# DOCUMENT RELEASE AND CHANGE FORM

Prepared For the U.S. Department of Energy, Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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10. **Related Structures, Systems, and Components**

   a. **Related Building/Facilities**
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12. **Impacted Documents (Outside SPF):**

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14. **Distribution**

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241-AZ-301 Hard-to-Detect Analysis

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U.S. Department of Energy Contract DE-AC27-08RV14800

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Abstract: Radiological characterization demonstrates that Hard-to-Detect nuclide evaluations are not necessary for activities associated with the 241-AZ-301 Catch Tank.

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Approved For Public Release
Radiological Calculation Checklist

Calculation Title/Subject:
RPP-RPT-60041, 241-AZ-301 Hard-to-Detect Analysis

Scope of Review:
Health Physicist
Project RadCon Manager

Calculations, formulas, raw data source

Jeff Hunter  
Tom George

Date: 04/05/2017  
Date: 04/16/2017

Yes  No  NA

a. The objective/purpose of the calculation is clearly stated and the problem is completely defined by the purpose statement.

b. Analytical and technical approaches and results are reasonable and appropriate.

c. Input data are adequately described, referenced to their source, and checked for consistency with original source information.

d. Necessary assumptions are reasonable, explicitly stated, and supported. Assumptions requiring verification prior to use are clearly stated and identified.

e. For both qualitative and quantitative data, uncertainties are recognized and discussed and the data is presented in a manner to minimize design interpretations.

f. Mathematical derivations were checked, including dimensional consistency of results.

g. Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information.

h. Hand and MathCAD® calculations were verified, including review that correct input data are used, formulae correctly interpret intended expressions, correct units are used, and results are reasonable and appropriate.

i. Software applications used are identified by the program name and version/release number as required by Attachment A (Section 7, Use of Computer Software).

j. Software input data is identified and/or attached/included, the input data is correct, and consistent with the calculation document.

k. Software output is consistent with the input and with the results reported in the calculation document.

l. Software verification and validation are addressed adequately in accordance with TFC-BSM-IRM_HS-C-01. Software verification documentation, (typically the Software Management Plan or Test Report), is included in the calculation document, or a reference is provided as required by Attachment A (Section 7, Use of Computer Software).

m. Software verification show that software produces correct solution for the encoded mathematical model within defined limits for each parameter employed and the software is used within its limits.

n. The encoded mathematical model (method), produces a valid solution to the physical problem associated with the particular application (i.e., the methodology used is applicable to the problem being solved).

o. Multiple-Use spreadsheets used in the calculation are identified, verified, and documented in accordance with TFC-ENG-DESIGN-C-32. Reference to the corresponding Software
Management Plan or Spreadsheet Verification Form (for legacy spreadsheets) is included in calculation as required by Attachment A (Section 7, Use of Computer Software).

[X] [ ] [ ] p. Single-Use spreadsheets used in the calculation are identified, verified, and documented as part of the calculation or other technical document as prescribed in TFC-ENG-DESIGN-C-10.

[X] [ ] [ ] q. Data or results presented in tables and graphs have been checked against original source.

[X] [ ] [ ] r. The number of significant digits is appropriate and consistent.

[X] [ ] [ ] s. Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references.

[X] [ ] [ ] t. Conclusions are consistent with analytical results and applicable limits.

[X] [ ] [ ] u. Results and conclusions address all points in the purpose.

[X] [ ] [ ] v. Referenced documents are retrievable or otherwise available and the version or revision of each reference is cited.

[X] [ ] [ ] w. The calculation was prepared in accordance with Attachment A, “Calculation Format and Preparation Instructions,” of TFC-ESHQ-RP ADM-P-01 or TFC-ESHQ-RP ADM-D-24, as applicable.

[X] [ ] [ ] x. Impacts on requirements have been assessed and change documentation initiated to incorporate revisions to affected documents, as appropriate.

[X] [ ] [ ] y. All checker comments have been dispositioned.

[X] [ ] [ ] z. The report matches the calculations.

Jeff Hunter 04/05/2017
Checker (printed name and signature) Date
EXECUTIVE SUMMARY

Recent sampling and characterization data confirms that an evaluation of Hard-to-Detect nuclides, including Tritium, is not necessary when performing surveys associated with the 241-AZ-301 Catch Tank.

ACRONYMS

CL  Confidence Level
dpm Disintegrations per Minute
ETD Easy to Detect
GM  Geiger Muller
HTD  Hard to Detect
MDA Minimum Detectable Activity

1.0 PURPOSE

The purpose of this analysis is to substantiate that an evaluation of Hard-to-Detect nuclides (Group 4), including Tritium (Group 5), is not necessary when performing release surveys, shipment surveys and job coverage surveys associated with the 241-AZ-301 Catch Tank.

2.0 SCOPE

This analysis is specific to surveys performed on the 241-AZ-301 Catch Tank system.
3.0 ADMINISTRATIVE REQUIREMENTS

The technical basis for determining when Hard-to-Detect surveys are required is driven by RPP-53057, *TOC Technical Basis for Evaluation of Hard-to-Detect Beta-Emitting Radionuclides*. The current revision to RPP-53057 was issued November 02, 2016 and it identified that an evaluation of Group 4 Hard-to-Detect nuclides is necessary for surveys performed at the 241-AZ-301 Catch Tank.

On March 2, 2017 new characterization data became available for the 241-AZ-301 Catch Tank and it was documented in RPP-RPT-59865, *Final Report for AZ-301 Catch Tank Liquid Samples Taken in December 2016*. The new characterization data indicates that an evaluation of Group 4 Hard-to-Detect nuclides and Tritium is not necessary for surveys performed at the 241-AZ-301 Catch Tank.

RPP-53057 states:

*Deviations from the ETD and HTD classifications in this document are permissible provided the following two conditions are met:*

- **Representative sample data is obtained to support any conclusions made concerning the current radiological characterization of the tank/location in question.**
- **All conclusions that deviate from this RPP are documented in a technical basis document (RPP) containing assumptions, calculations and supporting evidence that is equivalent in rigor to this RPP and approved by the Radiological Engineering Manager.**
- **New data is incorporated into this document at the next revision.**

This document utilizes representative sample data and constitutes a technical basis that is equivalent in rigor to RPP-53057. It requires approval from the Radiological Engineering Manager prior to becoming effective.

This document reviews Group 4 beta-emitting Hard-to-Detect nuclides and Tritium (Group 5) because the existing technical basis in RPP-53057 already excludes Group 1 nuclides.

4.0 CHARACTERIZATION DATA

The sampling campaign for the 241-AZ-301 Catch Tank was performed by Washington River Protection Solutions (WRPS) Integration and Control utilizing an approved sampling plan (RPP-PLAN-55317, *Sampling and Analysis Plan for Tank AZ-301 Liquid*). The results were published in RPP-RPT-59865, *Final Report for AZ-301 Catch Tank Liquid Samples December 2016*.

Sampling methods and laboratory analysis methods are described exhaustively in the final report and are not detailed below. Table 1 summarizes the pertinent results drawn from the final sampling report for Group 4 ETD and HTD nuclides. Table 2 documents the Tritium (Group 5) results. The results are used over the remainder of this document in all subsequent calculations.
### Table 1: Group 4 Nuclide Values used in this Analysis

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>ETD or HTD</th>
<th>Value used (µCi/ml)</th>
<th>Technical Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony-125</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 34)</td>
</tr>
<tr>
<td>Barium-137m</td>
<td>ETD</td>
<td>1.34E-03</td>
<td>Assumed to be in equilibrium with Cs-137</td>
</tr>
<tr>
<td>Cadmium-113m</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 19)</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>HTD</td>
<td>1.66E-07</td>
<td>Not detected - conservatively chosen at MDA in RPP-59865 (page 27)</td>
</tr>
<tr>
<td>Cesium-134</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 21)</td>
</tr>
<tr>
<td>Cesium-137</td>
<td>ETD</td>
<td>1.34E-03</td>
<td>Nominal value from RPP-59865 (page 21)</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 22)</td>
</tr>
<tr>
<td>Europium-152</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 21)</td>
</tr>
<tr>
<td>Europium-154</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 21)</td>
</tr>
<tr>
<td>Europium-155</td>
<td>HTD</td>
<td>2.06E-06</td>
<td>Not detected - conservatively chosen at MDA in RPP-59865 (page 21)</td>
</tr>
<tr>
<td>Nickel-59</td>
<td>HTD</td>
<td>0</td>
<td>Total nickel is not present in significant amounts (RPP-59865 page 32)</td>
</tr>
<tr>
<td>Nickel-63</td>
<td>HTD</td>
<td>1.04E-07</td>
<td>Not detected - conservatively chosen at MDA in RPP-59865 (page 27)</td>
</tr>
<tr>
<td>Niobium-93m</td>
<td>HTD</td>
<td>0</td>
<td>Not present in significant amounts (RPP-59865 page 48)</td>
</tr>
<tr>
<td>Plutonium-241</td>
<td>HTD</td>
<td>1.53E-07</td>
<td>Nominal value from RPP-59865 (page 21)</td>
</tr>
<tr>
<td>Ruthenium-106</td>
<td>HTD</td>
<td>2.11E-05</td>
<td>Not detected (conservatively chosen at MDA in RPP-59865 page 22)</td>
</tr>
<tr>
<td>Samarium-151</td>
<td>HTD</td>
<td>6.69E-06</td>
<td>Not present in significant amounts (RPP-59865 page 34)</td>
</tr>
<tr>
<td>Selenium-79</td>
<td>HTD</td>
<td>6.88E-08</td>
<td>Not detected - conservatively chosen at MDA in RPP-59865 (page 22)</td>
</tr>
<tr>
<td>Strontium-90</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 48)</td>
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<tr>
<td>Technecium-99</td>
<td>ETD</td>
<td>6.71E-05</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 33)</td>
</tr>
<tr>
<td>Tin-126</td>
<td>HTD</td>
<td>2.3E-04</td>
<td>Not present in significant amounts (RPP-59865 page 33)</td>
</tr>
<tr>
<td>Yttrium-90</td>
<td>ETD</td>
<td>0</td>
<td>No credit taken as an ETD for conservatism (RPP-59865 page 48)</td>
</tr>
<tr>
<td>Zirconium</td>
<td>HTD</td>
<td>0</td>
<td>Not present in significant amounts (RPP-59865 page 49)</td>
</tr>
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### Table 2 Tritium (Group 5) Results

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>ETD or HTD</th>
<th>Value used (µCi/ml)</th>
<th>Technical Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritium</td>
<td>HTD</td>
<td>5.67E-03</td>
<td>RPP-59865 (page 27)</td>
</tr>
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</table>
5.0 CALCULATIONS

Group 4:

One of the technical requirements for a deviation from RPP-53057 is that the deviating document is equivalent in rigor to the analysis in RPP-53057. For that purpose the following formulas are taken directly from, and used exactly as intended by, RPP-53057.

The weighted MDA (MDA\(_w\)) for the AZ-301 source term is calculated using the calculations identified in RPP-53057. Specifically, Equation 6-1 in RPP-53057 is applied with the exception that activity is expressed in units of µCi/ml instead of Curies.

\[
MDA_w = \left[ \frac{A_{90\text{Sr}Y}}{A_{ETD}} (MDA_{90\text{Sr}Y}) + \frac{A_{137\text{Cs}}}{A_{ETD}} (MDA_{137\text{Cs}}) + \frac{A_{\text{remainder}}}{A_{ETD}} (MDA_{99\text{Tc}}) \right]
\]

Where:

- \(MDA_w\) = Weighted MDA for the mixture of eleven ETD nuclides (dpm/100cm\(^2\))
- \(A_{90\text{Sr}Y}\) = Concentration of \(^{90}\text{Sr} + ^{90}\text{Y}\) (µCi/ml)
- \(MDA_{90\text{Sr}Y}\) = MDA \(^{90}\text{Sr}Y\) for Hanford GM at 2"/sec 67% CL (2,000 dpm/100cm\(^2\))
- \(A_{ETD}\) = Total Activity of \(^{137}\text{Cs}, ^{137m}\text{Ba}, ^{90}\text{Sr}Y, ^{60}\text{Co}, ^{99}\text{Tc}, ^{113m}\text{Cd}, ^{134}\text{Cs}, ^{154}\text{Eu}, ^{152}\text{Eu}, ^{125}\text{Sb}\) (µCi/ml)
- \(A_{137\text{Cs}}\) = Activity of \(^{137}\text{Cs} + ^{137m}\text{Ba}\) (µCi/ml)
- \(MDA_{137\text{Cs}/\text{Ba}}\) = MDA \(^{137}\text{Cs}/^{137m}\text{Ba}\) for Hanford GM at 2"/sec 67% CL (2,900 dpm/100cm\(^2\))
- \(A_{\text{remainder}}\) = Activity of \(^{60}\text{Co}, ^{99}\text{Tc}, ^{113m}\text{Cd}, ^{134}\text{Cs}, ^{154}\text{Eu}, ^{152}\text{Eu}, ^{125}\text{Sb}\) (µCi/ml)
- \(MDA_{99\text{Tc}}\) = MDA \(^{99}\text{Tc}\) for Hanford GM at 2"/sec 67% CL (4,400 dpm/100cm\(^2\))

Applying the values identified in Table 1, \(MDA_w\) is:

\[
\left[ \left( \frac{\text{µCi/ml}}{2.75 - 0.3\text{µCl/ml}} \right) \left(2,000 \text{ dpm/100cm}^2\right) + \left( \frac{2.68E+03 \text{ µCl/ml}}{2.75 - 0.3\text{ µCl/ml}} \right) \left(2,900 \text{ dpm/100cm}^2\right) + \left( \frac{6.71E-05 \text{ µCl/ml}}{2.75 - 0.3\text{ µCl/ml}} \right) \left(4,400 \text{ dpm/100cm}^2\right) \right] = 2,933 \text{ dpm/100cm}^2
\]
The MDA\(_w\) represents the combined activity of all eleven ETD radionuclides when the decision is made that there is a detectable count rate above background. From this, the fractional activity limit for ETDs is:

\[
F_{\text{ETD Limit}} = \left( \frac{\text{MDA}_w}{5,000 \text{ dpm/100cm}^2} \right) = \left( \frac{2933 \text{ dpm/100cm}^2}{5,000 \text{ dpm/100cm}^2} \right) = 0.587
\]

This fractional limit for ETD constitutes the numerator of the screening criteria for HTD surveys. The next step is to calculate the fraction of actual ETD activity for Group 4 MFP as the denominator of the screening criteria as follows:

\[
F_{\text{ETD Actual}} = \left( \frac{A_{\text{ETD}}}{A_{\text{Total MFP}}} \right)
\]

Where:

\[
F_{\text{ETD Actual}} = \text{Total fraction of Group 4 MFP that is detectable (decimal)}
\]

\[
A_{\text{ETD}} = \text{Total Activity of } ^{137}\text{Cs}, ^{137m}\text{Ba}, ^{90}\text{Sr}, ^{90}\text{Y}, ^{60}\text{Co}, ^{99}\text{Tc}, ^{113m}\text{Cd}, ^{134}\text{Cs}, ^{154}\text{Eu}
\]

\[
A_{\text{Total MFP}} = \text{Total Activity of } ^{59}\text{Ni}, ^{63}\text{Ni}, ^{79}\text{Se}, ^{93m}\text{Nb}, ^{93}\text{Zr}, ^{106}\text{Ru}, ^{125}\text{Sn}, ^{151}\text{Sm}, ^{152}\text{Eu}, ^{155}\text{Eu}, ^{241}\text{Pu}, ^{14}\text{C}, \text{and all ETD nuclides}
\]

Applying the values identified in Table 1, \(F_{\text{ETD Actual}}\) is:

\[
\left( \frac{2.75E-03 \text{ uCl/ml}}{3.01E-03 \text{ uCl/ml}} \right) = 0.914
\]

In accordance with RPP-53057, if the ratio of \((F_{\text{ETD Limit}}/F_{\text{ETD Actual}})\) is < 1.00, no HTD surveys are necessary for Group 4 MFP. In the case of AZ-301 the ratio is:

\[
\frac{(0.587)}{(0.914)} = 0.642
\]

Therefore, HTD surveys are not necessary for Group 4 MFP.

**Group 5 (Tritium):**

Group 5 contains only Tritium and has a higher contamination limit than Group 4 MFP. Group 5 Tritium has a removable contamination limit of 10,000 dpm/100 cm\(^2\). Because Tritium is in a separate group, the limit is applied independently and not summed with Group 4 MFP. If we compare the tritium removable contamination limit of 10,000 dpm/100 cm\(^2\) to the Group 4 MFP removable contamination limit of 1,000 cpm/100 cm\(^2\), we get a tritium fraction of 10 times the MFP removable limit. In short, if the actual fraction of Group 5 Tritium to Group 4 MFP is less than 10.00, HTD surveys for Group 5 Tritium are not required.

The below equation calculates the fraction of actual tritium activity for Group 5 Tritium comparable to the actual Group 4 MFP activity.
\[ F_{\text{Trit Actual}} = \left( \frac{A_{\text{Trit}}}{A_{\text{Total MFP}}} \right) \]

Where:

\( F_{\text{Trit Actual}} \) = Actual fraction of Group 5 Tritium to Group 4 MFP (decimal)

\( A_{\text{Trit}} \) = Activity of Tritium

\( A_{\text{Total MFP}} \) = Total activity of Group 4 MFP, ETD + HTD_MFP: \(^{137}\)Cs, \(^{137}\)mBa, \(^{90}\)SrY, \(^{60}\)Co, \(^{99}\)Tc, \(^{113}\)mCd, \(^{134}\)Cs, \(^{14}\)C, \(^{59}\)Ni, \(^{62}\)Ni, \(^{79}\)Se, \(^{93m}\)Nb, \(^{93}\)Zr, \(^{106}\)Ru, \(^{125}\)Sb, \(^{126}\)Sn, \(^{151}\)Sm, \(^{152}\)Eu, \(^{155}\)Eu, and \(^{241}\)Pu

Applying the values identified in Table 1 and 2, \( F_{\text{Trit Actual}} \) is:

\[ \left( \frac{5.67 \times 10^{-3} \text{ uCi/ml}}{3.01 \times 10^{-3} \text{ uCi/ml}} \right) = 1.88 \]

The fraction of Tritium to Group 4 MFP is 1.88, which is much less than 10. Therefore Tritium surveys are not necessary.

**REFERENCES**


PLAN-55317, *Sampling and Analysis Plan for Tank AZ-301 Liquid*.