sample preparation and analysis.

**Method blank.** An analyte-free matrix to which all reagents are added in the same volumes or proportions as those used in the environmental sample processing and which is prepared and analyzed in the same manner as the corresponding environmental samples. The method blank is used to assess the potential for contamination to the sample during preparation and analysis.

**Method detection limit (MDL).** The minimum concentration of a substance that can be measured and reported with a known statistical confidence that the analyte concentration is greater than zero. The MDL is determined from analysis of samples of a given matrix type that contain the analyte after subjecting the sample to the usual preparation and analyses. The MDL is used to establish detection status.

**Minimum detectable activity.** For the *analysis of radionuclides*, the minimum detectable activity is the lowest detectable radioactivity for a given analytical technique. The following equation shall be used to calculate the MDA unless otherwise noted or approved by the Laboratory:

$$\text{MDA} = \frac{4.65(\text{BKG})^{0.5} + 2.71}{2.22 \times \text{EFF} \times V \times T_s \times Y}$$

where BKG = the total background counts,  
EFF = the fraction detector efficiency,  
V = the volume or unit weight,  
T<sub>s</sub> = the *sample* count duration, and  
Y = the fractional *chemical* recovery obtained from the *tracer* recovery.

Depending on the type of *analysis*, other terms may also be required in the denominator (e.g., gamma abundance).

**Mixed waste.** Waste that contains both hazardous waste (as defined by RCRA) and radioactive waste (as defined by the Atomic Energy Act [AEA] and its amendments).

**Model.** A mathematical approximation of a physical, biological, or social system.

**No further action (NFA).** A recommendation that not further investigation or remediation is warranted based on specific criteria.

**Nondetect.** Sample result that is less than the MDL. The laboratory reports nondetects as undetected at the EQL.

**Notice of deficiency (NOD).** A notice issued to DOE and the Laboratory by the administrative authority which states that some aspect(s) of a plan, report, or application does not meet their requirements or that requires clarification or correction.

**Operable unit (OU).** At the Laboratory, one of 24 areas originally established for administering the ER Project. Set up as groups of potential release sites, the OUs were aggregated based on geographic proximity for the purpose of planning and conducting the cleanup effort. As the project matured, it became apparent that 24 were too many to allow efficient communication and to ensure consistency in approach. Therefore, in 1994, the 24 OUs were reduced to six administrative "field units."

**Percent recovery (%R).** Amount of material detected in a sample (minus any amount already in the sample) divided by the amount added to the sample and expressed as a percentage.

**Perched groundwater.** Groundwater that lies above the regional water table and is separated from it by an unsaturated zone.

**Polychlorinated biphenyls (PCBs).** Any chemical substance that is limited to the biphenyl molecule that has been chlorinated to varying degrees or any combination of substances which contains such substances. PCBs are colorless, odorless compounds that are chemically, electrically, and thermally stable and have proven to be toxic to both humans and animals.

**Potential release site (PRS).** A site suspected of releasing or having the potential to release contaminants into the environment. PRS is a generic term that includes solid waste management units, hazardous waste sites listed in Module 7 of the Laboratory's Hazardous Waste Facility Permit, and sites that have been identified as potentially contaminated by radioactivity.

**Quality assurance.** All those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily in service.

**Quality control (QC).** (1) All those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. QC is the process through which actual quality performance is measured and compared with standards. (2) All methods and procedures used to obtain accurate and reliable results from environmental sampling and analysis. Includes rules for when, where, and how samples are taken; sample storage, preservation and transport; and the use of blanks, duplicates, and split samples during the analysis.

**RCRA facility investigation (RFI).** The investigation that determines if a release has occurred and the nature and extent of the contamination at a hazardous waste facility. The RFI is generally equivalent to the remedial investigation portion of the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA) process.

**Receptor.** A person, plant, animal, or geographical location that is exposed to a chemical or physical agent released to the environment by human activities.

**Recharge.** The process by which water is added to the zone of saturation, either directly from the overlying unsaturated zone or indirectly by way of another material in the saturated zone.

**Regional aquifer.** Geologic material(s) or unit(s) of regional extent whose saturated portion yields significant quantities of water to wells, contains the regional zone of saturation, and is characterized by the regional water table or potentiometric surface.

**Relative percent difference (RPD).** The measure used to assess the *precision* between parent *sample* results and their associated duplicate results. The RPD is calculated as follows:

$$|\text{RPD}| = \frac{S - R}{\left(\frac{S + R}{2}\right)} 100$$

where: RPD = relative percent difference,  
 S = parent *sample* result, and  
 R = duplicate *sample* result.

The Los Alamos National Laboratory ER Project criteria for the RPD is less than 20% for aqueous *samples* and less than 35% for soil *samples* when the *sample* concentrations are greater than or equal to five times the *method detection limit (MDL)*. For *samples* with concentrations less than five times the *MDL*, but greater than the *MDL*, the control is  $\pm$ -*MDL*. No *precision* criterion applies to *samples* with concentrations less than the *MDL*.

**Resource Conservation and Recovery Act (RCRA).** The Solid Waste Disposal Act as amended by the Resource Conservation and Recovery Act of 1976. (40 CFR 270.2)

**Rill erosion.** An erosion process in which numerous small channels only several inches deep are formed by concentrated runoff that flows during and immediately following rain storms.

**Runoff.** The portion of the precipitation on a drainage area that is discharged from the area either by sheet flow or adjacent stream channels.

**Run-on.** Surface water flowing onto an area as a result of runoff occurring higher up the slope.

**Sample.** A portion of a material (e.g., rock, soil, water, air), which, alone or in combination with other samples, is expected to be representative of the material or area from which it is taken. Samples are typically sent to a laboratory for analysis or inspection or are analyzed in the field. When referring to samples of environmental media, the term field sample may be used.

**Sample matrix.** In chemical analysis, that portion of a sample which is exclusive of the analytes of interest. Together, the matrix and analytes of interest form the sample.

**Screening action level (SAL).** Medium-specific concentration level for a chemical derived using conservative criteria below for which it is generally assumed that there is no potential for unacceptable risk to human health. The derivation of a SAL is based on conservative exposure and land-use assumptions. However, if an applicable regulatory standard exists that is less than the value derived by risk-based computations, it will be used for the SAL.

**Screening assessment.** A process designed to determine whether contamination detected in a particular medium at a site may present a potentially unacceptable human-health and /or ecological risk. The assessment utilizes screening levels that are either human-health or ecologically based concentrations derived by using chemical-specific toxicity information and standardized exposure assumptions below which no additional actions are generally warranted.

**Sediment.** (1) A mass of fragmented inorganic solid that comes from the weathering of rock and is carried or dropped by air, water, gravity, or ice; or a mass that is accumulated by any other natural agent and that forms in layers on the earth's surface such as sand, gravel, silt, mud, fill, or loess. (2) A solid material that is not in solution and either is distributed through the liquid or has settled out of the liquid.

**Site characterization.** Defining the pathways and methods of migration of the hazardous waste or constituents, including the media affected, the extent, direction and speed of the contaminants, complicating factors influencing movement, concentration profiles, etc. (U.S. Environmental Protection Agency, May 1994. "RCRA Corrective Action Plan, Final," Publication EPA-520/R-94/004, Office of Solid Waste and Emergency Response, Washington, DC)

**Site conceptual model.** A qualitative or quantitative description of sources of contamination, environmental transport pathways for contamination, and biota that may be impacted by contamination (called receptors) and whose relationships describe qualitatively or quantitatively the release of contamination from the sources, the movement of contamination along the pathways to the exposure points, and the uptake of contaminant by the receptors.

**Solid waste management unit (SWMU).** Any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at a facility at which solid wastes have been routinely and systematically released. This definition includes regulated units (i.e., landfills, surface impoundments, waste piles, and land treatment units) but does not include passive leakage or one-time spills from production areas and units in which wastes have not been managed (e.g., product storage areas).

**Standard operating procedure (SOP).** A document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and is officially approved as the method for performing certain routine or repetitive tasks.

**Stratigraphy.** The science dealing with the succession, age, composition, and history of strata.

**Surrogate compound or surrogate.** An organic compound used in the analyses of organic target analytes that is similar in composition and behavior to target analytes but is not normally found in field samples. Surrogates are added to every blank and spike sample to evaluate the efficiency with which analytes are recovered during extraction and analysis.

**Target analyte.** An element, chemical, or parameter, the concentration, mass, or magnitude of which is designed to be quantified by use of a particular test method.

**Technical area (TA).** The Laboratory established technical areas as administrative units for all its operations. There are currently 49 active TAs spread over 43 square miles.

**Tentatively identified compound (TIC).** Chemical compound detected in a sample that is not a target analyte, IS, or surrogate compound. Up to 30 chromatographic peaks may be subject to mass spectral matching for identification as TICs.

**Total propagated uncertainty (TPU).** The range of concentrations (expressed as plus or minus the measured concentration) that include the theoretical or true concentration of an analyte with a specific degree of confidence. Radiochemical results are required to be accompanied by sample-specific uncertainty bounds (TPU) that reflect the 67% confidence level (1-sigma TPU). The TPU includes not only the measurement or counting error but also the technique-specific error term that includes uncertainty values for each contributing measurement process and a sample-specific contribution reflecting specific chemical recoveries, detectors used, etc. All radiochemical result uncertainties incorporate terms for technique-related and sample-specific measurement errors.

**Tracer.** A substance, usually a radioactive isotope, added to a sample to determine the efficiency (chemical or physical losses) of the chemical extraction, reaction, or analysis. The tracer is assumed to behave in the same manner as that of the target radionuclides. Recovery guidelines for tracer results are 30% to 110% under the current contract laboratory statement of work and will be 40% to 105% under the new statement of work. Correction of the analytical results for the tracer recovery is performed for each sample. The concentration of the tracer added needs to be sufficient to result in a maximum of 10% uncertainty at the 95% confidence level in the measured recovery.

**Tuff.** A compacted deposit of volcanic ash and dust that contains rock and mineral fragments accumulated during an eruption.

**U.S. Department of Energy (DOE).** Federal agency that sponsors energy research and regulates nuclear materials for weapons production.

**U.S. Environmental Protection Agency (EPA).** Federal agency responsible for enforcing environmental laws. While state regulatory agencies may be authorized to administer some of this responsibility, the EPA retains oversight authority to ensure protection of human health and the environment.

**Vadose zone.** The unsaturated zone. Portion of the subsurface above the regional water table in which pores are not fully saturated.

**Welded tuff.** A volcanic deposit hardened by the action of heat, pressures from overlying material, and hot gases.

### Metric to English Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns ( $\mu\text{m}$ )	0.0000394	inches (in.)
square kilometers ( $\text{km}^2$ )	0.3861	square miles ( $\text{mi}^2$ )
hectares (ha)	2.5	acres
square meters ( $\text{m}^2$ )	10.764	square feet ( $\text{ft}^2$ )
cubic meters ( $\text{m}^3$ )	35.31	cubic feet ( $\text{ft}^3$ )
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter ( $\text{g}/\text{cm}^3$ )	62.422	pounds per cubic foot ( $\text{lb}/\text{ft}^3$ )
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram ( $\mu\text{g}/\text{g}$ )	1	parts per million (ppm)
liters (l)	0.26	gallons (gal.)
milligrams per liter (mg/l)	1	parts per million (ppm)
degrees Celsius ( $^{\circ}\text{C}$ )	$9/5 + 32$	degrees Fahrenheit ( $^{\circ}\text{F}$ )

### Metric Prefixes

Term	Power of 10	Symbol
mega-	$10^6$	M
kilo-	$10^3$	k
deci-	$10^{-1}$	d
centi-	$10^{-2}$	c
milli-	$10^{-3}$	m
micro-	$10^{-6}$	$\mu$
nano-	$10^{-9}$	n
pico-	$10^{-12}$	p

# **Appendix B**

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*Operational and Environmental Setting*



## **APPENDIX B OPERATIONAL AND ENVIRONMENTAL SETTING**

### **B-1.0 OPERATIONAL HISTORY AND LAND USE**

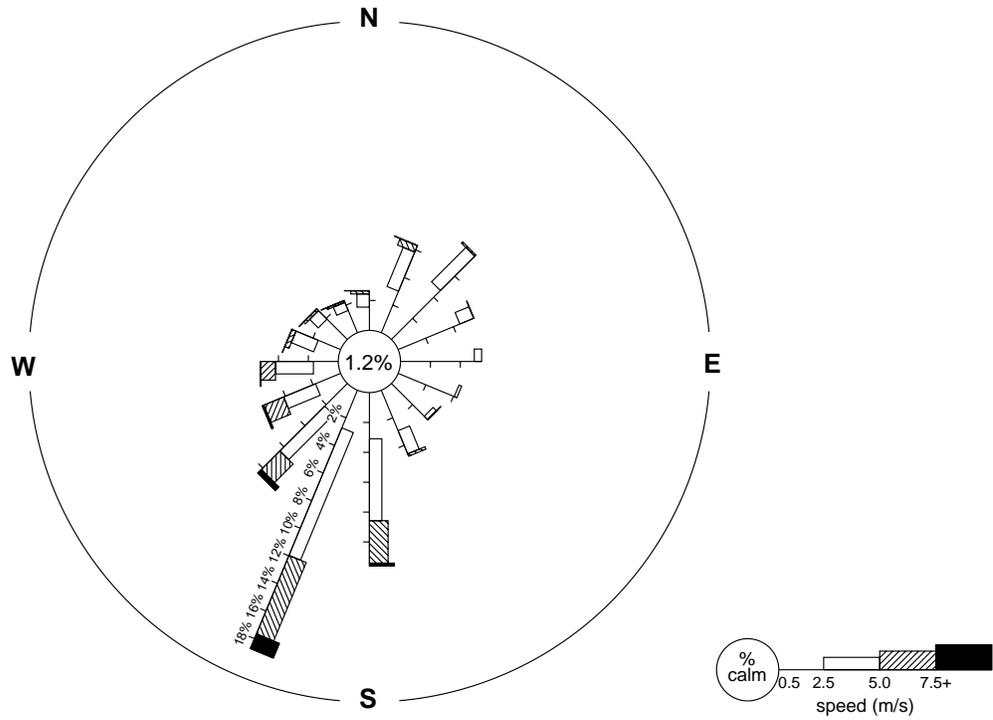
Technical Area (TA) 54 is located in the east-central portion of the Los Alamos National Laboratory (Laboratory) (Figure 1.2-1, Section 1) on Mesita del Buey between Pajarito Canyon (south) and Cañada del Buey (north) (Figure 1.2-2, Section 1). During the late 1950s, the Laboratory, with approval of the US Atomic Energy Commission and upon recommendation of the US Geological Survey, selected TA-54 for disposal of Laboratory-derived waste. Since that time, the site has functioned as a major storage and disposal facility with some permitted treatment of Laboratory-derived wastes since that time. There are four material disposal areas (MDAs) at TA-54 (Figure 1.2-2), which have been used to store and/or dispose of solid, sensitive (classified), hazardous, radioactive, or mixed waste generated at the Laboratory.

MDA G, the first disposal area, accepted its first shipment of radioactive waste in 1957 and is still in operation. The Department of Energy (DOE) authorized MDA G for the disposal of low-level and transuranic (TRU) radioactive waste and certain radioactively contaminated infectious waste, asbestos-contaminated material, and polychlorinated biphenyls (PCBs) and for the temporary placement of TRU waste. New Mexico Environment Department (NMED) issued a permit for the site for the storage of mixed waste. MDA L opened during the late 1950s for the disposal of liquid chemical waste; it is operating as a storage facility permitted by the Resource Conservation and Recovery Act (RCRA). MDA H opened in 1960 and was used for the disposal of classified, noncontainerized, solid wastes, some of which were residually contaminated with radioactive, hazardous, and high-explosive constituents. MDA H is no longer operational but has not undergone formal closure. Finally, MDA J has been used since 1961 for the disposal of administratively controlled solid wastes and for the storage and disposal of special wastes. MDA J will be closed in Fiscal Year 2001 as a solid waste and special waste facility in accordance with New Mexico Solid Waste Management Regulations, 20 NMAC 9.1, Subpart V. A closure plan has been submitted (Plum 1999, 63136). Rogers (1977, 5707 and 5708) and Chapter 2 of the RCRA facility investigation (RFI) work plan (LANL 1992, 7669) describe the TA-54 area and document the uses of the MDAs. The performance assessment and composite analysis report (Hollis et al. 1997, 63131) and the safety analysis report (LANL 1995, 63300) present additional information on MDA G.

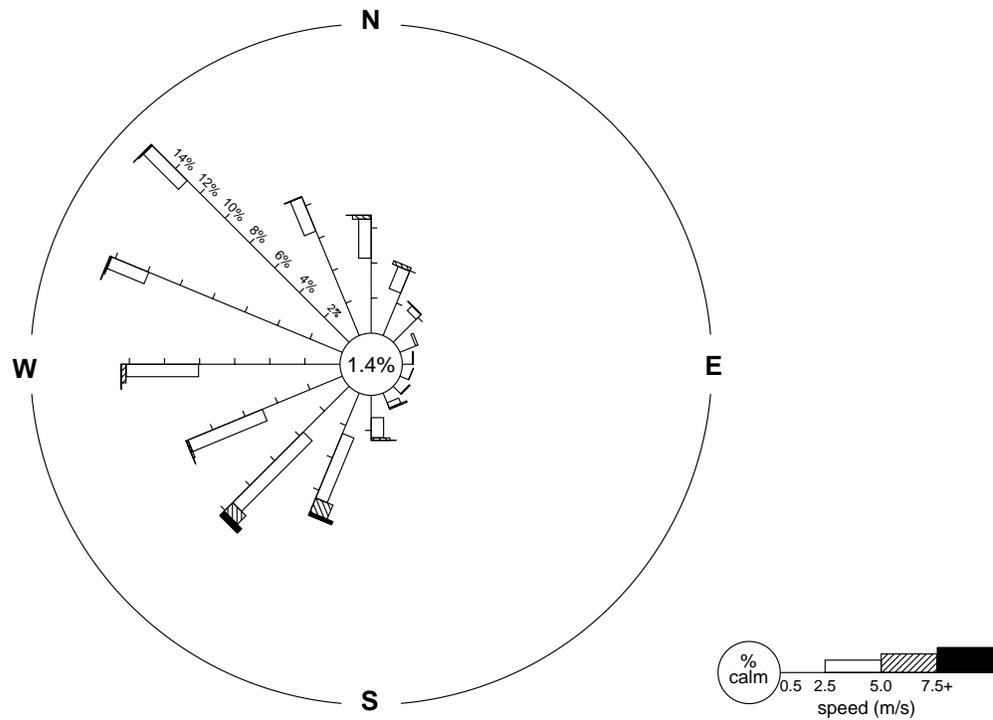
### **B-2.0 CLIMATE**

Mesita del Buey has a semiarid, temperate mountain climate (Bowen 1990, 6899). Average annual precipitation at a weather station at MDA G is approximately 14 in. (35.6 cm); about 40% of this occurs as brief, intense thunderstorms during July and August. Snowfall is greatest from December through March; heavy snowfall is infrequent during other months. Surface water runoff can occur during summer thunderstorms, frontal storms, and snowmelt periods, but the majority of runoff and resultant erosion probably occurs during the summer thunderstorm period. The canyon-mesa topography at TA-54 affects wind speed and direction in a dramatic way, as indicated by measurements taken at meteorological stations on Mesita del Buey and within Cañada del Buey and Pajarito Canyon. Comparisons of average annual wind roses (Figures B-2.0-1 and B-2.0-2) from the mesa-top and canyon meteorological towers reveal the channeling effect of the mesa-canyon topography. Mesa-top winds flow predominately south to southwest during the day. Canyon winds are strongly channeled; they flow predominately up canyon (north-northwest) during the day and down canyon (south-southeast) and across the mesa (east) at night. The strongest winds typically occur in the spring. Summer afternoon temperatures generally range between 70°F and 90°F, and typical winter temperatures range between 30°F and 50°F during the day and 15°F and 25°F at night.

Daytime



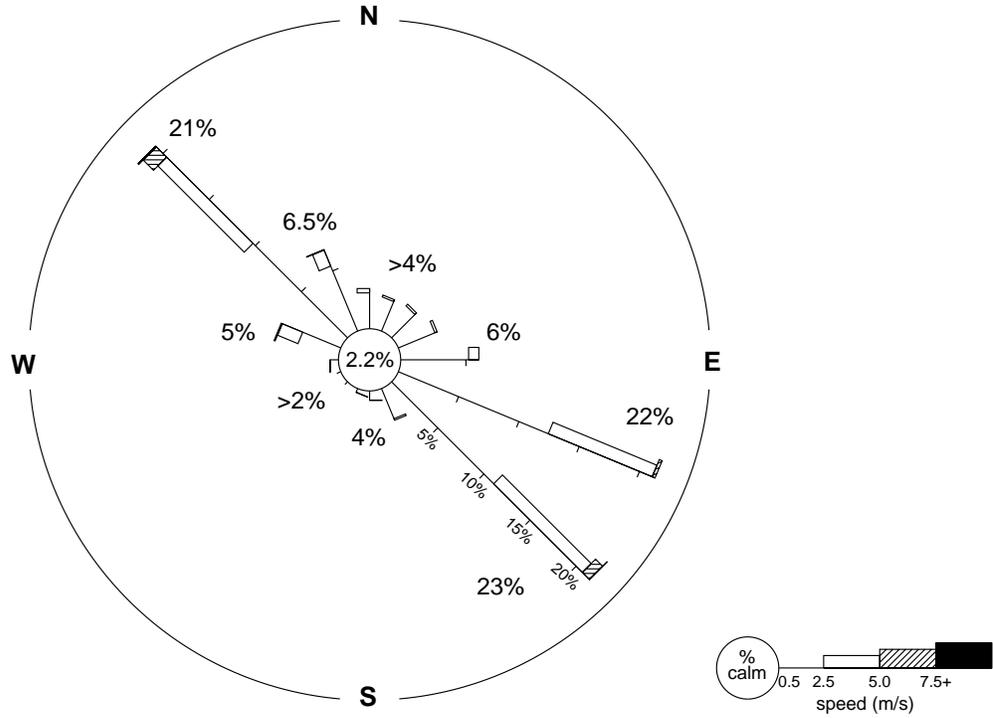
Nighttime



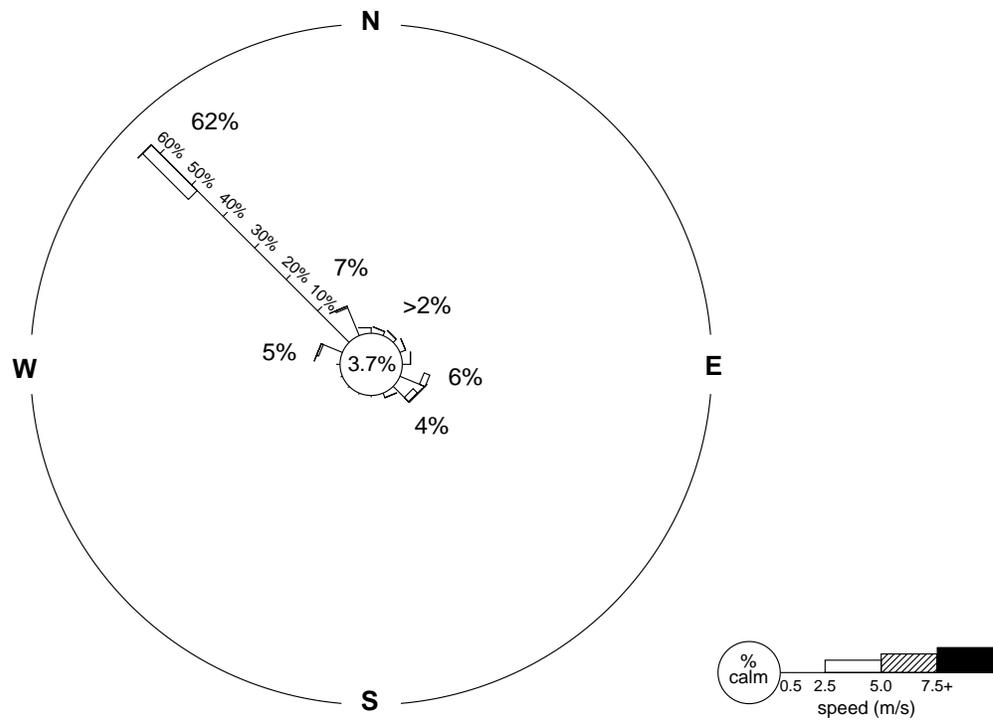
FB2.0-1/021401/RM

Figure B-2.0-1. Windroses from Mesita del Buey (1998)

Daytime



Nighttime



FB2.0-2/021401/RM

Figure B-2.0-2. Windroses from Pajarito Canyon (1995)

### **B-3.0 GEOLOGY**

Mesita del Buey is relatively flat and narrow, with steep sides draining into Cañada del Buey to the north and Pajarito Canyon to the south. The north-facing slope of the mesa has a gentler gradient than the south-facing slope. The south-facing slope of Mesita del Buey is almost vertical near the rim and becomes more gently sloped toward the canyon floor approximately 100 ft (30 m) below.

#### **B-3.1 Stratigraphy**

In the discussions below of Bandelier Tuff, the term *welding* is used to differentiate between tuffs that are uncompacted and porous (nonwelded) and those that are more compacted and dense (welded). In the field, the degree of welding in tuff is quantified by the degree of flattening of pumice fragments (a higher degree of flattening and elongation equals a higher degree of welding). Petrographically, welded tuffs show adhesion (welding) of grains while nonwelded tuffs do not. The term *devitrified* is applied to tuff whose volcanic glass has crystallized.

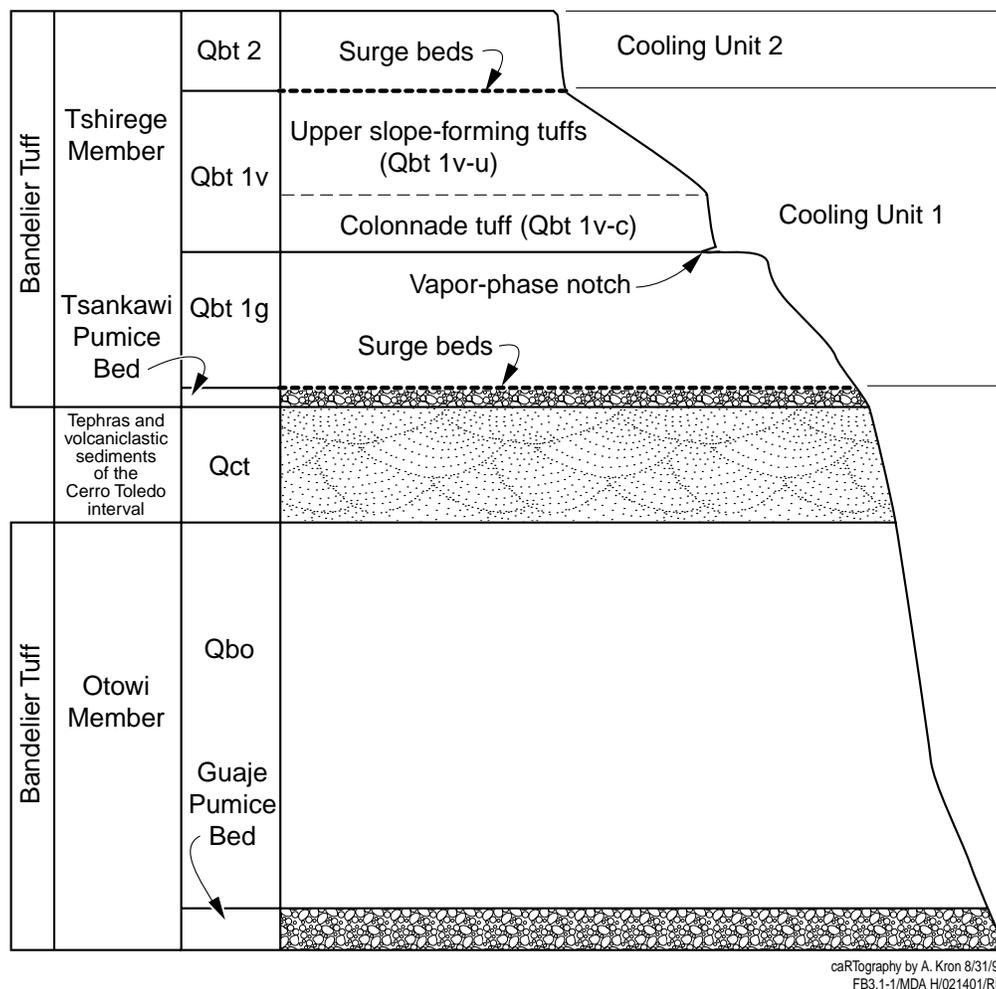
The Tshirege Member of the Bandelier Tuff is a compound cooling unit that resulted from several successive ash-flow deposits separated by periods of inactivity, which allowed for partial cooling of each unit. Properties related to water flow and contaminant migration (e.g., density, porosity, degree of welding, fracture content, and mineralogy) vary both vertically and laterally as a result of localized emplacement temperature, thickness, gas content, and composition. Figure B-3.1-1 shows the generalized stratigraphy of the area.

#### **Tshirege Member Unit 2 of the Bandelier Tuff**

Unit 2 of the Tshirege Member of the Bandelier Tuff is competent, resistant caprock that forms the surface of Mesita del Buey. Its thickness varies from 35 ft (10.7 m) near MDA H to 45 ft to 50 ft (13.7 m to 15.2 m) near MDA L to 39 ft (11.9 m) near MDA G. Where it is exposed, unit 2 forms nearly vertical cliffs on the sides of the mesa. The rock is described as a moderately welded ash-flow tuff composed of crystal-rich, devitrified pumice fragments in a matrix of ash, shards, and phenocrysts (primarily potassium feldspar and quartz).

Unit 2 is extensively fractured as a consequence of contraction during postdepositional cooling. The cooling-joint fractures are visible on mesa edges and on the walls of pits. In general, the fractures dissipate at the bottom of unit 2. On average, fractures in unit 2 are nearly vertical. Mean spacing between fractures ranges between 1.9 ft and 2.6 ft (0.6 m and 8.8 m), and fracture width ranges between less than 0.03 in. and 0.51 in. (1 mm and 13 mm) with a median of 0.12 in. (3 mm). Fractures are typically filled with clays to a depth of about 9.9 ft (3 m); smectites are the dominant clay minerals present. Smectites are known for their tendency to swell when water is present and for their ability to strongly bind certain elements, both of which have implications for transport of radionuclides in fractures. Opal and calcite can occur throughout the fractured length, usually in the presence of tree and plant roots (live and decomposed); the presence of both the minerals and the roots suggests some water at depth in fractures.

At the base of unit 2 is a series of thin, less than 3.9-in.-thick (10-cm-thick), discontinuous, crystal-rich, fine- to coarse-grained surge deposits. Bedding structures are often observed in these deposits. The surge beds mark the base of unit 2.



**Figure B-3.1-1. Generalized stratigraphy of TA-54**

### **Tshirege Member Unit 1v of the Bandelier Tuff**

Tshirege Member unit 1v is a vapor-phase-altered cooling unit underlying unit 2. This unit forms sloping outcrops, which contrast with the near-vertical cliffs of unit 2. Unit 1v is further subdivided into units 1vu and 1vc.

*Unit 1vu.* The uppermost portion of unit 1v is devitrified and vapor-phase-altered ash-fall and ash-flow tuff and has been designated unit 1vu, where u signifies upper. It is about 90 ft (27.4) thick near MDA H and thins to the east to about 46 ft (14 m) near MDA G. Unit 1vu is unconsolidated at its base and becomes moderately welded nearer the overlying unit 2. Only the more prominent cooling fractures originating in unit 2 continue into the more welded upper section of unit 1vu but die out in the less-consolidated lower section. More typically, fractures in unit 2 do not extend into unit 1vu.

*Unit 1vc.* Beneath unit 1vu is unit 1vc, where c stands for colonnade, named for the columnar jointing visible in cliffs formed from this unit. Unit 1vc is a poorly welded, devitrified ash-flow tuff at its base and top, becoming more welded in its interior. Unit 1vc is 23 ft to 26 ft (7 m to 8 m) thick in the eastern reaches of Mesita del Buey and 49 ft (15 m) thick in the western reaches.

### **Tshirege Member Unit 1g of the Bandelier Tuff**

The basal contact of unit 1vc is marked by a rapid change (within 0.7 ft [0.2 m] vertical) from devitrified (crystallized) matrix in unit 1vc to vitric (glassy) matrix in the underlying unit 1g. Vitric pumices in unit 1g stand out in relief on weathered outcrops, while devitrified pumices above this interval are weathered out. In outcrop, this devitrification interval forms a prominent erosional recess termed the *vapor-phase notch*. There is no depositional break associated with the vapor-phase notch; the abrupt transition suggests that this feature is the base of the devitrification that occurred in the hot interior of the cooling ash-flow sheet after emplacement.

Unit 1g is a vitric, pumiceous, nonwelded ash-flow tuff underlying the devitrified unit 1vc. It is about 150 ft (45.7 m) thick beneath MDA H and about 49 ft (15 m) thick beneath MDA G. Borehole 54-1023 at MDA H penetrated this unit. Few fractures are observed in the visible outcrops of this unit, and weathered cliff faces have a distinctive Swiss-cheese appearance because of the softness of the tuff. The uppermost 5 ft to 20 ft (1.5 m to 6.1 m) of unit 1g are iron-stained and slightly welded. This portion of unit 1g is resistant to erosion, helping to preserve the vapor-phase notch in outcrop. A distinctive pumice-poor surge deposit forms the base of unit 1g.

### **Tshirege Member of the Bandelier Tuff, Tsankawi Pumice Bed**

The Tsankawi Pumice Bed is the basal air-fall deposit of the Tshirege Member of the Bandelier Tuff. It is a thin bed of gravel-sized vitric pumice. It is about 3 ft (1 m) thick in the vicinity of MDA L and about 2 ft (0.6 m) thick at the eastern terminus.

### **Cerro Toledo Interval**

The Cerro Toledo interval consists of thin beds of tuffaceous sandstones, paleosols, siltstones, ash, and pumice falls; the Cerro Toledo interval separates the Tshirege and Otowi Members of the Bandelier Tuff. The Cerro Toledo interval also includes localized gravel- and cobble-rich fluvial deposits predominantly derived from intermediate composition lavas eroded from the Jemez Mountains west of the Pajarito Plateau. The interval thins to 20 ft (6.1 m) at the eastern portion of MDA G. Borehole 54-1023 at MDA H penetrated this unit.

### **Otowi Member of the Bandelier Tuff**

The Otowi Member tuffs are about 98 ft (30 m) thick in the northwestern portion of Mesita del Buey and become thinner toward MDA G. The tuffs are a massive, nonwelded, pumice-rich, and mostly vitric ash flow. The pumices are fully inflated, supporting tubular structures that have not collapsed as a result of welding. The matrix is an unsorted mix of glass shards, phenocrysts, perlite clasts, and minute, broken pumice fragments.

### **Otowi Member of the Bandelier Tuff, Guaje Pumice Bed**

The Guaje Pumice Bed is the basal air-fall deposit of the Otowi Member of the Bandelier Tuff. The thickness of the unit has been measured as 10 ft (3 m) in the northwestern reaches of Mesita del Buey and as 12 ft (3.7 m) in Pajarito Canyon south of MDA G. It has not been penetrated by drilling at the eastern part of the mesa. The pumice bed is nonwelded but brittle. Pumice tubes are partially filled with silica cement.

## **Cerros del Rio Basalts**

Few data exist to describe the Cerros del Rio basalts directly beneath TA-54. Local borehole cores at MDA L show that the basalts consist of both angular rubble and dense, fractured masses, with zones of moderately to very porous lavas. Based on the borehole data at MDA L, it is inferred that the Cerros del Rio basalts exist beneath Mesita del Buey. The thickness of the basalt beneath TA-54 is extrapolated to be between 262 ft (79.9 m) and 492 ft (150 m).

## **Puye Formation**

The depth to and thickness of the Puye Formation beneath TA-54 has not been determined. However, 1750 ft (533 m) of Puye Formation sedimentary rocks were encountered beneath 82 ft (24 m) of basalt in a water-supply well in Pajarito Canyon about 0.9 mi (1.5 km) west of Mesita del Buey. The lower part of the Puye Formation hosts the regional aquifer beneath Mesita del Buey.

### **B-3.2 Geochemistry**

Certain minerals present in Bandelier Tuff are important in terms of sorption of chemical species from water. Among them are alkali feldspar and a combination of three silica polymorphs (i.e., quartz, cristobalite, and tridymite). These minerals are found throughout the thickness of the Bandelier Tuff, and their absolute abundance throughout the tuff can have a significant effect on the retardation of several constituents in the TA-54 MDA inventories. Less important in terms of transport are organic materials, which can react with certain constituents to form relatively mobile compounds. The organic content of geologic materials on the Pajarito Plateau mesas is typically less than 1 wt %. However, the fractures can contain higher organic concentrations than the tuff matrix.

In addition to the minerals found in the tuff matrix, clay minerals are found in abundance in fractures and interbeds in the Bandelier Tuff. The primary clay minerals are smectites, with lesser amounts of kaolinite. The clay minerals have high sorptive capacity for many TA-54 inventory constituents. Hematite (i.e., iron oxide) coatings are also found but with less frequency than clay coatings. Hematite has a very large surface area for binding certain metals and is therefore also important when considering transport in fractures.

Clay, iron oxide, carbonate minerals, and solid organic matter are known to be present in ancient, buried soils (paleosols) found elsewhere across the Laboratory. In particular, the Cerro Toledo interval, Guaje Pumice Bed, and Puye Formation are known to have buried soils. The occurrence of clay-rich horizons in the subsurface is not known beneath TA-54; however, they may be important (e.g., the Cerro Toledo interval commonly contains paleosol horizons). Vertical water flow may be inhibited and lateral flow enhanced by clay layers; clay has a low permeability. Furthermore, certain inventory constituents would be sorbed onto or complexed with the soil minerals and organic matter present in such zones. Because of these potentially important effects, field and laboratory investigations are underway to identify and characterize clay-rich soil horizons beneath Mesita del Buey.

### **B-3.3 Seismology**

There are three major faults that are considered significant with respect to seismic potential across the Laboratory complex: the Pajarito, the Guaje Mountain, and the Rendija Canyon faults. The locations of these faults with respect to TA-54 are shown in Figure B-3.3-1.

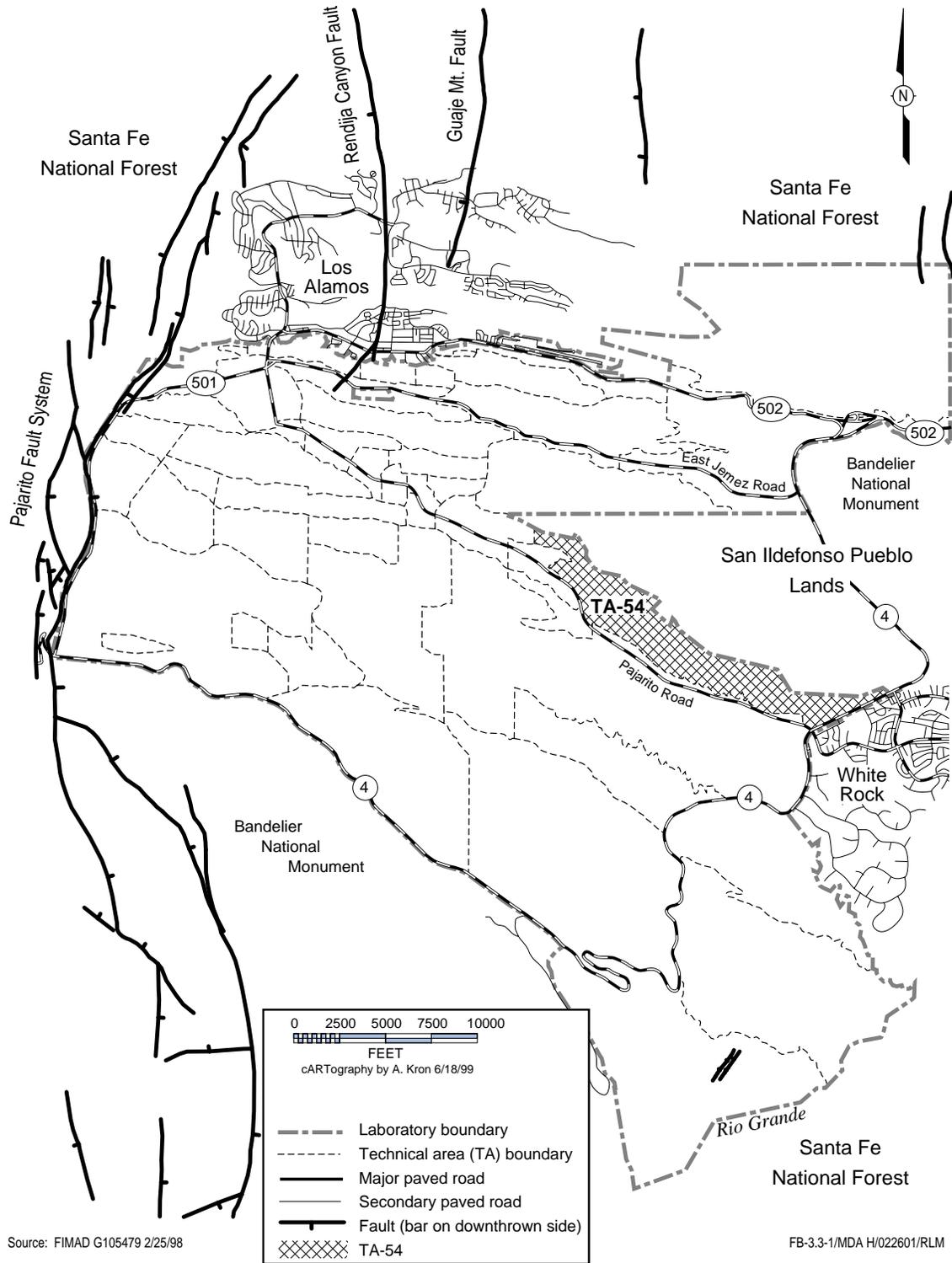


Figure B-3.3-1. Locations of major faults in Laboratory complex

The Pajarito fault is a normal fault, is downthrown to the east, and extends along the western margin of the Laboratory. It defines the active western boundary of the Rio Grande rift and has an average slip rate of 0.003 in./yr (0.07 mm/yr). The Rendija Canyon and Guaje Mountain faults are also normal faults, are downthrown to the west, and are considered secondary faults within the Pajarito fault system. The Rendija Canyon fault is located 3 mi (3 km) east of the Pajarito fault, and the Guaje Mountain fault is located about 1.2 mi (2 km) east of the Rendija Canyon fault. Geologic evidence reveals that the Pajarito fault has ruptured within the past 1.2 million yr, perhaps as recently as 50,000 yr ago. Field investigations show that the Rendija Canyon fault has ruptured within the past 10,000 yr and that the Guaje Mountain fault has ruptured within the past 6000 yr. The recurrence interval of seismic events along the Rendija Canyon and Guaje Mountain faults is estimated to be between 10,000 and 150,000 yr.

A number of small to moderate earthquakes not associated with mapped faults (termed *background* earthquakes) have occurred in north-central New Mexico within the past 100 yr. Since 1973, local seismicity has been monitored by the Los Alamos Seismograph Network. Measured events have not exceeded a magnitude of 4, which is relatively weak compared with earthquakes producing damage to buildings and structures.

Recently, a seismic hazard evaluation was completed to estimate ground motion from possible earthquakes at several sites around the Laboratory. The objective was to determine the design criteria for several nuclear facilities based on potential seismic hazards in accordance with DOE Order 5480.28, "Natural Phenomena Hazards Mitigation." The evaluation led to the following conclusions:

- within 100 yr, a magnitude 6 background earthquake is considered likely, and
- within 10,000 yr, a magnitude 7 Pajarito fault system quake is considered unlikely.

Whether a magnitude 6 or 7 earthquake would result in surface rupture depends on the local geologic conditions, including mesa topography and sequential welded and nonwelded Bandelier Tuff. Peak horizontal accelerations between 0.4 g and 0.6 g were estimated for the sites included in the study. While TA-54 was not included in the study, its geology is similar to two other sites considered (TA-18 and TA-46); results of the study were applied in the safety analysis report for MDA G (LANL 1995, 63300). In the SAR, the maximum design-basis earthquake considered that facility structures must be capable of withstanding was 0.57 g. Such an earthquake was determined not to pose a risk in terms of waste buried below the surface.

### **B-3.4 Soils**

Soils of Mesita del Buey form from the weathering of the Tshirege Member tuffs (phenocrysts and phenocryst fragments, devitrified glass, and minor lithic fragments) and wind-blown sources. Soils on the flanks of the mesa are developed on Tshirege Member tuffs and colluvium with additions from wind-blown and water-transported sources. Native soils have been disturbed by waste management operations over much of the surface of the mesa, but when present, native soils are thickest near the center of the mesa and thinner toward the edges. In general, soils can be considered thin and poorly developed on the mesa surface; they tend to be sandy in texture near the surface and are more clay-like beneath the surface. More highly developed soil profiles exist on the north-facing slopes; they tend to be richer in organic matter. Soil profiles on the south-facing slopes tend to be poorly developed. Soil-forming processes have been identified along fractures in the upper part of the mesa, and the translocation of clay minerals from surface soils into fractures has been described at Mesita del Buey (Reneau and Vaniman 1998, 63135). A discussion of the soils in the Los Alamos area is located in Section 2.5.1.3 of the Environmental Restoration (ER) Project installation work plan (LANL 1995, 49822). The soils on the mesa top at TA-54 were mapped by Nyhan et al. (1978, 5702).

## B-4.0 HYDROLOGY

The hydrogeology of the Pajarito Plateau is generally separable in terms of mesas and canyons forming the plateau. Mesas are generally devoid of water, both on the surface and within the rock forming the mesa. Canyons range from wet to relatively dry; the wettest canyons contain continuous streams and contain perennial groundwater in the canyon-bottom alluvium. Dry canyons have only occasional stream flow and may lack alluvial groundwater. Intermediate perched groundwater has been found at certain locations on the plateau at depths ranging between 100 ft and 400 ft (30 m and 122 m). The regional aquifer is found at depths of about 600 ft to 1200 ft (180 m and 360 m).

### B-4.1 Hydrogeologic Conceptual Model

The hydrogeologic model (Figure B-4.1-1) shows that relatively small volumes of water move beneath mesa tops under natural conditions; this is because of low rainfall, high evaporation, and efficient water use by vegetation. Atmospheric evaporation may extend deeper into mesas, further inhibiting downward flow.

The amount of mesa-top recharge along the western portion of the Laboratory is uncertain. Higher rainfall, increased vegetative cover, and increased welding and jointing of the tuff might lead to different recharge rates than those observed in better-studied portions of the Laboratory. Mesa-top recharge can be locally significant under disturbed surface conditions. Such change occurs when the soil is compacted, when the vegetation is disturbed, or when more water is artificially added to the hydrologic system by features such as blacktop, lagoons, or effluent disposal. Fractures within mesas do not enhance the movement of dissolved contaminants unless saturated conditions develop. Contaminants in vapor form readily migrate through mesas. Vapors denser than air will sink.

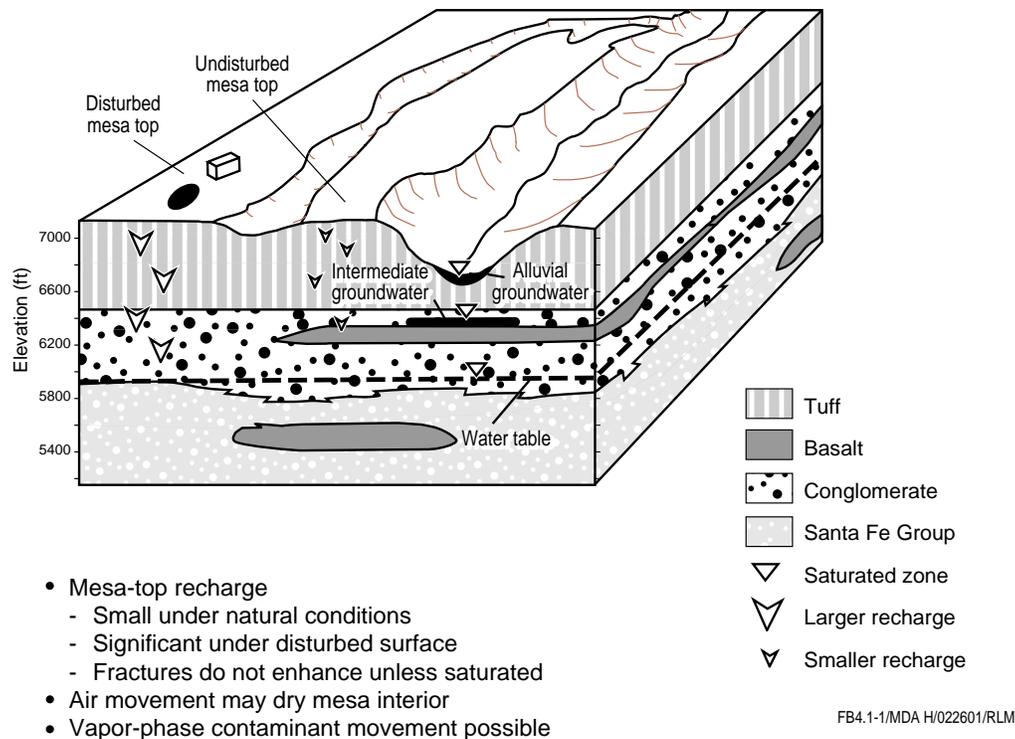


Figure B-4.1-1. Hydrogeologic conceptual model for mesas

## B-4.2 Surface Water

The Rio Grande is the master stream in north-central New Mexico. All surface water drainage and groundwater discharge from Pajarito Plateau ultimately arrive at the Rio Grande. The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 14,300 mi<sup>2</sup> (37,180 km<sup>2</sup>) in southern Colorado and northern New Mexico. The discharge for the period of record (1890–1985) has ranged between a minimum of 6980 ft<sup>3</sup> per second (1.7 m<sup>3</sup> per second) in 1902 and 24,400 ft<sup>3</sup> per second (690.8 m<sup>3</sup> per second) in 1920. The river transports about 1 million tons (910,000 metric tons) of suspended sediments past Otowi annually (Graf 1993, 23251). Essentially all Rio Grande flow passes through Cochiti Reservoir (downstream of the Laboratory), which began filling in 1976. The dam is expected to trap at least 90% of the sediments carried by the river (Graf 1993, 23251).

Figure B-4.2-1 shows the locations of the major surface water drainages in the Los Alamos area. Included in Figure B-4.2-1 are the ephemeral, intermittent, and perennial reaches of surface waters; the major wastewater effluent-created reaches; and springs. Naturally perennial surface water reaches are located in Ancho, Pajarito, and Chaquehui Canyons. Within Laboratory boundaries, perennial reaches in the lower portions of Ancho Canyon and Chaquehui Canyon are close enough to the Rio Grande that they extend to the river without being depleted. 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, followed by an intermittent reach that flows varying distances, depending on climate conditions. Another perennial reach in Pajarito Canyon is located west of the Laboratory boundary below PC Spring; it terminates by infiltration into the alluvium (LANL 1998, 59577). Occasionally, during heavy runoff years, Pajarito Canyon sustains flow, which sometimes extends as far as the Rio Grande (LANL 1998, 59577). Essentially all other reaches of canyons (including Cañada del Buey) within the Laboratory's boundaries are ephemeral; that is, they flow in response to precipitation or snowmelt in the immediate locality. Snowmelt recharges the alluvial groundwater, and discharge from springs supports stream flow for a somewhat longer period.

The canyons of 11 drainage areas, with a total area of 82 mi<sup>2</sup> (213.2<sup>2</sup> km), pass through the Laboratory's eastern boundary. Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year in some drainages. Los Alamos, Pajarito, and Water Canyons have drainage areas upstream of the east Laboratory boundary that are greater than 10 mi<sup>2</sup> (26 km<sup>2</sup>). Pueblo Canyon has 8 mi<sup>2</sup> (20.8 km<sup>2</sup>), and the rest have less than 5 mi<sup>2</sup> (13 km<sup>2</sup>). Theoretical maximum flood peaks range between 24 ft<sup>3</sup> per second (0.68 m<sup>3</sup> per second) for a 2-yr frequency and 686 ft<sup>3</sup> per second (19.4 m<sup>3</sup> per second) for a 50-yr frequency (McLin 1992, 12014). The overall flooding risk to community and Laboratory buildings is low because nearly all the structures are located on the mesa tops, from which runoff drains rapidly into the deep canyons.

There are no streams on Mesita del Buey; water flows only as stormwater and snowmelt runoff on the mesa and in small drainages off the mesa to the north and the south. Stormwater flows at a number of points along the perimeter of TA-54, as identified and characterized in the "Stormwater Pollution Prevention Plan," which is being prepared for the National Pollutant Discharge Elimination System Permit pursuant to the Clean Water Act. Flooding of the facility is, therefore, not a concern. As a result of runoff, surface erosion occurs, primarily as shallow sheet erosion on the relatively flat parts of the mesa and as channel erosion in major drainages from the mesa top. Runoff from summer storms reaches a maximum in less than 2 hr and lasts less than 24 hr. In contrast, runoff from spring snowmelt occurs over a period of several weeks at a low discharge rate. The amount of eroded material transported in runoff waters is generally higher in summer rainfall events than during snowmelt (Hollis et al. 1997, 63131, p. 2-33).



The Laboratory's ER Project has assessed sediment transport and erosion concerns at over 1000 potential release sites (PRSs). The surface water assessment provides a basis for prioritizing and scheduling actions to control erosion of potentially contaminated soils at specific PRSs. The procedure is a two-part evaluation. Part A is a compilation of existing PRS analytical data, site maps, and knowledge-of-process information. Part B is an assessment of the erosion/sediment transport potential at the PRS. Erosion potential is numerically rated from 1 to 100 using a matrix system. PRSs that score below 40 have a low erosion potential, those that score from 40 to 60 have a medium erosion potential, and those that score above 60 have a high erosion potential. Part A of this assessment is initiated and completed by the Laboratory's ER Project; Part B is completed by the Laboratory's Water Quality and Hydrology Group (ESH-18). A Surface Water Assessment Team, composed of representatives from the ER Project, ESH-18, the Laboratory's Facility Management Group (FSS-7), and the NMED DOE Oversight Bureau, evaluates each completed assessment. If necessary, a best management practice or other action is implemented based on the results of the assessment. PRS 54-004, MDA H, has a score of 45.6, indicating a moderate erosion potential. The calculated erosion matrix score includes 3.6 for site setting, a runoff score of 35.0, and a run-on score of 7.0. The surface water assessment for MDA H is attached at the end of this appendix.

### **B-4.3 Groundwater**

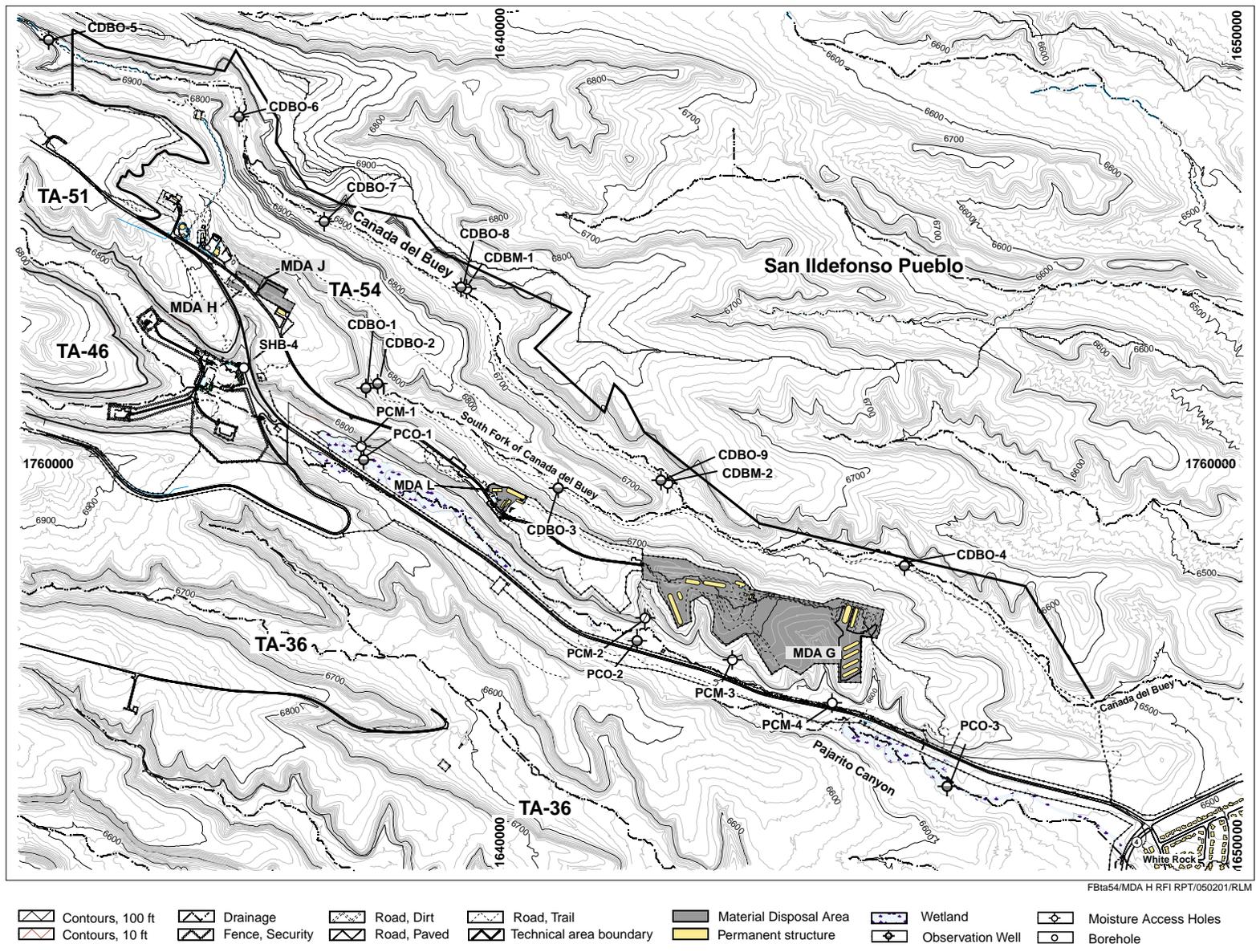
Groundwater in the area of the Laboratory occurs as

- shallow alluvial groundwater in canyons,
- perched zones beneath some canyons and along the Jemez Mountains (within the Bandelier Tuff, the Cerros del Rio basalts, and the upper part of the Puye Formation), and
- the regional aquifer.

#### **B-4.3.1 Alluvial Waters**

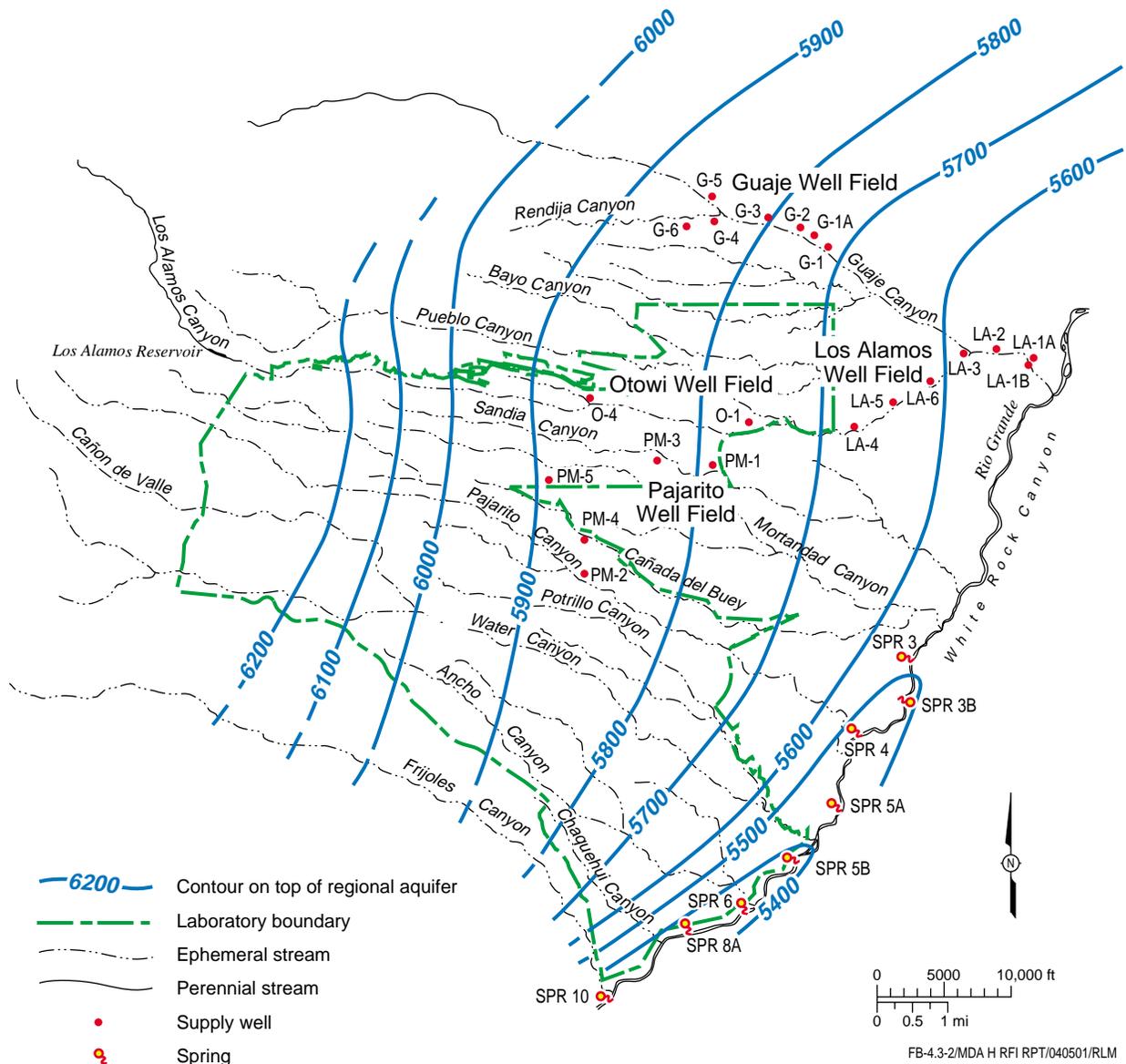
The hydrologic characteristics of the canyons bordering Mesita del Buey may influence the hydrology beneath the mesa. To the north, Cañada del Buey contains an intermittent stream. The alluvium is thin; it ranges between 4 ft (1.2 m) and 19 ft (5.7 m), but the underlying weathered tuff ranges in thickness between 12 ft (3.7 m) and 39.6 ft (12 m) (LANL 1999, 64617, p. D-11). Nine observation wells and two moisture-access holes have been installed in Cañada del Buey (CDBO-1 through CDBO-4 in 1985 and CDBO-5 through CDBO-9, CDBM-1, and CDBM-2 in 1992) to detect alluvial water (Figure B-4.3-1). Groundwater has been observed and sampled annually in two of the wells (CDBO-6 and CDBO-7) since their installation (Environmental Protection Group 1994, 45363; Environmental Surveillance Program 1999, 64034); the remaining holes are dry (Purtymun 1995, 45344, pp. 113–114). However, the saturation observed in CDBO-6 and CDBO-7 appears not to be present in the alluvium but rather is perched in the underlying tuff; additional discussion of this groundwater is presented in Section B-4.3.2.

Pajarito Canyon, to the south, also contains an intermittent stream, but the larger flow in this canyon maintains perennial groundwater in the alluvium. Semipermanent wetlands have developed in borrow pits that were excavated in lower Pajarito Canyon east of TA-18 and south of Mesita del Buey. The wetlands frequently contain ponded water from local stormwater runoff, Laboratory discharges, or streamflow (LANL 1998, 59577, p. 3-37). The surface of the water in the wetlands probably coincides with the alluvial water table (Environmental Restoration Project 1996, 55120, p. 6). Potentially one of the largest volumes of discharge to Pajarito Canyon may be from occasional purging of nearby municipal water supply well PM-2 (Figure B-4.3-2). Some years this well is only operated during the summer months, which requires several days of pumping 1000 to 1500 gpm (3800 to 5700 L/m) to clean out the well bore. At times, this may be one of the primary sources of surface water in lower Pajarito Canyon (LANL 1998, 59577, p. 3-37).



FBIa54/MDA H RFI RPT/050201/RLM

Figure B-4.3-1. Locations of wells and holes for locating alluvial and perched water at TA-54



**Figure B-4.3-2. Locations of wells and generalized water-level contours on top of the regional aquifer (modified from Purtymun 1984, 6513)**

In 1985, three observation wells (PCO-1 through PCO-3) were installed in lower Pajarito Canyon east of TA-18 (Figure B-4.3-1). The three wells were drilled and cased in the canyon near the stream channel to outline the geology and provide a monitoring network of the water in the alluvium perched on the underlying tuff. Alluvial water was identified at depths of 1.3 ft (0.4 m) in PCO-1, 6.3 ft (1.9 m) in PCO-2, and 3.1 ft (0.93 m) in PCO-3 (Devaurs and Purtymun 1985, 7415, p. 12).

In Cañada del Buey, the infiltration rate estimated for the MDA G performance assessment (Hollis et al. 1997, 63131) using in situ moisture contents and hydrologic properties determined from cores is 0.17 in./yr (0.44 cm/yr). Data are not available to estimate infiltration rates in Pajarito Canyon. However, data are available from Mortandad Canyon, which has similar characteristics. Estimates of infiltration rates in that canyon range between 0.8 and 4 in./yr (2 and 10 cm/yr).

Evapotranspiration data for alluvial groundwater in Pajarito Canyon and Cañada del Buey are not available. However, estimates for nearby watersheds are available for comparison. Some studies for Mortandad Canyon indicate approximately 20% of the input to the stream channel is ultimately lost to evapotranspiration (Purtymun 1974, 5476, p. 7). A study of the Los Alamos Canyon system indicated that approximately 75% to 85% of the total input to the watershed is lost to evapotranspiration (Gray 1997, 58208, p. 68).

#### **B-4.3.2 Perched Waters**

No perched groundwater has been identified below Mesita del Buey (LANL 1998, 59599). In 1985, four moisture-access holes (PCM-1 through PCM-4) were installed in lower Pajarito Canyon north of the stream channel along the mesa wall to outline the aquifer and to determine whether the aquifer extended beyond the alluvium (Figure B-4.3-1). The moisture-access holes were drilled to depths ranging between 60 ft (18 m) and 100 ft (30 m); all four holes were dry. These holes “document that perched water in Pajarito Canyon, adjacent to Mesita del Buey, is confined to the alluvium in the stream channel and does not extend to the flank of the canyon” (Devaurs and Purtymun 1985, 7415, p. 12).

No perched intermediate zones of saturation have been delineated beneath Pajarito Canyon; however, possible intermediate wet zones have been reported in two boreholes at TA-18. In borehole SHB-4 (Figure B-4.3-1), wet core samples were retrieved from the interval of 125 ft to 145 ft (38 m to 44 m) within the Cerro Toledo interval. RFI borehole 54-1023 at MDA H (Figure 2.2-1) was drilled into the top of the Cerro Toledo interval but did not encounter saturation within or beneath the mesa. In PM-2 (Figure B-4.3-2), a possible wet zone was reported as “a show of water at 335 ft” (102 m), which may indicate a zone of intermediate perched groundwater (Cooper et al. 1965, 8582, p. 56; Davis et al. 1996, 55446). The pilot hole for this well was drilled using cable tools to a depth of 617 ft (185 m). No other mention of water in the unsaturated zone is found in the descriptive log of drill cuttings for this well (Cooper et al. 1965, 8582, pp. 55–61). Electrical resistivity (geophysical) logs of the borehole at PM-2 did not confirm the presence of water at 335 ft (102 m). The middle of the Otowi Member is present in PM-2 at a depth of 335 ft (102 m); this zone has not previously been observed to contain perched groundwater.

In Cañada del Buey, an isolated 0.5-mi-long (0.8-km-long) segment of saturation has been identified in boreholes CDBO-6 and CDBO-7 (Figure B-4.3-1). The saturation may represent a perched groundwater zone present in the colonnade tuff at the base of unit 1v of the Tshirege Member of the Bandelier Tuff (LANL 1999, 64617, p. 115) (Figure B-4.3-1). When the holes were drilled in 1992, a 10-ft-thick (3-m-thick) perched water zone was encountered from 34 ft to 44 ft (10.3 m to 13.4 m) in CDBO-6, and a 1-ft- to 2-ft-thick (0.3-m- to 0.6-m-thick) zone of perched groundwater was encountered in CDBO-7 (the depth of the zone was not stated in the drilling information but was probably between 38 ft and 39 ft [11.6 m and 11.9 m]) (Environmental Protection Group 1995, 50285, p. VII-26; Purtymun 1995, 45344, p. 131; LANL 1999, 64617, p. 115). The depth of the alluvium at these two boreholes is 19 ft (5.7 m); the tops of the 10-ft screened intervals within the boreholes are located approximately 15 ft (CDBO-6) and 10 ft (CDBO-7) below the base of the overlying alluvium and are within the tuff (LANL 1999, 64617, pp. D-9 and D-11). Since 1992, water levels have ranged between 0 ft (dry) and 12 ft (saturated) in CDBO-6 and between 0 ft (dry) and 7 ft (saturated) in CDBO-7 (LANL 1996, 55430, p. 4-16). Water levels have typically been measured three times each year since 1995. Significant seasonal variations are not apparent, and the water levels have typically varied by less than 5 ft (1.5 m) (LANL 1999, 64617, p. 3-117). Laboratory group ESH-18 has previously identified the source of the saturation as purge water from nearby municipal water supply well PM-4 (Figure B-4.3-2) because the alluvium is dry upstream of the purge water entry point. Discharges from PM-4 occurred twice in 1998 but only once in the previous four years. Such limited releases would be insufficient to maintain saturation found at the two alluvial observation wells

(Environmental Surveillance Program 1999, 64034, p. 136). It is unknown whether the observed perched saturated zone extends laterally in a direction perpendicular to the stream channel.

### B-4.3.3 Regional Aquifer

The regional aquifer of the Los Alamos area is the only aquifer capable of large-scale municipal water supply (Purtymun 1984, 6513). There have been 21 supply wells and 10 test wells drilled into the regional aquifer on or adjacent to the Pajarito Plateau. The 21 supply wells are in four well fields: Los Alamos (seven wells), Guaje (seven wells), Pajarito (five wells), and Otowi (two wells). These well fields are identified in Figure B-4.3-2. The hydrologic characteristics of the regional aquifer measured at each of the supply wells and at eight of the test wells differ because of the geology of the aquifer and the thickness of the saturated zone penetrated by the well.

The Pajarito Field (the field nearest TA-54) contains the most productive supply wells, as suggested by the characteristics shown in Table B-4.3-1. The average saturated thickness of the regional aquifer penetrated by the Pajarito Field wells is 1810 ft (550 m). The age of water in the regional aquifer ranges between a few thousand and more than 40,000 yr, with the youngest water occurring to the west and the oldest to the east. A portion of the regional aquifer discharges into the Rio Grande east of the Laboratory; the 11-mi (18-km) reach of the Rio Grande in White Rock Canyon receives about 5500 acre-ft (6.8 million m<sup>3</sup>) annually as discharge from the aquifer.

**Table B-4.3-1**  
**Hydrologic Characteristics of Pajarito Field Water Supply Wells**

Well Designation	Saturated Thickness, ft (m)	Pumping Rate, gal./min. (L/m)
PM-2	1739 (530)	1401 (5390)
PM-4	1870 (570)	1489 (5728)
PM-5	1910 (582)	2019 (7764)

The surface of the regional aquifer rises westward from the Rio Grande within the Santa Fe Group into the lower part of the Puye Formation beneath the central and western part of the Pajarito Plateau (Figure B-4.3-2). The depths to groundwater below the mesa tops range between about 1200 ft (366 m) along the western margin of the plateau and about 600 ft (183 m) at the eastern margin. The regional aquifer is separated from the alluvial groundwater and intermediate perched zone groundwater by 350 ft to 620 ft (106.7 m to 189 m) of tuff, basalt, and sediments (Environmental Protection Group 1993, 23249). The regional aquifer exhibits artesian conditions in the eastern part along the Rio Grande (Purtymun 1984, 6513). Continuously recorded water-level measurements collected in test wells since the fall of 1992 indicate that, throughout the plateau, the regional aquifer responds to barometric and earth tide effects in the manner typical of confined aquifers.

The hydraulic gradient of the regional aquifer averages about 60 to 80 ft/mi within the Puye Formation but increases to 80 to 100 ft/mi along the eastern edge of the plateau as the groundwater enters the less permeable sediments of the Santa Fe Group. The rate of movement of groundwater in the upper section of the aquifer varies depending on the materials in the aquifer. Aquifer tests indicate that the rate of movement ranges between 20 ft/yr in the Tesuque Formation and 345 ft/yr in the more permeable Puye Formation (Purtymun 1984, 6513). The highest-yielding water supply wells are located within the late Miocene trough described by Purtymun (1984, 6513).

There is considerable uncertainty regarding recharge along the Jemez Mountains. Infiltration of stream flow occurs along the mountain flanks, but the limited drilling to date generally has not indicated the presence of significant recharge. Major recharge of the regional aquifer from the west is inferred because the piezometric surface slopes downward to the east (Figure B-4.3-2). Cushman (1965, 8584) suggested three sources of recharge: infiltration of runoff in canyons, underflow from the Valles Caldera through the Tschicoma Formation, and infiltration on mesas. However, a large quantity of hydrologic, structural, and geochemical data indicate that the caldera may not serve as an appreciable source of recharge to the regional aquifer (Conover et al. 1963, 57044; Griggs 1955, 8795; Goff 1991, 57039). Furthermore, natural recharge through undisturbed Bandelier Tuff on the mesa tops is believed to be insignificant (Purtymun and Kennedy 1971, 4798; Kearl et al. 1986, 15368), and few or no data exist to support an evaluation of canyon runoff as a recharge source.

The total volume of annual recharge near the Pajarito Plateau is apparently less than the quantity of municipal water production (approximately 5000 acre-ft/yr). This is based on an overall decline in regional aquifer water levels across the plateau since pumping began in the 1950s.

#### **B-4.4 Vadose Zone**

The region beneath the mesa surface and above the regional aquifer is referred to as the vadose zone. The source of moisture in the vadose zone is precipitation, but much of the precipitation is removed as runoff, evaporation, and transpiration. The subsurface vertical movement of the remaining water (often referred to as recharge) is influenced by properties and conditions of the vadose zone.

Two properties of rock that influence fluid flow are the degree of welding and devitrification, which are both effects of prolonged presence of residual gases and high temperatures when the rock was deposited. Because different units of the Bandelier Tuff were deposited at different temperatures and because individual units were laid out in variable thicknesses over different landscapes, cooling was not uniform. Consequently, welding varies spatially, both between and within separate depositional layers. There are several competing effects that determine moisture content and fluid flux in welded, devitrified tuff. Welded tuffs tend to be more fractured than nonwelded tuffs. While water moves slowly through the unsaturated tuff matrix, it can move relatively rapidly through fractures if nearly saturated conditions exist (Hollis et al. 1997, 63131). Modeling studies indicate that when fractures disappear at contacts between stratigraphic subunits, when fracture fills are encountered, or when coatings are interrupted, moisture is absorbed into the matrix. Thus, fractures may provide conduits for fluid flow but only in discrete, disconnected intervals of the subsurface. Because they are open to the passage of both air and water, fractures can have both wetting and drying effects, depending on the relative abundance of water in the fractures and matrix.

As a rule, the Bandelier Tuff, which forms Mesita del Buey, is very dry and does not readily transmit moisture. Most of the pore spaces in the tuff are small enough to be of capillary size and have a strong tendency to hold water against gravity by surface-tension forces. Moisture content is generally more variable near the top of the mesa than in the central portions as a result of variations in temperature, humidity, and evapotranspiration. Vegetation is very effective at removing moisture near the surface. During the summer rainy season when rainfall is highest, near-surface moisture content is variable because of the effects of higher rates of evaporation and of transpiration by vegetation, which flourishes during this time.

Table B-4.4-1 summarizes measurements and observations on core samples retrieved from boreholes drilled at MDA G. The properties listed in the table are

- lithology, which is a general macroscopic description of the rock;
- fracture spacing, which is the distance measured between fractures (in meters);
- fracture dip, which is the angle of the fracture relative to horizontal (in degrees);
- fracture aperture, which is the width of the fracture (in millimeters);
- mean density, which is the mass of rock per unit volume of rock (in grams per cubic centimeter);
- mean porosity, which is the ratio of the air-filled volume to the total volume of the rock (in percent);
- mean volumetric moisture, which is the ratio of the water volume to the total volume of the rock (in percent);
- saturation, which is the ratio of the pore volume containing water to the total porosity (in percent);
- saturated hydraulic conductivity ( $K_{\text{sat}}$ ), which is the rate at which moisture moves through rock under the influence of gravity when the rock is fully saturated (in centimeters per second); and
- van Genuchten parameters  $\theta_r$ ,  $\alpha$ , and  $n$ , which are derived parameters used to model moisture movement in rock (van Genuchten 1980, 63542).

These data are obtained from either intact tuff (e.g., fracture spacing), from direct measurements of rock samples from TA-54 (e.g., density), or from experiments performed on rock samples (e.g.,  $K_{\text{sat}}$ ). The van Genuchten parameters are derived from characteristic curves, which are relationships required to model unsaturated liquid flow through rock. They include moisture retention curves that describe the energy state or tension of pore water in tuff and the hydraulic conductivity ( $K$ ) of the rock. The moisture tension curve of a material is the relationship between suction within the matrix and the volumetric water content (i.e., the volume of water contained in a volume of tuff) for a porous material. Hydraulic conductivity is simply the rate at which water can travel through a sample of rock or soil under the influence of gravity. In general, soils and rock have higher hydraulic conductivity when more moisture is present; the maximum occurs when the material is fully saturated with water and is called the saturated hydraulic conductivity. In unsaturated media, both the hydraulic conductivity and the tension are highly nonlinear functions of the water content and are complicated by hysteresis.

Unsaturated hydraulic conductivity curves for five units of the TA-54 subsurface are plotted in Figure 2-13 of the performance assessment report (Hollis et al. 1997, 63131). The graphs were made using samples of rock taken in each of the five main geologic units found within and below TA-54. The data plotted on the graph were obtained in experiments conducted on small samples of rock recovered from borehole cores. Unsaturated hydraulic conductivities are calculated using the van Genuchten parameters (van Genuchten 1980, 63542) and Mualem's model (Mualem 1976, 63543).

Characteristic curves like these are often used as a basis for mathematical models of unsaturated flow. For modeling purposes, the curves must be translated into mathematical equations. One popular curve-fitting function is the van Genuchten formulation. The van Genuchten method (van Genuchten 1980, 63542) requires three variables,  $\alpha$ ,  $n$ , and  $\theta_r$ , to be evaluated to fit the curve to the measured data. The van Genuchten parameters  $\alpha$  and  $n$  are derived hydraulic properties for modeling moisture flow in unsaturated materials. In general, materials with relatively high values of  $\alpha$  can hold more water with less suction, while materials with a relatively large value of  $n$  may undergo large changes in moisture content with small changes in suction. The residual moisture content,  $\theta_r$ , is defined as moisture that cannot be removed from the rock surface under natural conditions; it is typically an uncertain parameter in van Genuchten. Residual moisture is not well defined in arid regions where moisture may be transported in the vapor phase rather than the liquid phase. The van Genuchten parameters are listed in Table B-4.4-1.

**Table B-4.4-1**  
**Hydraulic Characteristics of MDA G Vadose Zone**

Property	Tshirege Member Unit 2	Tshirege Member Unit 1vu	Tshirege Member Unit 1vc	Tshirege Member Unit 1g	Tsankawi/Cerro Toledo Interval	Otowi Member	Guaje Pumice	Cerros del Rio Basalts	Puye Formation
<b>Thickness, ft (m)</b>	40 (12.2)	45 (13.7)	25 (7.6)	50 (15.2)	5.9 (1.8)	120 (36.6)	12 (3.7)	>119 (>36.3)	~656 (~200)
<b>Lithology Summary</b>	Massive, crystal-rich, slightly welded, devitrified tuff; vapor-phase altered; pumice swarms; basal surge	Massive, crystal-rich nonwelded tuff; devitrified; pumiceous; crystal-rich lapilli	Massive, crystal-rich nonleaded tuff; pumiceous; pumice swarms; ash fall; crystal-rich lapel	Massive, nonwelded nonindurated tuff; vitric; pumiceous; crystal-rich lapilli	Massive air-fall tuff; large white-pumice lapilli; topical surge bed of crystals and ash	Massive, moderately crystal-rich, nonwelded, vitric tuff; ~30% pumice	Basal, nonwelded pumice lapilli bed; vitric	Dense, fractured, basaltic lava flows, with flow breccias and Puye interbeds	Fanglomerates and conglomerates; fluvialite and debris-flow deposits; interbedded ash and pumice falls, basalt flows
<b>Fracture Spacing</b>	3.3–4.3 ft, 1.0–1.3 m	3.3–4.3 ft, 1.0–1.3 m	No data, few fractures	No data, some fractures	No data, rare fractures	No data, few fractures	No data, rare fractures	~1.0 ft (~0.3 m) from observation	No data, poorly developed in outcrop
<b>Fracture Dip and Aperture</b>	87° median; .12-in. (3-mm) median	84° median; .12-in. (3-mm) median	No data, assumed vertical	No data, assumed vertical	No data, assumed vertical	No data	No data	~0.2 in. (~5 mm) from observation	No data, poorly developed in outcrop
<b>Fracture Fill</b>	72% filled; 9% plated; 19% open	82% filled or plated; 18% open	No data	No data	No data	No data; some caliche observed	No data	None observed	No data
<b>Mean Density (g/cc)</b>	1.37	1.26	1.20	1.14	1.12	1.2	No data	No data, 2.4–3.1 estimated	No data
<b>Mean Porosity (%)</b>	45.7	48.7	49.3	46.2	47.3	43.5	No data	No data	No data
<b>Mean Volume Moisture (%)</b>	2.57	1.89	10.88	8.94	14.00	11.5	No data	No data	No data
<b>Saturation (%)</b>	5.7	3.7	21.3	16.9	30.3	26.4	No data	No data	No data
<b>Mean <math>K_{sat}</math> (cm/sec)</b>	4.37E-7	1.48E-4	1.67E-4	188E-4	8.65E-4	2.49E-4	No data	No data	No data
<b>van Genuchten</b>									
$\theta_r$	0.0	0.0	0.0	0.0	0.8	2.1	No data	No data	No data
$\alpha$	0.0060	0.0030	0.0033	0.0053	0.0152	0.059	No data	No data	No data
$n$	1.890	1.932	1.647	1.745	1.506	1.713	No data	No data	No data

The data in Table B-4.4-1 show that the units beneath MDA G have volumetric moisture contents between about 2% and 14% by volume. The curves are very steep at low moisture contents, indicating that for a unit increase in water, there is a very large increase in hydraulic conductivity. The slopes of the conductivity curves generally level out when moisture content reaches about 7% by volume. The relatively flat portion of the curves indicates that hydraulic conductivities remain constant over moisture contents ranging between 10% and 30% by volume. This behavior is a function of the sample's pore-size distribution. At moisture contents greater than about 34% by volume, the conductivity curves again become very steep. Note that these are artificially high moisture contents obtained under experimental conditions. Such high moisture contents would naturally occur in the region of the Laboratory only with a major climatic change or artificial input of water, such as from an outfall.

Taken as a group, the hydraulic conductivity curves and tension curves are very similar among the geologic units, with one exception: the Tsankawi Pumice/Cerro Toledo interval characteristic curves show a much greater spread than the others. This reflects the highly varied size of the pore spaces in the rock as compared with other units because of the varied lithologies characteristic of this interval. In general, the curves indicate that the Tsankawi Pumice/Cerro Toledo interval may conduct water more readily than the other units of the Bandelier Tuff.

## B-5.0 ECOLOGICAL RESOURCES

Biological resource field surveys have been conducted in the TA-54 area for compliance with the Federal Endangered Species Act of 1973; the New Mexico Wildlife Conservation Act; the New Mexico Endangered Species Act; Executive Order 11990, "Protection of Wetlands"; Executive Order 11988, "Floodplain Management"; 10 CFR 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements"; and DOE Order 5400.1, "General Environmental Protection Program."

No wetlands exist in the TA-54 area, but wetlands and floodplains exist in the lower portion of Pajarito Canyon. Possible threatened and endangered species for the area were identified, but no habitats were located. Further information is contained in "Biological Assessment of Environmental Restoration Program, Operable Unit 1148, TA-54" (Banar 1996, 58192).

### Local Plant Species

The vegetation on Mesita del Buey is dominated by the piñon-juniper series of the Great Basin conifer woodland. One-seed juniper and piñon pines are the dominant tree species in undisturbed areas. Common shrub species include big sagebrush (*Artemisia tridentata*), wax currant (*Ribes cerceum*), four-wing salt bush (*Atriplex canescens*), currant (*Ribes* sp.), and mountain mahogany (*Cercocarpus betuloides*). Blue grama grass (*Bouteloua gracilis*), cryptogamic soil crust, and prickly pear cactus (*Opuntia* spp.) are the most common low-growing (understory) plants on the mesa top. Other common understory plants include snake weed (*Gutierrezia microcephala* and *Gutierrezia sarothrae*), pinque (*Hymenoxys richardsonii*), wild chrysanthemum (*Bahia dissecta*), leafy golden aster (*Chrysopsis filiosa*), purple horned-toothed moss (*Ceratodon purpureus*), several lichen species, three-awn grass (*Aristida* spp.), bottlebrush squirreltail (*Sitanion hystrix*), bluegrass (*Poa* spp.), false tarragon (*Artemisia dracuncululus*), and a species of *Mammalaria* cactus (Hollis et al. 1997, 63131, p. 2-13). A representative list of average rooting depths for native plants is presented in Table B-5.0-1.

**Table B-5.0-1**  
**Average Rooting Depths of Piñon and Juniper Woodland Plants**

Species	Common Name	Root Depth, ft (m)
<i>Quercus</i> spp.	Oak	10.5 (3.2)
<i>Gutierrezia sarothrae</i>	Snakeweed	9.5 (2.9)
<i>Ribes cereum</i>	Wax currant	9.5 (2.9)
<i>Falugia paradoxa</i>	Apache plume	8.5 (2.6)
<i>Rhus trilobata</i>	Squawbush	7.5 (2.3)
<i>Atriplex canescens</i>	Saltbush	7.2 (2.2)
<i>Chrysothamnus nauseosus</i>	Chamisa	6.9 (2.1)
<i>Artemisia tridentata</i>	Sagebrush	5.9 (1.8)
<i>Juniperus monosperma</i>	One-seed juniper	5.6 (1.7)
<i>Pinus ponderosa</i>	Ponderosa pine	4.9 (1.5)
<i>Bouteloua gracilis</i>	Blue grama	1.9 (0.58)
<i>Cercocarpus montanus</i>	Mountain mahogany	1.6 (0.5)
<i>Helianthus petiolaris</i>	Wild sunflower	1.5 (0.45)
<i>Opuntia polykantha</i>	Cactus	0.9 (0.28)
<i>Yucca angustifolia</i>	Yucca	0.3 (0.1)

In a study of 21 species of plants common at the Laboratory, roots were found to be most abundant in the upper 6.4 ft (2 m) of soil. Biomass of annual and perennial plant roots was greatest in the upper 3.3 ft (1 m), whereas ponderosa pine roots were nearly always found within the top 6.6 ft of the soil surface. Tap roots of chamisa, Apache plume, and oak extended over 6.6 ft (2 m) into the soil, and piñon pine and one-seed juniper roots have been found to extend greater than 20 ft (6 m) through fractures in the tuff (Hollis et al. 1997, 63131, p.2-13).

As a result of waste management operations at TA-54, many of the native understory plants on Mesita del Buey are being replaced by new species. Recently disturbed areas support plants such as goosefoot (*Chenopodium fremontii*), tumbleweed (*Salsola kali*), cutleaf evening primrose (*Oenothera caespitosa*), common sunflower (*Helianthus annuus*), and other colonizing species. As pits are closed, native grass species (e.g., blue grama) are planted on the top; these species provide extensive ground cover and have short roots. The density of this vegetative cover protects against erosion, while the shallow roots maximize transpiration of water.

### Local Animal Species

Insects, reptiles, mammals, and birds inhabit the Laboratory region. Harvester ants are the most abundant insect at TA-54, while common reptiles include fence lizards (*Sceloporus undulatus*), Plateau striped whiptails (*Cnemidophorus velux*), gopher snakes (*Pituophis melanoleucus*), and garter snakes (*Thamnophis elegans*). Many mammals inhabit the Pajarito Plateau, including rodents, mule deer, elk, black bear, mountain lion, bobcat, fox, and coyote, all of which pass through the TA-54 vicinity at least occasionally. Pajarito Canyon and Cañada del Buey support a wide variety of bird species. In addition to a range of songbirds, a variety of nesting and migrating raptors have been identified in less-disturbed areas of the canyons (Hollis et al. 1997, 63131, p. 2-13).

Table B-5.0-2 lists some burrowing animals observed at TA-54, along with their maximum reported burrowing depths.

**Table B-5.0-2  
Maximum Recorded Depth of Burrows of Animals at TA-54**

Species or Taxon	Common Name	Burrow Depth, ft (m)
<i>Pogonomyrmex spp.</i>	Harvester ant	9.8 (3.0)
<i>Gopheropus polyphemus</i>	Gopher tortoise	2.5 (0.75)
<i>Terrapene carolina</i>	Box turtle	0.3 (0.1)
<i>Blarina brevicaudata</i>	Short-tailed shrew	1.6 (0.5)
<i>Scalopus aquaticus</i>	Mole	2.0 (0.6)
<i>Microtus ochrogaster</i>	Prairie vole	0.7 (0.2)
<i>Peromyscus gossypinus</i>	Cotton mouse	2.5 (0.75)
<i>Ochrotomys nuttalli</i>	Golden mouse	0.4 (0.13)
<i>Perognathus parvus</i>	Pocket mouse	4.6 (1.4)
<i>Thomomys talpoides</i>	Pocket gopher	3.2 (<1)
<i>Dipodomys ordii</i>	Kangaroo rat	2.3 (0.7)
<i>Cynomys leucurus</i>	Prairie dog	6.0 (1.83)
<i>Peromyscus maniculatus</i>	Deer mouse	3.2 (<1)
<i>Marmota monax</i>	Woodchuck	4.9 (1.5)

## B-6.0 CULTURAL RESOURCES

A cultural resource survey was conducted during the summer of 1991 at Operable Unit 1148, as required by the National Historic Preservation Act of 1966. A total of 68 archaeological sites have been located within the boundary of the operable unit. Of this number, 56 are eligible for inclusion on the National Register of Historic Places, and 12 have been declared ineligible. According to the RFI work plan, a report documenting the survey area, methods, results, and monitoring recommendations was to be transmitted to the New Mexico State Historic Preservation officer for concurrence in a determination of no effect (LANL 1992, 7669).

## REFERENCES

The following list includes all references cited in this appendix. Parenthetical information following each reference provides the author, publication date, and the ER identification (ID) number. This information also is included in the citations in the text. ER ID numbers are assigned by the Laboratory's ER Project to track records associated with the Project. These numbers can be used to locate copies of the actual documents at the ER Project's Records Processing Facility and, where applicable, with the ER Project reference library titled "Reference Set for Material Disposal Areas, Technical Area 54."

Copies of the reference library are maintained at the NMED Hazardous Waste Bureau; the DOE Los Alamos Area Office; United States Environmental Protection Agency, Region VI; and the ER Project Material Disposal Areas Focus Area. This library is a living collection of documents that was developed to ensure that the administrative authority has all the necessary material to review the decisions and actions

proposed in this document. However, documents previously submitted to the administrative authority are not included.

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# **Appendix C**

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*Results of Quality Assurance/Quality Control Activities*



## APPENDIX C RESULTS OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

### C-1.0 SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

This appendix consists of an assessment of the quality of analytical results obtained in Resource Conservation and Recovery Act facility investigation (RFI) activities at Material Disposal Area (MDA) H. The data include results for sediment and borehole samples. Borehole samples were analyzed for radionuclides (by gamma spectroscopy), americium-241, tritium, inorganic chemicals (target analyte list [TAL] metals and cyanide), semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), pesticides, and polychlorinated biphenyls (PCBs). Sediment samples were analyzed for radionuclides (by gamma spectroscopy), americium-241, isotopic plutonium, isotopic thorium, isotopic uranium, strontium-90, tritium, inorganic chemicals (TAL metals and cyanide), pesticides, and PCBs. A summary of the analytical suites and method descriptions is included in Sections C-2.0, C-3.0, and C-4.0.

Quality assurance (QA), quality control (QC), and data validation procedures were implemented in accordance with the requirements of "Quality Assurance Project Plan Requirements for Sampling and Analysis" (LANL 1996, 54609) and the Los Alamos National Laboratory (the Laboratory) Environmental Restoration (ER) Project analytical services statement of work (SOW) for contract laboratories (LANL 1995, 49738). Results of the QA/QC activities were used to estimate accuracy, bias, and precision of the analytical measurements. QC samples, including method blanks, matrix spike samples, matrix spike duplicates, QC blind samples, and laboratory control samples (LCSs), were used to assess accuracy and bias. Internal standards, external standards, surrogates, carriers, and tracers were also used to assess accuracy. Duplicate samples were used to determine precision. The type and frequency of QC analyses are described in the ER Project analytical services SOW (LANL 1995, 49738). Other QC factors, such as sample preservation and holding times, were also assessed. The requirements for sample preservation and holding times are given in the standard operating procedure (SOP) ER-SOP-1.02, Rev. 0, "Sample Containers and Preservation."

#### Past Data Validation

Before April 1995, Laboratory Group CST-3 (Chemical Science and Technology) performed data validation for the ER Project; data collected, analyzed, and validated from this period of time were qualified according to the CST-3 system. A numeric code was assigned to document the review of the raw data results generated by the analytical laboratory. Depending on the review level, not all QA/QC criteria were examined. The general meaning of the CST-3 numeric codes are in Table C-1.0-1; specific meanings for the codes are in Section C-5.

**Table C-1.0-1  
CST-3 Review Codes**

Review Level Numeric	Description
0	Invoked when personnel resources for data validation were low, workload volume was high, or expedited turnaround was requested
1	Less stringent review of data
2	More stringent review than level 1 but less stringent review than level 3
3	Most stringent review of data

Data validation results, including request numbers, sample identification numbers, and their associated qualifiers, are located in Section C-5.

### Current Baseline Data Validation

Starting in April 1995, the Laboratory's ER Project baseline validation procedure (similar to a CST-3 Level 3 data review) was implemented; sample results after April 1995 were qualified using this procedure (ER-SOP 15.17, Rev. 0, "Baseline Analytical Data Validation"). The ER Project data validation process incorporates Laboratory-specific reason codes for qualifying data and adheres to the Environmental Protection Agency's (EPA) "Contract Laboratory Program National Functional Guidelines for Inorganic Data Review" (EPA 1994, 48639) and "Contract Laboratory Program National Functional Guidelines for Organic Data Review" (EPA 1994, 48640). Data packages received from the analytical laboratory were reviewed with respect to the national functional guidelines and Laboratory quality procedures for data validation. Data validation results, including request numbers, sample identification numbers, and their associated qualifiers, are located in Section C-5.

## C-2.0 INORGANIC CHEMICALS

### C-2.1 Inorganic Chemical Methods

Samples were analyzed for TAL metals and cyanide. Methods for the data set are shown in Table C-2.1-1. Mercury was analyzed by EPA Method 7471A, cold vapor atomic absorption (CVAA), and cyanide was analyzed by either EPA Method 9012 colorimetric analysis (ACOLR) or EPA Method 6010B, inductively coupled plasma emission spectroscopy (ICPES). The other TAL metals were analyzed by EPA Method 6010B, ICPES; EPA Method 6020, inductively coupled plasma mass spectroscopy (ICPMS); or EPA Method 7000 series, graphite furnace atomic absorption (GFAA). The qualifiers for inorganic analytes are provided in Section C-5.1.

**Table C-2.1-1  
Analytical Methods for Inorganic Chemical Analysis**

Analytical Method	Analytical Description	Analytical Suite
EPA Method 6010B	ICPES	Aluminum, antimony, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, cyanide, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium, silver, thallium, vanadium, zinc
EPA Method 7060A	GFAA	Arsenic
EPA Method 9012	ACOLR	Cyanide
EPA Method 7721	GFAA	Lead
EPA Method 7741A	GFAA	Selenium
EPA Method 7841	GFAA	Thallium
EPA Method 6020	ICPMS	Antimony, lead, thallium
EPA Method 7471A	CVAA	Mercury

## C-2.2 Inorganic Chemical QA/QC Samples

The LCSs, method blanks, matrix spike samples, laboratory duplicate samples, interference check samples, and serial dilution samples were analyzed to assess accuracy, bias, and precision. Each of these QA/QC sample types is defined in the ER Project analytical services SOW (LANL 1995, 49738) and described briefly below.

*LCSs.* This sample type serves as a monitor of the overall performance of each step, including sample digestion, during sample analysis. The analytical results for the samples were qualified if the LCS indicated an unacceptable bias in the measurement.

*Method Blanks.* This sample type is used as a measurement of bias and potential cross contamination. The blank results for inorganic chemical analyses were within acceptable limits for all the analyses.

*Matrix Spike Samples.* This sample type is designed to provide information about the effect of each sample matrix on the sample preparation procedures and analytical techniques.

*Laboratory Duplicate Samples.* This sample type assesses precision of inorganic chemical analyses.

*Interference Check Samples.* This sample type checks to make sure the instrument interelement correction factors are correct. The interference check solution is prepared to contain known concentrations of interfering elements that will provide an adequate test of the correction factors.

*Serial Dilution Sample.* This sample type is required for each matrix in a sample delivery group, with a minimum of one serial dilution sample per 20 samples. The samples are diluted by a factor of five, and the dilution-corrected results are compared to those of the undiluted parent sample.

Acceptance limits for each QA/QC sample are shown in Table C-2.2-1.

**Table C-2.2-1  
Inorganic QC Checks and Acceptance Limits**

QC Check	Acceptance Limits
Initial and continuing calibration verifications	90 to 110% recovery
For ICPEs—interference check sample	80 to 120% recovery
LCS	Water: 80 to 120% recovery Soil: LCS vendor supplied
Method blank sample	Each analyte must be less than the IDL <sup>a</sup>
Duplicate sample	Water: RPD <sup>b</sup> <20% Soil: RPD <35%
Matrix spike sample	75 to 125% recovery
Serial dilution sample	90 to 110% recovery where undiluted results are greater than or equal to the method detection limit

<sup>a</sup> IDL = instrument detection limit.

<sup>b</sup> RPD = relative percent difference.

### C-3.0 ORGANIC CHEMICALS

Samples were analyzed for VOCs, SVOCs, pesticides, and PCBs. All QC procedures were followed as required in the ER Project analytical services SOW (LANL 1995, 49738). Pore-gas samples were also collected in SUMMA canisters for the analysis of VOCs using EPA Method TO-14. Table C-3.0-1 lists the organic analytical methods used for this report.

Acceptance criteria for the QA/QC samples for each organic chemical analytical suite are shown in Tables C-3.0-2 through C-3.0-4.

**Table C-3.0-1  
Analytical Methods for Organic Analyses**

Analytical Method <sup>a</sup>	Analytical Description	Target Compound List
EPA Method 8270 (3540)	SVOCs	ER Project analytical services SOW <sup>b</sup>
EPA Method 8260 (5030)	VOCs	ER Project analytical services SOW <sup>b</sup>
EPA Method 8080 or 8081 (3540)	Organochlorine pesticides	ER Project analytical services SOW <sup>b</sup>
EPA Method 8080 or 8082 (3540)	PCBs	ER Project analytical services SOW <sup>b</sup>

<sup>a</sup> Sample preparation methods are listed in parentheses.

<sup>b</sup> LANL 1995, 49738

**Table C-3.0-2  
VOC QC Checks and Acceptance Limits**

QC Check	Acceptance Limits												
Initial calibration	RRF <sup>a</sup> $\geq 0.05$ , percent RSD <sup>b</sup> $\leq 30\%$												
Continuing calibration	RRF $\geq 0.05$ , percent difference = $\pm 25\%$												
Method blank	All analytes must be less than the IDL <sup>c</sup> .												
Internal standard	The retention time of the internal standards should be $\pm 30$ seconds from the retention time of the associated 12-hr calibration standard. The chromatograph peak area of the internal standard in the sample must be 50% to 200% of the peak area exhibited on the last continuing calibration.												
Surrogate spikes	<table border="1"> <thead> <tr> <th></th> <th>Soil percent recovery</th> <th>Water percent recovery</th> </tr> </thead> <tbody> <tr> <td>Dibromofluoromethane</td> <td>80–20%</td> <td>86–118%</td> </tr> <tr> <td>Bromofluorobenzene</td> <td>74–121%</td> <td>86–115%</td> </tr> <tr> <td>Toluene-d8</td> <td>81–117%</td> <td>88–110%</td> </tr> </tbody> </table>		Soil percent recovery	Water percent recovery	Dibromofluoromethane	80–20%	86–118%	Bromofluorobenzene	74–121%	86–115%	Toluene-d8	81–117%	88–110%
	Soil percent recovery	Water percent recovery											
Dibromofluoromethane	80–20%	86–118%											
Bromofluorobenzene	74–121%	86–115%											
Toluene-d8	81–117%	88–110%											
Matrix spike/matrix spike duplicate	Each spike analyte should fall within the upper and lower QC limits and below the QC RPD. QC limits for each VOC vary. See SW-846 Method 8260 for a list of these limits.												

<sup>a</sup> RRF = relative retention factor.

<sup>b</sup> RSD = relative standard deviation.

<sup>c</sup> IDL = instrument detection limit.

**Table C-3.0-3  
SVOC QC Checks and Acceptance Limits**

QC Check	Acceptance Limits																					
Initial calibration	RRF $\geq 0.05$ , percent RSD $\leq 30\%$																					
Continuing calibration	RRF $\geq 0.05$ , percent difference = $\pm 25\%$																					
Method blank	All analytes must be less than the IDL.																					
Internal standards	The retention time of the internal standards should be $\pm 30$ seconds from the retention time of the associated 12-hr calibration standard. The chromatograph peak area of the internal standard in the sample must be 50% to 200% of the peak area exhibited on the last continuing calibration.																					
Surrogate spikes	<table border="1"> <thead> <tr> <th></th> <th>Soil percent recovery</th> <th>Water percent recovery</th> </tr> </thead> <tbody> <tr> <td>Nitrobenzene</td> <td>23–120%</td> <td>35–114%</td> </tr> <tr> <td>2-Fluorobiphenol</td> <td>30–115%</td> <td>43–116%</td> </tr> <tr> <td>p-Terphenol</td> <td>18–137%</td> <td>33–141%</td> </tr> <tr> <td>Phenol-d5</td> <td>24–113%</td> <td>10–94%</td> </tr> <tr> <td>2-Fluorophenol</td> <td>25–121%</td> <td>21–100%</td> </tr> <tr> <td>2,4,6-Tribromophenol</td> <td>19–122%</td> <td>10–123%</td> </tr> </tbody> </table>		Soil percent recovery	Water percent recovery	Nitrobenzene	23–120%	35–114%	2-Fluorobiphenol	30–115%	43–116%	p-Terphenol	18–137%	33–141%	Phenol-d5	24–113%	10–94%	2-Fluorophenol	25–121%	21–100%	2,4,6-Tribromophenol	19–122%	10–123%
	Soil percent recovery	Water percent recovery																				
Nitrobenzene	23–120%	35–114%																				
2-Fluorobiphenol	30–115%	43–116%																				
p-Terphenol	18–137%	33–141%																				
Phenol-d5	24–113%	10–94%																				
2-Fluorophenol	25–121%	21–100%																				
2,4,6-Tribromophenol	19–122%	10–123%																				
Matrix spike/matrix spike duplicate	Each spike analyte should fall within the upper and lower QC limits and below the QC RPD. QC limits for each SVOC vary. See SW-846 Method 8270 for a list of these limits.																					

**Table C-3.0-4  
Pesticide/PCB QC Checks and Acceptance Limits**

QC Check	Acceptance Limits						
Initial calibration	Percent RSD $\leq 20\%$ , resolution between two adjacent peaks $\geq 90\%$						
Calibration verification	RPD $\leq 20\%$ , resolution between two adjacent peaks $\geq 90\%$						
Method blank	All analytes must be less than the IDL.						
Surrogate spikes	<table border="1"> <thead> <tr> <th></th> <th>Soil and water percent recovery</th> </tr> </thead> <tbody> <tr> <td>Tetrachloro-m-xylene</td> <td>50–150%</td> </tr> <tr> <td>Decachlorobiphenyl</td> <td>50–150%</td> </tr> </tbody> </table>		Soil and water percent recovery	Tetrachloro-m-xylene	50–150%	Decachlorobiphenyl	50–150%
	Soil and water percent recovery						
Tetrachloro-m-xylene	50–150%						
Decachlorobiphenyl	50–150%						
Matrix spike/matrix spike duplicate	Each spike analyte should fall within the upper and lower QC limits and below the QC RPD. QC limits for each SVOC vary. See SW-846 Methods 8080, 8081, and 8082 for a list of these limits.						

## C-4.0 RADIOCHEMICALS

### C-4.1 Radiochemical Analyses

MDA H samples were analyzed for radionuclides by the methods listed in Table C-4.1-1. Radionuclides with reported values less than the minimum detectable activity were qualified as undetected (U). Each radionuclide result was also compared with the corresponding 1-sigma total propagated uncertainty (TPU). If the result was not greater than three times the TPU, it was qualified as undetected (U).

**Table C-4.1-1  
Analytical Methods for Radiochemical Analyses**

<b>Analytical Method</b>	<b>Radionuclide(s)</b>
Gamma spectroscopy	Gamma-emitting radionuclides: americium-241, cobalt-60, cesium-134, cesium-137, europium-152, sodium-22, ruthenium-105, uranium-235
Radiochemical separation alpha spectroscopy	Americium-241, isotopic plutonium, isotopic thorium, and isotopic uranium
Liquid scintillation counting	Tritium
Radiochemical separation/air proportional beta analysis	Strontium-90

The results for the gamma spectroscopy analyses were reviewed with respect to their uncertainty values and parent decay series. Based on Laboratory ER guidelines, the eight gamma-emitting radionuclides listed in Table C-4.1-1 are routinely evaluated as part of an RFI data set. These radionuclides are potential Laboratory contaminants, have half-lives greater than one year, and are reliably measured by gamma spectroscopy.

#### **C-4.2 Discussion of Radiochemical QA/QC Samples**

CST Division used QC blind samples, matrix spike samples, LCSs, method blanks, duplicates, carriers, and tracers to assess precision, bias, and accuracy of radiochemical analyses performed at off-site fixed laboratories. The acceptance criteria for radionuclide QC samples are shown in Table C-4.2-1.

**Table C-4.2-1  
Radionuclide QC Checks and Acceptance Limits**

<b>QC Check</b>	<b>Acceptance Limits and Qualifiers</b>
QC blind sample	75% to 125% recovery
Method blank	All analytes must be less than the IDL (LANL 1995, 49738)
LCS	Soil: 75% to 125% recovery (LANL 1995, 49738)
Matrix spike sample	75 to 125% recovery (LANL 1995, 49738)
Tracer/carrier recovery	<30% for alpha spectroscopy, <40% for strontium-90, or greater than 110% for either analytical measurement

#### **C-5.0 DATA VALIDATION**

If QC samples for each of the analytical suites are outside of the acceptance limits, the data associated with the samples are assigned qualifiers to indicate potential data quality issues. The tables presented in this section summarize the data qualifiers applied to each analyte for a given sample and the rationale for the assigned qualifier. The data qualifiers are defined in Table C-5.0-1.

**Table C-5.0-1**  
**Explanation of Data Qualifiers Used in the Data Validation Procedure**

Qualifier	Explanation
U	The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
J	The reported value should be regarded as estimated.
J+	The reported value should be regarded as estimated and biased high.
J-	The reported value should be regarded as estimated and biased low.
UJ	The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.
UJ+	The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or reporting limit with a high bias.
UJ-	The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or reporting limit with a low bias.
R	The sample results were rejected because of serious deficiencies in the ability to analyze the sample and meet QC criteria; presence or absence cannot be verified.

### **C-5.1 Inorganic Data Review**

CST Division (Section C-1.0, Past Data Validation) assigned a numeric review level code to raw data results generated by the analytical laboratory. Depending on the review level, not all criteria were examined. The CST numeric review levels are defined as follows:

- Level 0: Review samples to make sure they are all present; data are not validated at this review level.
- Level 1: Review LCS and QC blind sample; sometimes holding times are addressed.
- Level 2: Review LCS, QC blind sample, matrix spike sample, and holding times.
- Level 3: Review method blank, calibration data, LCS, matrix spike sample, QC blind sample, and holding times.

For data packages where CST-3 did not perform a Level 3 review, not all QA/QC data are available for review. These data packages were all reviewed but are not complete for QA/QC data.

According to the national functional guidelines for data review (EPA 1994, 48639), data from LCSs, matrix spike samples, and QC samples that have recoveries between 30% and 74% can be qualified as estimated and biased low (UJ- or J-). If the recoveries are below 30%, the data are rejected (R).

Table C-5.1-1 presents the inorganic data quality evaluation for the data set presented in Appendix D.

**Table C-5.1-1  
Inorganic Data Quality Evaluation**

Request Number	Sample ID	Location ID	Analyte	Explanation
557	0554-95-0282	54-1023	Manganese	The result for this analyte should be regarded as estimated and biased low (J-) because the matrix spike recovery for this analyte was low.
557	0554-95-0282	54-1023	Barium Calcium Cobalt Magnesium Nickel Potassium Sodium Thallium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0292 0554-95-0294 0554-95-0298	54-1023 54-1023 54-1023 54-1023 54-1023 54-1023	Antimony	The reporting limits for this analyte should be regarded as estimated (UJ) because the matrix spike recovery for this analyte was low.
587	0554-95-0284	54-1023	Barium Beryllium Chromium Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0286	54-1023	Barium Beryllium Cadmium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0288	54-1023	Barium Beryllium Chromium Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0290	54-1023	Barium Beryllium Magnesium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0292	54-1023	Barium Beryllium Calcium Chromium Magnesium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
587	0554-95-0294	54-1023	Barium Beryllium Calcium Copper Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0298	54-1023	Arsenic Barium Beryllium Chromium Copper Magnesium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
587	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0292 0554-95-0294 0554-95-0298	54-1023 54-1023 54-1023 54-1023 54-1023 54-1023 54-1023	Manganese	The results for this analyte should be regarded as estimated and biased low (J-) because the matrix spike recovery for this analyte was low.
587	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0292 0554-95-0294 0554-95-0298	54-1023 54-1023 54-1023 54-1023 54-1023 54-1023 54-1023	Cyanide	The results for this analyte should be regarded as unusable (R) because the matrix spike recovery for this analyte was low (<10%).
619	0554-95-0300 0554-95-0302 0554-95-0304 0554-95-0306 0554-95-0308 0554-95-0310 0554-95-0312 0554-95-0316 0554-95-0318 0554-95-0321	54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1024	Antimony	The reporting limits for this analyte should be regarded as estimated (UJ) because the matrix spike recovery for this analyte was low.
619	0554-95-0304	54-1026	Thallium	The result for this analyte should be regarded as not detected (U) because the result is less than five times the result for this analyte in the preparation blank.
619	0554-95-0300	54-1026	Barium Calcium Magnesium Potassium Selenium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0302	54-1026	Barium Beryllium Calcium Magnesium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
619	0554-95-0304	54-1026	Arsenic Barium Beryllium Copper Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0306	54-1026	Barium Beryllium Chromium Copper Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0308	54-1026	Barium Beryllium Calcium Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0310	54-1026	Barium Beryllium Calcium Copper Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0312	54-1026	Barium Beryllium Calcium Copper Magnesium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0316	54-1026	Barium Beryllium Cadmium Calcium Chromium Copper Magnesium Selenium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0318	54-1026	Barium Beryllium Calcium Cobalt Magnesium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
619	0554-95-0321	54-1024	Barium Beryllium Calcium Cobalt Magnesium Nickel Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
619	0554-95-0300 0554-95-0302 0554-95-0304 0554-95-0306 0554-95-0308 0554-95-0310 0554-95-0312 0554-95-0316 0554-95-0318 0554-95-0321	54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1024	Manganese	The results for this analyte should be regarded as estimated and biased low (J-) because the matrix spike recovery for this analyte was low.
644	0554-95-0323	54-1024	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0327	54-1024	Copper	The result for this analyte should be regarded as not detected (U) because the result is less than five times the result for this analyte in the preparation blank.
650	0554-95-0325	54-1024	Barium Copper Magnesium Potassium Sodium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0327	54-1024	Barium Calcium Magnesium Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0329	54-1024	Barium Calcium Copper Magnesium Potassium Silver Sodium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0331	54-1024	Barium Copper Magnesium Potassium Sodium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0333	54-1024	Barium Copper Magnesium Potassium Sodium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
650	0554-95-0337	54-1024	Selenium	The reporting limits for this analyte should be regarded as estimated (UJ) because the matrix spike recovery for this analyte was low.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
650	0554-95-0325 0554-95-0327 0554-95-0329 0554-95-0331 0554-95-0333	54-1024 54-1024 54-1024 54-1024 54-1024	Lead	The results for this analyte should be regarded as estimated and biased high (J+) because the matrix spike recovery for this analyte was high.
650	0554-95-0325 0554-95-0327 0554-95-0329 0554-95-0331 0554-95-0333	54-1024 54-1024 54-1024 54-1024 54-1024	Manganese	The results for this analyte should be regarded as estimated and biased low (J-) because the matrix spike recovery for this analyte was low.
659	0554-95-0339	54-1025	Antimony Barium Beryllium Calcium Cobalt Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0341	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0343	54-1025	Antimony Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0345	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
659	0554-95-0347	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0349	54-1025	Arsenic Barium Beryllium Calcium Cobalt Copper Magnesium Mercury Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0351	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Mercury Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0355	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Mercury Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.
659	0554-95-0356	54-1025	Arsenic Barium Beryllium Calcium Chromium Cobalt Copper Magnesium Mercury Nickel Potassium Sodium Vanadium	The results for these analytes should be regarded as estimated (J) because the results for these analytes were below the estimated detection limit but above the IDL.

Table C-5.1-1 (continued)

Request Number	Sample ID	Location ID	Analyte	Explanation
18645	AAB3142 AAB3129 AAB3175 AAB3131	54-5126 54-5130 54-5131 54-5132	Aluminum	The results for aluminum should be regarded as estimated (J for detected results and UJ for not detected results) because the recovery for this analyte in the QC sample was low.

### C-5.2 Organic Data Review

CST Division (Section C-1.0, Past Data Validation) assigned a numeric review level code to raw data results generated by the analytical laboratory. Depending on the review level, not all criteria were examined. Unless a Level 3 review was performed, not all QA/QC data are available in the data packages. The numeric review levels are defined as follows:

- Level 0: Review samples to make sure they are all present; data are not validated at this review level.
- Level 1: Review surrogates, QC blind sample, and internal standards.
- Level 2: Review blank, surrogates, QC blind sample, and internal standards.
- Level 3: Review blank, surrogates, QC blind sample, internal standards, and tentatively identified compounds.

Table C-5.2-1 presents the organic data quality evaluation for the data set presented in Appendix D.

**Table C-5.2-1  
Organic Data Quality Evaluation**

Request Number	Sample ID	Location ID	Analytical Suite	Analyte	Explanation
586	0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0292	54-1023 54-1023 54-1023 54-1023	SVOCs	Di-n-butylphthalate	The results for this analyte should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
586	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0292 0554-95-0294 0554-95-0298	54-1023 54-1023 54-1023 54-1023 54-1023 54-1023 54-1023	SVOCs	Bis(2-ethylhexyl)phthalate	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
586	0554-95-0284 0554-95-0288	54-1023 54-1023	VOCs	Butanone[2-]	The results for this analyte should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
586	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0294	54-1023 54-1023 54-1023 54-1023 54-1023	VOCs	Acetone	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
618	0554-95-0300	54-1026	SVOCs	Benzoic acid	The result for this analyte should be regarded as estimated (J) because the result was less than the practical quantitation limit but above the method detection limit.

Table C-5.2-1 (continued)

Request Number	Sample ID	Location ID	Analytical Suite	Analyte	Explanation
618	0554-95-0302	54-1026	SVOCs	Di-n-butylphthalate	The result for this analyte should be regarded as estimated (J) because the result was less than the practical quantitation limit but above the method detection limit.
618	0554-95-0300 0554-95-0302 0554-95-0304 0554-95-0306 0554-95-0308 0554-95-0310 0554-95-0312 0554-95-0316 0554-95-0318 0554-95-0321	54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1024	SVOCs	Bis(2-ethylhexyl)phthalate	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
618	0554-95-0308	54-1026	VOCs	Toluene	The result for this analyte should be regarded as estimated (J) because the result was less than the practical quantitation limit but above the method detection limit.
618	0554-95-0310	54-1026	VOCs	Acetone Toluene	The results for these analytes should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
618	0554-95-0312	54-1026	VOCs	Benzene Toluene	The results for these analytes should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
618	0554-95-0300 0554-95-0302 0554-95-0304 0554-95-0318	54-1026 54-1026 54-1026 54-1026	VOCs	Acetone	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
643	0554-95-0323	54-1024	VOCs	Methylene chloride	The result for this analyte should be regarded as not detected (U) because the result was less than 10 times the concentration of this analyte in the method blank. The result is therefore indistinguishable from laboratory contamination.
649	0554-95-0325	54-1024	SVOCs	Diethyl phthalate Dimethyl phthalate	The results for these analytes should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
649	0554-95-0337	54-1024	SVOCs	Di-n-butylphthalate	The result for this analyte should be regarded as estimated (J) because the result was less than the practical quantitation limit but above the method detection limit.
649	0554-95-0325 0554-95-0333 0554-95-0327 0554-95-0329 0554-95-0331 0554-95-0337	54-1024 54-1024 54-1024 54-1024 54-1024 54-1024	SVOCs	Bis(2-ethylhexyl)phthalate	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
649	0554-95-0333	54-1024	SVOCs	Nitrosodimethylamine[N-]	The result for this analyte should be regarded as not detected (U) because the result was less than five times the concentration of this analyte in the method blank. The result is therefore indistinguishable from laboratory contamination.

Table C-5.2-1 (continued)

Request Number	Sample ID	Location ID	Analytical Suite	Analyte	Explanation
649	0554-95-0325 0554-95-0329	54-1024 54-1024	VOCs	Trichlorofluoromethane	The results for this analyte should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
649	0554-95-0327 0554-95-0331 0554-95-0333	54-1024 54-1024 54-1024	VOCs	Methylene chloride	The results for this analyte should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
649	0554-95-0325 0554-95-0327 0554-95-0329 0554-95-0331 0554-95-0333 0554-95-0337	54-1024 54-1024 54-1024 54-1024 54-1024 54-1024	VOCs	Acetone	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
658	0554-95-0339 0554-95-0347 0554-95-0355 0554-95-0356	54-1025 54-1025 54-1025 54-1025	SVOCs	Bis(2-ethylhexyl)phthalate	The results for this analyte should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
658	0554-95-0347	54-1025	VOCs	Butylbenzene[sec-] Trichlorobenzene[1,2,3-]	The results for these analytes should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
658	0554-95-0349	54-1025	VOCs	Butylbenzene[n-] Butylbenzene[sec-] Hexachlorobutadiene Naphthalene Trichlorobenzene[1,2,3-] Trichlorobenzene[1,2,4-]	The results for these analytes should be regarded as estimated (J) because the results were less than the practical quantitation limit but above the method detection limit.
658	0554-95-0341 0554-95-0343 0554-95-0345 0554-95-0347 0554-95-0349 0554-95-0351 0554-95-0355 0554-95-0356 0554-95-0339	54-1025 54-1025 54-1025 54-1025 54-1025 54-1025 54-1025 54-1025 54-1025	VOCs	Methylene chloride	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
658	0554-95-0339 0554-95-0356 0554-95-0343 0554-95-0345 0554-95-0347 0554-95-0349 0554-95-0351 0554-95-0355	54-1025 54-1025 54-1025 54-1025 54-1025 54-1025 54-1025 54-1025	VOCs	Acetone	The results for this analyte should be regarded as not detected (U) because the results were less than 10 times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.

### C-5.3 Radionuclide Data Review

Radionuclides qualified as undetected (U) because the result was less than the minimum detectable activity or because the result was less than three times the 1-sigma TPU are summarized in Table C-5.3-1. This table presents the radionuclide data quality evaluation for the data set presented in Appendix D.

**Table C-5.3-1  
Radionuclide Data Quality Evaluation**

Request Number	Sample ID	Location ID	Method Code	Analyte	Explanation
558	0554-95-0282	54-1023	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
588	0554-95-0284 0554-95-0286 0554-95-0288 0554-95-0290 0554-95-0292 0554-95-0294 0554-95-0298 0554-95-0300	54-1023 54-1023 54-1023 54-1023 54-1023 54-1023 54-1023 54-1026	Gamma spectroscopy	Americium-241 Cesium-134 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22 Uranium-235	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
620	0554-95-0302 0554-95-0304 0554-95-0306 0554-95-0308 0554-95-0310 0554-95-0312 0554-95-0316 0554-95-0318 0554-95-0321	54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1026 54-1024	Gamma spectroscopy	Americium-241 Cesium-134 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22 Uranium-235	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
645	0554-95-0323	54-1024	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
651	0554-95-0325 0554-95-0327 0554-95-0329 0554-95-0331 0554-95-0333 0554-95-0337	54-1024 54-1024 54-1024 54-1024 54-1024 54-1024	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Europium-152 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0339	54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Ruthenium-106	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0341	54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0345	54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0347	54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Europium-152 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0349 0554-95-0351	54-1025 54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.

Table C-5.3-1 (continued)

Request Number	Sample ID	Location ID	Method Code	Analyte	Explanation
660	0554-95-0355	54-1025	Gamma spectroscopy	Americium-241 Cesium-137 Sodium-22 Cesium-137 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0343	54-1025	Gamma spectroscopy	Cesium-137 Cobalt-60 Ruthenium-106 Sodium-22	The results for these analytes should be regarded as not detected (U) because the results were below the minimum detectable concentration.
660	0554-95-0351 0554-95-0355	54-1025	Gamma spectroscopy	Europium-152	The results for this analyte should be regarded as not detected (U) because the results were less than five times the concentration of this analyte in the method blank. The results are therefore indistinguishable from laboratory contamination.
19010	AAB3143 AAB3160 AAB3150 AAB3139 AAB3122 AAB3120 AAB3123 AAB3126 AAB3173 AAB3133 AAB3202 AAB3147 AAB3183	54-5015 54-5016 54-5017 54-5018 54-5027 54-5029 54-5031 54-5034 54-5053 54-5055 54-5055 54-5058 54-5060	Tritium	Tritium	The results for this analyte should be regarded as estimated (J) because the recovery for this analyte in the QC blind sample was high.

## C-6.0 REFERENCES

The following list includes all references cited in this appendix. Parenthetical information following each reference provides the author, publication date, and the ER record identification (ID) number. This information also is included in the citations in the text. ER ID numbers are assigned by the Laboratory's ER Project to track records associated with the Project. These numbers can be used to locate copies of the actual documents at the ER Project's Records Processing Facility and, where applicable, with the ER Project reference library titled "Reference Set for Material Disposal Areas, Technical Area 54."

Copies of the reference library are maintained at the new Mexico Environment Department Hazardous Waste Bureau; the Department of Energy Los Alamos Area Office; United States EPA, Region 6; and the ER Project Material Disposal Areas Focus Area. This library is a living collection of documents that was developed to ensure that the administrative authority has all the necessary material to review the decisions and actions proposed in this document. However, documents previously submitted to the administrative authority are not included.

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