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Special Analysis: Disposal Plan for Pit 38 at Technical Area 54, Area G

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Acronyms and Abbreviations

D&D	Decontamination and decommissioning
DOE	Department of Energy
ER	Environmental restoration
FY	Fiscal Year
IWL	Institutional waste layer
LANL	Los Alamos National Laboratory
LLW	Low-level radioactive waste
MDA	Material Disposal Area
TA	Technical Area
WAC	Waste acceptance criteria

1.0 Introduction

Los Alamos National Laboratory (LANL) generates radioactive waste as a result of various activities. Operational waste is generated from a wide variety of research and development activities including nuclear weapons development, energy production, and medical research; environmental restoration (ER), and decontamination and decommissioning (D&D) waste is generated as contaminated sites and facilities at LANL undergo cleanup or remediation. The majority of this waste is low-level radioactive waste (LLW) and is disposed of at the Technical Area 54 (TA-54), Area G disposal facility.

U.S. Department of Energy (DOE) Order 435.1 (DOE, 2001) requires that radioactive waste be managed in a manner that protects public health and safety, and the environment. To comply with this order, DOE field sites must prepare site-specific radiological performance assessments for LLW disposal facilities that accept waste after September 26, 1988. Furthermore, sites are required to conduct composite analyses that account for the cumulative impacts of all waste that has been (or will be) disposed of at the facilities and other sources of radioactive material that may interact with the facilities.

Revision 4 of the Area G performance assessment and composite analysis was issued in 2008 (LANL, 2008). These analyses estimate rates of radionuclide release from the waste disposed of at the facility, simulate the movement of radionuclides through the environment, and project potential radiation doses to humans for several on- and off-site exposure scenarios. The assessments are based on existing site and disposal facility data, and on assumptions about future rates and methods of waste disposal.

The Area G disposal facility consists of Material Disposal Area (MDA) G and the Zone 4 expansion area. To date, disposal operations 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. Given its impending closure, efforts have been made to utilize the remaining disposal capacity within MDA G to the greatest extent possible. One approach for doing this has been to dispose of low-activity waste from cleanup operations at LANL in the headspace of selected disposal pits. Waste acceptance criteria (WAC) for the material placed in the headspace of pits 15, 37, and 38 have been developed (LANL, 2010) and the impacts of placing waste in the headspace of these units has been evaluated (LANL, 2012a).

The efforts to maximize disposal efficiency have taken on renewed importance because of the disposal demands placed on MDA G by the large volumes of waste that are being generated at LANL by cleanup efforts. For example, large quantities of waste were recently generated by the retrieval of waste formerly disposed of at TA-21, MDA B. A portion of this material has been disposed of in the headspace of pit 38 in compliance with the WAC developed for that disposal strategy; a large amount of waste has also been sent to off-site facilities for disposal. Nevertheless, large quantities of MDA B waste remain that require disposal.

An extension of pit 38 was proposed to provide the disposal capacity that will be needed to dispose of institutional waste and MDA B waste through 2013. A special analysis was prepared to evaluate the impacts of the pit extension (LANL, 2012b). The analysis concluded that the disposal unit could be extended with modest increases in the exposures projected for the Area G performance assessment and composite analysis, as long as limits were placed on the radionuclide concentrations in the waste that is placed in the headspace of the pit. Based, in part, on the results of the special analysis, the extension of pit 38 was approved and excavation of the additional disposal capacity was started in May 2012.

The special analysis presented here uses performance modeling to identify a disposal plan for the placement of waste in pit 38. The modeling uses a refined design of the disposal unit and updated radionuclide inventories to identify a disposal configuration that promotes efficient utilization of the pit and ensures continued compliance with DOE Order 435.1 performance objectives. Section 2 describes the methods used to conduct the analysis; the results of the evaluation are provided in Section 3. The disposal plan for pit 38 is provided in Section 4 and the conclusions of the investigation are provided in Section 5.

Throughout the report, pit 38 is used to refer to the entire disposal unit, including the existing pit and the extension that is currently under construction. Where a distinction between the two portions of the pit is necessary, the existing unit is referred to as pit 38 proper and the new portion of the pit as the pit 38 extension or, more simply, the extension.

2.0 Methods

The special analysis for the pit 38 extension evaluates waste placement strategies to identify an approach that allows efficient utilization of the disposal unit and continued compliance with DOE Order 435.1 performance objectives. Section 2.1 addresses the types and quantities of waste that will require disposal in pit 38. The modeling approach used to estimate the long-terms impacts of disposing of this waste in pit 38 is described in Section 2.2.

2.1 Waste Disposal Capacities, Volume Estimates, and Inventory Projections

The disposal pits at MDA G are typically large, rectangular units excavated to depths as great as 18 m (60 ft). Bulk and packaged waste is placed in these units until the material reaches the minimum depth allowed. Prior to the use of headspace for the disposal of low-activity waste, the disposal of waste was permitted as long as the surface of the material was at least 3 m (9.8 ft) below natural grade of the disposal site. With the advent of headspace disposal, waste could be placed to within 0.3 m (1 ft) of the soil-tuff interface, but no less than 2.5 m (8.2 ft) below the surface of the final cover placed over the facility. For simplicity, the term institutional waste layer (IWL) is used in this report to refer to the portion of the pit profile that is 3 m (9.8 ft) or more below natural grade; headspace is used to refer to the overlying layer of waste.

Pit 38 is the only disposal pit at Area G that has unused disposal capacity. As of the middle of May 2012, an estimated 3,670 m^3 (4,800 yd^3) of waste capacity remained within pit 38 proper; this capacity includes 765 m^3 (1,000 yd^3) in the unit's IWL and 2,905 m^3 (3,800 yd^3) in the headspace. The pit 38 extension, shown in Figure 2-1, will be sized to accommodate the institutional waste that is expected to require disposal from mid-May 2012 through December 2013, as well as the remaining MDA B waste. Current plans call for 3,306 m^3 (4,324 yd^3) of capacity within the headspace of the extension and 7,380 m^3 (9,653 yd^3) available for disposal in the IWL.

The two major types of waste that will require disposal in pit 38 include the institutional waste that is generated on a routine basis as a result of LANL operations and the MDA B waste that is currently staged for disposal at Area G. Current estimates call for the disposal of 1,911 m^3 (2,500 yd^3) of LANL institutional waste from mid-May through the end of 2013. The volume of MDA B waste that remains to be disposed of is 6,194 m^3 (8,101 yd^3). Assuming waste emplacement efficiencies of 0.5 for the LANL institutional waste and of 0.75 for the MDA B waste, these waste volumes equate to disposal volumes of 3,823 m^3 (5,000 yd^3) and 8,258 m^3 (10,801 yd^3), respectively.

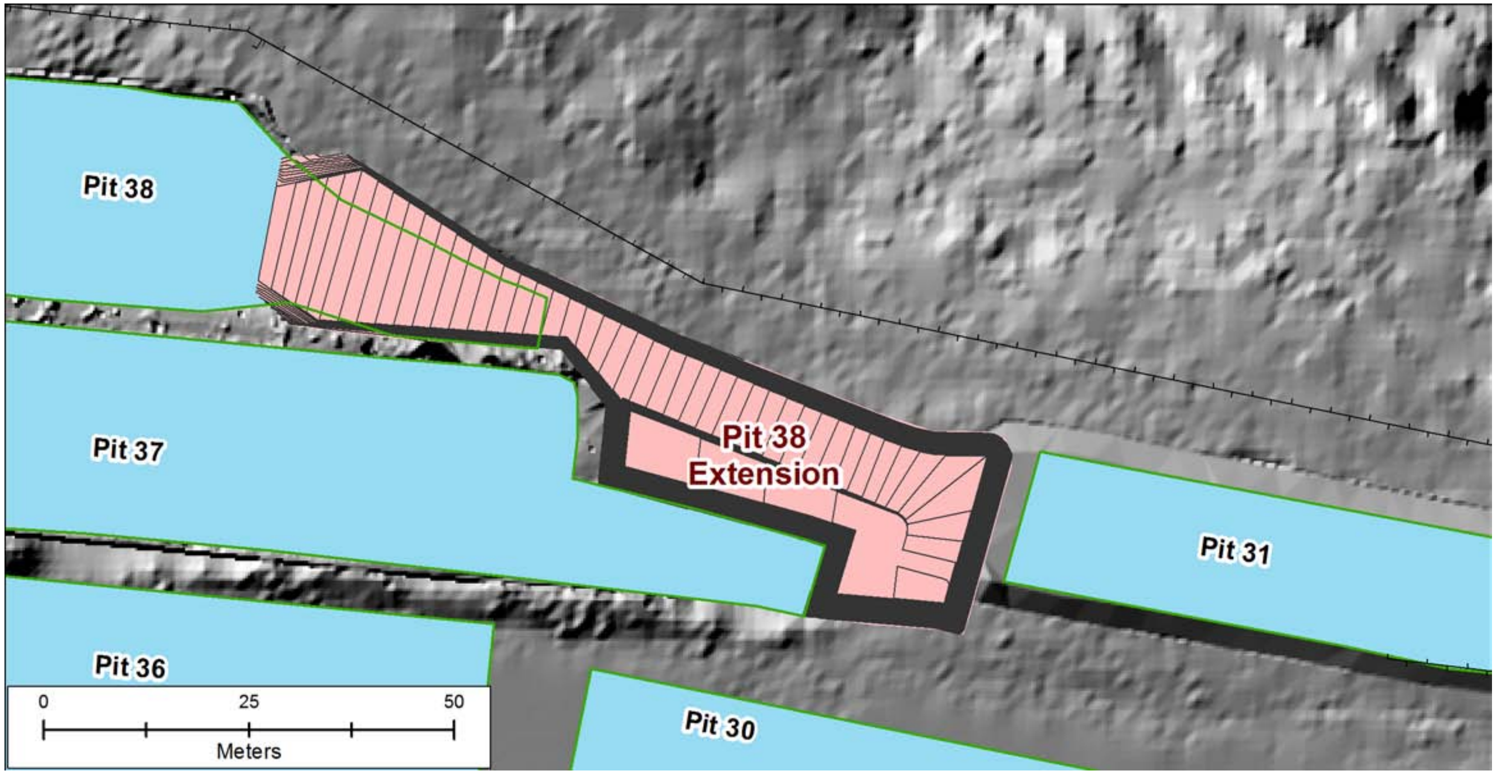

Figure 2-1
Pit 38 Extension Area

The performance modeling described in Section 2.2 requires the development of radionuclide inventories for pit 38, accounting for waste that has already been placed in the disposal unit and waste that will be disposed of from mid-May 2012 through 2013. The existing inventory, all of which resides in pit 38 proper, was estimated using data from a variety of sources. These include the 2008 inventory characterization (Shuman, 2008), the Fiscal Year (FY) 2011 Area G disposal receipt review (LANL, 2012c), waste management database queries conducted for the period from October 1, 2011 through May 8, 2012, and a characterization of the radionuclide inventories in the MDA B waste. This waste was assigned to the IWL and headspace on the basis of the disposal layers indicated in the database. Waste disposed of in layers 1 through 7 occupies the IWL; material placed in layers 8 and higher resides in the headspace of the pit.

Cleanup activities at MDA B have generated more than 3,000 containers of waste. To identify the radionuclides and measure the isotopic concentrations in the MDA B waste, 92 composite samples were collected from waste containers and sent to an analytical laboratory. A description of this characterization effort is included in this report as Appendix A. The data collected from the characterization effort were used to prepare radionuclide inventories for the containers of waste that were not sampled. These estimates were used to identify where the containers of waste were to be shipped for disposal and, for the waste disposed of at Area G, to determine if the waste should be placed in the IWL or headspace of disposal pits 37 and 38 proper.

The methods used to estimate radionuclide inventories in the containers of MDA B waste were generally considered to be conservative. In general, the modeling conducted in support of the performance assessment and composite analysis incorporates realistic estimates of radionuclide inventories and quantifies the uncertainty associated with those estimates. Towards this end, the characterization data collected from the 92 samples were re-evaluated and used to establish radionuclide concentration distributions for all long-lived isotopes included in the dataset. The methods used to conduct this evaluation and the assumptions upon which it is based are described in Appendix B of this report.

The distributions developed to describe the radionuclide concentrations in the MDA B waste are summarized in Table 2-1. Correlations exist between the Am-241, Pu-238, and Pu-239 concentrations and between the concentrations of U-234, U-235, and U-238. The correlation coefficients used to describe the relationships between the two sets of radionuclides are included in the table. Concentration distributions are provided in the table for all radionuclides included in the performance modeling, generally those with half-lives of one or more years. The distributions for Am-241 and the plutonium isotopes address waste that has already been disposed of at Area G (in pits 37 and 38), and the waste awaiting disposal. In terms of the waste that had undergone disposal, separate distributions address the waste that has been placed in the IWL and headspace. The distributions developed for lower- and higher-activity MDA B waste that is awaiting disposal provide an opportunity to consider different waste placement strategies.

Table 2-1
Radionuclide Concentration Distributions in the MDA B Waste

Radionuclide	Concentration Distribution (pCi/g)	Correlation Coefficient
Am-241		
Higher activity disposed waste	LN(213.9, 13.9)	NA[a]
Lower activity disposed waste	LN(4.6, 0.2)	NA
Higher activity waste awaiting disposal	LN(192.5, 17.1)	NA
Lower activity waste awaiting disposal	LN(25.8, 1.1)	NA
Co-60	LN(0.009, 0.002)	NA
Cs-137	LN(0.5, 1.0)	NA
Eu-152	LN(0.1, 0.04)	NA
H-3	LN(0.7, 0.2)	NA
K-40	LN(26.3, 0.4)	NA
Pu-238		
Higher activity disposed waste	LN(37.9, 12.0)	Am-241 – 0.16[b]
Lower activity disposed waste	LN(2.0, 0.5)	Am-241 – 0.14
Higher activity waste awaiting disposal	LN(36.8, 12.1)	Am-241 – 0.18
Lower activity waste awaiting disposal	LN(7.6, 2.0)	Am-241 – 0.15
Pu-239		
Higher activity disposed waste	LN(17474.7, 6427.9)	Pu-238 – 0.57
Lower activity disposed waste	LN(277.7, 74.8)	Pu-238 – 0.71
Higher activity waste awaiting disposal	LN(15195.0, 6034.8)	Pu-238 – 0.55
Lower activity waste awaiting disposal	LN(1744.0, 508.6)	Pu-238 – 0.66
Ra-226	LN(1.1, 0.3)	NA
Ra-228	LN(1.6, 0.03)	NA
Sr-90	LM(0.3, 0.1)	NA
U-234	LN(6.4, 1.9)	NA
U-235	LN(0.6, 0.1)	U-234 – 0.90
U-238	LN(5.8, 2.0)	U-234 – 0.99

[a] Indicates that no statistically significant, process-based correlation with another radionuclide was observed.

[b] The radionuclide to which the distribution is correlated is listed first, followed by the correlation coefficient.

A portion of the MDA B waste that has been disposed of at Area G was characterized using the methods described in Appendix A; this waste has been disposed of in the headspace of pit 37 and headspace and IWL of pit 38 proper. The radionuclide inventories for this waste were extracted from the disposal database and the distributions listed in Table 2-1 were used to calculate updated inventories; the distributions were used to estimate all radionuclide inventories for the MDA B waste currently awaiting disposal.

The radionuclide inventories in the LANL institutional waste that will require disposal from mid-May through 2013 were calculated using the average radionuclide concentrations in the waste placed in the IWL of pit 38 proper between the start of pit operations and May 8, 2012. Multiplying these concentrations by the volume of the waste yields total inventories. Estimates of the headspace and IWL disposal capacities developed for pit 38 were modestly higher than the required disposal capacities discussed earlier. This additional capacity was assumed to be filled with waste having average radionuclide concentrations equal to those found in the headspace and institutional waste placed in pit 38 proper from the start of disposal operations through May 8, 2012. Means of the radionuclide concentration distributions developed for the MDA B waste were used to estimate average radionuclide concentrations in waste that had already undergone disposal.

2.2 Performance Modeling

The Area G performance assessment and composite analysis project the long-term impacts of waste disposal at Area G and estimate potential doses for members of the public who live in the vicinity of the disposal facility and for persons who inadvertently intrude into the waste disposed of at the facility. The members of the public receive exposures from groundwater contaminants, from airborne releases from Area G, and from radionuclides transported off site with surface runoff. Three intruder scenarios are evaluated. The post-drilling scenario estimates doses for a person who lives over the closed disposal facility and is exposed to contamination brought to the surface during the drilling of a domestic well. The construction and agricultural scenarios consider exposures to a person who constructs a house over the closed disposal units and a person who resides in the completed structure, respectively. The house is assumed to be constructed with a 3-m (9.8-ft) deep basement, the excavation of which may contact waste and bring contamination to the surface.

The ability of Area G to safely contain the waste disposed of therein is judged, in part, by comparing the doses projected for the members of the public and inadvertent intruders to a series of performance objectives. The pit 38 disposal plan was developed to efficiently utilize the remaining disposal capacity while maintaining Area G’s ability to safely dispose of the waste. Specifically, the plan was developed in a manner that ensures any increases in the doses brought about by the extension of pit 38 remain well within the pertinent performance objectives while maintaining operational flexibility.

Two models developed using GoldSim® were used to estimate the exposures received by members of the public: the Area G inventory and site models. The first of these is used to develop initial radionuclide inventories for the site model. The site model simulates exposures received by the public following the release and transport of radionuclides from the waste. The GoldSim modeling divides Area G into eight waste disposal regions, each of which includes a subset of the 35 pits and over 200 shafts found at the facility (Figure 2-2).

Pit 38 is one of six pits assigned to waste disposal region 5 in the performance assessment and composite analysis modeling. The inventory model was modified to estimate the radionuclide inventories in the IWL of the units included in waste disposal region 5 and to calculate inventories placed in the headspace of the various pits. Input data used in the site model were altered to reflect the extension of pit 38 and to model the erosion behavior of disposal region 5. The changes made to the models are summarized in Table 2-1.

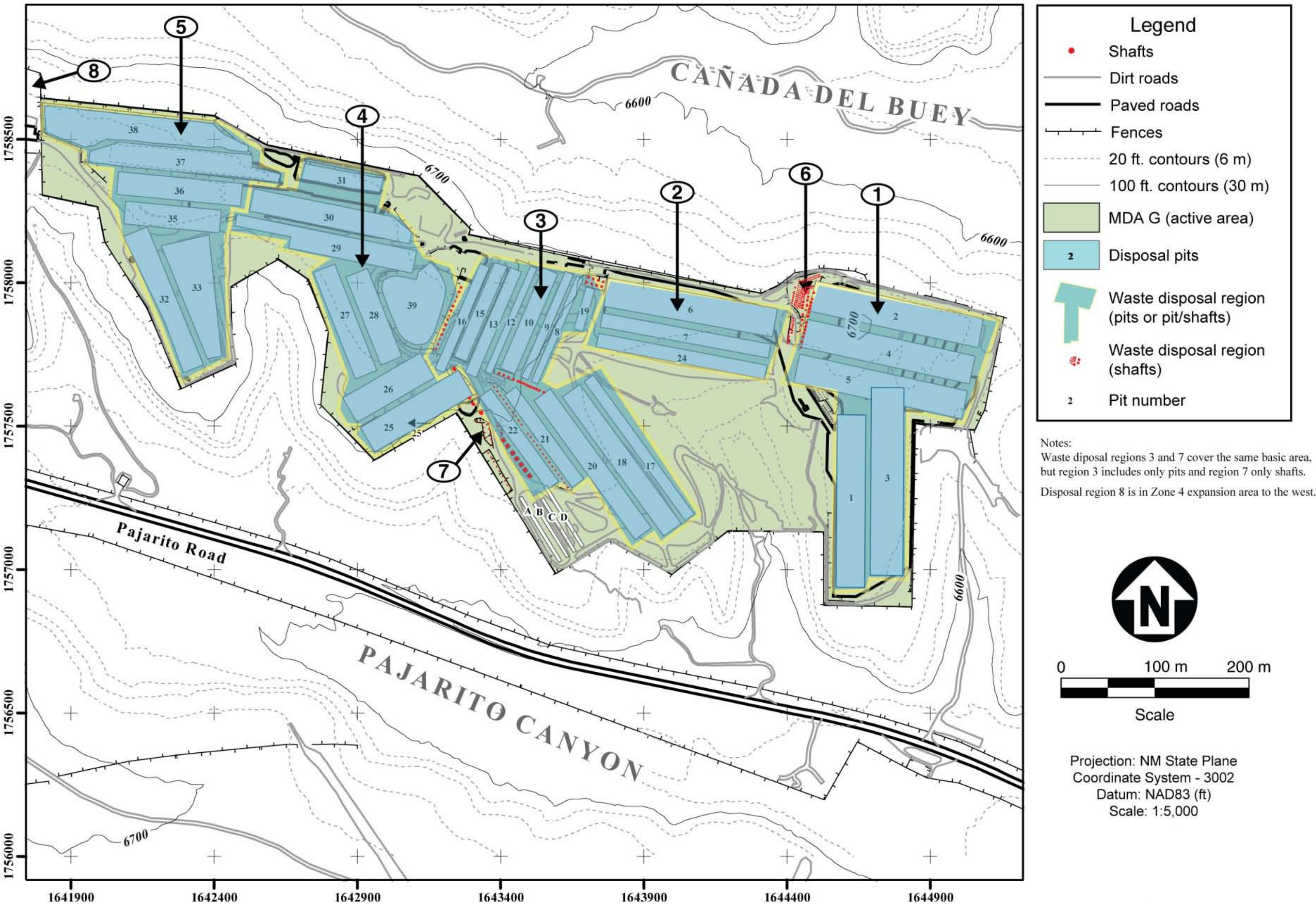

Figure 2-2
Waste Disposal Regions at MDA G

Table 2-2
Changes Made to the GoldSim Models Used in the Area G Performance Assessment and Composite Analysis

Model	Model Modification
Area G Inventory	Changes to the model varied, depending upon the inventory of interest. To calculate IWL inventories, the waste thickness for the MDA G pits was set to 10.9 m to reflect the addition of the pit 38 extension. Layer thickness was set to 2.18 m to estimate existing inventories in the headspace of pits 15, 37, and 38; this value represents the average thickness of the headspace layer over the disposal units. Point estimates of radionuclide inventories were updated to reflect inventories disposed of through 5/8/12 and the institutional and headspace waste projected to require disposal after 5/8/12. Additional elements were added to the model to calculate radionuclide inventories for the MDA B waste, and to include those estimates in the final MDA G pits, composite analysis, and performance assessment inventories.
Area G Site	Model was configured to account for the addition of the pit 38 extension to waste disposal region 5. To simulate the waste placed in the IWL, the number of cover nodes was set to 3,943, the waste thickness to 13.0 m, the disposal area to 2.46E+04 m2, and the end year of disposal to 54 (to reflect the end of disposal in 2013). The initial cover thicknesses, cover loss functions, and catchment allocation factors were updated to reflect the presence of the extended pit. The headspace waste simulation modified the input data for waste disposal regions 3 and 5 so they represented only the pits that have experienced, or will experience, disposal in this layer. For waste disposal region 3, which includes pit 15, the number of cover nodes was set to 218, the waste thickness to 2.91 m, and the disposal area to 1.36E+03 m2. For waste disposal region 5, which includes pits 37, 38, and 38 extension, the number of cover nodes was set to 1,741, the waste thickness to 1.82 m, and the disposal area to 1.09E+04 m2. Initial cover thicknesses and cover loss functions were input to represent the headspace waste layer.
Area G Intruder	Model was configured for the MDA G pits institutional waste simulation by setting the number of cover nodes to 3,943 (the number of nodes assigned to represent waste disposal region 5), the waste thickness to 10.9 m (the average thickness over pits 15, 30, 31, 36, 37, 38, and 39), the disposal area to 2.48E+04 m2 (to reflect seven pits), and the end year of disposal to 25 (to reflect the end of disposal in 2013). The initial cover thicknesses and cover loss functions were updated to reflect depths to institutional waste and cover losses over the 3.943 nodes.
	Model was configured for the MDA G pits headspace waste simulation by setting the number of cover nodes to 1,959 (the number of nodes that overlie pits 15, 37, and 38), the waste thickness to 2.18 m (the average thickness over the headspace waste in pits 15, 37, and 38), the disposal area to 2.48E+04 m2 (so the doses are averaged over the entire disposal area for the MDA G pits), and the end year of disposal to 25 (to reflect the end of disposal in 2013). The initial cover thicknesses and cover loss functions were updated to reflect depths to headspace waste and cover losses over the 1,959 nodes.
Area G Intruder Diffusion	Model was configured for the MDA G pits institutional waste simulation by setting the number of cover nodes to 3,943 (the number of nodes assigned to represent waste disposal region 5), the waste thickness to 10.9 m (the average thickness over pits 15, 30, 31, 36, 37, 38, and 39), the disposal area to 2.48E+04 m2 (to reflect seven pits), and the end year of disposal to 24 (to reflect the end of disposal in 2013). The initial cover thicknesses and cover loss functions were updated to reflect depths to institutional waste and cover losses over the 3,943 nodes.
	Model was configured for the MDA G pits headspace waste simulation by setting the number of cover nodes to 1,959 (the number of nodes that overlie pits 15, 37, and 38), the waste thickness to 2.18 m (the average thickness over the headspace waste in pits 15, 37, and 38), the disposal area to 2.48E+04 m2 (so the doses are averaged over the entire disposal area for the MDA G pits), and the end year of disposal to 25 (to reflect the end of disposal in 2013). The initial cover thicknesses and cover loss functions were updated to reflect depths to headspace waste and cover losses over the 1,959 nodes.

The intruder analysis presented in the performance assessment estimates potential exposures for four subsets of the disposal units found at MDA G. For the current analysis, these include the pits used to dispose of waste from September 27, 1988 through 2013 and from 2014 through FY 2044, and the disposal shafts used over the same periods of time. The disposal units included in each group were, effectively, combined to form a single virtual disposal unit; the modeling did not evaluate the impacts of individual pits and shafts. Three models developed using GoldSim were used to conduct the analysis: the Area G inventory, intruder, and intruder-diffusion models. The first of these is used to develop the initial radionuclide inventories for the other models. The intruder model projects doses received by intruders from radionuclides that are unaffected by vapor- and gas-phase diffusion; the intruder diffusion model addresses diffusive species.

Pit 38 is one of the seven pits that have been, or will be, used for the disposal of waste from September 27, 1988 through 2013. It was necessary to modify the inventory model to update the inventory for this collection of disposal units, including the pit 38 extension; these changes are listed in Table 2-2. The revised model was used to estimate radionuclide inventories in the IWL and headspace across the subset of disposal pits. Modifications were made to the intruder and intruder diffusion models to reflect changes introduced by including the pit 38 extension. These changes are also listed in Table 2-2.

Model simulations were conducted for the intruder scenarios first. The exposures projected for these receptors are subject to greater impacts, depending upon how the remaining LANL institutional waste and MDA B waste is placed in pit 38. Modeling was conducted to estimate exposures for the members of the public once an acceptable disposal strategy was identified in terms of the intruder impacts.

The intruder modeling was conducted using two simulations: one to address the waste disposed of in the IWL and one for the waste placed in the headspace. Exposures projected by the two simulations were combined to estimate total exposures from all of the waste. The input parameters used in the inventory and intruder models were modified to reflect the waste and cover thickness, cover loss rates, and radionuclide inventories specific to the two waste layers; disposal unit and operational data used in the modeling are summarized in Table 2-3.

The potential impacts of extending pit 38 on the health and safety of members of the public were evaluated using the performance assessment and composite analysis. Two simulations were conducted for each analysis using the site model. These simulations addressed waste that has been, or will be, disposed of in the IWL and waste placed in the headspace. Exposures projected by the two simulations were combined to estimate total exposures from all the waste. Input parameters used in the site model were modified to reflect waste and cover thicknesses, cover loss rates, and radionuclide inventories specific to the two waste layers; disposal unit and operational data used in the modeling are summarized in Table 2-4.

Table 2-3
Input Data used to Conduct the Intruder Analysis

Input Parameter	Value		Description/Source
	Institutional Waste Simulation	Headspace Waste Simulation	
Disposal unit area (m2)	2.48E+04	2.48E+04	The disposal area represents the total surface area overlying pits 15, 30, 31, 36, 37, 38 (including the extension), and 39.
Waste density (kg/m3)	1,119	1,119	Average density of 815 containers of MDA B waste
Number of cover nodes	3,943	1,959	The number of nodes is used to structure the sampling of the initial cover thicknesses and cover loss functions. The erosion modeling is conducted for the institutional waste using the characteristics of waste disposal region 5, which includes the listed number of nodes. The modeling conducted for the headspace waste considers only the pits that include waste in this layer.
Waste thickness (m)	10.9	2.18	The listed depth for the operational waste simulation represents an average depth of the IWL over pits 15, 30, 31, 36, 37, 38 (including the extension), and 39. The value listed for the headspace waste simulation is the average headspace layer thickness over pits 15, 37, and 38 (including the extension).
Start of Disposal (yr)	0	0	The starting year of disposal is counted relative to 1988.
End of Disposal (yr)	25	25	The ending year of disposal is counted relative to 1988. Values for both simulations are based on the assumption that disposal will cease in 2013.

Table 2-4
Input Data Used to Conduct the Performance Assessment and Composite Analysis Simulations

Input Parameter	Value			Description/Source
	Pit 15	Pits 37 and 38	Waste Disposal Region 5	
Headspace layer thickness (m)	2.91	1.82	NA	Average thickness of layer for nodes overlying headspace and operational waste within the indicated disposal unit(s). The modeling did not require an average headspace thickness for waste disposal region 5.
Number of cover nodes	218	1,741	3,943	Number of nodes overlying headspace and operational waste.
Disposal unit area (m2)	1.36E+03	1.09E+04	2.46E+04	Areas are calculated as the product of the number of nodes overlying headspace and operational waste within the disposal unit and 6.25 m2, the area of each node.
Density of MDA B waste (kg/m3)	948	948	948	Average density of 497 containers of MDA B waste awaiting disposal.
IWL thickness (m)	NA	NA	13.0	Average thickness of IWL for nodes overlying headspace and operational waste; the modeling did not require an IWL thickness for pit 15 or pits 37 and 38.

NA = Not applicable

The latest versions of the inventory, site, and intruder models were used to conduct the modeling described here. The inventory model includes the FY 2011 disposal receipt review inventories and incorporates updates to permit estimation of the MDA B waste inventories in the already disposed-of waste and the waste awaiting disposal. The site and intruder models used to conduct the FY 2011 disposal receipt review impacts analysis (LANL, 2012c) were modified, as necessary, to address the extension of pit 38.

The pit 38 extension was not addressed by the 2008 performance assessment and composite analysis. However, the cover and erosion characteristics for this portion of MDA G had been developed for the 2008 analyses, and were updated recently (Crowell, 2010). The latest erosion rate projections for pit 37, pit 38, and the pit 38 extension were used in the special analysis.

3.0 Results

The intruder modeling conducted for the 1988–2013 disposal pits under the pit 38 disposal plan projected peak mean doses of 8.3, 47.3, and 9.2 mrem/yr for the post-drilling, agricultural, and construction intruder scenarios, respectively (Table 3-1). These exposures represent increases of 38, 58, and 142 percent relative to the post-drilling, construction, and agricultural scenario doses presented in the FY 2011 disposal receipt review (LANL, 2012c). However, they remain well below the 100 mrem/yr performance objective for chronic exposures received by the post-drilling and agricultural intruders, and the 500 mrem/yr objective for acute exposures received by the construction worker. The largest doses projected for the intruder continue to be those estimated for the MDA G and Zone 4 shafts; the peak mean dose for the agricultural intruder is about 90 mrem/yr for both sets of disposal units. The exposures projected for these units are unaffected by the disposal of waste in pit 38.

Table 3-1
Exposures for Inadvertent Intruders: Pit 38 Disposal Plan Analysis Projections vs. FY 2011 Disposal Receipt Review Projections

Exposure Scenario	Performance Objective (mrem/yr)	Peak Mean Dose (mrem/yr)		Change in Dose Projection (%)
		Pit 38 Disposal Plan	2011 Disposal Receipt Review	
Intruder-Post-Drilling	100	8.3E+00	6.0E+00	38
Intruder-Agriculture	100	4.7E+01	3.0E+01	52
Intruder-Construction	500	9.2E+00	3.8E+00	142

The peak mean doses projected for the members of the public under the performance assessment and composite analysis are summarized in Table 3-2. The doses are compared to the peak mean doses projected for the FY 2011 disposal receipt review (LANL, 2012c). The doses projected for the Atmospheric Scenario decrease modestly under the performance assessment, primarily because of changes in the configuration of the facility; changes in inventory have relatively little impact. The air pathway exposures projected for the current analysis under the composite analysis are the same as those projected for the FY 2011 disposal receipt review. Unlike the performance assessment, the composite analysis considers the impacts from the entire disposal facility; changes in facility configuration and inventory brought about by the extension of pit 38 have little impact in this larger context. The extension of pit 38 impacts the exposures estimated for the All Pathways – Canyon Scenario under the performance assessment and composite analysis. The greatest increases are observed for the catchments that lie closest to, and downstream of, pit 38. The doses projected for the all exposure scenarios remain well within the performance objectives that pertain to the performance assessment and composite analysis.

Table 3-2
Exposures for Members of the Public: Pit 38 Disposal Plan Analysis Projections vs. FY 2011 Disposal Receipt Review Projections

Exposure Scenario and Exposure Location	Performance Objective (mrem/yr)	Performance Assessment			Composite Analysis		
		Peak Mean Dose (mrem/yr)		Change in Dose Projection (%)	Peak Mean Dose (mrem/yr)		Change in Dose Projection (%)
		Pit 38 Disposal Plan	2011 Disposal Receipt Review		Pit 38 Disposal Plan	2011 Disposal Receipt Review	
Atmospheric							
LANL Boundary	10	3.7E-01	4.4E-01	–18	2.8E-01	2.8E-01[a]	0
Area G Fence Line	10	4.0E-03	4.4E-03	–10	5.1E-01	5.1E-01[a]	0
All Pathways–Canyon							
Catchment CdB1	25/30[b]	7.7E-01	5.7E-01	35	8.5E-01	6.1E-01	38
Catchment CdB2	25/30[b]	1.3E+00	2.2E-01	486	1.8E+00	1.0E+00	75
Catchment PC0	25/30[b]	7.6E-04	7.6E-04	0	9.0E-04	9.0E-04 0	0
Catchment PC1	25/30[b]	5.7E-01	4.2E-02	1,261	4.7E-01	4.7E-02	897
Catchment PC2	25/30[b]	2.1E+00	1.6E-01	1,167	1.7E+00	3.1E-01	457
Catchment PC3	25/30[b]	5.9E-01	1.4E-01	328	5.5E-01	2.5E-01	118
Catchment PC4	25/30[b]	3.5E-01	2.2E-01	54	4.1E-01	3.3E-01	24
Catchment PC5	25/30[b]	3.6E-01	3.2E-01	14	2.2E+00	2.1E+00	2
Catchment PC6	25/30[b]	1.8E-01	1.7E-01	9	2.4E+00	2.4E+00	1
Groundwater Pathway Scenarios							
All Pathways–Groundwater	25/30[b]	0.0E+00	0.0E+00	0	0.0E+00	0.0E+00	0
Groundwater Resource Protection	4	0.0E+00	0.0E+00	0	NA	NA	0

[a] *The doses for the LANL boundary and fence line receptors were incorrectly listed in the FY 2011 disposal receipt review as 0.21 and 0.54 mrem/yr, respectively.*
[b] *An all-pathways performance objective of 25 mrem/yr applies to the performance assessment; doses projected for the composite analysis must comply with the 30 mrem/yr dose constraint.*

The radon fluxes projected for the disposal plan analysis are compared in Table 3-3 to the quantities estimated for the FY 2011 disposal receipt review. The peak mean flux for waste disposal region 5 increases relative to the earlier analysis due to changes in inventory and the configuration of the pits in this region. The fluxes for the other disposal regions are identical; the facility-wide flux increases from 0.40 to 0.41 pCi/m^2/s.

Table 3-3
Radon Fluxes: Pit 38 Disposal Plan Analysis Projections vs. FY 2011 Disposal Receipt Review Projections

Waste Disposal Region	Peak Mean Flux (pCi/m^2/s)		Change in Flux Projection (%)
	Pit 38 Disposal Plan	2011 Disposal Receipt Review	
1	1.3E-06	1.3E-06	0
2	—	—	--
3	9.2E-01	9.2E-01[a]	0
4	3.6E-02	3.6E-02	0
5	3.1E-01	2.6E-01[a]	19
6	3.6E-03	3.6E-03	0
7	1.3E+01	1.3E+01	0
8	2.1E-02	2.1E-02	0
Entire Facility	4.1E-01	4.0E-01	3

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

[a] *The radon fluxes for waste disposal regions 3 and 5 were incorrectly listed in the FY 2011 disposal receipt review as 15 and 0.29 pCi/m^2/s, respectively.*

4.0 MDA B Waste Placement

The modeling results presented in Section 3 indicate that pit 38 can be safely extended and used for the disposal on LANL institutional waste and the material generated by the retrieval of waste from MDA B. The modeling is based on assumptions about where the waste awaiting disposal will be placed within pit 38 proper and the extension. In general, waste having higher concentrations of Am-241 and Pu-239 will be placed in the IWL to minimize exposures to this waste; lower activity waste will be placed closer to the surface in the headspace.

Table 4-1 lists the MDA B waste containers that are to be placed in the IWL and headspace of pit 38 proper and the containers of waste that are to be disposed of in corresponding layers in the pit 38 extension. The IWL within pit 38 proper will accommodate 43 containers of waste, based on an estimated disposal capacity of 765 m^3 (1,000 yd^3) and a 0.75 waste emplacement efficiency. The disposal capacity of the headspace in pit 38 proper is estimated to be 2,905 m^3 (3,800 yd^3), enough to accommodate the 162 containers of waste listed in the table at an emplacement efficiency of 0.75.

The disposal capacities estimated for the IWL and headspace of the pit 38 extension are large enough to accommodate the remaining containers of waste. A total of 104 containers are to be placed in the IWL; the remaining 188 containers are to be disposed of in the headspace layer. A subset of the containers listed for disposal in the IWL of the extension is presented in bold italicized type in Table 4-1; these containers are to be placed as deeply as possible within the layer.

Table 4-1
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10148745		X		
10148847			X	
10148848			X	
10148849			X	
10148850			X	
10148884			X	
10148885		X		
10148892		X		
10148905				X
10148917				X
10148948		X		
10148954				X
10148964		X		
10148967		X		
10148973		X		
10148978		X		
10149021		X		
10149022		X		
10149026		X		
10152511		X		
10152545		X		
10152548		X		
10152550		X		
10152553		X		
10152555		X		
10152556		X		
10154301				X
10155497		X		
10155501		X		
10155552				X
10155553				X
10155567		X		
10155574				X
10155599		X		
10155611				X
10155621			X	

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10156457			X	
10156511	X			
10156518			X	
10156521				X
10156522				X
10156533		X		
10156559			X	
10156595			X	
10156598				X
10156609				X
10156613	X			
10156642			X	
10156644			X	
10156645			X	
10156651				X
10156655				X
10156681			X	
10156694			X	
10156702			X	
10156714			X	
10156717		X		
10156755			X	
10156785	X			
10156792				X
10156793				X
10156801			X	
10156807				X
10156810	X			
10156811				X
10156812				X
10156819				X
10156820				X
10156836				X
10156847			X	
10156866		X		
10160661			X	
10160666				X

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10160672	X			
10160683		X		
10160684			X	
10160691		X		
10160699	X			
10160734			X	
10160739	X			
10160742			X	
10160753	X			
10160755				X
10160758			X	
10160759	X			
10160769	X			
10160779			X	
10160808			X	
10160816				X
10160832			X	
10160836				X
10160843				X
10160844				X
10160848			X	
10160850		X		
10160857				X
10160874		X		
10160877				X
10160882			X	
10160888			X	
10160892			X	
10160898			X	
10160904	X			
10160912				X
10160922		X		
10160935				X
10160959			X	
10160964				X
10160983	X			
10160985			X	

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

	Waste Disposal Location		Waste Disposal Location	
LANL ID Number	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10161001			X	
10161011			X	
10161019				X
10161022			X	
10161033			X	
10161035				X
10161039		X		
10161041				X
10161050			X	
10161081		X		
10161147	X			
10161148				X
10161155	X			
10161457	X			
10161458				X
10161503		X		
10161506		X		
10161515				X
10161518				X
10161556	X			
10161561	X			
10161562			X	
10161565	X			
10161566				X
10161579			X	
10161593				X
10161594		X		
10161596				X
10161597				X
10161598				X
10170107				X
10170109				X
10170111			X	
10170118		X		
10170130			X	
10170132		X		
10170138			X	

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10170140				X
10170141	X			
10170146			X	
10170153				X
10170154				X
10170159				X
10170162				X
10170167		X		
10170186				X
10170194				X
10170340				X
10170350			X	
10170351	X			
10170353			X	
10170356	X			
10170370			X	
10170386				X
10170388				X
10170395				X
10170397			X	
10170398		X		
10170404				X
10170420				X
10170440				X
10170447				X
10170451				X
10170452				X
10170454				X
10170455				X
10170457			X	
10170470			X	
10170478			X	
10170480			X	
10170483			X	
10170484				X
10170486			X	
10170488				X

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

	Waste Disposal Location		Waste Disposal Location	
LANL ID Number	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10170489				X
10170493				X
10170493				X
10170496				X
10170497			X	
10170498			X	
10170501				X
10170505			X	
10170506			X	
10170513			X	
10170515				X
10170517			X	
10170519			X	
10170520			X	
10170521			X	
10170542		X		
10170545	X			
10170547	X			
10170548				X
10170551	X			
10170556			X	
10170557	X			
10170558			X	
10170560			X	
10170566			X	
10170569			X	
10170572			X	
10170573			X	
10170578				X
10170594				X
10170597				X
10170608	X			
10179097				X
10179111		X		
10179113				X
10179117		X		
10179120				X

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10179121				X
10179124				X
10179126				X
10179136		X		
10179169			X	
10179171		X		
10179172		X		
10179176				X
10179181			X	
10179186			X	
10179193			X	
10179195	X			
10179201			X	
10179202				X
10179203	X			
10179214	X			
10179215				X
10179216	X			
10179224		X		
10179246				X
10179251	X			
10179252				X
10179253				X
10179255			X	
10179257				X
10179262				X
10179264				X
10179267				X
10179268		X		
10179269			X	
10179270	X			
10179271				X
10179272		X		
10179276	X			
10179277	X			
10179279	X			
10179281				X

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

	Waste Disposal Location		Waste Disposal Location	
LANL ID Number	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10179282		X		
10179284		X		
10179290		X		
10179292	X			
10179304				X
10179308				X
10179309				X
10179311				X
10179317		X		
10179318		X		
10179320		X		
10179336		X		
10179341		X		
10179361		X		
10179363	X			
10179376		X		
10179381				X
10179385				X
10179394		X		
10179397			X	
10179498				X
10179706				X
10179714				X
10179715				X
10179716				X
10179717			X	
10179718			X	
10179722				X
10179723			X	
10179724				X
10179728		X		
10179729		X		
10179730				X
10179734			X	
10179735			X	
10179737			X	
10179739			X	

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10179745			X	
10179748	X			
10179750	X			
10179752				X
10179759				X
10179760			X	
10179763			X	
10179772				X
10179773				X
10179784				X
10179786			X	
10179791		X		
10179793		X		
10179794		X		
10179795				X
10179800		X		
10179801				X
10179802				X
10179805				X
10179806		X		
10179807		X		
10179809		X		
10179811				X
10179813				X
10179815				X
10179819				X
10179820				X
10179821		X		
10179822		X		
10179823		X		
10179824		X		
10179825		X		
10179830				X
10179834				X
10179845		X		
10179846				X
10179850		X		

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10179851		X		
10179852		X		
10179854		X		
10179855		X		
10179960				X
10179961		X		
10179962		X		
10179963		X		
10179966		X		
10179967		X		
10179968		X		
10179969				X
10179971			X	
10179972		X		
10179973		X		
10179974		X		
10179975		X		
10179976		X		
10179977		X		
10179978		X		
10179979				X
10183207				X
10183208				X
10183209	X			
10183210				X
10183211				X
10183214		X		
10183215	X			
10183216				X
10183217				X
10183218				X
10183219				X
10183220				X
10183221				X
10183222				X
10183223		X		
10183224		X		

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

	Waste Disposal Location		Waste Disposal Location	
LANL ID Number	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10183225				X
10183226		X		
10183227				X
10183228				X
10183229				X
10183230				X
10183234		X		
10183329				X
10183330	X			
10183331				X
10183332				X
10183333				X
10183334				X
10183335				X
10183336				X
10183337	X			
10183338				X
10183339				X
10183340				X
10183341				X
10183342				X
10183343				X
10183344				X
10183345				X
10183346		X		
10183347		X		
10183348				X
10183349		X		
10183350		X		
10183351		X		
10183352		X		
10183353		X		
10183354				X
10183355				X
10183356				X
10183357				X
10183358		X		

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10183359				X
10183360				X
10183361				X
10183362				X
10183363				X
10183364		X		
10183365		X		
10183366		X		
10183367		X		
10183368		X		
10183369		X		
10183370		X		
10183371		X		
10183372		X		
10183373		X		
10183374		X		
10183375		X		
10183376		X		
10183377		X		
10183378				X
10183378			X	
10183379		X		
10183380		X		
10183381		X		
10183382		X		
10183383		X		
10183383			X	
10183384		X		
10183385		X		
10183386		X		
10183387		X		
10183388		X		
10183389		X		
10183390		X		
10183391		X		
10183392		X		
10183393				X

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

	Waste Disposal Location		Waste Disposal Location	
LANL ID Number	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10183394		X		
10183395				X
10183396				X
10183397		X		
10183398		X		
10183400		X		
10183401				X
10183402				X
10183403		X		
10183404			X	
10183405				X
10183406				X
10183407				X
10183408		X		
10183409		X		
10183410		X		
10183411		X		
10183412		X		
10183413		X		
10183414		X		
10183415				X
10183416				X
10183418		X		
10183419		X		
10183420		X		
10183421		X		
10183422				X
10183423				X
10183424				X
10183426			X	
10183427			X	
10183428			X	
10183429				X
10183430				X
10183431			X	
10183432		X		
10183433			X	

Table 4-1 (Cont.)
MDA B Waste Container Disposal Locations

LANL ID Number	Waste Disposal Location		Waste Disposal Location	
	Pit 38 Proper IWL	Pit 38 Proper Headspace	Pit 38 Extension IWL	Pit 38 Extension Headspace
10183434			X	
10183435			X	
10183436			X	
10183437			X	
10183438				X
10183439		X		
10183440		X		
10183441		X		
10183442		X		
10183443		X		
10183444		X		
10183445		X		
10183446		X		
10183447		X		
10183448		X		
10183450		X		
10183451		X		

5.0 Conclusions

This special analysis was conducted to identify a disposal plan for pit 38 that allows efficient utilization of the disposal unit. The performance modeling conducted in support of this plan projects peak mean doses for inadvertent intruders and members of the public that exceed, in some cases, the exposures projected for the FY 2011 disposal receipt review by more than 25 percent. The projected peak mean doses, however, remain well within the pertinent DOE Order 435.1 performance objectives. On this basis, disposal locations have been identified for the containers of MDA B waste that are awaiting disposal at Area G.

Accommodation of the MDA B waste will require disposal in a portion of MDA G that was not identified for such by the 2008 performance assessment and composite analysis. Nevertheless, the final cover design that was adopted and the erosion modeling that was conducted for those analyses adequately address the pit 38 extension. Therefore, no changes to the design of the final cover are required prior to placement of waste in the pit 38 extension.

6.0 References

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LANL, 2012b, *Special Analysis: Extension of Disposal Pit 38 at Technical Area 54, Area G,* SA-2012-003, January.

LANL, 2012c, *Evaluation of Low-Level Waste Disposal Receipt Data for Los Alamos National Laboratory Technical Area 54, Area G – Fiscal Year 2011.* Los Alamos National Laboratory Report LA-UR-12-20651, April.

Appendix A
MDA B Radiological Waste Characterization Using MAR Gamma Spectroscopy, Revision 1

MDA B Radiological Waste Characterization Using MAR Gamma Spectroscopy
Revision 1

Introduction

The excavation and cleanup of the historic Manhattan Project Landfill, now referred to as MDA B, at Los Alamos is approximately 50% complete. Since the inception of this cleanup project, thorough sampling and analysis of this 6 acre landfill has been performed. Historic characterization of the MDA B landfill is summarized in the *Investigation/Remediation Work Plan for Material Disposal Area B, Solid Waste Management Unit 21-015, at Technical Area 21, Revision 1*, LA-UR-06-6918 October 2006 (IRWP). Appendix B of the IRWP, titled Historical Investigation Report (HIR), presents summaries of the historical data collected on the contaminants from the MDA B site over the past 50 years (1966-2001). Based on historical assessment of the MDA B landfill, "Am-241, Cs-137, Pu-238, Pu-239 and tritium were detected consistently across the surface of MDA B. Plutonium 239 is the most consistently detected radionuclide..."

In September 2009, the *Final Investigation Report for Direct-Push Sampling of MDA B* was submitted to the New Mexico Environmental Restoration Program. This report summarized a sampling effort of the MDA B landfill involving 124 sampling points at various depths. The results from the Direct-Push sampling have proven to be consistent with the historic sampling completed in MDA B summarized in the HIR.

Purpose

This paper describes a basis and a calculation for defining a radiological distribution based on the use of the MAR analysis of Am-241. Table 1 provides the necessary scaling factors for the individual isotopes based on the gamma spectroscopy analysis of Am-241.

Scope

This document is limited in that it will define the radiological characterization to the contaminated MDA B "soils" and "landfill" material. The fill material and soil in MDA B is the contaminated material, located below the clean cap (fill material) covering the surface of the landfill.

Characterization of the MDA B landfill as a hazardous waste is outside of the scope of this document; never the less, GEL sampling data, with the exception of anomalies identified in the field, has determined that that the waste as a whole is not RCRA hazardous waste. See Due Diligence Review for Excavation Materials From MDA B (TA21-MDAB-RPT-00001). Characterization of anomalies is addressed in the MDA B Sampling and Analysis Plan.

Assumptions

1. The isotopic distribution is based on validated analytical results from a NELAC certified laboratory of MDA B waste samples.
2. Radionuclides are evaluated as reported on analytical reports; LANL background concentrations of these nuclides are not (subtracted out) considered. In other words, all radionuclides are assumed to have a background value of zero.

3. U-234, U-235 and U-238 are reported at their highest analyzed values due to their low concentrations in the waste. Although the highest concentrations found for these uranium isotopes do not reflect the ratios found in natural uranium (nat-U), process knowledge suggests that a significant portion of the uranium activity is derived from nat-U.
4. Th-234 in the U-238 decay chain will not be reported. Daughter products of natural occurring uranium are assumed to be in secular equilibrium within the waste.
5. The average concentration of K-40 measured in the MDA B waste is below the LANL background concentration and therefore will not be reported.
6. The Tritium concentration will be assigned based on twice the average concentration measured in the GEL data (1.5 pCi/g).

MDA B Sampling and Analysis Plan

From the outset, the radiological characterization of waste removed from MDA B has been defined by the MDA B Sampling and Analysis Plan. This plan called for the collection of increment (composite) samples collected from the contaminated soil / fill material. Each of these composite samples typically represented six 20 yard bins. Each of these bins were analyzed off site by General Engineering Laboratories, a NELAC certified analytical laboratory. The following radiological analytes were evaluated within each sample.

- Am-241: Alpha Spectroscopy
- Pu-238, Pu-239/240: Alpha Spectroscopy
- Tritium: Liquid Scintillation
- Gamma Spectroscopy
- U-234, U-235/236 and U-238 by ISO_U
- Sr-90

By February of 2011 over 800 bins of contaminated soil / fill material have been removed from MDA B. These 800 bins have been characterized from 92 composite samples, analyzed for the full suite of radioactive contaminants listed above. 92 samples, representing 3348 individual isotopic data points collected within the MDA B Area of Concern (AOC) will be used to establish the average properties of the waste and form the basis for the "bounding characterization" based on the MAR gamma spectroscopy.

The development of this bounding characterization will permit the safe transportation and disposal of MDA B waste without the need for continuous sampling. Per the latest revision of the MDA B Sampling and Analysis Plan, sampling will only be required when anomalies are identified.

Characterization of Pu-239 from MAR Gamma Spectroscopy

In addition to the comprehensive radiological sampling and analysis of the MDA B contaminated soil by GEL, on site gamma spectroscopy (MAR) has been used extensively in the identification of radiological contaminants. The MAR gamma spectroscopy has an advantage over the GEL radiological data in that a MAR sample is not a composite from multiple bins, but an individual sample collected and analyzed from each waste bin; or alternatively, one sample for approximately 30,000 lbs of waste. This gamma spectroscopy uses the ISOCS modeling software from Canberra to measure gamma emitting contaminants. This analytical method, referred to as the "MAR characterization" is effective for the measurement of gamma emitting nuclides. It is recognized that the gamma spectroscopy by the MAR method does a relatively poor job of measuring Pu-239, the primary radiological contaminant in this wastestream.

Given that the MAR analysis does a reasonable job at measuring Am-241 but not Pu-239, calculation of the Pu-239 to Am-241 ratios from GEL data has been employed to indirectly and conservatively characterize the Pu-239 concentration. This process of characterizing Pu-239 in MDA B based on the Am-241: Pu-239 ratio was initiated in November of 2010 based on the complete composite population of 81 samples at that time.

This characterization protocol considered the population of 92 composite samples of contaminated soil analyzed by GEL where the concentration of Pu-239 by alpha spectroscopy was compared to the Am-241 as measured by gamma spectroscopy. In order to improve the quality of the data, the data was reviewed and scrubbed by the following techniques.

- Am-241 values below 2 pCi/g were eliminated due to their proximity to the MDA value, where data quality is suspect.
- The two highest ratios of Pu-239 to Am-241 and the two lowest ratios of Pu-239 to Am-241 were removed from the data to prevent outliers from inappropriately skewing the data set.

For the remaining 52 sample pairs of Pu-239 and Am-241, the individual Pu-239 to Am-241 ratios were calculated. For this ratio data, the standard deviation, and upper 95% confidence interval was calculated. The 95% confidence interval for the Pu-239 to Am-241 ratio was calculated at 44. In order to conservatively estimate the Pu-239 concentration from the Am-241 value from the onsite (MAR) gamma spectroscopy, one can multiply by the 95% confidence interval for the Pu-239: Am-241 ratio (44) x the Am-241 concentration. For example, where the MAR gamma spectroscopy measures Am-241 at 10 pCi/g, the Pu-239 concentration is determined by multiplying the Am-241 value of 10 pCi/g x 44 to obtain a value of 440 pCi/g Pu-239.

Importantly, based on the historic data from more than 92 composite samples representing greater than 50% of the MDA B cleanup, Am-241 and Pu-239 taken together represent greater than 96% of the radiological activity in the contaminated soil/fill material.

Characterizing the Minor Isotopes

The minor isotopes within the MDA B cumulatively account for 4% of the activity in the waste. The quantification of the major isotopes is based on the analysis by GEL of the 92 composite samples of the MDA B waste collected in 2010. The relative percents of the minor isotopes were determined based on the average concentrations measured in the 92 bin population. The average concentrations of the minor isotopes were compared to, scaled against, the average Am-241 concentration to obtain a multiplier or scaling factor that allows the concentrations of the minor isotopes to be derived from the onsite MAR analysis of Am-241. For example, Cs-137 in the GEL sample population has an average concentration of 43 pCi/g. This represents 54% (.54x) of the average Am-241 concentration of 79.5 pCi/g measured in the MDA B waste. For future samples then, to obtain the Cs-137 from the Am-241 concentration obtained via the MAR analysis, you multiply by the scaling factor of .54.

In addition to obtaining Am-241 scaling factors for certain isotopes based on the average percent radioactivity, the maximum reported values are also used to assign isotopic concentrations for the uranium isotopes and tritium. For the MDA B waste this approach is reasonable since the uranium isotopes are found at such low levels. The total uranium concentration (from all isotopes) in the waste, on average is less than 13 pCi/g. For tritium, the average concentration measured within the MDA B waste is .68 pCi/g. Conservatively, tritium activity is defined at roughly twice the average concentration, or 1.5 pCi/g.

See Table 1 below for the quantification methods of the minor and major isotopes, including the applicable Am-241 scaling factors and assigned fixed concentrations for uranium and tritium.

Table 1. Radioactive Composition and Waste Characterization Information.

Isotope	Average Conc. pCi/g	% Activity by Isotope	Isotope Category	Basis for Quantification	Am-241 Scaling Factor or Fixed Value pCi/g
Pu-239	3210.59	93.84	Major	Statistical Evaluation of MDA B GEL Sample Analysis	44x
Am-241	79.49	2.32	Major	MAR Gamma Spectroscopy	1.0
Cs-137	42.85	1.25	Minor	Relative percent of Radioactivity in MDA B GEL Sample Population	.54x (1.25/2.32)
Pu-238	16.83	.49	Minor	Relative percent of Radioactivity in MDA B GEL Sample Population	.22x (.49/2.32)
Sr-90	6.33	.19	Minor	Relative Percent of Radioactivity in MDA B GEL Sample Population	.08x (.16/2.32)
U-234	6.40	.19	Minor	Maximum value measured in GEL sample population. Reported 49% of Natural Uranium. (152 pCi/g)	@ 152 pCi/g
U-238	5.75	.17	Minor	Maximum value measured in GEL sample population. 159 pCi/g	159 pCi/g
U-235	.56	.02	Minor	Maximum value measured in GEL Sample Population. 8.24 pCi/g	8.24 pCi/g
H-3	.68	.02	Minor	Twice the average concentration.	1.5 pCi/g
Various: K-40, Th-234	N/A	~1.0	NORM & Rad. Decay	MDA B GEL Sample Analysis. See	N/A

MAR Gamma Spectroscopy Values below MDA

A significant portion, approximately 20% of MAR measurements for Am-241 are expected to be reported as less than "Minimum Detectable Activity", or < MDA. The onsite MAR gamma spectroscopy has difficulty measuring Am-241 at less than 2 pCi/g and therefore reports the Am-241 concentration as a less than value, such as < 1.5 pCi/g Am-241. In this case, in order to estimate the radioactivity contributed by the other isotopes, the less than symbol is discounted and the numerical value is used as the Am-241 concentration. If Am-241 is reported as < 2.0 pCi/g, the Am-241 concentration is reported as 2.0 pCi/g allowing the other isotopes to be assigned based on the Am-241 scaling factors described previously.

It is understood that the MAR characterization is conservative and environmentally protective, and may result in a small quantity of industrial waste being managed as low level waste. However it is believed that the labor cost, sampling cost and schedule delays from sampling and processing the associated paperwork to insure that the waste is indeed industrial waste far exceeds the environmental and budgetary cost of managing the waste as low level.

Radioactivity Characterization via MAR Gamma Spectroscopy

An Excel spreadsheet has been employed as a template that contains each of the Am-241 scaling factors and fixed concentrations for the uranium and tritium constituents. Using this template the required waste information is input including:

- Container identification number
- Waste description
- Waste Weight
- Waste Volume
- MAR Am-241 concentration or Am-241 MDA

Once these five pieces of information are input into the Excel template, each of the isotopes is automatically quantified in the three commonly used units: pCi/g, Ci/bin and Ci/M^3 of waste.

Summary

At MDA B, the Am-214 concentration is accurately characterized in the waste by skilled chemists via gamma spectroscopy using ISOCs modeling software. Although the gamma spectroscopy analysis does a relatively poor job of measuring Pu-239, the major contaminant in the contaminated soil / fill material, historical analytical data from GEL has been used with the MAR analysis to determine the relative abundance of the various isotopes in the MDA B waste. The relative concentration of Am-241 to Pu-239 is the most important value because Pu-239 represents 94% of the radioactivity in the waste. The Pu-239 to Am-241 ratio was statistically evaluated from 92 composite samples from the soil removed from MDA B over the course of the last 7 months. Using this GEL data, a Pu-239 ratio (read scaling factor) of 44 was conservatively established based on a 95% confidence interval. To obtain a Pu-239 radioactivity concentration, the Am-241 concentration from the bin specific MAR analysis is obtained by multiplying by 44. By following the MDA B sampling and analysis plan, seven minor isotopes were identified. Three of the seven minor isotopes are quantified from Am-241 scaling factors obtained based on their relative abundance measured in the GEL data set. The uranium isotopes, since there concentrations are so low, are defined based on their maximum measured values. Although tritium is a minor isotope, with an average concentration of .68 pCi/g; a conservative approach is employed where all packages are assumed to contain 1.5 pCi/g of tritium.

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Reviewer, Glenn Siry [signature] Date 2-16-2011

Appendix B
Radionuclide Concentration Distributions for Material Disposal Area B Waste

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B.1 Introduction

This appendix discusses the methods used to develop radionuclide concentration distributions for Material Disposal Area (MDA) B waste that has been, or will be, disposed of at the Technical Area 54, Area G disposal facility. The distributions were developed on the basis of sample data collected from containers or bins of waste following retrieval of the material from the disposal units at MDA B. They describe the variance about the mean activity concentrations in the waste, rather than the variance of the sample data. Using distributions of the mean activity concentrations is consistent with the spatio-temporal scale of the modeling conducted in support of the Area G performance assessment and composite analysis. Those analyses evaluate the impacts of radionuclide releases from the totality of the waste disposed of at the facility. In terms of the MDA B waste, then, the inventory of interest is the activity of each radionuclide summed across all containers of waste, which corresponds to the average concentration across all such containers.

For these statistical distributions, the lognormal distribution was used since it is strictly positive, can fit a variety of shapes, and may be easily parameterized using maximum likelihood methods. Although a truncated normal distribution may fit the data when the distribution of the mean activity concentration is not highly skewed, a lognormal distribution provides a better fit when the distribution is skewed. For consistency, then, lognormal distributions were applied for all radionuclides.

B.2 Development of Waste Distributions

Radionuclide activity concentration data are available from several sources. Concentrations were measured for a full suite of radionuclides in 92 composite samples that were typically collected from six 15.3 m^3 (20 yd^3) containers or bins of waste and combined to form the composite sample; Am-241 concentrations were measured in 497 bins awaiting disposal and an additional 944 containers of waste that have already been disposed of at Area G. The goal of this characterization was to address the mean concentration of each radionuclide for the 497 and 944 containers that have been, or will be, disposed of in Area G.

Mean concentration distributions for Am-241 were developed directly from the 497 and 944 Am-241 measurements. Concentrations of plutonium isotopes in the waste were found to correlate to the Am-241 contents; these correlations were used to estimate Pu-238 and Pu-239/240 concentrations in the waste awaiting disposal and the waste that has already been disposed of at Area G. Concentration distributions were established for the remaining radionuclides directly from the analytical data collected from the 92 composite samples. These samples were assumed to be representative of all 497 and 944 waste containers. Although these data come from a different set of waste containers the source of the waste, MDA B, is the same.

B.2.1 Assumptions

Several assumptions were made prior to modeling the radionuclide distributions of interest:

- The data are statistically exchangeable. This means that later samples behave like earlier samples, so that all possible orderings in which data are collected are equally likely, and that the future is based on the past. Implicit in this assumption is that the waste in the bins is a random mixture of the original contaminated waste retrieved at MDA B.

  Under this assumption, differences in radionuclide contents between subsets of bins are not expected a priori. It can, perhaps, be argued that this is the case for the MDA B waste, although examination of the Am-241 data for the 497 containers awaiting disposal suggests some subsets of bins have different characteristics than others. These bins were divided into different categories based on the type of waste they contain or the origin of the waste (e.g., regular, roadside, and debris); the roadside bins were found to contain much lower concentrations of Am-241 than other bins. On the other hand, large numbers of bins have been, and will be, placed adjacent to one another in the disposal pits at Area G, functionally mixing the different types of bins. Using statistical methods that are aimed at averaging across potential differences is not unreasonable under these conditions.

  More complex statistical modeling than that presented here would be required if the data cannot be considered exchangeable. For example, it may be more appropriate to develop concentration distributions for each sub-population of interest (e.g., roadside bins). If the exchangeability assumption does not hold, it is possible that the variance in the distributions presented here is overestimated. However, the effect is likely to be small given the final use of the distributions in the performance assessment and composite analysis modeling.

- The multivariate statistical approach described below includes the estimation of correlation structures, such as those that exist between Am-241, Pu-238, and Pu-239. However, the GoldSim® models used to conduct the performance assessment and composite analysis cannot handle multivariate correlation structures. In a case such as this, GoldSim accommodates the correlations between two of the three pairs of interest. The third correlation is, in effect, induced through simulation, although that correlation is likely to be under-estimated by the software. The impact on the GoldSim output of underestimating correlation between activity concentrations for these radionuclides is to underestimate the variance in the projected distributions of radionuclide concentrations in environmental media and dose. This effect is, however, likely to be small.

- The sampling and analytical methods used to establish Am-241 concentrations in the 92 composite samples differ from those used in conjunction with the 497 containers of waste awaiting disposal and the 944 containers of waste that have undergone disposal. These differences may have an effect on relative precision and bias between the two sets of reported concentrations.

  In terms of sampling, the 92 samples were collected from several bins and combined to form the composite samples. In contrast, the Am-241 concentrations were estimated for the 497 and 944 containers using an on-site gamma spectroscopy unit; external measurements were taken of each bin. Because of these sampling differences, it is reasonable to expect differences in relative bias and precision for the two sets of measurements. However, for this statistical development of distributions of mean concentrations, it is assumed that no differences exist.

  Am-241 concentrations were estimated for the 92 composite samples using alpha spectroscopy, whereas gamma spectroscopy was used to determine the concentrations of this isotope in individual waste bins. The different analytical methods used can cause relative bias and can exhibit different measurement precision. Examination of the data reveals that the Am-241 concentrations in the 92 samples have a different distribution than concentrations measured using gamma-spectroscopy measurements. These differences could be due to differences in the analytical methods, or could indicate that there are two populations of containers having different concentrations. For this statistical analysis, it is assumed that bias and precision differences do not exist and that all data are equally representative of the waste.

  It is not clear if testing or quality assurance was performed to ensure that the results from the different sampling and analytical approaches are comparable. Nevertheless, an assumption was made that they are comparable, and that all data are equally representative and exchangeable. This assumes that there is no relative systematic bias among any of the measurements from the different sampling and analysis methods, and that the variance or precision is the same for all measurements.

- The 92 composite samples subjected to full characterization are representative of the other waste for which distributions are developed, including the 944 bins already disposed of at Area G and the 497 containers awaiting disposal. As discussed in conjunction with the first assumption, there are clear differences in the data between some subsets of waste. However, it is assumed that they are equally representative of the waste, following the assumption of exchangeability.

In general, the U.S. Environmental Protection Agency has established data quality indicators that support evaluation of the quality of environmental data. These include precision, accuracy, representativeness, comparability and completeness. The issues of representativeness and comparability are in question without recourse to further information. The assumption is made here that there are no representativeness and comparability issues so that the required statistical analysis can be performed.

B.2.2 Exploratory Data Analysis

Exploratory data analysis was conducted to better understand the nature of the data collected from the 92 composite samples, the 497 bins awaiting disposal, and the 944 containers of waste that have already been disposed of at Area G. The assumption regarding data representativeness (the fourth assumption discussed above) can be roughly checked using box plots of the Am-241 concentrations in the three datasets. These boxplots are provided in Figure B-1; separate plots are provided for the original data and the log-transformed data. For simplicity, these datasets are referred to as MDA B, TBD (to-be-disposed-of), and PD (previously disposed) in the plots.

Overall, the Am-241 concentrations from the 497 bins awaiting disposal appear to be greater than those observed for the other two datasets, but they fall within the same range as the others. The plots suggest that these bins and, perhaps, the previously disposed bins (both groups of which were measured using on-site gamma spectroscopy) exhibit some relative bias compared to the alpha spectroscopy measurements collected from the 92 composite samples.

Some of the radionuclide concentrations measured in the 92 composite samples were reported as zero pCi/g; zero values were replaced with half of each isotope's lowest non-zero measurement. Box plots of the data were developed for each radionuclide found in the 92 composite samples, using original and log scales. Correlations were calculated on both the original and log scales, and the radionuclides divided into distinct groups based on their correlation structures. The correlations are shown in Figures B-2 through B-5; the boxplots appear in Figures B-6 through B-21. A summary of the data is provided in Table B-1.

Statistically significant correlations were found to exist in the 92 composite samples between Am-241, Pu-238, and Pu-239/240; U-234, U-235, U-238, and Th-234; and Bi-214, Pb-214, Ra-226, and Ra-228. Significant correlations were not found to exist for Co-60, Cs-137, Eu-152, H-3, K-40, and Sr-90.

Table B-1
Summary Statistics for Radionuclides of Interest

Radionuclide	Sample Size	Minimum	Median	Mean	Maximum	Standard Deviation
Am-241 (MDA B)	92	0.0141	3.44	79.49	1360	250.2
Am-241 (TBD)	496	0.0977	42.75	74.72	1200	135.7
Am-241 (PD)	944	0.0213	9.24	94.39	1260	210.3
Bi-214	92	0.807	1.615	1.573	2.26	0.3387
Cs-137	92	0.164	1.13	1.098	1.99	0.256
Co-60	92	0.02595	2.13	6.861	150	18.24
Eu-152	92	0.0003815	0.157	0.6797	17.8	1.979
H-3	92	0.547	1.95	6.402	152	18.03
K-40	92	0.0003205	0.1815	0.5581	8.24	1.13
Pb-214	92	0.001	0.06665	6.334	566	58.99
Pu-238	92	0.000625	0.000625	0.008519	0.127	0.01588
Pu-239/240	92	0.0002155	0.002705	42.85	3920	408.7
Ra-226	92	0.164	1.13	1.098	1.99	0.256
Ra-228	92	0.528	1.455	5.755	159	18.59
Sr-90	92	0.0004425	0.0004425	0.1057	2.34	0.3272
Th-234	92	0.0154	108	3211	44000	9438
U-234	92	18.1	26.7	26.32	33.6	3.612
U-235	92	0.659	1.35	1.312	2.42	0.3055
U-238	92	0.004705	0.577	16.83	245	50.86

MDA B = the 92 composite samples from MDA B that form the basis for the estimation of distributions of mean activity concentrations.
TBD = to-be-disposed-of waste (awaiting disposal)
PD = previously disposed-of waste

B.2.3 Fitting Distributions

The methods used to fit distributions for the radionuclide concentrations found in the MDA B waste are discussed below. Different approaches were used for the groups of correlated isotopes and the radionuclides for which no correlations were found.

The lognormal distributions developed from this effort are summarized in Table B-2. A lognormal distribution may be parameterized in several ways; the parameters listed here represent the mean and standard deviation of the lognormal distribution (m and s), which can be used directly in the GoldSim models used to conduct the Area G performance assessment and composite analysis.

The distributions listed for Am-241, Pu-238, and Pu-239/240 are specific to the waste that is awaiting disposal and the material already disposed of at Area G, and to the layer (headspace [H] or institutional waste layer [IWL]) in which it is placed. The distributions developed for the remaining radionuclides are applied to all waste regardless of its disposal status and the layer in which it is placed.

B.2.3.1 Uranium and Thorium

The uranium isotopes (U-234, U-235 and U-238) and Th-234 are highly correlated; the high correlation between Th-234, U-234, and U-238 is probably an indication that these isotopes are in secular equilibrium. The only measurements of uranium and thorium concentrations are those collected from the 92 composite samples. Consequently, a multivariate bootstrap technique is used to develop distributions of the mean values for each radionuclide using the following steps:

1. Bootstrap the MDA B U-234, U-235, U-238, and Th-234 dataset by sampling the data records (for these four radionuclides) with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).
2. Take the mean of the 92 samples for each of the four isotopes.
3. Store the means from Step 2.
4. Repeat 10,000 times.

The resulting sets of 10,000 means represent the sampling distributions of the mean for each isotope. These sampling distributions accurately reflect the correlations among the data themselves. A lognormal distribution was fit to each distribution using maximum-likelihood calculations; correlation coefficients were established for use in the performance assessment and composite analysis modeling. Histograms of the uranium and Th-234 distributions are provided in Figure B-26. A single set of distributions was developed for the uranium and thorium isotopes, and applied to all disposed-of and to-be-disposed-of waste regardless of whether the waste was placed in the headspace or the institutional waste layer.

B.2.3.2 Americium-241 and Plutonium Isotopes

Americium-241, Pu-238, and Pu-239/240 are highly correlated in the 92 composite samples, both on the original and log scales (Figure B-2). Since Am-241 values are known for the 497 waste bins awaiting disposal and the 944 disposed-of containers, the Pu-238 and Pu-239/240 values were predicted using a multivariate lognormal regression model, with Am-241 as the independent variable. The regression model was established using the 92 composite sample dataset.

The regression model is fit 10,000 times; each iteration consists of the following steps:

5. Bootstrap the MDA B Am-241, Pu-238, and Pu-239/240 dataset by sampling the data records (for these three radionuclides) with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).

6. Fit a bivariate regression on the log-scale using the bootstrapped data, and store the regression coefficients and the covariance matrix of the residuals. This bivariate regression model is used to predict Pu-238 and Pu-239/240 activity concentrations from the Am-241 activity concentrations. The equations for the bivariate regression are as follows:

$$E[\log(Pu\text{-}238)] = \beta_0 + \beta_1 * \log(Am\text{-}241) + \varepsilon_1 \quad (1)$$

$$E[\log(Pu\text{-}239/240)] = \beta_2 + \beta_3 * \log(Am\text{-}241) + \varepsilon_2 \quad (2)$$

$$\Sigma = \begin{bmatrix} \varepsilon_1{}^2 & Cov(residuals(Eq.1)) \\ Cov(residuals(Eq.2)) & \varepsilon_2{}^2 \end{bmatrix} \quad (3)$$

7. Four distributions were developed for each radionuclide. These represent the subsets of the 944 bins of waste that have been disposed of in the headspace and institutional waste layers of pits 37 and 38, and the subsets of the 497 containers that will be placed in the headspace and institutional waste layers. Specific to the waste awaiting disposal, distributions were defined for the 350 containers having the lowest Am-241 concentrations (to be placed in the headspace) and the 147 bins having the highest Am-241 concentrations (to be placed in the institutional waste layer).

Table B-2
Summary of Lognormal Distributions Developed for Material Disposal Area B Waste.

Radionuclide	Waste Layer/ Type [a,b]	Mean (pCi/g)	Standard Deviation (pCi/g)	Correlation [c]
Am-241	H / TBD	25.8	1.1	NA
Am-241	H / PD	4.6	0.2	NA
Am-241	IWL / TBD	192.5	17.1	NA
Am-241	IWL / PD	213.9	13.9	NA
Bi-214	All waste	1.1	0.03	NA
Cs-137	All waste	0.5	1.0	NA
Co-60	All waste	0.009	0.002	NA
Eu-152	All waste	0.1	0.04	NA
H-3	All waste	0.7	0.2	NA
K-40	All waste	26.3	0.4	NA
Pb-214	All waste	1.3	0.03	Ra-226: 0.83
Pu-238	H / TBD	7.6	2.0	Am-241: 0.15
Pu-238	H / PD	2.0	0.5	Am-241: 0.14
Pu-238	IWL / TBD	36.8	12.1	Am-241: 0.18
Pu-238	IWL / PD	37.9	12.0	Am-241: 0.16
Pu-239/240	H / TBD	1744.0	508.6	Pu-238: 0.66
Pu-239/240	H / PD	277.7	74.8	Pu-238: 0.71
Pu-239/240	IWL / TBD	15195.0	6034.8	Pu-238: 0.55
Pu-239/240	IWL / PD	17474.7	6427.9	Pu-238: 0.57
Ra-226	All waste	1.1	0.03	NA
Ra-228	All waste	1.6	0.03	NA
Sr-90	All waste	0.3	0.1	NA
Th-234	All waste	6.9	1.9	U-234: 0.96
U-234	All waste	6.4	1.9	NA
U-235	All waste	0.6	0.1	U-234: 0.90
U-238	All waste	5.8	2.0	U-234: 0.99

[a] Waste layers include the headspace (H) and the institutional waste layer (IWL).

[b] Waste types included previously disposed-of (PD) and to-be-disposed-of (TBD).

[c] The radionuclide to which the distribution is correlated is listed first, followed by the correlation coefficient. NA is listed for those cases for which no statistically significant or for which the correlation was considered inconsequential for the performance modeling.

NA=Not applicable

8. Compute the logarithm of the Am-241 measurements from Step 3 (all bootstrapped data from the four data sets) and fit values for Pu-238 and Pu-239/240 given the regression coefficients and covariance matrix from Step 2. This step provides bootstrapped data for the plutonium isotopes in the log-scale.

9. Exponentiate the plutonium isotope results so they are on the original scale. This step provides four sets of fitted Pu-238 and Pu-239/240 values.

10. Take the mean of each of the four sets of fitted plutonium values.

11. Store the means from Step 6.

At the end of the simulation, the 10,000 stored means for the plutonium isotopes in each of the four bin types represent the sampling distributions of the means. These sampling distributions were parameterized through maximum-likelihood calculations assuming a lognormal distribution for the fits. A lognormal distribution was chosen for fitting because several of the distributions are skewed and using the lognormal distribution guarantees that the mean radioactivity of the radionuclides will always be greater than zero. Histograms of the final simulated distributions of the plutonium isotopes are provided in Figures B-22 through B-25.

The correlations between the simulated means for Am-241, Pu-238, and Pu-239/240 are not as high as the correlations found among the data themselves. The likely reason for the lower correlations is that lognormal distributions can exhibit unusual behavior in the upper tail. The box plots for the Am-241 data (Figure B-1) show that there is extreme right-skew in the data, which can be hard to fit with any distribution. This behavior may call into question the assumption made regarding data exchangeability, and suggest a statistical model that addresses separate sub-populations of bins would better fit the overall data. However, as noted in Section B.2.2, the overall goal is to estimate the mean radionuclide concentrations over large numbers of bins placed in the headspace or institutional waste layer. The exchangeability model used here is likely to provide reasonable results or fits for that endpoint, but may overestimate the variance of the mean concentrations for each radionuclide.

B.2.3.3 Radium, Bismuth and Lead

The radium isotopes (Ra-228 and Ra-226), Bi-214, and Pb-214 are highly correlated; the Ra-226 and Bi-214 data are identical, suggesting that the Ra-226 data were used as a surrogate for Bi-214. Otherwise, the strong correlations between Ra-226, Bi-214, and Pb-214 are indicative of secular equilibrium and common relative abundance. Of interest, however, is the fact that the activity concentrations of Ra-226 and those of U-234 and U-235 are quite low. This might indicate that secular equilibrium is not maintained through the uranium chain, or it might indicate analytical issues at low activity concentrations.

For this group of isotopes, the multivariate bootstrap technique described in Section B.2.3.2 was used to calculate the distributions of the mean activity concentrations, using the data collected from the 92 composite samples. Lognormal distributions were fit to each isotope via maximum-likelihood, and correlations were preserved so they can be used in the performance assessment and composite analysis modeling. Histograms of the distributions are provided in Figure B-27. A single set of distributions was developed for the isotopes in this group and applied to all of the MDA B waste, regardless of the layer in which it was placed.

B.2.3.4 Remaining Isotopes

The distributions of the mean activity concentrations for the remaining radionuclides were calculated using a univariate bootstrap technique, applied to the 92 composite sample dataset. The approach is as follows:

1. Bootstrap each radionuclide's dataset by sampling the data records with replacement (the bootstrap sample size is set to 92 to match the number of composite samples).
2. Take the mean of the 92 samples for each radionuclide.
3. Store the mean from Step 2.
4. Repeat 10,000 times.

The resulting set of 10,000 means represents the sampling distribution of the mean for a particular isotope. The distribution was parameterized as lognormal using maximum-likelihood calculations. Correlations between each of the distributions calculated through this technique and the other isotopes were assumed to be zero. Histograms of the distributions are provided in Figures B-28 through B-33. A single distribution was estimated for each radionuclide and applied to all of the MDA B waste, regardless of the layer in which the material was placed.

Figures

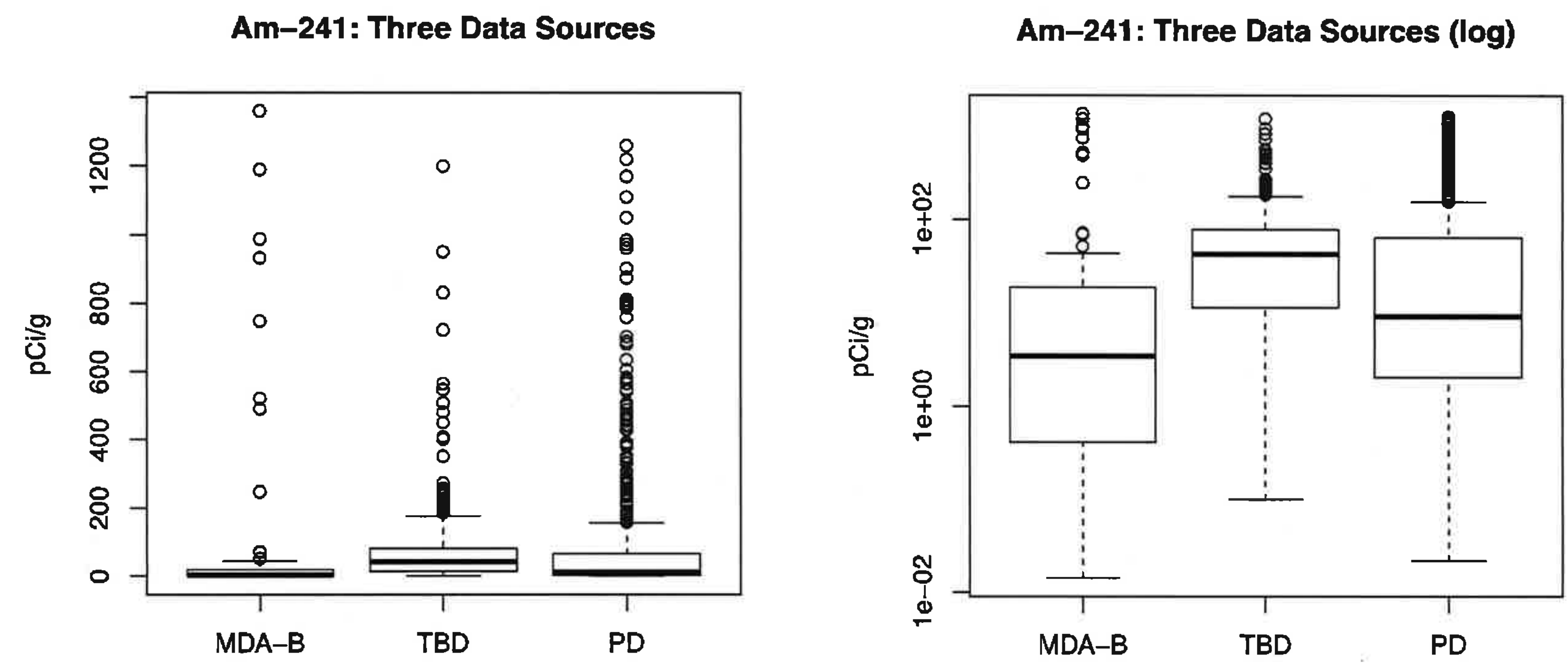
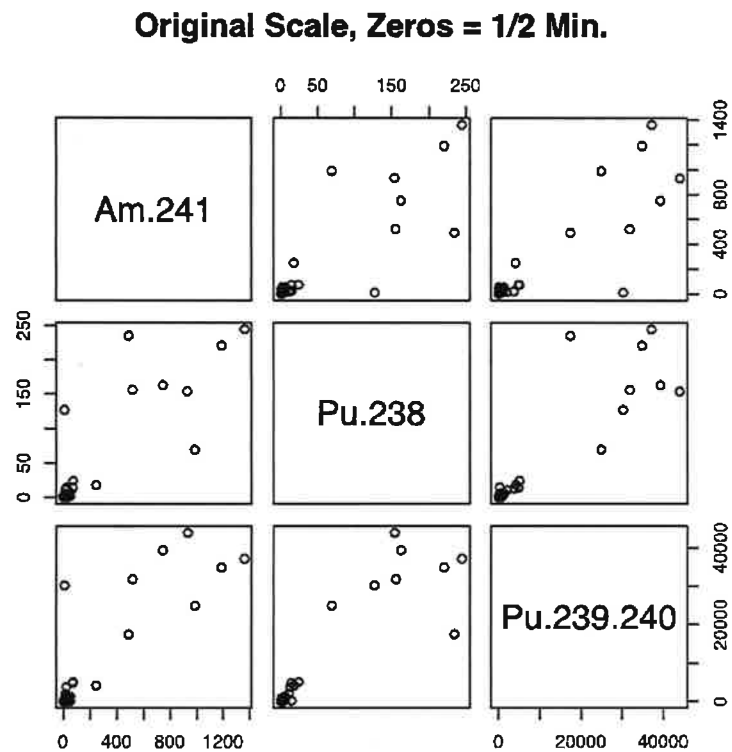


Figure B-1
Boxplots of Am-241 Measurements (from 92 MDA B waste bins, 497 to-be-disposed-of bins , and 944 previously disposed-of bins)



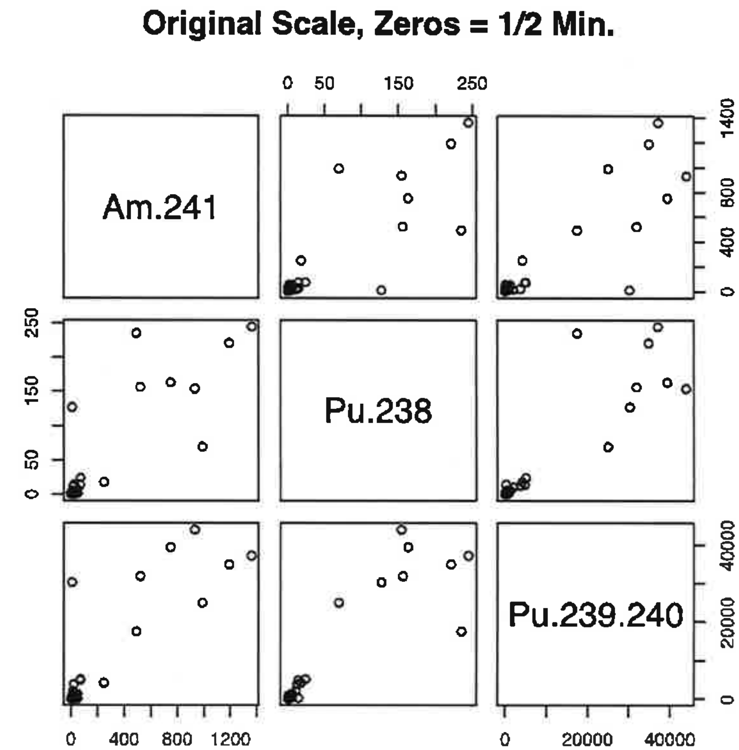


Figure B-2
Group Correlations for Am-241, Pu-238, and Pu-239/240, MDA-B data

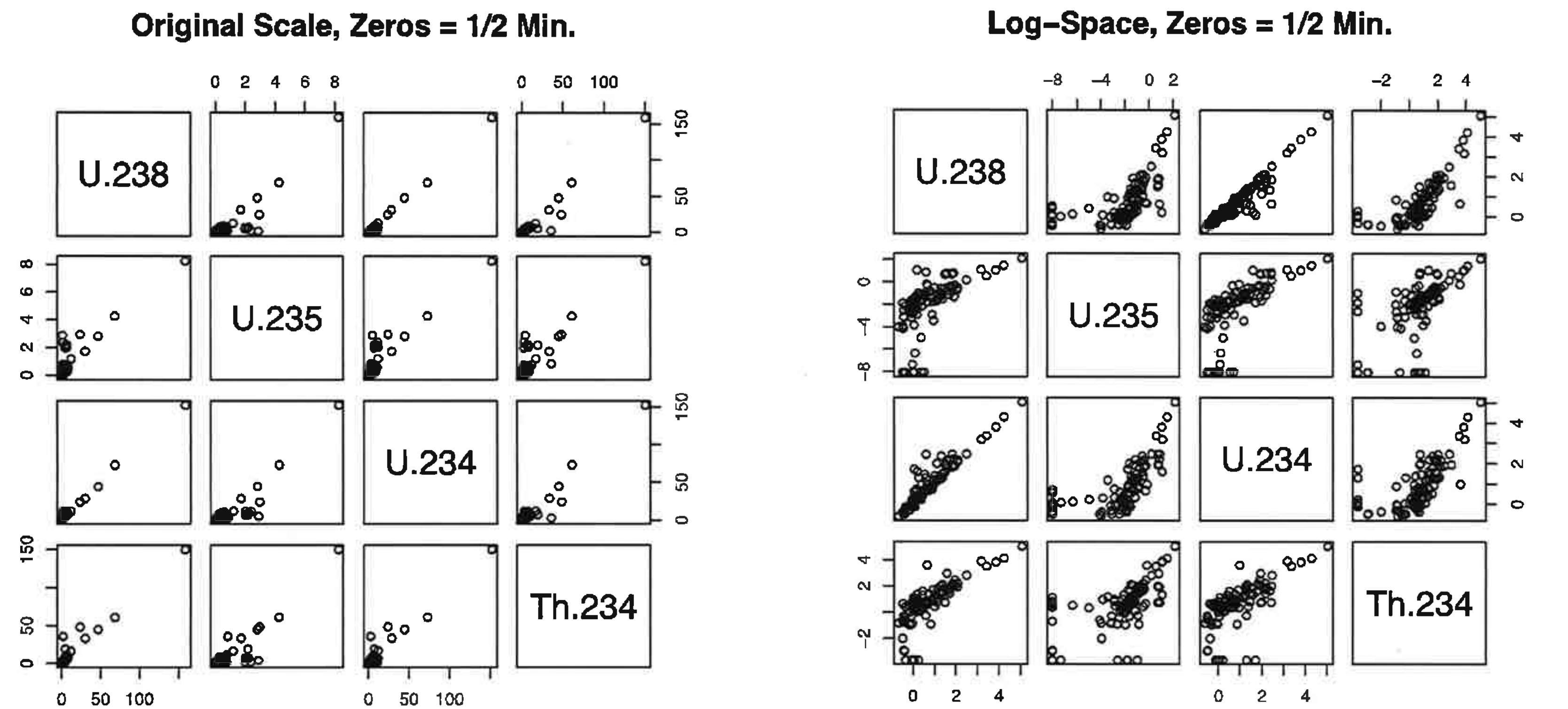


Figure B-3
Group Correlations for U-234, U-235, U-238, and Th-234, MDA-B Data

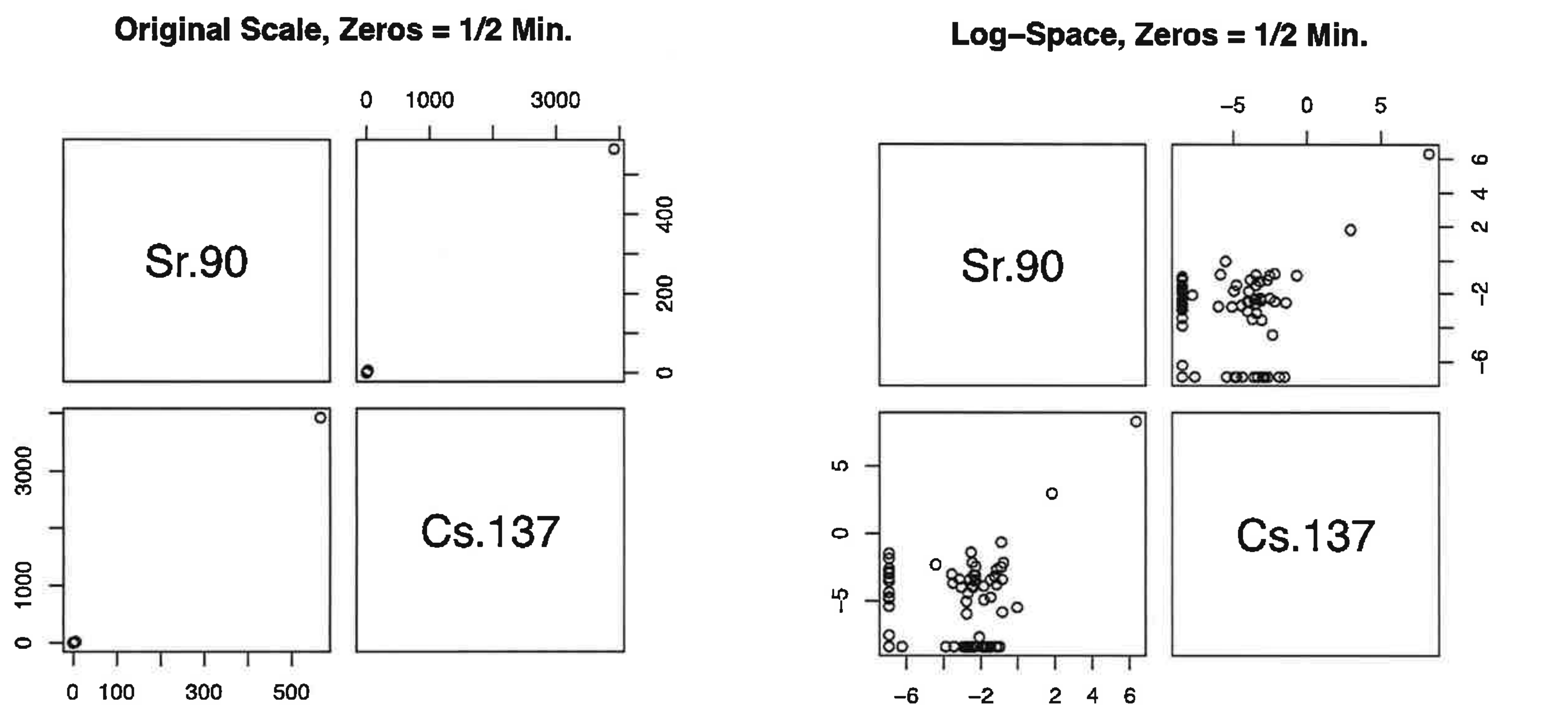


Figure B-4
Apparent Correlation for Cs-137 and Sr-90 Breakdown on Logscale, MDA-B Data

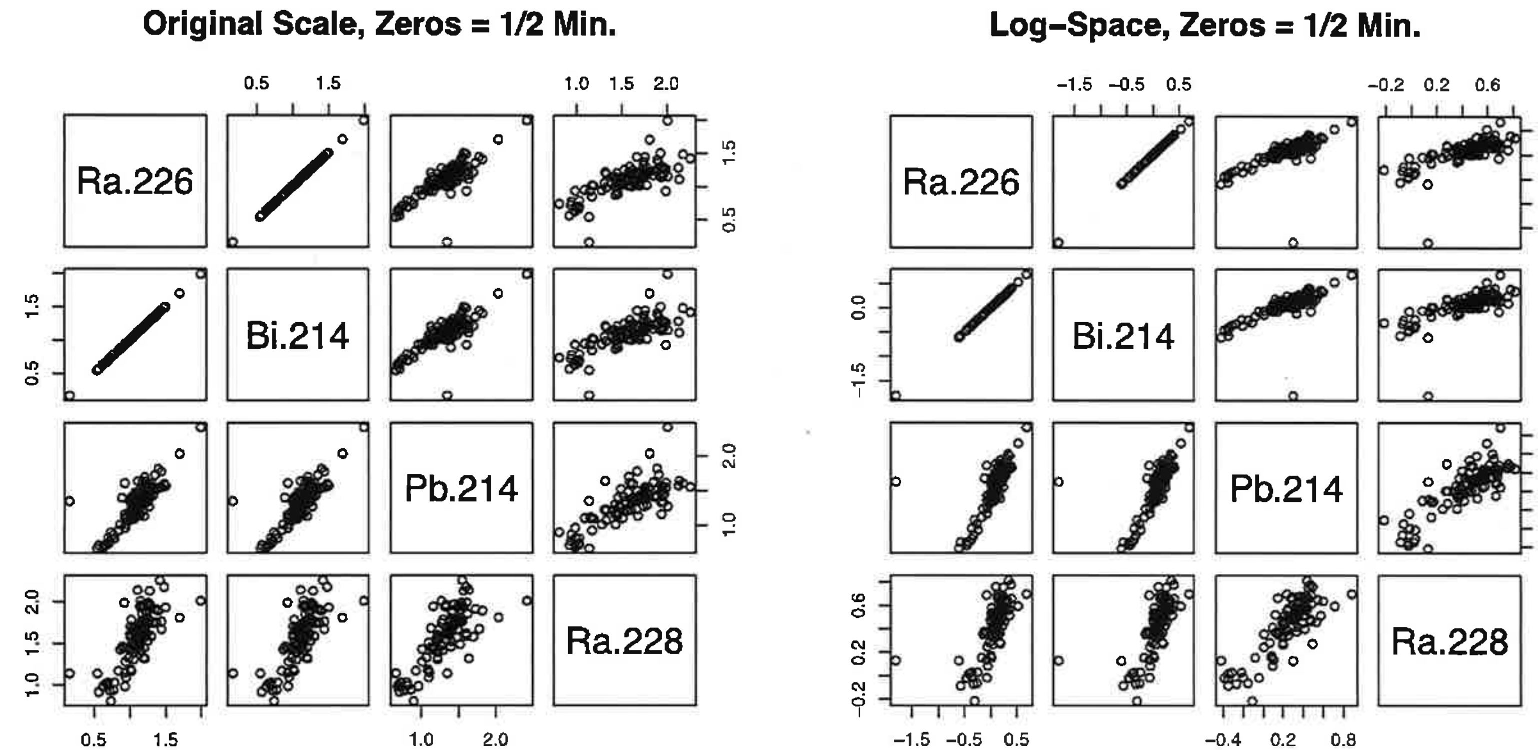
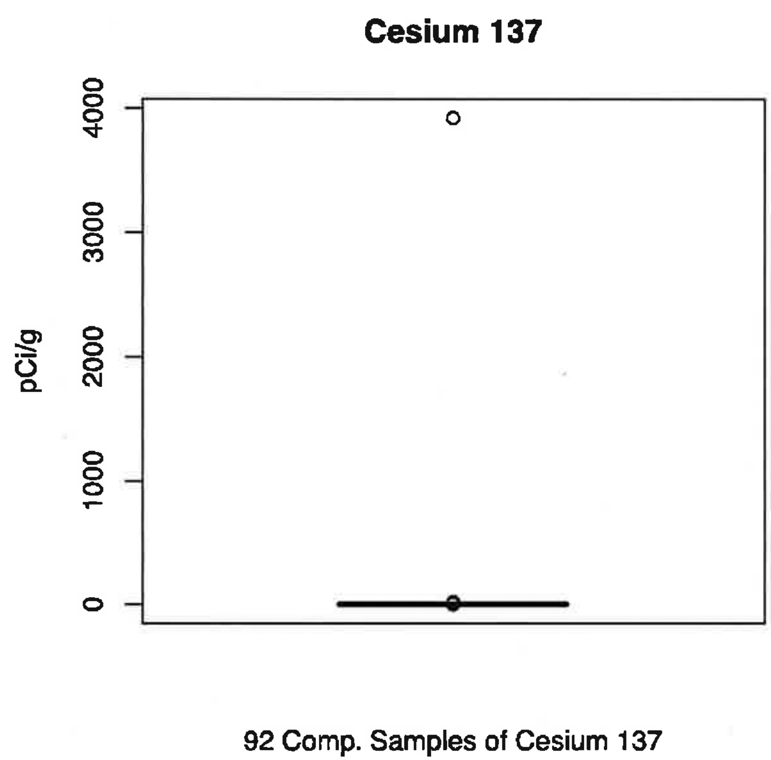


Figure B-5
Group Correlations for Bi-214, Pb-214, Ra-226, and Ra-228, MDA-B Data



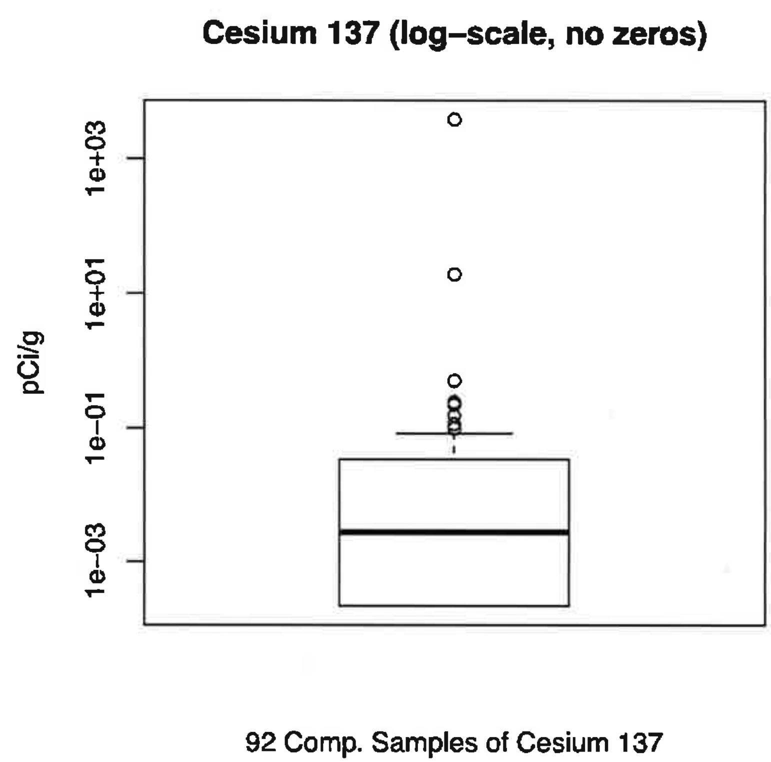


Figure B-6
Boxplots for Cs-137, MDA-B Data

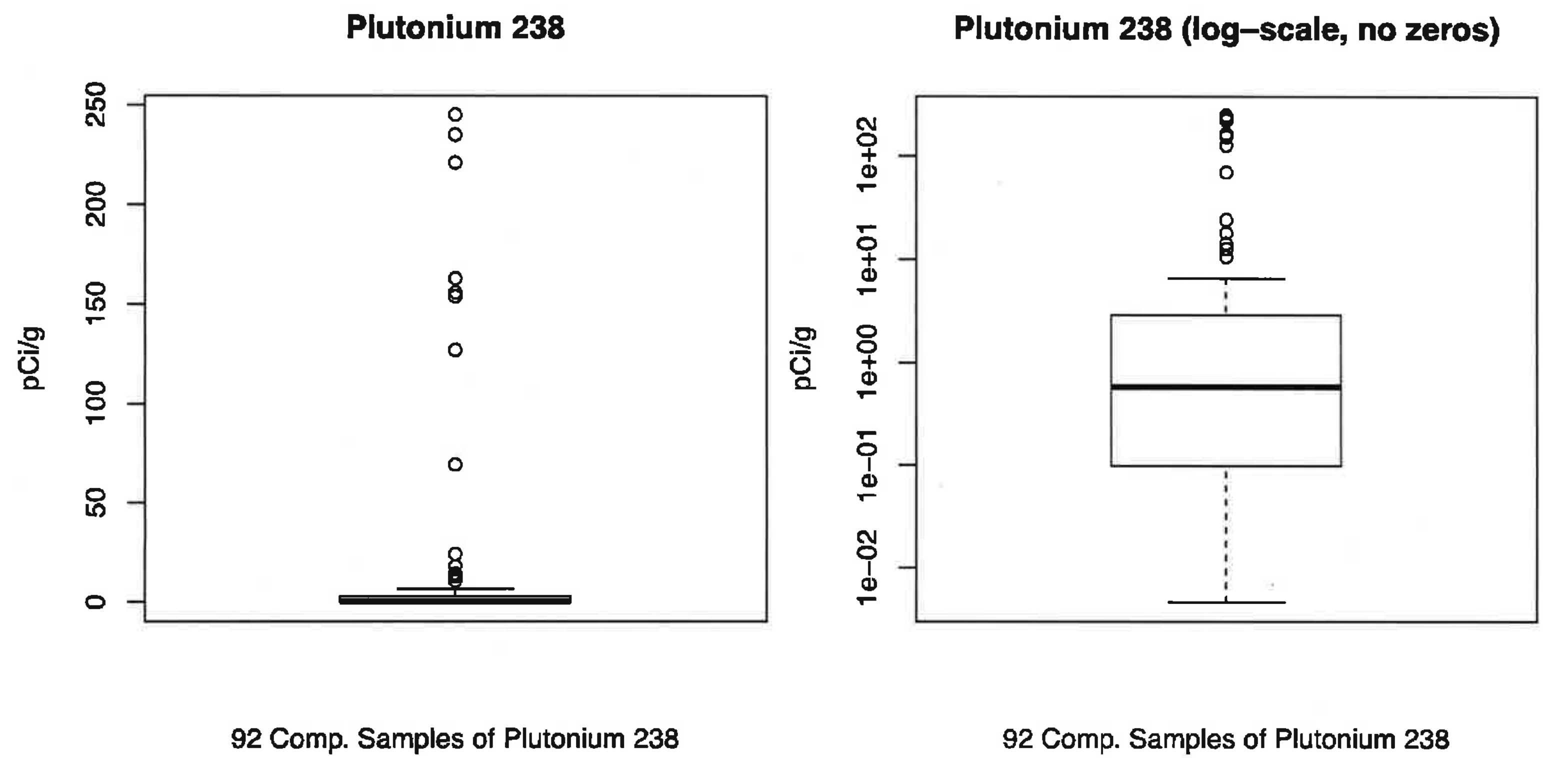


Figure B-7
Boxplots for Pu-238, MDA-B Data

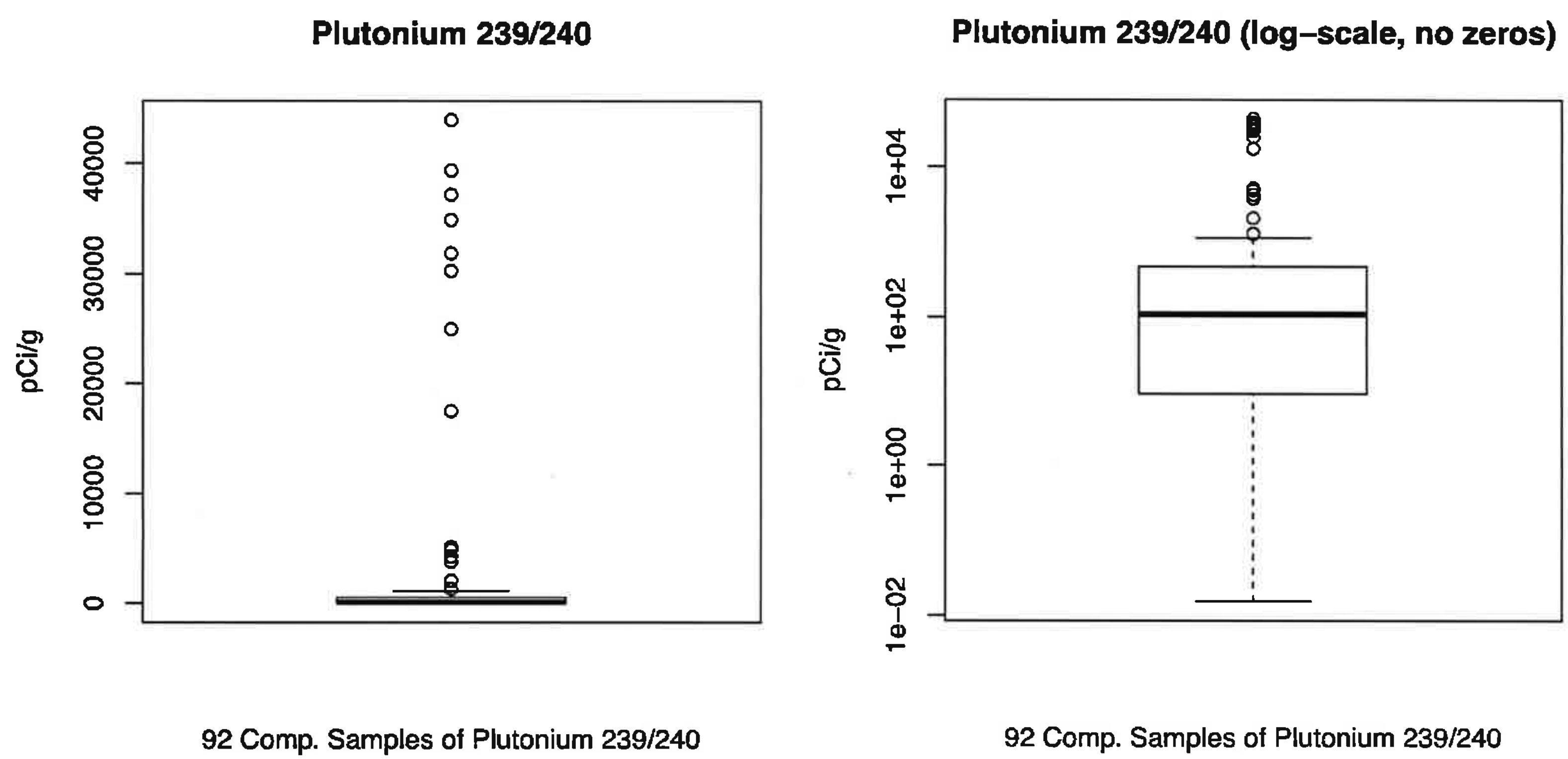


Figure B-8
Boxplots for Pu-239/240, MDA-B Data

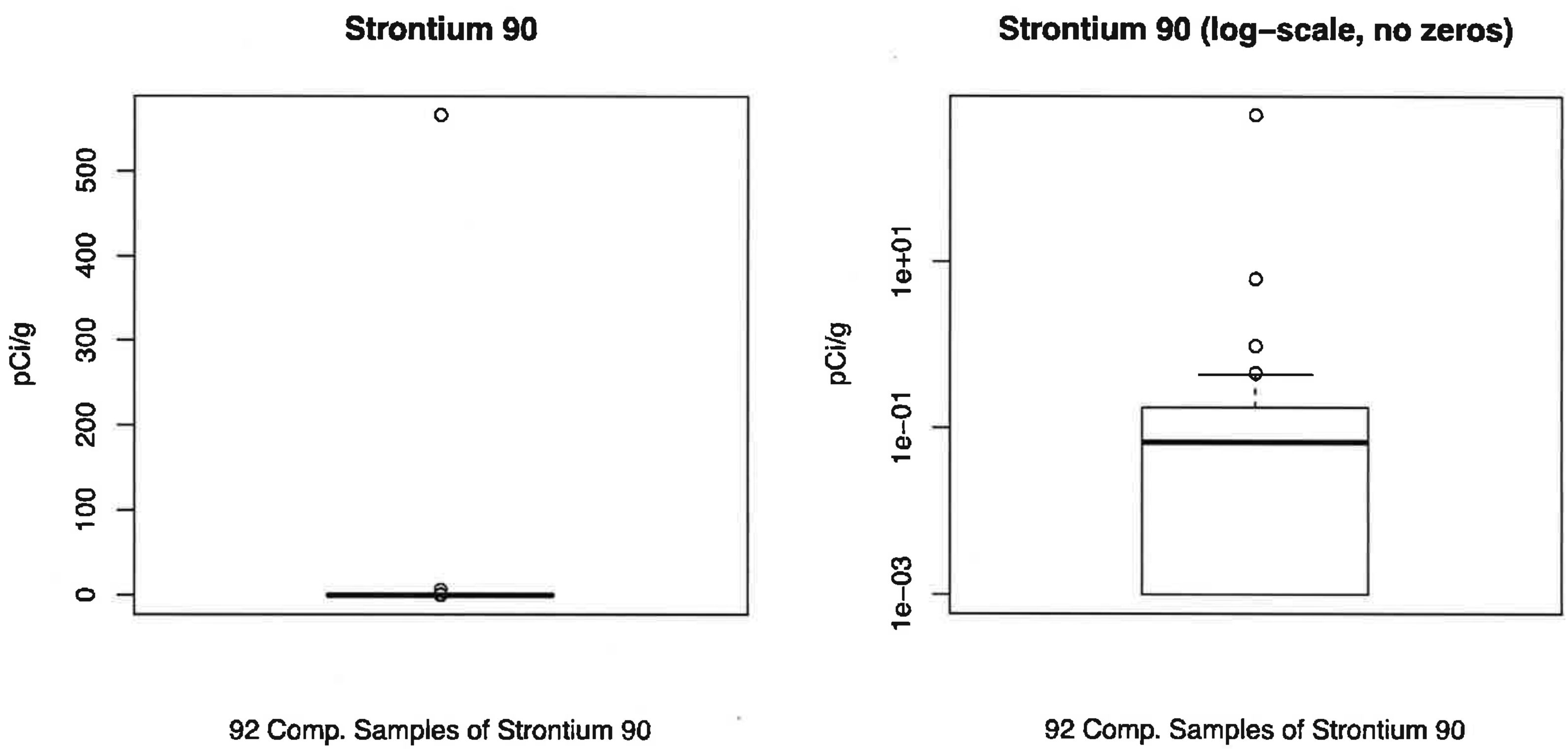


Figure B-9
Boxplots for Sr-90, MDA-B Data

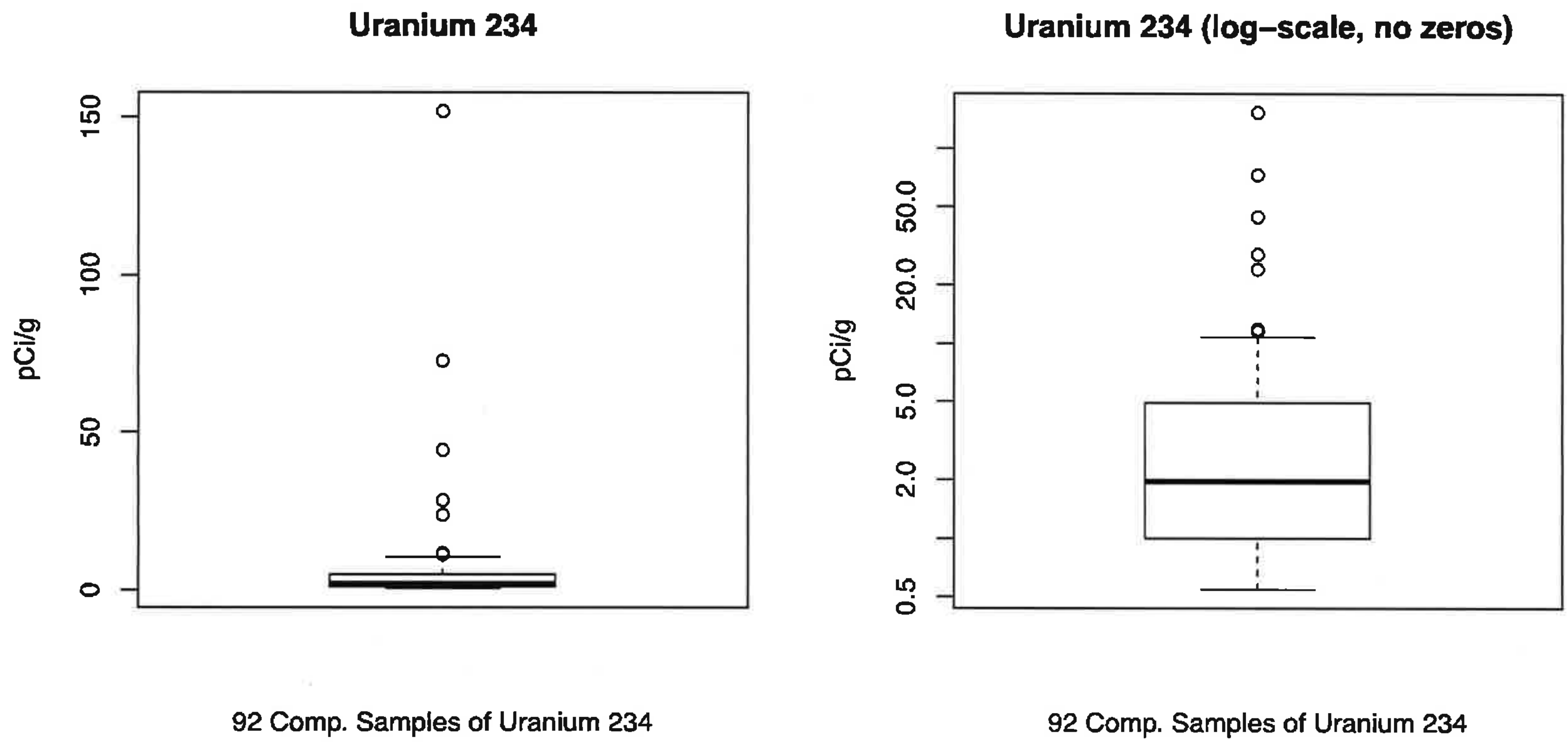


Figure B-10
Boxplots for U-234, MDA-B Data

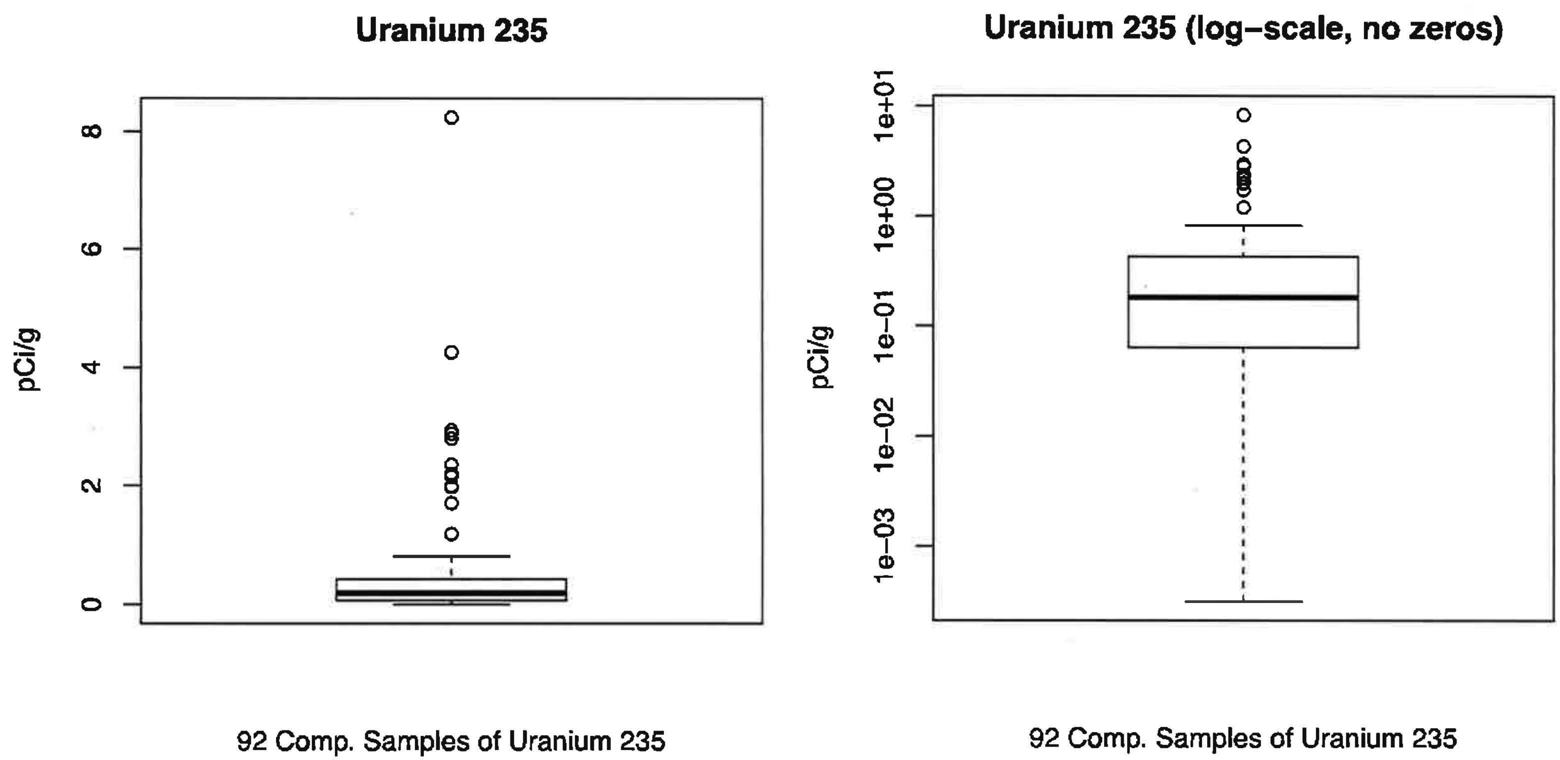


Figure B-11
Boxplots for U-235, MDA-B Data

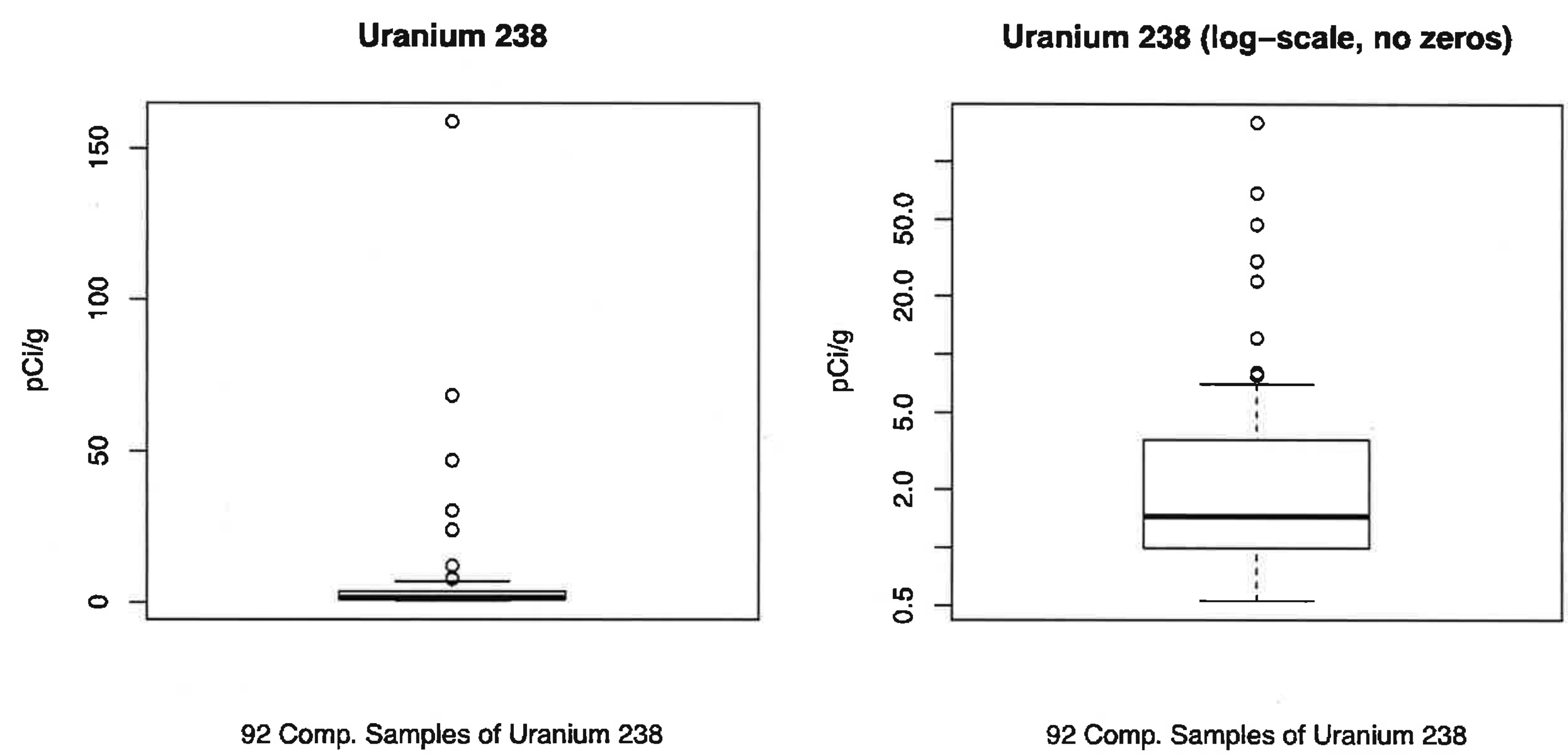


Figure B-12
Boxplots for U-238, MDA-B Data

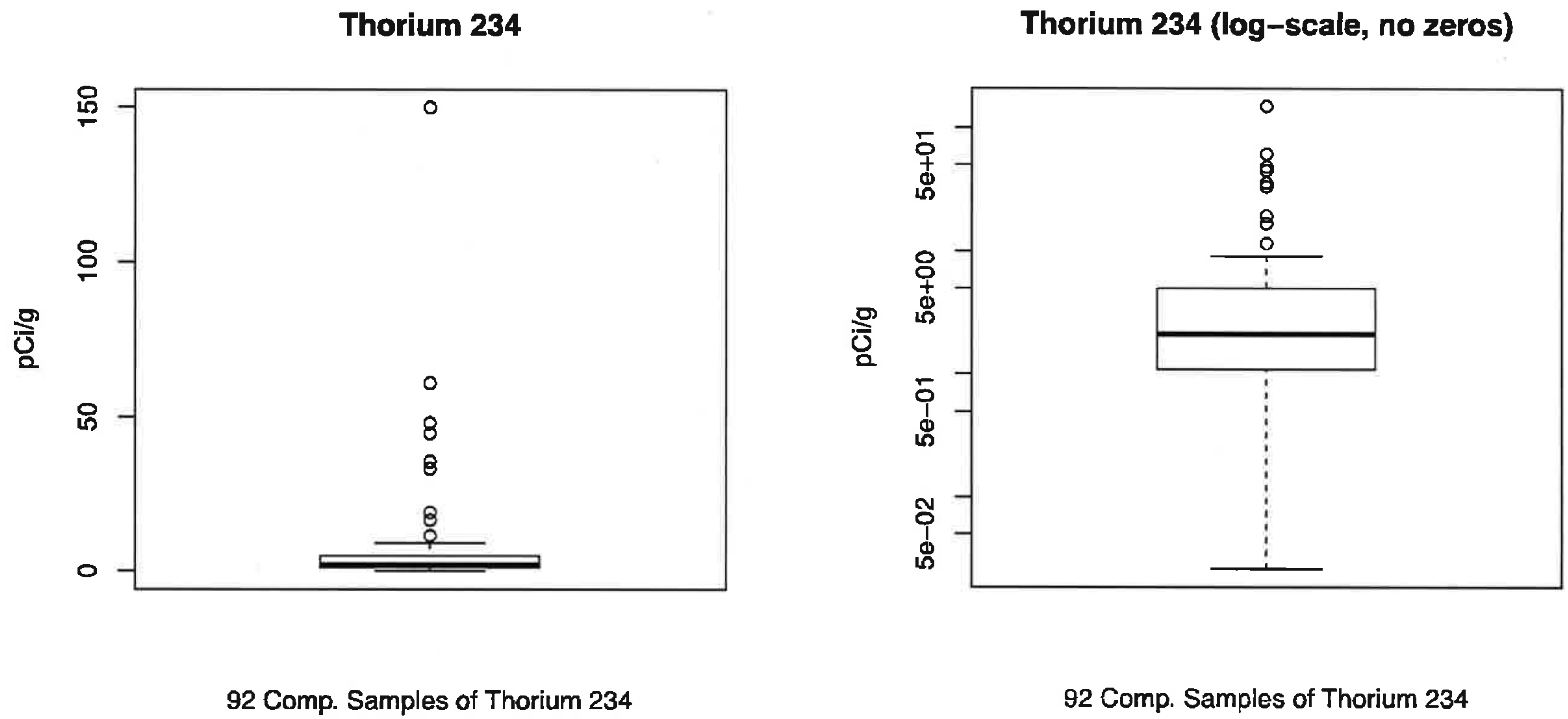


Figure B-13
Boxplots for Th-234, MDA-B Data

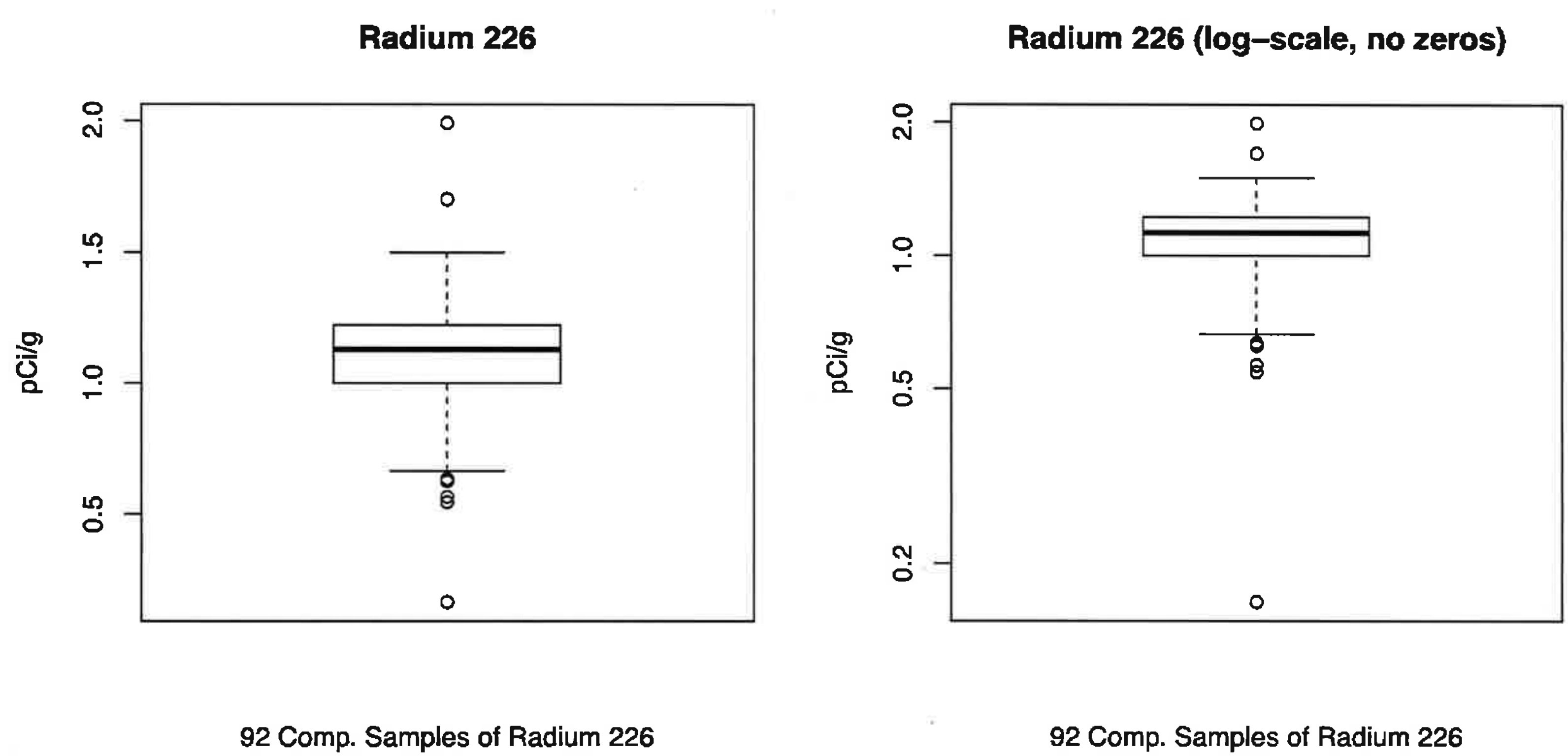
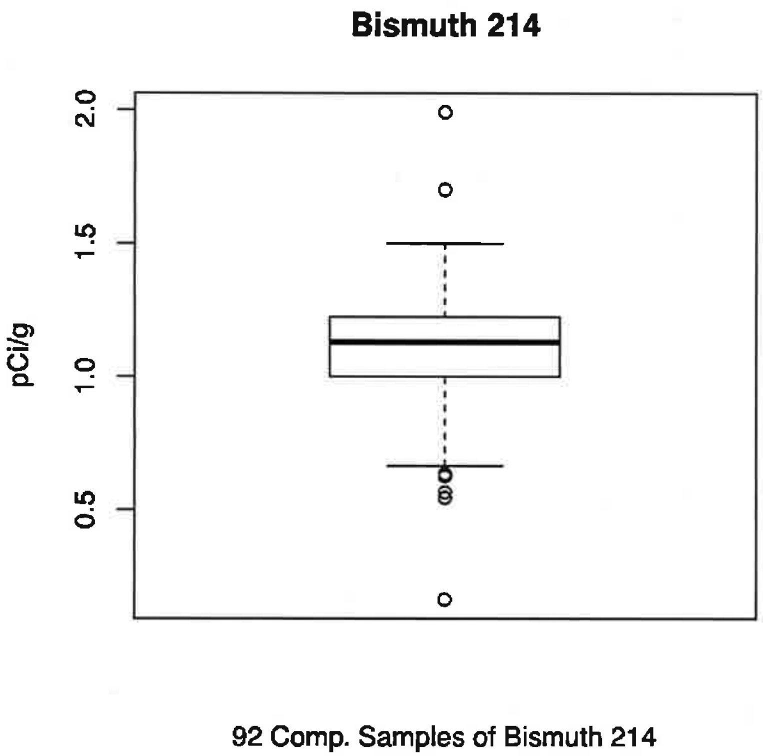


Figure B-14
Boxplots for R-226, MDA-B Data



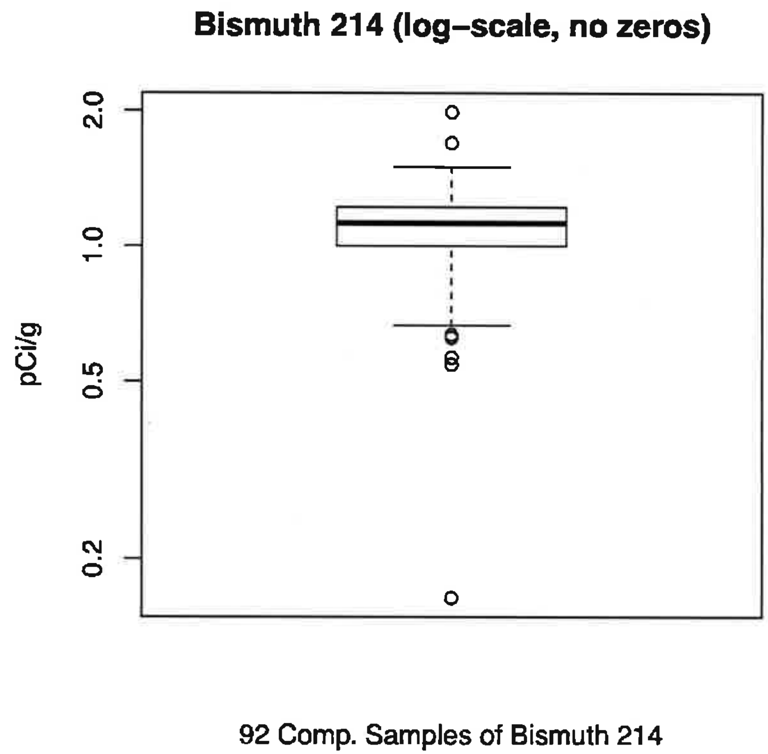


Figure B-15
Boxplots for Bi-214, MDA-B Data

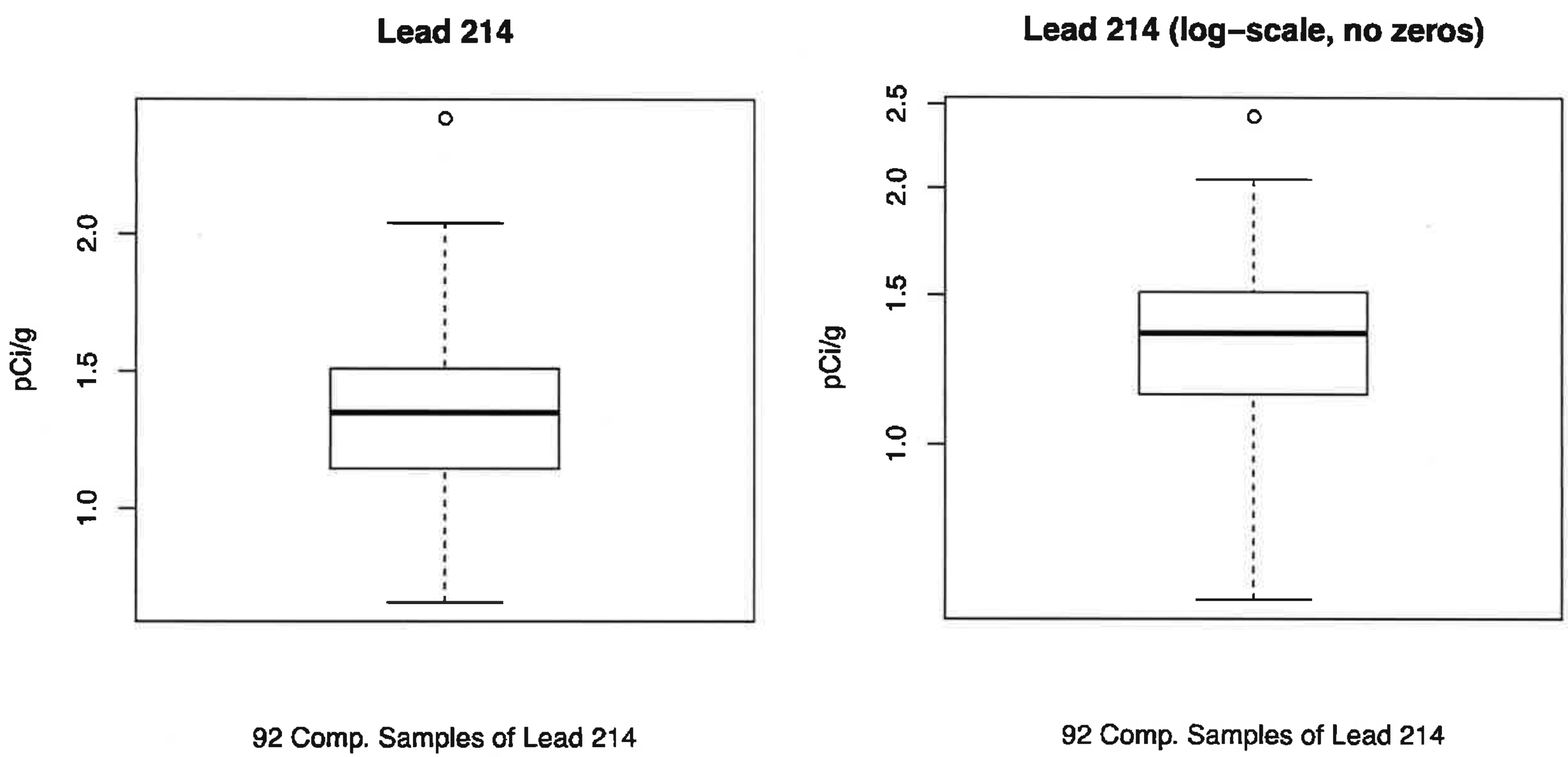


Figure B-16
Boxplots for Pb-214, MDA-B Data

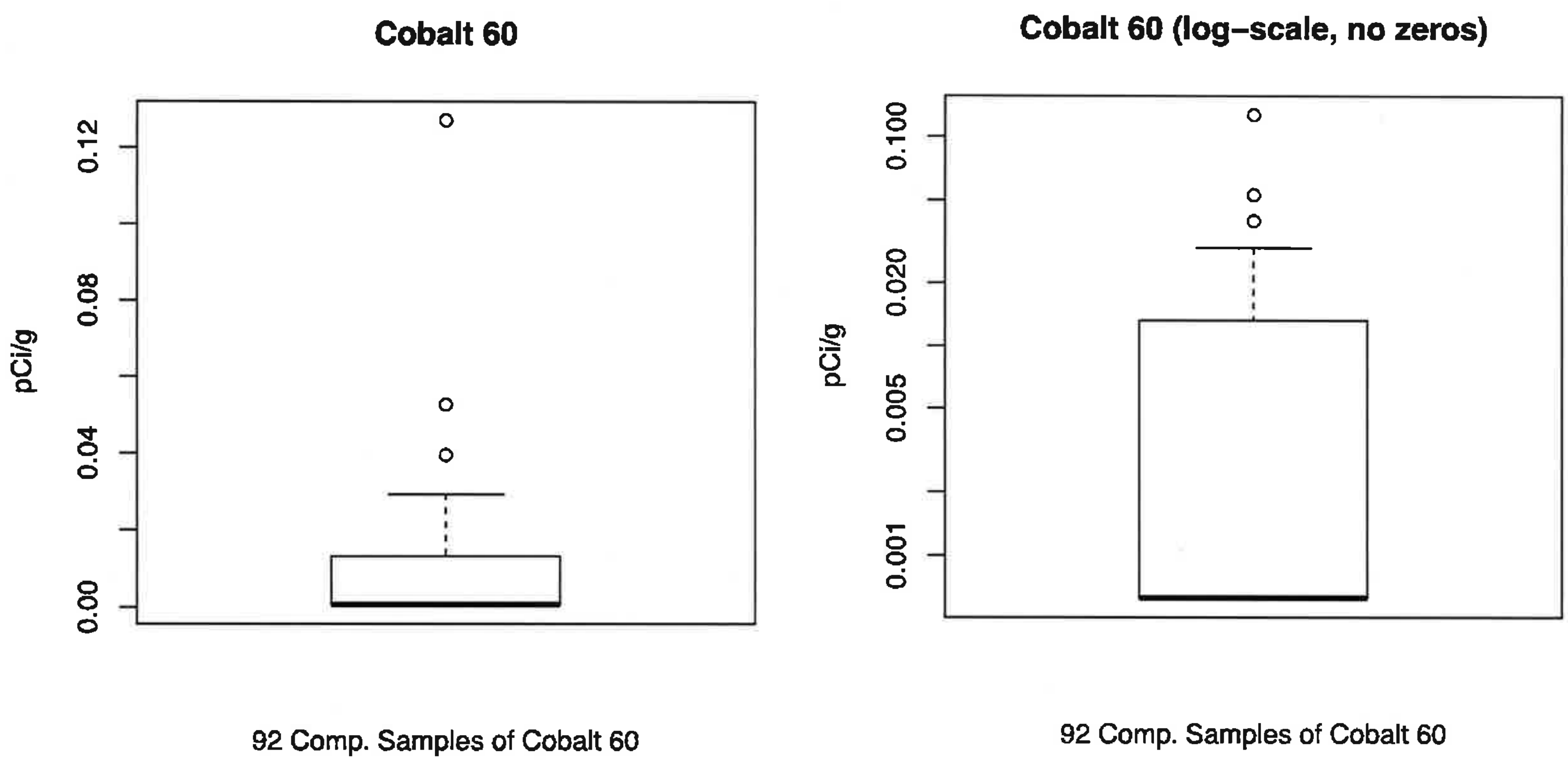


Figure B-17
Boxplots for Co-60, MDA-B Data

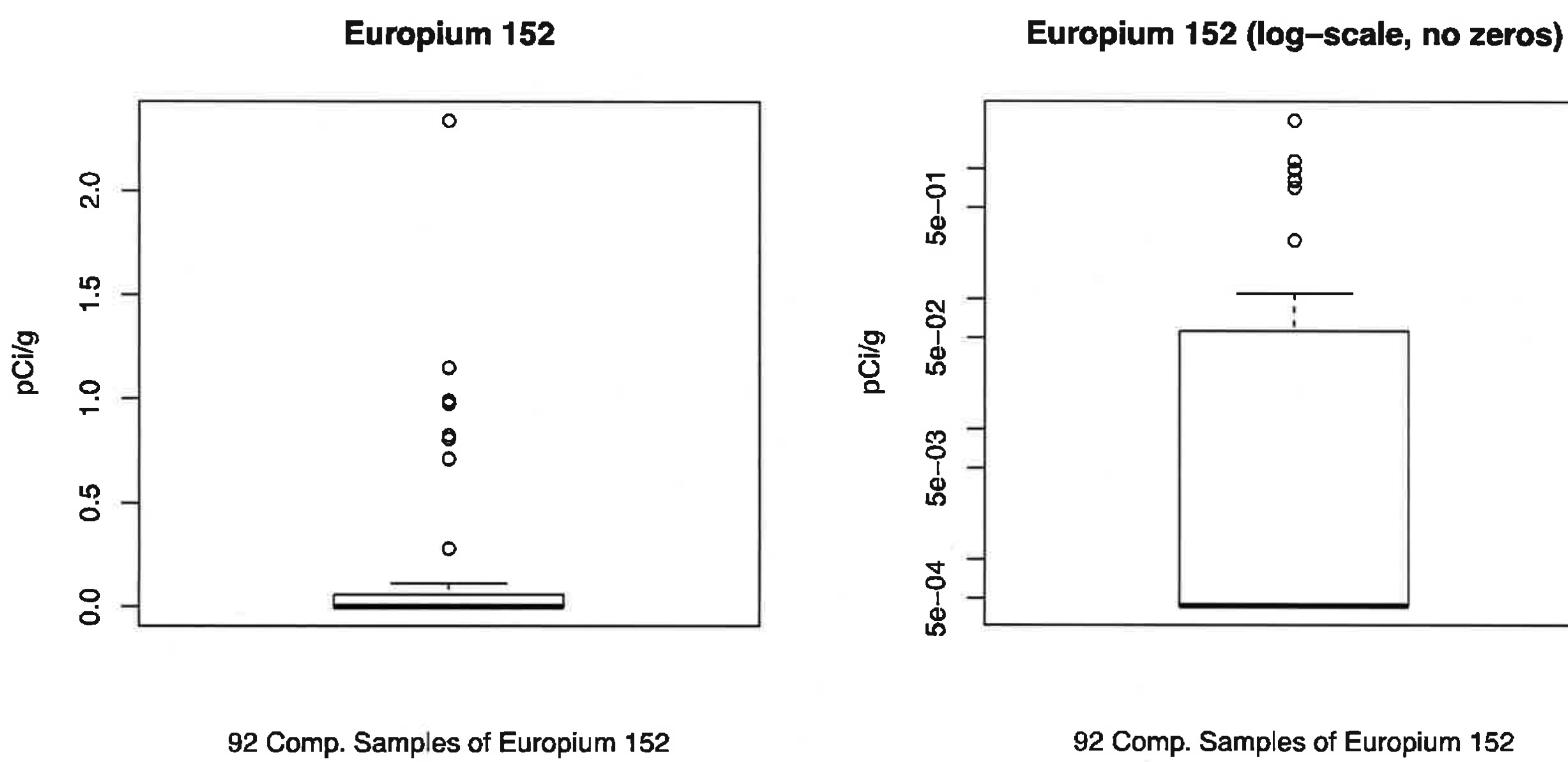


Figure B-18
Boxplots for Eu-152, MDA-B Data

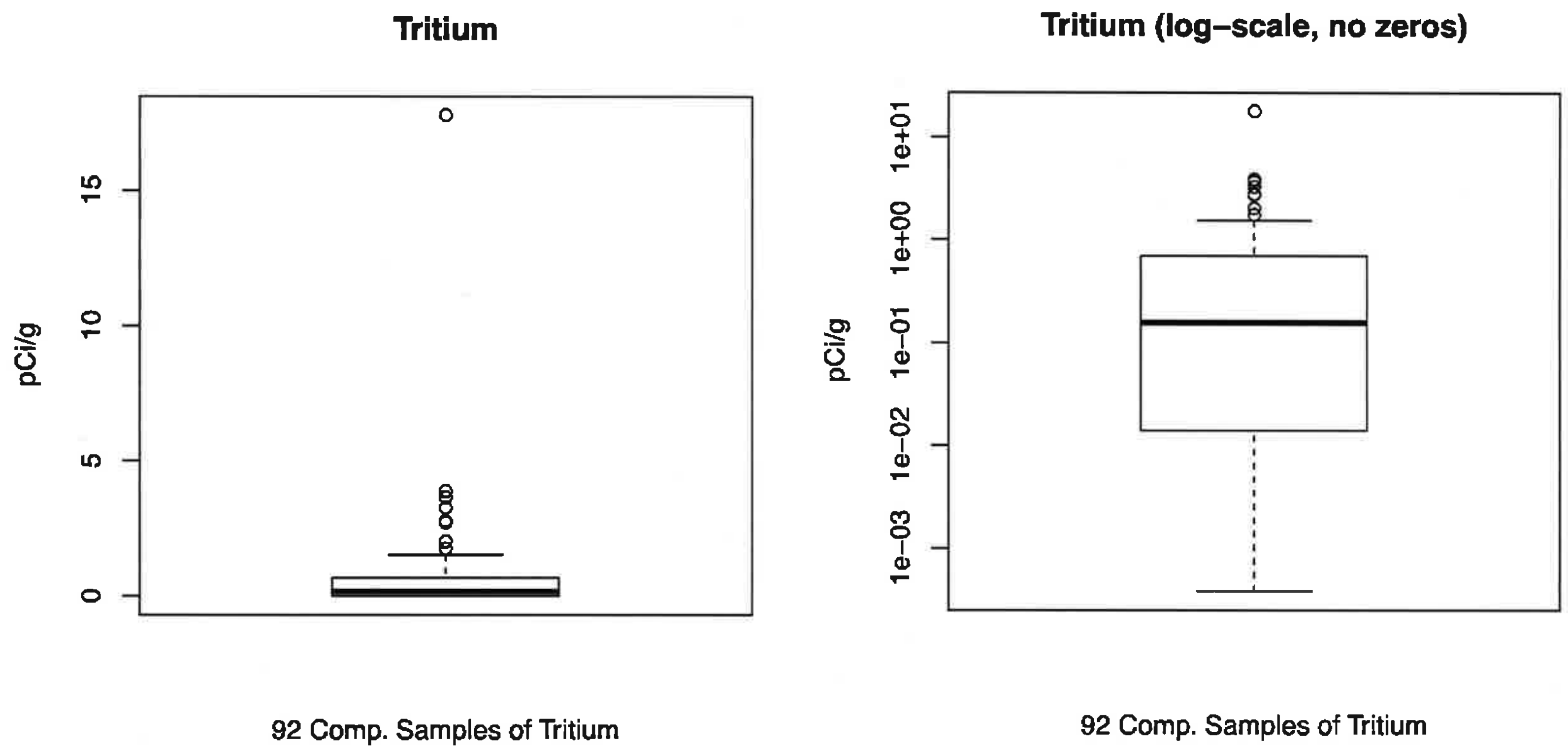
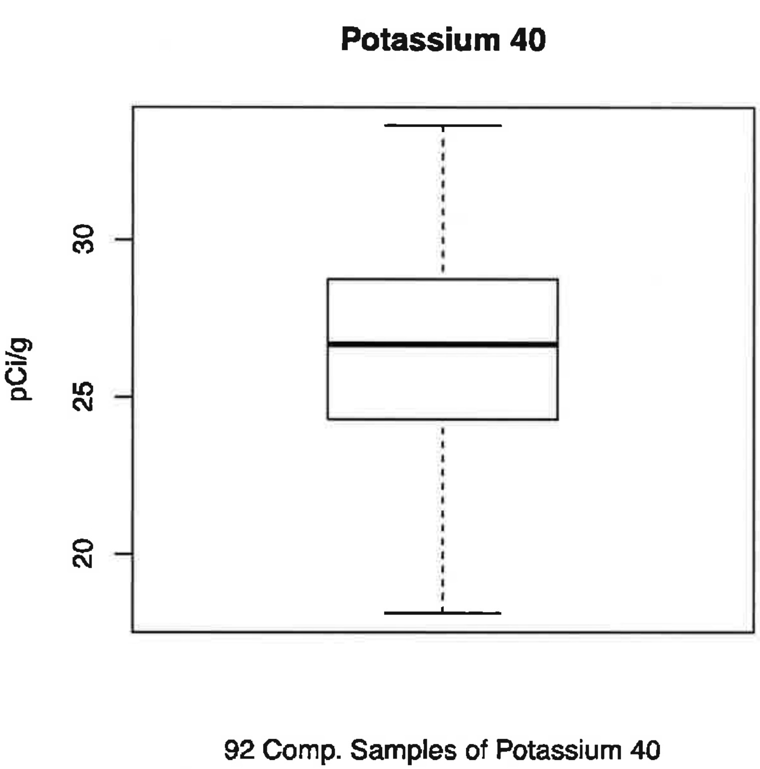


Figure B-19
Boxplots for Tritium, MDA-B Data



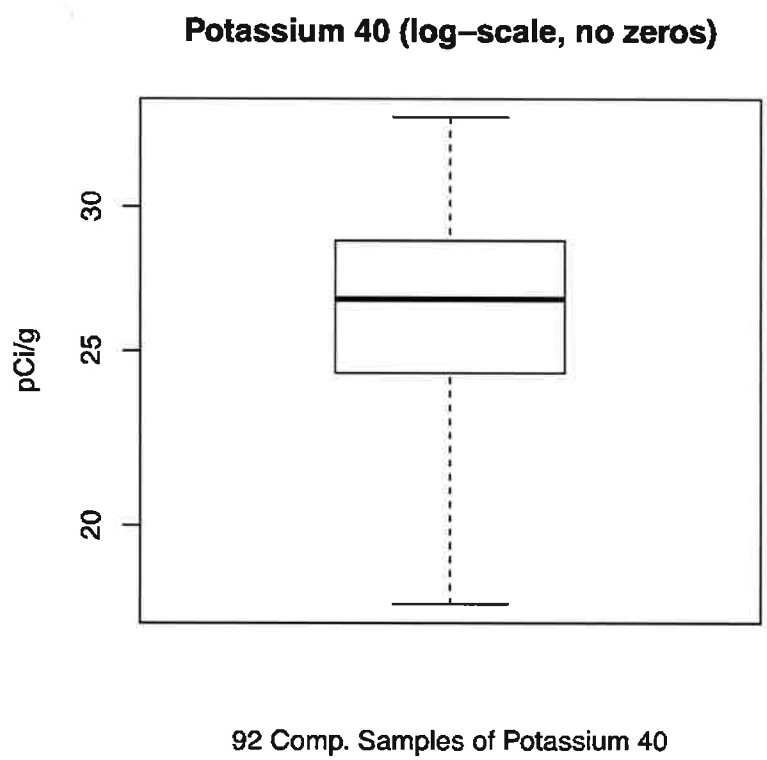
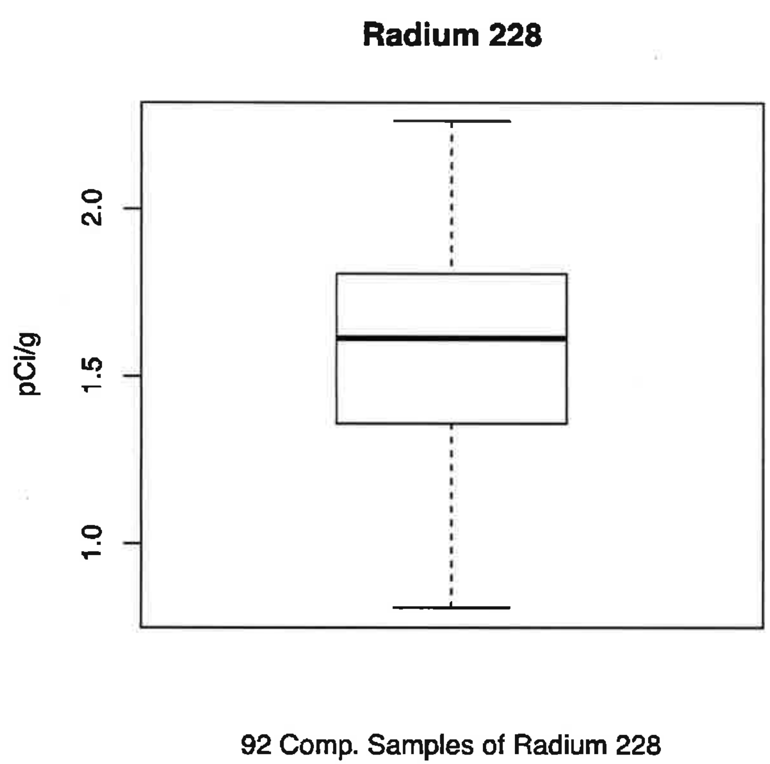


Figure B-20
Boxplots for K-40, MDA-B Data



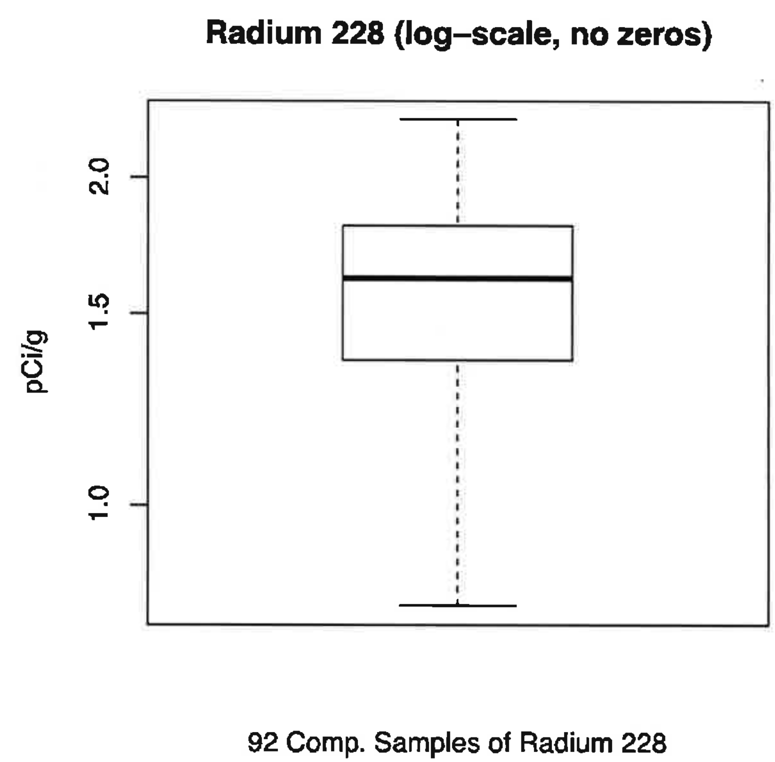


Figure B-21
Boxplots of Ra-228, MDA-B Data

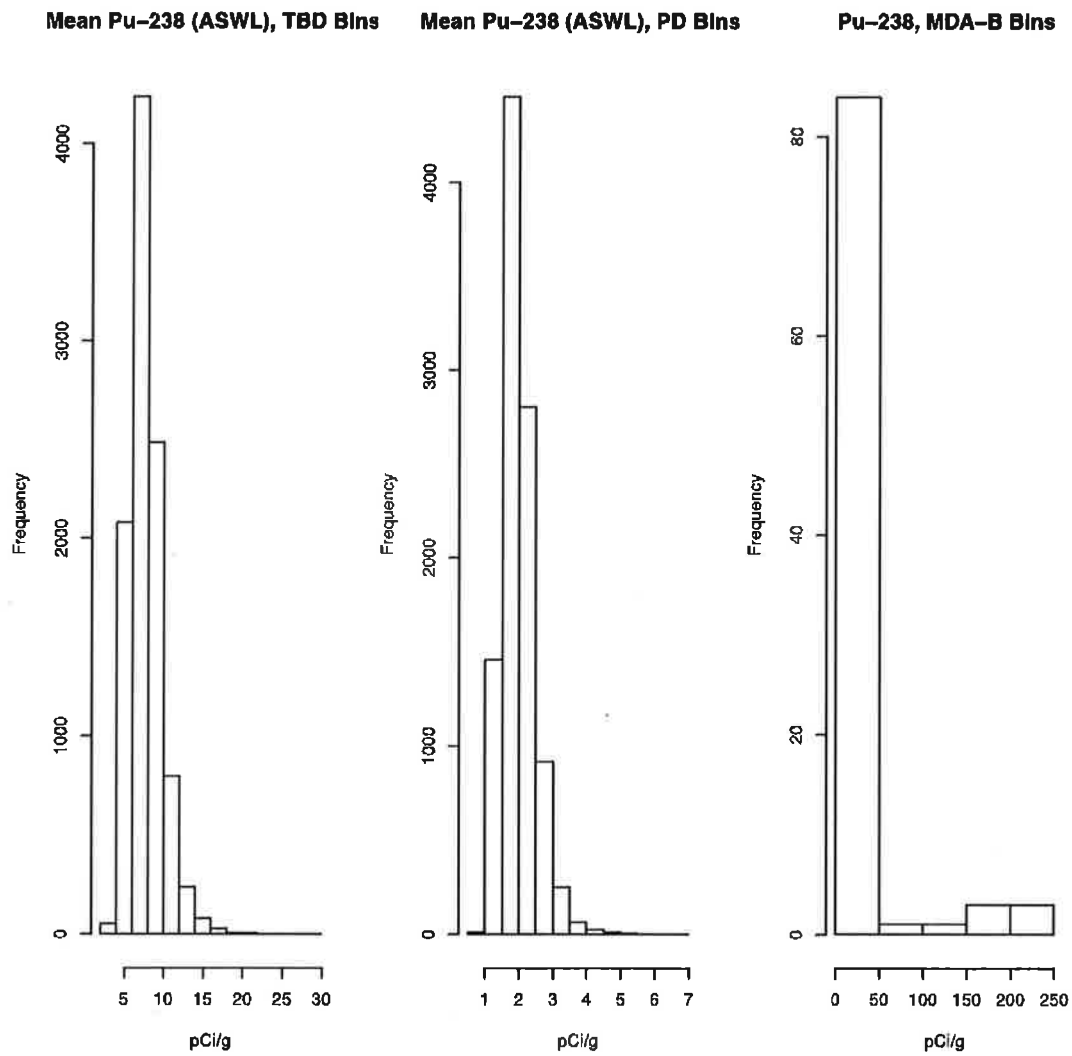


Figure B-22
Histograms of Pu-238 Simulated Means in Headspace and MDA-B Data

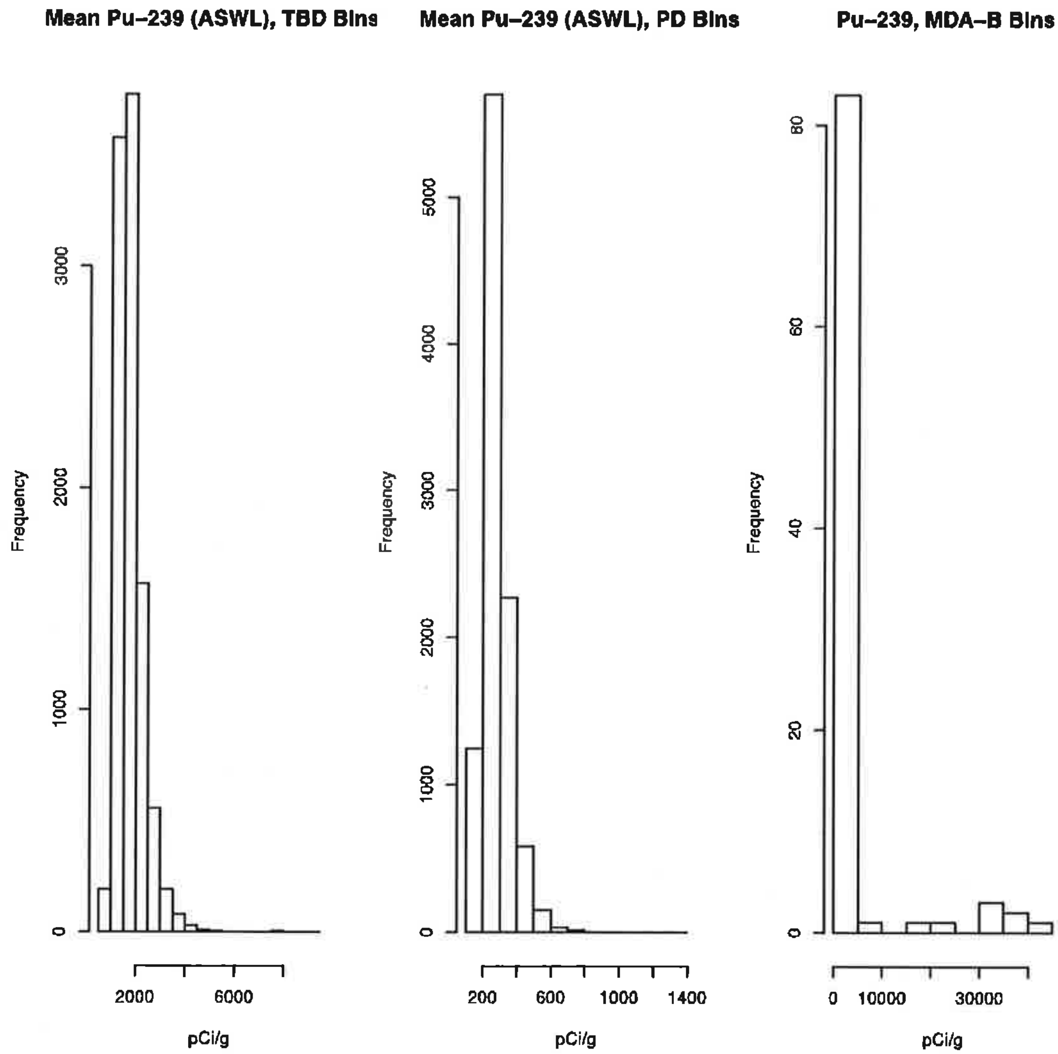


Figure B-23
Histograms of Pu-239/240 Simulated Means in Headspace and MDA-B Data

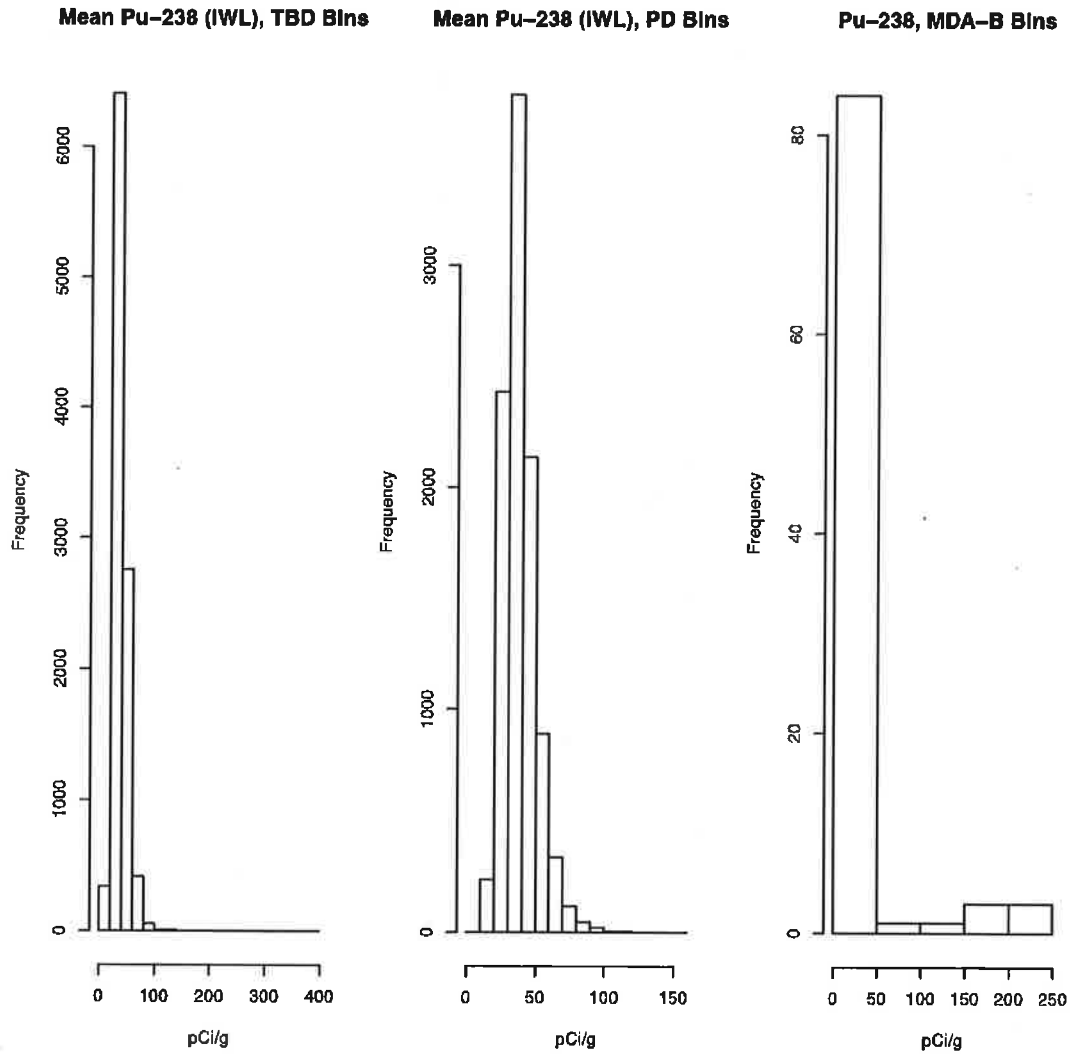


Figure B-24
Histograms of Pu-238 Simulated Means in Institutional Waste Layer and MDA-B Data

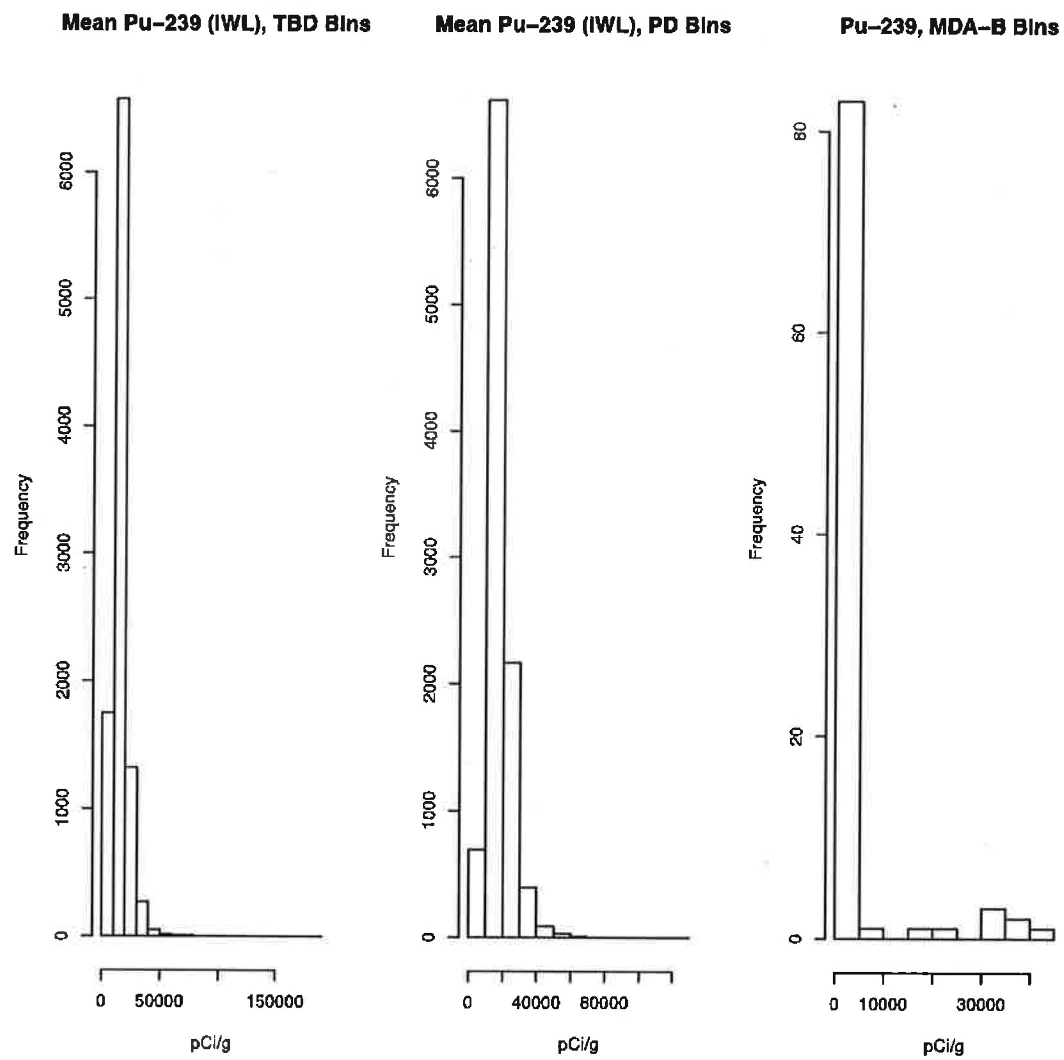


Figure B-25
Histograms of Pu-239/240 Simulated Means in Institutional Waste Layer and MDA-B Data

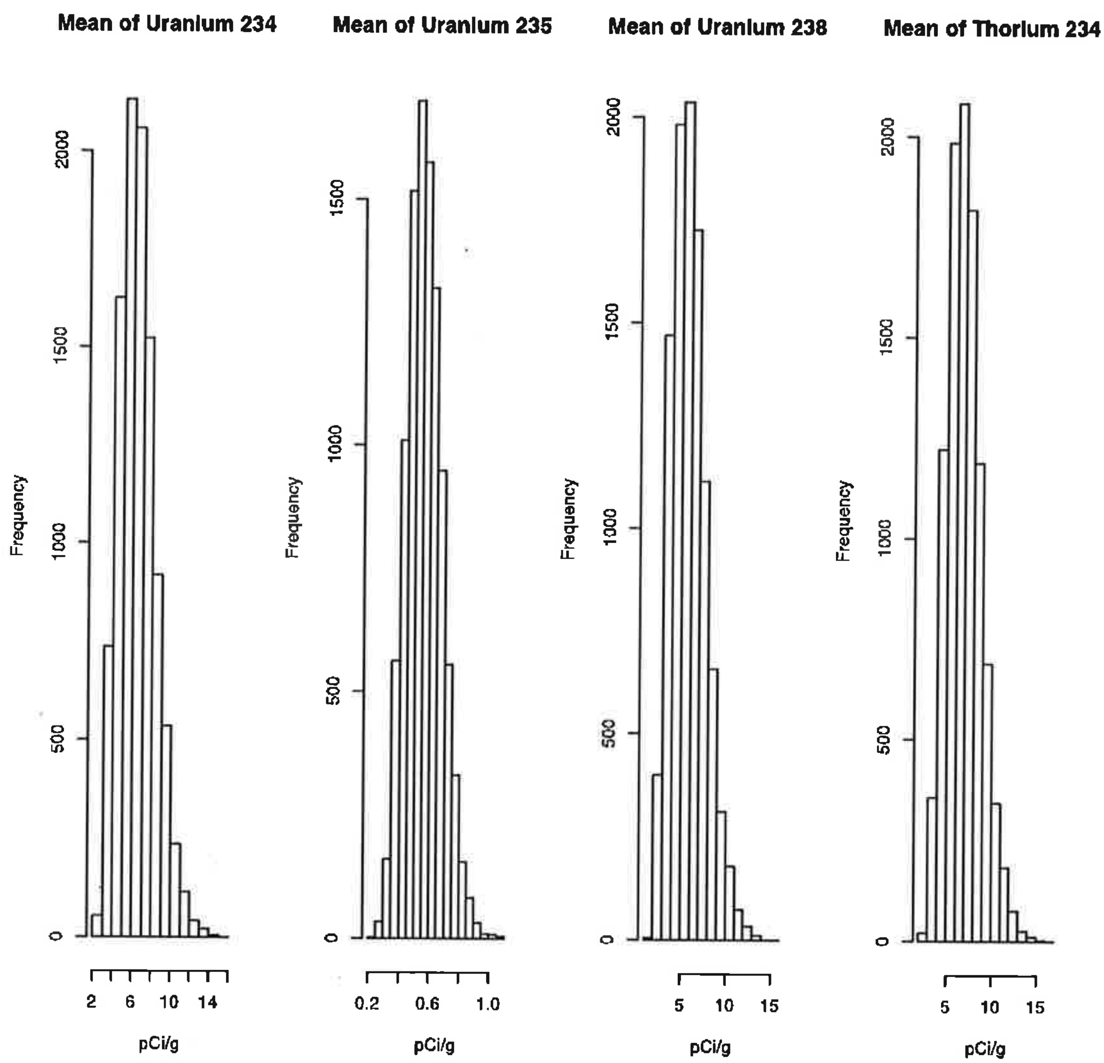


Figure B-26
Histograms of Simulated Means for U-234, U-235, U-238, Th-234

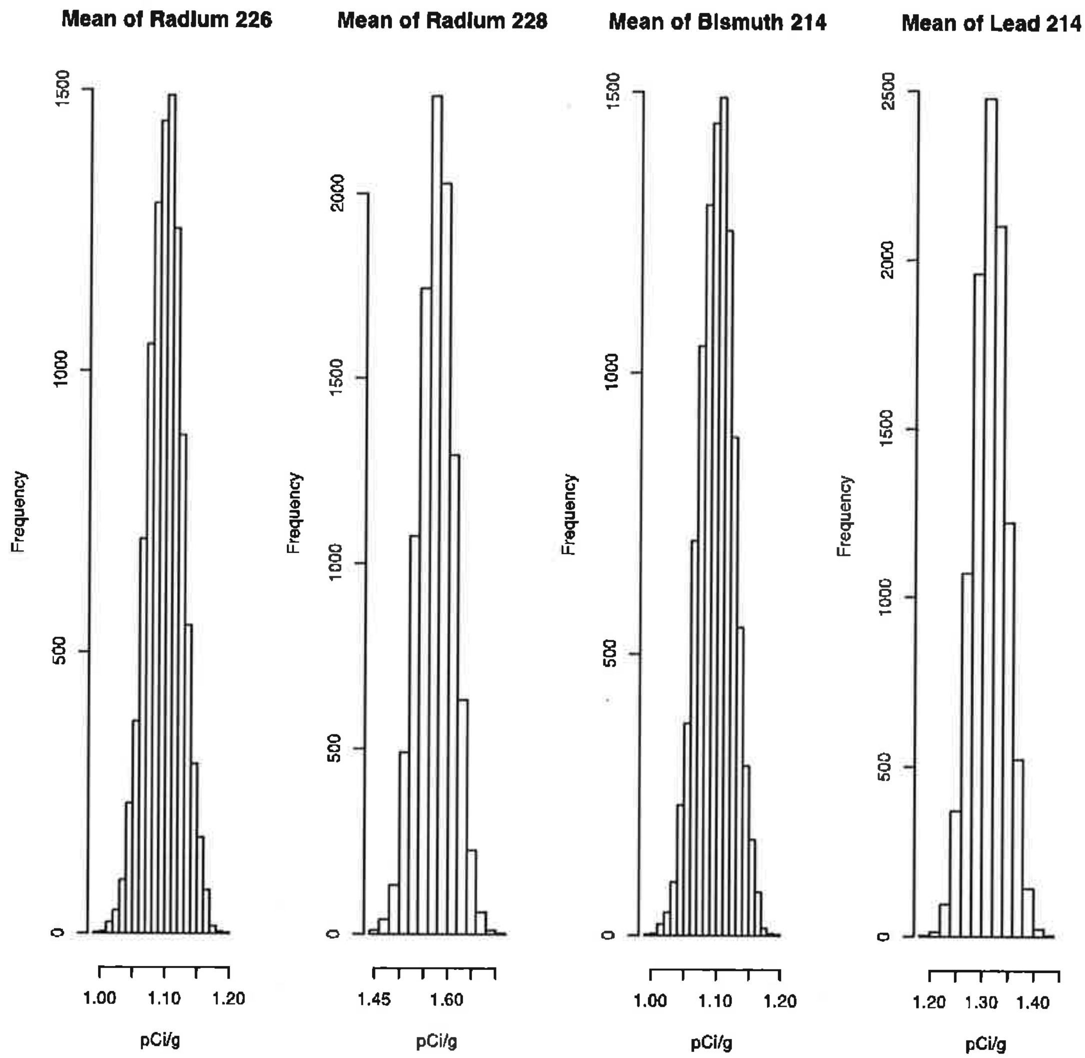


Figure B-27
Histograms of Simulated Means for Bi-214, Pb-214, Ra-226, and Ra-228

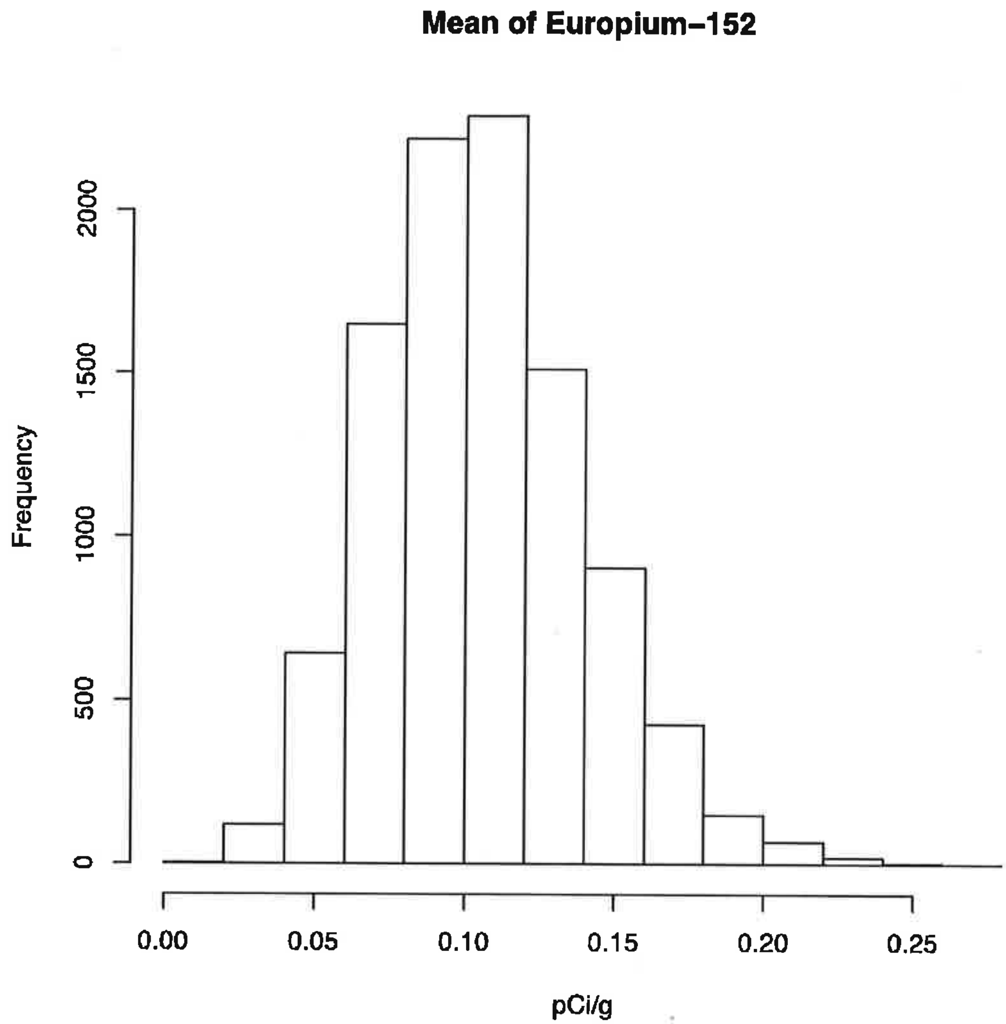


Figure B-28
Histogram of Simulated Means for Eu-152

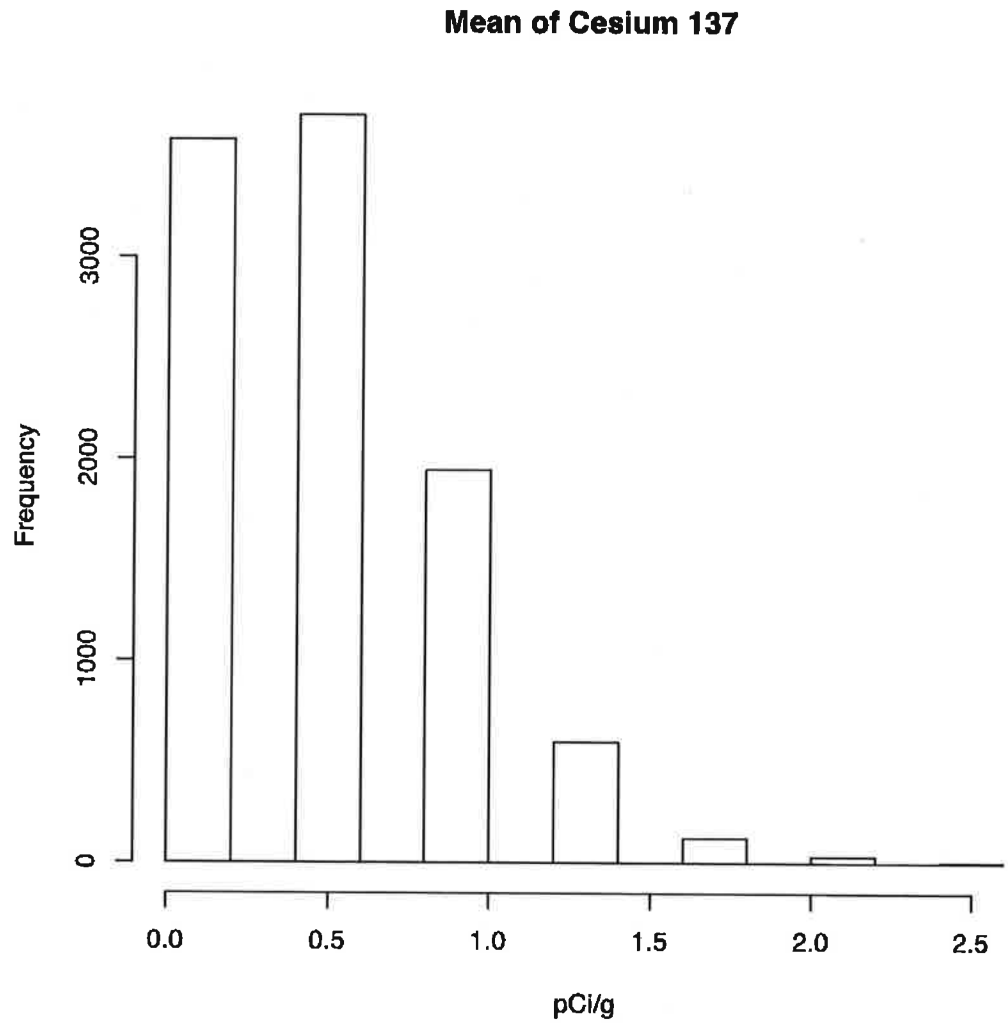


Figure B-29
Histogram of Simulated Means for Cs-137

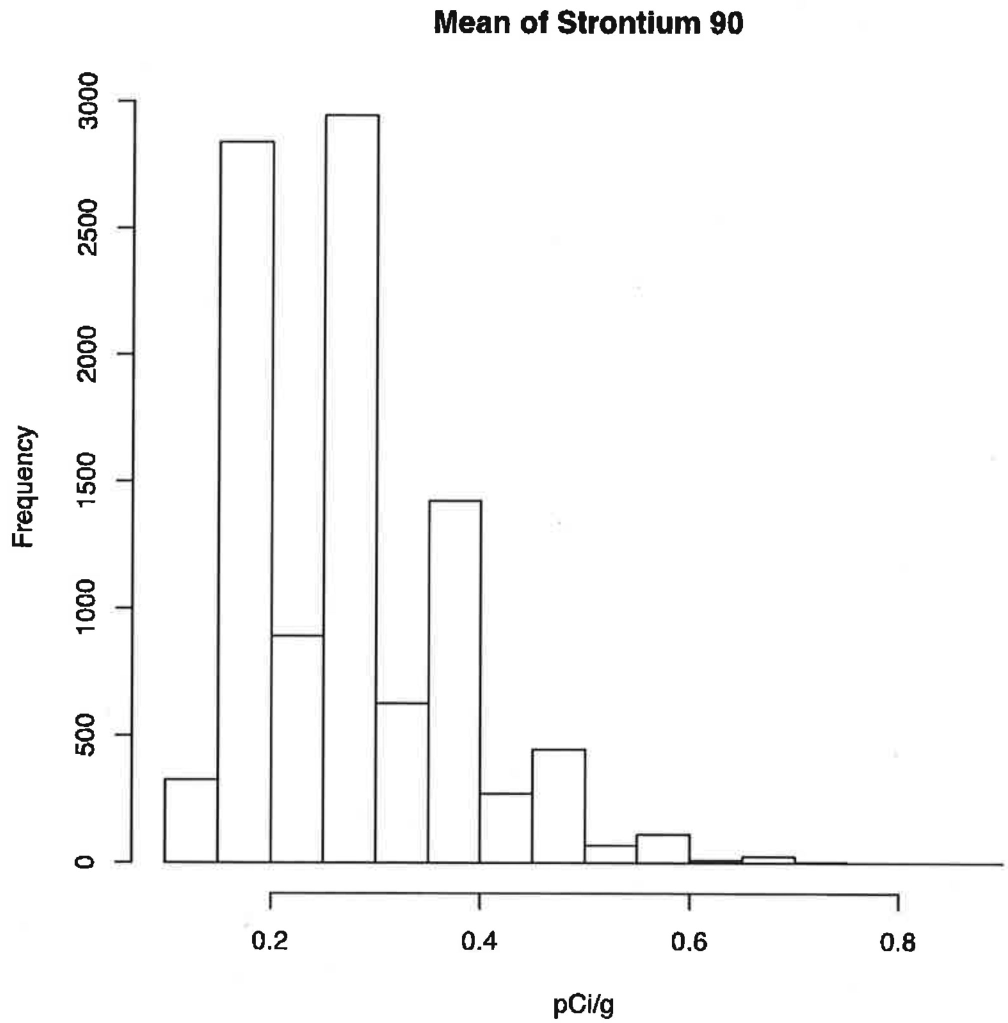


Figure B-30
Histogram of Simulated Means for Sr-90

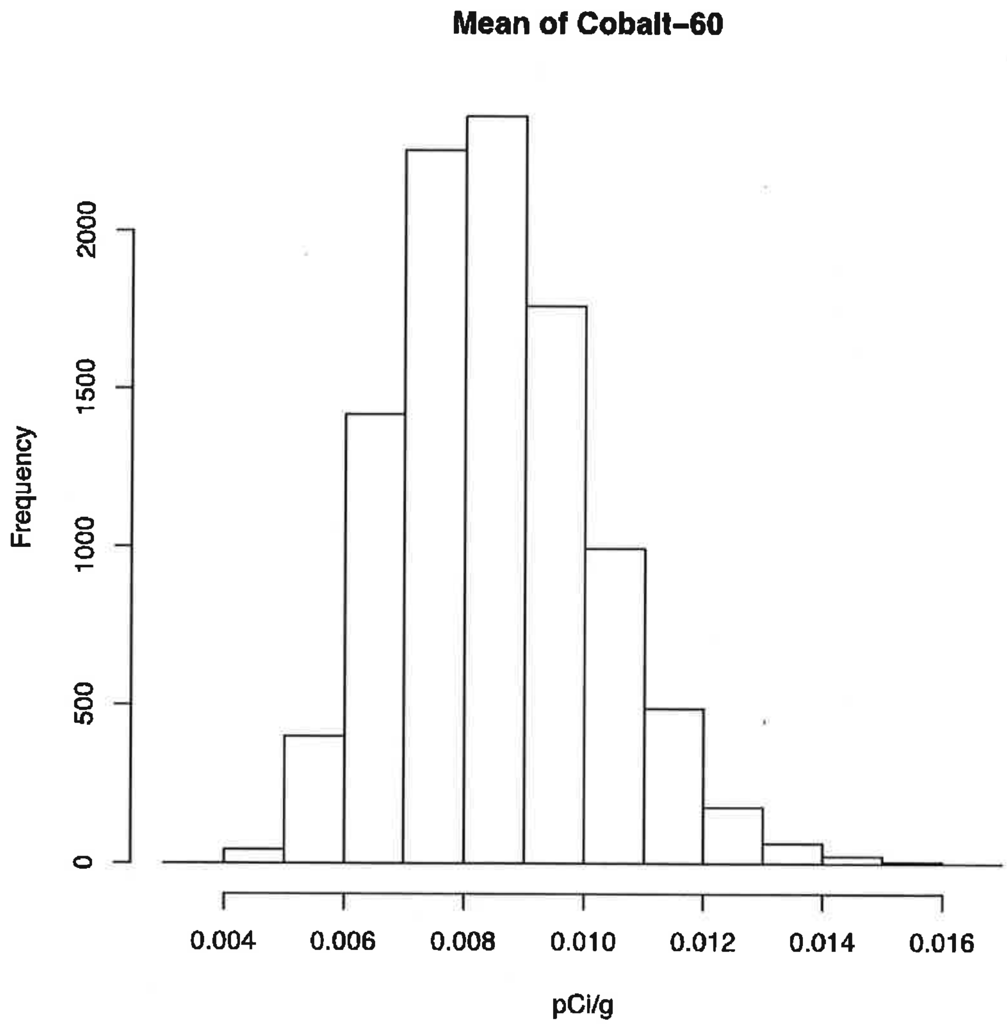


Figure B-31
Histogram of Simulated Means for Co-60

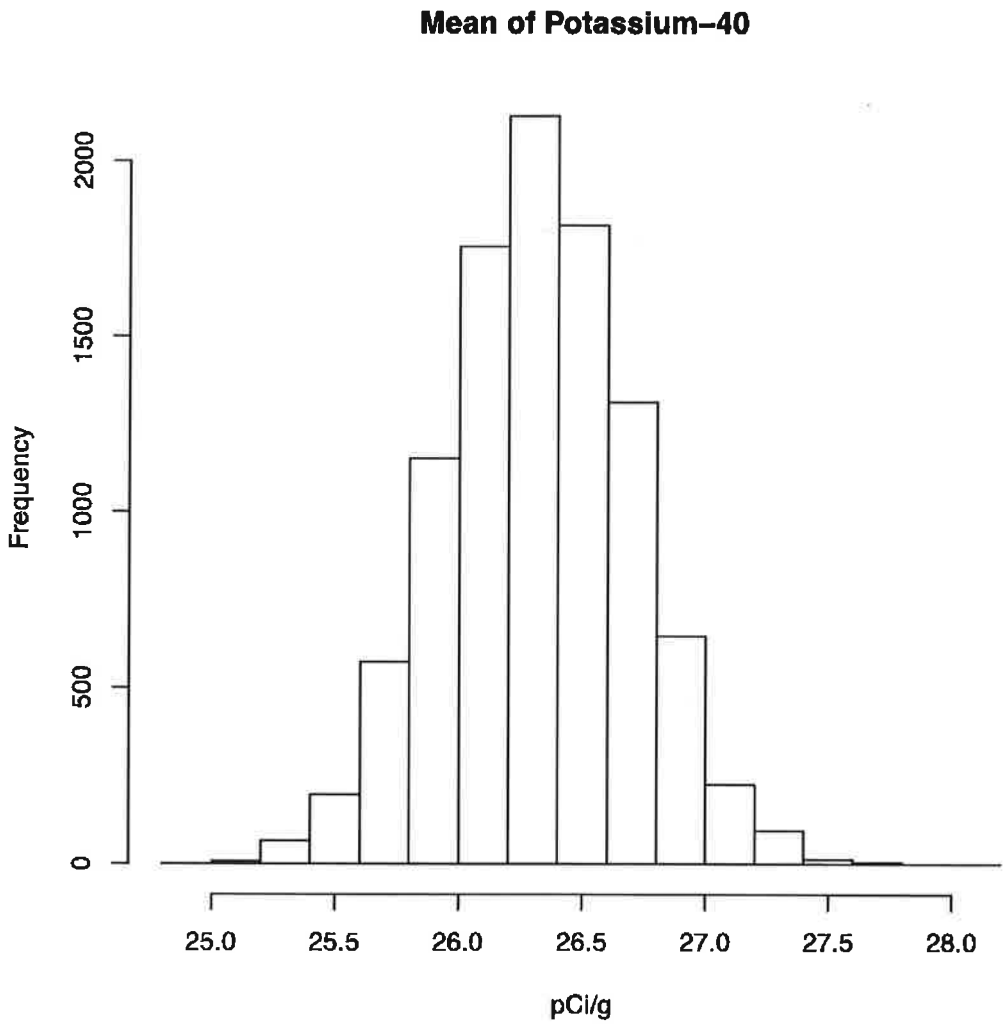


Figure B-32
Histogram of Simulated Means for K-40

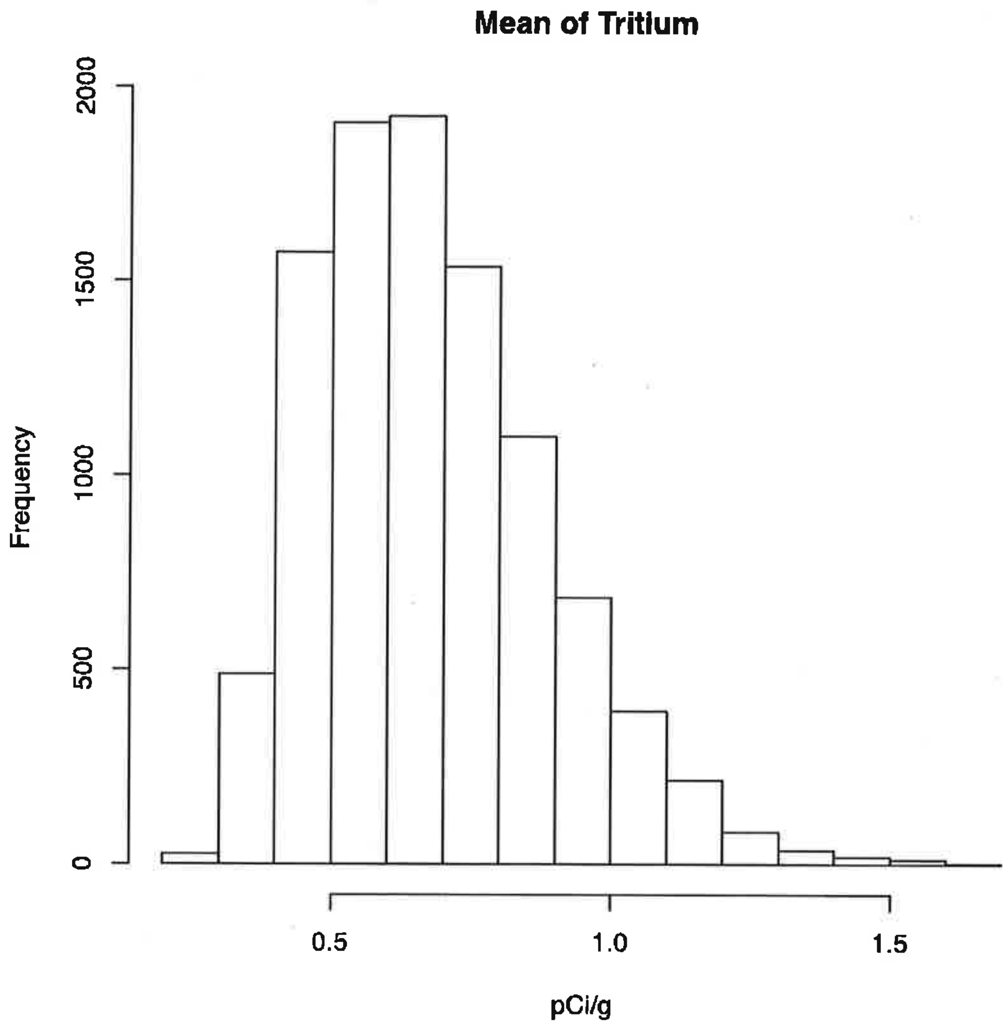


Figure B-33
Histogram of Simulated Means for Tritium

Appendix C
Unreviewed Disposal Question Evaluation 1206: Disposal of LLW in Pit 38 and Pit 38 Extension

ATTACHMENT 1
Page 1 of 3

UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet	
8.1[1] UDQE Number: 1206	8.1[2] Date: 05-Jun-2012
Section 1: Proposed Activity	
8.1[3] Disposal of LLW in Pit 38 and Pit 38 Extension.	
8.1[4]Section 1.1: Summary description of activity/change ~~USQD~~ UDQE SF, 6-12-12 1203 and SA 2012-003 considered the impact of constructing an extension to LLW disposal pit 38. LASO approved construction of the pit 38 extension in a letter from Juan Griego to Michael Graham dated March 29, 2012 (ERID-520068). This UDQE (1206) considers disposal of LLW within the remaining, available disposal capacity in Pit 38 (proper) and the Pit 38 Extension.	
8.1 [6] Section 1.2: Reference UDQE 1203, *Pit 38 Expansion* Special Analysis 2012-003, *Extension of Disposal Pit 38 at Technical Area 54, Area G* ERID-520068, *Authorization to Construct an Extension to Pit 38 within Material Disposal Area G at Technical Area 54*	

8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?	☐ YES	☒ NO
8.1[8][A][a] UDQE No.:	Date of UDQE:	
8.1[8][A][b] Justification for not requiring a UDQE n/a		

ATTACHMENT 1
Page 2 of 3

UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1206	8.1[2] Date: 05-Jun-2012		
8.1[10]	**Section 2: UDQE– Screening**		
2.1	Waste Characteristics	☐ Not Applicable	
a.	Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?	☒ YES	☐ NO
b.	Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?	☒ YES	☐ NO
c.	Does the proposed activity involve the retrieval of below ground waste?	☐ YES	☒ NO
2.2	Disposal Practices SF, 6-12-12	☒ Not Applicable	
a.	Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?	☐ YES	☒ NO
b.	Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?	☐ YES	☒ NO
2.3	Procedures /Documents/Systems	☐ Not Applicable	
a.	Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?	☐ YES	☒ NO
b.	Does the activity invoke changes to DAS?	☐ YES	☒ NO
c.	Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?	☒ YES	☐ NO
2.4	Site/Facility Construction	☒ Not Applicable	
a.	Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?	☐ YES	☐ NO
b.	Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?	☐ YES	☐ NO
c.	Does the proposed activity involve the drilling of new boreholes or monitoring wells?	☐ YES	☐ NO
d.	Will the proposed activity require changes in site grading or storm waste runoff control provisions?	☐ YES	☐ NO
2.5	New Disposal Unit Construction	☒ Not Applicable	
a.	Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.	☐ YES	☐ NO
b.	Is there construction of new site structures or facilities?	☐ YES	☐ NO
c.	Is there contruction activities for removal of existing site structures or features?	☐ YES	☐ NO
d.	Is there construction activities for creation of new disposal units (pits and shafts)?	☐ YES	☐ NO
2.6	Interim/ Final Disposal Unit Closure	☒ Not Applicable	
a.	Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?	☐ YES	☐ NO
b.	Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.	☐ YES	☐ NO
c.	Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?	☐ YES	☐ NO

ATTACHMENT 1
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8.1[1] UDQE Number: 1206	8.1[2] Date: 05-Jun-2012
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.	

Section 3: UDQ Evaluation Summary and Approval

UDQ Number: 1206	Date: 05-Jun-2012

8.1[11] ☐ This activity/change does not (all responses are "No") constitute a UDQ

☒ This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change

8.1[12] UDQ Evaluator

Name (Print) Sean French	Signature: [signature]	Date: 6-12-2012

8.1[13] UDQE Reviewer

Name (Print)Rob Shuman	Signature: Rob Shuman	Date: 6.13.2012

ADC: ☒ Unclassified ☐ OUO ☐ UCNI ☐ Classified

Derivative Classifier

Name (Print) Sean French	Signature: [signature]	Date: 6-12-2012

Section 4 FINAL APPROVAL

8.1[19]/9.[7] LLW Operations Manager:

Name (Print)	Signature:	Date: