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Special Analysis for the Disposal of the Materials & Energy Corporation Sealed 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	becquerel
Bq m^{-3}	becquerel per cubic meter
Bq m^{-2} s^{-1}	becquerel per square meter per second
DOE	U.S. Department of Energy
ft	foot/feet
FY	(Federal) fiscal year
GSD	Geometric standard deviation
LHS	Latin hypercube sample
m	meter(s)
M&EC	Materials & Energy Corporation
mSv	millisievert(s)
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
PA	Performance Assessment
Ra	radium
Rn	radon
RWMS	Radioactive Waste Management Site
SA	Special Analysis
SLB	Shallow land burial
SOFs	Sum of fractions
TED	Total effective dose
WAC	Waste Acceptance Criteria
y	years

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1.0 Executive Summary

This special analysis (SA) evaluates whether the Materials and Energy Corporation (M&EC) Sealed Source waste stream (PERM000000036, Revision 0) is suitable for shallow land burial (SLB) at the Area 5 Radioactive Waste Management Site (RWMS) on the Nevada National Security Site (NNSS). Disposal of the M&EC Sealed Source waste meets all 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 M&EC Sealed Source waste stream is recommended for acceptance without conditions.

2.0 Introduction

This SA evaluates disposal of the M&EC Sealed Source waste stream at the Area 5 RWMS on the NNSS. The waste stream requires an SA because the activity concentration of radium-226 (^{226}Ra) exceeds the NNSS Waste Acceptance Criteria (WAC) Action Level (U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office [NNSA/NFO] 2016).

3.0 Analysis of Performance

The SA evaluates the performance for 1,000 years of the Area 5 RWMS with the M&EC Sealed Source waste stream disposed in a SLB disposal cell.

3.1 Waste Description

The M&EC Sealed Source waste stream consists of sealed sources from multiple DOE facilities. The sealed sources were originally used for various applications, including instrument calibration, industrial measurements, analytical chemistry instrumentation, and electrostatic charge elimination.

The M&EC Sealed Source waste stream radionuclide activities are assumed to be lognormally distributed. The geometric mean of the distribution is assumed to be the product of the representative activity concentration and the total remaining volume, 0.212 m^3, as reported on the waste profile (M&EC 2017, Section D.5) (Table 1).

Table 1. M&EC Sealed Source Waste Stream Activity Concentration and Total Activity at the Time of Disposal Assumed for Performance Assessment Modeling

Nuclide	Geometric Mean Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	Geometric Mean Activity (Bq)	95th Percentile Activity (Bq)	Geometric Standard Deviation
^{3}H	4.5E+11	5.4E+11	9.6E+10	1.2E+11	1.12
^{14}C	7.0E+07	8.4E+07	1.5E+07	1.8E+07	1.12
^{36}Cl	2.5E+03	3.0E+03	5.2E+02	6.3E+02	1.12
^{63}Ni	3.7E+07	4.4E+07	7.8E+06	9.3E+06	1.12
^{60}Co	3.8E+05	4.5E+05	8.0E+04	9.6E+04	1.12
^{90}Sr	4.0E+08	4.9E+08	8.6E+07	1.0E+08	1.12
^{137}Cs	1.1E+10	1.3E+10	2.2E+09	2.7E+09	1.12
^{210}Pb	7.0E+06	8.4E+06	1.5E+06	1.8E+06	1.12
^{226}Ra	1.1E+10	1.3E+10	2.2E+09	2.7E+09	1.12

Nuclide	Geometric Mean Concentration (Bq m^{-3})	95th Percentile Concentration (Bq m^{-3})	Geometric Mean Activity (Bq)	95th Percentile Activity (Bq)	Geometric Standard Deviation
^{232}Th	6.7E+05	8.1E+05	1.4E+05	1.7E+05	1.12
^{238}U	1.6E+09	1.9E+09	3.4E+08	4.0E+08	1.11
^{239}Pu	8.4E+03	1.0E+04	1.8E+03	2.1E+03	1.11

The upper limit activity concentration is assumed to be the 95th percentile of the lognormal distribution. 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 M&EC Sealed Sources waste stream required a special analysis because ^{226}Ra exceeded the NNSS WAC action level. Disposal of the total waste stream inventory would cause a 0.2% relative increase in the ^{226}Ra SLB inventory (Table 2). The Area 5 RWMS SLB sum of fractions (SOFs) increases 0.02% with addition of the waste stream activity.

Table 2. Expected Increase in the Disposed Inventory of Radionuclides Exceeding their Action Levels and the Area 5 RWMS SOFs at Closure (10/1/2028) (NSTec 2017)

Nuclide	FY 2016 SLB Disposed Geometric Mean Inventory	Geometric Mean PERM000000036_0 Inventory	Relative Percent Change
^{226}Ra	1.2E+12	2.2E+09	0.2
SLB SOFs	0.87	0.87	0.02

3.2 Performance Assessment Modeling

The PA modeling adds the inventory of the M&EC Sealed Source waste stream to the Area 5 RWMS v 4.200 model and determines if there is a reasonable expectation of meeting the DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual," Chapter IV, Section P performance objectives (DOE 1999). The PA model evaluates the M&EC Sealed Source waste stream radionuclide activity added to the inventory of post-1988 SLB waste disposed through FY 2016. The SA inventory also 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 provides stable estimates of the mean and 95th percentile results 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. The SA only reports the mean results.

For comparison purposes, baseline results are obtained by running the model with the inventory disposed through FY 2016 and without the M&EC Sealed Source waste stream.

4.0 Results and Interpretation

4.1 Performance Assessment Results

4.1.1 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 a reference person residing in a home at the 100-meters (m) (330-feet [ft]) Area 5 RWMS boundary. A complete description of the exposure scenario can be found in the earlier 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 M&EC Sealed Source waste stream has no significant effect on the maximum resident air pathway TED.

Table 3. Maximum Air Pathway Annual TED for a Resident at the Area 5 RWMS 100-m (330-ft) Site Boundary and the Waste Inventory Disposed through FY 2016

Scenario	Time of Maximum†	Mean (mSv)	95th Percentile (mSv)
Resident without PERM000000036_0 Waste Stream	1,000 y	1.7E-4	5.8E-4
Resident with PERM000000036_0 Waste Stream	1,000 y	1.7E-4	5.8E-4

† - years after closure

Addition of the M&EC Sealed Source waste stream has no significant effect on the air pathway mean annual TED throughout the compliance period (Figure 1).

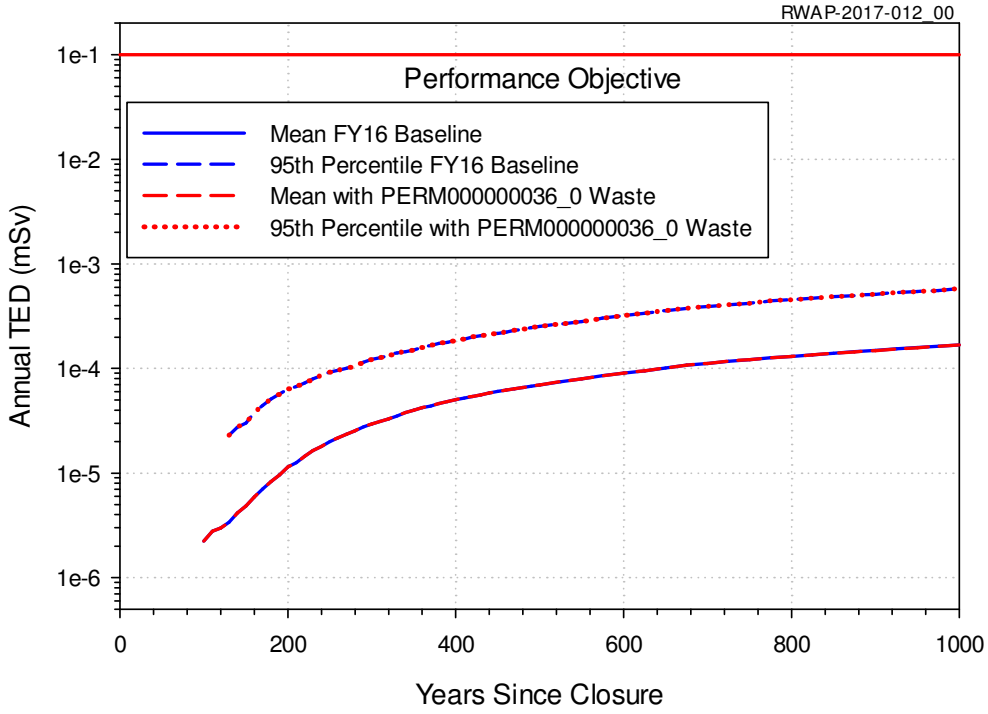

Figure 1. Air Pathway Annual TED Time History for a Resident at the 100-m (330-ft) Boundary with and without the PERM000000036_0 Waste Stream

4.1.1.1 Alternative Air Pathway Scenarios

Uncertainty contributed by the selected exposure scenario was evaluated by calculating the air pathway annual TED for alternative scenarios. The scenarios evaluated are the transient occupancy scenario, the resident with agriculture scenario, and open rangeland scenarios for a ranch at two plausible locations: one at the NNSS boundary closest to the Area 5 RWMS and another at Cane Spring. The scenarios and their assumptions are described in the PA (BN 2006).

The maximum mean and the 95th percentile TEDs 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 M&EC Sealed Source waste stream has no significant effect on the maximum result for all alternative scenarios.

Table 4. Maximum Air Pathway Annual TEDs for Alternative Scenarios with the FY 2016 Inventory

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2016 Baseline Inventory	1,000 y	6.8E-5	2.4E-4
	FY 2016 with PERM000000036_0	1,000 y	6.8E-5	2.4E-4
Resident with Agriculture	FY 2016 Baseline Inventory	1,000 y	3.6E-4	1.3E-3
	FY 2016 with PERM000000036_0	1,000 y	3.6E-4	1.3E-3
Open Rangeland/Cane Spring	FY 2016 Baseline Inventory	1,000 y	5.7E-9	1.4E-8
	FY 2016 with PERM000000036_0	1,000 y	5.7E-9	1.4E-8
Open Rangeland/NNSS Boundary	FY 2016 Baseline Inventory	1,000 y	9.6E-8	2.3E-7
	FY 2016 with PERM000000036_0	1,000 y	9.6E-8	2.3E-7

4.1.2 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 4). Addition of the M&EC Sealed Sources waste stream has no significant effect on the maximum resident all-pathways annual TED.

Table 4. Maximum All-Pathways Annual TED for a Resident at the Area 5 RWMS 100-m (330-ft) Site Boundary and the Waste Inventory Disposed through FY 2016

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Resident without PERM000000036_0 Waste Stream	1,000 y	9.3E-4	2.6E-3
Resident with PERM000000036_0 Waste Stream	1,000 y	9.3E-4	2.6E-3

Addition of the M&EC Sealed Sources waste stream has no significant impact on the all-pathways annual TED throughout the compliance period (Figure 2). The largest relative increase in the mean, approximately 0.2%, occurs at 200 years after closure.

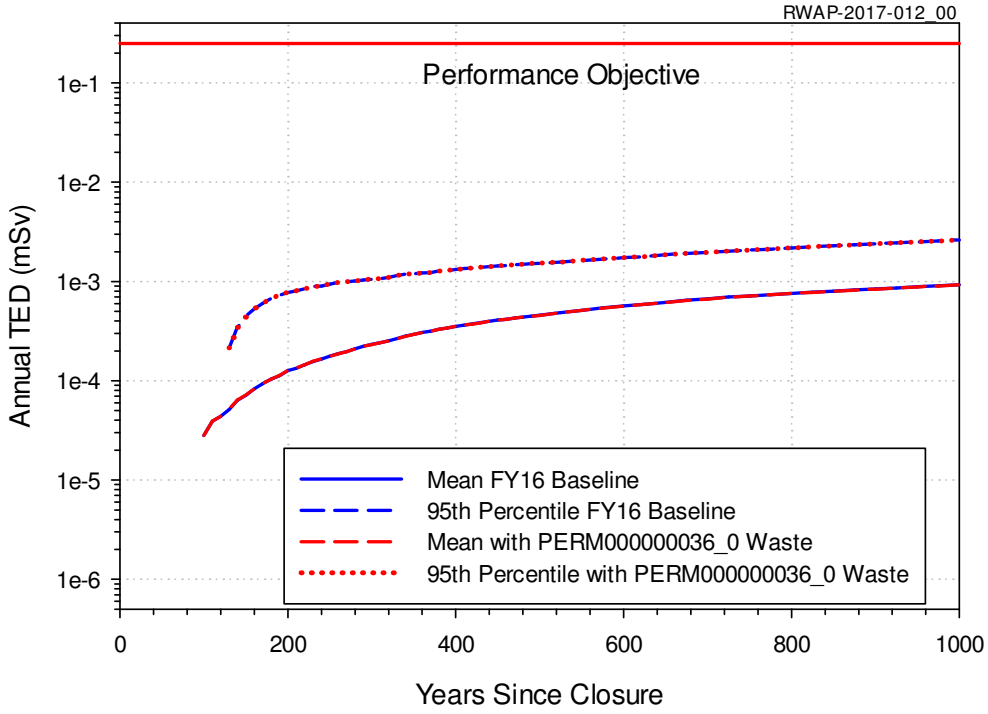

Figure 2. All-Pathways Annual TED Time History for a Resident at the 100-m (330-ft) Boundary with and without the PERM000000036_0 Waste Stream

4.1.2.1 Alternative All-Pathways Scenarios

Uncertainty contributed by the selected exposure scenarios was evaluated by calculating the all-pathways annual TED for alternative scenarios. The scenarios evaluated are the transient occupancy scenario, the resident with agriculture scenario, and open rangeland scenarios for a ranch with two plausible exposure locations: one at the NNSS boundary closest to the Area 5 RWMS and another at Cane Spring. The scenarios and their assumptions are described in the PA (BN 2006).

The mean and 95th percentile all-pathways annual TEDs are all less than the performance objective for all alternative scenarios (Table 5). 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 M&EC Sealed Source waste stream has no significant effect on the maximum annual TED.

Table 5. Maximum All-Pathways Annual TEDs for Alternative Scenarios

Scenario	Inventory	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Transient Occupancy	FY 2016 Baseline Inventory	1,000 y	5.3E-3	1.3E-2
	FY 2016 with PERM000000036_0	1,000 y	5.3E-3	1.3E-2
Resident with Agriculture	FY 2016 Baseline Inventory	1,000 y	2.5E-2	7.9E-2
	FY 2016 with PERM000000036_0	1,000 y	2.5E-2	7.9E-2
Open Rangeland/Cane Spring	FY 2016 Baseline Inventory	1,000 y	4.3E-3	1.5E-2
	FY 2016 with PERM000000036_0	1,000 y	4.3E-3	1.5E-2
Open Rangeland/NNSS Boundary	FY 2016 Baseline Inventory	1,000 y	4.5E-3	1.6E-2
	FY 2016 with PERM000000036_0	1,000 y	4.5E-3	1.6E-2

4.1.3 Intruder Results

Intruder results are evaluated for acute intruder scenarios only. NNSA/NFO institutional control policy is to maintain and enforce use restrictions (NNSA/NFO 2015). 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 acute intruder TED for drilling and construction acute intruder scenarios occur at 1,000 years and are less than the 5 mSv performance measure (Table 6). The maximum 95th percentile results occur at 100 years and are also less than the performance measure. Addition of the M&EC Sealed Sources waste stream has no significant effect on the maximum acute intruder scenario results.

Table 6. Maximum TED for Acute Intrusion Scenarios at the Area 5 RWMS and the Waste Inventory Disposed through FY 2016

Scenario	Time of Maximum	Mean (mSv)	95th Percentile (mSv)
Drilling Intruder without PERM000000036_0	1,000 y	1.3E-3	2.3E-3
Drilling Intruder with PERM000000036_0	1,000 y	1.3E-3	2.3E-3
Construction Intruder without PERM000000036_0	1,000 y	1.0	1.7
Construction Intruder with PERM000000036_0	1,000 y	1.0	1.7

Addition of the M&EC Sealed Sources waste stream has no significant impact on the mean acute construction TED throughout the compliance period (Figure 3). The mean and 95th percentile results are less than the performance measure throughout the compliance period.

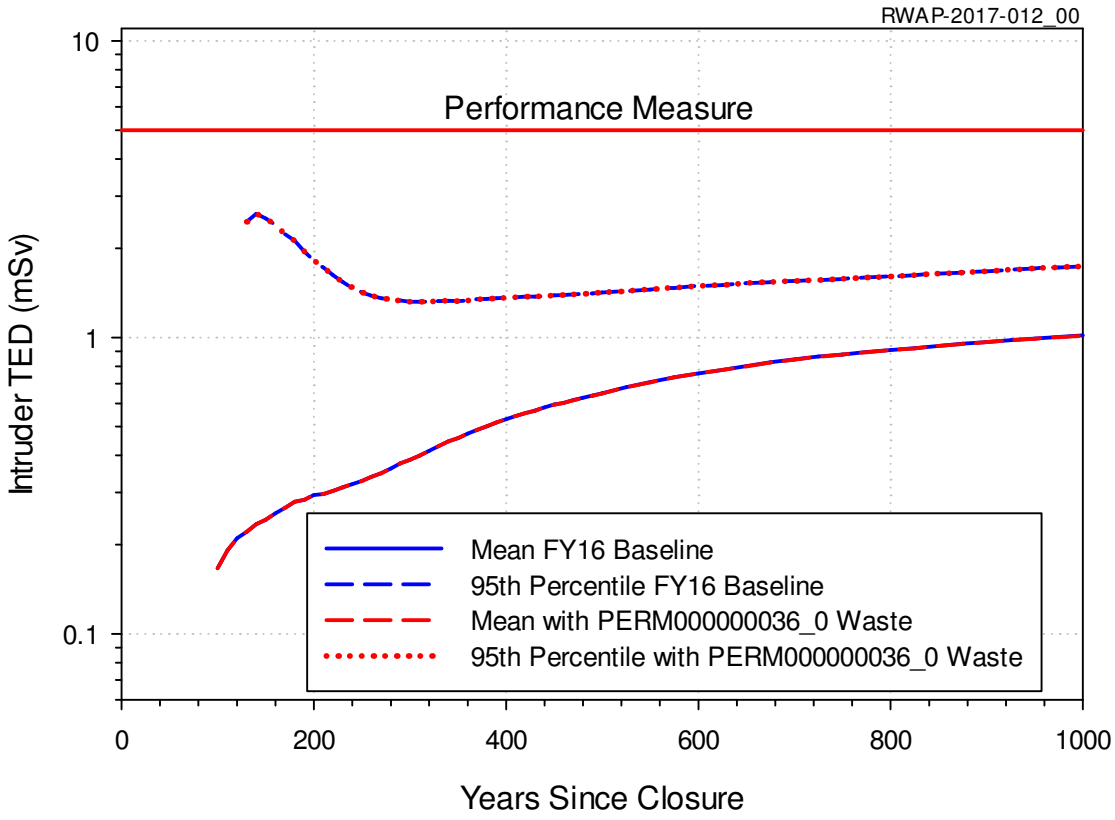

Figure 3. Acute Construction Intrusion Scenario TED Time History with and without the PERM000000036_0 Waste Stream

4.1.4 ^{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 densities 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 7). Addition of the M&EC Sealed Sources waste stream has no significant effect on the maximum ^{222}Rn flux density. This waste stream does not require an increased depth of burial to attenuate ^{222}Rn flux

Table 7. Maximum ^{222}Rn Flux Density at the Area 5 RWMS and the Waste Inventory Disposed through FY 2016

Inventory	Time of Maximum	Mean (Bq m^{-2} s^{-1})	95th Percentile (Bq m^{-2} s^{-1})
FY 2016 Baseline Inventory	1,000 y	0.18	0.42
FY 2016 with PERM000000036_0	1,000 y	0.18	0.42

Addition of the M&EC Sealed Sources waste stream causes the ^{222}Rn flux density to increase a maximum of approximately 0.2% at closure and decreases slightly thereafter (Figure 4).

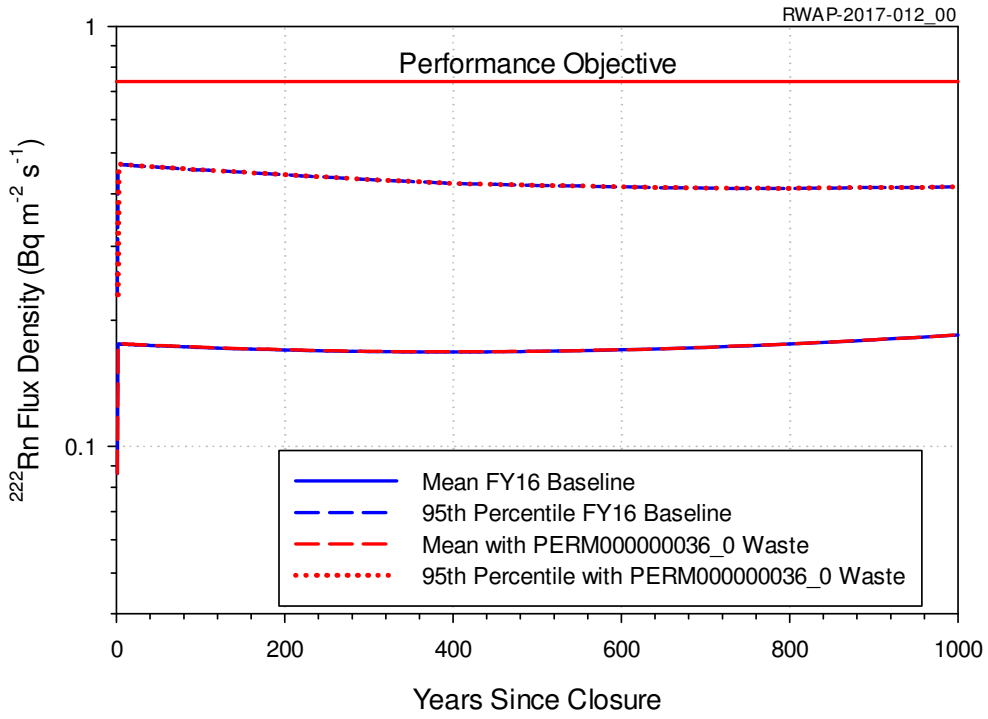

Figure 4. ^{222}Rn Flux Density Time History with and without the PERM000000036_0 Waste Stream

5.0 Conclusions

The effect of adding the M&EC Sealed Source waste stream inventory to the inventory of waste disposed through the end of FY 2016 was evaluated with the Area 5 RWMS v 4.200 PA model. The results indicate that all performance objectives can be met with disposal of the M&EC Sealed Source in an Area 5 RWMS SLB unit. Addition of the M&EC Sealed Source inventory has no significant effect on the maximum PA results. All maximum mean and 95th percentile results remain less than their performance objectives throughout the compliance period. No result exceeds the Low-Level Radioactive Waste Review Group notification criterion of exceeding 50% of a performance objective. The M&EC Sealed Source waste stream is acceptable for disposal without conditions.

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6.0 References

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