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Engineering Design File

Groundwater Pathway Risk Assessment for CPP-601, CPP-602, CPP-627, and CPP-640 Fuel Reprocessing Complex Non-Time-Critical Removal Action

Idaho Cleanup Project

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ENGINEERING DESIGN FILE

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This Engineering Design File was prepared in support of the CPP-601, CPP-602, CPP-627, and CPP-640 Fuel Reprocesing Complex non-time-critical removal action to evaluate if the decontamination and decommissioning (D&D) of the facility meets the Waste Area Group 3 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) groundwater performance criteria. The groundwater performance criteria require contaminant concentrations in the Snake River Plain Aquifer not to exceed a cumulative carcinogenic risk level of 1E-04, a hazard quotient of one, or applicable State of Idaho groundwater quality standards in 2095 and beyond. The Fuel Reprocessing Complex contains both radionuclide and chemical contaminants. This risk assessment demonstrates that the inventory that was left in place after the D&D of the complex meets the CERCLA groundwater performance criteria of contaminant concentrations.

7. Signatures: (See instructions for significance of signatures. Add or delete signatories as needed.)

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* Not required for commercial level calculations.

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Groundwater Pathway Risk Assessment for CPP-601, CPP-602, CPP-627, and CPP-640 Fuel Reprocessing Complex Non-Time-Critical Removal Action

1. INTRODUCTION

The Idaho Nuclear Technology and Engineering Center (INTEC) Fuel Reprocessing Complex facilities CPP-601, CPP-602, CPP-627, and CPP-640 at the Idaho National Laboratory (INL) Site have undergone decontamination and decommissioning (D&D) as non-time-critical removal actions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The primary transport mechanism for the migration of contaminants from the residual material that is remaining after D&D of the Fuel Reprocessing Complex is hydrologic transport to the underlying Snake River Plain Aquifer. This risk assessment estimates the groundwater pathway risk (e.g., ingestion of contaminated drinking water) to potential human receptors. The Fuel Reprocessing Complex areas evaluated are shown in Figure 1 and briefly described below:

- CPP-601 – The facility had six levels with one above grade. Spent fuel was reprocessed in this facility.
  - Upper level used for storage, makeup, and transfer of non-radioactive process chemicals and for transfer of the spent fuel elements to the process cells below
  - Lower levels had process cells, numerous corridors, auxiliary cells, vaults, and tanks.
- CPP-602 – A laboratory and office building—inventory is the remaining contamination after the removal of gloveboxes, caves, hoods, tanks, and piping.
- CPP-627 – A building with laboratories, decontamination areas, and an area for spent nuclear fuel dissolution—the building was removed to the slab with the exception of four piping segments that remained below the floor slab.
- CPP-640 – A five-level structure attached to the west side of CPP-601—formerly known as the Hot Pilot Plant—contained five shielded process cells and a mechanical handling cave. Facility was used to recover uranium from spent reactor fuel.
- Contaminated CERCLA soils – In addition to the contamination left in the buildings, contamination exists in the soils beneath the buildings from historic releases. These CERCLA sites include CPP-80, CPP-117, CPP-118, CPP-119, CPP-120, CPP-121, CPP-122, and CPP-123. CPP-86 was encompassed by CPP-117 when that site was approved in 2005.

The objective of this analysis is to demonstrate whether the contaminants remaining after removal of CPP-601, CPP-602, CPP-627, and CPP-640, along with the contaminants left in place within the CERCLA sites beneath the buildings, meet the Waste Area Group (WAG) 3 CERCLA groundwater performance criteria. The groundwater performance criteria require contaminant concentrations in the Snake River Plain Aquifer to not exceed a cumulative carcinogenic risk level of 1E-04, a hazard quotient of one, or applicable State of Idaho groundwater quality standards in 2095 and beyond.

In Fiscal Year 2008, a groundwater pathway risk assessment for CPP-601/640 was completed (EDF-8412). Since that time, the remaining inventory at CPP-601/640 has been reevaluated. In addition, the inventory remaining at CPP-602 and CPP-627 has been included in the evaluation. In order to

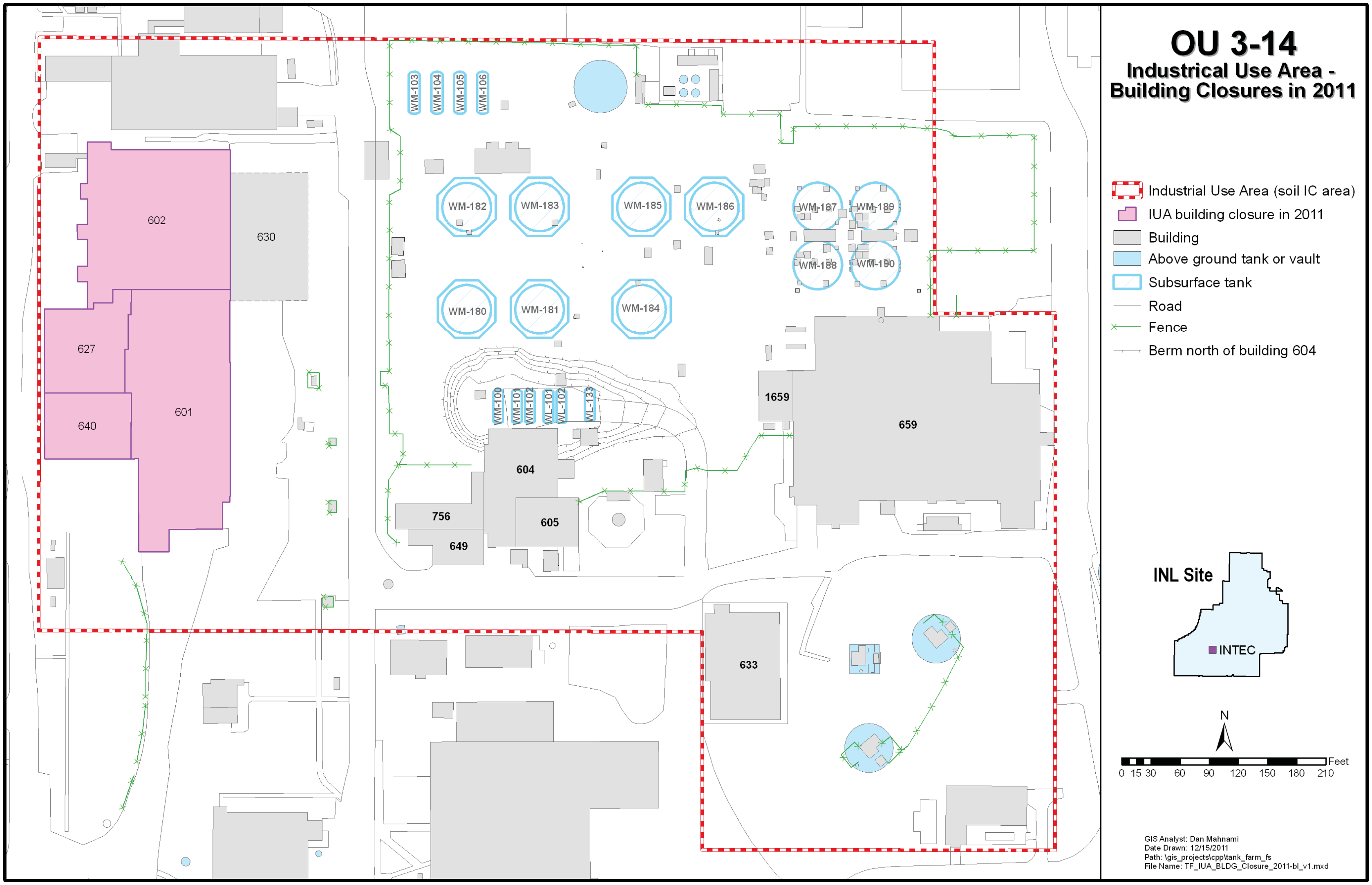

Figure 1. Fuel Reprocessing Complex facilities CPP-601, CPP-602, CPP-627, and CPP-640.

evaluate the cumulative impact from all four facilities, as well as the CERCLA soils, the contaminant inventories from all four facilities and the contaminated CERCLA soils were assumed to be collocated within the footprint of the CPP-601/640 and evaluated in a manner similar to EDF-8412. This is a conservative assumption as it concentrates the contamination in a footprint smaller than the actual area of contamination. In addition, this is a simplifying assumption for analysis because the groundwater flow and transport model used for CPP-601/640 and documented in EDF-8412 can also be used to evaluate the groundwater pathway risk from all four facilities. The source term dimensions used in EDF-8412 were also used in this report: 55 m long × 55 m wide × 10 m thick.

The Analysis Plan for this Engineering Design File can be found in Appendix A. The GWSCREEN input files are included in Appendix B. Electronic files, including spreadsheets as well as input, output, and executable files for GWSCREEN, are attached in a zip file included with the native file for this Engineering Design File. The zip file is provided under "Click here for additional information" (select Native File) in the CH2M-WG Idaho, LLC, (CWI) Electronic Document Management System.

2. CONTAMINANT INVENTORY FOR THE FUEL REPROCESSING COMPLEX

The contaminant inventory for the Fuel Reprocessing Complex contains both radionuclide and chemical contaminants. The final contaminant inventory to be evaluated in this risk assessment was developed in accordance with Figure 2.

The final radionuclide inventory left in place after D&D of the Fuel Reprocessing Complex is presented in EDF-10239. EDF-10239 generates a cumulative radioactive inventory from the individual facilities and releases beneath the buildings. It uses information from TBL-226 for CPP-601/640 (updates the information from EDF-8293), from TBL-247 for the CPP-627 buried lines, and from TBL-324 for the CPP-602 basement. The radiological inventory for the CERCLA sites (CPP-80, CPP-117, CPP-118, CPP-119, CPP-120, CPP-121, CPP-122, and CPP-123) beneath the building was unchanged as a result of the non-time-critical removal actions and, therefore, was brought forward unchanged from EDF-8293.

The chemical inventory associated with the D&D of the Fuel Reprocessing Complex is described in EDF-9367. EDF-9367 updates the non-radiological information for CPP-601, CPP-640, and CERCLA sites CPP-80, CPP-118, CPP-119, CPP-120, CPP-121, CPP-122, and CPP-123 from EDF-8192 that was used to support the 2007 risk assessment. In addition, this EDF adds in the non-radiological contaminants that were left in place in the CPP-601 deep tanks (EDF-9318), the contaminants left within the floor slab at CPP-627 (EDF-9317), the contaminants in the CERCLA site CPP-117 beneath CPP-602 (EDF-9357), and the lead that was determined to be impracticable to remove.

Table 1 lists the radionuclides and respective inventory left in place after the non-time-critical removal actions. In addition to the radionuclide inventory in Table 1, the radionuclide decay half-lives are listed for use in screening. As discussed later in this report, the modeling results show that water will take more than 300 years to move through the vadose zone to the aquifer. If it takes a radionuclide 10 half-lives to reach the aquifer (30-year half-life), then only one part in 1,000 will reach the aquifer. If it takes 20 half-lives to reach the aquifer (15-year half-life), then only one part in a million will reach the aquifer. Any chemical retardation in the vadose zone will increase the travel time to the aquifer, and radionuclides with much larger decay half-lives will also decay in the vadose zone and not reach the aquifer. For this analysis, the radioactive decay screening level is conservatively chosen to be a 5-year half-life. Any radionuclides with greater than a 5-year half-life will be evaluated in the risk assessment.

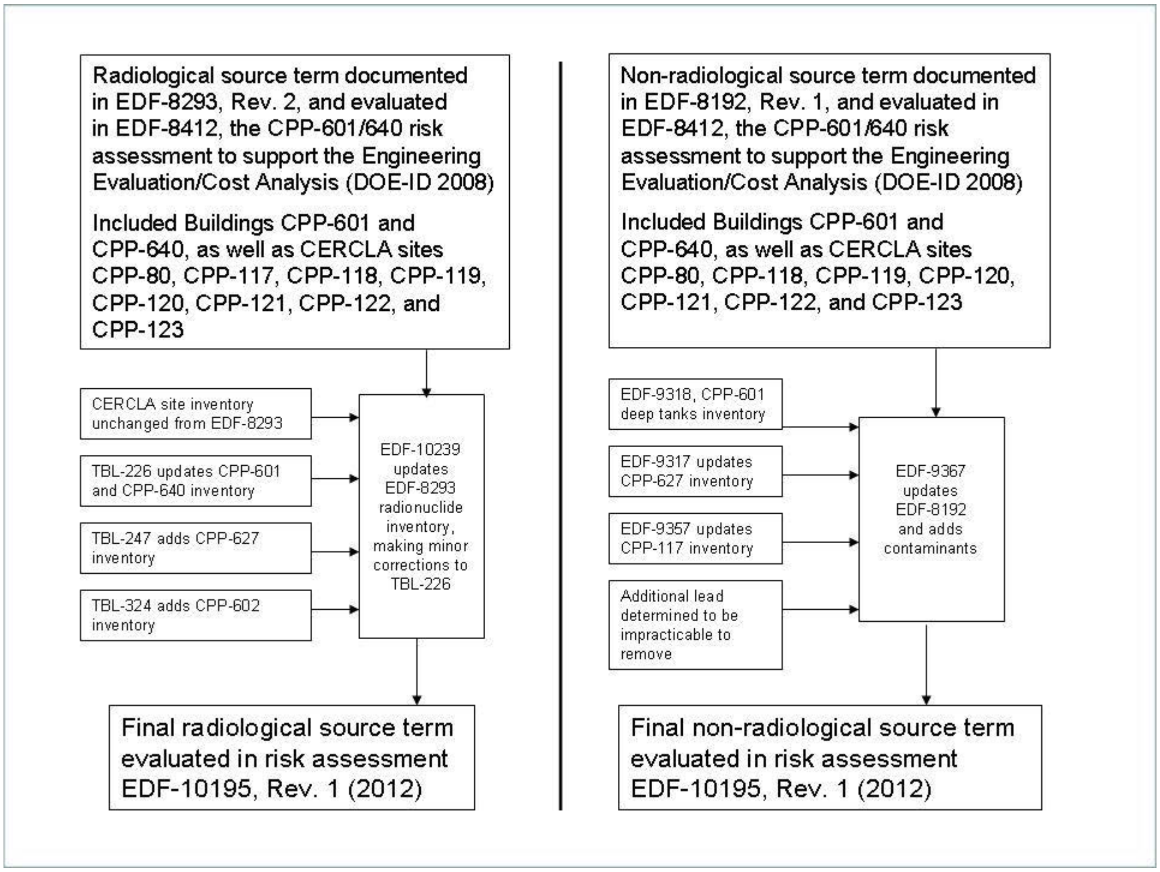

Figure 2. Flowchart showing all the contributors to the final residual inventory to be evaluated in this risk assessment.

Table 1. Radionuclide inventory (Table 9 in EDF-10239), half-lives, and screening based on half-lives.

Radionuclide	Radionuclide Decay Half-Life (yr)	CPP-601/640 Complex Totals (Ci)	CPP-627 Pipe Residual (Ci)	CPP-602 Basement (Ci)	CERCLA Soils (Ci)	Total Activity (Ci)	Contaminants of Concern (decay half-lives >5 years)
Ac-227	2.18E+01	1.77E-06			1.74E-06	3.51E-06	Ac-227
Am-241	4.32E+02	4.71E-02	1.63E-05	2.36E-06	1.82E-01	2.29E-01	Am-241
Am-242m	1.41E+02	2.87E-05			2.78E-05	5.65E-05	Am-242m
Am-243	7.37E+03	1.96E-04			1.89E-04	3.85E-04	Am-243
Bi-212	1.15E-04			2.17E-07		2.17E-07	
C-14	5.70E+03	4.69E-04		3.48E-09	4.49E-04	9.18E-04	C-14
Cm-242	4.46E-01	4.25E-03	8.89E-10		4.10E-03	8.36E-03	
Cm-243	2.91E+01	3.68E-06			3.56E-06	7.25E-06	Cm-243
Cm-244	1.81E+01	3.63E-03	3.19E-06		3.51E-03	7.15E-03	Cm-244
Co-60	5.27E+00	7.20E-01	4.52E-07		1.54E-01	8.75E-01	Co-60

Table 1. (continued).

Radionuclide	Radionuclide Decay Half-Life (yr)	CPP-601/640 Complex Totals (Ci)	CPP-627 Pipe Residual (Ci)	CPP-602 Basement (Ci)	CERCLA Soils (Ci)	Total Activity (Ci)	Contaminants of Concern (decay half-lives >5 years)
Cs-134	2.07E+00	1.44E-01	2.22E-06		1.40E-01	2.84E-01	
Cs-135	2.30E+06	4.63E-03			4.47E-03	9.09E-03	Cs-135
Cs-137	3.01E+01	4.89E+02	7.41E-03	1.38E-03	1.78E+02	6.67E+02	Cs-137
Eu-152	1.35E+01	5.84E-01			5.64E-01	1.15E+00	Eu-152
Eu-154	8.59E+00	2.70E+00	3.56E-05		2.61E+00	5.31E+00	Eu-154
Eu-155	4.76E+00	4.91E-01	5.11E-06		4.74E-01	9.66E-01	
H-3	1.23E+01	4.15E-01		3.11E-06	2.50E+00	2.91E+00	H-3
I-129	1.57E+07	4.31E-04		3.21E-09	1.80E-04	6.11E-04	I-129
Ni-59	7.60E+04	2.69E-04			2.60E-04	5.29E-04	Ni-59
Ni-63	1.00E+02	3.48E-02			3.37E-02	6.85E-02	Ni-63
Np-237	2.14E+06	2.44E-02	8.89E-06	1.80E-07	1.06E-01	1.31E-01	Np-237
Pa-231	3.28E+04	6.22E-06			6.01E-06	1.22E-05	Pa-231
Pa-233	7.38E-02			1.15E-07		1.15E-07	
Pa-234m	2.22E-06			3.87E-08		3.87E-08	
Pb-212	1.21E-03			2.17E-07		2.17E-07	
Pd-107	6.50E+06	1.16E-04			1.12E-04	2.27E-04	Pd-107
Pm-146	5.53E+00	3.27E-04			3.15E-04	6.42E-04	Pm-146
Pm-147	2.62E+00	2.47E+00			2.39E+00	4.85E+00	
Pu-236	2.86E+00	3.27E-06			3.16E-06	6.42E-06	
Pu-238	8.77E+01	2.17E+00	4.52E-04	2.21E-05	6.12E+00	8.29E+00	Pu-238
Pu-239	2.41E+04	1.41E-01	1.48E-05	5.10E-07[a]	1.73E-01	3.14E-01	Pu-239
Pu-240	6.56E+03	1.81E-02		5.10E-07[a]	1.75E-02	3.55E-02	Pu-240
Pu-241	1.43E+01	5.23E+00		2.21E-05	5.04E+00	1.03E+01	Pu-241
Pu-242	3.73E+05	3.94E-05			3.80E-05	7.73E-05	Pu-242
Ra-224	1.00E-02			2.17E-07		2.17E-07	
Ra-226	1.60E+03	1.73E-03				1.73E-03	Ra-226
Rn-220	1.76E-06			2.17E-07		2.17E-07	
Sb-125	2.76E+00	3.10E+00			2.81E+00	5.91E+00	
Se-79	1.10E+06	1.73E-03			1.68E-03	3.41E-03	Se-79
Sm-151	9.00E+01	1.06E+00			1.02E+00	2.08E+00	Sm-151
Sn-121m	5.50E+01	2.34E-03			2.27E-03	4.61E-03	Sn-121m

Table 1. (continued).

Radionuclide	Radionuclide Decay Half-Life (yr)	CPP-601/640 Complex Totals (Ci)	CPP-627 Pipe Residual (Ci)	CPP-602 Basement (Ci)	CERCLA Soils (Ci)	Total Activity (Ci)	Contaminants of Concern (decay half-lives >5 years)
Sn-126	1.00E+05	1.18E-03			1.13E-03	2.31E-03	Sn-126
Sr-90	2.88E+01	1.18E+02	4.15E-03	1.09E-04	1.78E+02	2.96E+02	Sr-90
Tc-99	2.11E+05	9.73E-02		6.90E-06	2.06E-02	1.18E-01	Tc-99
Th-228	1.91E+00			2.30E-08		2.30E-08	
Th-231	2.91E-03			3.22E-07		3.22E-07	
Th-234	6.60E-02			3.87E-08		3.87E-08	
U-232	6.89E+01	5.76E-05		2.19E-07	5.56E-05	1.13E-04	U-232
U-233	1.59E+05	5.21E-07			2.71E-06	3.23E-06	U-233
U-234	2.46E+05	2.32E-01	2.74E-06	1.43E-05	1.81E-01	4.13E-01	U-234
U-235	7.04E+08	1.05E-02	9.63E-08	3.58E-07	3.19E-02	4.24E-02	U-235
U-236	2.34E+07	2.55E-03		2.58E-06	2.46E-03	5.01E-03	U-236
U-238	4.47E+09	1.02E-03	1.41E-08	7.55E-08	8.94E-04	1.92E-03	U-238
Zn-65	6.69E-01	1.54E-04				1.54E-04	
Zr-93	1.53E+06	8.24E-03			7.96E-03	1.62E-02	Zr-93

a. The inventory for Pu-239 and Pu-240 was listed together in TBL-324, Table 1. For this analysis, the combined Pu-239 and Pu-240 inventory was counted twice, both assuming it was all Pu-239 and all Pu-240.

Table 2 lists the chemicals and respective inventory left in place after the non-time-critical removal action as presented in EDF-9367.

Table 2. Chemical inventory taken from EDF-9367 (Table 7).

Constituent	Inventory for CPP-601 (kg)	Inventory for CPP-640 (kg)	Inventory for CPP-627 (kg)	CERCLA Soils Inventory (kg)	Total Non-radionuclide Inventory (kg)
Aluminum	1.90E-01	0.00E+00	2.39E-02	1.25E+00	1.46E+00
Antimony	1.05E+00	1.95E-01	0.00E+00	0.00E+00	1.25E+00
Arsenic	2.70E-02	5.00E-03	2.45E-03	0.00E+00	3.45E-02
Barium	1.37E+01	2.50E+00	4.28E-02	0.00E+00	1.63E+01
Beryllium	5.00E-03	9.00E-05	0.00E+00	0.00E+00	5.09E-03
Boron	9.07E+02	0.00E+00	0.00E+00	0.00E+00	9.07E+02
Cadmium	4.40E+01	8.40E+00	0.00E+00	2.08E-03	5.24E+01
Calcium	5.00E-02	0.00E+00	4.07E-01	0.00E+00	4.57E-01
Chloride	0.00E+00	0.00E+00	0.00E+00	3.74E+00	3.74E+00
Chromium	1.04E+05	3.36E+03	5.43E+00	2.39E+00	1.08E+05
Cobalt	1.00E-02	0.00E+00	3.02E-02	0.00E+00	4.02E-02

Table 2. (continued).

Constituent	Inventory for CPP-601 (kg)	Inventory for CPP-640 (kg)	Inventory for CPP-627 (kg)	CERCLA Soils Inventory (kg)	Total Non-radionuclide Inventory (kg)
Copper	1.05E+05	8.44E+03	9.50E-02	0.00E+00	1.13E+05
Di-n-butylphthalate	0.00E+00	0.00E+00	3.00E-03	0.00E+00	2.91E-03
Fluoride	0.00E+00	0.00E+00	0.00E+00	1.25E+00	1.25E+00
Hexone	0.00E+00	0.00E+00	0.00E+00	2.76E+02	2.76E+02
Iron	1.51E+01	0.00E+00	2.09E+01	0.00E+00	3.60E+01
Lead	3.15E+02	7.80E+01	1.47E-01	9.18E+01	4.85E+02
Lead -bulk, impractical to remove	1.16E+05	1.64E+03	0.00E+00	0.00E+00	1.17E+05
Magnesium	4.00E-02	0.00E+00	1.30E-02	0.00E+00	5.30E-02
Manganese	8.00E-02	0.00E+00	5.22E-01	0.00E+00	6.02E-01
Mercury	2.40E-02	3.00E-03	1.81E-03	1.30E+00	1.33E+00
Nickel	5.50E+04	3.18E+03	3.33E+00	1.13E+00	5.82E+04
Nitrate	0.00E+00	0.00E+00	0.00E+00	1.06E+03	1.06E+03
Polychlorinated biphenyls (PCBs)	9.09E+01	1.76E+01	0.00E+00	0.00E+00	1.09E+02
Potassium	4.00E-02	0.00E+00	3.41E-03	0.00E+00	4.34E-02
Selenium	2.00E-02	4.00E-03	0.00E+00	0.00E+00	2.40E-02
Silver	5.60E-01	4.00E-03	0.00E+00	0.00E+00	5.64E-01
Sodium	0.00E+00	0.00E+00	7.39E-02	0.00E+00	7.39E-02
Sulfates	0.00E+00	0.00E+00	0.00E+00	2.20E+00	2.20E+00
Thallium	3.00E-02	5.00E-03	0.00E+00	0.00E+00	3.50E-02
Tin	1.20E+02	9.00E+00	0.00E+00	0.00E+00	1.29E+02
Uranium	2.52E-01	8.94E-01	0.00E+00	0.00E+00	1.15E+00
Vanadium	3.00E-02	4.00E-03	1.47E-02	0.00E+00	4.87E-02
Zinc	2.72E+02	2.72E+01	3.27E-03	0.00E+00	3.00E+02
PCB polychlorinated biphenyl					

3. RISK ASSESSMENT

This section describes the methodology and results of the risk assessment for the contaminant inventory left in place after the removal of CPP-601, CPP-602, CPP-627, and CPP-640. The risk assessment evaluates potential adverse health effects to human receptors via the groundwater pathway. The GWSCREEN model was used to estimate groundwater concentrations in the Snake River Plain Aquifer from the contaminants left in place.

3.1 Radionuclide Risk Assessment

The risk assessment uses the semi-analytical model GWSCREEN Version 2.5 (Rood 2003) to calculate groundwater concentrations for the radionuclide contaminants of concern with radioactive decay half-lives greater than 5 years. The GWSCREEN model was developed to address CERCLA sites on the INL Site. Risks for the groundwater pathway are computed using risk coefficients published in *Cancer*

Risk Coefficients for Environmental Exposure to Radionuclides (EPA 1999). The conceptual model and mathematical model for the source term are discussed in detail in the Idaho CERCLA Disposal Facility (ICDF) Performance Assessment (DOE-ID 2003) and the groundwater risk assessment for CPP-601/640 (EDF-8412). The 2003 ICDF model was calibrated to mimic the results of the WAG 3 Comprehensive Remedial Investigation/Feasibility Study model (DOE-ID 1997) of the INTEC subsurface and is assumed to be a reasonable representation of flow and transport in the INTEC subsurface.

As previously stated, for this analysis the CPP-601/640 groundwater flow and transport model documented in EDF-8412 was used with updated inventories for CPP-601/640 and assuming that the inventory at CPP-627 and CPP-602, as well as the CERCLA sites CPP-80, CPP-117, CPP-118, CPP-119, CPP-120, CPP-121, CPP-122, and CPP-123, is added to the CPP-601/640 inventory.

Contaminant-independent parameter values for the subsurface pathway models are provided in Table 3. The dimension of the waste disposal site and the sedimentary interbed thickness in the unsaturated zone are site-specific values. The sedimentary interbed thickness was set to 13 m at the request of the Idaho Department of Environmental Quality during preparation of EDF-8412 in Fiscal Year 2008. The ICDF calibrated model used in the ICDF Performance Assessment (DOE-ID 2003) assumed an interbed thickness of 22.7 m. Therefore, the 13-m estimate of sedimentary interbed thickness should provide conservative estimates of vadose travel times and dispersion in the vadose zone.

Contaminant-dependent source term (assumed to be in soil) Kd values are shown in Table 4. The aquifer Kd values are assumed to be $1/25^{th}$ of the source Kd. With the exception of plutonium, the vadose zone interbed Kd values are assumed to be the same as the source term soil values. For plutonium, the source term (soil) Kd value is assumed to be 140 mL/g, and the interbed Kd value is assumed to be 22 mL/g. This assumption is used to be consistent with the ICDF Performance Assessment (DOE-ID 2003; Jenkins 2001). More detail on the parameter values used in the modeling can be found in the GWSCREEN input files included in Appendix B.

The GWSCREEN model considers transport of radioactive progeny. In the GWSCREEN code, progeny are assumed to travel at the same rate as their parent. Under most circumstances, this assumption leads to conservative risk estimates at the receptor point. However, when considering the transport of a short-lived immobile parent that has a long-lived mobile progeny, results can be distorted and are not conservative. This is the situation for the following radionuclide decay chains evaluated in this report:

- Am-241⇒Np-237
- Am-242m⇒ U-234
- Cm-243⇒Pu-239
- Cm-244⇒Pu-240
- Pu-238⇒U-234
- Pu-241⇒Am-241⇒Np-237.

Table 3. Contaminant-independent parameter values used in the risk assessment.

Parameter	Value	Reference
Source Volume		
Length parallel to groundwater flow	55 m	Contaminant footprint at CPP-601/640 and at the water table (assumes no spreading in the vadose zone)
Width perpendicular to groundwater flow	55 m	Contaminant footprint at CPP-601/640 and at the water table (assumes no spreading in the vadose zone)
Thickness of source	10 m	Based on the facility description
Background percolation rate	0.01 m/yr	Undisturbed soil background rate (DOE-ID 2003)
Bulk density—source	1.5 g/cm^3	Track 2 report (DOE-ID 1994)
Van Genuchten α in source volume	1.066 m^{-1}	ICDF PA (DOE-ID 2003)
Van Genuchten η in source volume	1.53	ICDF PA (DOE-ID 2003)
Saturated hydraulic conductivity	31.5 (m/y)	ICDF PA (DOE-ID 2003)
Total porosity in source volume	0.266	ICDF PA (DOE-ID 2003)
Residual moist content in source volume	0.072	ICDF PA (DOE-ID 2003)
Unsaturated Zone		
Cumulative vadose zone interbed thickness	13.0 m	Recommended by staff of State of Idaho. Calibrated value used for INTEC in ICDF PA (DOE-ID 2003) is 22.7 m.
Bulk density—unsaturated zone	1.359 g/cm^3	ICDF PA (DOE-ID 2003)
Van Genuchten α in interbeds	1.066 m^{-1}	ICDF PA (DOE-ID 2003)
Van Genuchten η in interbeds	1.53	ICDF PA (DOE-ID 2003)
Saturated hydraulic conductivity in interbeds	21.3 (m/y)	ICDF PA (DOE-ID 2003)
Total porosity in interbeds	0.487	ICDF PA (DOE-ID 2003)
Residual moist content in interbeds	0.072	ICDF PA (DOE-ID 2003)
Longitudinal dispersivity in interbeds	2.92 mL/g	ICDF PA (DOE-ID 2003)
Aquifer		
Aquifer thickness	76 m	ICDF PA (DOE-ID 2003)
Well screen thickness	15 m	ICDF PA (DOE-ID 2003)
Aquifer porosity	0.06	ICDF PA (DOE-ID 2003)
Darcy velocity in aquifer	21.9 m/yr	ICDF PA (DOE-ID 2003)
Average linear velocity	365 m/yr	ICDF PA (DOE-ID 2003)
Longitudinal dispersivity	3.31 m	ICDF PA (DOE-ID 2003)
Transverse dispersivity	0.662 m	ICDF PA (DOE-ID 2003)
Vertical dispersivity	3.84E-03 m	ICDF PA (DOE-ID 2003)
Bulk density—saturated zone	2.491 g/cm^3	ICDF PA (DOE-ID 2003)
Receptor Distance from the Center of the Source		
Parallel to groundwater flow direction	27.5 m	Point of maximum (DOE-ID 1994)
Perpendicular to groundwater flow direction	0 m	Point of maximum (DOE-ID 1994)

ICDF Idaho CERCLA Disposal Facility
INTEC Idaho Nuclear Technology and Engineering Center
PA performance assessment

In general, the relatively short-lived immobile parent nuclide never leaves the waste zone and, instead, decays to its more mobile long-lived progeny. The sorption characteristics of the progeny then determine the overall transit time of the decay chain along with accompanying risk. For the contaminant of concern radionuclide decay chains evaluated in this report, the following conservative assumptions are made for the flow and transport simulations:

- Am-241 and Pu-241 instantaneously decayed to Np-237 and the model treats them as Np-237.
- Am-242m instantaneously decays to U-234 and the model treats it as U-234.
- Cm-243 instantaneously decays to Pu-239 and the model treats it as Pu-239.
- Cm-244 instantaneously decays to Pu-240 and the model treats it as Pu-240.
- Pu-238 instantaneously decays to U-234 and the model treats it as U-234.

For radionuclides, the cancer risk was calculated assuming the receptor ingests water at the peak concentration for a duration of 30 years. The radiological risk coefficients are published in *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999). The calculation was performed using the GWSCREEN model. The groundwater cancer risk was calculated in Equation (1) as:

$$R = C \times I \times EF \times ED \times RC \quad (1)$$

Where

R	=	cancer risk
C	=	predicted peak aquifer concentration (pCi/L)
I	=	ingestion rate (2 L/d)
EF	=	exposure frequency (350 d/yr)
ED	=	exposure duration (30 years)
RC	=	risk coefficient or slope factor (risk/pCi).

The groundwater pathway risk results for the radionuclides of concern after D&D of the Fuel Reprocessing Complex are shown in Tables 4 and 5. Table 4 presents the peak groundwater concentration, time to peak, and risk. During the first 1,000 years, the peak cumulative risk is less than 5E-07, with I-129 and Tc-99 the risk contributors. In the long term, the peak cumulative risk is about 2E-06, with U-234 the primary risk contributor. The long-term risk is overestimated as a result of how GWSCREEN estimates the concentration of progeny in the aquifer (see discussion in Section 4). The risk for all radionuclides are orders of magnitude below the U.S. Environmental Protection Agency (EPA) cumulative carcinogenic risk level of 1E-04 and near the bottom of the acceptable target risk range of 1E-06 to 1E-04.

Table 5 compares the predicted aquifer concentrations to the maximum contaminant levels (MCLs). The predicted peak concentration of I-129 and the total beta-gamma dose are about 6% of the MCL. The peak concentration of Np-237 and the total alpha are less than 2% of the MCL. The predicted peak concentrations for the other radionuclides are orders of magnitude smaller than the MCLs in all cases.

Table 4. Groundwater pathway risk assessment results for the radionuclides of concern.

Radionuclide	Progeny	Initial Inventory (Ci)	Carcinogenic Risk Slope Factor[a] (risk/Ci)	Kd Source (mL/g)	Kd Vadose Zone (mL/g)	Kd Aquifer (mL/g)	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
Ac-227		3.51E-06	4.86E+02	450	450	18	NA	0.00E+00	0.00E+00	0E+00
Am-241 (Np-237)[b]		4.70E-05	6.74E+01	8	8	0.32	18,691	7.71E-05	1.09E-10	1E-10
	U-233		7.18E+01			0.24		7.89E-06	1.19E-11	
	Th-229		5.28E+02			4		2.77E-07	3.08E-12	
Am-242m (U-234)[b]		3.35E-08	7.07E+01	6	6	0.24	13,908	7.04E-17	1.04E-13	1E-13
	Th-230		9.10E+01			4		5.65E-19	1.08E-15	
	Ra-226		3.86E+02			4		4.77E-19	3.86E-15	
	Pb-210		1.27E+03			4		4.75E-19	1.27E-14	
Am-243[c]		3.85E-04	1.08E+02	340	340	13.6	86,500	4.56E-12	1.04E-17	4E-15
	Pu-239		1.35E+02			5.6		1.38E-09	3.90E-15	
	U-235		7.18E+01			0.24		7.41E-12	1.12E-17	
	Pa-231		1.73E+02			22		5.55E-14	2.02E-19	
	Ac-227		4.86E+02			18		6.78E-14	6.91E-19	
C-14		9.18E-04	1.55E+00	0.1[d]	0.1[d]	0.004	563	4.78E-02	1.55E-09	2E-09
Cm-243 (Pu-239)[b]		8.90E-09	1.35E+02	140	22	5.6	38,627	3.56E-10	1.01E-15	1E-15
	U-235		7.18E+01			0.24		5.29E-13	7.97E-19	
	Pa-231		1.73E+02			22		2.32E-15	8.43E-21	
	Ac-227		4.86E+02			18		2.83E-15	2.89E-20	
Cm-244 (Pu-240)[b]		2.00E-05	1.35E+02	140	22	5.6	21,298	9.65E-08	2.74E-13	3E-13
	U-236		6.70E+01			0.24		4.89E-09	6.88E-15	
	Th-232		1.01E+02			4		2.26E-16	4.80E-22	
	Ra-228		1.04E+03			4		2.26E-16	4.94E-21	
	Th-228		3.00E+02			4		2.26E-16	1.42E-21	
Co-60		8.75E-01	1.57E+01	10	10	0.4	NA	0.00E+00	0.00E+00	0E+00
Cs-135		9.09E-03	4.74E+00	500	500	20	1,007,300	1.77E-04	1.76E-11	2E-11
Cs-137		6.67E+02	3.04E+01	500	500	20	NA	0.00E+00	0.00E+00	0E+00

Table 4. (continued).

Radionuclide	Progeny	Initial Inventory (Ci)	Carcinogenic Risk Slope Factor[a] (risk/Ci)	Kd Source (mL/g)	Kd Vadose Zone (mL/g)	Kd Aquifer (mL/g)	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
Eu-152		1.15E+00	6.07E+00	340	340	13.6	NA	0.00E+00	0.00E+00	0E+00
Eu-154		5.31E+00	1.03E+01	340	340	13.6	NA	0.00E+00	0.00E+00	0E+00
H-3		2.91E+00	1.12E-01	0	0	0	81	1.47E-01	3.28E-10	3E-10
I-129		6.11E-04	1.48E+02	0	0	0	343	5.84E-02	1.81E-07	2E-07
Ni-59		5.29E-04	2.74E-01	100	100	4	134,200	1.50E-05	8.62E-14	9E-14
Ni-63		6.85E-02	6.70E-01	100	100	4	NA	0.00E+00	0.00E+00	0E+00
Np-237		1.31E-01	6.74E+01	8	8	0.32	18,691	2.15E-01	3.04E-07	3E-07
	U-233		7.18E+01			0.24		2.19E-02	3.31E-08	
	Th-229		5.28E+02			4		7.72E-04	8.56E-09	
Pa-231		1.22E-05	1.73E+02	550	550	22	233,650	5.88E-11	2.13E-16	9E-16
	Ac-227		4.86E+02			18		7.19E-11	7.33E-16	
Pd-107		2.27E-04	2.50E-01	55	55	2.2	126,020	5.47E-05	2.87E-13	3E-13
Pm-146		6.42E-04	4.18E+00	240	240	9.6	NA	0.00E+00	0.00E+00	0E+00
Pu-238 (U-234)[b]		3.00E-03	7.07E+01	6	6	0.24	13,908	6.32E-03	9.38E-09	1E-08
	Th-230		9.10E+01			4		5.07E-05	9.69E-11	
	Ra-226		3.86E+02			4		4.28E-05	3.47E-10	
	Pb-210		1.27E+03			4		4.27E-05	1.14E-09	
Pu-239		3.14E-01	1.35E+02	140	22	5.6	38,627	1.26E-02	3.56E-08	4E-08
	U-235		7.18E+01			0.24		1.87E-05	2.81E-11	
	Pa-231		1.73E+02			22		8.19E-08	2.97E-13	
	Ac-227		4.86E+02			18		9.99E-08	1.02E-12	
Pu-240		3.55E-02	1.35E+02	140	22	5.6	21,298	1.71E-04	4.85E-10	5E-10
	U-236		6.70E+01			0.24		8.67E-06	1.22E-11	
	Th-232		1.01E+02			4		4.01E-13	8.51E-19	
	Ra-228		1.04E+03			4		4.01E-13	8.76E-18	
	Th-228		3.00E+02			4		4.01E-13	2.53E-18	

Table 4. (continued).

Radionuclide	Progeny	Initial Inventory (Ci)	Carcinogenic Risk Slope Factor[a] (risk/Ci)	Kd Source (mL/g)	Kd Vadose Zone (mL/g)	Kd Aquifer (mL/g)	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
Pu-241 (Np-237)[b]		6.97E-05	6.74E+01	8	8	0.32	18,691	1.14E-04	1.62E-10	2E-10
	U-233		7.18E+01			0.24		1.17E-05	1.76E-11	
	Th-229		5.28E+02			4		4.11E-07	4.56E-12	
Pu-242		7.73E-05	1.28E+02	140	22	5.6	78,120	1.25E-05	3.35E-11	3E-11
	U-238		8.71E+01			0.24		3.46E-09	6.33E-15	
	U-234		7.07E+01			0.24		3.63E-10	5.38E-16	
	Th-230		9.10E+01			4		4.94E-12	9.43E-18	
	Ra-226		3.86E+02			4		4.56E-12	3.69E-17	
	Pb-210		1.27E+03			4		4.55E-12	1.21E-16	
Ra-226		1.73E-03	3.86E+02	100	100	4	NA	0.00E+00	0.00E+00	0E+00
	Pb-210		1.27E+03			4		0.00E+00	0.00E+00	
Se-79		3.41E-03	7.29E+00	4	4	0.16	9,522	1.10E-02	1.68E-09	2E-09
Sm-151		2.08E+00	5.55E-01	240	240	9.8	NA	0.00E+00	0.00E+00	0E+00
Sn-121m		4.61E-03	2.34E+00	130	130	5.2	NA	0.00E+00	0.00E+00	0E+00
Sn-126		2.31E-03	2.56E+01	130	130	5.2	175,150	5.11E-05	2.75E-11	3E-11
Sr-90		2.96E+02	7.40E+01	12	12	0.48	NA	0.00E+00	0.00E+00	0E+00
Tc-99		1.18E-01	2.75E+00	0.2	0.2	0.008	809	4.63E+00	2.67E-07	3E-07
U-232		1.13E-04	2.92E+02	6	6	0.24	NA	0.00E+00	0.00E+00	0E+00
	Th-228		3.00E+02			4		0.00E+00	0.00E+00	
U-233		3.23E-06	7.18E+01	6	6	0.24	13,784	6.65E-06	1.00E-11	1E-11
	Th-229		5.28E+02			4		3.25E-07	3.60E-12	
U-234		4.13E-01	7.07E+01	6	6	0.24	13,908	8.68E-01	1.29E-06	2E-06
	Th-230		9.10E+01			4		6.97E-03	1.33E-08	
	Ra-226		3.86E+02			4		5.88E-03	4.76E-08	
	Pb-210		1.27E+03			4		5.86E-03	1.56E-07	

Table 4. (continued).

Radionuclide	Progeny	Initial Inventory (Ci)	Carcinogenic Risk Slope Factor[a] (risk/Ci)	Kd Source (mL/g)	Kd Vadose Zone (mL/g)	Kd Aquifer (mL/g)	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
U-235		4.24E-02	7.18E+01	6	6	0.24	14,143	9.27E-02	1.40E-07	1E-07
	Pa-231		1.73E+02			22		2.87E-04	1.04E-09	
	Ac-227		4.86E+02			18		3.50E-04	3.57E-09	
U-236		5.01E-03	6.70E+01	6	6	0.24	14,141	1.10E-02	1.54E-08	2E-08
	Th-232		1.01E+02			4		5.00E-10	1.06E-15	
	Ra-228		1.04E+03			4		4.99E-10	1.09E-14	
	Th-228		3.00E+02			4		4.99E-10	3.15E-15	
U-238		1.92E-03	8.71E+01	6	6	0.24	14,143	4.19E-03	7.67E-09	8E-09
	U-234		7.07E+01			0.24		1.64E-04	2.43E-10	
	Th-230		9.10E+01			4		6.74E-07	1.29E-12	
	Ra-226		3.86E+02			4		4.93E-07	4.00E-12	
	Pb-210		1.27E+03			4		4.90E-07	1.31E-11	
Zr-93		1.62E-02	1.11E+00	600	600	24	1,107,200	2.08E-04	4.84E-12	5E-12

a. The carcinogenic risk slope factors are from *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (EPA 1999).

b. Am-241 and Pu-241 are simulated as Np-237; Am-242m is simulated as U-234; Cm-243 is simulated as Pu-239; Cm-244 is simulated as Pu-240; and Pu-238 is simulated as U-234.

c. If Am-243 is assumed to decay instantaneously to Pu-239, it would create 1.27E-06 Ci of Pu-239 or only 0.001% of the Pu-239 inventory. Am-243 is an insignificant contributor to the Pu-239 inventory and need not be simulated as Pu-239.

d. C-14 was not simulated in the 2003 ICDF PA, and Jenkins (2001) lists a relatively high Kd value of 5 mL/g. A conservative value of 0.1 mL/g was used (from the 2000 RWMC PA [Case et al. 2000]).

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NA not applicable
PA performance assessment
RWMC Radioactive Waste Management Complex

Table 5. Comparison of the maximum contaminant levels to predicted peak groundwater concentrations for radionuclides of concern. Total alpha contributors are shown in red and total uranium contributors in blue.

Radionuclide	Initial Inventory (Ci)	Peak Concentration		Beta-Gamma Dose (mrem/y)	Maximum Contaminant Level
		(pCi/L)	(ug/L)		
C-14	9.18E-04	4.78E-02	NA	9.55E-05	2,000 pCi/L
Co-60	8.75E-01	0.00E+00	NA	0.00E+00	100 pCi/L
Cs-135	9.09E-03	1.77E-04	NA	1.77E-06	400 pCi/L
Cs-137	6.67E+02	0.00E+00	NA	0.00E+00	200 pCi/L
Eu-152	1.15E+00	0.00E+00	NA	0.00E+00	200 pCi/L
Eu-154	5.31E+00	0.00E+00	NA	0.00E+00	60 pCi/L
H-3	2.91E+00	1.47E-01	NA	2.94E-05	20,000 pCi/L
I-129	6.11E-04	5.84E-02	NA	2.34E-01	1 pCi/L
Ni-59	5.29E-04	1.50E-05	NA	2.00E-07	300 pCi/L
Ni-63	6.85E-02	0.00E+00	NA	0.00E+00	50 pCi/L
Np-237[a]	1.31E-01	**2.15E-01**	NA	NA	Total alpha <15 pCi/L
Total Pu[b,c,d]	3.50E-01	**1.28E-02**	NA	NA	Total alpha <15 pCi/L
Ra-226 and -228[e]	1.73E-03	**5.92E-03**	NA	NA	5 pCi/L
Sm-151	2.08E+00	0.00E+00	NA	0.00E+00	1,000 pCi/L
Sr-90	2.96E+02	0.00E+00	NA	0.00E+00	8 pCi/L
Tc-99	1.18E-01	4.63E+00	NA	2.06E-02	900 pCi/L
U-232	**1.13E-04**	0.00E+00	**0.00E+00**	NA	NA
U-233	**3.23E-06**	2.20E-02	**2.27E-06**	NA	NA
U-234	**4.13E-01**	8.74E-01	**1.40E-04**	NA	NA
U-235	**4.24E-02**	9.27E-02	**4.29E-02**	NA	NA
U-236	**5.01E-03**	1.10E-02	**1.69E-04**	NA	NA
U-238	**1.92E-03**	4.19E-03	**1.24E-02**	NA	NA
Total uranium[c,d,f]	**4.65E-01**	NA	**5.56E-02**	NA	30 ug/L
Total alpha[d]	NA	**2.33E-01**	NA	NA	Total alpha <15 pCi/L
Total beta-gamma[d]	NA	NA	NA	2.55E-01	Total beta-gamma dose <4 mrem/y

a. Np-237 includes the contributions from decay of Am-241 and Pu-241.
b. Total Pu inventory includes the inventory from Pu-239, Pu-240, and Pu-242. Pu-238 and Pu-241 decay in the vadose zone.
c. Total Pu and U concentrations include contributions from decay of other actinides (insignificant contributors in all cases).
d. An inventory is shown for total uranium and total plutonium because those simulate the transport of unique chemicals. The alpha and beta-gamma are the result of transport of a number of different chemicals. Addition of these chemicals to define a total inventory is not meaningful; therefore, the total alpha and total beta-gamma inventory are not applicable for this table.
e. Ra-226 and Ra-228 are included in the total alpha limit and have a 5-pCi/L limit. For this analysis, all inventory is from Ra-226.
f. Total uranium inventory includes the uranium isotopes plus the uranium contribution from the decay of Am-242m and Pu-238.

NA not applicable

3.2 Chemical Risk Assessment

The chemical risk assessment used the same modeling assumptions as the radionuclide risk assessment discussed previously in Section 3.1. The sorption coefficients, solubility limits, and MCLs are shown in Table 6. Chemicals were eliminated from evaluation against the MCL, risk, and hazard quotients if there are no limits, slope factors, or reference doses. Chemicals were also eliminated if the chemicals are essential nutrients. More detail on the parameter values used in the modeling can be found in the GWSCREEN input files included in Appendix B.

Since the mass concentration for radionuclides in water is generally very low, the radionuclide simulations assumed the solubility in water is infinite. The assumption of complete solubility is overly conservative for some chemicals, in particular, chromium and lead. Therefore, for chromium and lead, the solubility, rather than a simple Kd process, was assumed to simulate the availability of chromium and lead for transport in the environment. The estimated solubility of chromium is 0.052 mg/L, and the estimated solubility of lead is 0.165 mg/L (see Table 7). The chromium and lead solubilities are taken from the solubility limits developed for use at the Radioactive Waste Management Complex in buried waste (Dicke 1997). These are appropriate for solubility in soil. The MCL for total chromium is 0.1 mg/L or about twice the chromium solubility limit. There is no MCL for lead, but there is an action limit of 0.015 mg/L or about 9% of the lead solubility limit.

Human exposure is expressed in terms of intake and is defined as the amount of a contaminant taken into the body per unit body weight per unit time (mg/kg-day). Intake values were calculated using the standard equation below (EPA 1989):

$$\text{Intake (mg/kg/day)} = (C \times I \times EF \times ED)/(BW \times AT) \quad (2)$$

Where:

- C = predicted peak aquifer concentration (mg/L)
- I = ingestion rate (2 L/day)
- EF = exposure frequency (350 day/year)
- ED = exposure duration (30 years)
- BW = body weight (70 kg)
- AT = averaging time (days) (10,950 days noncarcinogen; 25,550 days carcinogen).

The carcinogenic effects of probability that an individual will develop cancer over a lifetime of exposure are estimated from the projected intakes and chemical-specific dose-response relationships by multiplying the slope factor (SF) for each carcinogen by the estimated chronic intake value. The SF represents a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over an individual's lifetime. The risk is expressed probabilistically and is compared to the acceptable EPA target risk range of 1E-04 to 1E-06.

Noncarcinogenic effects are characterized by comparing projected intakes of substances to toxicity. The hazard potential from toxic effects is computed as the ratio of estimated intake to the reference dose (RfD) and is referred to as the hazard quotient. Hazard quotients less than 1.0 indicate the intake is less than the RfD. The hazard quotient is an index of relative health hazard and does not provide a probabilistic expression of risk. A value less than or equal to 1.0 indicates that it is unlikely for even sensitive subpopulations to experience adverse health effects (EPA 1989). The Integrated Risk Information System database (from EPA) provided information on the toxicity values for the contaminants of concern.[a]

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a. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/xls/master_sl_table_run_NOV2011.xls.

Table 6. Specific parameters for chemical contaminants of concern.

Chemical	Inventory (kg)	Soil to Water Partitioning Coefficient (Kd)[a]			Solubility Limit (mg/L)	MCL (mg/L)	Comment
		Source Zone (mL/g)	Unsaturated Zone (mL/g)	Aquifer (mL/g)			
Aluminum	1.46E+00	250	250	10	1.00E+06	5.00E-02	Secondary MCL (essential element)
Antimony	1.25E+00	50	50	2	1.00E+06	6.00E-03	
Arsenic	3.45E-02	3	3	0.12	1.00E+06	1.00E-02	
Barium	1.63E+01	50	50	2	1.00E+06	2.00E+00	
Beryllium	5.09E-03	250	250	10	1.00E+06	4.00E-03	
Boron	9.07E+02	5	5	0.2	1.00E+06	NA	No MCL
Cadmium	5.24E+01	6	6	0.24	1.00E+06	5.00E-03	
Calcium	4.57E-01	5	5	0.2	1.00E+06	NA	No MCL (essential element)
Chloride	3.74E+00	0	0	0	1.00E+06	2.50E+02	Secondary MCL
Chromium-III[b]	1.08E+05	1.2	1.2	0.048	5.20E-02	1.00E-01	
Chromium-VI[b]	1.08E+05	1.2	1.2	0.048	5.20E-02	1.00E-01	
Cobalt	4.02E-02	10	10	0.4	1.00E+06	NA	No MCL
Copper	1.13E+05	20	20	0.8	1.00E+06	1.30E+00	Action level
Di-n-butylphthalate[c]	2.91E-03	0	0	0	1.00E+06	NA	No MCL
Fluoride	1.25E+00	0	0	0	1.00E+06	4.00E+00	
Hexone[c]	2.76E+02	0	0	0	1.00E+06	NA	No MCL
Iron	3.60E+01	220	220	8.8	1.00E+06	3.00E-01	Secondary MCL (essential element)
Lead	1.17E+05	100	100	4	1.65E-01	1.50E-02	Action level
Magnesium	5.30E-02	5	5	0.2	1.00E+06	NA	No MCL (essential element)
Manganese	6.02E-01	50	50	2	1.00E+06	5.00E-02	Secondary MCL
Mercury	1.33E+00	100	100	4	1.00E+06	2.00E-03	
Nickel	5.82E+04	100	100	4	1.00E+06	1.00E-01	Remanded MCL
Nitrate	1.06E+03	0	0	0	1.00E+06	4.50E+01	10 mg/L as N and 45 mg/L as NO_3
PCB[b]	1.09E+02	1,500	1,500	60	1.00E+06	5.00E-04	
Potassium	4.34E-02	15	15	0.6	1.00E+06	NA	No MCL (essential element)
Selenium	2.40E-02	4	4	0.16	1.00E+06	5.00E-02	

Table 6. (continued).

Chemical	Inventory (kg)	Soil to Water Partitioning Coefficient (Kd)[a]			Solubility Limit (mg/L)	MCL (mg/L)	Comment
		Source Zone (mL/g)	Unsaturated Zone (mL/g)	Aquifer (mL/g)			
Silver	5.64E-01	90	90	3.6	1.00E+06	1.00E-01	Secondary MCL
Sodium	7.39E-02	76	76	3.04	1.00E+06	NA	No MCL (essential element)
Sulfate	2.20E+00	0	0	0	1.00E+06	2.50E+02	Secondary MCL
Thallium	3.50E-02	100	100	4	1.00E+06	2.00E-03	
Tin	1.29E+02	130	130	5.2	1.00E+06	NA	No MCL
Uranium	1.15E+00	6	6	0.24	1.00E+06	3.00E-02	
Vanadium	4.87E-02	1,000	1,000	40	1.00E+06	NA	No MCL
Zinc	3.00E+02	16	16	0.64	1.00E+06	5.00E+00	Secondary MCL

a. The Kd values are from Jenkins (2001).
b. Chromium Kd value is from DOE-ID (1994) Table F-1, and the PCB Kd is from DOE-ID (1994) Table F-2.
c. Di-n-butylphthalate and hexone Kd values were not researched so were conservatively set to zero.

MCL maximum contaminant level
NA not applicable
PCB polychlorinated biphenyl

Table 7. Solubility limits for chromium and lead calculated from the log solubility.

Chemical	Log Solubility (M)[a]	M (Molar Solubility in Water) Mole (solute)/L (solution)	Molecular Weight (g/mole)	Solubility Limited Concentration	
				(g/L)	(mg/L)
Chromium (Cr)	-6	1.00E-06	51.996	5.20E-05	5.20E-02
Lead (Pb)	-6.1	7.94E-07	207.19	1.65E-04	1.65E-01

a. The log solubility is from *Distribution Coefficients and Contaminant Solubilities for the Waste Area Group 7 Baseline Risk Assessment* (Dicke 1997).

Since the chemical constituents are used for comparison with the MCLs as well as the calculation of the risk and hazard quotient, only one of these measures can be simulated in GWSCREEN. The comparison with the MCLs was incorporated into GWSCREEN. The risks and hazard quotient were calculated in the spreadsheet. All three results are shown in Table 8. Many of the chemicals do not have MCLs but do have secondary MCLs, action limits, or remanded MCLs. Limits other than the MCLs are not enforceable standards but are used in this analysis for comparison with chemical concentrations in the aquifer in order to evaluate the potential for harm to the groundwater pathway.

The groundwater pathway risk assessment results for the Fuel Reprocessing Complex chemicals of concern are shown in Table 8, along with the hazard quotients and a comparison of peak groundwater concentrations to the chemical's respective MCL as well as EPA secondary MCLs and action limits.

For the chemicals exhibiting noncarcinogenic effects, the hazard quotients (Table 8) are all much less than 1.0, indicating it is unlikely for even sensitive subpopulations to experience adverse health effects. The maximum predicted hazard quotients are for copper (5E-02) and nickel (1E-02).

For the chemicals exhibiting carcinogenic effects, the risk (Table 8) are orders of magnitude below the EPA cumulative carcinogenic risk level of 1E-04 and less than the acceptable target risk range of 1E-06 to 1E-04. The maximum predicted risk is for chromium(VI) (5E-07).

All predicted maximum groundwater concentrations are less than the chemical's respective MCL (Table 8) as well as the secondary MCLs, action limits, and remanded MCLs (which are not enforceable). Of the chemicals with actual MCLs, cadmium and lead are the closest to their respective MCLs, but all are more than an order of magnitude below the MCL.

4. SENSITIVITY ANALYSIS

The State of Idaho reviewers have asked in the past that the simulation assume a Kd of zero in the aquifer. Therefore, the sensitivity of the predicted peak aquifer concentrations and the associated risk were evaluated by setting the aquifer Kd to zero rather than $1/25^{th}$ the source Kd for all contaminants.

For chemicals, assuming sufficient mass moving from the vadose zone to the aquifer, the predicted peak aquifer concentration is insensitive to the aquifer Kd. The water concentration will reach the peak aquifer concentration at a slightly different time, but the peak concentration will be the same regardless of the Kd value. Therefore, the predicted peak aquifer concentrations and risk are insensitive to the aquifer Kd for all of the chemicals. A table supporting this is not included in this report.

For radionuclides with progeny, changing the aquifer Kd will change the predicted progeny peak aquifer concentration and associated risk. The progeny impact is a GWSCREEN model artifact and not realistic. GWSCREEN is formulated with the assumption that progeny move with the parent, while, in almost all cases, they do not. Thus, the GWSCREEN simulations are very conservative for radionuclides with progeny. Therefore, the results are shown here, but it should be recognized that the progeny contribution is very conservative with or without sorption in the aquifer.

The radionuclide sensitivity analysis results are shown in Table 9. For radionuclides with no progeny, the predicted peak aquifer concentration and risk are insensitive to the aquifer Kd except some slight decay half-life sensitivity (similar to chemicals). In addition, for each of the parent radionuclides with progeny, the predicted peak aquifer concentration and associated risk have very little sensitivity to the aquifer Kd. However, for the progeny, the predicted peak aquifer concentration and associated risk

Table 8. Groundwater pathway risk assessment results for the chemical contaminants of concern.

Chemical	Inventory (kg)	Hazard Quotient for Chemicals with Reference Doses: Noncarcinogenic Intake (mg/kg/d)	Reference Dose[a] (Oral) (mg/kg/d)	Hazard Quotient	Risk for Chemicals with Carcinogenic Slope Factors: Carcinogenic Intake (mg/kg/d)	Oral Slope Factor[a] $(mg/kg/d)^{-1}$	Risk	Comparison of Peak Concentration to MCL: Time to Peak (yr)	Predicted Peak Concentration (mg/L)	MCL[b] (mg/L)	MCL Notes[b]
Aluminum	1.46E+00	2.15E-09	1.0E+00	2E-09	9.20E-10			5.75E+05	7.84E-08	5.0E-02	1
Antimony	1.25E+00	9.17E-09	4.0E-04	2E-05	3.93E-09			1.15E+05	3.35E-07	6.0E-03	
Arsenic	3.45E-02	4.04E-09	3.0E-04	1E-05	1.73E-09	1.5E+00	3E-09	7.25E+03	1.47E-07	1.0E-02	
Barium	1.63E+01	1.20E-07	2.0E-01	6E-07	5.13E-08			1.15E+05	4.37E-06	2.0E+00	
Beryllium	5.09E-03	7.49E-12	2.0E-03	4E-09	3.21E-12			5.75E+05	2.73E-10	4.0E-03	
Boron	9.07E+02	6.49E-05	2.0E-01	3E-04	2.78E-05			1.18E+04	2.37E-03	No MCL	
Cadmium	5.24E+01	3.14E-06	5.0E-04	6E-03	1.35E-06			1.41E+04	1.15E-04	5.0E-03	
Calcium	4.57E-01	3.27E-08			1.40E-08			1.18E+04	1.19E-06	No MCL	2
Chloride	3.74E+00	9.80E-06			4.20E-06			3.43E+02	3.58E-04	2.5E+02	1
Chromium-III[c]	1.08E+05	2.39E-06	1.5E+00	2E-06	1.03E-06			>2.01E+03	8.74E-05	1.0E-01	
Chromium-VI[c]	1.08E+05	2.39E-06	3.0E-03	8E-04	1.03E-06	5.0E-01	5E-07	>2.00E+03	8.74E-05	1.0E-01	
Cobalt	4.02E-02	1.46E-09	3.0E-04	5E-06	6.25E-10			2.33E+04	5.32E-08	No MCL	
Copper	1.13E+05	2.06E-03	4.0E-02	5E-02	8.85E-04			4.63E+04	7.53E-02	1.3E+00	3
Di-n- butylphthalate	2.91E-03	7.63E-09	1.0E-01	8E-08	3.27E-09			3.43E+02	2.78E-07	No MCL	
Fluoride	1.25E+00	3.28E-06	6.0E-02	5E-05	1.40E-06			3.43E+02	1.20E-04	4.0E+00	
Hexone	2.76E+02	7.24E-04	8.0E-02	9E-03	3.10E-04			3.43E+02	2.64E-02	No MCL	
Iron	3.60E+01	6.02E-08	7.0E-01	9E-08	2.58E-08			5.06E+05	2.20E-06	3.0E-01	1,2
Lead[c]	1.17E+05	7.59E-06			3.25E-06	8.5E-03	3E-08	>2.00E+05	2.77E-04	1.5E-02	3
Magnesium	5.30E-02	3.79E-09			1.63E-09			1.18E+04	1.38E-07	No MCL	2
Manganese	6.02E-01	4.42E-09	2.4E-02	2E-07	1.89E-09			1.15E+05	1.61E-07	5.0E-02	1
Mercury	1.33E+00	4.89E-09	3.0E-04	2E-05	2.09E-09			2.30E+05	1.78E-07	2.0E-03	
Nickel	5.82E+04	2.14E-04	2.0E-02	1E-02	9.16E-05			2.30E+05	7.80E-03	1.0E-01	4
Nitrate	1.06E+03	2.78E-03	1.6E+00	2E-03	1.19E-03			3.43E+02	1.01E-01	4.5E+01	5
PCB[d]	1.09E+02	2.67E-08	7.0E-06	4E-03	1.15E-08	2.0E+00	2E-08	3.45E+06	9.76E-07	5.0E-04	
Potassium	4.34E-02	1.05E-09			4.52E-10			3.48E+04	3.85E-08	No MCL	2
Selenium	2.40E-02	2.13E-09	5.0E-03	4E-07	9.14E-10			9.55E+03	7.78E-08	5.0E-02	
Silver	5.64E-01	2.30E-09	5.0E-03	5E-07	9.87E-10			2.07E+05	8.40E-08	1.0E-01	1
Sodium	7.39E-02	3.57E-10			1.53E-10			1.75E+05	1.30E-08	No MCL	2
Sulfate	2.20E+00	5.77E-06			2.47E-06			3.43E+02	2.11E-04	2.5E+02	1

Table 8. (continued).

Chemical	Inventory (kg)	Hazard Quotient for Chemicals with Reference Doses			Risk for Chemicals with Carcinogenic Slope Factors			Comparison of Peak Concentration to MCL			MCL Notes[b]
		Noncarcinogenic Intake (mg/kg/d)	Reference Dose[a] (Oral) (mg/kg/d)	Hazard Quotient	Carcinogenic Intake (mg/kg/d)	Oral Slope Factor[a] $(mg/kg/d)^{-1}$	Risk	Time to Peak (yr)	Predicted Peak Concentration (mg/L)	MCL[b] (mg/L)	
Thallium	3.50E-02	1.29E-10	1.0E-05	1E-05	5.51E-11			2.30E+05	4.69E-09	2.0E-03	
Tin	1.29E+02	3.65E-07	6.0E-01	6E-07	1.56E-07			2.99E+05	1.33E-05	No MCL	
Uranium	1.15E+00	6.89E-08	3.0E-03	2E-05	2.95E-08			1.41E+04	2.52E-06	3.0E-02	
Vanadium	4.87E-02	1.79E-11	5.0E-03	4E-09	7.68E-12			2.30E+06	6.54E-10	No MCL	
Zinc	3.00E+02	6.84E-06	3.0E-01	2E-05	2.93E-06			3.71E+04	2.50E-04	5.0E+00	1

a. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/xls/master_sl_table_run_NOV2011.xls
b. MCLs and related values are from the National Primary Drinking Water Regulations (EPA 2011). MCL notes are:
1. Secondary drinking water standards (aluminum, chloride, iron, silver, sulfate, and zinc).
2. Essential elements (calcium, iron, magnesium, potassium, and sodium).
3. Action level (copper).
4. Remanded MCL (nickel).
5. The nitrate MCL is 10 mg/L as N and 45 mg/L as NO_3.
c. Chromium and lead were simulated separately to simulate the entire inventory (instead of a unit inventory) in order to evaluate the impact of the solubility limits.
d. The reference dose for Arochlor 1254 was used as a conservative value for all PCBs.

MCL maximum contaminant level
PCB polychlorinated biphenyl

Table 9. Comparison of risk assessment results with and without sorption in the aquifer.

		Risk Assessment Results with Aquifer Kd 1/25th of Source Kd				Risk Assessment Results with Aquifer Kd Zero			
Radionuclide	Progeny	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
Ac-227		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Am-241 (Np-237)		18,691	7.71E-05	1.09E-10	1.24E-10	18,690	7.71E-05	1.09E-10	1.54E-10
	U-233		7.89E-06	1.19E-11			6.05E-06	9.12E-12	
	Th-229		2.77E-07	3.08E-12			3.24E-06	3.60E-11	
Am-242m (U-234)		13,908	7.04E-17	1.04E-13	1.22E-13	13,907	7.04E-17	1.04E-13	3.73E-13
	Th-230		5.65E-19	1.08E-15			8.61E-18	1.65E-14	
	Ra-226		4.77E-19	3.86E-15			7.26E-18	5.89E-14	
	Pb-210		4.75E-19	1.27E-14			7.24E-18	1.93E-13	
Am-243		86,500	4.56E-12	1.04E-17	3.93E-15	86,448	4.59E-12	1.04E-17	1.63E-15
	Pu-239		1.38E-09	3.90E-15			5.69E-10	1.61E-15	
	U-235		7.41E-12	1.12E-17			1.44E-13	2.16E-19	
	Pa-231		5.55E-14	2.02E-19			8.96E-14	3.26E-19	
	Ac-227		6.78E-14	6.91E-19			8.96E-14	9.14E-19	
C-14		563	4.78E-02	1.55E-09	1.55E-09	563	4.78E-02	1.55E-09	1.55E-09
Cm-243 (Pu-239)		38,627	3.56E-10	1.01E-15	1.01E-15	38,605	3.56E-10	1.01E-15	1.01E-15
	U-235		5.29E-13	7.97E-19			2.48E-14	3.74E-20	
	Pa-231		2.32E-15	8.43E-21			9.07E-15	3.30E-20	
	Ac-227		2.83E-15	2.89E-20			9.07E-15	9.25E-20	
Cm-244 (Pu-240)		21,298	9.65E-08	2.74E-13	2.81E-13	21,276	9.67E-08	2.74E-13	2.75E-13
	U-236		4.89E-09	6.88E-15			2.30E-10	3.23E-16	
	Th-232		2.26E-16	4.80E-22			1.62E-16	3.43E-22	
	Ra-228		2.26E-16	4.94E-21			1.62E-16	3.53E-21	
	Th-228		2.26E-16	1.42E-21			1.62E-16	1.02E-21	
Co-60		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Cs-135		1,007,300	1.77E-04	1.76E-11	1.76E-11	1,007,300	1.77E-04	1.76E-11	1.76E-11
Cs-137		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Eu-152		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Eu-154		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00

Table 9. (continued).

		Risk Assessment Results with Aquifer Kd 1/25th of Source Kd				Risk Assessment Results with Aquifer Kd Zero			
Radionuclide	Progeny	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
H-3		81	1.47E-01	3.28E-10	3.28E-10	81	1.47E-01	3.28E-10	3.28E-10
I-129		343	5.84E-02	1.81E-07	1.81E-07	343	5.84E-02	1.81E-07	1.81E-07
Ni-59		134,200	1.50E-05	8.62E-14	8.62E-14	134,190	1.50E-05	8.62E-14	8.62E-14
Ni-63		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Np-237		18,691	2.15E-01	3.04E-07	3.45E-07	18,690	2.15E-01	3.04E-07	4.29E-07
	U-233		2.19E-02	3.31E-08			1.68E-02	2.54E-08	
	Th-229		7.72E-04	8.56E-09			9.02E-03	1.00E-07	
Pa-231		233,650	5.88E-11	2.13E-16	9.47E-16	233,560	5.89E-11	2.14E-16	8.15E-16
	Ac-227		7.19E-11	7.33E-16			5.89E-11	6.01E-16	
Pd-107		126,020	5.47E-05	2.87E-13	2.87E-13	126,010	5.47E-05	2.87E-13	2.87E-13
Pm-146		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Pu-238 (U-234)		13,908	6.32E-03	9.38E-09	1.10E-08	13,907	6.32E-03	9.38E-09	3.35E-08
	Th-230		5.07E-05	9.69E-11			7.73E-04	1.48E-09	
	Ra-226		4.28E-05	3.47E-10			6.52E-04	5.28E-09	
	Pb-210		4.27E-05	1.14E-09			6.50E-04	1.73E-08	
Pu-239		38,627	1.26E-02	3.56E-08	3.56E-08	38,605	1.26E-02	3.57E-08	3.57E-08
	U-235		1.87E-05	2.81E-11			8.76E-07	1.32E-12	
	Pa-231		8.19E-08	2.97E-13			3.20E-07	1.16E-12	
	Ac-227		9.99E-08	1.02E-12			3.20E-07	3.27E-12	
Pu-240		21,298	1.71E-04	4.85E-10	4.97E-10	21,276	1.71E-04	4.86E-10	4.87E-10
	U-236		8.67E-06	1.22E-11			4.07E-07	5.73E-13	
	Th-232		4.01E-13	8.51E-19			2.87E-13	6.08E-19	
	Ra-228		4.01E-13	8.76E-18			2.87E-13	6.26E-18	
	Th-228		4.01E-13	2.53E-18			2.86E-13	1.80E-18	
Pu-241 (Np-237)		18,691	1.14E-04	1.62E-10	1.84E-10	18,690	1.14E-04	1.62E-10	2.29E-10
	U-233		1.17E-05	1.76E-11			8.98E-06	1.35E-11	
	Th-229		4.11E-07	4.56E-12			4.81E-06	5.34E-11	

Table 9. (continued).

		Risk Assessment Results with Aquifer Kd 1/25th of Source Kd				Risk Assessment Results with Aquifer Kd Zero			
Radionuclide	Progeny	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
Pu-242		78,120	1.25E-05	3.35E-11	3.35E-11	78,098	1.25E-05	3.35E-11	3.35E-11
	U-238		3.46E-09	6.33E-15			1.62E-10	2.97E-16	
	U-234		3.63E-10	5.38E-16			1.70E-11	2.53E-17	
	Th-230		4.94E-12	9.43E-18			3.53E-12	6.75E-18	
	Ra-226		4.56E-12	3.69E-17			3.26E-12	2.64E-17	
	Pb-210		4.55E-12	1.21E-16			3.25E-12	8.68E-17	
Ra-226		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
	Pb-210		0.00E+00	0.00E+00			0.00E+00	0.00E+00	
Se-79		9,522	1.10E-02	1.68E-09	1.68E-09	9,522	1.10E-02	1.68E-09	1.68E-09
Sm-151		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Sn-121m		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Sn-126		175,150	5.11E-05	2.75E-11	2.75E-11	175,130	5.11E-05	2.75E-11	2.75E-11
Sr-90		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
Tc-99		809	4.63E+00	2.67E-07	2.67E-07	809	4.63E+00	2.67E-07	2.67E-07
U-232		NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	0.00E+00
	Th-228		0.00E+00	0.00E+00			0.00E+00	0.00E+00	
U-233		13,784	6.65E-06	1.00E-11	1.36E-11	13,783	6.65E-06	1.00E-11	6.50E-11
	Th-229		3.25E-07	3.60E-12			4.95E-06	5.49E-11	
U-234		13,908	8.68E-01	1.29E-06	1.51E-06	13,907	8.68E-01	1.29E-06	4.60E-06
	Th-230		6.97E-03	1.33E-08			1.06E-01	2.03E-07	
	Ra-226		5.88E-03	4.76E-08			8.96E-02	7.26E-07	
	Pb-210		5.86E-03	1.56E-07			8.93E-02	2.38E-06	
U-235		14,143	9.27E-02	1.40E-07	1.44E-07	14,142	9.27E-02	1.40E-07	4.70E-07
	Pa-231		2.87E-04	1.04E-09			2.39E-02	8.69E-08	
	Ac-227		3.50E-04	3.57E-09			2.39E-02	2.44E-07	

Table 9. (continued).

		Risk Assessment Results with Aquifer Kd 1/25th of Source Kd				Risk Assessment Results with Aquifer Kd Zero			
Radionuclide	Progeny	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk	Peak Time (yr)	Peak Concentration (pCi/L)	Peak Risk	Total Risk
U-236		14,141	1.10E-02	1.54E-08	1.54E-08	14,140	1.10E-02	1.54E-08	1.54E-08
	Th-232		5.00E-10	1.06E-15			7.61E-09	1.61E-14	
	Ra-228		4.99E-10	1.09E-14			7.61E-09	1.66E-13	
	Th-228		4.99E-10	3.15E-15			7.60E-09	4.79E-14	
U-238		14,143	4.19E-03	7.67E-09	7.93E-09	14,142	4.19E-03	7.67E-09	8.19E-09
	U-234		1.64E-04	2.43E-10			1.64E-04	2.43E-10	
	Th-230		6.74E-07	1.29E-12			1.03E-05	1.96E-11	
	Ra-226		4.93E-07	4.00E-12			7.51E-06	6.09E-11	
	Pb-210		4.90E-07	1.31E-11			7.47E-06	1.99E-10	
Zr-93		1,107,200	2.08E-04	4.84E-12	4.84E-12	1,107,100	2.08E-04	4.84E-12	4.84E-12

NA not applicable

are significantly impacted by the aquifer Kd assumption. This is an artifact of the simplifying assumption in GWSCREEN that the progeny travels with the parent. With the exception of U-238 decaying to U-234, for the contaminants of concern, all parent radionuclides decay to progeny that are transported in the subsurface at different rates than the parent radionuclide. The assumption that the progeny travels with the parent is conservative both for faster-moving progeny and slower-moving progeny:

- If the radionuclide parent moves faster than the progeny – For example, U-234 has a Kd of 6 mL/g in the source and vadose zone and 0.24 in the aquifer. Its progeny (Th-230, Ra-226, and Pb-210) all have Kd values of 100 mL/g in the source and vadose zone and 4 mL/g in the aquifer. The progeny will not travel with the U-234. Rather U-234 will move through the vadose zone and aquifer and, as it decays, the progeny will be left behind traveling at about 1/16th the rate of the U-234. The progeny will be spread out in the transport path of the U-234 and will not accumulate in the aquifer with the U-234 at the time of the peak U-234 concentrations, as assumed in the GWSCREEN formulation.
- If the radionuclide parent moves slower than the progeny – For example, Pu-239 has a Kd of 140 mL/g in the source, 22 mL/g in the vadose zone, and 5.6 mL/g in the aquifer. Its primary progeny is U-235, which has a Kd of 6 mL/g in both the source and the vadose zone and 0.24 mL/g in the aquifer. As Pu-239 decays to U-235, the U-235 (vadose zone Kd = 6 mL/g) will be transported in the vadose zone out ahead of the Pu-239 (vadose zone Kd = 22 mL/g) and reach the aquifer before the Pu-239. The U-235 produced from the Pu-239 will not accumulate in the aquifer with the Pu-239 as assumed in the GWSCREEN formulation.

As shown in Table 9, when comparing simulations with sorption in the aquifer versus no sorption, GWSCREEN calculates a larger progeny risk with sorption in the aquifer than without sorption in the aquifer if the progeny moves faster than the parent (such as Np-237 decays to U-233 or Pu-239 decaying to U-235). GWSCREEN calculates a smaller progeny risk with sorption in the aquifer if the progeny moves slower than the parent (such as all the uranium decay chains).

For example, the maximum risk calculated assuming no sorption in the aquifer is for U-234 (4.6E-06). Of that risk, 72% is contributed by the progeny (primarily Pb-210), which is an artifact of the GWSCREEN model formulation. Since there will be very little accumulation of progeny with the U-234 as it moves through the subsurface, the U-234 risk calculated by GWSCREEN is almost four times larger than it should be when the aquifer Kd is set to zero. When the aquifer Kd is assumed to be $1/25^{th}$ of the source Kd, the results are still conservative but more realistic. The progeny contribute 15% of the risk. The progeny contribution is still conservative if the aquifer Kd is $1/25^{th}$ the source Kd but much less so than when the aquifer Kd is assumed to be zero.

For this project, U-234 is the primary risk contributor of the radionuclides with progeny. As discussed above, the progeny contribution to the U-234 total risk is overestimated by GWSCREEN both with and without sorption assumed in the aquifer. However, the results are more realistic assuming sorption in the aquifer. Therefore, sorption in the aquifer was assumed for this analysis.

5. SUMMARY

This risk assessment estimates the groundwater pathway risk (e.g., ingestion of contaminated drinking water) to potential human receptors from contaminants left behind after removal of the Fuel Reprocessing Complex areas CPP-601, CPP-602, CPP-627, CPP-640, and the contaminated CERCLA soils beneath the buildings (from historical releases CPP-86, CPP-117, CPP-118, CPP-119, CPP-120, CPP-121, CPP-122, and CPP-123). In order to evaluate the cumulative impact from what remains after removal of all four facilities, it was conservatively assumed that the contaminant inventories from all four facilities and the contaminated CERCLA soils beneath those buildings are collocated within the footprint of CPP-601/640.

The objective of this analysis is to demonstrate whether the contaminants remaining after removal of CPP-601, CPP-602, CPP-627, and CPP-640 meet the WAG 3 CERCLA groundwater performance criteria. The groundwater performance criteria require contaminant concentrations in the Snake River Plain Aquifer to not exceed a cumulative carcinogenic risk level of 1E-04, a hazard quotient of one, or applicable State of Idaho groundwater quality standards in 2095 and beyond.

The inventory left in place after the D&D of the facilities CPP-601, CPP-602, CPP-627, and CPP-640 consists of a variety of radionuclides and chemicals. A radioactive decay half-life screening was used to eliminate radionuclides with decay half-lives less than 5 years. Chemicals were eliminated from evaluation against the MCL, risk, and hazard quotients if there are no limits, slope factors, or reference doses. Chemicals were also eliminated if the chemicals are essential nutrients.

The results of the radionuclide risk assessment indicate the peak cumulative risk is less than 4E-07 over the next 1,000 years (from I-129 and Tc-99) and about 2E-06 over the next 14,000 years (primarily from U-234). This risk is near the bottom of the EPA acceptable target risk range of 1E-06 to 1E-04 and meets the CERCLA groundwater performance criteria of 1E-04 risk. The predicted maximum groundwater concentrations for the radionuclides of concern were compared to the State of Idaho MCLs and all predicted maximum groundwater concentrations are well below the MCLs.

For chemicals exhibiting noncarcinogenic effects, the hazard quotients are all much less than 1.0, indicating it is unlikely for even sensitive subpopulations to experience adverse health effects. For chemicals exhibiting carcinogenic effects, the risks are all well below the EPA target risk range of 1E-04 to 1E-06. The predicted maximum groundwater concentrations for the chemicals of concern were compared to the State of Idaho MCLs. All predicted maximum groundwater concentrations are much less than the chemical's respective MCL.

This risk assessment demonstrates that the inventory left in place after the D&D of CPP-601, CPP-602, CPP-627, CPP-640, and the contaminated CERCLA soils meets the CERCLA groundwater performance criteria.

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Appendix A

Analysis Plan

This appendix outlines the work plan for preparation of this EDF per MCP-2059, "Commercial Analyses and Calculations." The objective of this analysis is to document a screening-level risk assessment of the radionuclide source term inventory left in place from the D&D removal action of CPP-601, CPP-640, CPP-627, and CPP-602, along with the contaminants left in place within the CERCLA sites beneath the buildings.

A Microsoft Excel spreadsheet and GWSCREEN Version 2.5 (Rood 2003) simulation will be developed to generate groundwater risk results. The calculations to be performed are considered commercial level at Quality Level 3.

The spreadsheet to be used in the analysis contains soil concentration screening levels for the soil-to-groundwater exposure pathway. The GWSCREEN Version 2.5a (1/23/2007) computer code (Enterprise Architecture ID # 121200) is to be used to calculate the risk. GWSCREEN has been validated and controlled in accordance with MCP-550, "Software Management."

The deliverable for this project is an EDF documenting the calculations and computer files with the input and output for the simulations. The EDF will include tables from and copies of the electronic files that would allow reproduction of the results. The GWSCREEN input files are included in Appendix B. Electronic files, including spreadsheets as well as input, output, and executable files for GWSCREEN, are attached in a zip file included with the native file for this EDF. The zip file is provided under "Click here for additional information" (select Native File) in the CWI Electronic Document Management System.

Technical checking will be conducted in accordance with MCP-2059 and include verification that input data are appropriate and input and output documented in the EDF match the associated input and output files for GWSCREEN. The conclusions will be reviewed to ensure they are consistent with the analysis that is presented. The technical checker will also verify that GWSCREEN is appropriate for this use and that the formulas and calculations are correct.

Appendix B

GWSCREEN Risk Calculation Input Files

As explained in the main text, GWSCREEN was used to calculate aquifer concentrations and associated risk for the CPP-601, CPP-602, CPP-627, and CPP-640 groundwater pathway risk assessment. Below are the input files for the simulation runs.

Radionuclide Risk Calculations and Sensitivity Analysis

Radionuclide Peak Risk Calculation – Unit Inventories

Path and Input File name - J:\work-real-time\FY-2012\CPP-601-602-etc\Nov-Dec-2011-calcs-EDF-10195\Radionuclides-Dec-2011\ rads-unit-I-12-19-11.par

```
CPP-601, 640, 627, and 602 radionuclide calculations based on the ICDF-WAC parameters. 12-19-11. JMM
$  Unit inventory comparison based conc. Must multiply the results by the actual inventory.
$  Aquifer Kd values are assumed to be 1/25th the source term Kd value.
$  Parameter assumptions are generally from the ICDF PA assumptions made in 2003 and used for the
$  CPP-601/640 analysis (EDF-8412).
$
2 3 0 1 1                                   (Card 2) imode,itype,idisp,kflag,idil
1 1 2 2 2                                   (Card 3) imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                                  (Card 4) jstart jmax eps
70. 2.555E+04 2.0  350.  30. 1.0E-4         (Card 5) bw,at,wi,ef,ed,dlim
0.   0.                                     (Card 6) x0,y0
$ Dave Eaton gave me the dimensions 55m x 55m x 10m
$
55.  55.  0.010                            (Card 7) l,w,perc
10.  1.5                                   (Card 8b) thicks, rhos, (source term values)
$0.30                                      (Card 8c) thetas (source term mc)
1.066 1.53  31.5 0.266 0.072                (Card 8d) alpha n ksat pors thetar
13.0  1.359  2.92                           (Card 9) depth,rhou,axu
$ NOTE: The values of depth and axu are the ucode calibrated values
$ 0.30                                      (Card 9a) thetau
$ --- van Genuchten parameters from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
1.066 1.523  21.3 0.487 0.072               (Card 9b) alphau nu ksatu porsu thetaru
$ --- use calibrated values for ax and az ay=0.2ax and az=1.16e-3ax as stated in the MEPAS Manual
3.31 0.662  0.00384   76.  15.              (Card 10) ax,ay,az,b,z(well screen thickness)
$ --- Aquifer density and porosity from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
$ --- Darcy velocity based on an assumed pore vel of ~ 1 m/d in EDF-ER-275
21.9  0.06  2.491                           (Card 11) u,phi,rhoa
1                                           (Card 12a) nrecept
27.5 0.                                     (Card 12b) xrec yrec
39                                          (Card 14) ncontam
$ List in here the references for the risk slope factors
$  ------------------------- Ac-227  ------------------------------- 1
 0 450 450 227 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ac-227+D' 2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Am-241(Np-237) ------------------------ 2
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-241(Np-237)+D'  2.14E+06  0.32  6.74E+01         (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01       (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  4  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- Am-242m(as U-234) ---------------------- 2.5
 3  6    6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-242m(U-234)'  2.46E+05  0.24  7.07E+01 (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  4  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Am-243+D ------------------------------- 3
 4  340 340  243  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-243+D' 7.37E+03 13.6 1.08E+02  (card14b) cname thalf kda dcf
'Pu-239'  2.41E+04  5.6  1.35E+02  (card14b) cname thalf kda dcf
```

```
'U-235+D'  7.04E+08  0.24  7.18E+01        (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- C-14 ------------------------ 4
 0 0.1 0.1  14  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.004  1.55E+00            (card14b) cname thalf kda dcf
$  ------------------------- Cm-243(as Am-243+D) ------------------------------- 4.5
 3  140 22   243  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cm-243(Pu-239)'  2.41E+04  5.6  1.35E+02  (card14b) cname thalf kda dcf
'U-235+D'  7.04E+08  0.24  7.18E+01        (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Cm-244(Pu-240) ------------------------ 5
 4  140   22  240  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cm-244(Pu-240)'  6.56E+03  5.6  1.35E+02         (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0.24  6.70E+01      (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  4  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  4  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- Co-60 ------------------------ 6
 0  10  10  60  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Co-60'  5.27E+00  0.4  1.57E+01  (card14b) cname thalf kda dcf
$  ------------------------- Cs-135 ------------------------ 7
 0  500  500  135  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-135'  2.30E+06  20  4.74E+00          (card14b) cname thalf kda dcf
$  ------------------------- Cs-137 ------------------------ 8
 0  500  500  137  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-137+D'  3.01E+01  20  3.04E+01      (+D)   (card14b) cname thalf kda dcf
$  ------------------------- Eu-152 ------------------------ 9
 0  340  340  152  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-152'  1.35E+01  13.6  6.07E+00  (card14b) cname thalf kda dcf
$  ------------------------- Eu-154 ------------------------ 10
 0  340  340  154  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-154'  8.59E+00  13.6  1.03E+01  (card14b) cname thalf kda dcf
$  ------------------------- H-3 ------------------------ 11
 0  0  0  3  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0  1.12E-01  (card14b) cname thalf kda dcf
$  ------------------------- I-129 ------------------------ 12
 0  0  0  129  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0  1.48E+02  (card14b) cname thalf kda dcf
$  ------------------------- Ni-59 ------------------------ 13
 0  100  100  59  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-59'  7.60E+04  4  2.74E-01                         (card14b) cname thalf kda dcf
$  ------------------------- Ni-63 ----2095---------------- 14
 0  100  100  63  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-63'  1.00E+02  4  6.70E-01                         (card14b) cname thalf kda dcf
$  ------------------------- Np-237 ------------------------ 15
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Np-237+D'  2.14E+06  0.32  6.74E+01  (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  4  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pa-231 ------------------------ 16
 1 550 550 231 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pa-231'  3.28E+04  22  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pd-107 ------------------------ 17
 0   55   55  107  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pd-107'  6.50E+06  2.2  2.50E-01  (card14b) cname thalf kda dcf
$  ------------------------- Pm-146 ------------------------ 18
 0  240  240  147  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pm-146'  5.53E+00  9.6  4.18E+00  (card14b) cname thalf kda dcf
$  ------------------------- Pu-238(U-234) ------------------------ 19
 3  6  6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-238(U-234)'  2.46E+05  0.24  7.07E+01  (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  4  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Pu-239 ------------------------ 20
 3  140   22  239  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04  5.6  1.35E+02  (card14b) cname thalf kda dcf
'U-235+D'  7.04E+08  0.24  7.18E+01        (card14b) cname thalf kda dcf
```

```
'Pa-231'  3.28E+04  22  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pu-240 ------------------------ 21
 4  140   22  240  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240'  6.56E+03  5.6  1.35E+02  (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0.24  6.70E+01        (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  4  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  4  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pu-241(Np-237) ------------------------ 22
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-241(Np-237)+D'  2.14E+06  0.32  6.74E+01  (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0.24  7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  4  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pu-242 ------------------------ 23
 5 140   22  242  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-242' 3.75E+05  5.6    1.28E+02
'U-238+D'  4.47E+09  0.24  8.71E+01  (card14b) cname thalf kda dcf
'U-234'  2.46E+05  0.24  7.07E+01        (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  4  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Ra-226 ------------------------ 24
 1  100  100  226  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ra-226+D'  1.60E+03  4  3.86E+02  (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Se-79------------------------- 25
 0   4   4   79  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Se-79'   1.10E+06 0.16 7.29E+00  (card14b) cname thalf kda dcf
$  ------------------------- Sm-151 ------------------------ 26
 0  240  240  151  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sm-151'  9.00E+01  9.8  5.55E-01  (card14b) cname thalf kda dcf

$  ------------------------- Sn-121m ------------------------ 27
 0  130  130  121  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sn-121m' 5.50E+01  5.2  2.34E+00                      (card14b) cname thalf kda dcf
$  ------------------------- Sn-126 ------------------------ 28
 0  130  130  126  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sn-126'  1.00E+05  5.2  2.56E+01                      (card14b) cname thalf kda dcf
$  ------------------------- Sr-90 ------------------------ 29
 0  12  12  90 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sr-90+D'  2.88E+01  0.48  7.40E+01  (card14b) cname thalf kda dcf
$  ------------------------- Tc-99 ------------------------ 30
 0  0.2  0.2  99  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Tc-99'  2.11E+05  0.008  2.75E+00  (card14b) cname thalf kda dcf
$  ------------------------- U-232 ------------------------ 31
 1  6  6  232  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-232'  6.89E+01  0.24  2.92E+02  (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  4  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-233 ------------------------ 32
 1  6  6  233 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-233'  1.59E+05  0.24  7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  4  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-234 ------------------------ 33
 3  6  6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-234'  2.46E+05  0.24  7.07E+01  (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  4  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- U-235 ------------------------ 34
 2  6  6  235  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-235+D'  7.04E+08  0.24  7.18E+01  (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  22  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  18  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-236 ------------------------ 35
 3  6  6  236  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-236'  2.34E+07  0.24  6.70E+01  (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  4  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  4  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  4  3.00E+02        (card14b) cname thalf kda dcf
```

```
$  ------------------------- U-238 ------------------------ 36
 4  6  6  238  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-238+D'  4.47E+09  0.24  8.71E+01  (card14b) cname thalf kda dcf
'U-234'  2.46E+05  0.24  7.07E+01        (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  4  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  4  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  4  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Zr-93 ------------------------ 37
 0  600  600  93  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Zr-93'  1.53E+06 24  1.11E+00                      (card14b) cname thalf kda dcf
```

Radionuclide Peak Risk Sensitivity Analysis – Unit Inventories - Aquifer Kd = 0

Path and Input File name - J:\work-real-time\FY-2012\CPP-601-602-etc\Nov-Dec-2011-calcs-EDF-10195\Radionuclides-Dec-2011\ rads-unit-I-12-19-11-aq-kd-0.par

```
CPP-601, 640, 627, and 602 radionuclide calculations based on the ICDF-WAC parameters. 12-19-11. JMM
$  Unit inventory comparison based conc. Must multiply the results by the actual inventory.
$  Aquifer Kd values are assumed to be 0 for all radionuclides.
$  Parameter assumptions are generally from the ICDF PA assumptions made in 2003 and used for the
$  CPP-601/640 analysis (EDF-8412).
$
2 3 0 1 1                                  (Card 2) imode,itype,idisp,kflag,idil
1 1 2 2 2                                  (Card 3) imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                                 (Card 4) jstart jmax eps
70. 2.555E+04 2.0  350.  30. 1.0E-4        (Card 5) bw,at,wi,ef,ed,dlim
0.   0.                                    (Card 6) x0,y0
$ Dave Eaton gave me the dimensions 55m x 55m x 10m
$
55.  55.  0.010                           (Card 7) l,w,perc
10.  1.5                                  (Card 8b) thicks, rhos, (source term values)
$0.30                                     (Card 8c) thetas (source term mc)
1.066 1.53  31.5 0.266 0.072              (Card 8d) alpha n ksat pors thetar
13.0  1.359  2.92                         (Card 9) depth,rhou,axu
$ NOTE: The values of depth and axu are the ucode calibrated values
$ 0.30                                    (Card 9a) thetau
$ --- van Genuchten parameters from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
1.066 1.523  21.3 0.487 0.072             (Card 9b) alphau nu ksatu porsu thetaru
$ --- use calibrated values for ax and az ay=0.2ax and az=1.16e-3ax as stated in the MEPAS Manual
3.31 0.662  0.00384   76.  15.            (Card 10) ax,ay,az,b,z(well screen thickness)
$ --- Aquifer density and porosity from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
$ --- Darcy velocity based on an assumed pore vel of ~ 1 m/d in EDF-ER-275
21.9  0.06  2.491                          (Card 11) u,phi,rhoa
1                                          (Card 12a) nrecept
27.5 0.                                    (Card 12b) xrec yrec
39                                         (Card 14) ncontam
$ List in here the references for the risk slope factors
$  ------------------------- Ac-227  ------------------------------- 1
 0 450 450 227 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ac-227+D' 2.18E+01  0   4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Am-241(Np-237) ------------------------ 2
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-241(Np-237)+D'  2.14E+06  0     6.74E+01         (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0     7.18E+01       (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  0  5.28E+02         (card14b) cname thalf kda dcf
$  ------------------------- Am-242m(as U-234) ---------------------- 2.5
 3   6    6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-242m(U-234)'  2.46E+05  0     7.07E+01        (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0 9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  0  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Am-243+D----------------------- 3
 4  340 340  243  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Am-243+D' 7.37E+03  0   1.08E+02  (card14b) cname thalf kda dcf
'Pu-239'  2.41E+04  0    1.35E+02  (card14b) cname thalf kda dcf
'U-235+D'  7.04E+08  0     7.18E+01        (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0   1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  0   4.86E+02        (card14b) cname thalf kda dcf
```

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$  ------------------------- C-14 ------------------------ 34
 0 0.1 0.1  14  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'C-14'  5.70E+03  0.0    1.55E+00          (card14b) cname thalf kda dcf
$  ------------------------- Cm-243(as Pu-239) -------------------------------- 4.5
 3  140 22   243  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cm-243(Pu-239)'  2.41E+04  0.   1.35E+02  (card14b) cname thalf kda dcf
'U-235+D'  7.04E+08  0.    7.18E+01        (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04  0.  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  0   4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Cm-244(Pu-240) ------------------------ 5
 4  140   22  240  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cm-244(Pu-240)'  6.56E+03  0    1.35E+02        (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0     6.70E+01       (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  0  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  0  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- Co-60 ------------------------ 6
 0  10  10  60  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Co-60'  5.27E+00  0    1.57E+01  (card14b) cname thalf kda dcf
$  ------------------------- Cs-135 ------------------------ 7
 0  500  500  135  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-135'  2.30E+06   0  4.74E+00          (card14b) cname thalf kda dcf
$  ------------------------- Cs-137 ------------------------ 8
 0  500  500  137  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cs-137+D'  3.01E+01   0  3.04E+01      (+D)   (card14b) cname thalf kda dcf
$  ------------------------- Eu-152 ------------------------ 9
 0  340  340  152  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-152'  1.35E+01  0    6.07E+00  (card14b) cname thalf kda dcf
$  ------------------------- Eu-154 ------------------------ 10
 0  340  340  154  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Eu-154'  8.59E+00  0     1.03E+01  (card14b) cname thalf kda dcf
$  ------------------------- H-3 ------------------------ 11
 0  0  0  3  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'H-3'  1.23E+01  0  1.12E-01  (card14b) cname thalf kda dcf
$  ------------------------- I-129 ------------------------ 12
 0  0  0  129  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'I-129'  1.57E+07  0  1.48E+02  (card14b) cname thalf kda dcf
$  ------------------------- Ni-59 ------------------------ 13
 0  100  100  59  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-59'  7.60E+04  0  2.74E-01                     (card14b) cname thalf kda dcf
$  ------------------------- Ni-63 ----2095---------------- 14
 0  100  100  63  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ni-63'  1.00E+02  0  6.70E-01                     (card14b) cname thalf kda dcf
$  ------------------------- Np-237 ------------------------ 15
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Np-237+D'  2.14E+06  0     6.74E+01  (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0     7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  0  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pa-231 ------------------------ 16
 1 550 550 231 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pa-231'  3.28E+04   0  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01   0  4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pd-107 ------------------------ 17
 0   55   55  107  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pd-107'  6.50E+06    0  2.50E-01  (card14b) cname thalf kda dcf
$  ------------------------- Pm-146 ------------------------ 18
 0  240  240  147  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pm-146'  5.53E+00    0  4.18E+00  (card14b) cname thalf kda dcf
$  ------------------------- Pu-238(U-234) ------------------------ 19
 3  6  6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-238(U-234)'  2.46E+05  0     7.07E+01  (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  0  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Pu-239 ------------------------ 20
 3  140   22  239  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-239'  2.41E+04    0  1.35E+02  (card14b) cname thalf kda dcf
'U-235+D'  7.04E+08  0     7.18E+01        (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04   0  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01   0  4.86E+02        (card14b) cname thalf kda dcf
```

```
$  ------------------------- Pu-240 ------------------------ 21
 4  140   22  240  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-240'  6.56E+03    0  1.35E+02  (card14b) cname thalf kda dcf
'U-236'  2.34E+07  0     6.70E+01        (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  0  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  0  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pu-241(Np-237) ------------------------ 22
 2  8  8  237  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-241(Np-237)+D'  2.14E+06  0     6.74E+01  (card14b) cname thalf kda dcf
'U-233'  1.59E+05  0     7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  0  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- Pu-242(+Am-242m) ------------------------ 23
 5 140   22  242  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Pu-242' 3.75E+05    0    1.28E+02
'U-238+D'  4.47E+09  0     8.71E+01  (card14b) cname thalf kda dcf
'U-234'  2.46E+05  0     7.07E+01        (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  0  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Ra-226 ------------------------ 24
 1  100  100  226  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Ra-226+D'  1.60E+03  0  3.86E+02  (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- Se-79------------------------ 25
 0   4   4   79  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Se-79'   1.10E+06 0    7.29E+00  (card14b) cname thalf kda dcf
$  ------------------------- Sm-151 ------------------------ 26
 0  240  240  151  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sm-151'  9.00E+01    0  5.55E-01  (card14b) cname thalf kda dcf

$  ------------------------- Sn-121m ------------------------ 27
 0  130  130  121  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sn-121m' 5.50E+01    0  2.34E+00                      (card14b) cname thalf kda dcf
$  ------------------------- Sn-126 ------------------------ 28
 0  130  130  126  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sn-126'  1.00E+05  0    2.56E+01                      (card14b) cname thalf kda dcf
$  ------------------------- Sr-90 ------------------------ 29
 0  12  12  90 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sr-90+D'  2.88E+01  0     7.40E+01  (card14b) cname thalf kda dcf
$  ------------------------- Tc-99 ------------------------ 30
 0  0.2  0.2  99  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Tc-99'  2.11E+05  0.0    2.75E+00  (card14b) cname thalf kda dcf
$  ------------------------- U-232 ------------------------ 31
 1  6  6  232  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-232'  6.89E+01  0     2.92E+02  (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  0  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-233 ------------------------ 32
 1  6  6  233 1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-233'  1.59E+05  0.    7.18E+01        (card14b) cname thalf kda dcf
'Th-229+D'  7.34E+03  0  5.28E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-234 ------------------------ 33
 3  6  6  234  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-234'  2.46E+05  0     7.07E+01  (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  0  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------- U-235 ------------------------ 34
 2  6  6  235  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-235+D'  7.04E+08  0     7.18E+01  (card14b) cname thalf kda dcf
'Pa-231'  3.28E+04   0  1.73E+02        (card14b) cname thalf kda dcf
'Ac-227+D'  2.18E+01  0   4.86E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-236 ------------------------ 35
 3  6  6  236  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-236'  2.34E+07  0     6.70E+01  (card14b) cname thalf kda dcf
'Th-232'  1.41E+10  0  1.01E+02        (card14b) cname thalf kda dcf
'Ra-228+D'  5.75E+00  0  1.04E+03        (card14b) cname thalf kda dcf
'Th-228+D'  1.91E+00  0  3.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- U-238 ------------------------ 36
 4  6  6  238  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'U-238+D'  4.47E+09  0     8.71E+01  (card14b) cname thalf kda dcf
```

```
'U-234'  2.46E+05  0    7.07E+01        (card14b) cname thalf kda dcf
'Th-230'  7.54E+04  0  9.10E+01        (card14b) cname thalf kda dcf
'Ra-226+D'  1.60E+03  0  3.86E+02        (card14b) cname thalf kda dcf
'Pb-210+D'  2.23E+01  0  1.27E+03        (card14b) cname thalf kda dcf
$  ------------------------ Zr-93 ----------------------- 37
 0  600  600  93  1.00      0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Zr-93'  1.53E+06  0  1.11E+00                     (card14b) cname thalf kda dcf
```

Chemical Risk Calculations

Chemical Peak Risk Calculation – Unit Inventories

Path and Input File name - J:\work-real-time\FY-2012\CPP-601-602-etc\Nov-Dec-2011-calcs-EDF-10195\ \non-radionuclides-Dec-2011\ nonrad-unit-inv-12-19-11.par

```
CPP-601, 640, 627, and 602 chemical calculations based on the ICDF-WAC parameters. 12-19-11
$  Unit inventory comparison is with the MCLs. Must multiply the results by the actual inventory
$  There are chemicals included that do not have MCLs, 2ndary MCLs or Action Levels. They are
$  included so the concentrations can be used to calculate risk or hazard quotients if available.
$  Parameter assumptions are generally from the ICDF PA assumptions made in 2003 and used for the
$  CPP-601/640 analysis (EDF-8412).
4 3 0 1 1                                   (Card 2) imode,itype,idisp,kflag,idil
1 1 2 2 2                                   (Card 3) imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                                  (Card 4) jstart jmax eps
$ If imode=4 when comparing to MCLs the ed and dlim must both be 1.
$ The other variables are not used.
70. 2.555E+04 2.0  350.   1.  1.0        (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6) x0,y0
$ Dave Eaton gave me the dimensions 55m x 55m x 10m for use in EDF-8412 and this analysis
$
55.  55.  0.010                            (Card 7) l,w,perc
10.  1.5                                   (Card 8b) thicks, rhos, (source term values)
$0.30                                      (Card 8c) thetas (source term mc)
1.066 1.53  31.5 0.266 0.072               (Card 8d) alpha n ksat pors thetar
13.0  1.359  2.92                          (Card 9) depth,rhou,axu
$ NOTE: The values of depth and axu are the ucode calibrated values
$ 0.30                                     (Card 9a) thetau
$ --- van Genuchten parameters from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
1.066 1.523  21.3 0.487 0.072              (Card 9b) alphau nu ksatu porsu thetaru
$ --- use calibrated values for ax and az ay=0.2ax and az=1.16e-3ax as stated in the MEPAS Manual
3.31 0.662  0.00384   76.  15.             (Card 10) ax,ay,az,b,z(well screen thickness)
$ --- Aquifer density and porosity from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
$ --- Darcy velocity based on an assumed pore vel of ~ 1 m/d in EDF-ER-275
21.9  0.06  2.491                          (Card 11) u,phi,rhoa
1                                          (Card 12a) nrecept
27.5 0.                                    (Card 12b) xrec yrec
34                                         (Card 14) ncontam
$  ------------------------ Aluminum -2ndary 0.05 to 0.2 mg/L ----- 1
 0  250  250  26.98  1.0 0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Aluminum'  1.00E+12  10  5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------ Antimony --MCL 0.006 mg/L-------- 2
 0  50  50  121.76  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Antimony'  1.00E+12  2  6.00E+00          (card14b) cname thalf kda dcf
$  ------------------------ Arsenic --MCL 0.01 mg/L--------- 3
 0  3  3  74.92  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Arsenic'  1.00E+12  0.12  1.00E+01          (card14b) cname thalf kda dcf
$  ------------------------ Barium(andcompounds) --MCL 2 mg/L------------ 4
 0  50  50  137.33  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Barium'  1.00E+12  2  2.00E+03          (card14b) cname thalf kda dcf
$  ------------------------ Beryllium(andcompounds) --MCL 0.004 mg/L-------- 5
 0  250  250  9.01  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Beryllium'  1.00E+12  10  4.00E+00          (card14b) cname thalf kda dcf
$  ------------------------ Boron ----???----------------- 6
 0  5  5  10.81  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Boron'  1.00E+12  0.2  9.99E+99          (card14b) cname thalf kda dcf
```

```
$  ------------------------- Cadmium(andcompounds) ---MCL 0.005 mg/L------- 7
 0  6  6  112.41  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cadmium'  1.00E+12  0.24  5.00E+00          (card14b) cname thalf kda dcf
$  ------------------------- Calcium ----???----------------- 8
 0  5  5  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Calcium'  1.00E+12  0.2  9.99E+99               (card14b) cname thalf kda dcf
$  ------------------------- Cloride -2ndary 250 mg/L------  9
 0  0  0  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chloride'  1.00E+12  0  2.50E+05              (card14b) cname thalf kda dcf
$  ------------------------- Chromium-III ---MCL 0.1 mg/L--------- 10
 0  1.2  1.2  52.00  1.0  0. 5.20E-02  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium-III'  1.00E+12  0.048  1.00E+02          (card14b) cname thalf kda dcf
$  ------------------------- Chromium-VI ---MCL 0.1 mg/L--------- 11
 0  1.2  1.2  52.00  1.0  0. 5.20E-02  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium-VI'  1.00E+12  0.048  1.00E+02          (card14b) cname thalf kda dcf
$  ------------------------- Cobalt  ----???--------- 12
 0  10.  10.  58.9   1.0   0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Cobalt'       1.00E+12  0.4    9.99E+99          (card14b) cname thalf kda dcf
$  ------------------------- Copper(andcompounds) ---Action Level 1.3 mg/L ------ 13
 0  20  20  63.55  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Copper'  1.00E+12  0.8  1.30E+03          (card14b) cname thalf kda dcf
$  ---------------------di-n-butylphthalate----CAS 84-74-2--??- 14
 0  0  0  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Di-n-butylphthalate'  1.00E+12  0  9.99E+99              (card14b) cname thalf kda dcf
$  ------------------------- Fluoride ---MCL 4 mg/L----------------- 15
 0   0  0.  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Fluoride'  1.00E+12  0.    4.00E+03          (card14b) cname thalf kda dcf
$  -methyl isobutyl ketone- Hexone ---CAS 108-10-1-------- 16
 0  0  0  999.99 1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Hexone'  1.00E+12  0  9.99E+99          (card14b) cname thalf kda dcf
$  ------------------------- Iron ------2ndary 0.3 mg/L--------- 17
 0  220  220  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Iron'  1.00E+12  8.8  3.00E+02              (card14b) cname thalf kda dcf
$  ------------------------- Lead --Action Level 0.015 mg/L ---------- 18
 0  100  100  207.20  1.0  0. 1.65E-01  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  4  1.50E+01          (card14b) cname thalf kda dcf
$  ------------------------- magnesium --????------------------ 19
 0  5  5  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manesium'  1.00E+12  0.2  9.99E+99               (card14b) cname thalf kda dcf
$  ------------------------- Manganese --2ndary 0.05 mg/L------------ 20
 0  50  50  54.94  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Manganese'  1.00E+12  2  5.00E+01               (card14b) cname thalf kda dcf
$  ------------------------- Mercury ---MCL 0.002 mg/L------- 21
 0  100  100  200.59  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Mercury'  1.00E+12  4  2.00E+00          (card14b) cname thalf kda dcf
$  ------------------------- Nickel -----0.1 mg/L (old 2ndary MCL? ------- 22
 0  100  100  58.69  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nickel'  1.00E+12  4  1.00E+02          (card14b) cname thalf kda dcf
$  ------------------------- Nitrate ----MCL 10 mg/L as N --- 23
 0  0  0  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Nitrate'  1.00E+12  0  1.00E+04              (card14b) cname thalf kda dcf
$  ---------------polychlorinated biphenyls (PCBs) ---MCL 0.0005 --------- 24
 0 1500 1500  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'PCB'      1.00E+12 60  5.00E-01          (card14b) cname thalf kda dcf
$  ------------------------- Potassium ---???------------------ 25
 0  15  15  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Potassium'  1.00E+12  0.6  9.99E+99               (card14b) cname thalf kda dcf
$  ------------------------- Selenium ---MCL 0.05 mg/L-------- 26
 0  4  4  78.96  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Selenium'  1.00E+12  0.16  5.00E+01          (card14b) cname thalf kda dcf
$  ------------------------- Silver ---2ndary 0.1 mg/L------------ 27
 0  90  90  107.87  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Silver'  1.00E+12  3.6  1.00E+02          (card14b) cname thalf kda dcf
$  ------------------------- Sodium -----???---------------- 28
 0  76  76  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sodium'  1.00E+12  3.04  9.99E+99               (card14b) cname thalf kda dcf
$  ------------------------- Sulfate ---2ndary 250 mg/L------------ 29
 0  0  0  0.00  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Sulfate'  1.00E+12  0  2.50E+05              (card14b) cname thalf kda dcf
```

```
$  ------------------------- Thallium ---MCL 0.002 mg/L------- 30
 0  100  100  204.38  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Thallium'  1.00E+12  4  2.00E+00          (card14b) cname thalf kda dcf
$  ------------------------- Tin -----???---------------- 31
 0  130  130  118.69  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Tin'  1.00E+12  5.2  2.20E+04          (card14b) cname thalf kda dcf
$  ------------------------- Uranium ----MCL 0.03 mg/L------- 32
 0  6  6  238.03  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Uranium'  1.00E+12  0.24  3.00E+01          (card14b) cname thalf kda dcf
$  ------------------------- Vanadium ----???----------------- 33
 0  1000  1000  50.94  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Vanadium'  1.00E+12  40  1.00E+11          (card14b) cname thalf kda dcf
$  ------------------------- Zinc -----2ndary 5 mg/L------------ 34
 0  16  16  65.39  1.0  0. 1.00E+06  0.   (card14a) nprog kds kdu zmw qi rmi sl other
'Zinc'  1.00E+12  0.64  5.00E+03          (card14b) cname thalf kda dcf
```

Chemical Peak Risk Calculation – Chromium and Lead – Include Full Inventories and Solubility Limits

Path and Input File name - J:\work-real-time\FY-2012\CPP-601-602-etc\Nov-Dec-2011-calcs-EDF-10195\ \non-radionuclides-Dec-2011\ chem-sol-limited-sim-12-13-11.par

```
CPP-601, 640, 627, and 602 chemical calculations based on the ICDF-WAC parameters. 12-11-11
$  This simulation is only for chromium and lead. Solubility limits are used in the simulations.
$  The totla inventory is needed in order to use the solubility to limit the flux from the source
term.
$  Parameter assumptions are generally from the ICDF PA assumptions made in 2003 and used for the
$  CPP-601/640 analysis (EDF-8412).
4 3 0 1 1                                (Card 2) imode,itype,idisp,kflag,idil
1 1 2 2 2                                (Card 3) imodel,isolve,isolveu,imoist,imoistu
6 12 0.001                               (Card 4) jstart jmax eps
$ If imode=4 when comparing to MCLs the ed and dlim must both be 1.
$ The other variables are not used.
70. 2.555E+04 2.0  350.   1.  1.0         (Card 5)  bw,at,wi,ef,ed,dlim (c / MCL of interest)
0.   0.                                  (Card 6) x0,y0
$ Dave Eaton gave me the dimensions 55m x 55m x 10m for use in EDF-8412 and this analysis
$
55.  55.  0.010                          (Card 7) l,w,perc
10.  1.5                                 (Card 8b) thicks, rhos, (source term values)
$0.30                                    (Card 8c) thetas (source term mc)
1.066 1.53  31.5 0.266 0.072             (Card 8d) alpha n ksat pors thetar
13.0  1.359  2.92                        (Card 9) depth,rhou,axu
$ NOTE: The values of depth and axu are the ucode calibrated values
$ 0.30                                   (Card 9a) thetau
$ --- van Genuchten parameters from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
1.066 1.523  21.3 0.487 0.072            (Card 9b) alphau nu ksatu porsu thetaru
$ --- use calibrated values for ax and az ay=0.2ax and az=1.16e-3ax as stated in the MEPAS Manual
3.31 0.662  0.00384   76.  15.           (Card 10) ax,ay,az,b,z(well screen thickness)
$ --- Aquifer density and porosity from EDF-ER-275 60% Design Component Report Table 2-2 and 2-3
$ --- Darcy velocity based on an assumed pore vel of ~ 1 m/d in EDF-ER-275
21.9  0.06  2.491                        (Card 11) u,phi,rhoa
1                                        (Card 12a) nrecept
27.5 0.                                  (Card 12b) xrec yrec
2                                        (Card 14) ncontam
$  ------------------------- Chromium ---MCL 0.1 mg/L--------- 10
 0  1.2  1.2  52. 1.08E+11  0. 5.20E-02  0. (card14a) nprog kds kdu zmw qi rmi sl other
'Chromium-III'  1.00E+12  0.048  1.00E+02        (card14b) cname thalf kda dcf
$  ------------------------- Lead --Action Level 0.015 mg/L ---------- 18
 0 100 100 207.20 1.18E+11  0. 1.65E-01  0.  (card14a) nprog kds kdu zmw qi rmi sl other
'Lead'  1.00E+12  4  1.50E+01            (card14b) cname thalf kda dcf
```