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Special Analysis for the Disposal of the Lawrence Livermore National Laboratory Low Activity Beta/Gamma Sources Waste Stream at the Area 5 Radioactive Waste Management Site, Nevada National Security Site, Nye County, Nevada

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Acronyms and Abbreviations

Bq	Bequerel(s)
Ci	Curie(s)
FY	(Federal) fiscal year
LHS	Latin hypercube sample
LLNL	Lawrence Livermore National Laboratory
NNSS	Nevada National Security Site
PA	Performance Assessment
RWMS	Radioactive Waste Management Site
SA	Special Analysis
SLB	Shallow land burial
TED	Total effective dose
UGTA	Underground Test Area
WAC	Waste Acceptance Criteria
yr	year(s)

1.0 Introduction

This special analysis (SA) evaluates whether the Lawrence Livermore National Laboratory (LLNL) Low Activity Beta/Gamma Sources waste stream (BCLALADOEOSRP, Revision 0) is suitable for disposal by shallow land burial (SLB) at the Area 5 Radioactive Waste Management Site (RWMS) at the Nevada National Security Site (NNSS). The LLNL Low Activity Beta/Gamma Sources waste stream consists of sealed sources that are no longer needed (LLNL 2015a). The LLNL Low Activity Beta/Gamma Sources waste stream required a special analysis because cobalt-60 (^{60}Co), strontium-90 (^{90}Sr), cesium-137 (^{137}Cs), and radium-226 (^{226}Ra) exceeded the NNSS Waste Acceptance Criteria (WAC) Action Levels (U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office [NNSA/NFO] 2015).

2.0 Methods

The SA evaluates the impact of the LLNL Low Activity Beta/Gamma Sources waste stream inventory on the long-term performance of the Area 5 RWMS.

2.1 Waste Description

The LLNL Low Activity Beta/Gamma Sources waste stream consists of sealed sources that are no longer needed and cannot be transferred or reused. The sources are recovered from universities, hospitals, and commercial facilities in the interest of national security and public health and safety by the Department of Energy (DOE)/NNSA Off-Site Source Recovery Project. The waste stream is limited to radioactive sources that can be shipped in U.S. Department of Transportation Type A containers.

The LLNL Low Activity Beta/Gamma Sources waste stream includes four radionuclides that exceed their action levels. One radionuclide, ^{226}Ra, exceeds its action level by orders of magnitude more than the other nuclides. Therefore, the generator was requested to list ^{226}Ra sources identified for disposal. The generator identified 1.5E10 bequerels (Bq) (0.42 curies [Ci]) of ^{226}Ra sources for disposal and requested to dispose of an activity up to three times this value (LLNL 2015b). This total inventory was rounded up to 5.5E10 Bq (1.5 Ci) and analyzed in the SA. The waste stream inventory is small compared to the activity already disposed though Fiscal Year (FY) 2014 in the shallow land burial (SLB) trenches, except for ^{137}Cs inventory which may increase approximately 24% (Table 1). The estimated LLNL Low Activity Beta/Gamma Sources ^{226}Ra inventory represents 4.6 percent of the total inventory disposed.

Table 1. Comparison of LLNL Low Activity Beta/Gamma Sources Waste Stream Inventory and the Disposed Inventory of Radionuclides Exceeding their Action Levels (NSTEC 2015)

Nuclide	FY14 Disposed Post-1988 SLB Geometric Mean Disposed Inventory (Bq)	BCLALADOEOSRP_0 Geometric Mean Inventory (Bq)	% Change
^{60}Co	5.8E+14	4.20E+13	+7.2
^{90}Sr	2.6E+16	4.80E+13	+0.2
^{137}Cs	1.6E+15	3.88E+14	+24
^{226}Ra	1.2E+12	5.55E+10	+4.6

2.2 Performance Assessment Modeling

The performance assessment (PA) modeling is performed by adding the inventory of the LLNL Low Activity Beta/Gamma Sources waste stream to the current baseline PA model (A5 RWMS version [v] 4.119) and determining if there is a reasonable expectation of meeting the U.S. Department of Energy (DOE) Manual DOE M 435.1-1, "Radioactive Waste Management Manual," Chapter IV, Section P performance objectives (DOE 1999).

The LLNL Low Activity Beta/Gamma Sources waste stream radionuclide inventory is estimated from the waste profile sheet, except for ^{226}Ra, which is based on a generator estimate of the potential future inventory (LLNL 2015a, b). The waste stream radionuclide concentrations are assumed to be lognormally distributed. The geometric mean of the distribution is assumed to be the representative activity concentration, except for ^{226}Ra, which is estimated to be 5.5E10 Bq (1.5 Ci) based on generator estimates (LLNL 2015a, b). (Table 2).

Table 2. Estimated Geometric Mean, 95th Percentile, and Geometric Standard Deviation of the Inventory of the LLNL Low Activity Beta/Gamma Sources Waste Stream

Nuclide	Geometric Mean Inventory (Bq)	95th Percentile Inventory (Bq)	Geometric Standard Deviation
^{60}Co	4.20E+13	2.10E+14	2.65
^{137}Cs	3.88E+14	1.94E+15	2.65
^{85}Kr	1.01E+13	5.06E+13	2.66
^{226}Ra	5.55E+10	2.78E+11	2.65
^{90}Sr	4.80E+13	2.40E+14	2.65

The mean and 95th percentile activities are estimated by multiplying the corresponding concentration by the total remaining waste stream volume, 20 cubic meters (m^3). The geometric standard deviation of the lognormal distribution is calculated as:

$$GSD = e^{\frac{\ln(UL) - \ln(GM)}{1.65}}$$

where

GSD = geometric standard deviation (dimensionless)
UL = 95th percentile activity, Bq
GM = geometric mean, Bq

The SA is performed by adding the LLNL Low Activity Beta/Gamma Sources waste stream radionuclide inventory to the inventory of post-1988 SLB waste disposed through FY 2014. In addition to the SLB inventory, the SA includes the Pit 6, Pit 13, and post-1988 Greater Confinement Disposal borehole inventories. The model is run with a 2.5-meter (m) (8.2-foot [ft]) closure cover for SLB disposal units.

The mean and median model results are calculated using 5,000 Latin hypercube samples (LHS). A sample size of 5,000 has been previously shown to provide stable estimates of the mean and 95th percentile results for earlier versions of the PA model (Bechtel Nevada [BN] 2006). A reasonable expectation of compliance with the performance objectives is assumed if the mean

and median are less than the performance objectives for 1,000 years after closure. In every case, the mean was greater than the median. Only the mean results are reported in the SA.
For comparison purposes, baseline results are obtained by running the model with FY 2014 disposed inventory and without the LLNL Low Activity Beta/Gamma Sources waste stream.

3.0 Results

3.1 Performance Assessment Results

3.1.1 Air Pathway Results

The air pathway annual total effective dose (TED) is evaluated for the resident exposure scenario using 5,000 LHS realizations. The resident exposure scenario estimates the dose to an adult residing in a home at 100 m (330 ft) from the site's boundary. A complete description of the exposure scenario can be found in PA documentation (BN 2006). The annual TED is calculated for a period of 1,000 years after closure. The maximum mean and 95th percentile annual TED occur at 1,000 years and are both less than the 0.1 millisievert (mSv) limit (Table 3). Addition of the LLNL Low Activity Beta/Gamma Sources waste stream has no significant effect on the maximum resident air pathway results.

Table 3. Maximum Air Pathway Annual TED for a Resident at 100 m (330 ft) from the Area 5 RWMS Site Boundary due to the Waste Inventory Disposed through FY 2014

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Resident (Baseline)	1,000 yr	1.5E-4	5.2E-4
Resident (with Candidate Waste Stream)	1,000 yr	1.5E-4	5.2E-4

3.1.1.1 Alternative Air Pathway Scenarios

Uncertainty contributed by the selected exposure scenario was evaluated by calculating air pathway annual TED for alternative scenarios. The scenarios evaluated are the transient occupancy scenario, the resident farmer scenario, and the open rangeland scenario for a ranch at the nearest NNSS boundary and at Cane Spring. The scenarios and their assumptions have been described previously (BN 2006).

The maximum of the mean and 95th percentile are all less than the performance objective for all of the alternative scenarios (Table 4). Although the exposure scenario is a source of uncertainty, there is a high likelihood of compliance for a range of reasonable scenarios. Addition of the LLNL Low Activity Beta/Gamma Sources waste stream has no significant effect on the alternative scenarios' maximum air pathway results.

Table 4. Maximum Air Pathway Annual TED for Alternative Scenarios with the FY 2014 Inventory

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	Baseline	1,000 yr	7.6E-5	2.8E-4
	With Candidate Waste Stream	1,000 yr	7.6E-5	2.8E-4
Resident Farmer	Baseline	1,000 yr	4.1E-4	1.5E-3
	With Candidate Waste Stream	1,000 yr	4.2E-4	1.5E-3
Open Rangeland/Cane Spring	Baseline	1,000 yr	4.9E-9	1.3E-8
	With Candidate Waste Stream	1,000 yr	4.9E-9	1.3E-8
Open Rangeland/NNSS Boundary	Baseline	1,000 yr	8.3E-8	2.3E-7
	With Candidate Waste Stream	1,000 yr	8.3E-8	2.3E-7

3.1.2 All-Pathways Results

The all-pathways annual TED is also calculated for the resident exposure scenario. The maximum mean and 95th percentile resident all-pathways annual TEDs are less than the 0.25 mSv limit (Table 5). Addition of the LLNL Low Activity Beta/Gamma Sources waste stream slightly increases the maximum resident all-pathway annual TED.

Table 5. Maximum All-Pathways Annual TED for a Resident at 100 m (330 ft) from the Area 5 RWMS Site Boundary due to the Waste Inventory Disposed through FY 2014

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Resident (Baseline)	1,000 yr	7.6E-4	2.4E-3
Resident (with Candidate Waste Stream)	1,000 yr	7.8E-4	2.5E-3

Addition of the LLNL Low Activity Beta/Gamma Sources waste stream slightly increases the all-pathways annual TED throughout the compliance period (Figure 1). The largest relative increase, 13%, occurs at 110 years after closure.

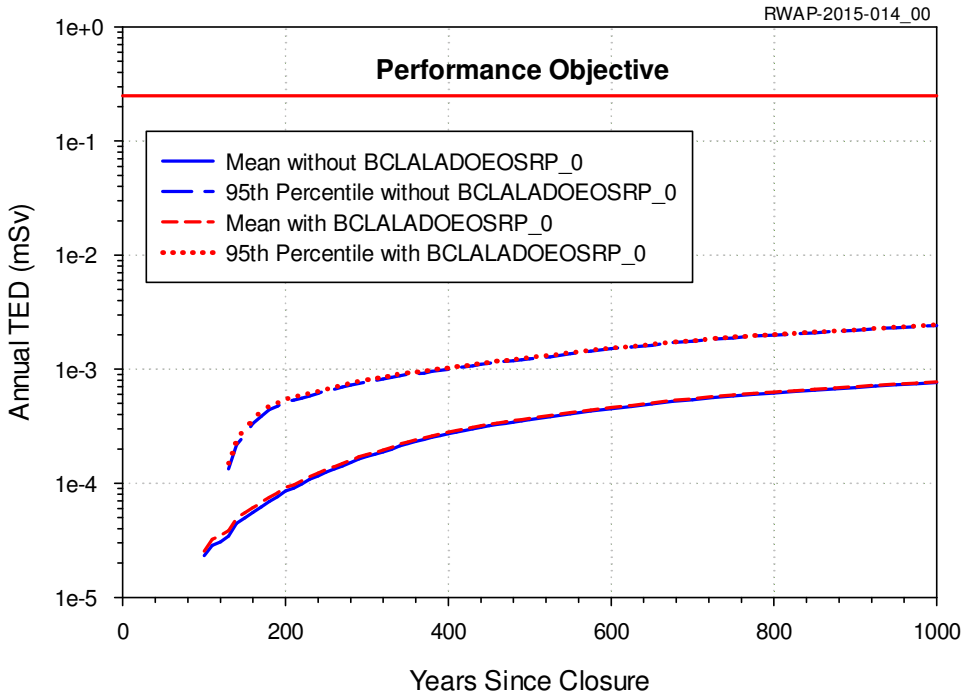

Figure 1. All-Pathways Annual TED Time History for a Resident at 100 m (330 ft) from the Boundary of the Area 5 RWMS with and without the BCLALADOEOSRP_0 Waste Stream

3.1.2.1 Alternative All-Pathways Scenarios

Uncertainty contributed by the selected exposure scenario was evaluated by calculating the all-pathway annual TED for alternative scenarios. The scenarios evaluated are the transient occupancy scenario, the resident farmer scenario, and the open rangeland scenario for a ranch at the nearest NNSS boundary and at Cane Spring. The scenarios and their assumptions have been described previously (BN 2006).

The mean and 95th percentile annual TEDs are all less than the performance objective for all alternative scenarios (Table 6). Although the exposure scenario is a source of uncertainty, there is a high likelihood of compliance for a range of reasonable scenarios. Addition of the LLNL Low Activity Beta/Gamma Sources waste stream has a slight effect on the alternative scenarios' maximum all-pathway results. The transient occupancy scenario annual TED increases slightly.

Table 6. Maximum All-Pathway Annual TED for Alternative Scenarios

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	Baseline	1,000 yr	5.9E-3	1.4E-2
	With Candidate Waste Stream	1,000 yr	6.1E-3	1.5E-2
Resident Farmer	Baseline	1,000 yr	2.2E-2	7.3E-2
	With Candidate Waste Stream	1,000 yr	2.2E-2	7.4E-2
Open Rangeland/Cane Spring	Baseline	1,000 yr	2.4E-3	8.8E-3
	With Candidate Waste Stream	1,000 yr	2.4E-3	8.8E-3
Open Rangeland/NNSS Boundary	Baseline	1,000 yr	2.6E-3	9.6E-3
	With Candidate Waste Stream	1,000 yr	2.6E-3	9.6E-3

3.1.3 Intruder Results

Intruder results are evaluated for acute intruder scenarios only. NNSA/NFO institutional control policy is to maintain and enforce use restrictions consistent with the Underground Test Area (UGTA) Federal Facilities Agreement and Consent Order closure strategies (U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office 2012). The Area 5 RWMS is within the Frenchman Flat UGTA (Corrective Action Unit 98) groundwater use restriction area. The proposed land-use restrictions are assumed to eliminate the possibility of chronic intrusion for 1,000 years.

The acute drilling scenario estimates the TED to a drill crew drilling a water well through a disposal unit. Exposure to contaminated drill cuttings occurs while augering a surface casing for the well. The acute construction scenario estimates the dose to construction workers building a residence on a disposal unit. Construction workers are exposed to waste exhumed from the construction excavation.

The maximum mean and 95th percentile acute intruder TEDs occur at 1,000 years and are less than the 5 mSv limit for both the drilling and construction acute intrusion scenarios (Table 7). Addition of the LLNL Low Activity Beta/Gamma Sources waste stream has no significant effect on the maximum acute intruder scenario results.

Table 7. Maximum TED for Acute Intrusion Scenarios at the Area 5 RWMS and the Waste Inventory Disposed through FY 2014

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Drilling Intruder (Baseline)	1,000 yr	1.5E-3	2.7E-3
Drilling Intruder (with Candidate Waste Stream)	1,000 yr	1.5E-3	2.7E-3
Construction Intruder (Baseline)	1,000 yr	1.2	2.1
Construction Intruder (with Candidate Waste Stream)	1,000 yr	1.2	2.1

3.1.4 ^{222}Rn Flux Density Results

The radon-222 (^{222}Rn) flux density is averaged over the area of all post-1988 disposal units. The maximum mean and 95th percentile ^{222}Rn flux density occur at 1,000 years and are less than the 0.74 becquerel per square meter per second (Bq m^{-2} s^{-1}) performance objective (Table 8). Addition of the LLNL Low Activity Beta/Gamma Sources waste stream slightly increases the maximum ^{222}Rn flux density.

Table 8. Maximum ^{222}Rn Flux Density at the Area 5 RWMS and the Waste Inventory Disposed through FY 2014

Inventory	Time of Maximum	Mean (Bq m^{-2} s^{-1})	95th Percentile (Bq m^{-2} s^{-1})
Baseline	1,000 yr	0.20	0.45
Baseline with Candidate Waste Stream	1,000 yr	0.21	0.47

Addition of the LLNL Low Activity Beta/Gamma Sources waste stream increases the ^{222}Rn flux density throughout the compliance period (Figure 2). The largest relative increase in the flux density, 6%, occurs at closure and decreases thereafter.

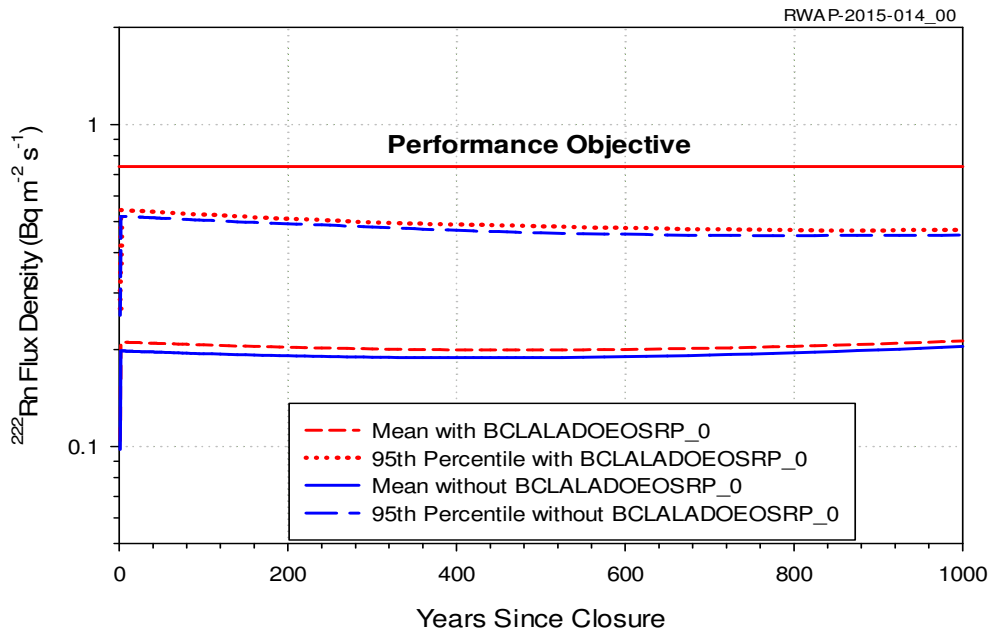

Figure 2. ^{222}Rn Flux Density Time History at the Area 5 RWMS with and without the BCLALADOEOSRP_0 Waste Stream

4.0 Conclusions

The effect of adding the LLNL Low Activity Beta/Gamma Sources waste stream inventory to the inventory of waste disposed through the end of FY 2014 was evaluated with the A5 RWMS v 4.119 PA model. The results indicate that all performance objectives can be met with disposal of the LLNL Low Activity Beta/Gamma Sources in a SLB trench. Addition of the LLNL Low Activity Beta/Gamma Sources inventory slightly increases the resident's all-pathways annual TED and the ^{222}Rn flux density. The maximum mean and 95th percentile of all performance assessment results remain less than the performance objective throughout the compliance period. The LLNL Low Activity Beta/Gamma Sources waste stream is suitable for disposal by SLB at the Area 5 RWMS.

The activity concentration of ^{226}Ra listed on the waste profile sheet significantly exceeds the action level. Approval of the waste profile sheet could potentially allow the disposal of high activity ^{226}Ra sources. To ensure that the generator does not include large ^{226}Ra sources in this waste stream without additional evaluation, a control is need on the maximum ^{226}Ra inventory. A limit based on the generator's estimate of the total ^{226}Ra inventory is recommended. The waste stream is recommended for approval with the control that the total ^{226}Ra inventory disposed shall not exceed 5.5E10 Bq (1.5 Ci).

5.0 References

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