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Determination of Reportable Radionuclides for DWPF Sludge Batch 2 (Macro Batch 3) (U)

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1.0 INTRODUCTION AND SUMMARY

The Waste Acceptance Product Specifications (WAPS) [1] 1.2 require that "The Producer shall report the inventory of radionuclides (in Curies) that have half-lives longer than 10 years and that are, or will be, present in concentrations greater than 0.05 percent of the total inventory for each waste type indexed to the years 2015 and 3115". As part of the strategy to meet WAPS 1.2, the Defense Waste Processing Facility (DWPF) will report for each waste type, all radionuclides (with half-lives greater than 10 years) that have concentrations greater than 0.01 percent of the total inventory from time of production through the 1100 year period from 2015 through 3115. The initial listing of radionuclides to be included is based on the design-basis glass as identified in the Waste Form Compliance Plan (WCP) [2] and Waste Form Qualification Report (WQR) [3]. However, it is required that this list be expanded if other radionuclides with half-lives greater than 10 years are identified that meet the greater than 0.01% criterion for Curie content.

Specification 1.6 of the WAPS, IAEA Safeguards Reporting for HLW, requires that the ratio by weights of the following uranium and plutonium isotopes be reported: U-233, U-234, U-235, U-236, U-238, Pu-238, Pu-239, Pu-240, Pu-241, and Pu-242. Therefore, the complete set of reportable radionuclides must also include this set of U and Pu isotopes.

The Defense Waste Processing Facility (DWPF) is receiving radioactive sludge slurry from High Level Waste Tank 40. The radioactive sludge slurry in Tank 40 is a blend of the contents of Tank 40 and the sludge that was transferred to Tank 40 from Tank 8. The blend of sludge from Tank 8 and Tank 40 defines Macro Batch 3 (also referred to as Sludge Batch 2). This report develops the list of reportable radionuclides and associated activities and determines the radionuclide activities as a function of time. The DWPF will use this list and the activities as one of the inputs for the development of the Production Records that relate to radionuclide inventory.

This work was initiated through Task Technical Request HLW/DWPF/TTR-00-0016, Revision 1 [4] entitled "Sludge Batch 2 (Macro Batch 3) High Level Cells Testing." Specifically, this report details results from performing Subtask 3 of the TTR and, in part, meets deliverable 7 of the TTR. The work was performed following the Technical Task Plan, WSRC-RP-2000-00698, Rev. 0 [5].

Twenty-seven radionuclides have been identified as reportable for DWPF Sludge Batch 2 (Macro Batch 3) as specified by WAPS 1.2. Consistent with the strategy detailed in the WCP and WQR, each of these radionuclides has a half-life greater than 10 years and contributes more than 0.01 % of the radioactivity on a Curie basis at some point from production through the 1100-year period between 2015 and 3115. The 27 reportable radionuclides are:

C-14	**Ni-59**	**Ni-63**	**Se-79**	**Sr-90**	**Zr-93**
Nb-93m	**Tc-99**	**Sn-121m**	**Sn-126**	**Cs-137**	**Sm-151**
U-233	**U-234**	**Np-237**	**U-238**	**Pu-238**	**Pu-239**
Pu-240	**Am-241**	**Pu-241**	**Pu-242**	**Am-243**	**Cm-244**
Cm-245	**Cm-246**	**Cf-251**			

The WCP and WQR require that all of the radionuclides present in the Design Basis glass be considered as the initial set of reportable radionuclides. For Sludge Batch 2 (Macro Batch 3) all of the radionuclides in the Design Basis glass are reportable except for three radionuclides: Pd-107, Cs-135, and Th-230. At no time through the year 3115 did any of these three radionuclides contribute to more than 0.01 % of the radioactivity on a Curie basis.

Two additional uranium isotopes (U-235 and U-236) must be added to the list of reportable radionuclides in order to meet WAPS 1.6. All of the Pu isotopes and other U isotopes (U-233, U-234 and U-238) identified in WAPS 1.6 were already determined to be reportable according to WAPS 1.2. This brings the total number of reportable radionuclides for Sludge Batch 2 to twenty-nine.

Five of the twenty-nine reportable radionuclides for Sludge Batch 2 are not part of either the design-basis list of radionuclides or the list of Pu and U isotopes identified in WAPS 1.6. These include C-14, Sn-121m, Cm-245, Cm-246 and Cf-251. Two of these radionuclides (C-14 and Cm-246) were also reported for Macro Batch 2 (Sludge Batch 1B) [6]. Both the Cf-251 and Cm-245 radionuclides were not detected and consequently, the detection limits for these isotopes were used as input to the calculations. Sn-121m was identified as described in Section 4.1 of this report.

The list of reportable radionuclides that were determined for Sludge Batch 1B (Macro Batch 2) contained five radionuclides that were not reportable for Sludge Batch 2 (Macro Batch 3). These radionuclides were Pd-107, I-129, Cs-135, Th-229, and Th-230.

2.0 EXPERIMENTAL

The details of sample acquisition from Tank 40 and measurement of the concentrations of most of the radionuclides of the washed sludge have been published separately [7,8]. The results for those radionuclides that required additional separation techniques that were not included in the referenced reports have been included in this report. Details of the separation and detection methods are provided. An Analytical Study Plan [9] was followed during the performance of this task.

3.0 RADIONUCLIDES IDENTIFIED FOR CONSIDERATION AS REPORTABLE

In order to determine the reportable radionuclides for Sludge Batch 2 (Macro Batch 3), a list of radioisotopes that may meet the criteria as specified by the Department of Energy's (DOE) Waste Acceptance Product Specification (WAPS) was developed. All radioactive U-235 fission products and all radioactive activation products that could be in the SRS HLW were considered. The DWPF further stipulated that initial list of radionuclides that must be considered include those radionuclides present in the design-basis glass. The design-basis glass radionuclides are identified by the superscript "e" in Table 1. In addition, all U and Pu isotopes identified in WAPS 1.6 have been included in this list.

Table 1 presents the list of radioisotopes [6] identified for consideration as reportable. The radioisotopes that were deleted from the list and the arguments [6] that support that decision are presented in Table 2.

Table 1 – List of Radioisotopes Considered for Sludge Batch 2

Radioisotope	Radioisotope	Radioisotope	Radioisotope
C-14[a]	**Sn-126[b,e]**	Ac-227[d]	**Pu-241[a,e]**
Ni-59[a,e]	I-129[b]	Th-229[d]	**Pu-242[a,e]**
Co-60[a]	**Cs-135[b,e]**	**Th-230[d,e]**	**Am-241[a,e]**
Ni-63[a,e]	**Cs-137[b,e]**	Pa-231[d]	Am-242m[a]
Se-79[b,e]	La-138[b,c]	Th-232[c]	**Am-243[a,e]**
Rb-87[b]	Ce-142[b,c]	U-232[a]	Cm-243[a]
Sr-90[b,e]	Nd-144[b,c]	U-233[a]	**Cm-244[a,e]**
Zr-93[b,e]	Sm-147[b,c]	**U-234[d,e]**	Cm-245[a]
Nb-93m[b,e]	Sm-149[b,c]	U-235[c]	Cm-246[a]
Nb-94[a]	Nd-150[b,c]	U-236[a]	Cm-247[a]
Zr-96[b,c]	**Sm-151[b,e]**	Np-236[a]	Cm-248[a]
Tc-99[b,e]	Eu-152[a,b]	**Np-237[a,e]**	Cf-249[a]
Cd-113[b,c]	Eu-154[a,b]	**U-238[c,e]**	Cf-250[a]
Pd-107[b,e]	Bi-210m[d]	**Pu-238[a,e]**	Cf-251[a]
In-115[b,c]	Pb-210[d]	**Pu-239[a,e]**	
Sn-121m[b]	Ra-226[d]	**Pu-240[a,e]**	

[a] Activation Product

[b] Fission Product

[c] Naturally Occurring Radionuclide that Resulted in the Waste from Processing at SRS

[d] Decay Product of an Actinide Isotope in SRS Waste

[e] Design Basis Glass Radionuclides (also in bold)

Table 2 – Radioisotopes Excluded for Determination of Reportable Radioisotopes for Sludge Batch 2 (Macro Batch 3)

Radioisotope	Radioisotope
Nb-94[1]	Sm-147[2]
Zr-96[2]	Sm-149[2]
Cd-113[2]	Eu-152[1]
In-115[2]	Np-236[3]
La-138[2]	U-232[4]
Ce-142[2]	Cm-248[5]
Nd-144[2]	
Nd-150[2]	

1. "Nb-94 and Eu-152 are shielded isotopes: the isobaric fission product decay chain for these stops at a stable isotope before reaching these. They are therefore produced predominately by secondary processes, and are present only in very small amounts. They have not been observed in the sludge slurry"[10].
2. Zr-96, Cd-113, In-115, La-138, Ce-142, Nd-144, Nd-150, Sm-147 and Sm-149 were deleted because their long half - lives (> 1.05E11 years) make their activities negligible at all times [10].
3. "No data was available for Np-236 but it is known to be made in only very small amounts in reactor irradiation. Np-236 is a minor product of fast neutron spallation. It was neglected" [10].
4. "U-232 is present only in very small amounts and decays rapidly compared to other actinide isotopes that are much more abundant (It is primarily obtained as a contaminant at a few ppm from the reactor irradiation of Th-232)" [10].
5. Cm-248 was deleted from the list due to the inability of the ICP-MS to uniquely detect this isotope due to interference from thorium oxide ion (used the special separation techniques as discussed in Section 4).

4.0 DETERMINATION OF THE ACTIVITIES OF THE SELECTED RADIONUCLIDES

The activities for a number of the radionuclides were documented elsewhere [7,8]. For the remaining isotopes being considered for reportability, the activities were determined by methods described in this section.

4.1 Special Separations

The determination of the activities of a number of isotopes requires that special separation techniques be employed prior to analysis for specific radionuclides.

4.1.1 Separation and Analysis for Pu-241 and Pu-238

Pu-241 is a beta-emitting Pu isotope that cannot be measured directly in the dissolved sludge slurry solutions because of its low concentration. Pu-241 has a relatively short half-life (15 years). Its concentration was determined by isolating Pu from each solution by a thenoyltrifluoroacteone extraction procedure. The extracted Pu was then analyzed by beta and alpha counting to determine the ratio of beta activity from Pu-241 to the alpha activity from the other isotopes of Pu (Pu-238, Pu-239, Pu-240, and Pu-242). In the original dissolution solutions, the total alpha activity from the Pu isotopes was determined by alpha counting and ICP-MS. Knowing the total alpha activity from Pu in the solutions resulting from the extraction allows the concentration of Pu-241 in the original dissolution solutions to be calculated using the beta/alpha ratio determined in the extracted solution. In the extracted solution, the alpha counting technique also gives the alpha counts due specifically to Pu-238 so that the total amount of Pu-238 can be determined.

4.1.2 Separation and Analyses for Am-241, Am-242m, Am-243, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cf-249, Cf-250, and Cf-251

Am-241, Am-242m, Am-243, Cm-243, Cm-244, Cm-245, Cm-246, Cm-247, Cf-249, Cf-250, and Cf-251 are neutron activation products produced in the SRS reactors. These isotopes are difficult to measure because of their low concentrations in the sludge slurry and the dilutions necessary to get the dissolved slurry samples out of the Shielded Cells. Most of these isotopes were not detected directly in any of the solutions by ICP-MS or any of the radioactive counting techniques. The Analytical Development Section (ADS) has developed a method for isolating Am and Cm in a dissolved sludge slurry solution by using a commercially available ion exchange resin. The resulting solution is then analyzed by gamma spectroscopy for Am-241, Am-243 and Cm-243, alpha spectroscopy for Cm-244, and ICP-MS for Am-241, Am-243, Cm-244, Cm-245, Cm-246 and Cm-247.

The concentrations of Am-241, Am-243, Cm-243 and Cm-244 in the separation solution were calculated from the gamma and alpha counting data. By knowing the measured ratios of Am-243, Cm-243 and Cm-244 to the Am-241 in that solution and knowing an accurate concentration of Am-241 in the original sludge slurry solution by gamma counting, the concentrations of these isotopes in the original sludge slurry solution could be calculated. The results of the ICP-MS analysis gave the concentrations of Am-241, Am-243, Cm-244, Cm-246 and Cm-247 in the separation solution. Again knowing the ratio of Am-241 in the separation solution to that in the original sludge slurry solution allowed the concentration of Am-243, Cm-244, Cm-246 and Cm-247 to be calculated in the original sludge slurry dissolution.

For the isotopes not detected (Cm-243, Cm-245, Am-242m, Cf-249, Cf-250, and Cf-251), detection limits were estimated. These detection limits were then used as the maximum concentrations of these isotopes that could be present.

4.1.3 Separation and Analysis for C-14

C-14 is a beta emitter with a half-life of 5730 years that could have been produced in the SRS reactors from a neutron-proton displacement reaction with N-14. This reaction involves hitting N-14 with a neutron so that it releases a proton to form C-14. In order to detect C-14 in the waste a special separation technique was developed by ADS [11]. In this method samples of dried sludge slurry were dissolved with HNO_3 in glass vessels that were inside sealed Teflon pressure vessels. The Teflon pressure vessels each had a basic solution in the bottom of the vessel which acted as a capture agent for the carbon dioxide which was generated from the dissolving the sample. The basic solutions were then transferred from the Shielded Cells and purified further. The base was acidified and the liberated carbon dioxide was captured in an amine-based capture agent. The agent was then slurried over into a liquid scintillation cocktail and analyzed by liquid scintillation analysis. A C-14 spike solution was run through the process in parallel with the sample and the sample was run in triplicate. The C-14 recovery result from the spike solution was used to correct the sample results for the separation yield. Based on the concentration of the spike, the C-14 recovery was 25%. A blank was also run in sequence with the samples. Results for the blank indicated that it contained a negligible amount of C-14. The liquid scintillation spectra of the three samples clearly indicated the presence of C-14 based on detection and counting to the characteristic C-14 beta particles that have an average energy of 0.0495 MeV and a maximum energy of 0.1565 MeV . The spectra were solely due to C-14 and were clear of any beta activity from other radioactive isotopes.

4.1.4 Separation and Analysis for I-129

I-129 is a long-lived beta emitting fission product ($t_{1/2}$ = 1.6E07 years) that could be in SRS wastes. I-129 was not detected by the ICP-MS in the dissolved dried sludge slurry samples. ADS then developed a special procedure to determine the I-129 present [12]. Three samples of the dried sludge slurry were dissolved in presence of a known amount of KI carrier. The resulting solution was further treated to remove Cs-137 and actinide elements. The solution was then treated with $AgNO_3$ in order to precipitate the iodide ion as AgI. The precipitate was removed from the Shielded Cells and counted by gamma spectroscopy to determine the amount of I-129 present. I-129, if present, is detected by its characteristic gamma ray. With Sludge Batch 2, no I-129 was detectable. Therefore, the detection limit for I-129 was used as input to the activity of Sludge Batch 2. This is in contrast to Sludge Batch 1B, where I-129 was detected.

4.1.5 Separation and Analysis for Sn-121m

To determine an upper limit to the Sn-121m activity, a low energy gamma analysis was carried out on a sample of SRS Waste Tank 37/44 supernate which had been pre-treated with the Caustic Side Solvent Extraction (CSSX) extractant to reduce Cs-137 levels. The CSSX process stripped enough Cs-137 out that the radioactive Sn isotopics in this SRS supernate could be measured using the low energy gamma assay. The Sn-121m activity was determined from the 37.2 keV gamma ray, and verified from the 26.2 and 29.7 keV x-rays arising from the decay to Sn-121m to Sb-121. The Sn-126 activity was determined from the 64.3 keV gamma ray, and the 86.94 and 87.57 keV gamma–ray multiplet. From that measurement, an activity ratio of Sn-121m/Sn-126 was determined.

The calculation of the fission yield for Sn-121m from available fission yield data is problematic. If you assume that the 121 isobaric cascade populated Sn-121m exclusively, the activity ratio of Sn-121m/Sn-126 would be 1.0E+3. However, the decay to Ag-121 populates two states of Cd-121, which populate two states of In-121, which populates two states of Sn-121, one of which is the Sn-121m state. The only In-121 state which would populate Sn-121m is the ground state, and that would only populate Sn-121m 12.2% of the time. As a result, if you assume the 121 isobaric cascade populated the ground state of In-121 exclusively, based on the In-121 decay to Sn-121m, the activity ratio of Sn-121m/Sn-126 would decrease to 1.22E+02. Experimentally, the activity ratio of Sn-121m/Sn-126 measured was 8.1E+01. Assuming a nominal 20-year decay of the waste, the theoretical ratio upper limit of 1.22E+02 would be 9.5E+01 at present.

The experimentally determined activity ratio was applied to the fission yield calculation of Sn-126 to determine a bounding case for Sn-121m in Sludge Batch 2.

4.1.6 Separation and Analysis for Pm-147

The Promethium-147 measurements were based on a Pm extraction followed by a liquid scintillation analysis for the Pm-147 beta. Initially, a carrier solution of Nd was activated by SRTC's Cf-252 Neutron Activation Analysis Facility. Nd-149 was formed which has a 1.73-hour half-life. The Nd-149 decayed to Pm-149, which has a 2.21 day half-life. The activated carrier solution was used as a tracer for the Pm-147 separations of the sludge digestions. Aliquots of aqua-regia and peroxide fusion dissolution of Sludge Batch 2 were spiked with the activated neodymium solutions, and subjected to a di(2-ethylhexyl) orthophosphoric acid (HDEHP) based Pm-147 extraction. A sample spiked with Sm-151 was run through the same procedure to establish the decontamination factor of Sm vs Pm in the extraction process. Aliquots of the Pm extract were analyzed by liquid scintillation analysis to determine the Pm-147 beta activity. Aliquots of sample were then analyzed by gamma spectroscopy to determine recoveries of the Pm-149 tracer, which was subsequently applied to the Pm-147 beta liquid scintillation results to yield the Pm separation. The results of the Sm-151 spiked extraction indicated that the Sm-151 was removed by a factor of 38. That clean-up would be more than adequate to reduce any positive bias introduced by any Sm-151 beta which was carried along with the Pm-147 to levels of less than 5% in sludge of a 20 year old type timeframe.

4.1.7 Separation and Analysis for Ni-59 and Ni-63

This separation is based on isolation of Ni from the dissolved sludge using a column containing dimethylglyoxime as an extractant that is specific for Ni. Details of this technique have been reported [13]. Nickel was then eluted from the extractant. The Ni-59 was measured by its characteristic X-rays and Ni-63 by its beta particles. Total Ni was measured by inductively coupled plasma excitation spectroscopy.

4.2 Determination of Radionuclide Activities by Fission Yield Scaling Factor (FYSF)

The FYSF is used to estimate concentrations of U-235 fission products that may be reportable but cannot be detected. In order to calculate the FYSF, as many as possible of the U-235 fission products were measured in the four sludge slurry samples. The fission products in SRS high level waste primarily result from the fission of U-235 used in the SRS reactors. The relative amounts (fission yields) of these products occur in a low and a high-mass fraction and their yields are well known from many studies. A compilation of these yields on an atom basis has been published [14].

The FYSF was determined using the fission yield and the measured concentrations in the sludge of those U-235 fission products that meet the following five criteria. These criteria are:

1. The isotopes had to have low solubilities in NaOH and thus occur predominantly in the sludge.
2. They had to have long half-lives and thus had not decayed significantly since the waste was generated.
3. The isotopes had to have low neutron cross-sections and thus were not transmuted in the SRS reactors during their operation.
4. The isotopes could not be formed in the reactors by neutron absorption.
5. Lastly, the isotopes had to have masses where interferences such as those from rare earth oxides formed in the Ar plasma did not create a problem.

Twelve isotopes meet these criteria. These isotopes are Ru-101, Ru-102, Rh-103, Ru-104, La-139, Pr-141, Nd-143, 144, 145, 146, Sm-147, and Sm-148. Note that isotopes from both the low mass and high mass fractions of the fission of U-235 are included. The fission yield scaling factor for each isotope was calculated by dividing the fission yield by the concentration of that respective isotope in the sludge and multiplying the resultant number by the atomic mass. The average FYSF based on the twelve isotopes was 3.98E+04. The RSD was 14.4% (See Table 3).

Table 3 – Isotopes Used for Calculation of the FYSF.

Isotope	Wt%	Fission Yield	FYSF
Ru-101	1.32E-02	5.18	3.98E+04
Ru-102	1.20E-02	4.29	3.66E+04
Rh-103	7.77E-03	3.03	4.02E+04
Ru-104	8.04E-03	1.88	2.43E+04
La-139	2.10E-02	6.60	4.37E+04
Pr-141	1.84E-02	5.90	4.52E+04
Nd-143	1.89E-02	6.00	4.55E+04
Nd-144	1.95E-02	5.45	4.02E+04
Nd-145	1.31E-02	3.95	4.36E+04
Nd-146	1.11E-02	3.00	3.94E+04
Sm-147	7.86E-03	2.26	4.23E+04
Sm-148	6.86E-03	1.69	3.64E+04
		Average FYSF	**3.98E+04**
		Standard Deviation	**5.71E+03**
		%RSD	**1.44E+01**

The weight percents of Se-79, Rb-87, In-115, and Sn-126 were calculated using the FYSF. These calculations were carried out by multiplying the fission yield for the respective radionuclide by its mass and then dividing by the FYSF. These concentrations represent the maximum values for these radionuclides in the sludge for two reasons. The radioisotope may have a significant solubility in caustic and therefore, may be predominantly in the SRS salt tanks or the radioisotope may have a large neutron capture cross section and be transmuted in the reactor.

4.3 Estimation of the Activities of the Remaining Radionuclides

Pd-107. For this radionuclide, the activity was calculated by multiplying the ratio of fission yields for Pd-107 and Pd-105 by the measured wt % for Pd-105 as determined by ICP-MS.

Cs-135. Cs-135 can not be detected by ICP-MS in the sludge slurry because of its low concentration in the sludge slurry and because of the large amount of natural Ba-135 existing at the same mass as the Cs-135. Cs-135 can not be detected by counting techniques either because of its long half-life (2.3E+06 years). The detection by ICP-MS of Cs-135 in the supernate is possible because Ba-135 is insoluble in caustic supernate. The same philosophy applies to Ba-137 and Cs-137. Thus, barium does not interfere with the analyses of Cs-135 or Cs-137 in the supernate. By using the ratio of Cs-135 to Cs-137 in the supernate, and the amount of Cs-137 (Gamma Scan) in the sludge slurry, the activity for Cs-135 in the sludge slurry can be calculated. It turns out that the ratios of the three cesium isotopes, normalized to Cs-133 are Cs-133 (1.0), Cs-135 (0.14), and Cs-137 (0.49). This can be compared to the results from Sludge Batch 1B where the corresponding ratios were 1.0, 0.16, and 0.45.

Zr-93, Sm-151, Th-232, U-236, and Pu-242. The activities for these radionuclides were obtained using ICP-MS analysis of the solution after dissolution using aqua regia. These results were obtained at the same time as the other radionuclides reported by Bibler and Ray, and by Fellinger et al. However, the inclusion of the activities for these radionuclides was not required for those reports.

4.4 Summary of the Activities and Radionuclides for Input

The complete list of radionuclides and their activities that were considered in the determination of reportable radionuclides are provided in Table 4. For those radionuclides with measured concentrations, the initial activities were calculated by using the weight percent reported for each radioisotope (converted to number of atoms), and its half-life by the following equation:
$A_o = N_o * \lambda$ where: A_o = Initial Activity, N_o = initial number of atoms, and λ = 0.693/half-life [15].

For each radionuclide listed in Table 4 there is an associated lambda (λ) in units of $(\text{seconds})^{-1}$, Wt % of the dried sludge, activities expressed in both Curies/kilogram and Micro-Curies/gram, and the source of the data. The sources are:

- Bibler and Ray. See reference 7.
- Special Separations. Section 4.1 of this report
- FYSF. Section 4.2 of this report
- ICP-MS-Aqua Regia. Analytical data in records package
- Section 4.3. Section 4.3 of this report

Several radionuclides that were listed in Table 1 were not included in Table 4 due to their very low concentrations and insignificant activities. These included Rb-87 (5.57E-03 wt% and a half-life of 4.90E+10 years), Cd-113 (1.64E-02 wt% and a half-life of 9.3E+15 years), In-115 (3.18E-05 wt% and a half-life of 4.40E+15 years), and Cf-250 (<1.32E-07 wt% and a half-life of 13.08 years).

Table 4 – List of Radionuclides and Activities used as Input to the Radioactive Decay Calculator. (Sn-121m was not included in the input to the program. See Section 4.5)

Radionuclide	Lamda	Wt%	Curies per Kilogram	Micro-Curies per Gram	Source
C-14	3.84E-12	1.82E-07	8.13E-06	8.13E-03	Special Separations
Ni-59	2.93E-13	3.88E-04	3.13E-04	3.13E-01	Special Separations
Co-60	4.16E-09	4.84E-07	5.47E-03	5.47E+00	Bibler and Ray
Ni-63	2E-10	3.97E-05	2.05E-02	2.05E+01	Special Separations
Se-79	3.38E-13	8.95E-05	6.23E-05	6.23E-02	FYSF
Sr-90	7.55E-10	3.32E-03	4.52E+00	4.52E+03	Bibler and Ray
Zr-93	1.44E-14	5.41E-03	1.36E-04	1.36E-01	ICPMS-Aqua Regia
Tc-99	1.04E-13	7.35E-04	1.26E-04	1.26E-01	Bibler and Ray
Pd-107	3.38E-15	8.10E-05	4.16E-07	4.16E-04	See Text
Sn-121m	**4.00E-10**	**6.77E-06**	**3.64E-03**	**3.64E+00**	**Special Separations**
Sn-126	2.2E-13	1.58E-04	4.49E-05	4.49E-02	FYSF
I-129	1.4E-15	4.29E-06	7.57E-09	7.57E-06	Special Separations
Cs-135	9.55E-15	9.34E-05	1.08E-06	1.08E-03	See Text
Cs-137	7.3E-10	3.17E-04	2.75E-01	2.75E+02	Bibler and Ray
Pm-147	8.39E-09	1.40E-05	1.30E-01	1.30E+02	Special Separations
Sm-151	2.44E-10	6.75E-04	1.77E-01	1.77E+02	ICPMS-Aqua Regia
Eu-154	2.56E-09	2.96E-06	8.01E-03	8.01E+00	Bibler and Ray
Th-232	1.56E-18	3.44E-02	3.76E-08	3.76E-05	ICPMS-Aqua Regia
U-233	1.38E-13	1.11E-04	1.07E-05	1.07E-02	Bibler and Ray
U-234	8.97E-14	5.72E-04	3.57E-05	3.57E-02	Bibler and Ray
U-235	3.12E-17	3.04E-02	6.57E-07	6.57E-04	Bibler and Ray
U-236	9.38E-16	1.46E-03	9.44E-07	9.44E-04	ICPMS-Aqua Regia
Np-237	1.03E-14	1.88E-03	1.33E-05	1.33E-02	Bibler and Ray
U-238	4.92E-18	7.53E+00	2.53E-05	2.53E-02	Bibler and Ray
Pu-238	2.5E-10	2.25E-04	3.85E-02	3.85E+01	Bibler and Ray
Pu-239	9.11E-13	1.24E-02	7.68E-03	7.68E+00	Bibler and Ray
Pu-240	3.35E-12	1.05E-03	2.38E-03	2.38E+00	Bibler and Ray
Pu-241	1.53E-09	2.71E-05	2.80E-02	2.80E+01	Bibler and Ray
Am-241	5.08E-11	9.53E-04	3.27E-02	3.27E+01	Special Separations
Am-242m	1.45E-10	1.13E-06	1.10E-04	1.10E-01	Special Separations
Pu-242	5.89E-14	1.16E-04	4.59E-06	4.59E-03	ICPMS-Aqua Regia
Am-243	2.98E-12	2.68E-04	5.34E-04	5.34E-01	Special Separations
Cm-243	7.71E-10	1.16E-06	6.01E-04	6.01E-01	Special Separations
Cm-244	1.21E-09	5.48E-05	4.42E-02	4.42E+01	Special Separations
Cm-245	2.59E-12	2.25E-06	3.86E-06	3.86E-03	Special Separations
Cm-246	4.65E-12	8.06E-06	2.48E-05	2.48E-02	Special Separations
Cm-247	1.41E-15	1.05E-06	9.75E-10	9.75E-07	Special Separations
Cf-249	6.26E-11	1.27E-07	5.20E-06	5.20E-03	Special Separations
Cf-251	2.44E-11	7.52E-07	1.19E-05	1.19E-02	Special Separations
Total			**5.30E+00**	**5.30E+03**	

4.5 Identification of Reportable Radionuclides

Based on radionuclides and activities provided in Table 4, a commercially available computer program was used to identify which radionuclides were reportable through calendar year 3115. The program called the "**Radioactive Decay Calculator**" [16] performed the calculations. A brief description of the program's technical basis and the validation process can be found in reference 6.

The initial activities for 38 isotopes were entered into the "**Radioactive Decay Calculator**" and the results of three calculations with time periods of 1 year (2003), 13 years (2015), and 1113 years (3115) are presented in Tables 5, 6 and 7. Those radionuclides that are reportable are designated in these Tables by a, "yes,"in each respective Table. Additional calculations were performed for every 100 years up to 1100 years. The results of these calculations have not been included in this report but are documented in the notebook, WSRC-NB-2001-00163 for this task. Excel spreadsheets were used to calculate the total activity (Micro-Curies/gram of dried sludge slurry) at each time and the percent of the activity that each of the radionuclides contributed. The value of the activity in Curies/kilogram can be obtained by multiplying the value in Micro-Curies/gram by 1.0E-03.

One of the radionuclides (Sn-121m) is not part of the database within the "**Radioactive Decay Calculator**". Consequently, the calculations for the decay of Sn-121m, with a half-life of 55 years, were performed separately (WSRC-NB-2001-00163) and then added to the output of the Calculator for each calculation. These calculations for Sn-121m were verified by "**RadDecay for Windows"**[17] (see discussion below).

The calculations performed by the "**Radioactive Decay Calculator"** were verified by a separate program called "**RadDecay for Windows"**[17]. A comparison between the output of the two programs showed equivalence for all of the reportable radionuclides out to 3115, except for Pu-238 in the year 3115 (5.87E-03 vs. 7.17E-03 Micro-Curies/gram). Calculations by Sigg (WSRC-NB-2001-00163) demonstrated that the "**RadDecay for Windows"** program correctly predicted the Pu-238 value of 7.17E-03 Micro-Curies/gram. The difference in the values between the two programs was due to the fact that the "**Radioactive Decay Calculator"** did not account properly for the generation of Pu-238 from the decay of Am-242m. Therefore, the value for Pu-238 in Table 7 was obtained from the output of the "**RadDecay for Windows"** program**.**

Table 5. Activities in MicroCuries/gram of Dried Sludge in Year 2003

Isotopes	MicroCuries per gram	Fraction of Activity	Reportable
C-14	8.13E-03	8.29E-07	
Ni-59	3.13E-01	3.19E-05	
Co-60	4.80E+00	4.89E-04	
Ni-63	2.04E+01	2.08E-03	yes
Se-79	6.23E-02	6.35E-06	
Sr-90	4.41E+03	4.50E-01	yes
Y-90	4.41E+03	4.50E-01	
Zr-93	1.36E-01	1.39E-05	
Nb-93m	6.30E-03	6.43E-07	
Tc-99	1.26E-01	1.28E-05	
Pd-107	4.16E-04	4.24E-08	
Sn-121m	3.59E+00	3.66E-04	yes
Sn-126	4.49E-02	4.58E-06	
Sb-126m	4.49E-02	4.58E-06	
Sb-126	6.29E-03	6.41E-07	
I-129	7.57E-06	7.72E-10	
Cs-135	1.08E-03	1.10E-07	
Cs-137	2.69E+02	2.74E-02	yes
Ba-137m	2.54E+02	2.59E-02	
Pm-147	9.98E+01	1.02E-02	
Sm-147	7.47E-10	7.61E-14	
Sm-151	1.76E+02	1.79E-02	yes
Eu-154	7.40E+00	7.55E-04	
Th-232	3.76E-05	3.83E-09	
Ra-228	4.27E-06	4.35E-10	
Ac-228	4.27E-06	4.35E-10	
Th-228	6.99E-07	7.13E-11	
Ra-224	6.81E-07	6.94E-11	
Rn-220	6.81E-07	6.94E-11	
Po-216	6.81E-07	6.94E-11	
Pb-212	6.79E-07	6.92E-11	
Bi-212	6.79E-07	6.92E-11	
Tl-208	2.44E-07	2.49E-11	
Po-212	4.35E-07	4.43E-11	
U-233	1.07E-02	1.09E-06	
Th-229	1.01E-06	1.03E-10	
Ra-225	9.51E-07	9.70E-11	
Ac-225	9.51E-07	9.70E-11	
Fr-221	9.51E-07	9.70E-11	
At-217	9.51E-07	9.70E-11	
Bi-213	9.51E-07	9.70E-11	
Tl-209	2.05E-08	2.09E-12	
Pb-209	9.50E-07	9.69E-11	
Po-213	9.30E-07	9.49E-11	
U-234	3.58E-02	3.65E-06	
Th-230	3.22E-07	3.28E-11	
Ra-226	6.96E-11	7.10E-15	
Rn-222	6.76E-11	6.89E-15	
Po-218	6.76E-11	6.89E-15	

Isotopes	MicroCuries per gram	Fraction of Activity	Reportable
Pb-214	6.75E-11	6.89E-15	
Bi-214	6.75E-11	6.89E-15	
Po-214	6.75E-11	6.88E-15	
Pb-210	6.85E-13	6.98E-17	
Bi-210	6.45E-13	6.58E-17	
Po-210	2.08E-13	2.12E-17	
U-235	6.57E-04	6.70E-08	
Th-231	6.57E-04	6.70E-08	
Pa-231	1.22E-08	1.24E-12	
Ac-227	1.91E-10	1.95E-14	
Fr-223	2.63E-12	2.68E-16	
Ra-223	1.50E-10	1.53E-14	
Rn-219	1.50E-10	1.53E-14	
Po-215	1.50E-10	1.53E-14	
Pb-211	1.50E-10	1.53E-14	
Bi-211	1.50E-10	1.53E-14	
Tl-207	1.49E-10	1.52E-14	
Th-227	1.62E-10	1.66E-14	
Po-211	6.50E-15	6.62E-19	
U-236	9.44E-04	9.62E-08	
Np-237	1.33E-02	1.36E-06	
Pa-233	1.33E-02	1.36E-06	
U-238	2.53E-02	2.58E-06	
Th-234	2.53E-02	2.58E-06	
Pa-234m	2.53E-02	2.58E-06	
Pa-234	4.05E-05	4.13E-09	
Pu-238	3.82E+01	3.89E-03	yes
Pu-239	7.68E+00	7.83E-04	yes
Pu-240	2.38E+00	2.43E-04	yes
Pu-241	2.67E+01	2.72E-03	yes
Am-241	3.27E+01	3.33E-03	yes
Am-242m	1.10E-01	1.12E-05	
Np-238	5.26E-04	5.36E-08	
Am-242	1.09E-01	1.11E-05	
Pu-242	4.59E-03	4.68E-07	
Am-243	5.34E-01	5.44E-05	
Np-239	5.34E-01	5.44E-05	
Cm-243	5.87E-01	5.98E-05	
Cm-244	4.25E+01	4.34E-03	yes
Cm-245	3.86E-03	3.94E-07	
Cm-246	2.48E-02	2.53E-06	
Cm-247	9.76E-07	9.95E-11	
Pu-243	9.76E-07	9.95E-11	
Cf-249	5.19E-03	5.29E-07	
Cf-251	1.19E-02	1.21E-06	
Total	9.81E+03	1.00E+00	

Table 6. Activities in MicroCuries/gram of Dried Sludge in Year 2015

Isotopes	MicroCuries per gram	Fraction of Activity	Reportable
C-14	8.12E-03	1.11E-06	
Ni-59	3.13E-01	4.28E-05	
Co-60	9.90E-01	1.36E-04	
Ni-63	1.87E+01	2.57E-03	yes
Se-79	6.23E-02	8.53E-06	
Sr-90	3.30E+03	4.52E-01	yes
Y-90	3.30E+03	4.52E-01	
Zr-93	1.36E-01	1.86E-05	
Nb-93m	6.26E-02	8.57E-06	
Tc-99	1.26E-01	1.72E-05	
Pd-107	4.16E-04	5.70E-08	
Sn-121m	3.09E+00	4.22E-04	yes
Sn-126	4.49E-02	6.15E-06	
Sb-126m	4.49E-02	6.15E-06	
Sb-126	6.29E-03	8.61E-07	
I-129	7.57E-06	1.04E-09	
Cs-135	1.08E-03	1.48E-07	
Cs-137	2.04E+02	2.79E-02	yes
Ba-137m	1.93E+02	2.64E-02	
Pm-147	4.19E+00	5.74E-04	
Sm-147	3.11E-09	4.26E-13	
Sm-151	1.60E+02	2.19E-02	yes
Eu-154	2.88E+00	3.94E-04	
Th-232	3.76E-05	5.15E-09	
Ra-228	2.98E-05	4.07E-09	
Ac-228	2.98E-05	4.07E-09	
Th-228	2.60E-05	3.56E-09	
Ra-224	2.60E-05	3.56E-09	
Rn-220	2.60E-05	3.56E-09	
Po-216	2.60E-05	3.56E-09	
Pb-212	2.60E-05	3.56E-09	
Bi-212	2.60E-05	3.56E-09	
Tl-208	9.34E-06	1.28E-09	
Po-212	1.66E-05	2.28E-09	
U-233	1.07E-02	1.46E-06	
Th-229	1.31E-05	1.80E-09	
Ra-225	1.31E-05	1.79E-09	
Ac-225	1.31E-05	1.79E-09	
Fr-221	1.31E-05	1.79E-09	
At-217	1.31E-05	1.79E-09	
Bi-213	1.31E-05	1.79E-09	
Tl-209	2.82E-07	3.86E-11	
Pb-209	1.31E-05	1.79E-09	
Po-213	1.28E-05	1.75E-09	
U-234	3.70E-02	5.07E-06	
Th-230	4.26E-06	5.83E-10	
Ra-226	1.19E-08	1.63E-12	
Rn-222	1.19E-08	1.62E-12	
Po-218	1.19E-08	1.62E-12	
Pb-214	1.19E-08	1.62E-12	
Bi-214	1.19E-08	1.62E-12	
Po-214	1.19E-08	1.62E-12	
Pb-210	1.44E-09	1.98E-13	
Bi-210	1.44E-09	1.97E-13	
Po-210	1.28E-09	1.75E-13	
U-235	6.57E-04	9.00E-08	
Th-231	6.57E-04	9.00E-08	
Pa-231	1.59E-07	2.17E-11	
Ac-227	2.88E-08	3.94E-12	
Fr-223	3.97E-10	5.43E-14	
Ra-223	2.83E-08	3.87E-12	
Rn-219	2.83E-08	3.87E-12	
Po-215	2.83E-08	3.87E-12	
Pb-211	2.83E-08	3.87E-12	
Bi-211	2.83E-08	3.87E-12	
Tl-207	2.82E-08	3.86E-12	
Th-227	2.81E-08	3.84E-12	
Po-211	1.06E-12	1.46E-16	
U-236	9.45E-04	1.29E-07	
Np-237	1.34E-02	1.84E-06	
Pa-233	1.34E-02	1.84E-06	
U-238	2.53E-02	3.46E-06	
Th-234	2.53E-02	3.46E-06	
Pa-234m	2.53E-02	3.46E-06	
Pa-234	4.05E-05	5.54E-09	
Pu-238	3.47E+01	4.76E-03	yes
Pu-239	7.68E+00	1.05E-03	yes
Pu-240	2.42E+00	3.32E-04	yes
Pu-241	1.50E+01	2.05E-03	yes
Am-241	3.25E+01	4.44E-03	yes
Am-242m	1.04E-01	1.42E-05	
Np-238	4.98E-04	6.81E-08	
Am-242	1.03E-01	1.41E-05	
Pu-242	4.59E-03	6.29E-07	
Am-243	5.33E-01	7.30E-05	
Np-239	5.33E-01	7.30E-05	
Cm-243	4.38E-01	6.00E-05	
Cm-244	2.69E+01	3.68E-03	yes
Cm-245	3.86E-03	5.29E-07	
Cm-246	2.48E-02	3.39E-06	
Cm-247	9.82E-07	1.34E-10	
Pu-243	9.82E-07	1.34E-10	
Cf-249	5.07E-03	6.94E-07	
Cf-251	1.18E-02	1.61E-06	
Total	7.31E+03	1.00E+00	

Table 7. Activities in MicroCuries/gram of Dried Sludge in Year 3115

Isotopes	MicroCuries per gram	Fraction of Activity	Reportable
C-14	7.11E-03	4.07E-04	yes
Ni-59	3.10E-01	1.78E-02	yes
Co-60	1.54E-63	8.83E-65	
Ni-63	9.23E-03	5.29E-04	yes
Se-79	6.16E-02	3.53E-03	yes
Sr-90	8.76E-09	5.02E-10	
Y-90	8.77E-09	5.03E-10	
Zr-93	1.36E-01	7.79E-03	yes
Nb-93m	1.36E-01	7.79E-03	yes
Tc-99	1.26E-01	7.20E-03	yes
Pd-107	4.16E-04	2.38E-05	
Sn-121m	2.95E-06	1.6923E-07	
Sn-126	4.46E-02	2.55E-03	yes
Sb-126m	4.46E-02	2.55E-03	
Sb-126	6.24E-03	3.58E-04	
I-129	7.57E-06	4.34E-07	
Cs-135	1.08E-03	6.19E-05	
Cs-137	2.17E-09	1.24E-10	
Ba-137m	2.05E-09	1.18E-10	
Pm-147	0.00E+00	0.00E+00	
Sm-147	3.22E-09	1.84E-10	
Sm-151	3.36E-02	1.92E-03	yes
Eu-154	6.89E-38	3.95E-39	
Th-232	3.76E-05	2.16E-06	
Ra-228	3.76E-05	2.16E-06	
Ac-228	3.76E-05	2.16E-06	
Th-228	3.76E-05	2.16E-06	
Ra-224	3.76E-05	2.16E-06	
Rn-220	3.76E-05	2.16E-06	
Po-216	3.76E-05	2.16E-06	
Pb-212	3.76E-05	2.16E-06	
Bi-212	3.76E-05	2.16E-06	
Tl-208	1.35E-05	7.74E-07	
Po-212	2.41E-05	1.38E-06	
U-233	1.07E-02	6.15E-04	yes
Th-229	1.07E-03	6.13E-05	
Ra-225	1.07E-03	6.13E-05	
Ac-225	1.07E-03	6.13E-05	
Fr-221	1.07E-03	6.13E-05	
At-217	1.07E-03	6.13E-05	
Bi-213	1.07E-03	6.13E-05	
Tl-209	2.31E-05	1.32E-06	
Pb-209	1.07E-03	6.13E-05	
Po-213	1.04E-03	5.97E-05	
U-234	4.94E-02	2.83E-03	yes
Th-230	4.78E-04	2.74E-05	
Ra-226	9.66E-05	5.54E-06	
Rn-222	9.66E-05	5.54E-06	
Po-218	9.66E-05	5.54E-06	

Isotopes	MicroCuries per gram	Fraction of Activity	Reportable
Pb-214	9.66E-05	5.54E-06	
Bi-214	9.66E-05	5.54E-06	
Po-214	9.66E-05	5.54E-06	
Pb-210	9.14E-05	5.24E-06	
Bi-210	9.14E-05	5.24E-06	
Po-210	9.13E-05	5.23E-06	
U-235	6.65E-04	3.81E-05	
Th-231	6.65E-04	3.81E-05	
Pa-231	1.35E-05	7.77E-07	
Ac-227	1.32E-05	7.55E-07	
Fr-223	1.82E-07	1.04E-08	
Ra-223	1.32E-05	7.55E-07	
Rn-219	1.32E-05	7.55E-07	
Po-215	1.32E-05	7.55E-07	
Pb-211	1.32E-05	7.55E-07	
Bi-211	1.32E-05	7.55E-07	
Tl-207	1.31E-05	7.53E-07	
Th-227	1.29E-05	7.40E-07	
Po-211	4.87E-10	2.79E-11	
U-236	1.02E-03	5.86E-05	
Np-237	1.89E-02	1.09E-03	yes
Pa-233	1.89E-02	1.09E-03	
U-238	2.53E-02	1.45E-03	yes
Th-234	2.53E-02	1.45E-03	
Pa-234m	2.53E-02	1.45E-03	
Pa-234	4.05E-05	2.32E-06	
Pu-238	5.87E-03	3.37E-04	yes
Pu-239	7.46E+00	4.27E-01	yes
Pu-240	2.23E+00	1.28E-01	yes
Pu-241	3.71E-03	2.13E-04	yes
Am-241	5.65E+00	3.24E-01	yes
Am-242m	6.88E-04	3.94E-05	
Np-238	3.30E-06	1.89E-07	
Am-242	6.85E-04	3.93E-05	
Pu-242	4.64E-03	2.66E-04	yes
Am-243	4.81E-01	2.76E-02	yes
Np-239	4.81E-01	2.76E-02	
Cm-243	1.06E-12	6.08E-14	
Cm-244	1.41E-17	8.07E-19	
Cm-245	3.70E-03	2.12E-04	yes
Cm-246	2.11E-02	1.21E-03	yes
Cm-247	1.37E-06	7.85E-08	
Pu-243	1.37E-06	7.85E-08	
Cf-249	5.76E-04	3.30E-05	
Cf-251	5.05E-03	2.90E-04	yes
Total	1.74E+01	1.00E+00	

The total Curie content of the dried sludge in the year 2015 is 7.31E+03 Micro-Curies/gram. This value is greater than the 3.80E+03 Micro-Curies/gram total represented by the reportable radionuclides in Table 6. The difference is due to the significant contribution to the activity from radionuclides having half-lives shorter than 10 years. These radionuclides include Co-60, Y-90, Ba-137m, Pm-147, and Eu-154.

Table 7 presents the reportable radionuclides indexed to the year 3115. The total Curie content of the dried sludge in 3115 is 1.74E+01 Micro-Curies/gram. This value is slightly greater than the 1.70E+01 Micro-Curies/gram total represented by the radionuclides identified as reportable. The difference is due to the minor contribution to the total activity from radionuclides having half-lives shorter than 10 years. These radionuclides include Sb-126m, Sb-126, Pa-233, Th-234, Pa-234m, and Np-239.

The calculations at every one hundred years out to 1100 years demonstrated that no additional radionuclides became reportable during this time period.

The WCP and WQR require that all of the radionuclides present in the Design Basis glass be considered as the initial set of reportable radionuclides. All of the radionuclides in the Design Basis glass are reportable except for three radionuclides: Pd-107, Cs-135, and Th-230. At no time during the 1100-year period between 2105 and 3115 did any of these three radionuclides contribute to more than 0.01 % of the radioactivity on a Curie basis.

It is also worth noting that the C-14 concentration in the glass may be lowered by volatility from the melter.

5.0 The Ratio by Weight of U and Pu Isotopes

The WQR requires that the relative concentrations of the uranium and plutonium isotopes be provided from the analysis of each Macro Batch (in this case Sludge Batch 2) in order to meet the WAPS IAEA Safeguards Reporting for HLW Specification (WAPS 1.6). The data for uranium isotopes are:

		% Distribution	Wt %
U-233	233	1.46E-03	1.11E-04
U-234	234	7.57E-03	5.72E-04
U-235	235	4.02E-01	3.04E-02
U-236	236	1.93E-02	1.46E-03
U-238	238	9.96E+01	7.53E+00
Total		1.00E+02	7.56E+00

The data for the plutonium isotopes are:

		% Distribution	Wt%
Pu-238	238	1.63E+00	2.25E-04
Pu-239	239	8.97E+01	1.24E-02
Pu-240	240	7.61E+00	1.05E-03
Pu-241	241	1.96E-01	2.71E-05
Pu-242	242	8.41E-01	1.16E-04
Total		1.00E+02	1.38E-02

All of the Pu isotopes and U-233, U-234, and U-238 are already reportable since they meet the requirement of having half-lives greater than 10 years and a contribution to the overall activity of greater than 0.01 % on a Curie basis through the year 3115. In order to be compliant with WAPS 1.6, U-235 and U-236 also become reportable even though they contribute less than 0.01 % to the total activity (U-235 at 0.004 % and U-236 at 0.006 % in 3115).

6.0 Conclusions

Twenty-seven radionuclides have been identified as reportable for DWPF Sludge Batch 2 (Macro Batch 3) as specified by WAPS 1.2. Consistent with the strategy detailed in the WCP and WQR, each of these radionuclides has a half-life greater than 10 years and contributes more than 0.01 % of the radioactivity on a Curie basis at some point from production through the 1100-year period between 2015 and 3115. The 27 reportable radionuclides are:

C-14	**Ni-59**	**Ni-63**	**Se-79**	**Sr-90**	**Zr-93**
Nb-93m	**Tc-99**	**Sn-121m**	**Sn-126**	**Cs-137**	**Sm-151**
U-233	**U-234**	**Np-237**	**U-238**	**Pu-238**	**Pu-239**
Pu-240	**Am-241**	**Pu-241**	**Pu-242**	**Am-243**	**Cm-244**
Cm-245	**Cm-246**	**Cf-251**			

The WCP and WQR require that all of the radionuclides present in the Design Basis glass be considered as the initial set of reportable radionuclides. For Sludge Batch 2 (Macro Batch 3) all of the radionuclides in the Design Basis glass are reportable except for three radionuclides: Pd-107, Cs-135, and Th-230. At no time through the calendar year 3115 did any of these three radionuclides contribute to more than 0.01 % of the radioactivity on a Curie basis.

Two additional uranium isotopes (U-235 and U-236) must be added to the list of reportable radionuclides in order to meet WAPS 1.6. All of the Pu isotopes and other U isotopes (U-233, U-234 and U-238) identified in WAPS 1.6 were already determined to be reportable according to WAPS 1.2. This brings the total number of reportable radionuclides for Sludge Batch 2 to twenty-nine.

Five of the twenty-nine reportable radionuclides for Sludge Batch 2 are not part of either the design-basis list of radionuclides or the list of Pu and U isotopes identified in WAPS 1.6. These include C-14, Sn-121m, Cm-245, Cm-246 and Cf-251. Two of these radionuclides (C-14 and Cm-246) were also reported for Macro Batch 2 (Sludge Batch 1B) [6]. Both the Cf-251 and Cm-245 radionuclides were not detected and consequently, the detection limits for these isotopes were used as input to the calculations. Sn-121m was identified as described in the Special Separations Section of this report.

The list of reportable radionuclides that were determined for Sludge Batch 1B (Macro Batch 2) contained five radionuclides that were not reportable for Sludge Batch 2 (Macro Batch 3). These radionuclides were Pd-107, I-129, Cs-135, Th-229, and Th-230.

7.0 References

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