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Title: Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility - Fiscal Year 2011

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Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2011

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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 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 2011 annual review for Area G.

Revision 4 of the Area G performance assessment and composite analysis was issued in 2008 and formally approved in 2009. 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.

Annual disposal receipt reviews indicate that smaller volumes of waste will require disposal in the pits and shafts at Area G relative to what was projected for the performance assessment and composite analysis. The future inventories are projected to decrease modestly for the pits but increase substantially for the shafts due to an increase in the amount of tritium that is projected to require disposal. Overall, however, 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 performance assessment and composite analysis models because the monitoring data collected are specific to operational releases or address receptors that are outside the domain of the performance assessment and composite analysis. In general, applicable monitoring data are supportive of some aspects of the performance assessment and composite analysis.

Several research and development (R&D) efforts have been initiated under the performance assessment and composite analysis 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 fiscal year 2011 are discussed in this report.

Special analyses have been conducted to determine the feasibility of disposing of specific waste streams, to address proposed changes in disposal operations, and to consider the impacts of changes to the models used to conduct the performance assessment and composite analysis. These analyses are described and the results of the evaluations are summarized in this report.

The Area G disposal facility consists of Material Disposal Area (MDA) G and the Zone 4 expansion area. To date, all disposal operations at Area G have been confined to MDA G. Material Disposal Area G is scheduled to undergo final closure in 2015; disposal of waste in the pits and shafts is scheduled to end in 2013. In anticipation of the closure of MDA G, plans are being made to ship the majority of the waste generated at LANL to off-site locations for disposal. It is not clear at this time if waste that will be disposed of at LANL will be placed in Zone 4 or if disposal operations will move to a new location at the Laboratory. Separately, efforts to optimize the final cover used in the closure of MDA G are underway; a final cover design different than that adopted for the performance assessment and composite analysis will likely emerge from that investigation. All of these changes will require re-examination of the assumptions upon which the performance assessment and composite analysis are based and, in all likelihood, revision of those analyses.

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Acronyms and Abbreviations

CME	Corrective Measures Evaluation
D&D	Decontamination and decommissioning
DAS	Disposal Authorization Statement
DOE	Department of Energy
DSA	Documented Safety Analysis
ER	Environmental restoration
FEHM	Finite Element Heat and Mass (model)
FY	Fiscal year
LANL or Laboratory	Los Alamos National Laboratory
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LHS	Latin Hypercube Sampling
LLW	Low-level (radioactive) waste
MDA	Material Disposal Area
NMED	New Mexico Environment Department
NNSS	Nevada National Security Site
NTS	Nevada Test Site
R&D	Research and development
TA	Technical Area
VMTran	Vegetation Modified Transport (model)
WAC	Waste acceptance criteria

1.0 Introduction

As a condition to Revision No. 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 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 M 435.1-1 (DOE, 2001b), and draft guidance for maintenance programs (DOE, 2001c), annual determinations of the adequacy of the performance assessment and composite analysis are to be conducted to ensure that the conclusions reached by those analyses continue to be valid. Annual reports are to be submitted which:

- 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 affect the conclusions of the performance assessment and composite analysis.
- Describe any changes in disposal facility design, operation, and maintenance, and discuss how such changes affect the performance assessment and composite analysis.
- Assess the need for modifications to the monitoring and R&D programs conducted in support of performance assessment and composite analysis maintenance.
- Discuss the need for changes in low-level waste (LLW) disposal operations or the performance assessment and composite analysis maintenance program.

This report summarizes the results of the fiscal year (FY) 2011 annual review for Area G. Section 2 presents the results of the adequacy determination for the Revision 4 Area G performance assessment and composite analysis (LANL, 2008a). Section 3 summarizes the results of the disposal receipt review 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 special analyses that were conducted to address changes in disposal strategies and to more accurately represent disposal conditions. 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

The Revision 4 Area G performance assessment and composite analysis (LANL, 2008a) 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, waste volume projections for disposal pits and shafts based on the FY 2011 disposal receipt review (LANL, 2012a) decreased significantly relative to the Revision 4 inventories. The revised pit radionuclide inventories were slightly less than the earlier estimates, while shaft inventories increased substantially because of a rise in the amount of tritium requiring disposal. The doses projected using the Revision 4 and disposal receipt-based inventories remain well within pertinent performance objectives for members of the public; limits on the 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 Material Disposal Area G (MDA G) and the Zone 4 expansion area. For consistency with previous PA 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 (NMED, 2005) 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 for purposes of the PA. Material Disposal Area G has been in continuous operation since Area G first received radioactive waste in the late 1950s. The performance assessment and composite analysis are based on the assumption that additional pits and shafts will be developed in Zone 4 to provide disposal capacity after the disposal units in MDA G are full. As discussed in Section 7, the disposal of waste in MDA G will cease at the end of 2013, in anticipation of final closure of that portion of Area G. It is not clear if disposal operations will move into Zone 4 after MDA G is full or, if Zone 4 is used for disposal, how much waste will be disposed of in that area.

Revision 4 of the performance assessment and composite analysis is consistent with the plans and procedures that are 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 and 2009a), as well as the final closure of the disposal facility (LANL, 2009b).

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 LANL waste acceptance criteria (WAC) (LANL, 2012b).

The conclusions of the Revision 4 performance assessment and composite analysis remain valid at present. However, the long-term strategy that will be adopted for disposal of LLW at LANL is difficult to predict at this time and could affect some of the premises upon which the analyses are based. The possibility exists that a consolidated solid waste management facility will be developed outside of TA-54; this would result in a decrease in the amount of waste disposed of at Area G relative to that projected by the performance assessment and composite analysis. Changes to MDA G disposal operations and modifications of the final MDA G closure strategy may also occur as that portion of the disposal facility nears final closure. To ensure that they continue to adequately represent conditions at Area G, the performance assessment and composite analyses will need to be updated as new policies and plans are solidified and put into place.

The performance assessment and composite analysis maintenance program plan (LANL, 2011a) takes into account findings from the Revision 4 performance assessment and composite analysis 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 Disposal Receipt Review and Alternate Source Evaluation

Annual reviews of LLW disposal receipts are conducted to ensure that the future inventories projected for the performance assessment and composite analysis remain consistent with the actual waste inventories disposed of at Area G. The results of the FY 2011 disposal receipt review (LANL, 2012a) are summarized in Section 3.1. 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 2011 disposal receipt review (LANL, 2012a) compiled LLW disposal data for October 1, 2007, through September 30, 2011, 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 FY 2012 through 2044 (the year in which disposal operations at Area G are expected to cease). The LLW generators at the Laboratory supply the data included in the review; all of these generators have been certified to send waste to Area G for disposal (LANL, 2011b). The conclusions reached by the latest disposal receipt review are summarized below; additional details are available in that document (LANL, 2012a).

Revision 4 performance assessment and composite analysis estimates of future operational, environmental restoration (ER), and decontamination and decommissioning (D&D) waste inventories (LANL, 2008a) were based on the assumption that all LLW generated at LANL will be disposed of at Area G (through 2044) and that future disposal rates will resemble those observed from 2000 to 2008. As discussed in greater detail in Section 7, most of the operational waste to be generated at LANL in the future is now expected to be disposed of off site. Consequently, Area G is expected to receive much less waste than was projected for the performance assessment and composite analysis. In response to this shift in disposal strategy, the FY 2011 disposal receipt review (LANL, 2012a) assumes significant reductions in the quantities of waste that will be disposed of in pits; waste disposal rates for shafts are assumed to be unaffected by the use of off-site disposal facilities. The disposal of waste at Area G is projected to occur through 2044.

Table 3-1 compares future waste volume and activity projections developed for the 2011 disposal receipt review to those used in the Revision 4 performance assessment and composite analysis. The disposal volume projected for the pits using the disposal receipt data is substantially smaller than the Revision 4 estimate for these units; this difference is due, primarily, to the shift to off-site disposal of waste. The total pit activity is similar between the two sets of projections despite the move toward off-site disposal, largely because of an increase in the activity of tritium that is projected to require disposal. The updated volume projection for the disposal shafts is about one-third of that projected for the performance assessment and composite analysis; a large increase in the total activity is also observed. These changes are caused by a lower-than-anticipated volume of tritium waste with a higher-than-anticipated activity. Some of the differences observed in the pit and shaft inventory projections are due to the fact that the two sets of projections address different periods of time: the estimates developed on the basis of the disposal receipt review address waste disposed of from FY 2012 through 2044, whereas those included in the Revision 4 performance assessment and composite analysis address waste that is disposed of from the beginning of 2008 through 2044.

Table 3-1
Future Waste Inventory Estimates for Area G: FY 2011 Disposal Receipt-Based Projections vs. Revision 4 Performance Assessment and Composite Analysis Projections

Disposal Unit	Disposal Receipt-Based Projections [a]		Area G Performance Assessment and Composite Analysis Projections [b]	
	Total Volume (m^3)	Total Activity (Ci)	Total Volume (m^3)	Total Activity (Ci)
Pits	1.1E+04	3.7E+02	1.6E+05	3.9E+02
Shafts	3.6E+02	4.3E+06	1.0E+03	9.8E+05
Total	1.1E+04	4.3E+06	1.7E+05	9.8E+05

[a] *Includes waste expected to require disposal from October 1, 2012, through 2044.*
[b] *Includes waste expected to require disposal from the beginning of 2008 through 2044.*

The radionuclide-specific inventories projected for the pits using the disposal receipt data are generally smaller than those estimated by the Revision 4 inventory characterization. The updated future inventories for about 80 percent of the radionuclides are 50 percent or less of those developed for the performance assessment and composite analysis; inventories of 11 radionuclides are greater than those estimated in 2008. The future radionuclide inventories projected for the shafts using the disposal receipt data are also generally smaller than those adopted for the performance assessment and composite analysis. However, the magnitudes of the differences between old and new projections tend to be smaller than those observed for the pits. For example, only 20 percent of the radionuclides have updated estimates that are less than half of the earlier estimates.

Relatively few radionuclides made significant contributions to the doses projected for the Revision 4 Area G performance assessment and composite analysis (LANL, 2008a). In general, the impacts of using the disposal receipt data to update the inventory projections depend upon changes to the quantities of these critical radionuclides. To evaluate the impacts, the inventories used in the Revision 4 performance assessment and composite analysis modeling were updated with the disposal receipt data and new dose and radon flux estimates were projected. The impacts that the disposal receipt-based inventories have on the dose and flux projections 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 performance assessment and composite analysis.

Preliminary modeling revealed that disposing of the entire projected tritium inventory in Zone 4 shafts may yield doses for the agricultural intruder scenario that are in excess of the 100 mrem/yr chronic dose limit. To avoid this, 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 shaft tritium inventory by 960,000 Ci; the model projections presented below take this reduction into account.

The exposures and radon fluxes projected using the FY 2011 disposal receipt review inventories are compared in Tables 3-2 through 3-4 to the quantities estimated using the site and intruder models documented in *Special Analysis: Headspace Waste Disposal Impacts at Technical Area 54, Area G* (LANL, 2012c). Table 3-2 compares the exposures projected for members of the public, Table 3-3 shows the radon flux estimates, and Table 3-4 provides the intruder exposure projections. 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.

The doses projected for members of the public under several exposure scenarios are unaffected by the updated inventories; however, the exposures projected for other scenarios increase significantly (Table 3-2). The higher exposures are the result of the large increase in the quantity of tritium that is projected to be disposed of at Area G. This waste has its greatest impact on the receptors located closest to the Zone 4 expansion area; exposures for receptors located farther away show little impact from the radionuclide. All projected exposures for members of the public are less than the pertinent DOE performance objectives.

The radon fluxes projected for the performance assessment decrease for the Zone 4 expansion area (waste disposal region 8) when the disposal receipt data are used to project future inventories (Table 3-3). Disposal region 8 is the portion of Area G that is most affected by changes in inventories because it will receive the bulk of the remaining waste to be disposed of at Area G. Overall, the facility-wide radon flux remains constant at 0.40 pCi/m^2/s, which is much less than the 20 pCi/m^2/s performance objective.

Table 3-2
Exposures Projected for Members of the Public: FY 2011 Disposal Receipt Review vs. Projections from the Site Model with Headspace Impacts

Exposure Scenario and Location	Peak Mean Dose (mrem/yr)			
	Performance Assessment		Composite Analysis	
	2011 Disposal Receipt Review	Site Model with Headspace Impacts [a]	2011 Disposal Receipt Review	Site Model with Headspace Impacts [a]
Atmospheric				
LANL Boundary	4.4E-01	1.9E-01	2.1E-01	2.2E-01
Area G Fence Line	4.4E-03	2.5E-03	5.4E-01	5.1E-01
All Pathways–Canyon				
Catchment CdB1	5.7E-01	1.5E-01	6.1E-01	4.6E-01
Catchment CdB2	2.2E-01	2.2E-01	1.0E+00	1.0E+00
Catchment PC0	7.6E-04	3.9E-04	9.0E-04	4.2E-04
Catchment PC1	4.2E-01	4.1E-02	4.7E-01	4.6E-02
Catchment PC2	1.6E-01	1.6E-01	3.1E-01	3.1E-01
Catchment PC3	1.4E-01	1.4E-01	2.5E-01	2.5E-01
Catchment PC4	2.2E-01	2.3E-01	3.3E-01	3.3E-01
Catchment PC5	3.2E-01	3.2E-01	2.1E+00	2.1E+00
Catchment PC6	1.7E-01	1.7E-01	2.4E+00	2.4E+00
Groundwater Pathway Scenarios				
All Pathways–Groundwater	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Groundwater Resource Protection	0.0E+00	0.0E+00	NA	NA

NA = Not applicable
[a] *As discussed in LANL (2012c)*

Table 3-3
Projected Radon Fluxes: FY 2011 Disposal Receipt Review vs. Projections from the Site Model with Headspace Impacts

Waste Disposal Region	Peak Mean Flux (pCi/m2/s)	
	2011 Disposal Receipt Review	Site Model with Headspace Impacts [a]
1	1.3E-06	1.3E-06
2	—	—
3	1.5E+01	1.5E+01
4	3.6E-02	3.6E-02
5	2.9E-01	2.9E-01
6	3.6E-03	3.6E-03
7	1.3E+01	1.3E+01
8	2.1E-02	2.5E-02
Entire facility	4.0E-01	4.0E-01

— = None of the performance assessment inventory was disposed of in the waste disposal region.

[a] *As discussed in LANL (2012c)*

Table 3-4
Projected Intruder Exposures: FY 2011 Disposal Receipt Review vs. Projections from the Intruder Models with Headspace Impacts

Disposal Units and Exposure Scenario	Peak Mean Dose (mrem/yr)	
	2011 Disposal Receipt Review	Intruder Models with Headspace Impacts [a]
MDA G Pits		
Intruder–Construction	3.8E+00	3.8E+00
Intruder–Agriculture	3.0E+01	3.0E+01
Intruder–Post-Drilling	6.0E+00	6.0E+00
Zone 4 Pits		
Intruder–Construction	3.5E-03	4.1E-03
Intruder–Agriculture	2.7E-02	6.3E-02
Intruder–Post-Drilling	5.2E-02	1.4E-01
MDA G Shafts		
Intruder–Construction	5.4E+00	5.5E+00
Intruder–Agriculture	9.1E+01	9.5E+01
Intruder–Post-Drilling	1.2E+01	1.2E+01
Zone 4 Shafts		
Intruder–Construction	3.8E+00	1.1E+00
Intruder–Agriculture	8.8E+01	2.5E+01
Intruder–Post-Drilling	1.1E+01	4.2E+00

[a] *As discussed in LANL (2012c)*

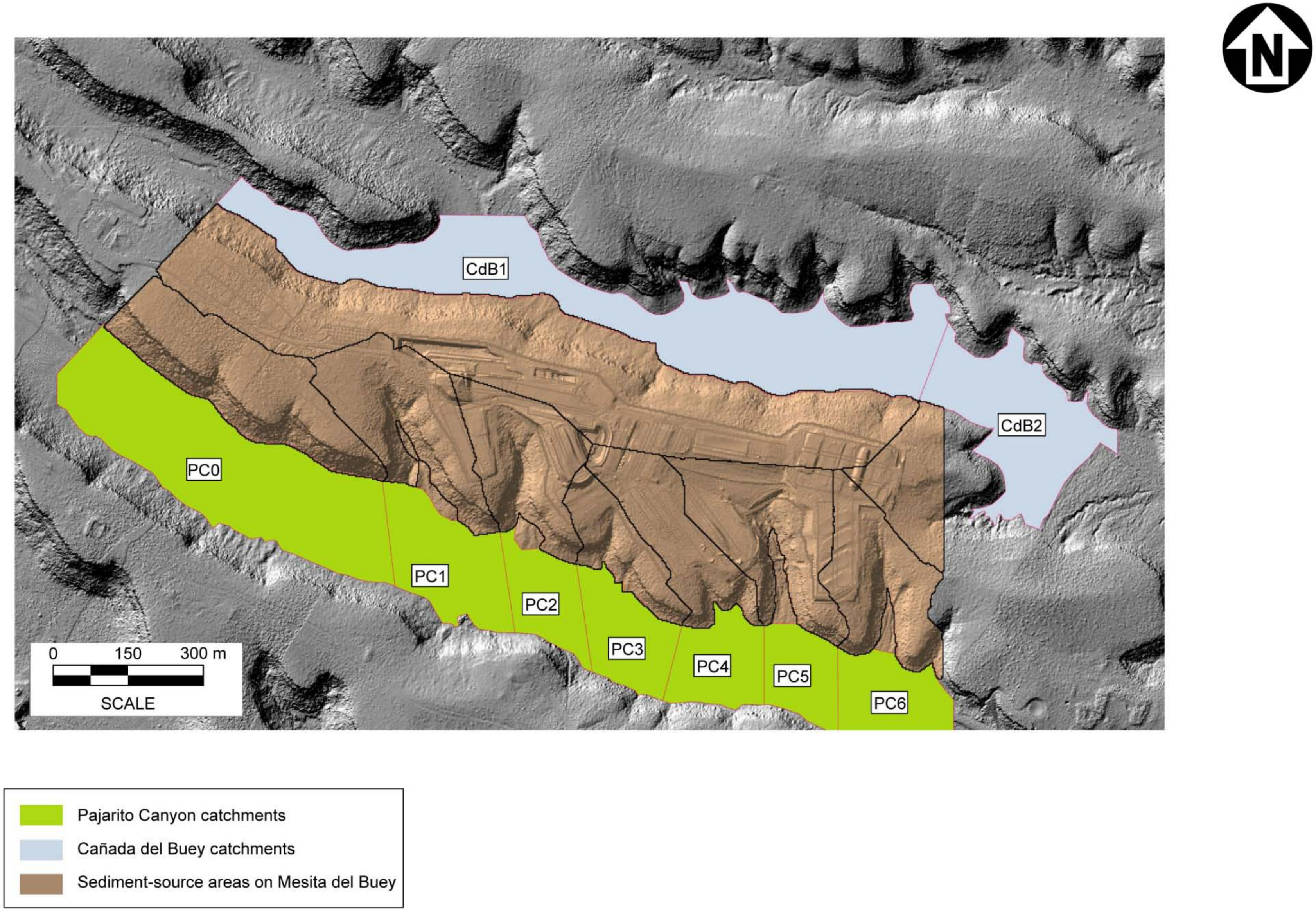

Figure 3-1
Area G Sediment Catchments in Pajarito Canyon and Cañada del Buey

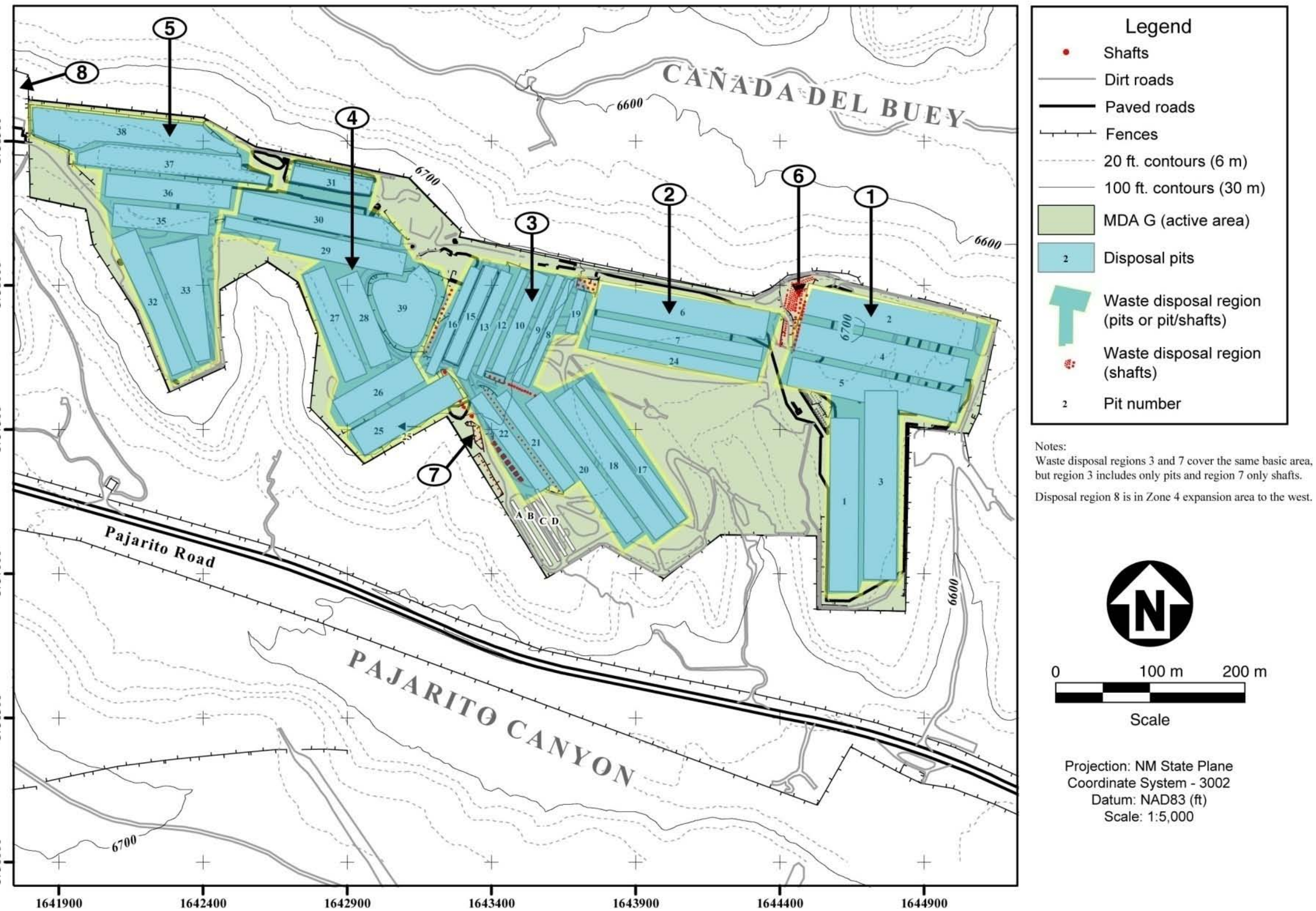

Figure 3-2
Waste Disposal Regions at Area G

Source: Apogen Technologies (formerly SEA)
LANL RRES Database, Map ID: 4531.021 (1) Rev . 2

Table 3-4 compares the intruder dose projections that were developed using the updated inventories to those estimated by the headspace impacts analysis (LANL, 2012c). The intruder doses projected using the two inventories are similar for the 1988–2013 pits and shafts; exposures for the 2014–2044 pits decrease slightly when the inventories are updated, while the exposures for the 2014–2044 shafts increase substantially. The increase in the doses projected for the 2014–2044 shafts is due primarily to the increased quantity of tritium placed in the disposal units. As mentioned earlier, it was necessary to restrict the amount of tritium placed in this portion of Area G to maintain intruder doses within acceptable limits. Specifically, it was assumed that the tritium generated during the last 8 years of disposal operations (960,000 Ci) was sent elsewhere for disposal.

It was assumed that the final elevation of the waste placed in the 2014–2044 shafts will be 1.5 m (4.9 ft) lower than that assumed for the performance assessment. As discussed in the FY 2010 annual report (LANL, 2011c), limiting the near-surface placement of Ti-44 waste was necessary to comply with the inadvertent intruder performance objectives. The large increase in the projected tritium inventory increases the need for placing the waste at greater depths.

The impacts of updating the future waste inventories to reflect the actual waste disposed of from FY 2008 through FY 2011 are mixed, but all doses and radon fluxes projected by the performance assessment and composite analysis remain within performance objectives. The peak mean doses projected under the performance assessment for the atmospheric scenario and two of the nine receptor locations considered in the All Pathways–Canyon Scenario increased more than 25 percent relative to the exposures projected using the models documented in LANL (2012c) (Table 3-2). This increase exceeds the threshold criterion cited in the LFRG Program Management Plan (DOE, 2000). The peak mean doses projected for two of the canyon receptors increased more than 25 percent under the composite analysis. Increases in dose projected for members of the public were small in an absolute sense; the greatest increase observed across all scenarios was about 0.4 mrem/yr. The exposures projected for the Zone 4 shaft intruder scenarios increased more than 25 percent, corresponding to increases in dose of 2.7 to 63 mrem/yr.

3.2 Alternate Source Evaluation

The alternate source evaluation conducted in support of the Area G composite analysis (LANL, 2008a) 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 either 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.

All of 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.

Past 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 performance assessment and composite analysis. 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 2010 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 LANL; 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 almost due east beneath Mortandad Canyon and is to the southeast at Area G.

3.2.1 MDA A

The sources of contamination at MDA A include two buried steel tanks—the liquid contents of which were recovered, treated, and disposed of in the 1970s—and 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.

Current plans call for the removal of all waste from the pits and tanks at MDA A and the subsequent removal of the tanks. Scheduled for completion in 2013, the removal action will prevent any significant interaction of releases from this area with releases from Area G.

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 due to biotic intrusion are expected to be low relative to those at Area G. 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 LANL 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, 2010b). An investigation report issued in 2010 (LANL, 2010c) characterized the nature and extent of surface and subsurface contamination at the site; concentrations of Am-241, Cs-137, Pu-238, and Pu-239/240 in excess of fallout values were detected in small numbers of soil and tuff samples. Further sampling is planned to better define the vertical and lateral extent of Am-241, Pu-238, and Pu-239/240 (LANL, 2011d)

The contamination found at MDA AB is not expected to interact with releases from Area G in a significant manner for two reasons. First, soil concentrations measured to date at MDA AB are low and likely due to secondary contamination of the site; the vast majority of the contamination at MDA AB resides at much greater depths. Second, contamination released to the atmosphere above MDA AB must be transported downwind to interact with releases from Area G. For locations immediately downwind of Area G, modeling conducted in support of the composite analysis indicates that airborne concentrations of contaminants released from MDA AB will be 100 times more dilute than the same release from Area G. Thus, the potential for significant interaction is small.

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 to 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; material was excavated until the contaminant concentrations in the native tuff encountered below the waste are less than residential soil screening levels. A total of 33,045 m^3 (43,222 yd^3) of waste was removed through September 14, 2011 (LANL, 2011e); all remaining waste has since been retrieved. This cleanup effort will prevent any significant interaction of releases from this area with releases from Area G.

3.2.4 MDA C

Material Disposal Area C was the primary radioactive waste disposal facility at LANL before Area G came into use. As discussed in the FY 2007 annual report (LANL, 2008b), one investigation report indicates inventories of U-235 and U-236 may exceed those found at Area G, but the DSA for nuclear environmental sites does not support this finding. In any event, airborne releases from MDA C will yield small contaminant concentrations relative to those from Area G, and releases due to leaching are expected to discharge to the regional aquifer long 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.

The MDA C Phase III Investigation Report was issued in 2011 (LANL, 2011f) and reported on the results of several sampling efforts at the facility. Field activities discussed in the report include the installation of four new vapor-monitoring wells, quarterly sampling of these wells and the 14 existing wells for volatile organic compounds and tritium, the establishment of a new groundwater well downgradient of the disposal facility, and the collection of groundwater samples. No information generated by these efforts contradicts the conclusions reached in the 2008 alternate source evaluation. Current estimates of the facility's radionuclide inventories are the same as those used to conduct 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. Field work conducted at MDA H during FY 2011 focused on vapor monitoring (e.g., LANL, 2011g). Tritium was found in 22 of the 28 samples collected from four boreholes; concentrations generally decreased with depth. The inventories of this isotope that were disposed of at MDA H are small compared to those placed in the shafts at Area G. Therefore, these findings do not call into question the conclusions of the alternate source analysis as it pertains to MDA H.

A revision to the MDA H Corrective Measures Evaluation (CME) was issued in FY 2011 (LANL, 2011h); the technical details presented in the report do not contradict any of those used in the conduct of the alternate source evaluation. Separately, the inventory estimates provided for MDA H in the 2010 DSA (LANL, 2010b) are the same as those used in the composite analysis. Overall, then, the conclusions of the composite analysis are unchanged with respect to MDA H.

The alternate source evaluation dismissed MDA L from consideration on the basis that no radioactive contaminants are included in the disposal records for the facility. Periodic vapor monitoring was conducted on a quarterly basis in FY 2011 (e.g., LANL, 2011i). The results of this monitoring indicate the presence of tritium in several boreholes and at several depths. Large variations in tritium levels were observed across the four quarters of data for FY 2011; these variations occurred across the 24 boreholes that were monitored and, in several cases, among the sampled depths within boreholes. These results are inconsistent with the fact that there are no MDA L disposal records which show evidence that tritium was disposed of at the site. In any event, any tritium inventories that may exist at MDA L will be small compared to the large quantities of this radionuclide that have been, and are projected to be, disposed of at Area G. Therefore, no significant interaction between releases from the two sites is expected.

A second revision to the MDA L CME was issued in FY 2011 (LANL, 2011j), in response to comments received from the New Mexico Environment Department (NMED). The technical details presented in the report do not contradict any of those used in the conduct of the alternate source evaluation. Therefore, the conclusions of the 2008 composite analysis are unchanged with respect to MDA L.

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 due to 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.

Limited work relevant to the alternate source analysis was conducted at MDA T in FY 2011. Vapor monitoring was conducted on a quarterly basis (e.g., LANL, 2011k); samples were analyzed for various volatile organic compounds and tritium. Tritium concentrations varied among the five boreholes and at different depths within each borehole. In any event, the quantities of tritium disposed of at MDA T are much less than tritium inventories projected for Area G. As a result, there is little or no potential for significant interactions between releases of this radionuclide from the two disposal areas. The LANL 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, 2010b) of this analysis. Overall, then, the conclusions reached about the likelihood of source interaction between MDA T and Area G remain unchanged.

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. Watershed sampling activities conducted in 2010 (LANL, 2011l) support the conclusions of the alternate source evaluation. Low concentrations of Am-241, Pu-238, Pu-239/240, and tritium were measured in sediments within the Cañada del Buey watershed. These sediments were collected from a small drainage below Area G; nearby stations were not sampled because they showed no evidence of flow. Results for 2010 fell within the range observed for prior years. Am-241, Pu-238, and Pu-239/240 were found at levels greater than background in sediments taken from small drainages channels within the Pajarito Canyon watershed. The channels in which the radionuclides were found drain Area G, suggesting operational releases were the source of the contamination.

As discussed in the FY 2009 annual report (LANL, 2010d), Pajarito Canyon investigations conducted in 2009 suggest interactions may occur between releases to the canyon from Area G and contaminants transported down-canyon following the Cerro Grande fire; releases of tritium from up-canyon sources may also be impacting the canyon adjacent to Area G. The Los Conchas fire of 2011 may exacerbate flood-related transport of contamination down the canyon. Although any exposures from the contamination detected in the canyon are expected to be small, the potential for interaction within Pajarito Canyon will need to be monitored. To date, the data collected continue to suggest that contamination found in the reach of Cañada del Buey adjacent to Area G originates from the disposal facility.

4.0 Monitoring Data Summary and Evaluation

Monitoring at Area G includes a variety of routine environmental surveillance activities and surveillance associated with site closure efforts. These activities are discussed below with respect to their relevance to the Area G performance assessment and composite analysis (LANL, 2008a).

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 LANL environmental surveillance reports. The surveillance information discussed in this annual report was taken from the environmental surveillance report for 2010 (LANL, 2011l), which contains the most recent published surveillance information.

The majority of the environmental surveillance data collected at or near Area G provides little or no opportunity for validating the performance assessment and composite analysis. 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. Although contaminated material from pits and shafts may be transported to the surface as a result of biotic intrusion during the facility's operational period, the impacts of biotic intrusion are expected to change significantly once the surface structures at Area G have been removed and the final cover has been applied. Thus, the conditions modeled by the performance assessment and composite analysis are typically quite different from those evaluated under the surveillance program.

Surveillance data such as air-monitoring data for particulates, direct radiation measurements, and information from soils and biota monitoring are not directly comparable to the performance assessment and composite analysis results because of the differences in environmental conditions discussed above. The results of the storm water and sediment sampling efforts are conceptually consistent with the Area G performance assessment and composite analysis insofar as both project that radionuclides will be transported off site with surface runoff. However, the contaminant concentrations detected in water and sediment under present-day conditions will tend to be greater than those expected after the disposal facility is closed and the final cover is applied. As a result, the monitoring results are not expected to be relevant indicators of the validity of the performance assessment and composite analysis modeling. Surveillance activities that are, or may be, pertinent to the performance assessment and composite analysis 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 2010 activities that are relevant to the Area G performance assessment and composite analysis 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. Sixty environmental samplers were operated at LANL in 2010 to collect water vapor and particulates at on-site and regional locations. The Area G sampling network includes nine of these samplers. The concentrations of radioactive constituents found in the collected samples are compared to background levels and 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 and, as discussed earlier, the associated data are of little use in validating the model projections of the performance assessment and composite analysis. On the other hand, 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 performance assessment and composite analysis is somewhat problematic, as discussed below. Nevertheless, the surveillance data can provide some insight into the validity of the modeling conducted in support of those analyses.

The performance assessment and composite analysis models do not project airborne tritium (as tritiated water) concentrations at the AIRNET network sampling locations at the disposal facility. Therefore, the airborne concentrations measured by the AIRNET sampling cannot be used to validate the models. However, the results of the AIRNET sampling were used to estimate doses, from all radionuclides, for a hypothetical person living at various locations near the town of White Rock, which lies about 2 km (1.2 mi) east of the disposal facility. These estimated exposures and the exposures projected by the performance assessment and composite analysis provide a basis of comparison.

It is reasonable to expect that the modeled and calculated exposures for a given time period will be similar if the model accurately represents the conditions at, and in the vicinity of, Area G. The diffusion of tritiated water vapor from the high-activity tritium waste disposed of at Area G was projected by the composite analysis to yield a peak mean exposure of 0.23 mrem/yr along the LANL boundary east of Area G. This dose is projected to occur in the year 2017; the mean exposure projected for 2010 is about 0.21 mrem/yr. Using the AIRNET sampling results, the average 2010 dose for a person living in White Rock was less than 0.1 mrem. This dose accounts for exposures to all radionuclides; the average dose from tritium is smaller. Based on these results, it appears the model projections of tritium exposure are conservative. However, the ability to draw firm conclusions about the validity of the modeling from these results is problematic because of the following differences in the modeling analysis and the manner in which the dose was calculated using the empirical data:

- The composite analysis dose accounts for the release of tritium from Area G only; the exposure estimated for a White Rock receptor using AIRNET data includes contributions from other sources at the Laboratory.
- The point of maximum exposure used in the composite analysis is not the same as the White Rock locations used to calculate the AIRNET data-based exposures. The composite analysis modeling would project lower doses than those cited above if the point of exposure was changed to White Rock.
- The composite analysis modeling and the exposure calculations conducted using the AIRNET data use different values for the exposure parameters. All else being equal, the composite analysis modeling would project higher doses if the values used in the AIRNET data exposure calculations were applied.

As mentioned above, sources of tritium release other than Area G exist at the Laboratory, some of which were not included in the composite analysis. The exposures received from tritium releases at Area G, however, 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. Some insight into the relative tritium source strengths found at LANL is provided by the airborne tritium concentrations measured by the AIRNET monitoring network in 2010. The maximum tritium concentration reported in 2010 occurred at Area G, near shafts used for the disposal of high-activity tritium waste. The mean annual concentration of tritium at this location is about 25 times greater than the next highest concentration measured at the Laboratory.

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 performance assessment and composite analysis. 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, 2011). Given that these evaluations used average conditions, the addition of a year's worth of meteorological data, such as those collected in 2010, will have a limited impact on the results of the performance assessment and composite analysis. Nevertheless, future updates of the modeling will take into account all available meteorological data.

4.1.2 Groundwater Surveillance

Groundwater sampling locations at the Laboratory are used to monitor the regional aquifer, alluvial groundwater in canyons, and intermediate-depth perched groundwater. Six observation wells located near Area G, two in Cañada del Buey (CDBO-4 and CDBO-9) and four in Pajarito Canyon (PCO-2 PCO-3, PCAO-8, and PCAO-9), are used to monitor alluvial waters in those canyons; wells PCAO-8 and PCAO-9 were added in 2008. Several wells in the immediate vicinity of Area G were used in 2010 to monitor the regional aquifer including regional characterization wells R-21, R-22, R-23, R-32, R-38, R-39, R-41, R-49, R-55, and R-57. Water from the regional aquifer is discharged to the Rio Grande via several springs located in White Rock Canyon; these springs are sampled as part of the groundwater surveillance efforts. Several of the springs are located downgradient of Area G, the possibility exists that contaminant releases from Area G could affect these waters.

No radionuclides were detected above screening levels or standards in the Cañada del Buey and Pajarito Canyon observation wells. Tritium was detected at small concentrations in deep wells R-23, R-38, R-39, R-41, R-49, and R-55 and in intermediate well R-23i. Tritium concentrations in the deep wells, which ranged from 3.1 to 6.3 pCi/L, fall within the range of tritium levels in rainfall (2 to 50 pCi/L). Concentrations at intermediate well R-23i are higher than rainfall background, ranging from about 20 to 150 pCi/L. Although the source of contamination for this well is not certain, Area G does not appear to be a likely contributor. Technical Area 18 is located near the well and is a source of tritium; the well may also be impacted by surface and alluvial water flow within Pajarito Canyon. No other radionuclides were detected in the deep or intermediate wells found near Area G. Low levels of tritium were detected at springs that fall within the Pajarito Canyon drainage; all concentrations are consistent with tritium concentrations in rainfall.

4.2 Waste Disposal Pit Monitoring

Periodic monitoring is conducted at Area G to determine volumetric moisture contents adjacent to, and within, disposal units at the facility. A final report documenting recent monitoring results is scheduled for release in FY 2012.

4.3 Groundwater Monitoring

LANL 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 LANL 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. Concurrently, an assessment was undertaken to determine where to locate additional monitoring wells.

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 TA-54. 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 current configuration of the monitoring well network at TA-54 is shown in Figure 4-1 (LANL, 2011m). The network includes perched-intermediate well screens at R-23i, R-37 screen 1, R-40i, R-40 screen 1, and R-55i, and the deep regional wells. The deep wells have one or two screens for sampling; well R-22 is not currently sampled. Sampling results for the groundwater monitoring effort are published in LANL's annual environmental surveillance report (e.g., LANL, 2011l).

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 reflected in the Laboratory's environmental surveillance reports. The latest published results from this effort (LANL, 2011n), include data for sampling conducted from April 18, 2011 through May 11, 2011. This report also includes sampling results from the portions of Cañada del Buey adjacent to Area G. None of the radionuclide concentrations reported during this period exceeded the adopted screening levels.

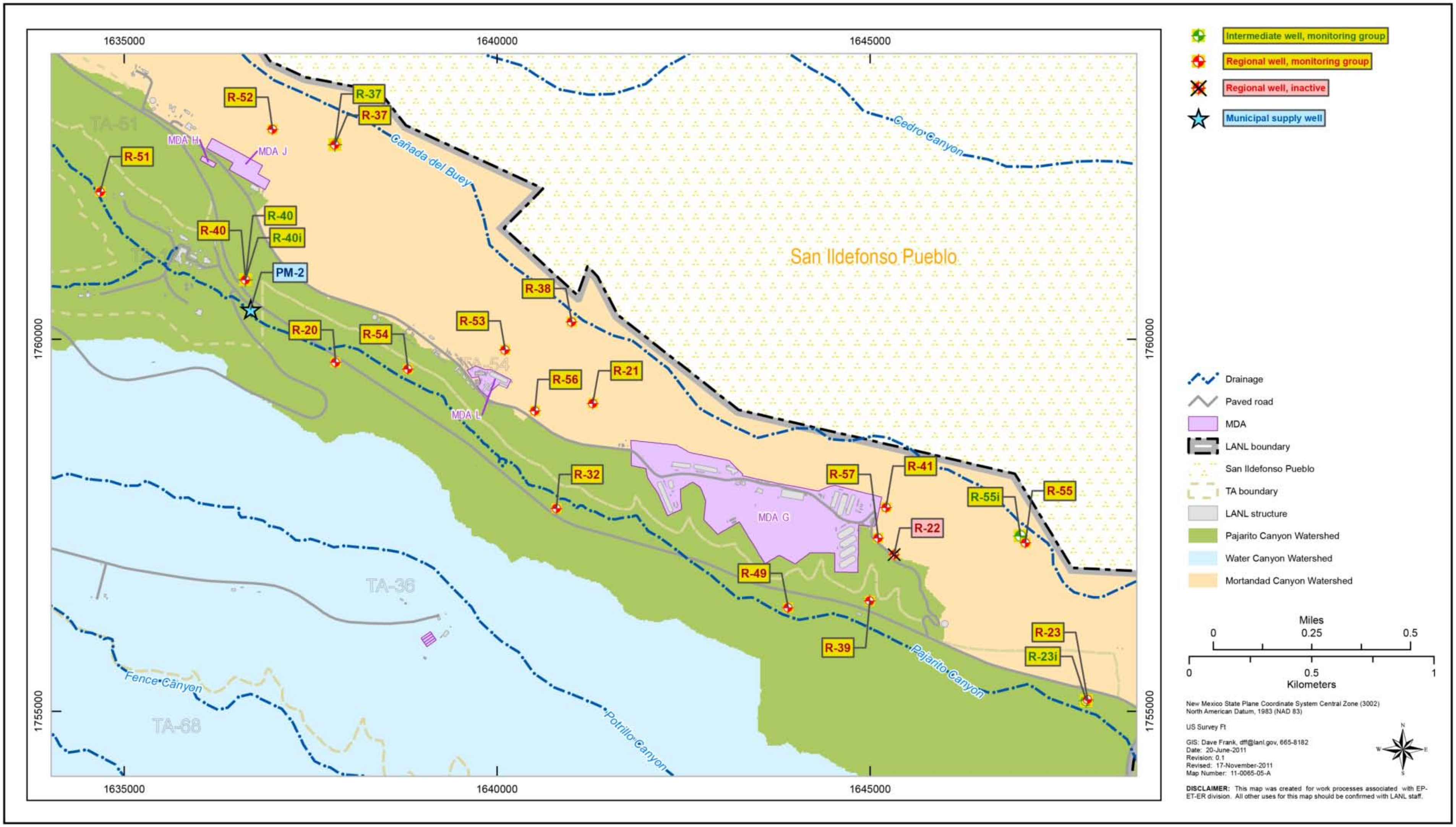

Figure 4-1
Locations of New and Existing Monitoring Wells

5.0 Summary of Research and Development Efforts

Several R&D activities were pursued or completed in FY 2011 and early FY 2012 under the Area G performance assessment and composite analysis maintenance program plan. These activities were conducted to address secondary issues identified by the LFRG (DOE, 2009) and, more generally, to reduce the uncertainty associated with the performance assessment and composite analysis. The progress made on the R&D efforts is discussed below.

5.1 Surface Erosion Modeling Sensitivity

The SIBERIA landscape evolution model was used to evaluate the impacts of surface erosion on the long-term performance of the final cover adopted for the performance assessment and composite analysis (Wilson et al., 2005). That work and the subsequent revision (Crowell, 2010) estimated patterns and rates of soil loss for three erosion scenarios that differed in terms of runoff volume and ground surface characteristics. These are referred to as the low-, moderate-, and high-erosion scenarios. The scenarios were defined using average properties of 17 hillslope profiles located within, or immediately adjacent to, Area G.

Modeling conducted in FY 2011 investigated the sensitivity of the erosion model projections; a report documenting this effort will be issued in FY 2012. Rather than averaging properties over the 17 hillslope profiles, data for each profile were used to calibrate the model; the model was run for each profile, examining a wide range of vegetation and ground cover conditions and runoff intensities in the process. Simulations were conducted for each profile using the same diffusion coefficients adopted for the 2005 and 2010 modeling and coefficients optimized for each profile; diffusion coefficients are used to account for gravity-driven sediment transport processes such as rainsplash, tree-throw, and animal burrowing.

Generally speaking, the median cover losses projected for the 17 hillslope profiles were similar to those estimated for the low-, moderate-, and high-erosion scenarios in the 2005 and 2010 modeling. Cover losses were more extreme for two profiles that were characterized by low ground and canopy cover. The variability observed in the hillslope-specific cover loss projections was similar to, or less than, that seen in the earlier modeling when the same diffusion coefficients were used in both sets of simulations. Variability increased substantially, however, when diffusion coefficients were optimized for each profile. Hillslope-specific coefficients tended to be smaller than those used in the earlier modeling, leading to higher rates of long-term erosion and more deeply incised channels. These effects were most apparent for simulations that addressed high-erosion conditions. Although the higher diffusion coefficients adopted for the 2005 and 2010 modeling appear to be more realistic on a qualitative basis, these results indicate a need to more fully understand diffusive processes at Area G.

5.2 Biotic Intrusion Field Investigation

The second phase of the biotic intrusion field investigation was completed in FY 2009. Once the evaluation of the field data is complete, the results will be used to help refine model projections of the impacts of plant intrusion on the long-term integrity of the disposal units at Area G.

5.3 Transient Flow Modeling

Rates of water infiltration through the disposal units at Area G were estimated for the Revision 4 performance assessment and composite analysis using the HYDRUS computer code (Levitt, 2008). The modeling projected rates of infiltration for the facility in its final closure configuration under steady-state conditions. It did not address the potential impacts of transient moisture introduced from the time of initial excavation through the interim closure period, or as a result of focused runoff. A modeling effort begun in FY 2009 evaluated the potential impacts of transient moisture on the rates at which radionuclides are leached from the waste and transported from the disposal units (Levitt, 2011).

The introduction of additional moisture into the disposal pits is projected to result in more rapid penetration of moisture below the disposal units than that projected for the 2008 performance assessment and composite analysis. Rates of infiltration through the disposal pits and the depths of moisture penetration are influenced by the depths of the disposal units and the periods the pits are active; waste properties such as porosity and initial water content also play an important role. If left in place, asphalt pads constructed at Area G to support waste management structures may lead to increased rates of infiltration through the disposal units. Elevated moisture contents below the disposal units are expected to dampen out and return to ambient conditions over time following closure of the disposal units and placement of final engineered covers over the disposal facility.

Although it has been shown that transient flow may significantly hasten rates of water movement through the disposal facility, the overall impacts of the additional moisture on groundwater pathway dose projections is not yet clear. The moisture profiles developed using HYDRUS will be used to update projections of groundwater flow and transport using the three-dimensional Finite Element Heat and Mass (FEHM) model developed for the performance assessment and composite analysis. The results of that analysis will be used to formulate a new groundwater modeling strategy, as appropriate.

5.4 Groundwater Model Update

The groundwater modeling conducted in conjunction with Revision 4 of the performance assessment and composite analyses used the FEHM program and took advantage of the latest geologic information available at the time (Stauffer et al., 2005); the geology model for Area G was extracted from the Laboratory's Geologic Framework Model. Information collected since the modeling was completed has been used to update the geologic model upon which the contaminant transport modeling was based. In conjunction with this work, an uncertainty analysis was conducted that examined the potential impact of uncertainties associated with the hydraulic properties used to conduct the modeling. A report documenting the results of the investigation will be issued in FY 2012.

An examination of the new geologic model indicates that the Bandelier Tuff contacts and thicknesses have changed significantly. Reductions in the thickness of the tuff are observed in some portions of Area G; these lead to reduced groundwater travel times to the regional aquifer in most portions of the disposal facility. The magnitudes of the reductions vary depending upon the rate at which water is assumed to infiltrate through the disposal units.

The groundwater pathway modeling conducted in support of the Area G performance assessment and composite analysis uses mean hydrologic properties of geologic strata to estimate rates of water flow and contaminant transport in the vadose zone below the disposal facility. The uncertainty analysis examined the variability in groundwater breakthrough times related to uncertainties in hydraulic properties used to characterize four units of the Bandelier Tuff. The hydraulic properties include the saturated conductivity, the pore size distribution parameter α, the van Genuchten fitting parameter n, and the residual and saturated water contents.

The results of the probabilistic analysis indicate that uncertainties in the hydraulic properties of the Bandelier Tuff may lead to substantial variability in the projected breakthrough curves. In general, projected groundwater travel times range over an order of magnitude, from thousands to tens of thousands of years. A small number of model realizations exhibited extremely long travel times, caused by very low hydraulic conductivities of some geologic units. The use of mean hydraulic properties to generate breakthrough curves is expected to overestimate contaminant fluxes at early times in a simulation, but underestimate actual fluxes at later times; the use of breakthrough curves based on median hydraulic properties appears to provide a more accurate representation of groundwater flow and transport at Area G.

5.5 Wind Erosion Investigation

The wind erosion study conducted in support of the performance assessment and composite analysis (Whicker and Breshears, 2005) found no net loss of soil due to wind erosion. However, that analysis did not address the potential for winds at the site to transport contaminated surface soils horizontally across the disposal facility and into the neighboring canyons. An effort begun in FY 2009 to collect the data and develop the models necessary to estimate the potential impacts of wind transport at Area G culminated in the development of the Vegetation Modified Transport (VMTran) model (Whicker et al., 2012).

Model simulations conducted using conditions representative of Area G demonstrate the potential for contaminant redistribution due to saltation. Rates of sediment transport are significantly impacted by the transition of the site from grassland, shortly after final closure, to piñon-juniper woodland. Rates of sediment transport are greatest when tree canopy cover is low, decreasing as shrubs and tree become established and prosper. Disturbances such as fire and drought tend to slow or reverse vegetation succession at the site, thereby affecting rates of sediment transport across the disposal site. The implications of the modeling conducted using VMTran will be incorporated into the GoldSim™ models used to conduct the performance assessment and composite analysis, to refine the projections of potential impact to human receptors.

6.0 Summary of Special Analyses

Special analyses were conducted during FY 2011 to evaluate the potential impacts of stockpiling waste at Area G, update the GoldSim models to operate under the latest version of the software, revise future tritium inventories, and dispose of wastes containing high-activity tritium and enriched uranium. Several additional analyses, conducted in FY 2012 prior to the FY 2011 disposal receipt review, evaluated the impacts associated with groundwater and surface erosion model updates and headspace waste disposal. These analyses and their results are summarized below.

6.1 Stockpiling of Waste

A large influx of low activity waste generated by clean-up activities at LANL required that a portion of the waste be stockpiled until room could be found for its disposal. Toward this end, it was proposed that all waste that could be accommodated should be disposed of at Area G, and that the remaining material be stockpiled within the headspace of pits 37 and/or 38. A special analysis was conducted to evaluate how stockpiling the waste might affect the assumptions that form the basis of the Area G performance assessment and composite analysis.

The temporary stockpiling of waste within the headspace of pits 37 and 38 does not violate any of the assumptions upon which the Area G performance assessment and composite analysis are based. In reaching this conclusion, it was assumed that the waste elevations within pits 37 and 38 will remain consistent with the depths of placement modeled in the performance assessment and composite analysis, as amended by Special Analysis 2009-001 (LANL, 2009c). The impacts of the stockpiled waste on worker and public health and safety were expected to be negligible because of actions taken to stabilize the material while it is being stored, and because of the limited radionuclide inventories in the waste.

6.2 GoldSim Software Version Upgrade

The Revision 4 performance assessment and composite analysis were conducted using models developed with the GoldSim modeling platform or environment, version 9.60, Service Pack 4 (SP4). Regular updates to GoldSim are issued to further its capabilities and to correct errors found in the software. Changes made in transitioning from version 9.60 to version 10 and later versions included updates in the solution algorithm for treating advective flux links and computing concentrations in cells, and improvements in the sampling and correlation algorithms used in Monte Carlo simulations. Depending upon the model and how it is applied, these changes may result in small changes in the simulation results (GoldSim, 2009). A special analysis was conducted to evaluate the potential impacts of changes to the solution, sampling, and correlation algorithms on the dose and radon fluxes estimates found in the Area G performance assessment and composite analysis.

The special analysis evaluated the impacts of running the performance assessment and composite analysis models under GoldSim Version 10.11, SP4. The performance assessment and composite analysis were conducted using four models: the Area G inventory model, the Area G site model, the Area G intruder model, and the Area G intruder diffusion model. Several changes to how the GoldSim software operates made it necessary to alter these models.

In general, the impacts of the software upgrade were evaluated by comparing model results for the performance assessment and composite analysis to projections obtained by running the models under GoldSim 10.11 SP4. The inventory model is used to prepare initial radionuclide inventories for the site, intruder, and intruder diffusion models. The effects of the software upgrade on inventory projections were evaluated by comparing the composite analysis inventory used in the 2008 revision to the inventory estimated using the newer software; the composite analysis inventory includes all of the waste disposed of at Area G. The doses and radon fluxes projected using the site model and the two intruder models were compared to the dose and radon flux projections found in the Revision 4 performance assessment and composite analysis (LANL, 2008a) and the pit 38 update (LANL, 2009c).

The peak mean doses projected using GoldSim 10.11 SP4 are smaller than the doses projected for the performance assessment and composite analysis for some exposure scenarios, and greater for others. The differences in the doses projected for members of the public and inadvertent intruders are summarized in Tables 6-1 and 6-2, respectively. Increases of 25 percent or more in the doses projected for members of the public were observed for as many as five of the All Pathways–Canyon Scenario receptors under the performance assessment, depending upon the Latin Hypercube Sampling (LHS) option that was used; doses for two of the canyon receptors increased more than 25 percent under the composite analysis. The peak mean dose projected for the 2011 pits under the Intruder–Construction Scenario also increased more than 25 percent relative to the performance assessment estimate. Although many of these increases are large in a relative sense, they tend to be small in an absolute sense. The greatest increase in dose observed for members of the public was 0.43 mrem/yr, and the greatest increase for intruder scenarios was 4.8 mrem/yr.

The observed differences resulted primarily from the manner in which the parameter distributions used in the Area G models are randomly sampled by the different versions of the software; changes in the projections do not appear to be the result of a fundamental change in way in which the two versions of GoldSim implement the models. No statistically significant differences were found between the doses and radon fluxes projected by GoldSim 9.60 SP4 and GoldSim 10.11 SP4. Upgrading the Area G performance assessment and composite analysis models to GoldSim 10.11 SP4 did not impact the ability of the disposal facility to comply with DOE Order 435.1. Examination of the peak mean doses listed in Tables 6-1 and 6-2 and the radon fluxes listed in Table 6-3 reveals that all model projections remain below the pertinent performance objectives.

Table 6-1 .
Summary of Differences Between Doses Projected for Members of Public Using GoldSim 9.60 SP4 and GoldSim 10.11 SP4

Area G Analysis / Exposure Scenario	Peak Mean Dose (mrem/yr)			Ratio of GoldSim 10.11 SP4 and GoldSim 9.60 SP4 Dose Projections	
	GoldSim 9.60 SP4	GoldSim 10.11 SP4 – Random LHS	GoldSim 10.11 SP4 – Midpoint LHS	Random LHS (%)	Midpoint LHS (%)
Performance Assessment					
Groundwater Resource Protection	—	—	—	NA	NA
All Pathways–Groundwater	—	—	—	NA	NA
Atmospheric					
LANL Boundary	1.82E-01	1.83E-01	1.83E-01	101	101
Area G Fence-line	1.39E-02	1.49E-02	1.40E-02	107	100
All Pathways–Canyon					
CdB1	2.31E+00	2.19E+00	2.16E+00	95	94
CdB2	3.95E-01	6.80E-01	7.30E-01	172	185
PC0	1.28E-02	1.66E-02	1.50E-02	130	117
PC1	9.45E-02	1.87E-01	2.06E-01	197	218
PC2	2.08E-01	4.45E-01	5.03E-01	214	242
PC3	1.18E-01	1.71E-01	1.90E-01	145	161
PC4	3.25E-01	3.12E-01	3.30E-01	96	101
PC5	3.59E-01	3.33E-01	3.39E-01	93	94
PC6	1.95E-01	1.79E-01	1.77E-01	92	91

Table 6-1
Summary of Differences Between Doses Projected for Members of Public Using GoldSim 9.60 SP4 and GoldSim 10.11 SP4 (continued)

Area G Analysis / Exposure Scenario	Peak Mean Dose (mrem/yr)			Ratio of GoldSim 10.11 SP4 and GoldSim 9.60 SP4 Dose Projections	
	GoldSim 9.60 SP4	GoldSim 10.11 SP4 – Random LHS	GoldSim 10.11 SP4 – Midpoint LHS	Random LHS (%)	Midpoint LHS (%)
Composite Analysis					
All Pathways–Groundwater	—	—	—	NA	N/A
Atmospheric					
LANL Boundary	2.29E-01	2.32E-01	2.31E-01	101	101
Area G Fence-line	6.35E-01	5.41E-01	5.34E-01	85	84
All Pathways–Canyon					
CdB1	2.24E+00	2.29E+00	2.29E+00	102	102
CdB2	2.05E+00	2.38E+00	2.28E+00	116	111
PC0	1.36E-02	2.05E-02	1.80E-02	151	132
PC1	9.76E-02	1.74E-01	1.75E-01	178	179
PC2	4.41E-01	4.13E-01	4.27E-01	94	97
PC3	4.19E-01	1.88E-01	1.93E-01	45	46
PC4	1.23E+00	4.04E-01	3.79E-01	33	31
PC5	4.39E+00	3.90E+00	3.72E+00	89	85
PC6	3.56E+00	3.99E+00	3.79E+00	112	107

— No exposures were projected for this exposure scenario.
LHS = Latin Hypercube Sampling
N/A = not applicable.

Table 6-2
Summary of Differences Between Doses Projected for Inadvertent Intruders Using GoldSim 9.60 SP4 and GoldSim 10.11 SP4

Disposal Units / Exposure Scenario	Peak Mean Dose (mrem/yr) [a]			Ratio of GoldSim 10.11 SP4 and GoldSim 9.60 SP4 Dose Projections	
	GoldSim 9.60 SP4	GoldSim 10.11 SP4 – Random LHS	GoldSim 10.11 SP4 – Midpoint LHS	Random LHS (%)	Midpoint LHS (%)
1988 Pits					
Intrude –Post-Drilling	3.91E+00	4.71E+00	3.74E+00	120	96
Intruder–Agriculture	4.16E+00	4.72E+00	4.28E+00	114	103
Intruder–Construction	4.61E-01	4.21E-01	3.99E-01	91	87
2011 Pits					
Intruder–Post-Drilling	6.87E-01	7.04E-01	6.99E-01	102	102
Intruder–Agriculture	4.55E-01	4.10E-01	4.57E-01	90	100
Intruder–Construction	2.78E-02	3.96E-02	4.88E-02	143	176
1988 Shafts					
Intruder–Post-Drilling	1.09E+01	1.11E+01	1.14E+01	102	104
Intruder–Agriculture	8.95E+01	9.17E+01	9.43E+01	102	105
Intruder–Construction	5.06E+00	5.58E+00	5.63E+00	110	111
2016 Shafts					
Intruder–Post-Drilling	3.09E+00	3.14E+00	3.27E+00	101	106
Intruder–Agriculture	4.90E+01	5.00E+01	4.98E+01	102	102
Intruder–Construction	2.51E+00	2.48E+00	2.48E+00	99	99

[a] Listed doses represent the sum of the peak mean doses projected by the intruder and intruder diffusion models.
LHS = Latin Hypercube Sampling

Table 6-3
Comparison of Radon Fluxes Projected Using GoldSim 9.60 SP4 and GoldSim 10.11 SP4

Waste Disposal Region	Projected Flux (pCi/m²/s)								
	Mean			5th Percentile			95th Percentile		
		GoldSim 10.11 SP4			GoldSim 10.11 SP4			GoldSim 10.11 SP4	
	GoldSim 9.60 SP4	Random LHS	Midpoint LHS	GoldSim 9.60 SP4	Random LHS	Midpoint LHS	GoldSim 9.60 SP4	Random LHS	Midpoint LHS
1	1.78E-06	1.51E-06	1.47E-06	3.29E-13	3.84E-13	2.24E-13	7.30E-06	6.28E-06	6.15E-06
2	—	—	—	—	—	—	—	—	—
3	3.47E-01	3.49E-01	3.49E-01	3.59E-02	3.39E-02	3.43E-02	1.03E+00	1.02E+00	1.04E+00
4	3.99E-02	4.07E-02	3.95E-02	2.18E-03	2.39E-03	2.26E-03	1.18E-01	1.14E-01	1.13E-01
5	5.32E-01	5.73E-01	5.67E-01	5.30E-02	5.39E-02	5.32E-02	1.33E+00	1.71E+00	1.71E+00
6	3.63E-03	3.34E-03	3.33E-03	4.09E-11	4.25E-11	4.25E-11	1.34E-02	1.34E-02	1.29E-02
7	1.45E+01	1.40E+01	1.39E+01	1.11E+00	1.18E+00	1.23E+00	4.31E+01	4.27E+01	4.25E+01
8	3.26E-01	3.36E-01	3.33E-01	4.52E-02	4.19E-02	4.44E-02	9.42E-01	9.57E-01	9.35E-01
Site-wide Average	4.36E-01	4.28E-01	4.27E-01	1.14E-01	1.13E-01	1.14E-01	1.01E+00	9.71E-01	9.51E-01

— No radon fluxes were projected for this waste disposal region.

LHS = Latin Hypercube Sampling

6.3 Disposal of High-Activity Tritium Waste Addendum

A special analysis was conducted in FY 2009 to evaluate the feasibility of disposing of four containers of high-activity tritium waste in disposal shafts located within MDA G (LANL, 2009d); tritium concentrations in the waste exceed the radionuclide concentration limit developed for these disposal units. That analysis concluded that the waste could be safely disposed of based on the fact that the waste would not cause the total tritium inventory projected for these disposal units to be exceeded. An addendum to that analysis was conducted following changes in decisions regarding the disposal of that waste (LANL, 2009e). Once again, it was determined that the waste can be safely placed within the disposal shafts.

The containers of high-activity tritium waste addressed by the special analysis (and addendum) are in storage, awaiting a decision on their final disposition. A second addendum was conducted to address the disposal of additional high-activity tritium waste (LANL, 2011o); tritium concentrations in this waste also exceed the radionuclide concentration limits developed for this isotope. Using the same methodology adopted for the special analysis and first addendum, it was determined that the tritium waste can be safely disposed of at Area G. This conclusion is based on the assumption that the waste will be placed in containers with specifications that comply with the LANL WAC and that the packages will be placed at least 1.5 m (4.9 ft) below the top of the waste horizon in the disposal unit(s).

6.4 Revision of FY 2010 Disposal Receipt Review Tritium Projections

Disposal receipt reviews are conducted annually as a means of updating the future inventory projections for Area G. An error was discovered in the FY 2010 disposal receipt review (LANL, 2011p) that caused double counting of a portion of the tritium, thereby inflating estimates of the quantities of tritium that will require disposal in the future. A special analysis was conducted to determine the magnitude of this error and its impact on the performance assessment and composite analysis. The analysis found that the future shaft inventories of tritium estimated for the FY 2010 disposal receipt review decreased by about 2 percent when waste generated by the WETF was properly excluded from the extrapolation-based inventory projections; the future inventory projections developed for tritium in pits were largely unaffected by waste generated by this facility.

6.5 Disposal of Drums Containing Enriched Uranium

Permission was sought to dispose of 10 drums of waste generated at the Chemical Metallurgy Research Facility; radionuclides found in the waste include U-235, U-238, and Th-232. The U-235 contents of the drums exceed the fissile material limits found in the LANL WAC; beryllium, a moderator, is also present in quantities greater than those permitted by the WAC (LANL, 2012b). A special analysis was conducted to evaluate the potential impacts of disposing of this waste on the assumptions that form the basis of the Area G performance assessment and composite analysis (LANL, 2011q). The disposal of the enriched uranium was not found to violate any of the assumptions upon which the Area G performance assessment and composite analysis are based. The characteristics of the waste which cause it to violate the LANL WAC do not play a role in the performance modeling, and radionuclide concentrations in the waste fall well within radionuclide concentration limits for the disposal shafts. Disposal of the waste should be conducted in a manner that addresses the fissile nature of the waste.

6.6 Groundwater Model Update

As discussed in Section 5.4, the groundwater model used for the Revision 4 performance assessment and composite analysis has been updated to incorporate new geologic information about the disposal site. A special analysis was conducted to evaluate the potential impacts of the updated groundwater modeling on the Area G performance assessment and composite analysis. Doses were projected for the composite analysis under the All-Pathways–Groundwater exposure scenario using the updated model, and compared to exposures projected using the old groundwater model for periods of 1,000 and 100,000 years following final closure of the disposal facility (LANL, 2011r).

The updated groundwater modeling results indicated that no radionuclides will discharge to the regional aquifer during the 1,000-year compliance period. Low rates of infiltration estimated for the final cover placed over the disposal facility were sufficient to delay the arrival of contamination at the aquifer for thousands of years beyond this period. The Revision 4 performance assessment and composite analysis also projected that no radionuclides will reach the regional aquifer within 1,000 years of facility closure.

Only one radionuclide, C-14, was projected by the Revision 4 performance assessment and composite analysis to discharge to the regional aquifer within 100,000 years of facility closure. The low rate of infiltration assumed for the deterministic modeling resulted in small groundwater velocities in the vadose zone, delaying the arrival of other radionuclides beyond this period. With a sorption coefficient set to zero m^3/kg, C-14 was sufficiently mobile and long-lived to reach the aquifer. The radionuclide reached a peak concentration about 43,000 years after disposal facility closure, resulting in a composite analysis dose of 0.025 mrem/yr for the All-Pathways-Groundwater exposure scenario. The updated groundwater model projected groundwater travel times shorter than those projected for the Revision 4 analyses, resulting in modestly higher C-14 exposures. A peak mean dose of 0.064 mrem/yr was projected to occur about 35,600 years after the disposal facility closed. No other radionuclides were projected to discharge to the regional aquifer within the 100,000-year period.

6.7 Erosion Model Update

The surface erosion model used to support the Revision 4 performance assessment and composite analysis was updated to run under the latest version 8.33 of SIBERIA and to more accurately model soil loss at Area G (Crowell, 2010). The updated modeling generally projected increased sediment yields for MDA G, relative to the modeling conducted for the Revision 4 performance assessment and composite analysis; sediment yields for Zone 4 tended to be lower using the newer SIBERIA version. Overall, the terrain that was projected to evolve over 1,000 years was qualitatively more realistic than that projected using the earlier version of the model.

A special analysis was conducted to evaluate the potential impacts of the updated erosion modeling on the Area G performance assessment and composite analysis. The doses projected for members of the public and inadvertent intruders under the performance assessment and composite analysis using the earlier erosion model were compared to exposures estimated using the updated model (LANL, 2012d). The facility-wide radon flux estimated using the updated erosion modeling was compared to the earlier projection.

The peak mean exposures projected for the performance assessment using the new erosion model were generally similar to the doses projected for the FY 2010 disposal receipt review, with small increases for some exposure scenarios and small decreases for others. An exception occurs in terms of the peak mean dose for the canyon receptor in catchment CdB1, which drops from 2.4 mrem/yr to 0.15 mrem/yr or to 6 percent of the FY 2010 projection. This reduction is caused by changes in the cover erosion rates and sediment transport patterns projected by the updated modeling. When the new erosion model is applied, the peak mean doses projected for the composite analysis remain the same or decrease for all but one receptor. A significant reduction in the peak mean dose projected under the All Pathways–Canyon scenario for catchment CdB1 is caused by changes in cover erosion rates and sediment transport off the mesa. The facility-wide radon flux projected using the performance assessment inventory is 0.45 pCi/m^2/s; the same value was estimated by the FY 2010 disposal receipt review.

The peak mean doses projected for the intruders increased modestly for the MDA G and Zone 4 pits and shafts. The greatest increase is observed for the MDA G pits; peak mean doses increase 1.6 to 2.8 times across the three receptors. In all cases, however, the projected exposures remain well within the 100 and 500 mrem/yr performance objectives for chronic and acute doses.

6.8 Disposal of Waste in Pit 15, 37, and 38 Headspace

Disposal operations at Area G have been confined to MDA G and are scheduled to continue in that region until MDA G undergoes final closure at the end of 2013. Various efforts have been made to maximize the usage of the remaining MDA G disposal capacity, including the disposal of low-activity waste in the headspace of pits 15, 37, and 38. Although waste acceptance criteria have been developed and implemented for this waste, which originates from LANL clean-up operations, the potential exposures and radon fluxes associated with the placement of the waste in headspace had been evaluated only for pit 15. A special analysis was conducted to address the waste in pits 37 and 38, and to correct an error found in the pit 15 modeling (LANL, 2012c).

The GoldSim modeling conducted in support of the performance assessment and composite analysis was updated to include the impacts of waste placed in the headspace. The results of this modeling were compared to the doses projected by versions of the site, intruder, and intruder diffusion models that incorporated the groundwater and erosion model updates discussed above. The radon fluxes projected by the updated modeling were compared to those from the FY 2010 disposal receipt review (LANL, 2011p). The results of the comparisons are summarized in Tables 6-4 through 6-6. Tables 6-4 and 6-5 compare the doses projected for members of the public and the radon fluxes estimated for the undisturbed site, respectively. Table 6-6 compares the doses projected for persons who inadvertently intrude into the MDA G pits; intruder doses projected for MDA G shafts and Zone 4 pits and shafts were unaffected by the disposal of waste in the headspace of pits 15, 37, and 38.

The disposal of waste in the headspace of pits 15, 37, and 38 had little impact on the exposures projected for members of the public (Table 6-4). Including the headspace waste caused peak mean doses projected under the performance assessment to increase for only two exposure scenarios. For the composite analysis, the updated exposures exceed the doses projected by the earlier version of the model for only one exposure scenario. All updated doses remain far below the pertinent performance objectives.

The updated radon fluxes projected for the performance assessment are generally similar to, or less than, those projected for the FY 2010 disposal receipt review (Table 6-5). A notable exception is the large increase seen in the flux for waste disposal region 3, which is directly attributable to the error made in modeling the pit 15 headspace waste. Changes in the other fluxes are the result of updating the site model to run under version 10.5 of the GoldSim software, the incorporation of different cover loss functions in conjunction with the erosion model upgrade, and changes in radionuclide inventories. Overall, the facility-wide radon flux decreases modestly to 0.40 $pCi/m^2/s$; this flux is slightly lower than the flux reported in the FY 2010 disposal receipt review and much lower than the 20 $pCi/m^2/s$ performance objective.

Table 6-4
Projected Doses for Members of the Public: Headspace Waste Impacts Analysis Results vs. Projections Developed Using the Site Model without Headspace Waste

Exposure Scenario and Location	Peak Mean Dose (mrem/yr)			
	Performance Assessment		Composite Analysis	
	Model including Headspace Waste	Model without Headspace Waste	Model including Headspace Waste	Model without Headspace Waste
Groundwater Pathway				
All Pathways – Groundwater	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Groundwater Resource Protection	0.0E+00	0.0E+00	NA	NA
Atmospheric				
LANL Boundary	1.9E-01	1.9E-01	2.2E-01	2.2E-01
Area G Fence Line	2.5E-03	1.7E-03	5.1E-01	5.4E-01
All Pathways–Canyon				
Catchment CdB1	1.5E-01	1.5E-01	4.6E-01	5.6E-01
Catchment CdB2	2.2E-01	2.4E-01	1.0E+00	1.3E+00
Catchment PC0	3.9E-04	2.5E-04	4.2E-04	2.5E-04
Catchment PC1	4.1E-02	5.1E-02	4.6E-02	9.7E-02
Catchment PC2	1.6E-01	2.0E-01	3.1E-01	4.0E-01
Catchment PC3	1.4E-01	1.8E-01	2.5E-01	2.6E-01
Catchment PC4	2.3E-01	3.1E-01	3.3E-01	3.8E-01
Catchment PC5	3.2E-01	4.5E-01	2.1E+00	2.4E+00
Catchment PC6	1.7E-01	2.4E-01	2.4E+00	2.9E+00

NA = not applicable

Table 6-5
Radon Fluxes: Headspace Waste Impacts Analysis Results vs. Projections for the FY 2010 Disposal Receipt Review

Waste Disposal Region	Peak Mean Flux ($pCi/m^2/s$)	
	Headspace Waste Impacts Analysis	2010 Disposal Receipt Review
1	1.3E-06	1.8E-06
2	—	—
3	1.5E+01	1.1E+00
4	3.6E-02	4.0E-02
5	2.9E-01	3.0E-01
6	3.6E-03	3.6E-03
7	1.3E+01	1.4E+01
8	2.5E-02	1.9E-02
Entire Facility	4.0E-01	4.5E-01

— = None of the performance assessment inventory was disposed of in the waste disposal region.

Table 6-6
Intruder Exposures: Headspace Waste Impacts Analysis Results vs. Projections Developed Using the Intruder and Intruder Diffusion Models without Headspace Waste

Exposure Scenario	Headspace Impacts Analysis	Models without Headspace Waste
Intruder-Construction	3.8E+00	1.2E+00
Intruder-Agriculture	3.0E+01	9.4E+00
Intruder–Post-Drilling	6.0E+00	5.3E+00

The peak mean doses projected for the construction and agricultural intruders increase threefold as a result of the inclusion of the headspace waste in pits 37 and 38 and the correction of the error made in modeling pit 15 (Table 6-6). The peak mean dose for the post-drilling scenario rises by a more modest 11 percent. The increase in the construction and agricultural intruder doses is due, primarily, to the placement of waste closer to the surface of the disposal site, where it can be accessed during excavation of a 3-m (9.8-ft) deep basement. The peak mean dose projected for the post-drilling scenario increases only modestly because radionuclide concentrations in the waste are low and the drill bit contacts the entire waste profile, regardless of the thickness of the cover placed over the waste. In any event, the doses projected for the three intruder scenarios fall well within the pertinent performance objectives.

7.0 Operational Changes and Status of Information Needs

LANL 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, 2012b) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *Waste Management* (LANL, 2012e) sets requirements for the Laboratory's management of various hazardous, mixed, and radioactive wastes.
  - *Waste Characterization* (LANL, 2012f) summarizes the waste characterization requirements found in various regulations, including DOE Order 435.1 and its companion manual M 435.1-1.
  - *Radioactive Waste Characterization* (LANL, 2011s) 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.
  - *Acceptable Knowledge Package Guidance for Low-Level Waste* (LANL, 2010e) summarizes information found in various regulations, including DOE M 435.1-1, regarding the use of acceptable knowledge in making radioactive waste determinations.
  - *Waste Generator Instructions for Completing the Waste Profile Form (WPF)* (LANL, 2009f) provides LANL waste generators with instructions for completing waste profile forms.
- Waste certification
  - *Radioactive Waste Certification Program* (LANL, 2011b) establishes the requirements for certifying radioactive waste, in compliance with DOE Order 435.1 and the accompanying manual M 435.1-1.
  - *Waste Certification and Certification Protection* (LANL, 2008c) summarizes the waste certification requirements found in DOE M 435.1-1.
- Waste packaging and transportation
  - *LANL Waste Acceptance Criteria* (LANL, 2012b) defines WAC for hazardous, mixed, and radioactive waste, including the LLW disposed of at Area G.
  - *LANL Packaging and Transportation Program Procedure* (LANL, 2010f) describes the requirements for packaging hazardous and nonhazardous waste for off-site shipments and on-site transfers.

- *Offsite Shipment of Chemical, Hazardous, or Radioactive Waste* (LANL, 2010g) establishes the controls necessary to prevent improper shipment of chemical, hazardous, or radioactive waste.

- Waste verification
  - *Waste Certification Program Waste Verification* (LANL, 2011t) outlines the processes and standards used to verify the accuracy of waste characterization data provided by waste generators.

- Low level waste management operations
  - *LLW Receipt and Disposal* (LANL, 2009a) establishes the requirements for the receipt, storage, and disposal of LLW at Area G and for in-service inspections of active pit, trench, and shaft covers.

- 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, 2010h) 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.

- Waste acceptance criteria exemption
  - *LANL Waste Acceptance Criteria* (LANL, 2012b) 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, 2010h) 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, 2009g) provides the requirements for reviewing and approving changes at Hazard Category 1, 2, and 3 nuclear facilities at LANL.

- Environmental monitoring
  - *EWMO Environmental Monitoring Plan* (LANL, 2011u) 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 performance assessment and composite analysis 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 performance assessments and composite analyses 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 performance assessment and composite analysis is addressed in Section 7.2. The 2010 DAS issued to LANL includes a number of conditions that must be satisfied under the performance assessment and composite analysis maintenance program; Section 7.3 discusses the status of LANL'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 MDA G and the Zone 4 expansion area. To date, all disposal operations at Area G have been confined to MDA G. Material Disposal Area G is scheduled to undergo final closure in 2015; all waste management activities within this portion of Area G are assumed to cease in 2013. The impending closure has had, and will continue to have, profound impacts on the types and quantities of waste that will be sent for disposal at Area G and the manner in which this material is disposed of for the next two years. Significant impacts on the performance assessment and composite analysis can be expected as a result.

The impending closure of MDA G has brought with it a distinct shift in disposal philosophy. Whereas prior to FY 2009 essentially all of the LLW generated at LANL was disposed of at Area G, plans were made to send an increasing portion of the LLW generated at the Laboratory to commercial facilities or the NNSS for off-site disposal. These plans called for off-site disposal of at least 50 percent of the operational waste in FYs 2010 and 2011; 75 percent of this waste was to be shipped off site in FYs 2012 and 2013, and 90 percent of the material was to be sent elsewhere thereafter. Plans called for off-site disposal of all ER and D&D waste after FY 2009, although provisions were put in place that permit on-site disposal of ER and D&D waste in instances where sending the material off site is not feasible.

The transition to off-site disposal has not been as rapid as planned. Essentially all of the operational LLW generated at LANL has been disposed of at Area G in during FYs 2010 and 2011. Although large amounts of ER and D&D waste have been shipped off site, large quantities of waste retrieved from MDA B have also been disposed of at Area G. As a result, pit 38 was the only pit that had not been filled by the end of FY 2011; this disposal unit is expected to be filled in FY 2012. An extension of pit 38 is being considered to provide the disposal capacity needed to accommodate operational waste and a portion of the ER and D&D waste through the end of 2013.

The imminent closure of MDA G, the shipment of a portion of the waste to off-site disposal facilities, and implementation of the pit 38 extension will influence the operational assumptions upon which the performance assessment and composite analysis are based. For example, the Revision 4 analyses are based on the assumption that waste will be placed in disposal pits through 2010 and shafts through 2015; waste requiring disposal after these times was assumed to be disposed of in the Zone 4 expansion area. The shipment of a portion of the ER and D&D waste off site and the extension of pit 38 will provide the capacity to dispose of waste in pits through 2013. As mentioned above, disposal of waste in shafts is now expected to end in 2013.

The Consolidated Waste Capability Program was initiated at LANL to ensure that the solid waste management functions needed to handle the Laboratory's waste are put in place as the waste management operations at MDA G are phased out. A preliminary siting study was conducted to identify suitable locations for a consolidated waste management facility. In terms of waste disposal, it is uncertain if Zone 4 will be used for disposal; this portion of Area G was assumed to receive waste under the performance assessment and composite analysis.

Regardless of where waste is disposed of at LANL after 2013, sending a major portion of the LLW generated at LANL for off-site disposal will significantly impact the performance assessment and composite analysis. In recognition of this, the disposal receipt review discussed in Section 3 assumed a significant reduction in the rate at which waste is disposed of in pits from 2014 through 2044 (LANL, 2012a). The future inventory estimated on the basis of this assumption is approximate at best; the actual volumes and activities of waste that are placed within Area G will become evident only in subsequent disposal receipt reviews.

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 performance assessment and composite analysis 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 performance assessment and composite analysis.

Changes to the operational status of one pit took place during FY 2011. Disposal activities in pit 37 were completed; an interim cover has not yet been placed over the disposal unit. Shaft 363 underwent interim closure during the year.

7.2 Status of Informational Needs

Sensitivity analyses conducted in support of the Revision 4 performance assessment and composite analysis 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 performance assessment and composite analysis to identify additional information needed to improve the quality of the performance assessment and composite analysis. Efforts to collect this information are ongoing under the Area G performance assessment and composite analysis 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 performance assessment and composite analysis (DOE, 2009)
- Issuance of the Area G Performance Assessment and Composite Analysis Maintenance Program Plan and Area G Environmental Monitoring Plan by March 17, 2011
- 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 performance assessment and composite analysis 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.

Table 7-1 summarizes the DAS conditions that have been satisfied to date; these include several secondary issues, issuance of the maintenance program and environmental monitoring plans (LANL, 2011a, 2011u), and reporting requirements. Research and development efforts discussed in Section 5 have provided information that will be used to satisfy other secondary issues. For example, the erosion modeling sensitivity work discussed in Section 5.1 will help address conditions 7.2.1 (criterion 3.1.1.1) and 7.2.5 (criterion 3.1.6); the wind erosion work described in Section 5.5 will also aid in addressing the latter condition. The transient flow modeling discussed in Section 5.3 is pertinent to some of the requirements listed in condition 7.2.4 (criterion 3.1.5.3).

7.4 Recommended Changes

The results of the Area G performance assessment and composite analysis 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 continued ability of the disposal facility to perform within acceptable limits will need to be formally assessed before any additional operational modifications are implemented. The analyses may also require updating as the selection of the final closure strategy for MDA G progresses. Changes to the closure strategy for MDA G will also require updates 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 performance assessment and composite analysis. These efforts will be pursued under the Area G performance assessment and composite analysis 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
Summary of LANL DAS Conditions that Have Been Satisfied

DAS Condition	Summary of Condition	Reference
LFRG Secondary Issue 7.2.2 - Criterion 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	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.2 - Criterion 3.1.3.6 - Intruder Scenarios	The human intruder scenarios are overly conservative	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.3 - Criterion 3.1.4.4 - Operational Documents	Finalize facility operations documents	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.5 - Criterion 3.1.6.3 - Infiltration Rate Distribution	Revise the method used to estimate the infiltration rate distribution	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.5 - Criterion 3.1.6.3 - Continuous Beta Distributions	Use continuous beta distributions to describe plant root and animal burrow distributions with depth	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.5 - Criterion 3.1.6.3 - Radon Partitioning	Account for the partitioning of radon between pore water and air-filled spaces	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.5 - Criterion 3.1.6.6 - HYDRUS Modeling	The HYDRUS modeling did not correctly account for initial moisture conditions	FY 2009 Annual Report (LANL, 2010d)
LFRG Secondary Issue 7.2.10 - Criterion 3.2.2.2 - Composite Analysis Inventory	Use alternate source inventories that are consistent with the LANL DSA for nuclear environmental sites	FY 2009 Annual Report (LANL, 2010d)
Area G Performance Assessment and Composite Analysis Maintenance Plan	Issue revised plan by March 17, 2011	LANL Maintenance Program Plan (LANL, 2011a)
Area G Environmental Monitoring Plan	Issue revised plan by March 17, 2011	Environmental Monitoring Plan (LANL, 2011u)
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	Annual Reports

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Appendix A

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

The DOE 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 PA/CA need to be rigorously pursued, including external review of work plans to ensure maximum defensibility and programmatic efficiency. 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. In order to evaluate the potential impacts of localized subsidence and cover degradation on migration and projected dose, it is necessary to modify the GoldSim™ 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 result in under-estimation of 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 pessimistic. 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. In Los Alamos there are very few 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), 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 PA maintenance program, the PA 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 PA/CA contains no reference to facility operations documents that are used to control parameters that could affect PA findings and conclusions. Important to the findings and conclusions of the PA 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. There is a draft operational document that contains this information but it 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 PA/CA that references operational controls and that describes and references documents used to control MDA G operations important to PA findings or conclusions. 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 due to 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 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 needs 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.

- PA Disruptive Processes and Events: There is no clear structured procedure for screening potentially disruptive processes or events for consideration in the PA. 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 PA. 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 PA/CA to provide additional confidence in the infiltration rate distribution. 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 CME, 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 PA 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 PA/CA 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 PA/CA model are made.

- 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 it is, in some ways, easier simply 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_d's (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 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, potentially, 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 mis-specified 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 PAs. Since the output is a distribution of the mean, the 95th percentile corresponds to the classical 95th upper confidence limit on which most EPA-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 layers – distribution 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 PA. 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 PA/CA 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 PA/CA model.

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 PA.

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) LLW disposal site PA/CAs.

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 non-linear 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 non-linear model. The previously mentioned approach taken to sensitivity analysis is appropriate for linear models. That is, it identifies linear effects. Non-linear sensitivity analysis methods are available and need to be used. The PA/CAs 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 the need to do this goes away if non-linear 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 a further uncertainty issue that should be addressed. That is the issue of 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, 5th and 95th 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 PA 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 PA models and other complex environmental models at this time. Correlation issues need to be dealt with in the future where appropriate and possible.

The PA/CA 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 due to 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: 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 PA 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 PA/CA. The QA summary needs to be included as an appendix to the PA/CA. 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 prior to the availability of the LFRG criteria could result in the need for users manual revisions. Furthermore, the criteria ultimately established by the LFRG may be satisfied by the existing 2006 PA/CA Appendix K, GoldSim™ Model Documentation and Data Selection for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G Performance Assessment and Composite Analysis (LAUR-06-4391, December 2006).

7.2.10. Radioactive Sources/Release Mechanism (3.2.2.2.)

Criterion 3.2.2.2.:

CA Inventory: Alternate source inventories are lower than and inconsistent with inventory estimates in documented safety analyses (DSAs) for nuclear environmental sites. The CA 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

Department of Energy (DOE), 2006, Low-Level Waste Disposal Facility Review Group Manual, Revision 2, Department of Energy Low-Level Waste Disposal Federal Review Group, October.

DOE, 2009, Review Team Report for the 2006 Performance Assessment and Composite Analysis for Material Disposal Area G in Technical Area 54 Los Alamos National Laboratory, Prepared by the Department of Energy Low-Level Waste Disposal Facility Federal Review Group Review Team, February 25.