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Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2015

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Executive Summary

As a condition to the disposal authorization statement issued to Los Alamos National Laboratory (LANL or the Laboratory) on March 17, 2010, a comprehensive performance assessment and composite analysis maintenance program must be implemented for the Technical Area 54, Area G disposal facility. Annual determinations of the adequacy of the performance assessment and composite analysis (PA/CA) are to be conducted under the maintenance program to ensure that the conclusions reached by those analyses continue to be valid. This report summarizes the results of the fiscal year (FY) 2015 annual review for Area G.

Revision 4 of the Area G PA/CA was issued in 2008 and formally approved in 2009. In conjunction with unreviewed disposal question evaluations and special analyses conducted under the Area G PA/CA maintenance program, these analyses are expected to provide reasonable estimates of the long-term performance of Area G and, hence, the disposal facility's ability to comply with Department of Energy (DOE) performance objectives.

The disposal of waste in pits is nearing its end as the disposal capacity in pit 38 is exhausted. Projections of the volumes and radionuclide inventories in the waste that will require disposal in shafts are similar to those presented in the second revision of the Area G inventory. Overall, changes in the projected future inventories of waste are not expected to compromise the ability of Area G to satisfy DOE performance objectives. The Area G composite analysis addresses potential impacts from all waste disposed of at the facility as well as other sources of radioactive material that may interact with releases from Area G. The level of knowledge about the other sources included in the composite analysis has not changed sufficiently to call into question the validity of that analysis.

Ongoing environmental surveillance activities are conducted at, and in the vicinity of, Area G. However, the information generated by many of these activities cannot be used to evaluate the validity of the PA/CA models because the monitoring data collected are specific to operational releases or address receptors that are outside the domain of the PA/CA. Monitoring data that are applicable support some aspects of the PA/CA.

Several research and development (R&D) efforts have been initiated under the PA/CA maintenance program. These investigations are designed to improve the current understanding of the disposal facility and site, thereby reducing the uncertainty associated with the projections of the long-term performance of Area G. The status and results of R&D activities that were undertaken in FY 2015 are discussed in this report.

Two unreviewed disposal question evaluations (UDQEs) were initiated during FY 2015 to evaluate an update to the radionuclide inventory for Material Disposal Area (MDA) B waste disposals at Area G, and an upgrade to the GoldSim modeling platform. Significant progress was made on the two special analyses related to these UDQEs. These are described and preliminary results are summarized herein.

The Area G disposal facility consists of MDA G and Zone 4. To date, all disposal operations at Area G have been confined to MDA G. Current plans call for pit and shaft disposal operations within MDA G to cease by October 2017. MDA G will undergo phased final closure after disposal operations end. In anticipation of the closure of MDA G, plans have been made to ship the majority of the waste generated at the Laboratory to off-site locations for disposal. It is assumed that the closure of MDA G will mark the end of pit disposal at Area G. If authorized by the DOE Los Alamos Field Office, shaft disposal operations may move to Zone 4 following the closure of MDA G. However, the Laboratory's most current Enduring Mission Waste Management Plan proposes that any further planning for Zone 4 expansion be deferred for the foreseeable future.

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Acronyms and Abbreviations

3-D	Three dimensional
Consent Order	Compliance Order on Consent
DAS	Disposal Authorization Statement
DOE	Department of Energy
DRR	Disposal receipt review
DSA	Documented safety analysis
EDE	Effective dose equivalent
EMWMP	Enduring Mission Waste Management Plan
FEHM	Finite Element Heat and Mass (model)
FY	Fiscal year
HDP	Heat dissipation probe
LANL or Laboratory	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	Low-level (radioactive) waste
MDA	Material Disposal Area
NMED	New Mexico Environment Department
NTS	Nevada Test Site
PA/CA	Performance Assessment and Composite Analysis
R&D	Research and development
SA	Special Analyses
TA	Technical area
TDR	Time-domain reflectometry probe
TRU	Transuranic
UDQ	Unreviewed disposal question
UDQE	Unreviewed disposal question evaluation
WAC	Waste acceptance criteria
WCATS	Waste Compliance and Tracking System

1.0 Introduction

As a condition to Revision 1 of the disposal authorization statement (DAS) issued to Los Alamos National Laboratory (LANL or the Laboratory) on March 17, 2010 (DOE, 2010), a comprehensive performance assessment and composite analysis (PA/CA) maintenance program must be implemented for the Technical Area 54 (TA-54), Area G disposal facility. As implemented under Department of Energy (DOE) Order 435.1 (DOE, 2001a), DOE Manual 435.1-1 (DOE, 2001b), and draft guidance for maintenance programs (DOE, 2001c), annual determinations of the adequacy of the PA/CA are to be conducted to ensure the conclusions reached by those analyses continue to be valid. Annual reports are to be submitted that

- Summarize the results of the adequacy determination;
- Describe monitoring and research and development (R&D) activities conducted at the site and discuss how the results from such activities affect the conclusions of the PA/CA;
- Describe any changes in disposal facility design, operation, and maintenance and discuss how such changes affect the PA/CA;
- Assess the need for modifications to the monitoring and R&D programs conducted in support of PA/CA maintenance; and
- Discuss the need for changes in low-level waste (LLW) disposal operations or the PA/CA maintenance program.

This report summarizes the results of the fiscal year (FY) 2015 annual review for Area G. Section 2 presents the results of the adequacy determination for Revision 4 of the Area G Performance Assessment and Composite Analysis (LANL, 2008). Section 3 summarizes the results of recent inventory revisions and discusses updates to the information used to conduct the alternate source evaluation for the composite analysis. Sections 4 and 5 present pertinent information collected through monitoring and R&D efforts, respectively, and Section 6 discusses unreviewed disposal question evaluations (UDQEs) and special analyses (SA) that were conducted to address changes in inventory characteristics and a software revision for the PA/CA model. Section 7 discusses the potential impacts of operational changes at Area G, considers informational needs, describes the progress made with respect to addressing the conditions found in the DAS, and discusses modifications that may need to be made in response to operational changes.

2.0 Performance Assessment and Composite Analysis Adequacy

Revision 4 of the Area G Performance Assessment and Composite Analysis (LANL, 2008) was issued in 2008 and formally approved in 2009. In conjunction with the UDQEs and SAs conducted under the Area G PA/CA maintenance program, these analyses are expected to provide reasonable estimates of the long-term performance of Area G and hence, the disposal facility's ability to comply with DOE performance objectives. As discussed in Section 3 of this report, the pit and shaft inventories projected for Area G have changed relative to the inventories used to conduct the Revision 4 analyses. Nevertheless, the doses projected using the PA/CA models remain well within pertinent performance objectives for members of the public; limits on the planned future disposal of high-activity tritium waste in the Zone 4 shafts will be required to maintain projected intruder exposures within acceptable limits.

The Area G disposal facility consists of existing Material Disposal Area (MDA) G and potential Zone 4. For consistency with previous performance assessment documentation, this document refers to the entire active and inactive disposal facility at Area G as MDA G. This nomenclature is different than that used in Compliance Order on Consent (the Consent Order) documents, which refer to MDA G as only those disposal units within Area G subject to the corrective action requirements of the Resource Conservation and Recovery Act. Thus, the disposal units comprising MDA G under the Consent Order are a subset of those comprising MDA G under the performance assessment.

Material Disposal Area G has been in continuous operation since Area G first received radioactive waste in the late 1950s. As discussed in Section 7, the disposal of waste in pits and shafts at MDA G is expected to be complete by October 2017 (LANL, 2016a). Revision 4 of the PA/CA assumes that additional pits and shafts will be developed in Zone 4 to provide disposal capacity after the disposal units in MDA G are full. However, the Laboratory's most current Enduring Mission Waste Management Plan (EMWMP) proposes that LLW generation at the Laboratory be minimized, and newly generated waste be shipped for off-site disposal (LANL, 2016a). The EMWMP proposes that MDA G be closed under DOE Environmental Management and that any further planning for Zone 4 expansion be deferred for the foreseeable future. Finally, the proposal in the EMWMP does not preclude the possible reopening of the site for use after all DOE-EM operations have been complete, and the overall site is returned to NNSA for long-term stewardship (LANL, 2016a). Revision 4 of the PA/CA is consistent with the plans and procedures used to manage LLW at Area G. These include documents that address disposal unit design and construction, placement of waste, and operational closure of pits and shafts (LANL, 2010a; 2015a) as well as the final closure of the disposal facility (LANL, 2009a).

The performance assessment was used to develop intruder-based radionuclide concentration limits for the disposal pits and shafts in MDA G. Radionuclide concentration limits have also been developed for the disposal of low-activity waste in the headspace of disposal pits 15, 37, and 38. These limits have been incorporated into the Laboratory waste acceptance criteria (WAC) (LANL, 2014a).

The conclusions of Revision 4 of the PA/CA remain valid at present. However, the long-term strategy that will be adopted for the disposal of LLW at the Laboratory is difficult to predict at this time and could affect some of the premises upon which the analyses are based. Increasing amounts of institutional waste and waste generated by cleanup efforts at the Laboratory are being shipped off-site for disposal. This trend is expected to continue for the foreseeable future. Disposal operations are expected to cease in MDA G by October 2017 when pit 38 and the remaining shafts are filled, and expansion into Zone 4 is deferred for the foreseeable future.

The increase in off-site shipments and the cessation of disposal will result in an overall decrease in the amount of waste disposed of at Area G relative to that projected by the PA/CA. Changes to MDA G disposal operations and modifications of the final MDA G closure strategy may also occur as the existing portion of the disposal facility nears final closure. To ensure that they continue to adequately represent conditions at Area G, the PA/CA will need to be updated as new policies and plans are solidified and put into place.

The PA/CA maintenance program plan (LANL, 2011a) takes into account findings from Revision 4 of the PA/CA and the comments received from the Low-Level Waste Disposal Facility Federal Review Group's (LFRG) review of the analyses (DOE, 2009). To address the secondary issues identified during that review and to improve the current understanding of the disposal facility and site, several R&D efforts have been, and will be, pursued. These efforts, which are identified in the plan, will reduce uncertainty in the projections of the long-term performance of Area G.

3.0 Area G Inventory Revision and Alternate Source Evaluation

Annual reviews of LLW disposal receipts are generally conducted to ensure that the future inventories projected for the PA/CA remain consistent with the actual waste inventories disposed of at Area G. The LLW generators at the Laboratory supply the data included in the inventory characterization; all these generators have been certified to send waste to Area G for disposal, as described in Section 7.0. Although complete revisions of the inventory supplanted these reviews in recent years (French and Shuman, 2013; 2015a), the more typical disposal receipt review (DRR) is used to calculate dose presented in this annual report. The results of the FY 2014 review (LANL, 2015b) are summarized in Section 3.1. During FY 2015, the disposal receipt review was not formally updated. However, we present a summary in Section 3.l of how the latest waste inventory data for FY 2015 compare with projected values used in the 2014 DRR. The Area G composite analysis addresses potential impacts from all waste disposed of at the facility as well as other sources of radioactive material that may interact with releases from Area G. As part of the composite analysis maintenance program, information about alternate sources of radioactive material that may interact with Area G releases is routinely reviewed to ensure that these alternate sources were adequately addressed. The results of this evaluation are provided in Section 3.2.

3.1 Disposal Receipt Review

The FY 2014 DRR (LANL, 2015b) compiled LLW disposal data for October 1, 2013, to September 30, 2014, and used that information to update existing inventories and estimates of the types and quantities of waste that will require disposal at Area G from October 1, 2014, through 2044, the year in which it is assumed that disposal operations at Area G will cease if disposal in Zone 4 occurs. The primary objective of the DRR is to ensure future waste inventory projections developed for the PA/CA are consistent with the actual types and quantities of waste being disposed of at Area G. Toward this end, the disposal data that are the subject of the review are used to update the future waste inventory projections for the disposal facility. Table 3-1 provides the future waste volume and activity projections developed for the FY 2014 DRR (LANL, 2015b) from October 1, 2014, through 2044. The FY 2014 DRR represents the most current inventory projections made for Area G, including Zone 4.

Table 3-1
Future Waste Inventory Estimates for Area G:
FY 2014 Disposal Receipt-Based Projections

Disposal Unit	FY 2014 Disposal Receipt-Review [a]	
	Volume (m³)	Inventory
Pits		
Headspace Layer	2.3E+03	6.2E+00 Ci
Institutional Waste Layer	2.0E+02	2.6E+01 Ci 2.3E+04 g
Shafts	2.8E+02	3.6E+06 Ci 1.6E+06 g

[a] *Includes waste expected to require disposal in pits from October 1, 2014, to 2015 and in shafts from October 1, 2014, through 2044.*

Table 3-2 compares the waste volume and activity projections developed for the FY 2014 DRR (LANL, 2015b) for FY 2015 (i.e., October 1, 2014, to September 30, 2015) with the reported FY 2015 disposal data pulled from the Laboratory's Waste Compliance and Tracking System (WCATS) in January 2016. In terms of the pit waste, a distinction is made between material placed in the headspace and institutional waste layers. The volumes of headspace and institutional waste projected by the FY 2014 DRR to require disposal in pits are significantly higher than those documented in the FY 2015 disposal data. This is consistent with the fact that very little waste was placed in pit 38 during FY 2015, and the pit was not filled and closed as planned. Based on the Laboratory's EMWMP, pit 38 is expected to be filled and closed by October 2017, and no other pits disposals will occur at the site (LANL, 2016a). Volumes and activities yet to be disposed of in pit 38 are not expected to exceed those projected by the FY 2014 DRR shown in Table 3-1. Similarly, the FY 2014 DRR projects on average, 1.2E+05 Ci per year of shaft disposal for each year from 2015 to 2044, where the actual FY 2015 data show that no waste was disposed in the shafts. The EMWMP currently proposes that the existing shafts in Area G be filled and closed by October 2017 and that further shaft disposal be deferred for the foreseeable future (LANL, 2016a). In that event, future inventory projections for the shafts from 2018 through 2044 will reflect no future waste disposal. Therefore, the FY 2014 DRR projections bound the expected future inventory for both the pit and shaft wastes.

Table 3-2
FY 2015 Waste Inventory Estimates for Area G: Projected FY 2015 Inventory Based on the FY 2014 Disposal Receipt-Based Projections vs. Actual 2015 Inventory Characterization

Disposal Unit	FY 2015 Projected Inventory Based on FY 2014 Disposal Receipt-Review [a]		FY 2015 Actual Waste Inventory [b]	
	Volume (m^3)	Inventory	Volume (m^3)	Inventory
Pits				
Headspace Layer	2.3E+03	6.2E+00 Ci	0.0	0.0 Ci
Institutional Waste Layer	2.0E+02	2.6E+01 Ci	7.0E+00	4.1E-02 Ci
Shafts	9.3E+00	1.2E+05 Ci	0.0	0.0 Ci

[a] Includes waste that was expected to require disposal in pits and shafts from October 1, 2014, to September 30, 2015.
[b] Includes actual waste disposal in pits and shafts from October 1, 2014, to September 30, 2015

Because the radionuclide inventories used to calculate dose based on the FY 2014 DRR are larger than the actual disposal data, predictions of dose based on the FY 2014 DRR are conservative (higher than would be calculated if a revision to the inventory were made based on FY 2015 data). Thus, for this annual report, we present dose calculations based on the FY 2014 DRR and plan to do a full update to the dose predictions as part of ongoing FY 2016 work.

The following discussion describes predicted doses based on the FY 2014 DRR. We note that if expansion into Zone 4 does not occur, predicted doses will decrease from those discussed below. The impacts of this operational change, if it occurs, will be assessed in future revisions to the PA/CA model.

A relatively small number of radionuclides make significant contributions to the doses projected for Revision 4 of the Area G PA/CA (LANL, 2008). In general, the impacts of using FY 2014 disposal receipt data to estimate future waste inventories depend upon how the quantities of these critical radionuclides are affected. These impacts were evaluated by revising the inventories used in Revision 4 of the PA/CA modeling and updating the dose and radon flux projections. The impacts that the disposal receipt-based inventories have on the dose and flux projections presented here based on the FY 2014 DRR were evaluated using the assumption that the waste will be distributed within Zone 4 over an area that is the same as that adopted for the PA/CA.

Preliminary modeling revealed that the disposal of the entire tritium inventory projected for the Zone 4 shafts may yield doses for the agricultural intruder scenario that are in excess of the 100 mrem/yr chronic dose limit. To prevent this from happening, it was assumed that the routine high-activity tritium waste generated during the last 8 years of the disposal facility's lifetime will be disposed of elsewhere. This restriction decreases the Zone 4 shaft tritium inventory by 960,000 Ci.

The exposures and radon fluxes projected using the updated pit and shaft inventories in the FY 2014 DRR are provided in Tables 3-3 through 3-5. These are the most current modeled projections as presented in the 2014 Annual Report for Area G (French and Shuman, 2015b), and they assume that expansion and disposal in Zone 4 will occur. Table 3-3 gives the exposures projected for members of the public, Table 3-4 shows the radon flux estimates, and Table 3-5 provides the intruder exposure projections for the performance assessment inventory as well as the composite analysis inventory. In Table 3-3, the performance assessment dose is presented based on waste disposed of at Area G after September 26, 1988, while the composite analysis accounts for all waste disposed of at Area G, beginning in 1957. Both the performance assessment and the composite analysis project future inventory based on assumptions about predicted waste disposal through 2044. The doses projected for the All Pathways–Canyon Scenario consider the exposures received within several catchments within Cañada del Buey and Pajarito Canyon; radon fluxes are projected for several waste disposal regions within Area G. These catchments and disposal regions are shown in Figures 3-1 and 3-2, respectively.

In summary, updating the Area G inventory to reflect the FY 2014 disposal data and the expected disposal trends does not compromise the ability of the disposal facility to safely contain the waste disposed therein. Disposal records from FY 2015 show that during this year, less waste was received than was predicted (Table 3-2); that is, the FY 2014 DRR projections are conservative with respect to dose projections. All doses and radon fluxes projected by the PA/CA remain within performance objectives.

Table 3-3
Exposures Projected for Members of the Public: FY 2014 Disposal Receipt Review

Exposure Scenario and Location	Performance Objective (mrem/yr)	Peak Mean Dose (mrem/yr)	
		Performance Assessment	Composite Analysis
		FY 2014 Disposal Receipt Review	FY 2014 Disposal Receipt Review
Atmospheric			
LANL Boundary	10	1.7E–01	2.4E–01
Area G Fence Line	10	3.0E–03	4.5E–01
All Pathways–Canyon			
Catchment CdB1	25/30[a]	5.3E–01	8.9E–01
Catchment CdB2	25/30	1.1E+00	2.0E+00
Catchment PC0	25/30	2.9E-04	2.9E-04
Catchment PC1	25/30	2.5E–02	2.8E–02
Catchment PC2	25/30	1.9E–02	1.7E–01
Catchment PC3	25/30	1.0E–01	1.7E–01
Catchment PC4	25/30	1.8E–01	2.7E–01
Catchment PC5	25/30	2.4E–01	2.9E+00
Catchment PC6	25/30	1.3E–01	3.2E+00
Groundwater Pathway Scenarios			
All Pathways–Groundwater	25/30	7.0E–03	7.1E–03
Groundwater Resource Protection	4	1.2E–02	NA

NA = Not applicable.

[a] An all-pathways performance objective of 25 mrem/yr applies to the performance assessment; doses projected for the composite analysis must comply with the 30 mrem/yr dose constraint.

Table 3-4
Projected Radon Fluxes: FY 2014 Disposal Receipt Review

Waste Disposal Region or Pit	Peak Mean Flux (pCi/m²/s) FY 2014 Disposal Receipt Review
Region 1	1.3E-06
Region 2	—[a]
Region 3	0.0E+00
Region 4	3.3E-02
Region 5	8.4E-05
Region 6	3.3E-03
Region 7	1.3E+01
Region 8	3.7E-03
Pit 15	1.4E+01
Pit 37	2.8E-01
Pit 38	1.2E+00
Entire facility	4.4E-01

[a] *— = None of the performance assessment inventory was disposed of in the waste disposal region.*

Table 3-5
Projected Intruder Exposures: FY 2014 Disposal Receipt Review

Disposal Units and Exposure Scenario	Performance Objective	Peak Mean Dose (mrem/yr) 2014 Disposal Receipt Review
MDA G Pits		
Intruder-Construction	500 mrem	3.9E+00
Intruder-Agriculture	100 mrem/yr	2.7E+01
Intruder-Post-Drilling	100 mrem/yr	1.3E+01
Zone 4 Pits		
Intruder-Construction	500 mrem	0.0E+00
Intruder-Agriculture	100 mrem/yr	0.0E+00
Intruder-Post-Drilling	100 mrem/yr	0.0E+00
MDA G Shafts		
Intruder-Construction	500 mrem	5.1E+00
Intruder-Agriculture	100 mrem/yr	8.5E+01
Intruder-Post-Drilling	100 mrem/yr	1.2E+01
Zone 4 Shafts		
Intruder-Construction	500 mrem	3.7E+00
Intruder-Agriculture	100 mrem/yr	8.6E+01
Intruder-Post-Drilling	100 mrem/yr	1.1E+01

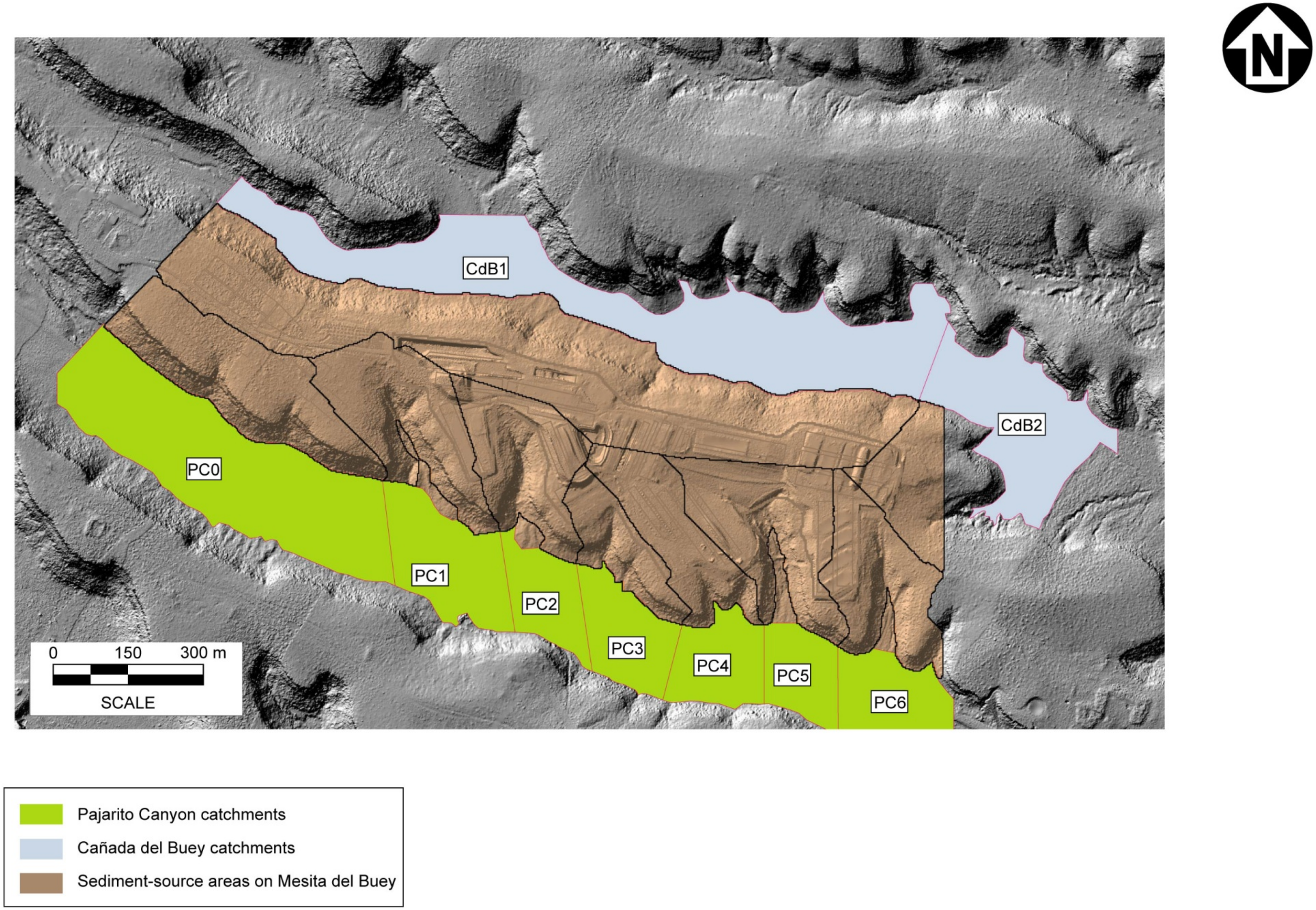

Figure 3-1
Area G Sediment Catchments in Pajarito Canyon and Cañada del Buey

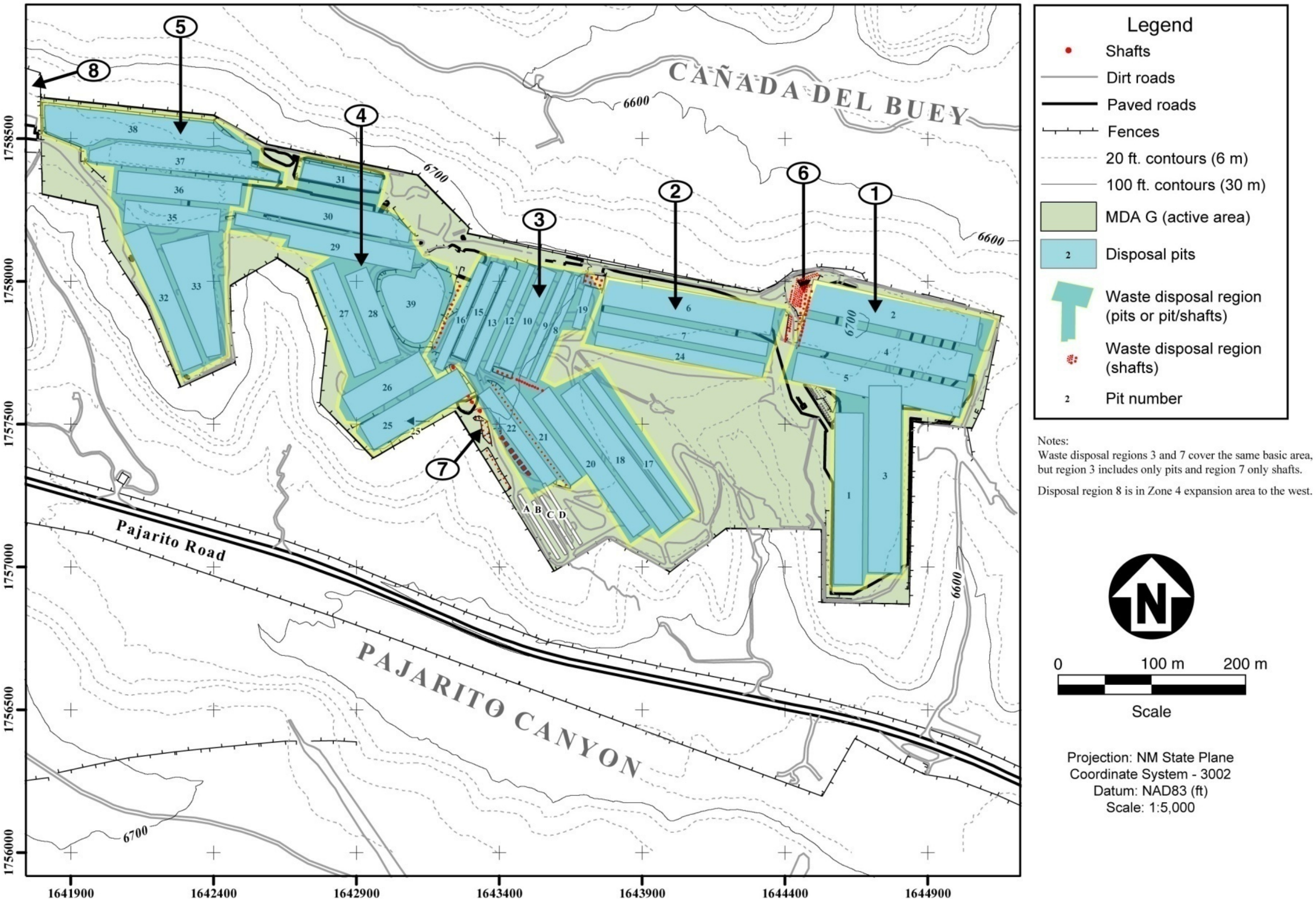

Figure 3-2
Waste Disposal Regions at Area G

Source: Apogen Technologies (formerly SEA)
LANL RRES Database, Map ID: 4531.021 (1) Rev.

3.2 Alternate Source Evaluation

The alternate source evaluation conducted in support of the Area G composite analysis (LANL, 2008) considered several sources of radioactive materials at the Laboratory: MDAs A, AB, B, C, H, J, L, and T; Cañada del Buey; and Pajarito Canyon. The MDAs, all of which are located on mesas, were included because they have been used to dispose of potentially large quantities of radioactive waste, are highly contaminated, or are located near Area G. The two canyons were included because they have received discharges of waste in the past or are otherwise contaminated and because they are adjacent to Area G. The alternate source evaluation concluded that the potential for significant interaction between Area G and other source areas is low; this conclusion was based on an assessment of the radionuclide inventories present at the various facilities, the likelihood of contaminant release, and the probability that releases from the alternate sources will come into contact with releases from Area G. Therefore, the composite analysis includes the Area G inventory; the alternative source evaluation is a qualitative evaluation of the alternative sources.

All the MDAs, except MDAs AB, C, H, and T, were excluded early in the alternate source evaluation on the basis of the relative activities disposed of at these facilities and at Area G. Specifically, the radionuclide inventories for each of the excluded MDAs were small fractions of the corresponding inventories at Area G, making it unlikely that releases from the alternate sources could significantly increase the exposures estimated for releases from Area G. MDAs AB, C, H, and T all had inventories of at least one radionuclide that were greater than the corresponding Area G inventory; however, the alternate source evaluation concluded that there was little likelihood of significant interaction between releases from these facilities and releases from Area G. Recently published information for all but one of the MDAs included in the alternate source evaluation was reviewed to determine if the conclusions of the evaluation remain valid; these reviews are summarized in Sections 3.2.1 through 3.2.6. No further consideration was given to MDA J because this facility never received radioactive waste.

Previous sampling data for Cañada del Buey and Pajarito Canyon suggest that Area G is the primary source of contamination in the canyon locations accessed by the receptors in the PA/CA. Contamination detected in canyon sediments is thought to be related to residual contamination rather than to releases from Area G pits and shafts. Rates of transport of surface contamination into the canyons will decrease as the facility undergoes closure and the final cover is applied; releases to the canyons after final closure is complete will come primarily from the disposal units. Based on this information, Revision 4 of the composite analysis concluded that no significant interactions between releases from Area G and other Laboratory facilities are likely to occur within the two canyons. Environmental surveillance data collected from Cañada del Buey and Pajarito Canyon in 2014 and other sources of information have been reviewed to determine if this conclusion remains valid.

The alternate source evaluation discussed the possibility of interactions between releases from Area G and contamination that has been discharged to other canyons at the Laboratory; it was noted that Pueblo, Los Alamos, and Mortandad Canyons have received contaminant discharges as a result of activities at the Laboratory. The evaluation concluded that existing contamination beneath Mortandad Canyon, located north of Cañada del Buey and TA-54, could, under some well-pumping scenarios, interact with releases from Area G. However, the fact that water-supply pumping has had little effect on water levels to date indicates that the likelihood of such interaction is low. Contaminants that reach the aquifer tend to follow the water table gradient; this gradient is eastward beneath Mortandad Canyon and is to the southeast at Area G.

Regular groundwater monitoring of perched-intermediate groundwater (where present) and the regional aquifer is conducted at each of the alternate sources according to sampling defined in the Laboratory's Interim Facility-Wide Groundwater Monitoring Plan for a given monitoring year (e.g., LANL, 2014b). Groundwater samples are collected annually or more frequently, and concentrations of radionuclides and other chemicals are measured and reported. Groundwater quality data collected at these sites and at background (i.e., not impacted by Laboratory operations) locations, including at the City of Santa Fe's Buckman well field and within the Pueblo de San Ildefonso, indicate the widespread presence of naturally occurring uranium (LANL, 2015c). Gross-alpha and gross-beta values sampled in groundwater are also consistent with the presence of uranium. Therefore, the presence of these constituents in groundwater at concentrations within background ranges does not indicate contamination has migrated from the sites to groundwater.

In the subsections that follow and in section 4.1.2, groundwater concentrations for radionuclides are compared with the Laboratory's screening levels. The screening levels used for individual radionuclides are the 4-mrem Drinking Water Derived Concentration Technical Standards provided in DOE Order 458.1.

3.2.1 MDA A

The sources of contamination at MDA A include two buried 190 m^3 (50,000-gal.) steel tanks that were used to store waste solutions from plutonium processing. The liquid contents of the tanks were recovered, treated, and disposed of between 1975 and 1983; radioactive sludge remains in the bottoms of the tanks (1.2 to 2.4 m^3 [330 to 640 gal.] in the east tank and 7 m^3 [1850 gal.] in the west tank) (Roback et al., 2011). Other sources of contamination are three pits that received solid waste and debris. The radionuclide inventories estimated for the facility are small fractions of the corresponding Area G inventories. On this basis, no significant interaction between releases from MDA A and Area G was expected.

Previously, plans were made calling for the removal of all waste from the pits and tanks at MDA A and the subsequent removal of the tanks; the Laboratory submitted an investigation/remediation work plan to the New Mexico Environment Department (NMED) in support of that action (LANL, 2009b). Subsequently, the Laboratory requested that the work plan be withdrawn; the intent was to submit a supplemental work plan to address data gaps that, once addressed, will support the evaluation of multiple remedies in a corrective measures evaluation (LANL, 2012a). Current plans call for submitting a corrective measures evaluation after completion of additional site investigations. Investigation reports will be reviewed for their relevance to the alternate source evaluation in future annual reports.

3.2.2 MDA AB

The alternate source evaluation considered the likelihood that the large inventories of Pu-239 and Pu-240 left behind from belowground hydronuclear experiments at MDA AB would interact with releases from Area G. Because of the depth of the contamination, the rates of release of these isotopes to the surface from biotic intrusion are expected to be low relative to those at Area G. Any releases of plutonium to the regional aquifer will likely occur long after the 1,000-year compliance period, and contaminant plumes from MDA AB and Area G are not expected to intersect. For these reasons, the Revision 4 alternate source evaluation concluded that no significant interaction between releases from MDA AB and Area G is likely.

The documented safety analysis (DSA) for nuclear environmental sites at the Laboratory was used to estimate radionuclide inventories for MDA AB under the alternate source evaluation. Although this report is revised periodically, no changes to the facility’s inventory have occurred since the composite analysis was conducted (LANL, 2015d). Groundwater monitoring conducted at the facility in September 2014 revealed detections of isotopes of uranium consistent with background levels (LANL, 2015e). These results do not contradict the conclusions reached in the alternate source evaluation.

3.2.3 MDA B

Material Disposal Area B was eliminated from the alternate source evaluation because the radionuclide inventories estimated for the facility are small compared with those at MDA G. Complete removal of the waste disposed of at the facility was proposed in 2006. The retrieval of waste commenced in June 2010 and was completed in September 2011; material was excavated until the contaminant concentrations in the native tuff encountered below the waste were less than residential soil screening levels. A total of 36,200 m^3 (47,350 yd^3) of LLW was shipped from MDA B (LANL, 2013a). Most of the waste was shipped off site, but some was disposed of in pits 37 and 38 at Area G. The inventory in that waste is now included in the Area G inventory model (see Section 6.1). Because the MDA B cleanup effort removed the entire inventory, no releases from the area will interact with releases from Area G.

3.2.4 MDA C

Material Disposal Area C was the primary radioactive waste disposal facility at the Laboratory before Area G came into use. Airborne releases from MDA C will yield small contaminant concentrations relative to those from Area G, and releases from leaching are expected to discharge to the regional aquifer after the 1,000-year compliance period. These findings led to the Revision 4 conclusion that releases from Area G and MDA C will not interact in a significant manner.

A corrective measures evaluation was issued in 2012 (LANL, 2012b), the objective of which is to recommend a corrective measures alternative that will provide long-term protection of human health and the environment. The report recommends placement of an evapotranspiration cover over the site to minimize water infiltration and exposures to the waste, soil-vapor extraction to limit the movement of volatile organic compounds toward groundwater, and institutional control and monitoring of the site for a period of 100 years following placement of the cover. Information provided in the report does not contradict the conclusions reached in the 2008 alternate source analysis. Periodic monitoring of the groundwater conducted in November 2014 and May 2015 (LANL, 2015f; 2015g) detected low levels of U-234 and U-238 consistent with background levels. These results are consistent with the conclusions reached in the alternate source evaluation.

3.2.5 MDAs H and L

Material Disposal Areas H and L are located on the same mesa as Area G. The alternate source evaluation assessed the likelihood that potentially high inventories of uranium at MDA H could interact with releases from Area G. It was concluded that any such interaction was unlikely because rates of radionuclide release to the surface are expected to be low and because contamination leached from the waste is unlikely to reach the regional aquifer within the 1,000-year compliance period.

Intermediate and regional groundwater monitoring was conducted at several locations in the vicinity of MDA H in FY 2014, including regional wells R-37, R-40, R-51, and R-52 (Figure 4-1), all of which are located in the immediate vicinity of the disposal facility. Low levels of gross-beta radiation, U-234, and U-238 measured during the two FY 2015 groundwater monitoring sampling events are consistent with background levels. A single detection of Sr-90 is also consistent with background levels. Finally, low-level tritium (33 pCi/L) was detected at R-37 (LANL, 2015h; 2015i). These results are consistent with monitoring results from FY 2013 and FY 2014.

The alternate source evaluation removed MDA L from consideration on the basis that no radioactive contaminants are included in the disposal records for the facility. Monitoring was conducted at several regional wells close to MDA L during two sampling events in FY 2015, including wells R-20, R-21, R-38, R-53, R-54, and R-56 (Figure 4-1) (LANL, 2015h; 2015i).

Low levels of gross beta, U-234, and U-235 were observed at concentrations consistent with background levels. Gross alpha was detected in the upper screen of well R-53 during October 2014 sampling at a value above background and slightly above half the Laboratory's screening level.

3.2.6 MDA T

The estimated inventory of Am-241 placed in the shafts at MDA T exceeds the Area G projection for this radionuclide. As a result, MDA T underwent further scrutiny in the alternate source evaluation. The evaluation concluded that rates of radionuclide release from the shafts because of biotic intrusion may be similar to those projected for Area G and that contamination deposited on the surface of the facility by plants and animals may be transported by prevailing winds to critical exposure locations downwind of Area G. However, for a given release rate, airborne concentrations of radionuclides originating at MDA T will be less than 1 percent of those originating at Area G. As a result, any increases in the air pathway exposures projected for Area G, which are low to begin with, will be insignificant. The alternate source evaluation also concluded that radionuclides leached from the shaft waste are not likely to reach the regional aquifer during the 1,000-year compliance period that applies to the composite analysis.

Groundwater monitoring locations at TA-21 include regional well R-6, R-64, and R-66. R-64 is adjacent to MDA T and the other two are located downgradient of MDA T (LANL, 2015j; 2016b); samples are drawn from deep and intermediate depths within the TA-21 monitoring group. Sampling conducted in 2014 and 2015 revealed low levels of gross-beta radiation, U-234 and U-238 in all three regional wells that are consistent with background levels. A low-level Pu-239/240 detection at R-64 in 2014 was reanalyzed and found to be nondetect; the 2015 sample at this well did not detect Pu-239/240 (LANL, 2015j; 2016b). Perched-intermediate wells downstream of MDA T do indicate elevated levels of radionuclides, but those are attributed to the Solid Waste Management Unit 21-011(k), which was an effluent outfall from industrial and radioactive waste treatment plants at TA-21. The Laboratory DSA for nuclear environmental sites was used to estimate radionuclide inventories for MDA T under the alternate source evaluation; no changes to these inventories were made in the latest revision (LANL, 2015d) of this analysis. Overall, then, the conclusions reached about the likelihood of source interaction between MDA T and Area G remain unchanged.

Additional site investigations are proposed that include the installation of a vadose-zone moisture monitoring network (LANL, 2011b). A future submittal of a corrective measures evaluation for MDA T is planned, following completion of site investigations. Investigation reports will be reviewed for their relevance to the alternate source evaluation in future annual reports.

3.2.7 Cañada del Buey and Pajarito Canyon

As discussed earlier, it was considered unlikely that discharges from Area G to Cañada del Buey and Pajarito Canyon will interact with canyon discharges from other facilities at the Laboratory. This conclusion was based on the fact that surface contamination at Area G appears to be the primary source of the radionuclides detected in the canyons and that this source of contamination will diminish as the facility undergoes closure and a final cover is applied.

Surface water and sediments are sampled in the Laboratory's major watersheds; the results of recent monitoring efforts are summarized in the Laboratory's 2014 Annual Site Environmental Report (LANL, 2015c). Surface water sampling locations near Area G include one gaging station each in Pajarito Canyon and Cañada del Buey at the east end of the disposal site and five storm water locations within or adjacent to Area G. Sediments were sampled at several locations along small drainages within the disposal site and in Pajarito Canyon and Cañada del Buey.

In terms of sediments, Pu-239/240 was detected in Pajarito Canyon at concentrations that were less than screening action levels but above regional background values near Area G before 2014. Similar concentrations were detected in 2014. Concentrations of U-234 and U-238 in sediments near Area G have been consistently below regional background values since 2004. Overall, the relative stability of radionuclide concentrations in sediments collected near Area G supports the contention that the disposal facility is the primary source of contamination in the adjacent canyons. Radionuclide concentrations in surface waters and storm water runoff tend to be more variable. Concentrations of Am-241, Cs-137, Pu-238, Pu-239/240, Sr-90, U-234, and U-238 detected in storm water have all been below the DOE's biota concentration guides.

4.0 Monitoring Data Summary and Evaluation

Monitoring at Area G includes a variety of routine Laboratory-wide environmental surveillance activities and a smaller set of site-specific monitoring activities associated with site closure efforts. These activities are discussed below with respect to their relevance to the Area G PA/CA (LANL, 2008).

4.1 Environmental Surveillance

Environmental surveillance activities typically include the monitoring of air and meteorological conditions, direct radiation, storm water and sediments, soils, biota, and vegetation. Surveillance data collected through these efforts are summarized annually in the Laboratory's annual site environmental reports. The surveillance information discussed in this annual report was taken from the Laboratory's Annual Site Environmental Report for 2014 (LANL, 2015c), which contains the most recent published surveillance information.

The environmental surveillance data collected at or near Area G support ongoing waste disposal operations and show that measured releases from the site are below thresholds of concern. The surveillance activities focus primarily on radionuclide concentrations in environmental media, the sources of which are typically waste storage and disposal operations; most of these sources will not exist after the facility has undergone final closure. Surveillance activities that are, or may be, pertinent to both ongoing disposal activities and the PA/CA are summarized in the following sections.

4.1.1 Air Surveillance

The air surveillance effort at the Laboratory monitors ambient air concentrations of contaminants generated and released at the Laboratory and characterizes the meteorological conditions at the facility. Results of the 2014 activities that are relevant to the Area G PA/CA are discussed below.

4.1.1.1 Ambient Air Sampling

The AIRNET radiological air sampling network measures environmental levels of radionuclides that may be released from facilities at the Laboratory. Twenty-five environmental data compliance stations were operated by the Laboratory in 2014 to collect particulates at on-site and regional locations, and a subset of these stations collected water vapor based on known associations of tritium. Environmental compliance stations are EPA-approved locations meant to capture yearly effective dose equivalent (EDE) in mrem/yr. In addition to the compliance stations, the Laboratory operates AIRNET stations around the Laboratory at locations of both known point sources and diffusive sources of airborne radionuclides. The Area G sampling network includes eight of these samplers. The concentrations of radioactive constituents found in the collected samples are used to estimate exposures received by a maximally exposed individual.

The majority of the radionuclides sampled by the AIRNET network at Area G enter the atmosphere following particulate resuspension. This contamination is generally the result of unplanned releases that occur during disposal operations. The atmospheric surveillance activities also target releases of vapor-phase tritium, most of which comes from the large quantities of tritium waste that have been disposed of in the shafts at Area G. The comparison of these measured releases and those projected by the PA/CA can provide some insight into the general validity of the modeling. However, because the PA/CA model does not include the same receptor locations as the AIRNET sampling, this comparison can only be done in a qualitative manner.

The PA/CA models project airborne tritium (as tritiated water) concentrations along the Laboratory boundary east of Area G, while the closest AIRNET network sampling location is located in the town of White Rock, which lies within 500 ft of the Laboratory boundary. The diffusion of tritiated water vapor from the high-activity tritium waste disposed of at Area G was projected by the most recent composite analysis (February 2015) to yield a peak mean exposure of 0.25 mrem/yr along the Laboratory boundary east of Area G. This dose is projected to occur in the year 2017; the mean exposure projected for 2014 is about 0.24 mrem/yr. Results from the 2014 AIRNET sampling show the average dose from tritium for a person living in White Rock was approximately 0.02 mrem (LANL, 2015k). Based on these results, it appears the PA/CA model projections of tritium exposure are higher than measured values at approximately the same location. Finally, we note that although sources of tritium release other than Area G exist at the Laboratory, the exposures from tritium releases at Area G are expected to dominate the exposures estimated for White Rock because of the large quantities of tritium placed in the shafts and because the town is only 2 km (1.2 mi) away. Data from past on-site air monitoring at Area G support this interpretation, indicating the highest on-site mean atmospheric concentrations of tritium (as tritiated water) have occurred at TA-54 near shafts used for the disposal of high-activity tritium waste.

4.1.1.2 Meteorological Monitoring

A network of six towers is used to collect meteorological information within the Laboratory boundaries; one of the towers is located at TA-54 along the eastern edge of Mesita del Buey. The information collected at the towers includes wind speed and frequency, temperature, pressure, relative humidity and dew point, precipitation, and solar and terrestrial radiation. Precipitation is also measured at three non-tower locations.

Information collected from the meteorological towers supports many Laboratory activities, including the Area G PA/CA. The atmospheric transport modeling conducted with CALPUFF modeling software (Jacobson, 2005) used wind speed and frequency data for 1992 through 2001 to estimate average meteorological conditions in the vicinity of the disposal site, and long-term averages of precipitation data were used in the infiltration modeling that was conducted using the HYDRUS computer code (Levitt, 2008 and 2011; LANL, 2013b). Given that these evaluations used average conditions, the addition of a year's worth of meteorological data will generally have a limited impact on the results of the PA/CA. Beginning in 2012 and continuing through 2016, analyses of the impacts of increased moisture introduced to pits while they were uncovered are being conducted using daily precipitation records. In this case, the impacts of the transient precipitation on water flow through the pits are being evaluated, including extreme events. For example, 13.2 in. of precipitation fell on Area G in the summer of 2013, at which time pit 38 was not fully covered. An update of this work is included in Section 5.1 and will be documented as part of ongoing R&D activities for the groundwater pathway. This work is being implemented to address the secondary issues identified by the LFRG (DOE, 2009). Results of this R&D will determine if increased moisture collected while pits were open needs to be included in future updates of the PA/CA model.

4.1.2 Groundwater Monitoring

The Laboratory has been required by the NMED to establish a groundwater monitoring network at TA-54 that will provide an understanding of the nature and extent of groundwater contamination, support Resource Conservation and Recovery Act monitoring requirements, and protect against off-site migration of contaminants and subsequent contamination of water supply wells. In compliance with this requirement, the Laboratory evaluated regional characterization wells drilled under the *Hydrogeologic Workplan, Los Alamos National Laboratory* (LANL, 1998) to determine if they were suitable for use in a final monitoring network. Subsequent assessments were undertaken to determine where to locate additional monitoring wells (LANL, 2007), and 13 additional regional wells were installed for monitoring at TA-54 between 2008 and 2011.

The Laboratory's groundwater monitoring plan is revised annually and submitted to NMED for approval. Monitoring is organized in terms of six monitoring groups, one of which is the TA-54 Monitoring Group. General surveillance activities are defined for surface water and groundwater in seven watersheds or watershed groupings; two of these, the Mortandad and Pajarito Canyon watersheds, include areas adjacent to Area G. The configuration of the TA-54 monitoring well network in FY 2015 is shown in Figure 4-1 (LANL, 2014b). In the vicinity of Area G, the network includes screens at R-23i and R-55i that sample perched-intermediate groundwater and deep regional wells R-21, R-23, R-32, R-39, R-41, R-49, R-55, R-56, and R-57. The deep wells have one or two screens for sampling the regional aquifer. Two wells that sample shallow alluvial groundwater are located slightly upgradient of and adjacent to Area G in Pajarito Canyon; alluvial wells close to Area G in Cañada del Buey are generally dry. Sampling results for the groundwater monitoring effort are published in periodic monitoring reports and the Laboratory's annual environmental report (e.g., LANL, 2015c).

Water from the regional aquifer discharges to the Rio Grande via several springs located in White Rock Canyon, several of which are located downgradient of Area G. As such, the possibility exists that contaminant releases from the disposal facility could affect these waters. Routine monitoring of these springs is conducted as part of the general groundwater surveillance efforts.

Gross-beta radiation, U-234, and U-238 were detected at most wells that monitor Area G, and concentrations are consistent with background values (LANL, 2015h; 2015i). The latest published results from the semiannual sampling indicate the presence of tritium at two screens in well R-23i and in R-39. The measured tritium concentrations fall within the range of tritium levels in rainfall (2 pCi/L to 50 pCi/L) and may indicate infiltration along Pajarito Canyon. Sr-90 was detected in wells R-23i and R-23 in 2015, with one value in R-23i exceeding the Laboratory's screening level, but the sample had high turbidity and this result was not repeated when the sample was reanalyzed. Gross alpha was detected in the upper screen of R-53 at just over half the Laboratory's screening value. All other radionuclides were present at concentrations less than half of the Laboratory's screening levels

Watershed surveillance is conducted in conjunction with the groundwater monitoring effort and includes sampling of alluvial and surface waters. Results of the sampling are published in periodic monitoring reports and are also presented in the Laboratory's environmental reports. The latest published results from the Pajarito Canyon watershed (LANL, 2015l) include data for sampling conducted during April 2015. Gross beta, U-234, and U-238 were detected in two alluvial wells in Pajarito Canyon (one upgradient of and one adjacent to Area G) and in two regional wells in the lower reaches of Cañada del Buey; all concentrations are consistent with background values.

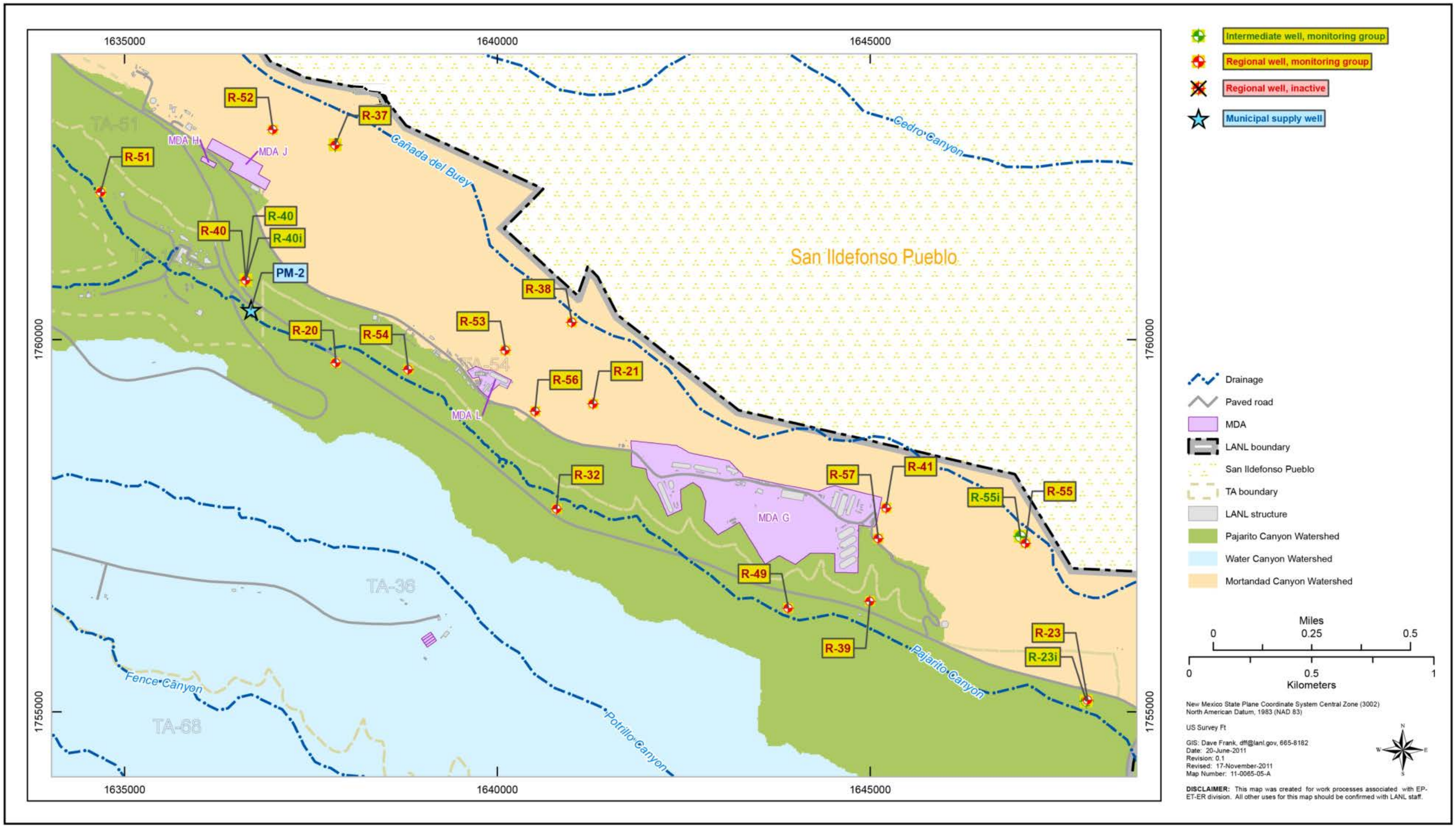

Figure 4-1
TA-54 Monitoring Network

4.2 Moisture Monitoring

Periodic monitoring is conducted at Area G to determine volumetric moisture contents adjacent to, and within, disposal units at the facility. These monitoring efforts include the collection of (1) water potentials in the floor of pit 38 using heat dissipation probes (HDPs), (2) water contents in the interim cover of pit 31 using time-domain reflectometry probes (TDRs), and (3) water contents collected from neutron access tubes. Moisture data were collected from the HDPs and TDRs during 2015. These field data are used for groundwater model calibration.

A report summarizing all available moisture monitoring data for Area G was completed during 2015 (Levitt et al., 2015). This report includes and analyzes the HDP data from the pit 38 extension and the TDR data from pit 31 downloaded in 2015 as well as neutron probe data measured in pits 37 and 38 in 2013. In addition to summarizing all available moisture monitoring data in the report, all the monitoring data, including the historical data sets that originated from a variety of sources, were compiled into a database. As part of this activity, a thorough investigation into the source and pedigree of neutron probe calibration equations used in previous reports was performed; these calibration equations are used to convert neutron counts into moisture content data. Investigations included analysis of original data files with measured water contents from core samples and initial neutron logs. As a result of this research, (1) both errors in calibration equations and lack of pedigree for calibration equations for the older data sets were found, (2) calibration equations were recalculated based on the original data files mentioned above, and (3) the historical moisture content data sets were reevaluated. This analysis allows for more consistent comparisons of historical neutron probe data sets to those collected in the future.

The following paragraphs summarize the results of more recent moisture monitoring activities conducted in pits 38 and 31 at Area G.

Three boreholes were drilled into the floor of the newly excavated pit 38 extension in 2012. Each hole was instrumented with 8 HDPs at depths ranging from 0.34 to 3.1 m (1.1 to 10.1 ft) below the pit floor. Through mid-2013, moisture contents fluctuated as the probes equilibrated with ambient conditions and in response to rainfall and snowfall events and subsequent drying.

Especially heavy rains fell at Area G in September 2013. The TA-54 meteorology station recorded 336 mm (13.2 in.) of rain between June 28, 2013, and September 19, 2013. Of this total, 180 mm (7.1 in.) fell from September 1 through September 19, including 170 mm (6.7 in.) from September 10 through September 15. At the time, the pit 38 extension had been excavated but the disposal of waste had not begun. Sensors closest to the floor of the pit measured infiltration from the major storm within days of its occurrence while it took more than a year for the deeper sensors to detect the wetting front. Wetting also occurred at the locations of the shallow sensors immediately following the start of disposal in July 2014; the increased moisture may have been caused by the application of dust suppression water to the active waste surface. As of February 2015, a matric potential of −1 bar was observed for all of the HDPs, which corresponds to a volumetric water content of about 10 percent, or approximately 25 percent saturation.

The TDRs are used to measure water contents at six depths in the interim cover of pit 31; data are collected at depths ranging from 0.76 to 2.3 m (2.5 to 7.5 ft) belowgrade using two probes at each depth. Data from late 2008 to April 2015 are summarized in Levitt et al. (2015). After a period of drying from mid-2010 to mid-2013, sharp increases in volumetric water contents occurred at all depths in response to the September 2013 rains referred to earlier. The cover steadily dried out following those storms through late 2014, possibly in response to snow melt. As of April 2015, volumetric water contents in the pit 31 cover range from about 13 to 19 percent or about 30 to 45 percent saturation.

5.0 Summary of Research and Development Efforts

Research and development activities are planned and implemented to address the secondary issues identified by the LFRG (DOE, 2009) and, more generally, to reduce the uncertainty associated with the PA/CA. Fiscal Year 2015 activities included ongoing work on groundwater modeling, surface erosion modeling, and characterization of cliff retreat.

5.1 Groundwater Modeling

The effort to understand the impacts of transient flow on infiltration rates through the disposal units at Area G and contaminant travel times to the regional aquifer continued in FY 2015. Tasks included infiltration modeling using the HYDRUS 2D computer code, validation of the models by comparison to site moisture monitoring data (Section 4.2), compilation of precipitation data needed to characterize past water inputs into the disposal units, creation of a 1000-year synthetic rainfall record, re-examination of the hydrological properties of waste, refinement of the time line for waste disposal and cover emplacement in pit 38, creation of a new three dimensional (3-D) Finite Element Heat and Mass (FEHM) model mesh for pit 31 and recalculation of conservative breakthrough using the latest version of FEHM. The updated HYDRUS 2D simulations of pit 38 include over 13 in. of rain that fell in September 2013. This change, combined with modifications to waste package properties, leads to increased moisture migration beneath the pits. Plans for FY 2016 include completion of HYDRUS models for pits 15, 31, and 39; simulation of conservative breakthrough using FEHM for pits 38 and 31; and continued validation using moisture monitoring data.

5.2 Erosion Modeling

The Area G PA/CA projects the long-term performance of the disposal facility, incorporating the final cover placed over the closed disposal units. The SIBERIA landscape evolution model is used to evaluate the impacts of surface erosion on the cover, taking into account the complex terrain characteristic of the disposal site (Wilson et al., 2005; Crowell, 2010).

Information regarding the locations of the disposal units at Area G has improved over time as archived records have been discovered and new data collected. This information was used to update the locations of the pits and shafts in the SIBERIA modeling to predict more accurately the impacts of erosion on the units' long-term performance. Shifting the locations of the disposal pits required adjustments to the final cover to ensure the minimum cover thickness criterion applied to the final cover design were satisfied. In conjunction with this effort, the locations of the waste surfaces (or ceilings) were reviewed to ensure they were consistent with current knowledge about the site and the maximum waste stacking guidelines that were in effect when each unit was closed.

Other archival information discovered impacts the representation of resistant tuff in the SIBERIA model domain. Engineering drawings were earlier found that provide topographic maps of Area G based on surveys performed in 1957 and 1962, before development of the site. However, the spot heights and elevation contours are mapped in the "Army" or "LASL" (Los Alamos Scientific Laboratory) coordinate system previously used across the Laboratory. A 1994 report (ICF Kaiser Engineers, 1994) provided a transformation between the LASL coordinate system and the current standard New Mexico State Plane coordinate system. This allowed the integration of the topographic data into the site modeling with a higher accuracy than previously possible. Revision of the top-of-tuff surface incorporating this data was initiated and is ongoing.

An event-based runoff model simulating a 500-year and a 1000-year storm was applied to the cover design to assess vulnerability to extreme rainfall events. Results of the simulations suggest that the gravel of the specified gravel mulch (Day et al., 2005) may be mobilized over limited areas of the cover. An effort is ongoing to estimate the quantity of gravel that may be eroded, as sediment transport models for gravel channels cannot be directly applied to shallow hillslope flows.

Results of SIBERIA simulations run on the revised cover and waste surface configurations were consistent with earlier work. A report documenting that effort, the revised top-of-tuff surface and the SIBERIA simulations incorporating that surface, and the extreme rainfall event modeling is scheduled to be issued in FY 2016.

5.3 Cliff Retreat

Work to characterize the mechanisms and rates of cliff retreat along the edges of Area G continued in FY 2015. Comparisons of photo-documentation from June 2012 and April 2014 revealed one location on the south side of Area G that experienced minimal cliff failure; all other locations remained unchanged. Information gathered from the April 2014 photo-documentation campaign was incorporated into the FY 2012 cliff retreat report to produce an updated internal report titled *Cliff Retreat Characterization for Los Alamos National Laboratory Technical Area 54*.

Cosmogenic dating analyses were started in FY 2015 and will continue in FY 2016. Cosmogenic dating can provide an estimate of the amount of time a particular surface has been exposed to bombardment by cosmic rays; this dating technique will provide insight into the long-term stability of the Area G cliffs and the length of time the cliffs have been in their current geometry. A total of 25 samples have been collected: 13 samples from the south side of Area G during one campaign, and an additional 12 samples from the south and north sides of Area G as well as central and eastern TA-54 during a later campaign. Tulane University will conduct the cosmogenic dating experiments during FY 2016. Results are expected in the spring of 2016 and will be incorporated into the existing cliff retreat report in FY 2017.

6.0 Summary of Unreviewed Disposal Question Evaluations and Special Analyses

Two UDQEs were conducted during FY 2015 to evaluate (1) an update to the radionuclide inventory for MDA B waste disposals at Area G, and (2) an upgrade to the GoldSim modeling platform. Significant progress was made on the two special analyses related to these UDQEs. These analyses and the results of these efforts are summarized below.

6.1 Update to the Radionuclide Inventory for MDA B Waste Disposals

Radioactive waste excavated from the trenches at MDA B (see Section 3.2.3) has been disposed of in pits at Area G since 2012. Most recently, the remaining 139 containers of this material were placed in pit 38 during 2014. To more accurately estimate radionuclide inventories in MDA B waste disposed at Area G, waste characterization data were re-evaluated and used to establish radionuclide concentration distributions for all isotopes included in the waste. These concentration distributions were used to estimate radionuclide activities in the affected waste, including uncertainty. UDQE 1501 concludes that updating the radionuclide inventories in WCATS to be consistent with concentration distributions for 139 MDA B waste containers recently disposed at Area G is an unreviewed disposal question (UDQ).

Special Analysis 2015-001 is being finalized to update the inventories listed in the WCATS database so they are consistent with the concentration distributions. A similar UDQE (1301) and Special Analysis 2013-001 were conducted in 2012 for 1,144 containers of MDA B waste that had undergone disposal.

The mean values of the radionuclide concentration distributions will be used to calculate updated inventories for the 139 containers of waste and those values will be incorporated into WCATS. The revised inventories for Am-241, Pu-238, and Pu-239 are modestly higher than those originally assigned to the waste packages. The revised inventories for the remainder of the radionuclides in the MDA B waste are 50 percent or less of those listed in the database because a less conservative approach was used to estimate the isotopes' inventories. The revisions to the MDA B waste inventories will not change the doses and radon fluxes projected for the Area G PA/CA because the reevaluated radionuclide concentration distributions were used to estimate inventories for this waste. That is, the inventory model currently included in the PA/CA already incorporates the re-evaluated inventory for the 139 MDA B waste containers. The updating of WCATS, to be consistent with the reevaluated inventory and the inventory model already included in the most recent PA/CA update, is the step that needs to be completed to close this UDQE.

6.2 Upgrade to GoldSim Modeling Software

The accuracy of the PA/CA depends upon the validity of the models, data, and assumptions used to conduct the analyses. If changes in these models, data, and assumptions are significant, they may invalidate or call into question certain aspects of the analyses. The long-term performance of the Area G disposal facility is evaluated using models developed with the GoldSim modeling platform. Version 11 of GoldSim was issued in July 2013. UDQE 1503 recommended that an SA be conducted to update the PA/CA modeling software from Goldsim version 10.11 to version 11.1.2.

The implementation of the PA/CA models under GoldSim version 11.1.2 was conducted. The transition had no significant impacts on the doses and radon fluxes projected by the site, intruder, and intruder diffusion models. Differences in the projected quantities were 1 percent or less. These differences are likely from changes in the causality sequence of the software, changes made to individual elements including those used in contaminant transport modeling, and improvements made in the numerical precision of various calculations. The modeling results continue to indicate that the disposal facility satisfies all DOE Order 435.1 performance objectives. An SA to document these finding will be prepared during FY 2016.

7.0 Operational Changes and Status of Information Needs

The Laboratory has implemented several processes, systems, and procedures that define the operational constraints and conditions for waste disposal at Area G. These include the following:

- **Waste characterization and documentation**
  - *LANL Waste Acceptance Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Waste Management* (LANL, 2015m) sets requirements for the Laboratory's management of various hazardous, mixed, and radioactive wastes.
  - *Waste Characterization* (LANL, 2015n) summarizes the waste characterization requirements found in various regulations.
  - Radioactive *Waste Characterization* (LANL, 2016c) establishes specific requirements for characterization of radioactive waste in a manner that is compliant with DOE Order 435.1 and its companion manual M 435.1-1.
  - *Radioactive Waste Management* (LANL, 2016d) summarizes information found in various regulations, including DOE M 435.1-1, regarding the use of acceptable knowledge in making radioactive waste determinations.
  - *Waste Compliance and Tracking System (WCATS) User's Manual* (LANL, 2015o) presents a general reference of the usage of WCATS and describes the different types of tasks provided by the system.

- **Waste certification and verification**
  - *LANL Waste Management* (LANL, 2015m) describes LANL's Waste Certification Program, which requires a documented approach to ensure that waste management (treatment, storage, and disposal) of waste streams complies with applicable requirements (including DOE Order 435.1 and the accompanying manual M 435.1-1) prior to shipment.
  - *Radioactive Waste Management* (LANL, 2016d) summarizes the requirements for certifying, staging, and storing radioactive waste in compliance with DOE Order 435.1 and the accompanying manual M 435.1-1.
  - *Waste Certification Program Waste Verification* (LANL, 2015p) is a quality procedure that specifies the responsibilities and describes the process for waste verification by the Laboratory's Waste Management Division.
  - *Waste Assessments* (LANL, 2015q) is a quality procedure that specifies the responsibilities and describes the process for waste management assessment by the Waste Certification Program.

- **Waste packaging and transportation**
  - *LANL Waste Acceptance Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Waste Management* (LANL, 2015m) establishes the controls necessary to prevent improper shipment of radioactive waste.
  - *LANL Packaging and Transportation Program Procedure* (LANL, 2016e) describes the requirements for packaging hazardous and nonhazardous waste for off-site shipments and on-site transfers.
- **LLW management operations**
  - *TA-54 Area G Low Level Waste Disposal and Pit/Shaft Deactivation* (LANL, 2015r) provides instructions for disposal of radioactive waste in active pits and shafts at Technical Area (TA)-54, Area G, and the subsequent deactivation of the pit/shaft.
  - *TA-54 Area G Waste Staging, Loading, and Off-Site Shipment* (LANL, 2015a) establishes the requirements for the receipt, storage, and disposal of LLW at Area G and for shipment of LLW/mixed LLW to off-site facilities for treatment and/or final disposition.
  - *TA-54 Area G Inactive Pit and Shaft Quarterly Inspections* (LANL, 2014c) provides instructions and requirements for performing inspections at TA-54 Area G for inactive pits and shafts.
- **Disposal unit design, construction, and operational closure**
  - *Pit and Shaft Design, Construction, and Operational Closure* (LANL, 2010a) provides guidelines for locating, designing, constructing, and performing operational closure of solid waste disposal pits and shafts at Area G.
  - *WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process* (LANL, 2010b) provides requirements for reviewing and approving proposed changes in LLW disposal activities and facilities to ensure that the implementation of a change will not challenge the assumptions, results, or conclusions of the Area G disposal authorization basis.
- **WAC exemption**
  - *LANL Waste* Acceptance *Criteria* (LANL, 2014a) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *WDP Unreviewed Disposal Question Evaluation (UDQE) and Special Analysis (SA) Process* (LANL, 2010b) provides requirements for reviewing and approving proposed changes in LLW disposal activities and facilities to ensure that the implementation of a change will not challenge the assumptions, results, or conclusions of the Area G disposal authorization basis.

   - *LANL Unreviewed Safety Question (USQ) Procedure* (LANL, 2014d) provides the requirements for reviewing and approving changes at Hazard Category 1, 2, and 3 nuclear facilities at the Laboratory.

- **Environmental monitoring**

   - *EWMO Environmental* Monitoring *Plan* (LANL, 2011c) describes the monitoring requirements for Area G.

An accurate assessment of the risks posed by the disposal of waste at Area G requires that the PA/CA be conducted in a manner that is consistent with the processes, systems, and procedures listed above. Deviations from these requirements (e.g., changes to disposal facility design, operations, and maintenance) may undermine PA/CAs that are intended to address different facility configurations or operational conditions. Consequently, an assessment of changes that have occurred at Area G and their potential effect on the underlying analyses is necessary. The results of this evaluation are provided in Section 7.1. Monitoring data evaluations and R&D activities are designed, in part, to address critical informational needs identified for the disposal facility and site. The status of these needs with respect to the Area G PA/CA is addressed in Section 7.2. The 2010 DAS issued to the Laboratory includes a number of conditions that must be satisfied under the PA/CA maintenance program; Section 7.3 discusses the status of the Laboratory's compliance with these conditions. Finally, changes to facility operations and their impact on monitoring and R&D needs are briefly considered in Section 7.4.

7.1 Impacts of Operational Changes

As discussed earlier, the Area G disposal facility consists of existing MDA G and potential Zone 4. To date, all disposal operations at Area G have been confined to MDA G. Pit and shaft disposal operations in MDA G are scheduled to cease by October 2017. Phased closure of MDA G will start after disposal operations have ended.

The impending closure of MDA G has caused a shift in disposal philosophy. Whereas before FY 2009 essentially all of the LLW generated at the Laboratory was disposed of at Area G, an increasing portion of the LLW generated at the Laboratory has been shipped to commercial facilities or the Nevada National Security Site for off-site disposal. The Laboratory's current strategy for LLW is to minimize the generation and ship all newly generated waste off-site while working to open disposal pathways for any problematic wastes. Existing LLW (including problematic wastes) will be campaigned for disposal in the remaining space at Area G (pit 38 and remaining shafts) by October 2017 and no new on-site disposal capacity will be developed for the foreseeable future (LANL, 2016a).

The imminent closure of MDA G and the shipment of waste to off-site disposal facilities influence the operational assumptions upon which the PA/CA are based. For example, the

Revision 4 analyses are based on the assumption that waste will be placed in disposal pits in this portion of Area G through 2010 and shafts through 2015; waste requiring disposal after these times was assumed to be disposed of in Zone 4. In fact, pits and shafts located in MDA G will be used for the disposal of waste until October 2017, and the current recommendation is that no additional pits or shafts be constructed in Zone 4. Assumptions made in the PA/CA regarding expansion for disposal shafts into Zone 4 do not align with this new recommendation.

The closure of MDA G is expected to coincide with an effort to optimize the final cover placed over the disposal pits and shafts. Although the cover adopted for the PA/CA is effective, it is anticipated that a more cost-effective design capable of achieving the same level of protection can be developed. Assuming an alternate design is proposed, a formal evaluation of the closure configuration will be undertaken through updates of the PA/CA. Development of the final cover design will also be coordinated with the Consent Order corrective measures implementation process.

Postclosure land use plans for MDA G will be developed in conjunction with the MDA G corrective measures evaluation process with NMED. These plans will be influenced by the closure configuration selected for the facility as well as the future disposal plans adopted for Zone 4. Once final plans for future land use are defined, a formal evaluation will be performed to ensure consistency with the assumptions in the Area G PA/CA. The Laboratory's UDQ process provides the mechanism for initiating this evaluation.

In FY 2016, responsibility for running and maintaining the Area G PA/CA models will transition to LANL staff. Concurrent with the special analysis to document the upgrade to GoldSim Version 11.1.2 (as recommended by UDQE 1503), the Laboratory will verify the reproducibility of the PA/CA model results based on a transition to new analysts and a new computing platform.

No operational closures were performed on any pits or shafts in Area G during FY 2015.

7.2 Status of Informational Needs

Sensitivity analyses conducted in support of Revision 4 of the PA/CA identified several parameters and processes that significantly influence the projected impacts of waste disposal at Area G; additional sources of uncertainty associated with the modeling were also identified. The results of these evaluations have been used in conjunction with comments from the 2007 LFRG review of the PA/CA to identify additional information needed to improve the quality of the PA/CA. Efforts to collect this information are ongoing under the Area G PA/CA maintenance program.

7.3 Status of Disposal Authorization Statement Compliance

Continued disposal of LLW at Area G is approved subject to the conditions in the DAS (DOE, 2010). Those conditions include the following:

- Resolution of all secondary issues identified by the LFRG in its review of the Revision 3 PA/CA (DOE, 2009)
- Issuance of the Area G PA/CA Maintenance Program Plan and Area G Environmental Monitoring Plan by March 17, 2011
- Development and implementation of operational procedures to ensure the disposal facility is operated in a manner that protects the workers, the public, and the environment
- Development and implementation of an UDQ process
- Report on progress made with respect to condition resolution to the National Nuclear Security Administration and LFRG via annual reports or other written communications

The secondary issues identified by the LFRG in its review of the PA/CA are listed in their entirety in Appendix A, along with the LFRG Review Team's recommendations regarding actions to be taken to resolve these issues. All the DAS conditions are summarized in Table 7-1, and the progress made in terms of complying with these conditions is noted. No secondary issues were fully resolved and closed during FY 2015 although progress was made.

7.4 Recommended Changes

The results of the Area G PA/CA indicate that the disposal facility is capable of satisfying all DOE Order 435.1 performance objectives. Several changes have taken place in conjunction with efforts to maximize the disposal capacity of the existing disposal units at the site and, as discussed in Section 7.1, many more changes are in store. In general, the changes anticipated for Area G are expected to result in the disposal of less waste at the facility. On this basis, the operational changes are not expected to undermine the disposal facility's ability to comply with the performance objectives. Nevertheless, the ability of the disposal facility to perform within acceptable limits will continue to be assessed using the Laboratory's UDQE process before any operational modifications are implemented. Similarly, the potential impacts of changes to the closure strategy for MDA G will be evaluated and appropriate updates made to the Area G Closure Plan issued in 2009 (LANL, 2009b).

A number of R&D efforts have been identified that will help reduce the uncertainty associated with the PA/CA. These efforts will be pursued under the Area G PA/CA maintenance program, and the results will be used to update the analyses as they become available. Modifications to the scope of the R&D efforts pursued under the maintenance program may be necessary to adequately respond to changes in operations and closure strategies.

Table 7-1
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
Secondary Issue 3.1.1.1 – Erosion Modeling	Wind, water, and cliff retreat modeling does not capture extreme events to the extent necessary to demonstrate adequate long-term performance.	In progress; impacts of 500-year and 1000-year storms on cover performance evaluated. Cliff retreat data collected.
Secondary Issue 3.1.1.5 – Cover Degradation	Modeling is required to evaluate the impacts of cover degradation from subsidence.	In progress
Secondary 3.1.3.1 – All-Pathways Dose Modeling	The impacts of airborne contaminants transported from Area G are not accounted for in the All-Pathways Canyon Scenario modeling.	In progress
Secondary Issue 3.1.3.5 – Point of Compliance	Point of compliance for groundwater protection should be located at the point of maximum concentration outside of a 100-m buffer zone.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.3.6 – Intruder Scenarios	The human intruder scenarios are overly conservative.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.4.4 – Operational Documents	Facility operations documents must be finalized.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.5.3 – Impacts of Focused Runoff	Modeling needs to account for the impacts of elevated water contents caused by focused runoff from surface structures.	In progress; focused runoff into open pits was simulated; transient impacts of extreme rain during September 2013 on both erosion and groundwater model were evaluated.
Secondary Issue 3.1.5.3 – Hydrogeologic Model Uncertainty	Conduct FEHM simulations to evaluate the impact of the potential conceptual model uncertainties on groundwater transport and dose estimates.	Resolved; see FY 2013 Annual Report (French and Shuman, 2014)
Secondary Issue 3.1.5.5 – Potential Ground Motion	Use site-specific data to assess potential impacts of seismic accelerations on facility design and long-term performance, including slope stability and the impacts of cliff retreat.	In progress
Secondary Issue 3.1.5.5 – Disruptive Processes and Events	Implement a structured screening approach to determine what potentially disruptive processes or events should be included in the performance assessment and composite analysis.	In progress
Secondary Issue 3.1.6.3 – Infiltration Rate Distribution	The manner in which the infiltration rate distribution was developed is incorrect.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.6.3 – Modeling Enhancements	Recommended modeling enhancements include reexamination of the erosion scenarios concept, partitioning of radon between gas and liquid phases, use of continuous beta distributions in the biotic intrusion modeling, consideration of contaminant redistribution from wind, and reexamination of the infiltration rate distribution.	Comments regarding radon gas, beta distributions, and infiltration-rate distribution have been resolved; see FY 2009 Annual Report (LANL, 2010c). Resolution of erosion scenario and contaminant redistribution comments is in progress.

Table 7-1 (Continued)
LANL DAS Conditions and Resolution Status

DAS Condition	Summary of Issue or Condition	Status of Resolution
Secondary Issue 3.1.6.3 – Input Parameter Probability Distributions	Specification of probability distributions needs to be improved in many cases. Review all parameter distributions used in the modeling.	In progress
Secondary Issue 3.1.6.6 – HYDRUS Modeling	The HYDRUS modeling did not correctly account for initial moisture conditions.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Secondary Issue 3.1.8.2 – Sensitivity and Uncertainty Analysis	Develop and implement sensitivity analysis methods suitable for complex time-dependent nonlinear systems.	In progress
Secondary Issue 3.1.8.3 – Spurious Sensitivity Analysis Results	Elaborate on statements that characterize some of the results of the sensitivity analysis as spurious.	In progress
Secondary Issue 3.1.9.1 – Presentation and Integration of Dose Projections	More fully integrate and interpret the probabilistic and deterministic projections provided in the performance assessment and composite analysis.	In progress
Secondary Issue 3.1.10.1 – Software and Database Quality Assurance	Develop and implement a software and database quality assurance program that includes configuration control for all software and databases used to conduct the performance assessment and composite analysis.	In progress; update of PA/CA model with latest GoldSim version completed; database for moisture monitoring data compiled.
Secondary Issue 3.2.2.2 – Composite Analysis Inventory	Use alternate source inventories that are consistent with the LANL DSA for nuclear environmental sites.	Issue resolved; see FY 2009 Annual Report (LANL, 2010c)
Condition – Operational Procedures	Operational procedures will be developed within 90 days of issuance of this statement and implemented to ensure the disposal facility is operated in a manner that protects the workers, the public, and the environment.	DAS Condition resolved (LANL, 2010d)
Condition – Area G Performance Assessment and Composite Analysis Maintenance Plan	A revised maintenance program plan must be issued by March 17, 2011.	DAS condition resolved; see LANL Maintenance Program Plan (LANL, 2011a)
Condition – Area G Environmental Monitoring Plan	A revised maintenance program plan must be issued by March 17, 2011.	DAS condition resolved, see Environmental Monitoring Plan (LANL, 2011c)
Condition – Unreviewed Disposal Question Process	Develop and implement an UDQ process that evaluates the potential impacts of changes in disposal facility operations, on-site policy or strategy, changes in facility controls, and discoveries on the continued proper functioning of the disposal facility.	Issue resolved; see Los Alamos National Laboratory Procedure EP-AP-2204 (LANL, 2010b)
DAS Condition – Annual Progress on Condition Resolution	Report on progress made with respect to condition resolution to the National Nuclear Security Administration and LFRG via annual reports and other written communications.	Issue resolved; see Annual Reports

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Appendix A

Secondary Issues Identified by the Low-Level Waste Disposal Facility Federal Review Group Review Team

The Department of Energy (DOE) Low-Level Waste Disposal Facility Federal Review Group (LFRG) Review Team identified 20 secondary issues in its review of the Revision 3 Area G performance assessment and composite analysis; these issues are listed below. This listing describes each issue and provides the LFRG Review Team's recommendations regarding actions to be taken to resolve it. The numbers assigned to the issues correspond to the numbering system adopted in the LFRG Review Team report (DOE, 2009), and include both the number of the issue and the review criteria addressed by the issue; a complete listing of the review criteria may be found in the LFRG Manual (DOE, 2006).

7.2.1. Facility/Site Characteristics (3.1.1.1., 3.1.1.5., and 3.1.1.6.)

Criterion 3.1.1.1.:

Erosion Modeling: The wind, cliff retreat, and water erosion models do not fully capture the extremes necessary to demonstrate adequate performance over the 1,000 year performance period. The recommendations delineated in sections 7.3.4 and 7.3.5 of the 2006 performance assessment and composite analysis need to be rigorously pursued, including external review of work plans to ensure maximum defensibility and programmatic efficiency (Shuman 2006). Running the erosion model with a 1,000 year precipitation event should be considered.

Criterion 3.1.1.5.:

Cover Degradation Due to Subsidence or other Localized Processes: Given the acknowledged potential for subsidence and the presence of containers with structural integrity that may outlive institutional controls, additional justification is needed for not considering degradation in performance of the cover after loss of institutional control. Considering the long times expected for degradation of some of the containers on the site, full remediation cannot be expected for subsidence occurring during the post-institutional control period. The justification for the cover to remain intact for 1,000 years is not provided and any such justification may be difficult to defend.

Modeling needs to be conducted to evaluate the influence of localized cover degradation on infiltration rate distributions used for the groundwater pathway model. Further, as information on expected cover performance is developed, the infiltration rate distributions need to be updated using this specific cover design information. It is expected that an optimal cover design will result in lower infiltration rates than those used in the current analysis. To evaluate the potential impacts of localized subsidence and cover degradation on migration and projected dose, it is necessary to modify the GoldSim™ Material Disposal Area (MDA) G model and inputs to incorporate potential increases in infiltration rate over time. Based on draft updates to cover modeling, the assumed performance of the cover is expected to improve. Thus, the net effect of improved performance and localized increases in infiltration is not expected to result in a significant increase in overall infiltration.

Criterion 3.1.1.6.:

See secondary issue under criterion 3.1.1.5.

7.2.2. Performance Objectives/Measures (3.1.3.1., 3.1.3.5., and 3.1.3.6.)

Criterion 3.1.3.1.:

All-Pathways Dose Problem: The exposure scenarios for the "member of the public" scenarios are not fully coupled with the performance objectives. They are, instead, separated by the transport mechanisms (groundwater, air, and surface water). A consequence of this is that the all pathways performance objective is not fully evaluated. A concern is that the air pathway does apply to the exposure scenarios in Cañada del Buey and Pajarito Canyon.

The effect or lack thereof of this pathway needs to be demonstrated so that the all pathways performance objective can be fully evaluated. This needs to be done by (1) making the separations in scenarios clearer in the text, (2) explaining more clearly why the separation in pathways does not underestimate dose at any of the receptors locations, and (3) (preferable) modeling the air pathway to the canyon receptors to estimate the all pathways dose for those receptors (for other receptors the need to combine across transport mechanisms can probably be explained away). Given the observed doses for the separated scenarios, this is extremely unlikely to change any conclusions, but from a regulatory as well as a technical perspective, this issue needs to be addressed.

Note also that the air pathway as evaluated through the atmospheric scenario includes exposure routes that do not need to be included. Inhalation and immersion are the only routes that need to be evaluated. Ingestion and shine can be omitted. This is relevant to modeling the air pathway to the canyons receptors.

Criterion 3.1.3.5.:

Point of Compliance for Groundwater Protection during Institutional Control: There is some confusion regarding the point of compliance for groundwater protection. Section 1.5 and Table 1-1 indicate that the point of assessment for groundwater protection is the site boundary during institutional control, but the results presented in Figures 4-29 and 4-30 are for the point of maximum concentration outside a 100-m buffer zone. The point of assessment, as specified at DOE Manual 435.1-1, Section IV.P.(2)(b), is to be at the point of maximum concentration outside a 100 m buffer zone for groundwater protection at all times unless justification is provided for some other point. Additional justification is needed if the point of compliance for groundwater protection is the site boundary during institutional control.

Criterion 3.1.3.6.:

Overly Conservative Intrusion Analysis: The inadvertent human intrusion scenarios are overly cautious. Appropriate credit should be taken for site-specific factors that limit the probability that intrusion will occur. Since the basement scenario is the constraining scenario in the current model, some credit could be taken for the likelihood of a basement in the presence of a house. Very few houses in Los Alamos have basements. Other possible considerations include the likelihood of construction and well drilling (given that current water in Los Alamos comes from wells drilled in the canyons) and the exposure routes, which include mixing of waste in the surface soils and subsequent use of those soils to support a vegetable garden, and dairy cows. There are many possibilities for reducing conservatism in this analysis so that the intrusion doses are more realistic. The main issue is one of using site-specific factors to support this analysis, instead of using a default scenario that does not apply well to this arid site.

Under the performance assessment maintenance program, the assessment needs to use site-specific factors to refine the intrusion model to better represent likely home construction and lifestyle characteristics of the intruder. The intent is to make the intrusion scenario more realistic for this arid site than is currently the case.

7.2.3. Point of Assessment (3.1.4.1., 3.1.4.2., and 3.1.4.4.)

Criterion 3.1.4.1.:

See secondary issues under criterion 3.1.3.5.

Criterion 3.1.4.2.:

See secondary issue under criterion 3.1.3.5.

Criterion 3.1.4.4.:

Operations Restrictions: The 2006 performance assessment and composite analysis contains no reference to facility operations documents that are used to control parameters that could affect performance assessment findings and conclusions (Shuman 2006). Important to the findings and conclusions of the performance assessment for the active portion of Area G is an operational restriction on the depth below the surface for placement of the uppermost waste container in a pit or shaft. A draft operational document that contains this information has yet to be finalized. For Zone 4, when new pits and shafts are excavated, other important operational restrictions will be minimum distance from canyon wall to pit or shaft and maximum depth of pit or shaft. If additional excavations were to occur in the active portion, these restrictions would also apply.

The draft operations document that addresses these parameters for MDA G needs to be finalized in a timely manner, ensuring that the scope is appropriate for current activities in MDA G and considering any planned activities and operations as appropriate. A subsection needs to be added to Section 1.4 of the 2006 performance assessment and composite analysis that references operational controls and that describes and references documents used to control MDA G operations important to performance assessment findings or conclusions (Shuman 2006). If there are other documents in effect for Technical Area 54 that are used to control activities that could affect MDA G (e.g., borehole drilling, utility, or other excavation in the canyon areas around the mesa), these need to be included.

7.2.4. Conceptual Model (3.1.5.3., 3.1.5.4., and 3.1.5.5.)

Criterion 3.1.5.3.:

- *Influence of Focused Runoff on Migration*: The current conceptual model assumes undisturbed conditions at the site. Field data have indicated localized high water contents in the subsurface from focused run-off from surface structures (e.g., asphalt pads). The influence of these structures on the conceptual model for long-term flow and transport needs to be evaluated. The on-going activities to address these issues as described in the maintenance plan need to be pursued.

- *Hydrogeologic Model Uncertainty*: Recent field sampling has detected radionuclides in the vicinity of MDA G. Multiple hypotheses have been proposed to explain the presence of the radionuclides, some of which include MDA G as a potential source.

  Groundwater transport in the current model is based on a single conceptual model, which does not address uncertainties that may result in shorter travel times. Potential uncertainties include hydraulic properties, overall hydrogeologic framework model, evaporative boundary at the base of the Tshirege Member Unit 2, assumed boundary conditions on the east and west boundaries (fixed head or vertical gradients), and Guaje Pumice/Cerros del Rio basalt interface properties. With the current computational approach, the potential influence of these uncertainties on expected doses is not represented in the current GoldSim™ model. Given this limitation, these Uncertainties are not included in the sensitivity analysis. Additional 3-dimensional simulations using the Finite Element Heat and Mass (FEHM) model need to be performed to evaluate the impact of the potential conceptual model uncertainties on groundwater transport and dose estimates.

Criterion 3.1.5.4.:

See secondary issue under criterion 3.1.1.5.

Criterion 3.1.5.5.:

- See secondary issue under Criterion 3.1.1.1.

- *Potential Ground Motion*: Seismic accelerations are not provided as required to assess potential impacts on facility design or long-term performance, including slope stability and potential impacts on disposal area integrity related to potential retreat of the steep mesa walls toward the disposal facility. Site-specific ground motion data need to be provided as appropriate for design, geotechnical slope stability analyses, and site suitability assessment.

- *Geomorphic Slope Stability*: Geotechnical data are required to confirm highly uncertain geomorphic slope stability estimates and assess the impact of facility construction and disposal area operations (excavation and compaction) on site and slope stability. Geotechnical data and analyses need to be acquired to confirm geomorphic stability assumptions and ensure operation and disposal configuration consistent with performance goals.

- *Performance Assessment Disruptive Processes and Events*: There is no clear structured procedure for screening potentially disruptive processes or events for consideration in the performance assessment. Criteria based on likelihood or consequence need to be developed that would help explain the inclusion or exclusion of potentially disruptive processes or events. Radiological assessment guidance from regulatory agencies and DOE's safety basis regulations should be consulted to develop the screening criteria.

7.2.5. Mathematical Models (3.1.6.2., 3.1.6.3., and 3.1.6.6.)

Criterion 3.1.6.2.:

See secondary issues under criteria 3.1.6.3. and 3.1.6.6.

Criterion 3.1.6.3.:

- *Infiltration Distribution Data Averaging*: Distribution averaging has been performed for infiltration rate, but not correctly. There are 17 data points for infiltration rate based on the chloride profiles. These data represent annual flux rates over a long period of time. Consequently, they are already time averaged for the scale of this performance assessment. What is missing is a spatial averaging. The data range from near 0 to 3 mm/year. The current model effectively resamples 1,000 times instead of 17 times for each resampled data set that is created. Hence, the uncertainty in the distribution used is narrower than it should be.

  An appropriate way to build a distribution of the average to accommodate spatial averaging is to bootstrap the data (resample with replacement 17 times because there are 17 data points) 1,000 (many) times, take the average of each of the 1,000 sets of 17 samples to arrive at a distribution of the average. This is the distribution that should be used in the model. In addition, the Pajarito Plateau infiltration map needs to be included in the 2006 performance assessment and composite analysis to provide additional confidence in the infiltration rate distribution (Shuman 2006). In the future, the infiltration distribution needs to be transitioned from being based on background field data, as described above, to being based on rates simulated for the proposed cover design for the corrective measures evaluation, when they become available.

- *Modeling Enhancements*: There are a series of modeling issues that can be addressed in the next refinement of the MDA G model (under the performance assessment maintenance program), including the following:

  – The erosion model currently uses three erosion rate models in SIBERIA that are respectively associated with low, moderate, and high erosion. It is not clear exactly how these designations were arrived at. Some clarification is needed. These three models (results) are sampled randomly in GoldSim™ with probabilities respectively of 10 percent, 80 percent, and 10 percent, meaning that the moderate erosion scenario is used most frequently. Refinement of this approach is needed. The rationale for these probabilities is weak and needs to be supported with expert judgment. The need for more than one model needs to be more fully explained, and the range of allowable models needs to be expanded. One option is to introduce more discrete cases. Another option is to restructure the model to allow a continuous range (if possible).

  – Air recycling of soil close to the surface is described but is dismissed based on zero net soil gain or loss. However, the movement of soil through this process also results in movement of contaminants. This transport mechanism needs to be evaluated. Options include formal modeling and justified explanation for why the effect of this transport mechanism is negligible.

  – A discrete set of beta functions are used in the biotic models for plants and animals to apportion root mass and burrow volume to different subsurface soil intervals. Inclusion of a single additional parameter is needed to allow a continuous range of beta functions to be used instead.

  – It does not appear that the diffusion model included partitioning of radon into water which would decrease radon fluxes and doses. This needs to be allowed.

  – The probability distribution for average infiltration rate needs to be revised per presentation in the issues column of the review criterion matrix. The performance assessment/composite analysis maintenance program needs to review all comments about model improvements that are made in this document and in the criterion matrix to ensure that appropriate refinements to the 2006 performance assessment and composite analysis model are made (Shuman 2006).

- *Input Data Probability Distributions*: Specification of probability distributions needs to be improved in many cases (too numerous to fully document here but see the review criterion matrix responses). There are numerous instances, and in some ways it is easier to require that all the distributions be revisited. For example, concerns have been expressed that some of the dose or exposure route distributions are very wide. Concerns have been expressed that based on very little data the input distributions for some physical parameters are too narrow. In many cases, the distributions need to be backed up by more technical/statistical rigor and need to be defended by showing the data and the statistical methods that were used. There are several, or perhaps many, cases of distributions that are formed based on disparate sources of data followed by some best professional judgment. In those cases, efforts need to be undertaken or reported to engage some subject matter expert in final formulation of the distribution. For example, the distributions for K_d are often very tight, yet they are based on very few data points. It would make more sense in these cases for the distributions to be wider considering the amount of uncertainty. This might lead to identification of these as sensitive parameters and hence a need for future data collection (which is clearly needed across the complex for some geochemical parameters). The same approach needs to be used for solubility limits.

Other examples of distributions that need to be revisited and improved or refined include the initial cover depth distributions (why are they assumed to be triangular given the amount of data that are available? either use the data empirically, or fit more appropriate distributions); radon emanation coefficient (many disparate sources of data, the highest values of which are not included in the final distribution with insufficient explanation for their exclusion); physical properties such as bulk density, porosity and K_ds (the distributions are the same for crushed tuff and waste; however, the text indicates that there should be more uncertainty for the waste); sediment allocation fractions have noted uncertainty but are modeled deterministically with no explanation; various biotic parameters (again data from many sources, but sometimes enough data that proper statistical methods could be used to estimate distributions); waste thickness (perhaps better information is available); carbon-14 gas generation rates (data from many disparate sources, but statistics and/or expert opinion could be used to combine these data).

Expert opinion can be used effectively to support a combination of data to form distributions, and in so doing greater credibility is bought by using domain experts. Also, for several parameters, probability distributions are not used when they could be used. The uncertainties can then be fully explored and supportable decisions can be made on how to allocate resources to collection of new information.

More general distribution issues relate to the types of distributions used. Triangular or truncated distributions in any form (uniform, truncated normal, truncated lognormal) are not ideal because they do not allow any chance of using values outside the range of the distribution. For example, a K_d for plutonium of 77 mL/gm is allowed, but 77.1 mL/gm is not allowed. This does not intuitively make sense. (Please note that the K_d distribution for Np appears to be misspecified in Table 16 in Appendix K.) From a decision analysis or statistical perspective, this assumption suggests that there is no chance ever in any sense that the K_d could be 77.1 mL/gm. In terms of uncertainty reduction, this can cause problems. However, a related issue is one of "distribution averaging" (see below), which would obviate the need for truncated distributions.

Consideration needs to be given to the spatio-temporal scale of the model when specifying distributions. Probability distributions need to be specified to match the spatio-temporal scale, which probably means that distributions should be of the average instead of the data in many cases. The point is that the model is run for many tens of acres over 1,000 (or more) years. A single data point for a parameter often represents a point in time and space. The spatio-temporal scales of the model and the data are different. However, the data can often be manipulated so that an estimate of a distribution on the right spatio-temporal scale can be developed. This might be referred to as distribution averaging.

There are many advantages to this approach to specifying probability distributions. One obvious advantage is that it is the right approach. The model is a systems-level model trying to understand risks (doses) to receptors at various locations—risk is inherently based on an average response. Another advantage is that the variance component of an input distribution now represents uncertainty instead of variability. This is important because uncertainty is reducible by collecting more data, whereas variability is not. Another advantage is that the end results are now probability distributions for the mean dose. These distributions are typically a lot tighter than the ones that are currently common in performance assessments. Since the output is a distribution of the mean, the 95_{th} percentile corresponds to the classical 95_{th} upper confidence limit on which most Environmental Protection Agency–type risk-based decisions are made. Also, since uncertainty is now the basis of the variance components, sensitivity analysis directly supports identification of sensitive parameters for which uncertainty can be reduced.

Note that a lot of care needs to be taken when performing distribution averaging. The effects are not always obvious (for example, directly averaging plant root depth data does not appropriately support separation of plant root mass into subsurface soil layedistribution averaging is still needed, but across the soil layers and not across the plant root depths). One last note on distribution averaging is that it is not easy when parameter distributions are based on disparate sources of data or expert opinion, but elicitation methods exist that can help with this when necessary.

Distribution averaging has been performed for one parameter in this model, and that is the infiltration rate (curiously, few or no other parameters in the groundwater model are specified in GoldSim™ as probability distributions). So, in the case of infiltration rates, distribution averaging has been performed, but not correctly. There are 17 data points for infiltration rate based on the chloride profiles. These data represent annual flux rates over a long period of time (1,000 years or more). Consequently, they are already time-averaged for the scale of this performance assessment. What is missing is a spatial averaging. The data range from near 0 to 3 mm/year. An appropriate way to build a distribution of the average to accommodate spatial averaging is to bootstrap the data (resample with replacement 17 times because there are 17 data points) 1,000 (many) times and then take the average of each of the 1,000 sets of 17 samples to arrive at a distribution of the average. This is the distribution that should be used in the model. The current model effectively re-samples 1,000 times instead of 17 times for each resampled data set that is created. Hence, the uncertainty in the distribution used is narrower than it should be.

The performance assessment/composite analysis maintenance program needs to review all specific comments about input probability distributions that are made in the report and in the criterion matrix to ensure that appropriate adjustments to the input distributions are made in the next versions of the 2006 performance assessment and composite analysis model (Shuman 2006).

Criterion 3.1.6.6:

Data for Infiltration Rate Distribution: Currently the infiltration rate distribution is based on both field data and HYDRUS simulations of the proposed cover. The current cover modeling using HYDRUS described in Appendix G is problematic. Simulated fluxes depend on initial conditions assumed and fluxes appear to increase with increasing cover thickness. These HYDRUS results should not be used as a basis for the development of the infiltration rate distributions used in the groundwater analysis. All references to HYDRUS results and Appendix G need to be removed from the performance assessment.

7.2.6. Exposure Pathways and Dose Analysis (3.1.7.1.)

Criterion 3.1.7.1.:

See secondary issues under criterion 3.1.3.6.

7.2.7. Sensitivity and Uncertainty (3.1.8.2. and 3.1.8.3.)

Criterion 3.1.8.2.:

Sensitivity and Uncertainty Analysis: The sensitivity analysis methods used need to be updated with currently available methods. Techniques exist now for sensitivity analysis of complex time-dependent non-linear systems. Some of these techniques were used for the Nevada Test Site (NTS) low-level waste (LLW) disposal site performance assessment/composite analysis.

A major strength of this model is that it was set up probabilistically. This allows sensitivity and uncertainty analyses to be performed globally instead of one parameter at a time and allows sensitive parameters to be identified using nonlinear methods. Sensitive parameters have been identified for most of the end-point results. It has been suggested that the results of the sensitivity analysis are used to drive decisions about further data/information collection and, hence, model refinement. However, the MDA G model is a complex, time-dependent, nonlinear model. The previously mentioned approach taken to sensitivity analysis is appropriate for linear models. That is, it identifies linear effects. Nonlinear sensitivity analysis methods are available and need to be used. The performance assessment/composite analyses performed for the NTS LLW sites used these methods. These methods might identify different sensitive parameters than can be found using the techniques employed for this model (Spearman rank correlation).

The results of the sensitivity analysis are presented in terms of correlation coefficients, where the correlations are between the input parameters (variables) and the output or response (variable). It was also noted that the correlations are all statistically significant at the 0.01 level. This statement is unnecessary and potentially can be incorrectly interpreted as providing evidence of successful identification of sensitive parameters. The correlations are based on 1,000 simulated responses or data points. Probably all (or nearly all) of the parameters would show a significant result at the 0.01 level. What is more appropriate is to present the p-values (observed significance levels) associated with each correlation, rank the p-values and use those as a separate line of evidence for identification of sensitive parameters. The smaller the p-value the greater the evidence of a sensitive parameter. The p-value approach and the correlation coefficient approach should match closely. Note that this is not needed if nonlinear sensitivity analysis methods are used, as suggested above.

The sensitivity analysis needs to be run at different time points in the model. A different set of sensitive parameters will probably be identified at 100 years than are identified at 1,000 years.

The uncertainties are inherent in the output distributions. That is, a probabilistic model explicitly addresses uncertainty numerically. Note that the model, like most probabilistic models, addresses parameter uncertainty only. It does not address other uncertainties such as decision uncertainty, model uncertainty, or scenario uncertainty. However, there is another uncertainty issue that should be addressed: the stabilization of the results of a probabilistic simulation. One thousand simulations were used for the model results, but there is no analysis of the stability of the output distributions based on this number of simulations. Since mean, 5^{th}, and 95^{th} percentiles are presented (see below, medians should be presented as well), these statistics all need to be subject to uncertainty stabilization analysis. This would be performed by running different numbers of simulations several times and evaluating the range of results for each of the statistics identified. The mean and median should stabilize before the more extreme percentiles, but this analysis needs to be performed so that the number of simulations used can be better justified, even if that means more simulations are needed. This needs to be a component of probabilistic modeling under the performance assessment maintenance program. An issue for the LFRG is that the criterion matrix does not address this issue.

There was some concern expressed at the review team meetings about the comparison of deterministic and probabilistic results. Based on subsequent discussions, the median results need to be reported for the probabilistic analysis, and the median of the input distributions needs to be used as input to the deterministic run. The median is much more likely to match reasonably than use of another statistic or use of ad hoc deterministic inputs.

Another issue that is not addressed is correlation between parameters. However, this is common to all probabilistic performance assessment models and other complex environmental models at this time. Correlation issues need to be dealt with in the future where appropriate and possible.

The performance assessment/composite analysis maintenance program needs to update sensitivity analysis methods, evaluate stabilization of the model for different numbers of simulations, compare the probabilistic and deterministic runs using medians (use medians as input to the deterministic runs, and compare to the median output for the probabilistic runs; note that the medians of the probabilistic output should be presented in the report), and evaluate the use of correlations between parameters where possible and appropriate.

Criterion 3.1.8.3.:

- *Spurious Sensitivity Analysis Results*: The statement is made (p. 4-86) that other parameters were also highly correlated to the expected dose in the sensitivity analysis for the all pathways case but were not deemed necessary for discussion because they were considered spurious results. This requires further elaboration. The parameters need to be identified and why the results are considered spurious should be explained. Why the spurious results do not indicate problems with the sensitivity analysis in general also needs to be explained.

- See secondary issue under criterion 3.1.8.2.

7.2.8. Results Integration (3.1.9.1. and 3.1.9.6.)

Criterion 3.1.9.1.:

- See secondary issues under criteria 3.1.1.5. and 3.1.8.3.

- *Presentation and Integration of Dose Results*: Additional effort is necessary for the integration and interpretation of the probabilistic and deterministic results. For example, in the presentation of doses for the all-pathways canyon scenario, the deterministic results cannot be directly compared with the probabilistic results. This precludes the ability to interpret and integrate the results from the two different modeling approaches. In general, the intent is for the different modeling approaches to complement each other and build confidence in the overall approach and conclusions. The ability to integrate and interpret the results is also made more difficult because of the lack of details regarding radionuclide-specific contributions to the doses over time and identification of significant pathways for key radionuclides.

The probabilistic simulations need to be run to peak dose or 10,000 years, whichever is smaller, and the deterministic and probabilistic results should be plotted together to enable a direct comparison. Additional figures need to be provided that illustrate the relative contributions of different radionuclides and some information is also needed regarding the pathways that dominate doses for specific radionuclides.

Criterion 3.1.9.6.:

See secondary issues under criteria 3.1.1.1. and 3.1.5.5.

7.2.9. Quality Assurance (3.1.10.1.)

Criterion 3.1.10.1.:

Software and Database QA: Quality assurance (QA) processes in place for checking, reviewing, and documenting calculations and input files are reasonable. Based on a review of the QA summary, configuration control process, and change control log for software and database changes were not evident for: FEHM, CALPUFF, CALMET, HYDRUS, SIBERIA, GoldSim™ Platform and MDA G implementation, Hill Slope Erosion Model, and Inventory, and other databases. It is generally required to have a user's manual for analysis software, and there was no user's manual for the specific MDA G GoldSim™ models. Also, the LFRG criteria require that the QA measures be discussed in the performance assessment and that is not currently the case.

QA processes need to be developed (using a graded approach) and implemented for configuration control for all software and databases used for the 2006 performance assessment and composite analysis (Shuman 2006). The QA summary needs to be included as an appendix to the performance assessment/composite analysis. A user's manual for the MDA G GoldSim™ models should be developed, but attention to this issue should await clarification of what is needed in such manuals. The LFRG is considering development of criteria that will describe the purpose, expected audience, and content of users manuals. Addressing this issue before the LFRG criteria are available could result in the need for user's manual revisions. Furthermore, the criteria ultimately established by the LFRG may be satisfied by the existing 2006 performance assessment and composite analysis Appendix K of the GoldSim™ model documentation and data selection (Shuman 2006).

7.2.10. Radioactive Sources/Release Mechanism (3.2.2.2.)

Criterion 3.2.2.2.:

Composite Analysis Inventory: Alternate source inventories are lower than and inconsistent with inventory estimates in documented safety analyses (DSAs) for nuclear environmental sites. The composite analysis inventory estimates for the material disposal areas need to be updated to be consistent with those of the DSAs, since these are viewed as official DOE-sanctioned estimates.

7.2.11. Assumptions (3.2.5.1.)

Criterion 3.2.5.1.:

See secondary issues under criteria 3.1.1.5. and 3.1.5.3.

7.2.12. Modeling (3.2.6.3., 3.2.6.5., and 3.2.6.7.)

Criterion 3.2.6.3.:

See secondary issues under criteria 3.1.1.5. and 3.1.5.3.

Criterion 3.2.6.5.:

See secondary issues under criteria 3.1.6.3. and 3.1.6.6.

Criterion 3.2.6.7.:

See secondary issue under criterion 3.1.1.5.

7.2.13. Sensitivity/Uncertainty (3.2.8.1.)

Criterion 3.2.8.1.:

See secondary issue under criterion 3.1.8.2.

7.2.14. Results Integration (3.2.10.1.)

Criterion 3.2.10.1.:

See secondary issues under criteria 3.1.1.5., 3.1.8.3., and 3.1.9.l.

7.2.15. Quality Assurance (3.2.11.1.)

Criterion 3.2.11.1.:

See secondary issue under criterion 3.1.10.1.

References

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