Zion*Solutions*, Inc.
Technical Support Document

TSD 14-010

RESRAD Dose Modeling for Basement Fill Model, Soil DCGL and Calculation of Basement Fill Model Dose Factors

Revision 2

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Summary of Changes in Revision 2:

- Miscellaneous typographical corrections
- Added factor of 2 "margin" to insignificant contributor dose fractions
- Calculated soil DCGLs using Industrial Use Scenario
- Added uncertainty analysis for Kd in surface and subsurface soil
- Revised Surface and Subsurface DCGLs for Ni-63 and Sr-90 based on uncertainty analysis results
- Various editorial changes required by new calculations
- Revised RESRAD report file names in Attachment 10
- Replaced Excel spreadsheet calculations in Attachment 6 with revised version

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1. Purpose

This Technical Support Document (TSD) provides the input parameters and results of all RESRAD dose assessment modeling required to support the development of the License Termination Plan (LTP) for the Zion Station Restoration Project (ZSRP). RESRAD modeling is required to determine the dose to the average member of the critical group for compliance with 10 CFR 20.1402. This TSD also documents spreadsheet calculations required to convert RESRAD results to Dose Factors for the Basement Fill Model (BFM).

The Resident Farmer Scenario includes the following exposure pathways (see LTP Chapter 6, section 6.5.4):

- Direct exposure to external radiation
- Inhalation dose from airborne radioactivity
- Ingestion dose from the following pathways;
  - Plants grown with irrigation water from onsite well,
  - Meat and Milk from livestock consuming fodder from fields irrigated with onsite well water and consuming water from onsite well,
  - Drinking water from onsite well,
  - Soil ingestion.
- Direct exposure, inhalation dose and ingestion dose from contaminated drilling spoils brought to the surface during installation of the onsite well into the fill material.

The calculation of the dose factors from the drilling spoils pathway, referred to as "BFM Drilling Spoils Dose Factors", is provided in *ZionSolutions Technical Support Document (TSD) 14-021 "Basement Fill Model Drilling Spoils and Alternate Exposure Scenarios*" (1).

The RESRAD parameters and modeling results used to support the calculation of BFM Dose Factors and to calculate Soil DCGLs are provided with minimal supporting discussion in this TSD. Full explanation and justification for the BFM and Soil Site Conceptual Models, critical group, exposure scenarios, etc. are provided in LTP Chapter 6. The applicable LTP Chapter 6 sections are referenced in this TSD as necessary.

The detailed RESRAD output reports are provided in this TSD and are used by reference in LTP Chapter 6 summary tables. Separate documentation of the RESRAD output reports in this TSD facilitates independent review and verification of the RESRAD runs. Providing the RESRAD output reports in this TSD, as opposed to the LTP, also allows revision of the RESRAD runs and output reports, if necessary, without full revision, replacement and resubmittal of a large number of LTP attachments. The corresponding summary reports in the LTP would then be revised as necessary.

There are two RESRAD analyses required to support the selection of the Radionuclides of Concern (ROC) for basements and soil in Zion Solutions TSD 14-019, *Radionuclides of Concern for Basement Fill Model Source Term and Surrogate Ratios* (2). RESRAD 'dose to source ratios' (DSRs) for BFM and soil were required for each of the 26 potential radionuclides in the initial suite to determine which radionuclides were insignificant dose contributors as defined in NUREG-1757, Volume 2, Revision 1, "*Consolidated Decommissioning Guidance: Characterization, Survey and Determination of Radiological Criteria*" (3). The discussion of methods, input parameters an output reports for the BFM

and soil RESRAD runs are provided in this TSD. The results of the RESRAD runs were used by reference in TSD 14-019 to determine the relative dose contribution from all radionuclides, identify the ROC for concrete and soil, and calculated the dose fraction attributable to the insignificant contributor radionuclides that were removed from further detailed calculations.

RESRAD runs were also required to calculate Area Factors (AF) for the initial suite of potential radionuclides for use in the calculation of Drilling Spoils Dose Factors in TSD 14-021 which were required to develop the total BFM Dose Factors.

In summary, the following RESRAD runs are required to support the LTP:

1. Basement Fill Model (BFM) sensitivity analysis for ROC,
2. BFM Groundwater Exposure Factors for ROC,
3. Soil Derived Concentration Guideline Level (DCGL) sensitivity analysis for ROC,
4. Soil DCGLs for ROC,
5. BFM modeling to determine Groundwater Exposure Factors for the initial suite of radionuclides in concrete,
6. Soil modeling to determine AFs for the initial suite of radionuclides in concrete to determine BFM Drilling Spoils Dose Factors,
7. Soil modeling for the initial suite of radionuclides in soil,
8. Soil RESRAD modeling for industrial use scenario, and
9. Soil RESRAD Modeling for Kd uncertainty analysis

Four spreadsheet calculations were required to determine the BFM Groundwater and Drilling Spoils Dose Factors, and the final Basement Dose Factors reported in LTP Chapter 6. The methods for calculating the Dose Factors, the documentation of the supporting spreadsheet calculations, and the development of corresponding summary tables reported in LTP Chapter 6 are provided in this TSD. The required spreadsheet calculations are listed below:

1. Calculation of DUST-MS Groundwater Concentration Factors
2. Calculation of BFM GW Exposure Factors
3. Calculation of BFM GW Dose Factors
4. Calculation of Basement Dose Factors

2. Basement Fill Model RESRAD Modeling and Spreadsheet Calculations

2.1. RESRAD Modeling to Determine BFM Groundwater Exposure Factors

The RESRADv7.0 computer code was used to calculate the Resident Farmer dose from a unit radionuclide concentration in the well water.

A Groundwater Exposure Factor, in units of mrem/y per pCi/L was generated for each Radionuclide of Concern (ROC). Detailed explanations of the process for determining ROC for the Basements to remain at ZNPS are provided in TSD 14-019 and LTP Chapter 6, section 6.5.2.

The ROC for Zion Nuclear Power Station (ZNPS) Basements are Co-60, Ni-63, Sr-90, Cs-134, Cs-137, H-3, Eu-152 and Eu-154. Note that H-3, Eu-152 and Eu-154 are concrete activation products and apply to the Containment Basements only.

The process and justification for the selection of RESRAD parameters to determine BFM Groundwater Exposure Factors are provided in LTP Chapter 6, section 6.6.3. There are two RESRAD analyses required; an uncertainty analysis and a dose analysis that incorporates the parameters deemed sensitive.

2.1.1. BFM RESRAD Uncertainty Analysis

The process for determining the input parameters for the BFM RESRAD uncertainty analysis is described in LTP Chapter 6, section 6.6.3.1. The parameter selection process is shown in the flowchart in Figure 1. A number of site-specific parameters were used from two sources; Zion*Solutions TSD 14-006, "Conestoga Rovers & Associates (CRA) Report, Evaluation of Hydrological Parameters in Support of Dose Modeling for the Zion Restoration Project"* (4) and *ZionSolutions TSD 14-004 "Brookhaven National Laboratory (BNL) Report, Recommended Values for the Distribution Coefficient (KD) to be used in Dose Assessments for Decommissioning the Zion Nuclear Station"* (5). The RESRAD parameter set used for the uncertainty analysis is provided in Attachment 1.

The uncertainty analysis was conservatively run for all ROC individually to maximize the parameter sensitivity. A more realistic approach would be to use the radionuclide mixture fractions which may reduce the sensitivity of some parameters for the low abundance radionuclides.

The RESRAD Uncertainty Reports and Summary Reports are provided in Attachment 2. Table 1 provides the parameters with |PRCC| values greater than 0.25 and the reported PRCC values. The reported PRCC values are the maximum from the three "RESRAD Regression and Correlation outputs" provided in the Uncertainty Reports.

Table 2 and Table 3 list the selected 75th or 25th percentile deterministic values from the NUREG/CR-6697 "*Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes*" (6) distributions for the sensitive parameters (i.e., those listed in Table 1).

2.1.2. BFM RESRAD Input Parameters, Output Reports, and BFM Groundwater Exposure Factor Calculation

The final RESRAD parameter set used to calculate the BFM Groundwater Exposure Factors is provided in Attachment 3. The parameters in Attachment 3 were developed using the process in Figure 1 and the results of the uncertainty analysis reported in Tables 2 and 3. The RESRAD BFM Summary Report and Concentration Report required for the calculation Groundwater Exposure Factors are provided in Attachment 4.

The Groundwater Exposure Factors are calculated by dividing the maximum dose by the well water concentration at t=0.

Equation 1

$$\boldsymbol{BFM\ GW\ Exposure\ Factor\ (i) = \frac{Max\ Dose\ (i)}{GW\ Concentration\ (i)}}$$

Where:

BFM GW Exposure Factor (i) = Total Resident Farmer dose for radionuclide (i) from unit concentration of groundwater (mrem/yr per pCi/L)
Max Dose (i) = Maximum Resident Farmer Dose for radionuclide (i) from RESRAD Summary Report (mrem/yr)
GW Concentration (i) = Well water concentration for radionuclide (i) from RESRAD Concentration Report (pCi/L)

The RESRAD dose and concentration results from Attachment 3 and the results of the Groundwater Exposure Factor calculations are provided in Table 4.

Table 1 BFM Uncertainty Analysis Results for Parameters with |PRCC| > 0.25

Parameter	PRCC Value							
	Co-60	**Cs-134**	**Cs-137**	**Eu-152**	**Eu-154**	**Ni-63**	**Sr-90**	**H-3**
Depth of Roots	0.33	NS[1]	NS	NS	NS	NS	NS	NS
Weathering Removal Constant of All Vegetation	-0.61	-0.88	-0.87	-0.87	-0.89	-0.78	-0.80	NS
Wet Weight Crop Yield of Fruit Grain and Non-Leafy Vegetables	NS	NS	NS	-0.51	-0.54	NS	NS	NS
Wet Foliar Interception Fraction of Leafy Vegetables	NS	NS	NS	0.56	0.59	NS	NS	NS
Plant Transfer Factor	NS	NS	NS	NS	NS	NS	0.31	NS
Meat Transfer Factor	0.90	0.86	0.85	0.75	0.77	0.32	0.59	NA
Milk Transfer Factor	0.56	0.91	0.90	NS	NS	0.97	0.68	NA
Saturated Zone Hydraulic Conductivity	NS	NS	NS	NS	NS	NS	-0.36	-0.54
Saturated Zone Hydraulic Gradient	NS	NS	NS	NS	NS	NS	-0.59	-0.77
Contaminated Zone Total Porosity	NS	NS	NS	NS	NS	NS	-0.41	-0.77
Density of Contaminated Zone	NS	NS	NS	NS	NS	NS	0.41	0.73

Note 1: NS indicates that the parameter is not sensitive

Table 2 BFM Deterministic Values for Sensitive Parameters from Table 6-12 that are Radionuclide Independent

Parameter	Percentile	Parameter Value
Depth of Roots	75th	3.1m
Weathering Removal Constant of All Vegetation	25th	21.5
Wet Weight Crop Yield of Fruit Grain and Non-Leafy Vegetables	25th	1.26 kg/m^2
Wet Foliar Interception Fraction of Leafy Vegetables	75th	0.70
Saturated Zone Hydraulic Conductivity	25th	1695
Saturated Zone Hydraulic Gradient	25th	0.0018
Contaminated Zone Total Porosity	25th	0.37
Density of Contaminated Zone	75th	1.68[1] g/cm^3

Note 1: Site specific density value of 1.8 used in the RESRAD run.

Table 3 BFM Deterministic Values for Sensitive Parameters from Table 6-14 that are Radionuclide Dependent

Radionuclide	Plant Transfer Factor 75th Percentile	Meat Transfer Factor 75th Percentile	Milk Transfer Factor 75th Percentile
Co-60	NS	0.058	0.0032
Cs-134	NS	0.065	0.014
Cs-137	NS	0.065	0.014
Eu-152	NS	0.004	NS
Eu-154	NS	0.004	NS
Ni-63	NS	0.0092	0.032
Sr-90	0.59	0.013	0.0028
H-3	NS	NS	NS

Table 4 RESRAD Results and Groundwater Exposure Factors for BFM model

Radionuclide	Dose (mrem/y)			Groundwater Concentration (pCi/L)	GW Exposure Factor (mrem/y per pCi/L)
	Drinking Water	Plant/Meat /Milk	Total		
Co-60	5.40E-02	5.82E-02	1.12E-01	4.48E+00	2.50E-02
Cs-134	6.58E-01	1.28E+00	1.94E+00	2.21E+01	8.75E-02
Cs-137	5.23E-01	1.01E+00	1.54E+00	2.21E+01	6.94E-02
Eu-152	3.17E-02	6.30E-03	3.80E-02	1.05E+01	3.62E-03
Eu-154	4.61E-02	9.14E-03	5.52E-02	1.05E+01	5.26E-03
H-3	1.38E-01	7.88E-02	2.17E-01	4.89E+03	4.43E-05
Ni-63	4.42E-03	1.13E-02	1.57E-02	1.61E+01	9.78E-04
Sr-90	2.87E+01	1.49E+01	4.36E+01	3.99E+02	1.09E-01

2.2. Calculation of Groundwater and Fill Concentration Factors from DUST-MS

The initial environmental transport pathway for the BFM Resident Farmer scenario is the release of radioactivity from Basement concrete (or steel liner surfaces for Containment Basements) to water in the interstitial space of the fill material. The water concentrations in the Basements are calculated using the DUST-MS computer code. The methods and results are provided in Zion*Solutions* TSD 14-009, "*Brookhaven National Laboratory Report (BNL), "Evaluation of Maximum Radionuclide Groundwater Concentrations for Basement Fill Model, Zion Station Restoration Project*" (7). See LTP Chapter 6, section 6.6.1 for detailed discussion of DUST-MS application in BFM.

The water concentrations and fill concentrations calculated by DUST-MS were used to in conjunction with the assumed radionuclide inventory in each Basement to calculate water and fill concentration factors for each Basement and ROC using Equation 2. The GW Concentration Factors are used in conjunction with RESRAD Groundwater Exposure Factors to calculate BFM Groundwater Dose Factors (see section 2.3). The Fill Concentration Factors are used in the BFM Drilling Spoils Scenario to calculate BFM Drilling Spoils Dose Factors (see section 2.4).

Equation 2

$$\boldsymbol{GW\ or\ Fill\ Concentration\ Factor}(i,b) = \boldsymbol{GW\ or\ Fill\ Concentration}\ (i,b)/\boldsymbol{Inventory}\ (i,b)$$

where:

GW or Fill Concentration Factor (i,b) = GW or Fill concentration factor for radionuclide (i) and Basement (b) (pCi/L or pCi/g per mCi)

GW or Fill Concentration (i,b) = GW or Fill concentration for radionuclide (i) and Basement (b) (pCi/L or pCi/g)

Inventory (i,b) = assumed inventory for Radionuclide (i) and Basement (b) (mCi)

The GW Concentration Factors and Fill Concentration Factors are calculated in Zion*Solutions* Excel Spreadsheet "Calculations in Support of TSD 14-010 Revision 2.xls". The Excel Worksheet results are provided in Attachment 5. The results are summarized in Tables 5 and 6.

Table 5 Peak Groundwater Concentration Factors (pCi/L per mCi Total Inventory)

Nuclide	Auxiliary (pCi/L/mCi)	Containment (pCi/L/mCi)	Turbine (pCi/L/mCi)	Fuel (pCi/L/mCi)	Crib House /Forebay (pCi/L/mCi)	WWTF (pCi/L/mCi)
Co-60	4.00E-03	4.57E-01	1.14E-01	5.45E-01	9.77E-02	2.08E+01
Cs-134	1.06E-01	2.26E+00	5.65E-01	1.45E+01	4.83E-01	1.03E+02
Cs-137	3.80E-01	2.26E+00	5.65E-01	5.22E+01	4.83E-01	1.03E+02
Eu-152	1.65E-02	1.07E+00	2.68E-01	2.24E+00	2.29E-01	4.83E+01
Eu-154	1.29E-02	1.07E+00	2.68E-01	1.76E+00	2.29E-01	4.88E+01
H-3	1.40E+02	6.13E+02	1.53E+02	1.91E+04	1.31E+02	2.78E+04
Ni-63	2.92E-01	1.64E+00	4.10E-01	4.23E+01	3.52E-01	7.47E+01
Sr-90	3.01E+00	4.13E+01	1.04E+01	4.12E+02	8.85E+00	1.89E+03

Table 6 Peak Fill Material Concentration Factors (pCi/g per mCi Total Inventory)

Nuclide	Auxiliary (pCi/g/mCi)	Containment (pCi/g/mCi)	Turbine (pCi/g/mCi)	Fuel (pCi/g/mCi)	Crib House /Forebay (pCi/g/mCi)	WWTF (pCi/g/mCi)
Co-60	8.92E-04	1.02E-01	2.55E-02	1.22E-01	2.18E-02	4.64E+00
Cs-134	4.77E-03	1.01E-01	2.54E-02	6.53E-01	2.18E-02	4.63E+00
Cs-137	1.71E-02	1.01E-01	2.54E-02	2.35E+00	2.18E-02	4.63E+00
Eu-152	1.58E-03	1.02E-01	2.55E-02	2.15E-01	2.18E-02	4.64E+00
Eu-154	1.22E-03	1.02E-01	2.55E-02	1.67E-01	2.18E-02	4.64E+00
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ni-63	1.81E-02	1.02E-01	2.54E-02	2.49E+00	2.18E-02	4.64E+00
Sr-90	6.94E-03	9.50E-02	2.38E-02	9.46E-01	2.03E-02	4.33E+00

2.3. BFM Groundwater Dose Factors

BFM Groundwater Dose Factors are dose conversion factors in units of mrem/yr per mCi total inventory. The Resident Farmer dose includes the exposure pathways listed in section 1. The BFM Groundwater Dose Factor accounts for all of the exposure pathways except the drilling spoils pathway which is discussed in section 2.4.

As discussed in detail in LTP Chapter 6, section 6.5.4, operation of a residential well in the Spent Fuel Basement is implausible due to the floor of the Spent Fuel Pool being only three feet below the water table. Therefore, the BFM GW Dose Factors for the Spent Fuel Pool are set to zero. Note that the BFM Drilling Spoils pathway remains active for the Spent Fuel Pool.

The BFM Groundwater Dose Factors are calculated using Equation 3. The spreadsheet calculation inputs and results are provided in Zion*Solutions* Excel Spreadsheet "Calculations in Support of LTP

Chapter 6, Rev 2.xls". The Excel Worksheet results are provided in Attachment 6. The results are summarized in Table 7.

Equation 3

$$\boldsymbol{BFM\ GW\ Dose\ Factor(i,b) = GW\ Concentration\ Factor(i,b) \times GW\ Exposure\ Factor(i)}$$

where:

BFM GW Dose Factor (i,b) = BFM Groundwater Dose Factor for radionuclide (i) and Basement (b) (mrem/y per mCi)

GW Concentration Factor (i,b) = Groundwater Concentration Factor for Radionuclide (i) and Basement (b) (pCi/L per mCi)

GW Exposure Factor (i) = Groundwater Exposure Factor for radionuclide (i) (mrem/y per pCi/L.

Table 7 BFM GW Dose Factors (mrem/yr per mCi Total Inventory)

Nuclide	Auxiliary (mrem/yr per mCi)	Containment (mrem/yr per mCi)	Fuel (mrem/yr per mCi)	Turbine (mrem/yr per mCi)	Crib House /Forebay (mrem/yr per mCi)	WWTF (mrem/yr per mCi)
Co-60	1.00E-04	1.14E-02	NA	2.87E-03	2.45E-03	5.21E-01
Cs-134	9.27E-03	1.98E-01	NA	4.94E-02	4.22E-02	9.03E+00
Cs-137	2.64E-02	1.57E-01	NA	3.92E-02	3.35E-02	7.17E+00
Eu-152	5.96E-05	3.87E-03	NA	9.69E-04	8.29E-04	1.75E-01
Eu-154	6.77E-05	5.62E-03	NA	1.41E-03	1.20E-03	2.56E-01
H-3	6.21E-03	2.72E-02	NA	6.80E-03	5.80E-03	1.23E+00
Ni-63	2.86E-04	1.61E-03	NA	4.01E-04	3.44E-04	7.31E-02
Sr-90	3.29E-01	4.51E+00	NA	1.13E+00	9.66E-01	2.06E+02

2.4. Basement Dose Factors

Compliance with the 25 mrem/yr dose criterion will be demonstrated after the remaining residual radioactivity inventory has been determined by the final radiation survey. The total inventory remaining for each ROC, in each Basement, will be multiplied by the applicable Basement Dose Factor. The dose contribution for each ROC in a given Basement will be accounted for using the "sum of fractions" rule.

The Basement Dose Factors are calculated as the sum of the BFM GW Dose Factors and BFM Drilling Spoils Dose Factors (calculated in TSD 14-021) which together account for the dose from all of the Resident Farmer exposure pathways listed in section 1. As discussed in section 6.5.4, only the BFM Drilling Spoils Dose Factors are applicable to the Spent Fuel Pool, i.e., the BFM GW Dose Factors are assumed to be zero.

An additional step in the calculation of the Basement Dose Factors is adjustment for the dose contribution from insignificant dose contributors. In accordance with NUREG 1757, the insignificant radionuclides can be removed from detailed assessment but the dose attributable to the removed radionuclides must be accounted for. From TSD 14-019, Table 19, the insignificant contributor dose contribution for the Containment and Auxiliary Basements was 0.514% and 1.32%, respectively. Although the calculated insignificant contributor dose fractions are conservative due to the application of minimum detectable concentrations (MDC) values in the calculation for the majority of HTD radionuclides, the dose fractions were multiplied by a factor of 2 (100% increase) to provide additional margin to account for potential uncertainty in the radionuclide mixture. The Auxiliary Basement percentage was applied to all Basements except Containment noting that the insignificant contributor dose will be reviewed and revised, if necessary, based on results of continued characterization.

The Basement Dose Factors are calculated using Equation 4. The insignificant contributor dose adjustment factors in Equation 4 are 1.010 (1/(1-2*0.00514) and 1.027 (1/(1-2*0.0132) for the Containment Basement and all other Basements, respectively.

Two additional basement-specific adjustments were made. First, there was a revision to the demolition plan for the Crib House/Forebay that entailed leaving interior walls as opposed to removing them. This resulted in a decrease in the basement mixing volume as compared to that assumed in the DUST-MS modeling provided in TSD-14-009, Revision 0 and a corresponding increase in the fill and groundwater concentrations calculated in TSD 14-009, Revision 0. The Basement Dose Factors are directly proportional to the fill and groundwater concentrations which are inversely proportional to the ratio of revised/original mixing volumes. The ratio of the revised/original mixing volumes for the Crib House /Forebay was calculated in TSD 14-013, Revision 1 and determined to be 0.86. The Crib House/Forebay BDFs were therefore adjusted higher by the inverse of 0.86 or a factor of 1.16. Second, the Basement Dose Factors for the SFP/Transfer Canal were adjusted to equal the higher of either the Containment or SFP/Transfer Canal values. This adjustment was driven by the commitment in LTP Chapter 6 section 6.5.4 to account for the potential groundwater dose from residual radioactivity in the SFP/Transfer Canal by adding the SFP/Transfer Canal inventory to the Containment inventory in order to ensure that the sum of the two inventories does not exceed the Containment inventory limit. Therefore, in practice, the SFP/Transfer Canal BILs cannot exceed the Containment BILs. Maximizing the Basement Dose Factors minimizes the inventory limit.

The final Basement Dose Factors for each Basement and ROC are listed in Table 8.

Equation 4

$$\boldsymbol{BDF\ (b,i) = (BFM\ DF(b,i) + DS\ DF\ (b,i)) * IC\ Dose\ Adjustment}$$

where:

BDF (b,i)	= Basement Dose Factor for Basement (b) and radionuclide (i) (mCi)
BFM DF (b,i)	= BFM Dose Factor for Basement (b) and radionuclide (i) (mrem/yr per mCi)
DS DF (b,i)	= Drilling Spoils Dose Factor for Basement (b) and radionuclide (i) (mrem/yr per mCi)
IC Dose Adjustment	= adjustment factor to account for the insignificant contributor dose

Table 8 Basement Dose Factors

Nuclide	Auxiliary (mrem/yr /mCi)	Containment (mrem/yr /mCi)	Fuel (mrem/yr /mCi)	Turbine (mrem/yr/ mCi)	Crib House/ Forebay (mrem/yr /mCi)	WWTF (mrem/yr /mCi)
Co-60	1.11E-02	4.15E-02	1.63E-01	1.28E-02	2.42E-02	7.68E-01
Cs-134	1.60E-02	2.17E-01	2.17E-01	5.64E-02	6.27E-02	9.41E+00
Cs-137	3.04E-02	1.66E-01	1.66E-01	4.27E-02	4.52E-02	7.42E+00
Eu-152	5.22E-03	1.78E-02	7.66E-02	5.56E-03	1.08E-02	2.88E-01
Eu-154	5.79E-03	2.05E-02	8.47E-02	6.30E-03	1.19E-02	3.78E-01
H-3	6.37E-03	2.74E-02	2.74E-02	6.98E-03	6.93E-03	1.27E+00
Ni-63	2.94E-04	1.62E-03	1.62E-03	4.12E-04	4.11E-04	7.51E-02
Sr-90	3.38E-01	4.56E+00	4.56E+00	1.16E+00	1.15E+00	2.12E+02

3. RESRAD Modeling for Soil DCGL Determination

Site-specific DCGLs were developed for residual radioactivity in surface and subsurface soil that represent the 10 CFR 20.1402 dose criterion of 25 mrem/yr. A DCGL was calculated for each ROC determined in TSD 14-019. The ROC are Cs-137, Cs-134, Co-60, Cr-90, and Ni-63.

Surface soil is defined as contamination contained in the first 0.15 m layer of soil. Subsurface soil is defined as a layer of soil beginning at the surface that extends beyond 0.15 m. The Subsurface soil thickness is arbitrarily set to a 1 m depth. DCGLs are calculated for both the 0.15 m and 1 m thicknesses. Both the surface and subsurface DCGLs assume a continuous source term layer from the ground surface downward. There are no expectations of encountering soil contamination in a geometry consisting of a clean surface layer of soil over a contaminated subsurface soil layer.

Detailed description of the soil DCGL conceptual model and parameter justification is provided in LTP Chapter 6, section 6.8.

RESRAD version 7.0 was used to calculate DCGLs for surface and subsurface soil.

3.1. Soil Uncertainty Analysis

Parameter uncertainty analysis was performed following the process described in LTP Chapter 6, section 6.9.2. The parameters used for the uncertainty analysis of the surface and subsurface soil dose modeling are the same as were used for the BFM RESRAD uncertainty analysis, with the exception of contaminated zone thickness. A 0.15 m thickness is used for surface soil and 1.0 m thickness for subsurface soil. The unsaturated zone depth was also adjusted to ensure that the depth to the water table remains constant for both the 0.15 m and 1.0 m contaminated zone thicknesses.

The RESRAD input parameters used for the uncertainty analysis of both surface and subsurface soil are provided in Attachment 7. The RESRAD Uncertainty Reports were generated for surface and subsurface soil and for each ROC individually. The reports are provided in Attachment 8.

Deterministic parameters were selected for behavioral, metabolic and Priority 3 physical parameters in accordance with the process in Figure 1. The majority of the Priority 1 and 2 physical parameters are assigned the parameter distributions from NUREG/CR-6697.

Surface soil parameters with a |PRCC| result greater than 0.25 are listed in Table 9. Tables 10 and 11 provide the selected 75th or 25th percentile deterministic values for surface soil from the NUREG/CR-6697 distributions for the positively and negatively correlated parameters, respectively.

Subsurface soil parameters with a |PRCC| result greater than 0.25 are listed in Table 12. Tables 13 and 14 provide the selected 75th or 25th percentile deterministic values for subsurface soil. The median of the NUREG/CR-6697 distributions was assigned to the Priority 1 and 2 parameters that were not sensitive (i.e., not listed in Tables 6-9 and 6-12).

Table 9 Surface Soil DCGL Uncertainty Analysis Results for Parameters with |PRCC| >0.25

Parameter	PRCC Value				
	Co-60	Cs-134	Cs-137	Ni-63	Sr-90
Depth of Soil Mixing Layer	NS	-0.30	-0.36	-0.56	NS
Depth of Roots	-0.30	-0.47	-0.53	-0.78	-0.90
External Gamma Shielding Factor	0.99	0.96	0.93	NS	NS
Density of Contaminated Zone	0.59	0.32	NS	NS	NS
Plant Transfer Factor	0.34	0.57	0.63	0.86	0.96
Meat Transfer Factor	0.26	0.25	0.31	NS	NS
Milk Transfer Factor	NS	0.25	0.31	0.88	0.36

Table 10 Selected Deterministic Values for Surface Soil DCGL Sensitive Parameters from Table 9 That Are Radionuclide Independent

Parameter	Percentile	Parameter Value
Depth of Soil Mixing Layer	25th	0.15
Depth of Roots	25th	1.22m
External Gamma Shielding Factor	75th	0.40
Density of Contaminated Zone	75th	1.68[1]

Note 1: Density identified as sensitive and positively correlated. The higher site-specific value for sand density is 1.8 g/cm^3 which was applied.

Table 11 Deterministic Values for Surface Soil DCGL Sensitive Parameters from Table 9 that are Radionuclide Dependent

Radionuclide	Plant Transfer Factor 75th Percentile	Meat Transfer Factor 75th Percentile	Milk Transfer Factor 75th Percentile
Co-60	0.15	0.058	NS
Cs-134	0.078	0.065	0.014
Cs-137	0.078	0.065	0.014
Ni-63	0.092	NS	0.032
Sr-90	0.59	NS	0.0027

Table 12 Subsurface Soil DCGL Uncertainty Analysis Results for Parameters with |PRCC| > 0.25

Parameter	PRCC Value				
	Co-60	Cs-134	Cs-137	Ni-63	Sr-90
Depth of Roots	-0.45	-0.60	-0.69	-0.86	-0.93
External Gamma Shielding Factor	0.97	0.90	0.84	NS	NS
Plant Transfer Factor	0.67	0.83	0.88	0.96	0.98
Meat Transfer Factor	0.40	0.29	0.37	NS	NS
Milk Transfer Factor	NS	0.35	0.45	0.91	0.44

Table 13 Selected Deterministic Values for Subsurface Soil DCGL Sensitive Parameters from Table 12 that are Radionuclide Independent

Parameter	Percentile	Parameter Value
Depth of Roots	25th	1.22m
External Gamma Shielding Factor	75th	0.40

Table 14 Deterministic Values for Subsurface Soil DCGL Sensitive Parameters from Table 12 that are Radionuclide Dependent

Radionuclide	Plant Transfer Factor 75th Percentile	Meat Transfer Factor 75th Percentile	Milk Transfer Factor 75th Percentile
Co-60	0.15	0.058	NS
Cs-134	0.078	0.065	0.014
Cs-137	0.078	0.065	0.014
Ni-63	0.092	NS	0.032
Sr-90	0.59	NS	0.0027

3.2. RESRAD Results and Soil DCGLs

The surface and subsurface soil DCGLs were calculated using the deterministic parameter set provided in Attachment 9. The RESRAD Summary Reports for surface and subsurface soil are provided in Attachment 10.

The surface and subsurface soil DCGLs are provided in Table 15. The insignificant contributor dose percentage calculated in TSD 14-019 is 0.171%. However, to provide additional margin and allow for simplified assessment of additional HTD analysis, if any, of soil during continuing characterization, the applied insignificant dose contribution was increased to 10%. The adjustment factor is 0.90 (1-0.1). The adjusted DCGL are calculated by multiplying the values in Table 15 by 0.9.

Table 15 RESRAD Surface and Subsurface Soil DCGLs

Radionuclide	Surface Soil DCGL (pCi/g)	Subsurface Soil DCGL (pCi/g)
Co-60	4.7	3.8
Cs-134	7.5	4.9
Cs-137	15.7	8.6
Ni-63	3969	847
Sr-90	13.4	1.8

Table 16 RESRAD Surface and Subsurface Soil DCGLs Adjusted to account for Insignificant Contributor Dose

Radionuclide	Adjusted Surface Soil DCGL (pCi/g)	Adjusted Subsurface Soil DCGL (pCi/g)
Co-60	4.2	3.4
Cs-134	6.7	4.4
Cs-137	14.1	7.7
Ni-63	3572	763.0
Sr-90	12.0	1.6

4. RESRAD Modeling for Concrete Radionuclide of Concern Selection

4.1. BFM GW Dose Factors for the Initial Suite of Potential Radionuclides

The set of radionuclides evaluated in section 2 was comprised of the ROC selected in TSD 14-019. The process of selecting the ROC entailed determining an “initial suite” of radionuclides that could potentially be present at ZNPS and then removing insignificant dose contributors from the initial suite. A systematic screening process was used to remove very low abundance or low probability radionuclides from a comprehensive list of all possible radionuclides resulting in the “initial suite” that is reproduced in Table 17. See LTP Chapter 6, Section 6.5.2 and TSD 14-019 for detailed discussions of the process for selecting the initial suite.

Table 17 List of 26 potentially significant radionuclides (from TSD 14-019)

H-3	Co-60	Tc-99	Cs-137	*Eu-155*	Pu-241
C-14	Ni-63	*Ag-108m*	Pm-147	Np-237	Am-241
Fe-55	Sr-90	Sb-125	Eu-152	Pu-238	Am-243
Ni-59	Nb-94	Cs-134	Eu-154	Pu-239/240	Cm-243/244

NUREG-1757, section 3.3 states that radionuclides contributing no greater than 10% percent of the dose criterion (i.e., 2.5 mrem/yr) are considered to be "insignificant contributors". This 10% percent criterion applies to the sum of the dose contribution from the aggregate of radionuclides designated as insignificant contributors.

TSD 14-019 uses the results of BFM RESRAD dose modeling for the initial suite in conjunction with DUST-MS modeling by TSD 14-031, "Brookhaven National Laboratory Report: Basement Fill Model Evaluation of Maximum Radionuclide Concentrations for Initial Suite of Radionuclides" (8) to determine the BFM Dose Factors from the initial suite radionuclides in the same manner as described in section 2 for the ROC radionuclides. The BFM Dose Factors calculated in TSD 14-019 are used with the radionuclide mixture fractions in ZNPS concrete to calculate relative dose. The relative dose contribution from insignificant contributors was calculated and the ROC nuclides selected.

The RESRAD parameters used for the BFM modeling of the initial suite radionuclides are provided in Attachment 11. The RESRAD Summary Report and Concentration Report are provided in Attachment 12.

The RESRAD parameter set is the same as was used for the BFM GW Exposure Factor modeling for ROC described in section 2, including adjustment for the radionuclide independent sensitive parameters in Table 2. The distribution coefficients for the initial suite radionuclides were the lowest values recommended in TSD 14-004 (5) which is the same reference used to select distribution coefficients for ROC BFM RESRAD modeling in section 2.

A detailed uncertainty analysis, including all 26 radionuclides, was not merited for the ROC screening calculations given the *apriori* understanding that only limited water dependent pathways are applicable to the BFM. ROC screening is based on relative dose between the 26 radionuclides in Table 17, not absolute dose, so the significance of parameter variability is reduced. Notwithstanding the relative nature of the ROC screening assessment, qualitative uncertainty analysis was performed which indicated that approximately 50% of the dose for Cs-137 (the predominate radionuclide) was attributable to the plant, meat and milk ingestion pathways with the remainder of the dose from drinking water. For simplicity and to ensure that the calculated dose is conservative for all radionuclides, the plant/meat/milk transfer factors were set to the 75th percentile of the NUREG-6697 distribution for all radionuclides. This was done to maximize the relative dose, particularly for the low abundance radionuclides, to ensure that the dose attributed to the insignificant contributors is maximized. Note that for the eight ROC, the plant transfer factors were set to the same values used in Table 3 based on sensitivity analysis. This ensures that the values for the ROC in both RESRAD runs are the same and further maximizes the impact of the low abundance radionuclides.

4.2. Soil Area Factors for Determining BFM Drilling Spoils Dose Factors for the Initial Suite of Potential Radionuclides

As described in TSD 14-021, soil AFs were required for the initial suite of radionuclides for four area sizes as listed below:

- 0.1 m^2
- 0.3 m^2
- 3.0 m^2
- 10 m^2

RESRAD runs were required for the above areas as well as the base case area of 64,500 m^2 to determine the AFs for the initial suite of radionuclides. The AFs are calculated in TSD 14-021 using the RESRAD results. The soil RESRAD input parameters for the AF runs were the same as those used for soil DCGLs (see Attachment 9) with the parameters for 'contaminated fraction of plant food, meat and milk' changed from 1 to -1 to allow RESRAD to account for smaller contaminated areas. The 'length parallel to aquifer flow' also required adjustment to be consistent with the smaller areas. The methods used for RESRAD modeling for AF's is the same as described in Zion Solutions TSD 14-011, "*Soil Area Factors*" (9). The RESRAD Summary Reports are provided in Attachment 13.

5. RESRAD Modeling for Soil Radionuclide of Concern Selection

As described in TSD 14-019, the initial suite radionuclides in Table 17 were also used to determine the ROCs, and insignificant contributors for soil. A RESRAD run was required to determine the 'dose to source ratio' for all initial suite radionuclides in order to identify the insignificant dose contributors and the dose from the aggregate of insignificant contributor radionuclides removed from detailed consideration.

The RESRAD parameter set was the same as used for the ROC DCGL calculation with two adjustments. First, soil distribution coefficients were required for all additional radionuclides in the initial suite which were selected from the same source that was used for the ROC RESRAD analysis, i.e., Reference 7. Daughter products were assigned the mean of the NUREG 6697 distribution as was done for the BFM initial suite evaluation for ROC determination. An additional change was setting all plant, meat, and milk transfer factors to the 75th percentile to maximize the dose contribution from all radionuclides. Note that for the 5 ROCs, the plant transfer factors were the same as were used in Table 11 based on sensitivity analysis. This ensures that the values for the ROCs in both RESRAD runs are the same and maximizes the impact of the low abundance radionuclides. The surface soil source thickness (0.15 m) was used in the initial suite runs for ROC determination because minimal, if any, soil contamination is expected below 0.15 m based on characterization results.

The RESRAD Summary Report for the RESRAD analysis of the initial suite radionuclides for soil ROC determination is provided in Attachment 14.

6. RESRAD Soil Dose Modeling for Industrial Use Alternate Scenario

An Alternate dose scenario is evaluated in TSD-021 that assumes large scale industrial excavation of the ZION basements after license termination. Excavation of the very deep basements would be prohibitively expensive and is considered a "less likely but plausible" scenario. NUREG-1757, Table 5.1, states that assessment of a "less likely but plausible scenario" is "not analyzed for compliance, but is used to risk-inform the decision."

If a large scale excavation of the basements, were to occur it would not be for residential use but to develop the property for industrial use. The cost and technical challenges of the excavation required for the deep basements, that are all below the water table, would only be justified for a large scale industrial project that would be present on the site for decades. Therefore, for the assessment of the large scale industrial excavation scenario a dose assessment is required that assumes industrial use as opposed to residential use. This section describes the RESRAD input parameters used for modeling an industrial use scenario for soil and provides the results of the dose assessment. The resulting "DCGLs" are used in TSD 14-021 to assess the large scale industrial excavation alternate scenario.
The large scale excavation scenario in TSD 14-021 assumes that the excavated material is spread on the surface over a 1 m depth. Therefore, the RESRAD parameters for the industrial use soil assessment were set to the same values as used for the Subsurface soil dose assessment (see Attachment 9) with the following changes:

Inhalation Rate: 1917 m^3/yr
NUREG/CR-5512, Vol. 3 Table 5.1.1 mean value is 8400/y which equates to 23 m3/d.
Industrial Scenario m3/yr =23 m3/d ÷ 24h/d * 2000 h/y.

Fraction of time spent indoors: 0.1875
NUREG-6697 Att. C, Table 7.6-1 recommends a median indoor work day as 8.76 hours/day. Assuming 5 days a week and 50 weeks per years this equates to 2190 hours per year. Majority of industrial work is expected to be indoors. Consistent with Table 2-3 of the "User's Manual for RESRAD Version 6", 75% of work time is indoors and 25% outdoors. The corresponding RESRAD indoor Fraction parameter = (2190*0.75)/(24*365) = 0.1875

Fraction of time spent outdoors (onsite): 0.0625
As explained in the basis for the Indoor Fraction parameter, the indoor time fraction was set at 75% and outdoor time fraction at 25%. The corresponding RESRAD outdoor time fraction is (2190*.25)/(24*365) = 0.0625.

Drinking water intake: 327 L/y
NUREG/CR-5512, Vol. 3 Table 6.87. Industrial Scenario water supply assumed to be from an onsite well. 478 L/y from NUREG/CR-5512 corresponds to 1.31 L/d which is considered a conservative value for 8 hour work day. 1.31 L/d * 250 work days = 327 L/y

Plant/Meat/Milk Pathways:
All food ingestion pathways inactive in industrial scenario.

Kds for Sr-90 and Ni-63:
Kds for Sr-90 and Ni-63 set to the minimum site-specific values to maximize dose through groundwater pathway which is predominant pathway with plant/meat/milk inactive. Kds for remaining radionuclides are set to minimum values in the Subsurface Soil parameter set used therefore no adjustment required.

The File name for the Industrial Use scenario RESRAD Summary Report is listed below. The full report is stored electronically.

- Zion Industrial Use Soil RESRAD Summary Report 5_27.pdf

The resulting Industrial Use DCGLs are listed in Table 7 column 2. Note that H-3, Eu-152, and Eu-154 were added to the list of radionuclides evaluated because the industrial use scenario DCGLs were used in TSD 14-021 to evaluate the excavation of backfilled concrete which includes and H-3, Eu-152 and Eu-154 as ROCs for the Containment Basement. Table 17, column 3 provides the DCGLs after adjustment to account for the dose fraction attributable for the removed insignificant contributors. The calculated insignificant dose fraction assigned to surface soil, i.e., 0.171% (see TSD 14-019 Revision 2 Table 24), was used to adjust the industrial use DCGLs. This is conservative because the plant pathways are not applicable to industrial use which reduces the relative dose fraction from non-gamma emitting radionuclides (i.e., HTD radionuclides) which are the vast majority of radionuclides removed as insignificant dose contributors.

Table 18 Industrial Use Concentrations "DCGLs"and Adjusted DCGLs

Radionuclide	Industrial Use DCGL (pCi/g)	Adjusted Industrial Use DCGL (pCi/g)
Co-60	12.36	12.34
Cs-134	23.37	23.33
Cs-137	55.86	55.76
Eu-152	27.48	27.43
Eu-154	25.47	25.43
H-3	1819.00	1815.89
Ni-63	9.50E+06	9.48E+06
Sr-90	14.09	14.07

7. Soil Kd Uncertainty and Sensitivity Assessment

An assessment was performed to determine the sensitivity of soil dose to Kd.

Four soil types were sampled from the Zion site and analyzed by Brookhaven National Laboratory for Kd; Disturbed Sand, Native Sand, Silt/Clay, and Clay (Reference 5). The site surface and subsurface soil is contained in the Upper Sand Unit and is a mix of Disturbed Sand and Native Sand. The majority of the site surface soil is Disturbed Sand. The Silt/Clay and Clay were sampled from depths of 24'-28' below ground surface (bgs) and 31'-36' bgs, respectively. These samples were collected to understand the characteristics of the Upper Silt/Clay Unit which underlies the Upper Sand Unit. The Upper Silt/Clay unit is an aquitard that inhibits groundwater flow between the Upper and Lower Sand Unit aquifers. The Zion dose model conservatively assumes that all wells are screened in the Upper Sand Unit as opposed to the Lower Sand Unit which is isolated from the Zion site source term by the clay aquitard.

The site soil type (down at least several feet) is predominantly Disturbed Sand as a result of excavation and backfill during plant construction. However, some areas could consist of Native Sand Kds. Therefore, both sand types are considered applicable to the surface (0.15 m depth) and subsurface

(1 m depth) soil categories. The site-specific Kds for Native Sand and Disturbed Sand are listed in Reference 5 for each ROC and shown in Tables 18 and 19.

The assessment included a probabilistic uncertainty analysis for Surface and Subsurface soil with the Kds being the only parameters considered probabilistically. This maximizes the effect of Kd on the dose results and the chance for a Kd being identified as sensitive (using the criteria described in section 3.1, i.e., absolute value of PRCC being greater than 0.25). The Kd parameter distributions were entered in RESRAD as uniform distributions with minimum and maximum values defined by the Native or Disturbed sand site-specific Kds. The uncertainty analysis did not identify any of the Kd parameters as being sensitive. The RESRAD Uncertainty Report file names are listed below. The reports are stored electronically.

- Zion Subsurface Soil Sensitivity RESRAD Uncertainty Report.pdf
- Zion Surface Soil Sensitivity RESRAD Uncertainty Report.pdf

An additional sensitivity analysis was performed that included deterministic RESRAD analyses of Surface Soil and Subsurface Soil using the maximum site-specific sand Kd. The resulting DCGLs were compared to the DCGLs calculated using the minimum site-specific sand Kd. The file names of the two RESRAD Summary Reports used for the analysis are listed below. The full reports are stored electronically.

- Zion Subsurface Soil Sensitivity RESRAD Summary Report.pdf
- Zion Surface Soil Sensitivity RESRAD Summary Report.pdf

The results are summarized in Tables 18-20. The deterministic approach is very conservative in that it includes each radionuclide independently and ignores the actual dose consequences of a given radionuclide in the context of the radionuclide mixture. As seen on Table 20, when Sr-90 is considered independently the maximum Kd resulted in a DCGL that was 6% lower. Ni-63 is lower by a very small fraction. The gamma emitters, which represent the vast majority of dose form soil were not affected by the Kd change.

Although the Sr-90 DCGL was lower by 6% with the maximum Kd, when the radionuclide mixture percentage of Sr-90 is considered the dose consequences are orders of magnitude lower than 6%. Notwithstanding the fact that the calculated dose increase if very low, the maximum Kds will be used for both Sr-90 and Ni-63 in the Surface and Subsurface DCGL modeling.

Table 19 Surface and Subsurface Soil DCGL with Minimum Site-Specific Sand Kds

Radionuclide	Kd	Surface Soil DCGL	Subsurface Soil
	(cm^3/g)	(pCi/g)	(pCi/g)
Co-60	1161	4.734	3.825
Cs-134	615	7.524	4.930
Cs-137	615	15.76	8.606
Ni-63	62	3995	848.6
Sr-90	2.3	14.36	1.860

Table 20 Surface and Subsurface Soil DCGL with Maximum Site-Specific Sand Kds

Radionuclide	Kd	Subsurface Soil DCGL	Subsurface Soil
	(cm^3/g)	(pCi/g)	(pCi/g)
Co-60	1161	4.734	3.825
Cs-134	635	7.523	4.930
Cs-137	635	15.76	8.606
Ni-63	331	3969	847.8
Sr-90	3.4	13.43	1.840

Table 21 Ratio of Maximum Kd DCGL/Minimum Kd DCGL for Surface and Subsurface Soil

Radionuclide	Surface Soil Ratio	Subsurface Soil Ratio
Co-60	1.00	1.00
Cs-134	1.00	1.00
Cs-137	1.00	1.00
Ni-63	0.99	1.00
Sr-90	0.94	0.99

8. Clean Concrete Fill

ZSRP will demonstrate that all concrete designated as backfill material in basements is clean by using the Unconditional Release Survey (URS) program at Zion presented in ZionSolutions procedure ZS-LT-400-001-001, "Unconditional Release of Materials, Equipment and Secondary Structures". The URS ensures that no detectable plant-derived radioactive material is released from the site. MARSAME guidance is used in establishing survey intensities, and NRC has reviewed and audited the ZSRP unconditional release programs and found them to be acceptable. Materials unconditionally released from Zion, regardless of their point of origin on the site, have been verified to contain no detectable plant-derived radioactivity and are free to be used and relocated anywhere offsite without tracking, controls, or dose considerations.

The URS is performed in accordance with procedure ZS-LT-400-001-001 which requires ambient background to be determined for the area of the survey and a "critical level" based on the ambient background be derived for the instrument used. If a measurement result is greater than the critical level established for the instrument in the area specific to the material being surveyed, then an investigation is performed, typically using a portable gamma spectroscopy instrument (Inspector) but in some cases a volumetric sample is taken. If the investigation positively identifies plant-derived radioactivity, then the material may not be "unconditionally released". In the case of concrete surveyed as candidate material for use as clean fill, the material would be disqualified for use as fill, segregated and disposed of as low level radioactive waste.

Although the concrete to be used as fill is clean and can be viewed as having a zero dose impact, a dose value will be assigned for the purpose of demonstrating compliance with 10 CFR 20.1402 in the same manner as other materials to remain at license termination that are surveyed and found to not

contain detectable activity. The "detection limit" used for the dose calculation is conservatively assumed to be the 5,000 dpm/100 cm^2 value in I&E Circular 81-07. Actual detection limits in the unconditional release program are lower than this value. Note that if the use of the 5,000 dpm/100 cm2 maximum non-detect limit is deemed to be too conservative, this dose calculation will be revised based on actual survey detection limits as opposed to the conservative 5,000 dpm/100 cm2 upper value.

The vast majority of clean concrete fill to be used will come from two buildings; Containment and Turbine. The source term for the dose assessment is calculated by determining the total surface area of the concrete to be used as backfill, assuming uniform surface contamination at 5,000 dpm/100 cm^2 gamma, and dividing the resulting total activity by the volume of concrete fill. The source term is then produced with units of mCi/m^3 for both Containment and Turbine. The resulting source terms were 8.57E-04 mCi/m^3 and 4.29E-04 mCi/m^3 for the Turbine Building and Containment, respectively. Consistent with the bounding and conservative approach used for this dose assessment, the maximum source term of 8.57E-04 mCi/m^3 was applied to all concrete fill.

Because the source term was from both Containment and Turbine concrete the dose calculation was performed using both the Containment and Auxiliary ROC mixtures. The dose was essentially the same for both mixtures but the dose with the Containment mixture was slightly higher (with trivial exception of WWTF). Consistent with the bounding approach used for the clean concrete assessment the Containment mixture was applied to all concrete. In addition, when applying the ROC mixture, the 5,000 dpm/100 cm^2 maximum detection limit was assumed to be 100% Cs-137. The remaining radionuclide concentrations were added to the Cs-137 concentration at their respective ratios to Cs-137. The dose values are calculated separately for each basement assuming that the entire basement void is filled with concrete only. This conservatively includes the top three feet of fill which will be soil for all basements and not concrete. The full spreadsheet calculation for clean concrete dose is provided in Attachment 15. The dose results for each basement are provided in Table 22. The dose values in Table 22 will be added to any basement where concrete fill is used regardless of the volume of concrete fill used. This is a conservative and bounding approach.

Table 22 Clean Concrete Fill Hypothetical Dose using Containment ROC Mixture

Radionuclide	Auxiliary	Containment	Spent Fuel Pool/ Transfer Canals	Turbine	Crib House/ Forebay	WWTF
	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Co-60	2.48E-02	2.98E-02	1.00E-02	3.23E-02	5.63E-02	4.60E-02
Cs-134	6.21E-05	2.71E-04	2.33E-05	2.49E-04	2.54E-04	9.83E-04
Cs-137	9.80E-01	1.72E+00	1.48E-01	1.56E+00	1.52E+00	6.42E+00
Eu-152	1.09E-03	1.19E-03	4.41E-04	1.31E-03	2.35E-03	1.61E-03
Eu-154	1.60E-04	1.82E-04	6.47E-05	1.97E-04	3.43E-04	2.81E-04
H-3	2.25E-04	3.12E-04	2.68E-05	2.79E-04	2.55E-04	1.20E-03
Ni-63	3.68E-03	6.55E-03	5.63E-04	5.85E-03	5.37E-03	2.53E-02
Sr-90	4.41E-03	1.91E-02	1.65E-03	1.72E-02	1.57E-02	7.42E-02
Total	**1.01E+00**	**1.78E+00**	**1.61E-01**	**1.62E+00**	**1.60E+00**	**6.57E+00**

9. Conclusion

This TSD documents the RESRAD runs and spreadsheet calculations required to determine the BFM Dose Factors for Basement Concrete and DCGLs for Soil that are provided in LTP Chapter 6.

Nine RESRAD analyses are required to support the LTP:

1. Basement Fill Model (BFM) sensitivity analysis for ROC,
2. BFM Groundwater Exposure Factors for ROC,
3. Soil Derived Concentration Guideline Level (DCGL) sensitivity analysis for ROC,
4. Soil DCGLs for ROC,
5. BFM RESRAD modeling to determine Groundwater Exposure Factors for the initial suite of radionuclides in concrete,
6. Soil RESRAD modeling to determine AFs for the initial suite of radionuclides in concrete to determine BFM Drilling Spoils Dose Factors,
7. Soil RESRAD modeling for the initial suite of radionuclides in soil,
8. Soil RESRAD modeling for industrial use scenario, and
9. Soil RESRAD Modeling for Kd uncertainty analysis

Four spreadsheet calculations were required to determine the BFM Dose Factors, and BFM Inventory Limits reported in LTP Chapter 6. The methods for calculating the Dose Factors and Inventory Limits, the documentation of the supporting spreadsheet calculations, and the development of corresponding summary tables reported in LTP Chapter 6 are provided in this TSD. The spreadsheet calculations are listed below:

1. Calculation of DUST-MS Groundwater Concentration Factors
2. Calculation of BFM GW Exposure Factors
3. Calculation of BFM GW Dose Factors
4. Calculation of Basement Inventory Limit (BIL)

10. References

1. ZionSolutions TSD 14-021 “BFM Drilling Spoils and Alternate Exposure Scenarios” December 2014

2. ZionSolutions TSD 14-019, “Radionuclides of Concern for Basement Fill Model Source Terms” December 2014

3. U.S. Nuclear Regulatory Commission NUREG-1757, Volume 2, Revision 1, "Consolidated Decommissioning Guidance: Characterization, Survey and Determination of Radiological Criteria". September 2006

4. ZionSolutions TSD 14-006 "Conestoga Rovers & Associates (CRA) Report, Evaluation of Hydrological Parameters in Support of Zion Restoration Project" October 2014

5. ZionSolutions TSD 14-004 Brookhaven National Laboratory (BNL) Report: “Recommended Values for the Distribution Coefficient (KD) to be used in Dose Assessments for Decommissioning the Zion Nuclear Stationt” October 2014

6. Argonne National Laborator NUREG/CR-6697 "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes" December 2000

7. ZionSolutions TSD 14-009 Brookhaven National Laboratory (BNL) Report “Evaluation of Maximum Radionuclide Groundwater Concentrations for Basement Fill Model” November 2014

8. ZionSolutions TSD 14-031, Brookhaven National Laboratory (BNL) Report: "Basement Fill Model Evaluation of Maximum Radionuclide Concentrations for Initial Suite of Radionuclides" December 2014
9. ZionSolutions TSD 14-011 "Soil Area Factors" December 2014

11. Attachments

11.1. Attachment 1: RESRAD Input Parameters for BFM Uncertainty Analysis

11.2. Attachment 2: RESRAD BFM Uncertainty Reports

11.3. Attachment 3: RESRAD Input Parameters for BFM Groundwater Exposure Factors

11.4. Attachment 4: RESRAD Summary Report and Concentration Report for BFM Groundwater Exposure Factors

11.5. Attachment 5: Calculation of Groundwater Concentration Factors and Fill Concentration Factors from DUST-MS Modeling Results

11.6. Attachment 6: Calculation of BFM Basement Dose Factors

11.7. Attachment 7: RESRAD Input Parameters for Soil DCGL Uncertainty Analysis

11.8. Attachment 8: RESRAD Uncertainty Reports for Soil DCGLs

11.9. Attachment 9: RESRAD Input Parameters for ZSRP Surface Soil and Subsurface Soil DCGL

11.10. Attachment 10: RESRAD Summary Reports for Soil DCGLs

11.11. Attachment 11: RESRAD Input Parameters for BFM Analysis of Initial Suite of Radionuclides

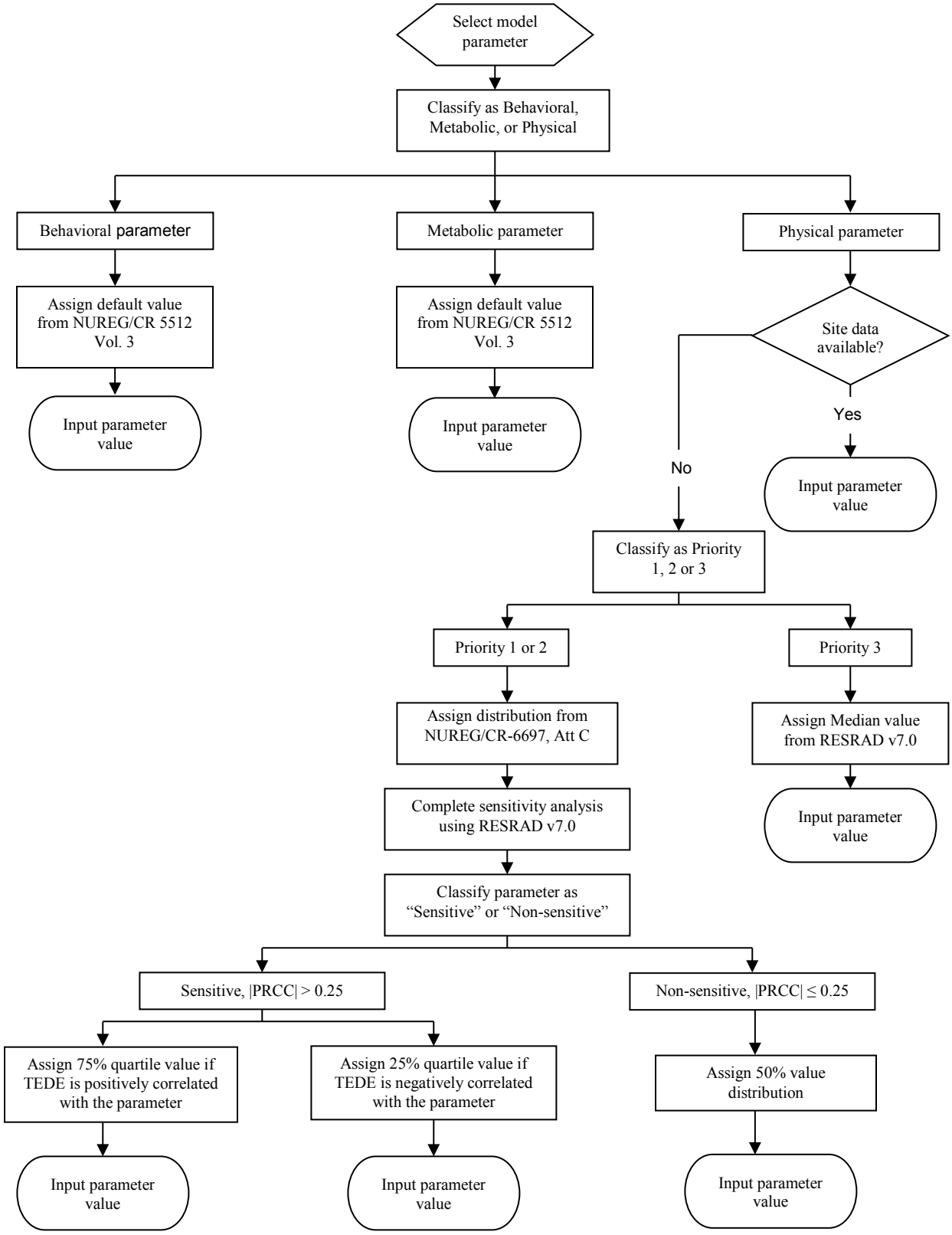
11.12. Attachment 12: RESRAD Summary Report and Concentration Report for BFM Analysis of Initial Suite of Radionuclides

11.13. Attachment 13: RESRAD Summary Reports for Soil Area Factors to Support Calculation of BFM Drilling Spoils Dose Factors for Initial Suite of Radionuclides

11.14. Attachment 14: RESRAD Summary Report for Soil Analysis of Initial Suite of Radionuclides

11.15. Attachment 15: Clean Concrete Fill Dose Assessment at Detection Limit

Figure 1 – RESRAD Parameter Selection Process



ATTACHMENT 1

RESRAD Input Parameters for BFM Uncertainty Analysis

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Co-60	P	1	D	223	TSD 14-004 (Reference 5)	5.46	2.53	0.001	0.999	235
Cs-134	P	1	D	45	TSD 14-004	6.1	2.33	0.001	0.999	446
Cs-137	P	1	D	45	TSD 14-004	6.1	2.33	0.001	0.999	446
Eu-152	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Eu-154	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Gd-152 (daughter for Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
H-3	P	1	D	0	TSD 14-004	-2.81	0.5	0.001	0.999	0.06
Nd-144 (daughter for Eu-152)	P	1	D	158	RESRADv.7.0 Default Neodymium (Nd) not listed in NUREG/CR-6697	NA	NA	NA	NA	NA
Ni-63	P	1	D	62	TSD 14-004	6.05	1.46	0.001	0.999	424
Sm-148 (daughter Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Sr-90	P	1	D	2.3	TSD 14-004	3.45	2.12	0.001	0.999	32
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	No existing groundwater contamination	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	1	For user convenience: Allows use of t=0 in dose and concentration output reports to calculate unitized Exposure Factors	NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	64,500	Area of the 'Security Protected Area' on Zion Site	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Thickness of contaminated zone (m)	P	2	D	11.2	Contaminated Zone is the Basement fill depth where mixing occurs. Depth of fill mixing zone depends on Basement floor elevation. 11.2 m is used as nominal value based on difference between elevations of the water table (579') and Auxiliary Basement floor (542') which equals 11.2m. Note: this parameter has no effect on the calculated values for unitized Exposure Factors.	NR	NR	NR	NR	
Length parallel to aquifer flow (m)	P	2	D	287	Diameter of 64,500 m2 contaminated area. Note: not applicable to Basement Fill Model because Mass Balance groundwater model used.	NR	NR	NR	NR	
Does the initial contamination penetrate the water table?	NA	NA	NA	Yes	100% of the contamination assumed to be in the basement fill water mixing zone	NA	NA	NA	NA	
Contaminated fraction below water table	P[e]	3[e]	D	1	100% of the contamination assumed to be in the basement fill water mixing zone	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	3.6m	Difference between ground level elevation at 591' (179.6m) and equilibrium water level in basements at 579' (176m)	NR	NR	NR	NR	NA
Density of cover material	P	2	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	NR	NR	NR	NR	
Cover erosion rate	P,B	2	D	Continuous Logarithmic	NUREG/CR-6697 Att. C	5E-08	0,0007	0,005	.2	0.0015

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Density of contaminated zone (g/cm^3)	P	1	S	Truncated Normal	NUREG/CR-6697 Att. C Fill to be comprised of undetermined combination of clean concrete and native sand. NUREG/CR-6697 distribution used as placeholder – parameter has no effect on calculation of unitized Exposure Factors	1.52	0.23	0.001	0.999	1.52
Contaminated zone erosion rate (m/y)	P,B	2	S	Continuous Logarithmic	NUREG/CR-6697 Att. C	5E-08	0.0007	0,005	0.2	0.0015
Contaminated zone total porosity	P	2	S	Truncated Normal	NUREG/CR-6697 Att. C Fill to be comprised of undetermined combination of clean concrete and native sand. NUREG/CR-6697 distribution used as placeholder – parameter has no effect on calculation of unitized Exposure Factors	0.425	0.0867	0.001	0.999	0.42
Contaminated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/y)	P	2	S	Loguniform	Site-specific distribution from Reference 4, Table 5.9	786	17000	NA	NA	3649
Contaminated zone b parameter	P	2	S	Bounded Lognormal - N	NUREG/CR-6697, Att. C Fill to be comprised of undetermined combination of clean concrete and native sand. NUREG/CR-6697 distribution used as placeholder – parameter has no effect on calculation of unitized Exposure Factors	1.06	0.66	0.5	30	2.89
Humidity in air (g/m^3)	P	3	D	7.2	Median NUREG/CR-6697 Att. C	1.98	0.334	0.001	0.999	7.2
Evapotranspiration coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	S	Bounded Lognormal n	NUREG/CR-6697 Att. C	1.445	0.2419	1.4	13	4.2
Precipitation (m/y)	P	2	D	0.83	Site-specific value from Reference 4, Table 5.12	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Irrigation (m/y)	B	3	D	0.19	NUREG-5512, Vol. 3, Table 6-18 (Illinois Average) Converted 0.52 L/m2/d to m/y.	NR	NR	NR	NR	
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C	0.1	0.8	NR	NR	0.45
Watershed area for nearby stream or pond (m^2)	P	3	D	1.0E+06	RESRAD Default	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	1.51	0.16	0.001	0.999	1.51
Saturated zone total porosity	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.43	0.06	0.001	0.999	0.43
Saturated zone effective porosity	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.383	0.0610	0.001	0.999	0.383
Saturated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Saturated zone hydraulic conductivity (m/y)	P	1	S	Loguniform	Site-specific distribution from REFERENCE 4 Table 5.9	786	17000	NA	NA	3649
Saturated zone hydraulic gradient	P	2	S	Bounded Lognormal - N	NUREG/CR-6697 Att. C	-5.11	1.77	0.00007	0.5	0.006
Saturated zone b parameter	P	2	D	NA saturated zone b not active because water table drop rate =0	NUREG/CR-6697	NR	NR	NR	NR	NR
Water table drop rate (m/y)	P	3	D	0	Basement fill water assumed to supply well with no water table drop.	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	S	Triangular	NUREG/CR-6697 Att. C	6	10	30		10
Model: Non-dispersion (ND) or Mass-Balance (MB)	P	3	D	MB	MB model most applicable to assumption that well located in center of basement fill.	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Well pumping rate (m^3/y)	B,P	2	D	2250	Calculated according to method described in NUREG/CR-6697, Att. C section 3.10 assuming 10,000m2 farming land area, Illinois average irrigation rate, and NUREG/CR-5512 Vol. 3 livestock water consumption rate.	NR	NR	NR	NR	NR
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	NA	NA	0	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone thickness (m)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil density (g/cm^3)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone total porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone effective porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone field capacity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone hydraulic conductivity (m/y)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil-specific b parameter	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Occupancy										
Inhalation rate (m^3/y)	M,B	3	D	8400	NUREG/CR-5512, Vol. 3[3] Table 6.29 (= 23m^3/d x 365d)	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P,B	2	S	Continuous Linear	NUREG/CR-6697, Att. C	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	2.35E-05
Exposure duration	B	3	D	30	RESRAD User's Manual (Parameter not used in dose calculation)	NR	NR	NR	NR	
Indoor dust filtration factor	P,B	2	S	Uniform	NUREG/CR-6697, Att. C	0.15	0.95			0.55
Shielding factor, external gamma	P	2	S	Bounded Lognormal - N	NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.27

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Fraction of time spent indoors	B	3	D	0.649	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.124	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, non-leafy vegetables, grain consumption (kg/y)	M,B	2	D	112	NUREG/CR-5512, Vol. 3 Table 6.87 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	M,B	3	D	21.4	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk consumption (L/y)	M,B	2	D	233	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	M,B	3	D	65.1	NUREG/CR5512, Vol. 3 Table 6.87 (beef + poultry)	NR	NR	NR	NR	
Fish consumption (kg/y)	M,B	3	D	20.6	NUREG/CR-5512, Vol. 3 Table 6.87 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Other seafood consumption (kg/y)	M,B	3	D	0.9	RESRAD User's Manual Table D.2 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Soil ingestion rate (g/y)	M,B	2	D	18.3	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Drinking water intake (L/y)	M,B	2	D	478	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	B,P	3		NA						
Contamination fraction of livestock water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of aquatic food	B,P	2	NA	NA	Assumption that pond is constructed that intercepts contaminated water not credible at Zion site	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contamination fraction of plant food	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of meat	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of milk	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	28.3	NUREG/CR5512, Vol. 3 Table 6.87 (forage, grain and hay for beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	65.2	NUREG/CR5512, Vol. 3 Table 6.87 (forage + grain + hay)	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87 (beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD User's Manual, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	S	Uniform	NUREG/CR-6697, Att. C	0.3	4.0			2.15
Drinking water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	B,P	3		NA	Not used					
Livestock water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	S	Truncated Lognormal - N	NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.89	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.91	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.25	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Growing Season for Leafy (y)	P	3	D	0.12	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	S	Triangular	NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	S	Triangular	NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef = 20d and poultry =1 day. Lowest value used)	NR	NR	NR	NR	
Fish	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Well water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	NA	NA	NA	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	NA	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	NA	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	NA	NA	NA	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	NA	NA	NA	NR	NR	NR	NR	
C-14 evasion flux rate from soil (1/sec)	P	3	NA	NA	NA	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	NA	NA	NA	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	NA	NA	NA	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	NA	NA	NA	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.62E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Nd-144[f]	M	3	D	7.04E-02	ICRP60	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Sm-148[e]	M	3	D	7.34E-02	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Nd-144[f]	M	3	D	1.51E-04	ICRP60	NR	NR	NR	NR	
Sm-148[f]	M	3	D	1.58E-04	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Co-60	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-2.53	0.9			7.9E-02
Cs-134	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Cs-137	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Eu-152	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Eu-154	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Gd-152	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
H-3	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	1.57	1.1			4.8E+00
Nd-144	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Ni-63	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.9			5.0E-02
Sm-148	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Sr-90	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-1.20	1.0			3.0E-01
Co-60	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.51	1.0			3.0E-02
Cs-134	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Cs-137	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Eu-152	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Eu-154	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Gd-152	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
H-3	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.42	1.0			1.2E-02
Nd-144	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Ni-63	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-5.30	0.9			5.0E-03
Sm-148	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Sr-90	P	2	S	Lognormal-N	NUREG/CR-6697, Att. C	-4.61	0.4			1.0E-02
Co-60	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	0.7			2.0E-03
Cs-134	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Cs-137	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Eu-152	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Eu-154	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Gd-152	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
H-3	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.6	0.9			1.0E-02
Nd-144	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Ni-63	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.91	0.7			2.0E-02
Sr-90	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	0.5			2.0E-03
Sm-148	P	2	S	Lognormal-N	NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Co-60	P	2	NA	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-134	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Cs-137	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Eu-152	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Eu-154	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Gd-152	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
H-3	P	2	NA	Inactive	NUREG/CR-6697, Att. C	0	0.1			1.0E+00
Nd-144	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E-01
Ni-63	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Sm-148	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
Sr-90	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Co-60	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-134	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-137	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Eu-152	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Eu-154	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Gd-152	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
H-3	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Nd-144	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ni-63	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sm-148	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sr-90	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:
a P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
b 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
c D = deterministic, S = stochastic
d Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum
e Sm-148 not listed in RESRAD FGR 11 DCF file

ATTACHMENT 2

RESRAD BFM Uncertainty Reports

See TSD 14-010 Attachment 2 (16 files)

Name	Date modified	Type	Size
Co-60 BFM Sensitivity Analysis Report.pdf	9/6/2014 11:50 AM	Adobe Acrobat D...	72 KB
Co-60 BFM Sensitivity Summary Report.pdf	9/6/2014 11:50 AM	Adobe Acrobat D...	62 KB
Cs-134 BFM Sensitivity Analysis Report.pdf	9/6/2014 11:53 AM	Adobe Acrobat D...	71 KB
CS-134 BFM Sensitivity Summary Report.pdf	9/6/2014 11:52 AM	Adobe Acrobat D...	62 KB
Cs-137 BFM Sensitivity Analysis Report.pdf	9/6/2014 11:59 AM	Adobe Acrobat D...	72 KB
Cs-137 BFM Sensitivity Summary Report.pdf	9/6/2014 11:59 AM	Adobe Acrobat D...	62 KB
Eu-152 BFM Sensitivity Analysis Report.pdf	9/6/2014 12:14 PM	Adobe Acrobat D...	72 KB
Eu-152 BFM Sensitivity Summary Report.pdf	9/6/2014 12:13 PM	Adobe Acrobat D...	65 KB
Eu-154 BFM Sensitivity Analysis Report.pdf	9/6/2014 12:17 PM	Adobe Acrobat D...	72 KB
Eu-154 BFM Sensitivity Summary Report.pdf	9/6/2014 12:17 PM	Adobe Acrobat D...	62 KB
H-3 BFM Sensitivity Analysis Report.pdf	9/6/2014 12:20 PM	Adobe Acrobat D...	72 KB
H-3 BFM Sensitivity Summary Report.pdf	9/6/2014 12:19 PM	Adobe Acrobat D...	62 KB
Ni-63 BFM Sensitivity Analysis Report.pdf	9/6/2014 12:23 PM	Adobe Acrobat D...	72 KB
Ni-63 BFM Sensitivity Summary Report.pdf	9/6/2014 12:22 PM	Adobe Acrobat D...	62 KB
Sr-90 BFM Sensitivity Analysis Report.pdf	9/6/2014 12:26 PM	Adobe Acrobat D...	72 KB
Sr-90 BFM Sensitivity Summary Report.pdf	9/6/2014 12:25 PM	Adobe Acrobat D...	62 KB

ATTACHMENT 3

RESRAD Input Parameters for BFM Groundwater Exposure Factors

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)	NA	3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Co-60	P	1	D	223	TSD 14-004 (Reference 5)	5.46	2.53	0.001	0.999	235
Cs-134	P	1	D	45	TSD 14-004	6.1	2.33	0.001	0.999	446
Cs-137	P	1	D	45	TSD 14-004	6.1	2.33	0.001	0.999	446
Eu-152	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Eu-154	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Gd-152 (daughter for Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
H-3	P	1	D	0	TSD 14-004	-2.81	0.5	0.001	0.999	0.06
Nd-144 (daughter for Eu-152)	P	1	D	158	RESRADv.7.0 Default Nd not listed in NUREG/CR-6697	NA	NA	NA	NA	NA
Ni-63	P	1	D	62	TSD 14-004	6.05	1.46	0.001	0.999	424
Sm-148 (daughter Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Sr-90	P	1	D	2.3	TSD 14-004	3.45	2.12	0.001	0.999	32
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	No existing groundwater contamination	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	1	For user convenience: Allows use of t=0 in dose and concentration output reports to calculate unitized Exposure Factors	NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	64,500	Area of the 'Radiological Protected Area' on Zion Site	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Thickness of contaminated zone (m)	P	2	D	11.2	Contaminated Zone is the Basement fill depth where mixing occurs. Depth of fill mixing zone depends on Basement floor elevation. 11.3 m is used as nominal value based on difference between elevations of the water table (579') and Auxiliary Basement floor (542') which equals 11.2m. Note: this parameter has no effect on the calculated values for unitized Exposure Factors.	NR	NR	NR	NR	
Length parallel to aquifer flow (m)	P	2	D	287	Diameter of 64,500 m2 contaminated area. Note: not applicable to Basement Fill Model because Mass Balance groundwater model used.	NR	NR	NR	NR	
Does the initial contamination penetrate the water table?	NA	NA	NA	Yes	100% of the contamination assumed to be in the basement fill water mixing zone	NA	NA	NA	NA	
Contaminated fraction below water table	P[e]	3[e]	D	1	100% of the contamination assumed to be in the basement fill water mixing zone	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	3.6m	Difference between ground level elevation at 591' (179.6m) and equilibrium water level in basements at 579' (176m)[7]	NR	NR	NR	NR	NA
Density of cover (g/cm^3)	P	1	D	1.8	Site-specific average native sand and disturbed sand from REFERENCE 4 Table 5.5.	1.52	0.23	0.001	0.999	1.52
Cover erosion rate (m/y)	P,B	2	D	0.0015	Median NUREG/CR-6697 Att. C	5E-08	0.0007	0,005	0.2	0.0015

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Density of contaminated zone (g/cm^3)	P	1	D	1.8	Density identified as sensitive and positively correlated. The 75th Percentile of the NUREG/CR-6697 Att. C distribution is 1.67 g/cm^3. However, the site-specific value for sand density is 1.8 g/cm^3. Fill to be comprised of undetermined combination of clean concrete and native sand therefore higher value for site-specific sand used.	1.52	0.23	0.001	0.999	1.52
Contaminated zone erosion rate (m/y)	P,B	2	D	0.0015	Median NUREG/CR-6697 Att. C	5E-08	0.0007	0,005	0.2	0.0015
Contaminated zone total porosity	P	2	D	0.37	25th Percentile NUREG/CR-6697 Att. C.	0.425	0.0867	0.001	0.999	0.42
Contaminated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4 Table 5.4	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/y)	P	2	D	2880	Site-specific value from Reference 4, Table 5.9	786	17000	NA	NA	3649
Contaminated zone b parameter	P	2	D	2.89	Median NUREG/CR-6697, Att. C	1.06	0.66	0.5	30	2.89
Humidity in air (g/m^3)	P	3	D	7.2	Median NUREG/CR-6697 Att. C	1.98	0.334	0.001	0.999	7.2
Evapotranspiration coefficient	P	2	D	0.625	Median NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	D	4.2	Median NUREG/CR-6697 Att. C	1.445	0.2419	1.4	13	4.2
Precipitation (m/y)	P	2	D	0.83	Site-specific value from Reference 4, Table 5.12	NR	NR	NR	NR	
Irrigation (m/y)	B	3	D	0.19	NUREG-5512, Vol. 3, Table 6-18 (Illinois Average). Converted 0.52 L/m2/d to m/y.	NR	NR	NR	NR	
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.2	Site-specific value from Reference 4, Section 5.10	0.1	0.8	NR	NR	0.45
Watershed area for nearby stream or pond (m^2)	P	3	D	1.0E+06	RESRAD Default	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	1	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	1.51	0.16	0.001	0.999	1.51
Saturated zone total porosity	P	1	D	0.35	Site-specific average native sand and disturbed sand from Reference 4, Table 5.6	0.43	0.06	0.001	0.999	0.43
Saturated zone effective porosity	P	1	D	0.29	Site-specific average native sand and disturbed sand from Reference 4 Table 5.7	0.383	0.0610	0.001	0.999	0.383
Saturated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Saturated zone hydraulic conductivity (m/y)	P	1	D	1695	25th percentile Site-specific distribution from Reference 4, Table 5.9.	786	17000	NA	NA	3649
Saturated zone hydraulic gradient	P	2	D	0.0018	25th Percentile NUREG/CR-6697 Att. C distribution Site-specific average native sand and disturbed sand from Reference 4, Table 5.10 is greater at 0.0039 but lower value used	-0.511	1.77	0.00007	0.5	0.006
Saturated zone b parameter	P	2	D	NA saturated zone b not active in RESRAD because water table drop rate =0	RESRAD User Manual	NR	NR	NR	NR	NR
Water table drop rate (m/y)	P	3	D	0	Basement fill water assumed to fully supply well.	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	D	5.6	Basement depths vary. 5.2m selected as nominal value based on mid-point of 11.2m contaminated zone for Auxiliary Basement. Note: this parameter has no effect on the calculated values for unitized Exposure Factors.	6	10	30	NA	10

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Model: Non-dispersion (ND) or Mass-Balance (MB)	P	3	D	MB	MB model most applicable to assumption that well located in center of basement fill.	NR	NR	NR	NR	
Well pumping rate (m^3/y)	B,P	2	D	2250	Calculated according to method described in NUREG/CR-6697, Att. C Section 3.10 assuming 10,000m2 land area, Illinois specific irrigation rate and NUREG/CR-5512 vol. 3 livestock water consumption rate	NR	NR	NR	NR	NR
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	NA	NA	0	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone thickness (m)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil density (g/cm^3)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone total porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone effective porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone field capacity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone hydraulic conductivity (m/y)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil-specific b parameter	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Occupancy										
Inhalation rate (m^3/y)	M,B	3	D	8400	NUREG/CR-5512, Vol. 3^3 Table 6.29 (= 23 m^3/d x 365 d/y)	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P,B	2	D	2.35E-05	Median NUREG/CR-6697, Att. C	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	2.35E-05
Exposure duration	B	3	D	30	RESRAD User's Manual (Parameter not used in dose calculation)	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Indoor dust filtration factor	P,B	2	D	0.55	Median NUREG/CR-6697, Att. C	0.15	0.95			0.55
Shielding factor, external gamma	P	2	D	0.27	Median NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.27
Fraction of time spent indoors	B	3	D	0.649	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.124	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, non-leafy vegetables, grain consumption (kg/y)	M,B	2	D	112	NUREG/CR-5512, Vol. 3 Table 6.87 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	M,B	3	D	21.4	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk consumption (L/y)	M,B	2	D	233	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	M,B	3	D	65.1	NUREG/CR5512, Vol. 3 Table 6.87 (beef + poultry)	NR	NR	NR	NR	
Fish consumption (kg/y)	M,B	3	D	20.6	NUREG/CR-5512, Vol. 3 Table 6.87 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Other seafood consumption (kg/y)	M,B	3	D	0.9	RESRAD User's Manual Table D.2 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Soil ingestion rate (g/y)	M,B	2	D	18.3	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Drinking water intake (L/y)	M,B	2	D	478	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	B,P	3		NA						
Contamination fraction of livestock water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contamination fraction of aquatic food	B,P	2	D	NA	Assumption that pond is constructed that intercepts contaminated water not credible at Zion site	NR	NR	NR	NR	
Contamination fraction of plant food	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of meat	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of milk	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	28.3	NUREG/CR5512, Vol. 3 Table 6.87 (forage, grain and hay for beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	65.2	NUREG/CR5512, Vol. 3 Table 6.87 (forage + grain + hay)	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87 (beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD User's Manual, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	D	0.23	Median NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	D	3.1	75^{th} Percentile NUREG/CR-6697, Att. C	0.3	4.0			2.15
Drinking water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	B,P	3		NA						
Livestock water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	D	1.26	25^{th} Percentile NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.89	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.91	NUREG/CR-5512, Vol. 3 Table 6.87 (maximum of forage, grain and hay)	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.25	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.12	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	D	21.5	25th Percentile NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	D	0.70	75th Percentile NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef = 20d and poultry =1 day. Lowest value used)	NR	NR	NR	NR	
Fish	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Crustacea and mollusks	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	
Well water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	NA	NA	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	D	NA	NA	NR	NR	NR	NR	
C-14 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	NA	NA	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.62E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Nd-144[e]	M	3	D	7.04E-02	ICRP60	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Sm-148[e]	M	3	D	7.34E-02	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
Nd-144[e]	M	3	D	1.51E-04	ICRP60	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Sm-148[e]	M	3	D	1.58E-04	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Co-60	P	1	D	7.9E-02	Median NUREG/CR-6697, Att. C	-2.53	0.9			7.9E-02
Cs-134	P	1	D	4.0E-02	Median NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Cs-137	P	1	D	4.0E-02	Median NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Eu-152	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Eu-154	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Gd-152	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
H-3	P	1	D	4.8E+00	Median NUREG/CR-6697, Att. C	1.57	1.1			4.8E+00
Nd-144	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Ni-63	P	1	D	5.0E-02	Median NUREG/CR-6697, Att. C	-3.00	0.9			5.0E-02
Sm-148	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Sr-90	P	1	D	5.9E-01	75th Percentile NUREG/CR-6697, Att. C	-1.20	1.0			3.0E-01
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Co-60	P	2	D	0.058	75th Percentile NUREG/CR-6697, Att. C	-3.51	1.0			3.0E-02
Cs-134	P	2	D	0.065	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Cs-137	P	2	D	0.065	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Eu-152	P	2	D	0.004	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Eu-154	P	2	D	0.004	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Gd-152	P	2	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
H-3	P	2	D	0.012	Median NUREG/CR-6697, Att. C	-4.42	1.0			0.012
Nd-144	P	2	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0			2.0E-03
Ni-63	P	2	D	0.0092	75th Percentile NUREG/CR-6697, Att. C	-5.30	0.9			5.0E-03
Sm-148	P	2	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1			2.0E-03
Sr-90	P	2	D	0.013	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.4			1.0E-02
Milk Transfer Factors (pCi/L)/(pCi/d)										
Co-60	P	2	D	0.0032	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.7			2.0E-03
Cs-134	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Cs-137	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Eu-152	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Eu-154	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Gd-152	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
H-3	P	2	D	0.010	Median NUREG/CR-6697, Att. C	-4.6	0.9			1.0E-02
Nd-144	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Ni-63	P	2	D	0.032	75th Percentile NUREG/CR-6697, Att. C	-3.91	0.7			2.0E-02
Sm-148	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9			6.0E-05
Sr-90	P	2	D	0.0028	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.5			2.0E-03
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Co-60	P	2	NA	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-134	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Cs-137	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Eu-152	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Eu-154	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Gd-152	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
H-3	P	2	NA	Inactive	NUREG/CR-6697, Att. C	0	0.1			1.0E+00
Nd-144	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E-01
Ni-63	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			1.0E+02
Sm-148	P	2	NA	Inactive	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
Sr-90	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Co-60	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-134	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-137	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	

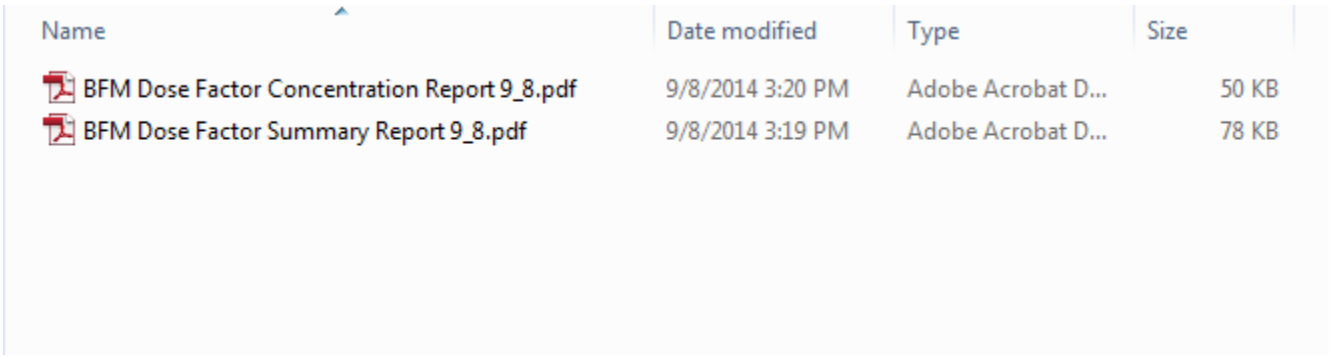
Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Eu-152	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Eu-154	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Gd-152	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
H-3	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Nd-144	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ni-63	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sm-148	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sr-90	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:
a P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
b 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
c D = deterministic, S = stochastic
d Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum
e Sm-148 and ND-144 not listed in RESRAD FGR 11 DCF file

ATTACHMENT 4

RESRAD Summary Report and Concentration Report for BFM Groundwater Exposure Factors

See TSD 14-010 Attachment 4 (2 files)



ATTACHMENT 5

Calculation of Groundwater Concentration Factors and Fill Concentration Factors from DUST-MS Modeling Results

ZionSolutions Excel Spreadsheet "Calculations in Support of TSD 14-010 Revision 2.xls"

CALCULATION OF GROUNDWATER AND FILL CONCENTRATION FACTORS FROM DUST-MS RESULTS

Reference:
ZionSolutions Technical Support Document 14-009, "Brookhaven National Laboratory Report (BNL), "Evaluation of Maximum Radionuclide Groundwater Concentrations for Basement Fill Model, Zion Station Restoration Project", December 2014

DUST-MS Assumed Basement Inventory:

	DUST-MS Inventory (pCi)
Auxiliary	6503
Containment	2759
Turbine	14679
Spent Fuel Pool/Transfer Canals	780
Crib House/Forebay	6940
Waste Water Treatment Facility	1124

Calculations:

Auxiliary Basement

	DUST-MS Results		GW Conc Factor	Fill Conc Factor
	pCi/L	pCi/g	pC/L per mCi	pCi/g per mCi
Co-60	2.60E-08	5.80E-09	4.00E-03	8.92E-04
Cs-134	6.89E-07	3.10E-08	1.06E-01	4.77E-03
Cs-137	2.47E-06	1.11E-07	3.80E-01	1.71E-02
Eu-152	1.07E-07	1.03E-08	1.65E-02	1.58E-03
Eu-154	8.38E-08	7.96E-09	1.29E-02	1.22E-03
H-3	9.10E-04	0.00E+00	1.40E+02	0.00E+00
Ni-63	1.90E-06	1.18E-07	2.92E-01	1.81E-02
Sr-90	1.96E-05	4.51E-08	3.01E+00	6.94E-03

Containment

	DUST RESULTS		GW Conc Factor	Fill Conc Factor
	pCi/L	pCi/g	pCi/L per mCi	pCi/g per mCi
Co-60	1.26E-06	2.81E-07	4.57E-01	1.02E-01
Cs-134	6.23E-06	2.80E-07	2.26E+00	1.01E-01
Cs-137	6.23E-06	2.80E-07	2.26E+00	1.01E-01

Eu-152	2.95E-06	2.81E-07	1.07E+00	1.02E-01
Eu-154	2.95E-06	2.81E-07	1.07E+00	1.02E-01
H-3	1.69E-03	0.00E+00	6.13E+02	0.00E+00
Ni-63	4.53E-06	2.81E-07	1.64E+00	1.02E-01
Sr-90	1.14E-04	2.62E-07	4.13E+01	9.50E-02

Spent Fuel Pool/Transfer Tunnels

	DUST RESULTS		**GW Conc Factor**	**Fill Conc Factor**
	pCi/L	**pCi/g**	**pC/L per mCi**	**pCi/g per mCi**
Co-60	4.25E-07	9.48E-08	5.45E-01	1.22E-01
Cs-134	1.13E-05	5.09E-07	1.45E+01	6.53E-01
Cs-137	4.07E-05	1.83E-06	5.22E+01	2.35E+00
Eu-152	1.75E-06	1.68E-07	2.24E+00	2.15E-01
Eu-154	1.37E-06	1.30E-07	1.76E+00	1.67E-01
H-3	1.49E-02	0.00E+00	1.91E+04	0.00E+00
Ni-63	3.13E-05	1.94E-06	4.01E+01	2.49E+00
Sr-90	3.21E-04	7.38E-07	4.12E+02	9.46E-01

Turbine

	DUST RESULTS		**GW Conc Factor**	**Fill Conc Factor**
	pCi/L	**pCi/g**	**pC/L per mCi**	**pCi/g per mCi**
Co-60	1.68E-06	3.74E-07	1.14E-01	2.55E-02
Cs-134	8.29E-06	3.73E-07	5.65E-01	2.54E-02
Cs-137	8.29E-06	3.73E-07	5.65E-01	2.54E-02
Eu-152	3.93E-06	3.74E-07	2.68E-01	2.55E-02
Eu-154	3.93E-06	3.74E-07	2.68E-01	2.55E-02
H-3	2.25E-03	0.00E+00	1.53E+02	0.00E+00
Ni-63	6.02E-06	3.73E-07	4.10E-01	2.54E-02
Sr-90	1.52E-04	3.49E-07	1.04E+01	2.38E-02

Crib House/Forebay

	DUST RESULTS		**GW Conc Factor**	**Fill Conc Factor**
	pCi/L	**pCi/g**	**pC/L per mCi**	**pCi/g per mCi**
Co-60	6.78E-07	1.51E-07	9.77E-02	2.18E-02
Cs-134	3.35E-06	1.51E-07	4.83E-01	2.18E-02

Cs-137	3.35E-06	1.51E-07	4.83E-01	2.18E-02
Eu-152	1.59E-06	1.51E-07	2.29E-01	2.18E-02
Eu-154	1.59E-06	1.51E-07	2.29E-01	2.18E-02
H-3	9.08E-04	0.00E+00	1.31E+02	0.00E+00
Ni-63	2.44E-06	1.51E-07	3.52E-01	2.18E-02
Sr-90	6.14E-05	1.41E-07	8.85E+00	2.03E-02

Waste Water Treatment Facility

	DUST RESULTS		**GW Conc Factor**	**Fill Conc Factor**
	pCi/L	**pCi/g**	**pC/L per mCi**	**pCi/g per mCi**
Co-60	2.34E-05	5.22E-06	2.08E+01	4.64E+00
Cs-134	1.16E-04	5.20E-06	1.03E+02	4.63E+00
Cs-137	1.16E-04	5.20E-06	1.03E+02	4.63E+00
Eu-152	5.43E-05	5.21E-06	4.83E+01	4.64E+00
Eu-154	5.48E-05	5.21E-06	4.88E+01	4.64E+00
H-3	3.13E-02	0.00E+00	2.78E+04	0.00E+00
Ni-63	8.40E-05	5.21E-06	7.47E+01	4.64E+00
Sr-90	2.12E-03	4.87E-06	1.89E+03	4.33E+00

ATTACHMENT 6

Calculation of BFM Basement Dose Factors

BFM Groundwater Dose Factors

	Auxiliary	Containment	Spent Fuel Pool/Transfer Canals	Turbine	Crib House/Forebay	WWTF
	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)
Co-60	1.00E-04	1.14E-02	0.00E+00	2.87E-03	2.45E-03	5.21E-01
Cs-134	9.27E-03	1.98E-01	0.00E+00	4.94E-02	4.22E-02	9.03E+00
Cs-137	2.64E-02	1.57E-01	0.00E+00	3.92E-02	3.35E-02	7.17E+00
Eu-152	5.96E-05	3.87E-03	0.00E+00	9.69E-04	8.29E-04	1.75E-01
Eu-154	6.77E-05	5.62E-03	0.00E+00	1.41E-03	1.20E-03	2.56E-01
H-3	6.21E-03	2.72E-02	0.00E+00	6.80E-03	5.80E-03	1.23E+00
Ni-63	2.86E-04	1.61E-03	0.00E+00	4.01E-04	3.44E-04	7.31E-02
Sr-90	3.29E-01	4.51E+00	0.00E+00	1.13E+00	9.66E-01	2.06E+02

BFM Drilling Spoils Dose Factors (Reference: TSD 14-021)

	Auxiliary	Containment(1)	Spent Fuel Pool/Transfer Canals	Turbine (1)	Crib (1) House/Forebay	WWTF (1)
	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)	(mrem/y per mCi)
Co-60	1.07E-02	2.97E-02	1.58E-01	9.58E-03	1.78E-02	2.26E-01
Cs-134	6.29E-03	1.72E-02	9.41E-02	5.54E-03	1.02E-02	1.31E-01
Cs-137	3.22E-03	7.27E-03	4.83E-02	2.35E-03	4.34E-03	5.57E-02
Eu-152	5.02E-03	1.38E-02	7.46E-02	4.45E-03	8.24E-03	1.05E-01
Eu-154	5.57E-03	1.46E-02	8.25E-02	4.73E-03	8.77E-03	1.12E-01
H-3	0.00E+00	0.00E+00	1.45E-09	0.00E+00	0.00E+00	0.00E+00
Ni-63	3.21E-08	5.57E-08	3.75E-07	1.84E-08	4.11E-08	4.13E-07
Sr-90	5.84E-05	1.30E-04	7.09E-04	4.31E-05	9.30E-05	9.69E-04

Basement Dose Factors

Basement Dose Factor = (BFM GW Dose Factors+Drilling Spoils Dose Factors)*Insignificant Contributor Dose Adjustment

	Auxiliary (mrem/y per mCi)	Containment (mrem/y per mCi)	Spent Fuel Pool/Transfer Canal (Note 1) (mrem/y per mCi)	Turbine (mrem/y per mCi)	Crib House/Forebay (Note 2) (mrem/y per mCi)	WWTF (mrem/y per mCi)
Co-60	1.11E-02	4.15E-02	1.63E-01	1.28E-02	2.42E-02	7.68E-01
Cs-134	1.60E-02	2.17E-01	2.17E-01	5.64E-02	6.27E-02	9.41E+00
Cs-137	3.04E-02	1.66E-01	1.66E-01	4.27E-02	4.52E-02	7.42E+00
Eu-152	5.22E-03	1.78E-02	7.66E-02	5.56E-03	1.08E-02	2.88E-01
Eu-154	5.79E-03	2.05E-02	8.47E-02	6.30E-03	1.19E-02	3.78E-01
H-3	6.37E-03	2.74E-02	2.74E-02	6.98E-03	6.93E-03	1.27E+00
Ni-63	2.94E-04	1.62E-03	1.62E-03	4.12E-04	4.11E-04	7.51E-02
Sr-90	3.38E-01	4.56E+00	4.56E+00	1.16E+00	1.15E+00	2.12E+02

Insignificant Contributor (IC) Dose Percentage[2]	IC Dose %
Containment Insignificant Contributor Dose Percentage	0.514%
Auxiliary Insignificant Dose Contributor Percentage	1.320%
All other Basments use the Auxilairy Insignificant Contributor Percentage	1.320%

Note 2: Reference TSD 14-019, Revision 1, Table 19

Multiplication Factor to provide additional margin and ensure conservatism	2

Insignificant Contributor (IC) Dose Adjustement Factor:	**IC Dose % multiplied by margin factor of 2**	**IC Dose Adjustment Factor**
Containment Insignificant Contributor Dose Percentage	1.028%	1.010
Auxiliary Insignificant Dose Contributor Percentage	2.640%	1.027
All other Basments use the Auxiliary Insignificant Contributor Percentage	2.640%	1.027

Note 1: Spent Fuel Pool/Transfer Canal Dose Factors set at the highest of either Containment or SFP/Transfer Canal

Note 2: The Crib House/Forebay Dose Factor was adjusted higher to account for a revision that lowered the void volume. The demolition plan for the Crib House was revised to leave the interior walls as opposed to removing all interior walls per the original demolition plan. This resulted in a decrease in the Crib House saturated zone fill mass in the Basement Fill Model with a corresponding increase in the pCi/g and pCi/L values calculated in TSD 14-009. The BFM and DS dose factors are both directly proportional to the pCi/g and pCi/L concentrations which are inversely proportional to the ratio of the Revised Volume to the Original Volume for the Crib House/Forebay combined. The revised Crib House/Forebay volume and the ratio of the Revised/Original volume is provided in TSD 14-013, Revision 1.
Ratio of Revised/Original Crib House/Forebay Volume = 8.60E-01

ATTACHMENT 7

RESRAD Input Parameters for Soil DCGL Uncertainty Analysis

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Co-60	P	1	D	1161	TSD 14-004 (Reference 5)	5.46	2.53	0.001	0.999	235
Cs-134	P	1	D	615	TSD 14-004	6.1	2.33	0.001	0.999	446
Cs-137	P	1	D	615	TSD 14-004	6.1	2.33	0.001	0.999	446
Ni-63	P	1	D	62	TSD 14-004	6.05	1.46	0.001	0.999	424
Sr-90	P	1	D	2.3	TSD 14-004	3.45	2.12	0.001	0.999	32
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	No existing groundwater contamination	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	0	RESRAD Default	NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	64,500	Area of the 'Security Protected Area' on Zion Site	NR	NR	NR	NR	
Thickness of contaminated zone (m)	P	2	D	0.15 or 1	Surface soil depth 0.15 Subsurface soil depth 1 m	NR	NR	NR	NR	
Length parallel to aquifer flow (m)	P	2	D	287	Diameter of 64,500 m2 contaminated area.	NR	NR	NR	NR	
Does the initial contamination penetrate the water table?	NA	NA	NA	No	No contamination in water table	NA	NA	NA	NA	
Contaminated fraction below water table	P[e]	3[e]	D	0	No contamination in water table	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	0	No Cover	NR	NR	NR	NR	NA
Density of cover (g/cm^3)	P	1	NA	NA	No Cover	NA	NA	NA	NA	NA
Cover erosion rate (m/y)	P,B	2	NA	Continuous Logarithmic	NUREG/CR-6697 Att. C Table 3.8-1	5E-08	0.0007	0.005	0.2	0.0015
Density of contaminated zone (g/cm^3)	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	1.51	0.16	0.001	0.999	1.51

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contaminated zone erosion rate (m/y)	P,B	2	S	Continuous Logarithmic	NUREG/CR-6697 Att. C Table 3.8-1	5E-08	0.0007	0.005	0.2	0.0015
Contaminated zone total porosity	P	2	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.43	0.06	0.001	0.999	0.43
Contaminated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/y)	P	2	S	Loguniform	Site-specific distribution from Reference 4, Table 5.9	786	17000	NA	NA	3649
Contaminated zone b parameter	P	2	S	Truncated Lognormal - N	NUREG 6697 distribution for site soil type - sand	-.0253	0.216	0.001	0.999	0.97
Humidity in air (g/m^3)	P	3	D	7.2	Median NUREG/CR-6697 Att. C	1.98	0.334	0.001	0.999	7.2
Evapotranspiration coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	S	Bounded Lognormal N	NUREG/CR-6697 Att. C	1.445	0.2419	1.4	13	4.2
Precipitation (m/y)	P	2	D	0.83	Site-specific value from Reference 4, Table 5.12	NR	NR	NR	NR	
Irrigation (m/y)	B	3	D	0.19	NUREG-5512, Vol. 3, Table 6-18 (Illinois Average) Converted 0.52 $L/m^2/y$ to m/y	NR	NR	NR	NR	0.56
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	S	Uniform	NUREG/CR-6697 Att. C	0.1	0.8	NR	NR	0.45
Watershed area for nearby stream or pond (m^2)	P	3	D	1.0E+06	RESRAD Default	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	1.51	0.16	0.001	0.999	1.51
Saturated zone total porosity	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.43	0.06	0.001	0.999	0.43
Saturated zone effective porosity	P	1	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.383	0.0610	0.001	0.999	0.383
Saturated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Saturated zone hydraulic conductivity (m/y)	P	1	S	Loguniform	Site-specific distribution from Reference 4, Table 5.9	786	17000	NA	NA	3649
Saturated zone hydraulic gradient	P	2	S	Bounded Lognormal - N	NUREG/CR-6697 Att. C	-5.11	1.77	0.00007	0.5	0.006

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Saturated zone b parameter	P	2	D	NA saturated zone b not active because water table drop rate =0	NUREG/CR-6697 Att. C	NR	NR	NR	NR	NR
Water table drop rate (m/y)	P	3	D	0	Well pumping rate assumed small relative to water table volume.	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	S	Triangular	NUREG/CR-6697	6	10	30		10
Model: Non-dispersion (ND) or Mass-Balance (MB)	P	3	D	ND	Non Dispersion Model used	NR	NR	NR	NR	
Well pumping rate (m^3/y)	B,P	2	S	2250	Calculated according to method described in NUREG/CR-6697, Att. C Section 3.10 assuming 10,000m2 land area, Illinois specific irrigation rate and NUREG/CR-5512 vol. 3 livestock water intake rate	NR	NR	NR	NR	NR
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	3	D	1	One unsaturated zone	NA	NA	NA	NA	
Unsat. zone thickness (m)	P	1	D	3.45 (for 0.15 m contaminated zone thickness) 2.6 (for 1.0 m contaminated zone thickness)	Distance from ground surface (591') to water table (579') = 3.6 Reference 4, Tables 5.1 and 5.2 For 0.15 m contaminated zone thickness unsaturated zone = 3.6 – 0.15 = 3.45 m For 1.0 m contaminated zone thickness unsaturated zone = 3.6 – 1.0 = 2.6 m	NA	NA	NA	NA	
Unsat. zone soil density (g/cm^3)	P	2	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	1.51	0.16	0.001	0.999	1.51
Unsat. zone total porosity	P	2	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.43	0.06	0.001	0.999	0.43
Unsat. zone effective porosity	P	2	S	Truncated Normal	NUREG 6697 distribution for site soil type - sand	0.383	0.0610	0.001	0.999	0.383
Unsat. zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Unsat. zone hydraulic conductivity (m/y)	P	2	S	Loguniform	Site-specific distribution from Reference 4, Table 5.9	786	17000	NA	NA	3649
Unsat. zone soil-specific b parameter	P	2	S	Truncated Lognormal - N	NUREG 6697 distribution for site soil type - sand	-.0253	0.216	0.001	0.999	0.97
Occupancy										
Inhalation rate (m^3/y)	M,B	3	D	8400	NUREG/CR-5512, Vol. 3[3] Table 6.29 (23 m^3/d x 365 d)	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P,B	2	S	Continuous Linear	NUREG/CR-6697, Att. C	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	2.35E-05
Exposure duration	B	3	D	30	RESRAD User's Manual (Parameter not used in dose calculation)	NR	NR	NR	NR	
Indoor dust filtration factor	P,B	2	S	Uniform	NUREG/CR-6697, Att. C	0.15	0.95			0.55
Shielding factor, external gamma	P	2	S	Bounded Lognormal - N	NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.2725
Fraction of time spent indoors	B	3	D	0.649	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.124	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, non-leafy vegetables, grain consumption (kg/y)	M,B	2	D	112	NUREG/CR-5512, Vol. 3 Table 6.87 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	M,B	3	D	21.4	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk consumption (L/y)	M,B	2	D	233	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	M,B	3	D	65.1	NUREG/CR5512, Vol. 3 Table 6.87 (beef + poultry)	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Fish consumption (kg/y)	M,B	3	D	20.6	NUREG/CR-5512, Vol. 3 Table 6.87 Note: Aquatic Pathway inactive	NR	NR	NR	NR	
Other seafood consumption (kg/y)	M,B	3	D	0.9	RESRAD User's Manual Table D.2 Note: Aquatic Pathway inactive	NR	NR	NR	NR	
Soil ingestion rate (g/y)	M,B	2	D	18.3	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Drinking water intake (L/y)	M,B	2	D	478	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	B,P	3		NA						
Contamination fraction of livestock water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of aquatic food	B,P	2	D	NA	Assumption that pond is constructed that intercepts contaminated water not credible at Zion site	NR	NR	NR	NR	
Contamination fraction of plant food	B,P	3	D	1	100% of food consumption assumed contaminated	NR	NR	NR	NR	
Contamination fraction of meat	B,P	3	D	1	100% of food consumption assumed contaminated	NR	NR	NR	NR	
Contamination fraction of milk	B,P	3	D	1	100% of food consumption assumed contaminated	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	28.3	NUREG/CR5512, Vol. 3 Table 6.87 (forage, grain and hay for beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	65.2	NUREG/CR5512, Vol. 3 Table 6.87 (forage + grain + hay)	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87 (beef cattle + poultry + layer hen)	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD User's Manual, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	S	Triangular	NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	S	Uniform	NUREG/CR-6697, Att. C	0.3	4.0			2.15
Drinking water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	B,P	3		NA						
Livestock water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	S	Truncated Lognormal - N	NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.90	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.90	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.246	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.123	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	S	Triangular	NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	D	Triangular	NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef = 20d and poultry =1 day. Lowest value used)	NR	NR	NR	NR	
Fish	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive	NR	NR	NR	NR	
Well water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	NA	NA	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
C-14 evasion layer thickness in soil (m)	P	2	D	NA	NA	NR	NR	NR	NR	
C-14 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	NA	NA	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.62E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Co-60	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-2.53	0.9			7.9E-02
Cs-134	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Cs-137	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Ni-63	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.9			5.0E-02
Sr-90	P	1	S	Lognormal - N	NUREG/CR-6697, Att. C	-1.20	1.0			3.0E-01

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Co-60	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.51	1.0			3.0E-02
Cs-134	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Cs-137	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Ni-63	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-5.30	0.9			5.0E-03
Sr-90	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.61	0.4			1.0E-02
Milk Transfer Factors (pCi/L)/(pCi/d)										
Co-60	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	0.7			2.0E-03
Cs-134	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Cs-137	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Ni-63	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-3.91	0.7			2.0E-02
Sr-90	P	2	S	Lognormal - N	NUREG/CR-6697, Att. C	-6.21	0.5			2.0E-03
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Co-60	P	2	NA	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-134	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Cs-137	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Ni-63	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Sr-90	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Co-60	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-134	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-137	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	

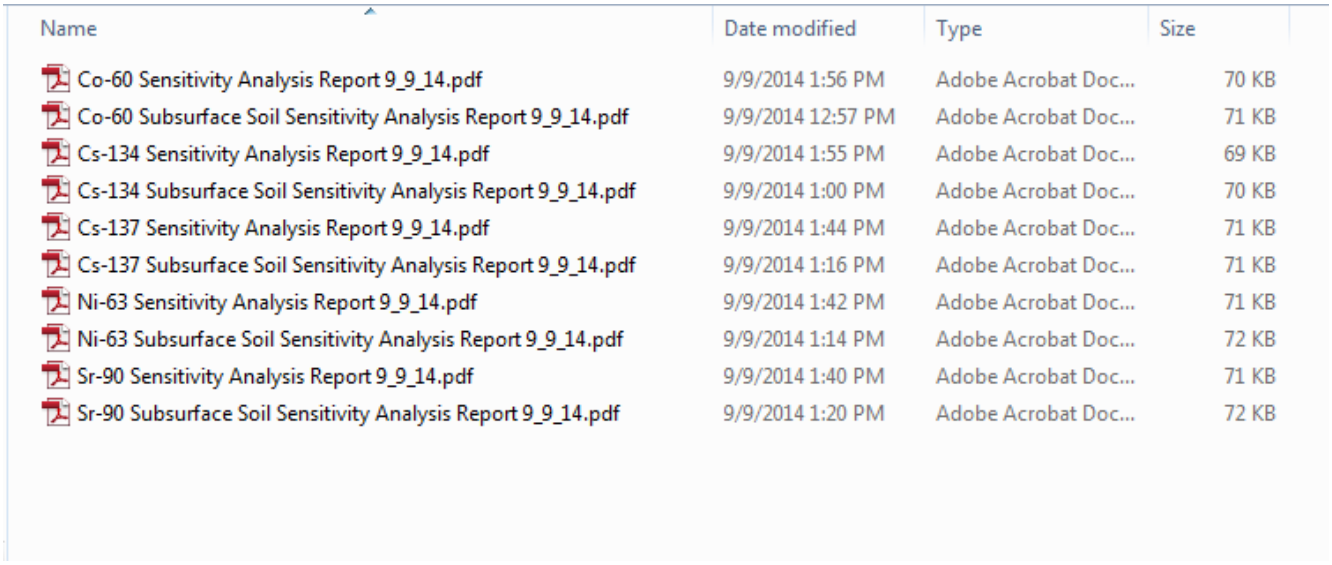
Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Ni-63	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sr-90	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:
a P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
b 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
c D = deterministic, S = stochastic
d Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum

ATTACHMENT 8

RESRAD Uncertainty Reports for Soil DCGLs

See TSD 14-010 Attachment 8 (10 files)



Name	Date modified	Type	Size
Co-60 Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:56 PM	Adobe Acrobat Doc...	70 KB
Co-60 Subsurface Soil Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 12:57 PM	Adobe Acrobat Doc...	71 KB
Cs-134 Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:55 PM	Adobe Acrobat Doc...	69 KB
Cs-134 Subsurface Soil Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:00 PM	Adobe Acrobat Doc...	70 KB
Cs-137 Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:44 PM	Adobe Acrobat Doc...	71 KB
Cs-137 Subsurface Soil Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:16 PM	Adobe Acrobat Doc...	71 KB
Ni-63 Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:42 PM	Adobe Acrobat Doc...	71 KB
Ni-63 Subsurface Soil Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:14 PM	Adobe Acrobat Doc...	72 KB
Sr-90 Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:40 PM	Adobe Acrobat Doc...	71 KB
Sr-90 Subsurface Soil Sensitivity Analysis Report 9_9_14.pdf	9/9/2014 1:20 PM	Adobe Acrobat Doc...	72 KB

ATTACHMENT 9

RESRAD Input Parameters for ZSRP Surface Soil and Subsurface Soil DCGL

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Co-60	P	1	D	1161	TSD 14-004, minimum site-specific sand value (see section 7)	5.46	2.53	0.001	0.999	235
Cs-134	P	1	D	615	TSD 14-004 minimum site-specific sand value (see section 7)	6.1	2.33	0.001	0.999	446
Cs-137	P	1	D	615	TSD 14-004 minimum site-specific sand value (see section 7)	6.1	2.33	0.001	0.999	446
Ni-63	P	1	D	331	TSD 14-004 maximum site-specific sand value (see section 7)	6.05	1.46	0.001	0.999	424
Sr-90	P	1	D	3.4	TSD 14-004 maximum site-specific sand value (see section 7)	3.45	2.12	0.001	0.999	32
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	No existing groundwater contamination	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	0	RESRAD Default	NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										
Area of contaminated zone (m^2)	P	2	D	64,500	Area of the 'Security Protected Area' on Zion Site	NR	NR	NR	NR	
Thickness of contaminated zone (m)	P	2	D	0.15 or 1.0	Surface Soil Depth = 0.15m Subsurface Soil Depth = 1m	NR	NR	NR	NR	
Length parallel to aquifer flow (m)	P	2	D	287	Diameter of 64,500 m2 contaminated area.	NR	NR	NR	NR	
Does the initial contamination penetrate the water table?	NA	NA	NA	No	No initial contamination in water table	NA	NA	NA	NA	
Contaminated fraction below water table	P[e]	3[e]	D	0	No initial contamination in water table	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	0	No Cover	NR	NR	NR	NR	NA

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Density of cover (g/cm^3)	P	1	NA	NA	No Cover	NA	NA	NA	NA	NA
Cover erosion rate (m/y)	P,B	2	NA	NA	No Cover	NA	NA	NA	NA	NA
Density of contaminated zone (g/cm^3)	P	1	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	1.51	0.16	0.001	0.999	1.51
Contaminated zone erosion rate (m/y)	P,B	2	D	0.0015	Median NUREG/CR-6697 Att. C	5E-08	0.0007	0.005	0.2	0.0015
Contaminated zone total porosity	P	2	D	0.35	Site-specific average native sand and disturbed sand from Reference 4, Table 5.6	0.43	0.06	0.001	0.999	0.43
Contaminated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/y)	P	2	D	2880	Site-specific value from Reference 4, Table 5.9	786	17000	NA	NA	3649
Contaminated zone b parameter	P	2	D	0.97	Median NUREG 6697 distribution for site soil type - sand	-0.0253	0.216	NA	NA	0.97
Humidity in air (g/m^3)	P	3	D	7.2	Median NUREG/CR-6697 Att. C	1.98	0.334	0.001	0.999	7.2
Evapotranspiration coefficient	P	2	D	0.625	Median NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	D	4.2	Median NUREG/CR-6697 Att. C	1.445	0.2419	1.4	13	4.2
Precipitation (m/y)	P	2	D	0.83	Site-specific value from Reference 4, Table 5.12	NR	NR	NR	NR	
Irrigation (m/y)	B	3	D	0.19	NUREG-5512, Vol. 3, Table 6-18 (Illinois Average)	NR	NR	NR	NR	
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.2	Site-specific value from Reference 4, Section 5.10	0.1	0.8	NR	NR	0.45
Watershed area for nearby stream or pond (m^2)	P	3	D	1.0E+06	RESRAD Default	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	2	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	1.51	0.16	0.001	0.999	1.52

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Saturated zone total porosity	P	1	D	0.35	Site-specific average native sand and disturbed sand from Reference 4, Table 5.6	0.43	0.0699	0.214	0.646	0.43
Saturated zone effective porosity	P	1	D	0.29	Site-specific average native sand and disturbed sand from Reference 4, Table 5.7	0.43	0.06	0.001	0.999	0.43
Saturated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Saturated zone hydraulic conductivity (m/y)	P	1	D	2880	Site-specific average from Reference 4, Table 5.9.	786	17000	NA	NA	3649
Saturated zone hydraulic gradient	P	2	D	0.0039	Site-specific average native sand and disturbed sand from Reference 4, Table 5.10	-5.11	1.77	0.00007	0.5	0.006
Saturated zone b parameter	P	2	D	NA saturated zone b not active because water table drop rate =0	NUREG/CR-6697, Att. A, Table 2	NR	NR	NR	NR	NR
Water table drop rate (m/y)	P	3	D	0	Well pumping rate assumed small relative to water table volume.	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	D	3.3	Mid-point of Shallow Aquifer Reference 4, Table 5.1	NA	NA	NA		NA
Model: Non-dispersion (ND) or Mass-Balance (MB)	P	3	D	ND	Non-dispersion model used	NR	NR	NR	NR	
Well pumping rate (m^3/y)	P	2	D	2250	Calculated according to method described in NUREG/CR-6697, Att. C Section 3.10 assuming 10,000m2 land area, Illinois specific irrigation rate and NUREG/CR-5512 vol. 3 livestock water intake rate	NR	NR	NR	NR	NR
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	3	D	1	One unsaturated zone	NA	NA	NA	NA	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Unsat. zone thickness (m)	P	1	D	3.45 (for 0.15 m contaminated zone thickness) 2.6 (for 1.0 m contaminated zone thickness)	Distance from ground surface (591') to water table (579') = 3.6 Reference 4, Tables 5.1 and 5.2 For 0.15 m contaminated zone thickness unsaturated zone = 3.6 – 0.15 = 3.45 m For 1.0 m contaminated zone thickness unsaturated zone = 3.6 – 1.0 = 2.6 m	NA	NA	NA	NA	
Unsat. zone soil density (g/cm^3)	P	2	D	1.8	Site-specific value from Reference 4, Table 5.5	NA	NA	NA	NA	
Unsat. zone total porosity	P	1	D	0.35	Site-specific average native sand and disturbed sand from Reference 4, Table 5.6	0.43	0.0699	0.214	0.646	0.43
Unsat. zone effective porosity	P	1	D	0.29	Site-specific average native sand and disturbed sand from Reference 4, Table 5.7	0.342	0.0705	0.124	0.56	0.342
Unsat. zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Unsat. zone hydraulic conductivity (m/y)	P	2	D	2880	Site-specific average from Reference 4, Table 5.9.	-0.511	1.77	0.00007	0.5	0.006
Unsat. zone soil-specific b parameter	P	2	D	0.97	Median NUREG/CR-6697 Att. C Sand soil type	-0.0253	0.216	0.501	1.90	0.97
Occupancy										
Inhalation rate (m^3/y)	M,B	3	D	8400	NUREG/CR-5512, Vol. 3[3] Table 6.29 (=23 m^3/d x 365 d/y)	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P,B	2	D	2.35E-05	Median NUREG/CR-6697, Att. C	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	2.35E-05
Exposure duration	B	3	D	30	RESRAD User's Manual (Parameter not used in dose calculation)	NR	NR	NR	NR	
Indoor dust filtration factor	P,B	2	D	0.55	Median NUREG/CR-6697, Att. C	0.15	0.95			0.55

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Shielding factor, external gamma	P	2	D	0.40	75th Percentile NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.272
Fraction of time spent indoors	B	3	D	0.649	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.124	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, non-leafy vegetables, grain consumption (kg/y)	M,B	2	D	112	NUREG/CR-5512, Vol. 3 Table 6.87 (other vegetables + fruits + grain)	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	M,B	3	D	21.4	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk consumption (L/y)	M,B	2	D	233	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	M,B	3	D	65.1	NUREG/CR5512, Vol. 3 Table 6.87 (beef + poultry)	NR	NR	NR	NR	
Fish consumption (kg/y)	M,B	3	D	20.6	NUREG/CR-5512, Vol. 3 Table 6.87 Note: Aquatic Pathway inactive	NR	NR	NR	NR	
Other seafood consumption (kg/y)	M,B	3	D	0.9	RESRAD User's Manual Table D.2 Note: Aquatic Pathway inactive	NR	NR	NR	NR	
Soil ingestion rate (g/y)	M,B	2	D	18.3	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Drinking water intake (L/y)	M,B	2	D	478	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	B,P	3		NA						
Contamination fraction of livestock water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contamination fraction of aquatic food	B,P	2	D	NA	Assumption that pond is constructed that intercepts contaminated water not credible at Zion site	NR	NR	NR	NR	
Contamination fraction of plant food	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of meat	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of milk	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	28.3	NUREG/CR5512, Vol. 3 Table 6.87 (forage, grain and hay for beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	65.2	NUREG/CR5512, Vol. 3 Table 6.87 (forage + grain + hay)	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87 (beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD User's Manual, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	D	0.15 for Surface Soil 0.23 for Subsurface Soil	25^{th} Percentile NUREG/CR-6697, Att. C Median NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	D	1.22	25^{th} Percentile NUREG/CR-6697, Att. C	0.3	4.0			2.15
Drinking water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	B,P	3		NA						
Livestock water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	D	1.75	Median NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.90	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.90	NUREG/CR-5512, Vol. 3 Table 6.87 (maximum of forage, grain and hay)	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.246	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.123	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	D	33	Median NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	D	0.58	Median NUREG/CR-6697, Att. C	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef = 20d and poultry =1 day. Lowest value used)	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Fish	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	RESRAD User's Manual Table D.6 Note: Aquatic pathway inactive in BFM	NR	NR	NR	NR	
Well water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD User's Manual Table D.6	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	NA	NA	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	D	NA	NA	NR	NR	NR	NR	
C-14 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	NA	NA	NR	NR	NR	NR	
Dose Conversion Factors (Inhalation mrem/pCi)										
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.62E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Dose Conversion Factors (Ingestion mrem/pCi)										
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Co-60	P	1	D	1.5E-01	75th Percentile NUREG/CR-6697, Att. C	-2.53	0.9			7.9E-02
Cs-134	P	1	D	7.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Cs-137	P	1	D	7.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.22	1.0			4.0E-02
Ni-63	P	1	D	9.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.9			5.0E-02
Sr-90	P	1	D	5.9E-01	75th Percentile NUREG/CR-6697, Att. C	-1.20	1.0			3.0E-01
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Co-60	P	2	D	5.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.51	1.0			3.0E-02
Cs-134	P	2	D	6.5E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Cs-137	P	2	D	6.5E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4			5.0E-02
Ni-63	P	2	D	5E-03	Median NUREG/CR-6697, Att. C	-5.30	0.9			5.0E-03
Sr-90	P	2	D	8E-03	Median NUREG/CR-6697, Att. C	-4.61	0.4			1.0E-02
Milk Transfer Factors (pCi/L)/(pCi/d)										
Co-60	P	2	D	2E-03	Median NUREG/CR-6697, Att. C	-6.21	0.7			2.0E-03
Cs-134	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Cs-137	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5			1.0E-02
Ni-63	P	2	D	3.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.91	0.7			2.0E-02

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Sr-90	P	2	D	2.7E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.5			2.0E-03
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Co-60	P	2	NA	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-134	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Cs-137	P	2	NA	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Ni-63	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Sr-90	P	2	NA	Inactive	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										
Co-60	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-134	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-137	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ni-63	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sr-90	P	3	NA	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:
a P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
b 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
c D = deterministic, S = stochastic
d Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum

ATTACHMENT 10

RESRAD Summary Reports for Soil DCGLs

See TSD 14-010 Attachment 10 (2 files)

ZION Surface Soil DCGL RESRAD Summary Report 5_26_16	5/26/2016 9:52 AM	Adobe Acrobat D...	69 KB
ZION Subsurface Soil DCGL RESRAD Summary Report 5_26_16	5/26/2016 9:54 AM	Adobe Acrobat D...	69 KB

ATTACHMENT 11

RESRAD Input Parameters for BFM Analysis of Initial Suite of Radionuclides

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Soil Concentrations										
Basic radiation dose limit (mrem/y)		3	D	25	10 CFR 20.1402	NR	NR	NR	NR	
Initial principal radionuclide (pCi/g)	P	2	D	1	Unit Value	NR	NR	NR	NR	
Distribution coefficients (contaminated, unsaturated, and saturated zones) (cm^3/g)										
Ac-227 (daughter of Cm-243 and Pu-239)	P	1	D	825	Median Value NUREG/CR-6697, Att. C[1]	6.72	3.22	0.001	0.999	825
Ag-108m	P	1	D	27	TSD 14-004 (Reference 5)	8.38	2.10	0.001	0.999	216
Am-241 (also daughter of Cm-245 and Pu-241)	P	1	D	177	TSD 14-004	7.28	3.15	0.001	0.999	1445
Am-243 (daughter for Cm-243)	P	1	D	177	TSD 14-004	7.28	3.15	0.001	0.999	1445
C-14	P	1	D	1.2	TSD 14-004	2.4	3.22	0.001	0.999	11
Cm-243	P	1	D	891	TSD 14-004	8.82	1.82	0.001	0.999	6761
Cm-244	P	1	D	891	TSD 14-004	8.82	1.82	0.001	0.999	6761
Co-60	P	1	D	223	TSD 14-004	5.46	2.53	0.001	0.999	235
Cs-137	P	1	D	45	TSD 14-004	6.1	2.33	0.001	0.999	446
Eu-152	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Eu-154	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Eu-155	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Fe-155	P	1	D	2857	TSD 14-004	5.34	2.67	0.001	0.999	209
Gd-152 (daughter for Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
H-3	P	1	D	0	TSD 14-004	NA	NA	NA	NA	NA
Nb-94	P	1	D	45	TSD 14-004	5.94	3.22	0.001	0.999	380
Nd-144 (daughter for Eu-152)	P	1	D	158	RESRADv.7.0 Default Nd not listed in NUREG/CR-6697	NA	NA	NA	NA	NA
Ni-59	P	1	D	62	TSD 14-004	6.05	1.46	0.001	0.999	424
Ni-63	P	1	D	62	TSD 14-004	6.05	1.46	0.001	0.999	424
Np-237 (also daughter for Am-241, Cm-245, and Pu-241)	P	1	D	1	TSD 14-004	2.84	2.25	0.001	0.999	17
Pa-231 (daughter for Cm-243 and Pu-239)	P	1	D	380	Median Value NUREG/CR-6697, Att. C	5.94	3.22	0.001	0.999	380
Pb-210 (daughter for Pu-238)	P	1	D	2392	Median Value NUREG/CR-6697, Att. C	7.78	2.76	0.001	0.999	2392
Pm-147	P	1	D	95	TSD 14-004	6.72	3.22	0.001	0.999	825
Po-210 (daughter Pu-238)	P	1	D	181	Median Value NUREG/CR-6697, Att. C	5.20	1.68	0.001	0.999	181

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pu-238	P	1	D	174	TSD 14-004	6.86	1.89	0.001	0.999	953
Pu-239 (also daughter for Cm-243)	P	1	D	174	TSD 14-004	6.86	1.89	0.001	0.999	953
Pu-240 (also daughter for Cm-244)	P	1	D	174	TSD 14-004	6.86	1.89	0.001	0.999	953
Pu-241	P	1	D	174	TSD 14-004	6.86	1.89	0.001	0.999	953
Ra-226 (daughter Pu-238)	P	1	D	3533	Median Value NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Ra-228 (daughter Cm-244 and Pu-240)	P	1	D	3533	Median Value NUREG/CR-6697, Att. C	8.17	1.7	0.001	0.999	3533
Sb-125	P	1	D	17	TSD 14-004	5.94	3.22	0.001	0.999	373
Sm-147 (daughter Pm-147)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Sm-148 (daughter Eu-152)	P	1	D	825	Median Value NUREG/CR-6697, Att. C	6.72	3.22	0.001	0.999	825
Sr-90	P	1	D	2.3	TSD 14-004	3.45	2.12	0.001	0.999	32
Te-125m (daughter Sb-125)	P	1	D	0	Median Value NUREG/CR-6697, Att. C	3.64	3.22	0.001	0.999	0
Tc-99	P	1	D	0	TSD 14-004	-0.67	3.16	0.001	0.999	0
Th-228 (daughter Cm-244 and Pu-240)	P	1	D	5884	Median Value NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-229 (daughter Am-241, Cm-245, Np-237, and Pu-241)	P	1	D	5884	Median Value NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-230 (daughter Cm-246 and Pu-238)	P	1	D	5884	Median Value NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
Th-232 (daughter Cm-244 and Pu-240)	P	1	D	5884	Median Value NUREG/CR-6697, Att. C	8.68	3.62	0.001	0.999	5884
U-233 (daughter fAm-241, Cm-245, Np-237, and Pu-241)	P	1	D	126	Median Value NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-234 (daughter Pu-238)	P	1	D	126	Median Value NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-235 (daughter Cm-243 and Pu-239)	P	1	D	126	Median Value NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
U-236 (daughter Cm-244 and Pu-240)	P	1	D	126	Median Value NUREG/CR-6697, Att. C	4.84	3.13	0.001	0.999	126
Initial concentration of radionuclides present in groundwater (pCi/l)	P	3	D	0	No existing groundwater contamination	NR	NR	NR	NR	
Calculation Times										
Time since placement of material (y)	P	3	D	1	Results in maximum concentration to be at t=0	NR	NR	NR	NR	
Time for calculations (y)	P	3	D	0, 1, 3, 10, 30, 100, 300, 1000	RESRAD Default	NR	NR	NR	NR	
Contaminated Zone										

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Area of contaminated zone (m^2)	P	2	D	64,500	Area of the 'Radiological Protected Area' on Zion Site	NR	NR	NR	NR	
Thickness of contaminated zone (m)	P	2	D	3	Depth of fill mixing zone depends on basement. 3m is used as nominal value based on assumed well screen depth. Note: this parameter has no effect on the calculated values for unitized Exposure Factors.	NR	NR	NR	NR	
Length parallel to aquifer flow (m)	P	2	D	287	Diameter of 64,500 m2 contaminated area. Note: not applicable to Basement Fill Model because Mass Balance groundwater model used.	NR	NR	NR	NR	
Does the initial contamination penetrate the water table?	NA	NA	NA	Yes	100% of the contamination assumed to be in the basement fill water mixing zone	NA	NA	NA	NA	
Contaminated fraction below water table	P[e]	3[e]	D	1	100% of the contamination assumed to be in the basement fill water mixing zone	NR	NR	NR	NR	
Cover and Contaminated Zone Hydrological Data										
Cover depth (m)	P	2	D	3.6m	Difference between ground level elevation at 591ft (179.6m) and equilibrium water level in basements at 579ft (176m)	NR	NR	NR	NR	
Density of cover material	P	2	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	NR	NR	NR	NR	
Cover erosion rate	P,B	2	D	0.0015	Median NUREG/CR-6697 Att. C	5E-08	0,0007	0,005	.2	0.0015
Density of contaminated zone (g/cm^3)	P	1	D	1.56	Median NUREG/CR-6697 Att. C	1.5635	0.2385	0.827	2.3	1.56
Contaminated zone erosion rate m/y)	P,B	2	D	0.0015	Median NUREG/CR-6697 Att. C	5E-08	0,0007	0,005	.2	0.0015

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Contaminated zone total porosity	P	2	D	0.42	Median NUREG/CR 6697	0.425	0.0867	0.001	0.999	0.42
Contaminated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	
Contaminated zone hydraulic conductivity (m/y)	P	2	D	2880	Site-specific value from Reference 4, Table 5.9	786	17000	NA	NA	3649
Contaminated zone b parameter	P	2	D	0.97	Median NUREG 6697 distribution for site soil type - sand	-.0253	0.216	0.501	1.90	0.97
Humidity in air (g/m^3)	P	3	D	7.2	Median NUREG/CR-6697 Att. C	1.98	0.334	0.001	0.999	7.2
Evapotranspiration coefficient	P	2	D	0.625	25^{th} Percentile NUREG/CR-6697 Att. C	0.5	0.75	NR	NR	0.625
Average annual wind speed (m/s)	P	2	D	4.2	Median NUREG/CR-6697 Att. C	1.445	0.2419	1.4	13	4.2
Precipitation (m/y)	P	2	D	0.83	Site-specific value from Reference 4, Table 5.12	NR	NR	NR	NR	
Irrigation (m/y)	B	3	D	0.19	NUREG-5512, Volume 3, Table 6-18 (Illinois Average) Converted 0.52 $L/m^2/y$ to m/y	0.36	0.76	NR	NR	0.56
Irrigation mode	B	3	D	Overhead	Overhead irrigation is common practice in U. S.	NR	NR	NR	NR	
Runoff coefficient	P	2	D	0.2	Site-specific value from Reference 4, Section 5.10	0.1	0.8	NR	NR	0.45
Watershed area for nearby stream or pond (m^2)	P	3	D	1.00E+06	RESRAD Default	NR	NR	NR	NR	
Accuracy for water/soil computations	-	3	D	1.00E-03	RESRAD Default	NR	NR	NR	NR	
Saturated Zone Hydrological Data										
Density of saturated zone (g/cm^3)	P	2	D	1.8	Site-specific average native sand and disturbed sand from Reference 4, Table 5.5.	NR	NR	NR	NR	
Saturated zone total porosity	P	1	D	0.35	Site-specific average native sand and disturbed sand from Reference 4, Table 5.6.	0.43	0.0699	0.214	0.646	0.43
Saturated zone effective porosity	P	1	D	0.27	Site-specific average native sand and disturbed sand from Reference 4, Table 5.7.	0.342	0.0705	0.124	0.56	0.342
Saturated zone field capacity	P	3	D	0.066	Site-specific value from Reference 4, Table 5.4	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Saturated zone hydraulic conductivity (m/y)	P	1	D	2880	Site-specific average from Reference 4, Table 5.9.	786	17000	NA	NA	3649
Saturated zone hydraulic gradient	P	2	D	0.0039	Site-specific average native sand and disturbed sand from Reference 4, Table 5.10.	NR	NR	NR	NR	
Saturated zone b parameter	P	2	D	NA saturated zone b not active in RESRAD because water table drop rate =0	NUREG/CR-6697	-.0253	0.216	0.501	1.90	0.97
Water table drop rate (m/y)	P	3	D	0	Basement fill water assumed to fully supply well.	NR	NR	NR	NR	
Well pump intake depth (m below water table)	P	2	D	1.5	Basement depths vary. 1.5m selected as nominal value based on mid-point of 3m well screen depth. Note: this parameter has no effect on the calculated values for unitized Exposure Factors.	NA	NA	NA		NA
Model: Nondispersion (ND) or Mass-Balance (MB)	P	3	D	MB	MB model most applicable to assumption that well located in center of basement fill.	NR	NR	NR	NR	
Well pumping rate (m^3/y)	P	2	S	2250	Calculated according to method described in NUREG/CR-6697, Att. C section 3.10 assuming 10,000m2 farming land area, Illinois average irrigation rate, and NUREG/CR-5512 Vol. 3 livestock water consumption rate.	NA	NA			NA
Unsaturated Zone Hydrological Data										
Number of unsaturated zone strata	P	NA	NA	0	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone thickness (m)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil density (g/cm^3)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone total porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Unsat. zone effective porosity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone field capacity	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone hydraulic conductivity (m/y)	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Unsat. zone soil-specific b parameter	P	NA	NA	NA	No unsaturated zone in Basement Fill Model	NA	NA	NA	NA	
Occupancy										
Inhalation rate (m^3/y)	M,B	3	D	8400	NUREG/CR-5512, Vol. 3[3] Table 6.29 (=23 m^3/d x 365 d)	NR	NR	NR	NR	
Mass loading for inhalation (g/m^3)	P,B	2	D	2.35E-05	NUREG/CR-6697, Att. C	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	See NUREG-6697 Table 4.6-1	2.35E-05
Exposure duration	B	3	D	30	RESRAD User's Manual parameter value not used in dose calculation	NR	NR	NR	NR	
Indoor dust filtration factor	P,B	2	D	0.55	Median NUREG/CR-6697, Att. C	0.15	0.95			0.55
Shielding factor, external gamma	P	2	D	0.27	Median NUREG/CR-6697, Att. C	-1.3	0.59	0.044	1	0.2725
Fraction of time spent indoors	B	3	D	0.649	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Fraction of time spent outdoors (on site)	B	3	D	0.124	NUREG/CR-5512, Vol. 3 Table 6.87 (outdoors + gardening)	NR	NR	NR	NR	
Shape factor flag, external gamma	P	3	D	Circular	Circular contaminated zone assumed for modeling purposes	NR	NR	NR	NR	
Ingestion, Dietary										
Fruits, non-leafyvegetables, grain consumption (kg/y)	M,B	2	D	112	NUREG/CR-5512, Vol. 3 (other vegetables + fruits + grain) Table 6.87	NR	NR	NR	NR	
Leafy vegetable consumption (kg/y)	M,B	3	D	21.4	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk consumption (L/y)	M,B	2	D	233	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Meat and poultry consumption (kg/y)	M,B	3	D	65.1	NUREG/CR5512, Vol. 3 (beef + poultry)	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Fish consumption (kg/y)	M,B	3	D	20.6	NUREG/CR-5512, Vol. 3 Table 6.87 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Other seafood consumption (kg/y)	M,B	3	D	0.9	RESRAD User's Manual Table D.2 Note: Aquatic Pathway inactive in BFM	NR	NR	NR	NR	
Soil ingestion rate (g/y)	M,B	2	D	18.3	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Drinking water intake (L/y)	M,B	2	D	478	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Contamination fraction of drinking water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of household water (if used)	B,P	3		NA						
Contamination fraction of livestock water	B,P	3	D	1	All water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of irrigation water	B,P	3	D	1	Alll water assumed contaminated	NR	NR	NR	NR	
Contamination fraction of aquatic food	B,P	2	D	NA	Assumption that pond is constructed that intercepts contaminated water not credible at Zion site	NR	NR	NR	NR	
Contamination fraction of plant food	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of meat	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Contamination fraction of milk	B,P	3	D	1	100% of food consumption rate from onsite source	NR	NR	NR	NR	
Ingestion, Non-Dietary										
Livestock fodder intake for meat (kg/day)	M	3	D	28.3	NUREG/CR5512, Vol. 3 Table 6.87 (forage, grain and hay for beef cattle + poultry + layer hen)	NR	NR	NR	NR	
Livestock fodder intake for milk (kg/day)	M	3	D	65.2	NUREG/CR5512, Vol. 3 Table 6.87, forage + grain + hay	NR	NR	NR	NR	
Livestock water intake for meat (L/day)	M	3	D	50.6	NUREG/CR5512, Vol. 3 Table 6.87, beef cattle + poultry + layer hen	NR	NR	NR	NR	
Livestock water intake for milk (L/day)	M	3	D	60	NUREG/CR5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Livestock soil intake (kg/day)	M	3	D	0.5	RESRAD User's Manual, Appendix L	NR	NR	NR	NR	
Mass loading for foliar deposition (g/m^3)	P	3	D	4.00E-04	NUREG/CR-5512, Vol. 3 Table 6.87, gardening	NR	NR	NR	NR	
Depth of soil mixing layer (m)	P	2	D	0.23	Median NUREG/CR-6697, Att. C	0	0.15	0.6		0.23
Depth of roots (m)	P	1	D	3.1	75th Percentile NUREG/CR-6697, Att. C	0.3	4.0			2.15
Drinking water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Household water fraction from ground water (if used)	B,P	3		NA	Not used					
Livestock water fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Irrigation fraction from ground water	B,P	3	D	1	All water assumed to be supplied from groundwater	NR	NR	NR	NR	
Wet weight crop yield for Non-Leafy (kg/m^2)	P	2	D	1.26	25th Percentile NUREG/CR-6697, Att. C	0.56	0.48	0.001	0.999	1.75
Wet weight crop yield for Leafy (kg/m^2)	P	3	D	2.89	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet weight crop yield for Fodder (kg/m^2)	P	3	D	1.91	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Non-Leafy (y)	P	3	D	0.25	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Leafy (y)	P	3	D	0.12	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Growing Season for Fodder (y)	P	3	D	0.082	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Non-Leafy	P	3	D	0.1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Leafy	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Translocation Factor for Fodder	P	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Weathering Removal Constant for Vegetation (1/y)	P	2	D	21.5	25th Percentile NUREG/CR-6697, Att. C	5.1	18	84		33
Wet Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Wet Foliar Interception Fraction for Leafy	P	2	D	0.70	75th Percentile	0.06	0.67	0.95		0.58
Wet Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Non-Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Dry Foliar Interception Fraction for Leafy	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Dry Foliar Interception Fraction for Fodder	P	3	D	0.35	NUREG/CR-5512, Vol. 3	NR	NR	NR	NR	
Storage times of contaminated foodstuffs (days):										
Fruits, non-leafy vegetables, and grain	B	3	D	14	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Leafy vegetables	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Milk	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87	NR	NR	NR	NR	
Meat and poultry	B	3	D	1	NUREG/CR-5512, Vol. 3 Table 6.87 (holdup period for beef = 20d and poultry =1 day. Lowest value used)	NR	NR	NR	NR	
Fish	B	3	D	7	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Crustacea and mollusks	B	3	D	7	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Well water	B	3	D	1	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Surface water	B	3	D	1	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Livestock fodder	B	3	D	45	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Special Radionuclides (C-14)										
C-12 concentration in water (g/cm^3)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 concentration in contaminated soil (g/g)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from soil	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of vegetation carbon from air	P	3	D	NA	NA	NR	NR	NR	NR	
C-14 evasion layer thickness in soil (m)	P	2	D	NA	NA					
C-14 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
C-12 evasion flux rate from soil (1/sec)	P	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in beef cattle feed	B	3	D	NA	NA	NR	NR	NR	NR	
Fraction of grain in milk cow feed	B	3	D	NA	NA	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Dose Conversion Factors (Inhalation mrem/pCi)										
Ac-227	M	3	D	6.70E+00	FGR11	NR	NR	NR	NR	
Am-241	M	3	D	4.44E-01	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	4.40E-01	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	3.07E-01	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.48E-01	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	4.55E-01	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	4.51E-01	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.19E-04	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	4.62E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	3.19E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	2.21E-04	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	2.86E-04	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	2.43E-01	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	1.74E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	4.14E-04	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.70E-06	FGR11	NR	NR	NR	NR	
Nd-144[e]	M	3	D	7.04E-02	ICRP60	NR	NR	NR	NR	
Ni-63	M	3	D	6.29E-06	FGR11	NR	NR	NR	NR	
Np-237	M	3	D	5.40E-01	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.28E+00	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	1.36E-02	FGR11	NR	NR	NR	NR	
Po-210	M	3	D	9.40E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.92E-01	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	4.29E-01	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	8.25E-03	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	4.11E-01	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	8.58E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	4.77E-03	FGR11	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Sm-148[e]	M	3	D	7.34E-02	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.30E-03	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	8.32E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.42E-01	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	2.15E+00	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	3.26E-01	FGR11	NR	NR	NR	NR	
Th232	M	3	D	1.64e+00	FGR11	NR	NR	NR	NR	
U-233	M	3	D	1.35E-01	FGR11	NR	NR	NR	NR	
U-234	M	3	D	1.32E-01	FGR11	NR	NR	NR	NR	
U-235	M	3	D	1.23E-01	FGR11	NR	NR	NR	NR	
U-236	M	3	D	1.25E-01	FGR11	NR	NR	NR	NR	
U-238	M	3	D	1.18E-01	FGR11	NR	NR	NR	NR	
Dose Conversion Factors (Ingestion mrem/pCi)										
Ac-227	M	3	D	1.41E-02	FGR11	NR	NR	NR	NR	
Am-241	M	3	D	3.64E-03	FGR11	NR	NR	NR	NR	
Am-243	M	3	D	3.62E-03	FGR11	NR	NR	NR	NR	
C-14	M	3	D	2.09E-06	FGR11	NR	NR	NR	NR	
Cm-243	M	3	D	2.51E-03	FGR11	NR	NR	NR	NR	
Cm-244	M	3	D	2.02E-03	FGR11	NR	NR	NR	NR	
Cm-245	M	3	D	3.74E-03	FGR11	NR	NR	NR	NR	
Cm-246	M	3	D	3.70E-03	FGR11	NR	NR	NR	NR	
Co-60	M	3	D	2.69E-05	FGR11	NR	NR	NR	NR	
Cs-134	M	3	D	7.33E-05	FGR11	NR	NR	NR	NR	
Cs-137	M	3	D	5.00E-05	FGR11	NR	NR	NR	NR	
Eu-152	M	3	D	6.48E-06	FGR11	NR	NR	NR	NR	
Eu-154	M	3	D	9.55E-06	FGR11	NR	NR	NR	NR	
Gd-152	M	3	D	1.61E-04	FGR11	NR	NR	NR	NR	
H-3	M	3	D	6.40E-08	FGR11	NR	NR	NR	NR	
I-129	M	3	D	2.76E-04	FGR11	NR	NR	NR	NR	
Nb-94	M	3	D	7.14E-06	FGR11	NR	NR	NR	NR	
Ni-59	M	3	D	2.10E-07	FGR11	NR	NR	NR	NR	
Ni-63	M	3	D	5.77E-07	FGR11	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Nd-144	M	3	D	1.51E-04	ICRP60	NR	NR	NR	NR	
Np-237	M	3	D	4.44E-03	FGR11	NR	NR	NR	NR	
Pa-231	M	3	D	1.06E-02	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	5.37E-03	FGR11	NR	NR	NR	NR	
Pb-210	M	3	D	1.90E-03	FGR11	NR	NR	NR	NR	
Pu-238	M	3	D	3.20E-03	FGR11	NR	NR	NR	NR	
Pu-239	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-240	M	3	D	3.54E-03	FGR11	NR	NR	NR	NR	
Pu-241	M	3	D	6.84E-05	FGR11	NR	NR	NR	NR	
Pu-242	M	3	D	3.36E-03	FGR11	NR	NR	NR	NR	
Ra-226	M	3	D	1.32E-03	FGR11	NR	NR	NR	NR	
Ra-228	M	3	D	1.44E-03	FGR11	NR	NR	NR	NR	
Sm-148	M	3	D	1.58E-04	ICRP60	NR	NR	NR	NR	
Sr-90	M	3	D	1.42E-04	FGR11	NR	NR	NR	NR	
Tc-99	M	3	D	1.46E-06	FGR11	NR	NR	NR	NR	
Th-228	M	3	D	3.96E-04	FGR11	NR	NR	NR	NR	
Th-229	M	3	D	3.53E-03	FGR11	NR	NR	NR	NR	
Th-230	M	3	D	5.48E-04	FGR11	NR	NR	NR	NR	
Th-232	M	3	D	2.73E-03	FGR11	NR	NR	NR	NR	
U-233	M	3	D	2.89E-04	FGR11	NR	NR	NR	NR	
U-234	M	3	D	2.83E-04	FGR11	NR	NR	NR	NR	
U-235	M	3	D	2.66E-04	FGR11	NR	NR	NR	NR	
U-236	M	3	D	2.69E-04	FGR11	NR	NR	NR	NR	
U-238	M	3	D	2.55E-04	FGR11	NR	NR	NR	NR	
Plant Transfer Factors (pCi/g plant)/(pCi/g soil)										
Ac-227	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	1.1	0.001	0.999	1.0E-03
Ag-108m	P	1	D	7.4E-03	75th Percentile NUREG/CR-6697, Att. C	-5.52	0.9	0.001	0.999	4.0E-03
Am-241	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	1.1	0.001	0.999	1.0E-03
Am-243	P	1	D	1.8E-03	75th Percentile[f] NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
C-14	P	1	D	1.28E+0	75th Percentile NUREG/CR-6697, Att. C	-0.36	0.9	0.001	0.999	7.0E-01

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Cm-243	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Cm-244	P	1	D	1.8E-03	N75th Percentile UREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Co-60	P	1	D	1.4E-01	75th Percentile NUREG/CR-6697, Att. C	-2.53	0.9	0.001	0.999	7.9E-02
Cs-134	P	1	D	7.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.22	1.0	0.001	0.999	4.0E-02
Cs-137	P	1	D	7.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.22	1.0	0.001	0.999	4.0E-02
Eu-152	P	1	D	4E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Eu-154	P	1	D	4E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Eu-155	P	1	D	4E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Fe-55	P	1	D	1.9E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Gd-152	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
H-3	P	1	D	9.92E+0	75th Percentile NUREG/CR-6697, Att. C	1.57	1.1	0.001	0.999	4.8E+00
Nb-94	P	1	D	2.1E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Nd-144	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Ni-59	P	1	D	9.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.9	0.001	0.999	5.0E-02
Ni-63	P	1	D	9.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.9	0.001	0.999	5.0E-02
Np-237	P	1	D	2.0E-02	Median NUREG/CR-6697, Att. C	-3.91	0.9	0.001	0.999	2.0E-02
Pa-231	P	1	D	1.0E-02	Median NUREG/CR-6697, Att. C	-4.61	1.1	0.001	0.999	1.0E-02
Pb-210	P	1	D	4.0E-03	Median NUREG/CR-6697, Att. C	-5.52	0.9	0.001	0.999	4.0E-03
Pm-147	P	1	D	4.2E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Po-210	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.90	0.9	0.001	0.999	1.0E-03
Pu-238	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pu-239	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-240	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Pu-241	P	1	D	1.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Ra-226	P	1	D	4.0E-02	Median NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Ra-228	P	1	D	4.0E-02	Median NUREG/CR-6697, Att. C	-3.22	0.9	0.001	0.999	4.0E-02
Sb-125	P	1	D	1.9E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	1.0	0.001	0.999	1.0E-02
Sm-147	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Sm-148	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.1	0.001	0.999	2.0E-03
Sr-90	P	1	D	5.9E-01	75th Percentile NUREG/CR-6697, Att. C	-1.20	1.0	0.001	0.999	3.0E-01
Tc-99	P	1	D	9.11E+00	75th Percentile NUREG/CR-6697, Att. C	1.61	0.9	0.001	0.999	5.0E+00
Te-125m	P	1	D	1.0E-01	Median NUREG/CR-6697, Att. C	-2.30	1.0	0.001	0.999	1.0E-01
Th-228	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-229	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-230	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Th-232	P	1	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
U-233	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-234	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-235	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
U-236	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	0.9	0.001	0.999	2.0E-03
Meat Transfer Factors (pCi/kg)/(pCi/d)										
Ac-227	P	2	D	2.0E-05	Median NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Ag-108m	P	2	D	3.2E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.7	0.001	0.999	2.0E-03

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Am-241	P	2	D	5.7E-05	75th Percentile NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05
Am-243	P	2	D	5.7E-05	75th Percentile NUREG/CR-6697, Att. C	-9.90	0.2	0.001	0.999	5.0E-05
C-14	P	2	D	6.0E-02	75th Percentile NUREG/CR-6697, Att. C	-3.47	1.0	0.001	0.999	3.1E-02
Cm-243	P	2	D	4.0E-05	75th Percentile NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Cm-244	P	2	D	4.0E-05	75th Percentile NUREG/CR-6697, Att. C	-10.82	1.0	0.001	0.999	2.0E-05
Co-60	P	2	D	5.8E-02	75th Percentile NUREG/CR-6697, Att. C	-3.51	1.0	0.001	0.999	3.0E-02
Cs-134	P	2	D	6.5E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4	0.001	0.999	5.0E-02
Cs-137	P	2	D	6.5E-02	75th Percentile NUREG/CR-6697, Att. C	-3.00	0.4	0.001	0.999	5.0E-02
Eu-152	P	2	D	4.0E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Eu-154	P	2	D	4.0E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Eu-155	P	2	D	4.0E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Fe-55	P	2	D	3.9E-02	75th Percentile NUREG/CR-6697, Att. C	-3.51	0.4	0.001	0.999	3.0E-02
Gd-152	P	2	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
H-3	P	2	D	2.3E-02	75th Percentile NUREG/CR-6697, Att. C	-4.42	1.0	0.001	0.999	1.2E-02
Nb-94	P	2	D	1.8E-06	75th Percentile NUREG/CR-6697, Att. C	-13.82	0.9	0.001	0.999	1.0E-06
Nd-144	P	2	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Ni-59	P	2	D	9.2E-03	75th Percentile NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Ni-63	P	2	D	9.2E-03	75th Percentile NUREG/CR-6697, Att. C	-5.30	0.9	0.001	0.999	5.0E-03
Np-237	P	2	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Pa-231	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	1.0	0.001	0.999	5.0E-06
Pb-210	P	2	D	8.0E-04	Median NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pm-147	P	2	D	4.0E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Po-210	P	2	D	5.0E-03	Median NUREG/CR-6697, Att. C	-5.30	0.7	0.001	0.999	5.0E-03
Pu-238	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-239	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-240	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Pu-241	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.21	0.2	0.001	0.999	1.0E-04
Ra-226	P	2	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Ra-228	P	2	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Sb-125	P	2	D	1.85E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.9	0.001	0.999	1.0E-03
Sm-147	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Sm-148	P	1	D	2.0E-03	Median NUREG/CR-6697, Att. C	-6.21	1.0	0.001	0.999	2.0E-03
Sr-90	P	2	D	1.3E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.4	0.001	0.999	1.0E-02
Tc-99	P	2	D	1.6E-04	75th Percentile NUREG/CR-6697, Att. C	-9.21	0.7	0.001	0.999	1.0E-04
Te-125m	P	2	D	7E-03	Median NUREG/CR-6697, Att. C	-4.96	0.9	0.001	0.999	7.0E-03
Th-228	P	2	D	1.0E-04	Median NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-229	P	2	D	1.0E-04	Median NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-230	P	2	D	1.0E-04	Median NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
Th-232	P	2	D	1.0E-04	Median NUREG/CR-6697, Att. C	-9.21	1.0	0.001	0.999	1.0E-04
U-233	P	2	D	8.0E-04	Median NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-234	P	2	D	8.0E-04	Median NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-235	P	2	D	8.0E-04	Median NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04
U-236	P	2	D	8.0E-04	Median NUREG/CR-6697, Att. C	-7.13	0.7	0.001	0.999	8.0E-04

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Milk Transfer Factors (pCi/L)/(pCi/d)										
Ac-227	P	2	D	2.0E-06	Median NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Ag-108m	P	2	D	9.5E-03	75th Percentile NUREG/CR-6697, Att. C	-5.12	0.7	0.001	0.999	5.5E-03
Am-241	P	2	D	3.2E-06	75th Percentile NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Am-243	P	2	D	3.2E-06	75th Percentile[e] NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
C-14	P	2	D	2E-02	75th Percentile NUREG/CR-6697, Att. C	-4.4	0.9	0.001	0.999	1.2E-02
Cm-243	P	2	D	3.7E-06	75th Percentile NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Cm-244	P	2	D	3.7E-06	75th Percentile NUREG/CR-6697, Att. C	-13.12	0.9	0.001	0.999	2.0E-06
Co-60	P	2	D	3.2E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.7	0.001	0.999	2.0E-03
Cs-134	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5	0.001	0.999	1.0E-02
Cs-137	P	2	D	1.4E-02	75th Percentile NUREG/CR-6697, Att. C	-4.61	0.5	0.001	0.999	1.0E-02
Eu-152	P	2	D	1.1E-03	75th Percentile NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Eu-154	P	2	D	1.1E-03	75th Percentile NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Eu-155	P	2	D	1.1E-03	75th Percentile NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Fe-55	P	2	D	4.7E-04	75th Percentile NUREG/CR-6697, Att. C	-8.11	0.7	0.001	0.999	3.0E-04
Gd-152	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
H-3	P	2	D	1.8E-02	75th Percentile NUREG/CR-6697, Att. C	-4.6	0.9	0.001	0.999	1.0E-02
Nb-94	P	2	D	3.2E-06	75th Percentile NUREG/CR-6697, Att. C	-13.12	0.7	0.001	0.999	2.0E-06
Nd-144	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Ni-59	P	2	D	3.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.91	0.7	0.001	0.999	2.0E-02
Ni-63	P	2	D	3.2E-02	75th Percentile NUREG/CR-6697, Att. C	-3.91	0.7	0.001	0.999	2.0E-02
Np-237	P	2	D	1E-05	Median NUREG/CR-6697, Att. C	-11.51	0.7	0.001	0.999	1.0E-05

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pa-231	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Pb-210	P	2	D	3.0E-04	Median NUREG/CR-6697, Att. C	-8.11	0.9	0.001	0.999	3.0E-04
Pm-147	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Po-210	P	2	D	4.0E-04	Median NUREG/CR-6697, Att. C	-7.82	0.7	0.001	0.999	4.0E-04
Pu-238	P	2	D	1.37E-06	75th Percentile NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-239	P	2	D	1.37E-06	75th Percentile[e] NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-240	P	2	D	1.37E-06	75th Percentile[e] NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Pu-241	P	2	D	1.37E-06	75th Percentile NUREG/CR-6697, Att. C	-13.82	0.5	0.001	0.999	1.0E-06
Ra-226	P	2	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Ra-228	P	2	D	1.0E-03	Median NUREG/CR-6697, Att. C	-6.91	0.5	0.001	0.999	1.0E-03
Sb-125	P	2	D	1.1E-04	75th Percentile NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Sm-147	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Sm-148	P	2	D	6.0E-05	Median NUREG/CR-6697, Att. C	-9.72	0.9	0.001	0.999	6.0E-05
Sr-90	P	2	D	2.8E-03	75th Percentile NUREG/CR-6697, Att. C	-6.21	0.5	0.001	0.999	2.0E-03
Tc-99	P	2	D	1.6E-03	75th Percentile NUREG/CR-6697, Att. C	-6.91	0.7	0.001	0.999	1.0E-03
Te-125m	P	2	D	5.0E-04	Median NUREG/CR-6697, Att. C	-7.60	0.6	0.001	0.999	5.0E-04
Th-228	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-229	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-230	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
Th-232	P	2	D	5.0E-06	Median NUREG/CR-6697, Att. C	-12.21	0.9	0.001	0.999	5.0E-06
U-233	P	2	D	4.0E-04	Median NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-234	P	2	D	4.0E-04	Median NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
U-235	P	2	D	4.0E-04	Median NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
U-236	P	2	D	4.0E-04	Median NUREG/CR-6697, Att. C	-7.82	0.6	0.001	0.999	4.0E-04
Bioaccumulation Factors for Fish ((pCi/kg)/(pCi/L))										
Ac-227	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.7	1.1			1.5E+01
Am-241	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Am-243	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
C-14	P	2	D	Inactive	NUREG/CR-6697, Att. C	10.8	1.1			4.9E+04
Cm-243	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-244	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-245	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Cm-246	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Co-60	P	2	D	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Cs-137	P	2	D	Inactive	NUREG/CR-6697, Att. C	7.6	0.7			2.0E+03
Eu-152	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Eu-154	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Gd-152	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.2	1.1			2.5E+01
H-3	P	2	D	Inactive	NUREG/CR-6697, Att. C	0	0.1			1.0E+00
I-129	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.7	1.1			4.0E+01
Nb-94	P	2	D	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Ni-59	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Ni-63	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Np-237	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Pa-231	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			9.9E+00
Po-210	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			1.0E+01
Pb-210	P	2	D	Inactive	NUREG/CR-6697, Att. C	5.7	1.1			3.0E+02
Pu-238	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-239	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-240	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-241	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Pu-242	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.4	1.1			3.0E+01
Ra-226	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Ra-228	P	2	D	Inactive	NUREG/CR-6697, Att. C	3.9	1.1			4.9E+01
Sr-90	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.1	1.1			6.0E+01
Tc-99	P	2	D	Inactive	NUREG/CR-6697, Att. C	3	1.1			2.0E+01
Th-228	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-229	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-230	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
Th-232	P	2	D	Inactive	NUREG/CR-6697, Att. C	4.6	1.1			9.9E+01
U-233	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-234	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-235	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-236	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
U-238	P	2	D	Inactive	NUREG/CR-6697, Att. C	2.3	1.1			1.0E+01
Bioaccumulation Factors for Crustacea/ Mollusks ((pCi/kg)/(pCi/L))										

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Ac-227	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Am-241	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Am-243	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
C-14	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cm-243	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cm-244	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cm-245	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cm-246	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Co-60	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Cs-137	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Eu-152	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Eu-154	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Gd-152	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
H-3	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
I-129	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Nb-94	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ni-59	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ni-63	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Np-237	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pa-231	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pb-210	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	

Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Po-210	P	S	D	Inactive	RESRAD User's Manual Appendix D					
Pu-238	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pu-239	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pu-240	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pu-241	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Pu-242	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ra-226	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Ra-228	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Sr-90	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Tc-99	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Th-228	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Th-229	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Th-230	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Th-232	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
U-233	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
U-234	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
U-235	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
U-236	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
U-238	P	3	D	Inactive	RESRAD User's Manual Appendix D	NR	NR	NR	NR	
Graphics Parameters										
Number of points				32	RESRAD Default	NR	NR	NR	NR	
Spacing				log	RESRAD Default	NR	NR	NR	NR	
Time integration parameters										

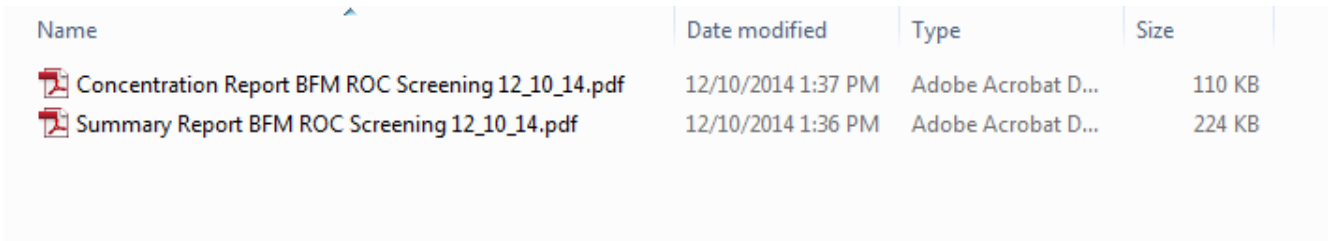
Parameter (unit)	Type[a]	Priority[b]	Treatment[c]	Value/Distribution	Basis	Distribution's Statistical Parameters[d]				
						1	2	3	4	Mean/ Median
Maximum number of points for dose				17	RESRAD Default	NR	NR	NR	NR	

Notes:
a P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4.)
b 1 = high-priority parameter, 2 = medium-priority parameter, 3 = low-priority parameter (see NUREG/CR-6697, Attachment B, Table 4.1)
c D = deterministic, S = stochastic
d Distributions Statistical Parameters:
Lognormal-n: 1= mean, 2 = standard deviation
Bounded lognormal-n: 1= mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Truncated lognormal-n: 1= mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Bounded normal: 1 = mean, 2 = standard deviation, 3 = minimum, 4 = maximum
Beta: 1 = minimum, 2 = maximum, 3 = P-value, 4 = Q-value
Triangular: 1 = minimum, 2 = mode, 3 = maximum
Uniform: 1 = minimum, 2 = maximum
e Sm-148 and ND-144 not listed in RESRAD FGR 11 DCF file

ATTACHMENT 12

RESRAD Summary Report and Concentration Report for BFM Analysis of Initial Suite of Radionuclides

See TSD 14-010 Attachment 12 (2 files)

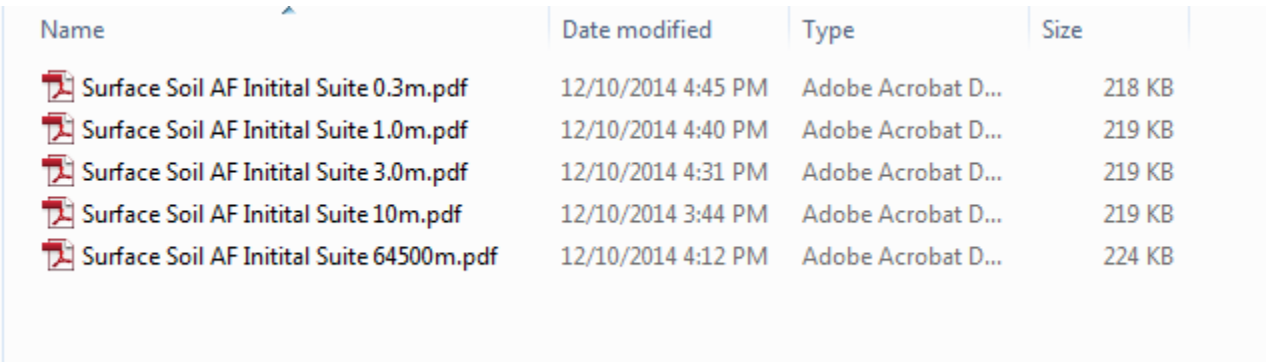


Name	Date modified	Type	Size
Concentration Report BFM ROC Screening 12_10_14.pdf	12/10/2014 1:37 PM	Adobe Acrobat D...	110 KB
Summary Report BFM ROC Screening 12_10_14.pdf	12/10/2014 1:36 PM	Adobe Acrobat D...	224 KB

ATTACHMENT 13

RESRAD Summary Reports for Soil Area Factors to Support Calculation of BFM Drilling Spoils Dose Factors for Initial Suite of Radionuclides

See TSD 14-010 Attachment 13 (5 files)



Name	Date modified	Type	Size
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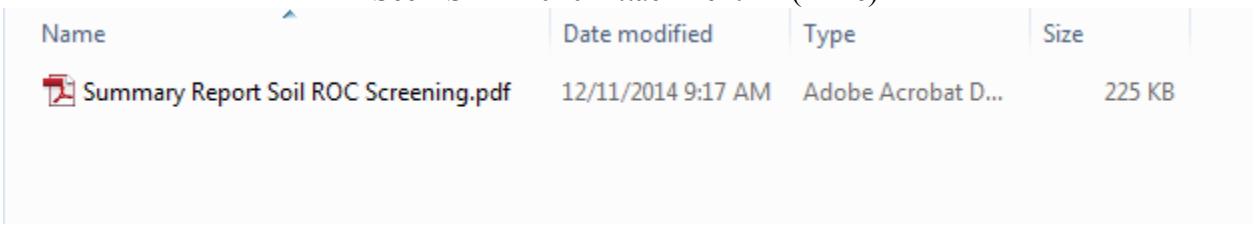
Surface Soil AF Initital Suite 1.0m.pdf	12/10/2014 4:40 PM	Adobe Acrobat D...	219 KB
Surface Soil AF Initital Suite 3.0m.pdf	12/10/2014 4:31 PM	Adobe Acrobat D...	219 KB
Surface Soil AF Initital Suite 10m.pdf	12/10/2014 3:44 PM	Adobe Acrobat D...	219 KB
Surface Soil AF Initital Suite 64500m.pdf	12/10/2014 4:12 PM	Adobe Acrobat D...	224 KB

ATTACHMENT 14

RESRAD Summary Report for Soil Analysis of Initial Suite of Radionuclides

See TSD 14-010 Attachment 14 (1 file)



ATTACHMENT 15

Clean Concrete Fill Dose Assessment at Detection Limit

Dose Assessment Clean Concrete Fill at Detection Limit

Inputs to Calculation

Turbine Clean Clean Concrete Fill Surface Area and Volume (Reference: 6/29/16 email from Don Roth)

Surface Area of Turbine Building Clean Concrete to be Used as Fill

	U1 SURFACE AREA (SQ. FT.)	U2 SURFACE AREA (SQ. FT.)
EL 592 SLABS	61,164	61,164
EL 609 & 617 SLABS	52,848	52,848
EL 630 SLABS	14,654	14,654
EL 642 SLABS	83,420	83,420
EL 592 BEAMS	3,800	3,800
TURBINE FOUNDATIC	59,981	59,981
PERIMETER WALLS	1,728	1,728
MASONRY WALLS	56,570	56,570
TOTALS	**334,165**	**334,165**

Volume of Clean Turbine Concrete to be Used as Fill

Volume	21,525	cubic yard
Volume	1.65E+04	m3

Containment Clean Concrete Fill Surface Area and Volume (Drawing B-210, Reactor Building Containment Structural Arrangement Zion Station Unit No. 1&2 Commonwealth Edison Co. Chicago

Containmant Dimensions (cylinder)				
Diameter Exterior	147.00	ft		
Diameter Interior	140.00	ft		
Cylinder Height	171.50	ft		
Thickness	3.50	ft		
Containment Dimensions (Roof)				
Dome Radius Exteric	20.17	ft		
Dome Radius Interio	17.50	ft		
Thickness	2.67	ft		
Conversion Factor	929.03	cm2/ft2		
Conversion Factor	28316.80	cm3/ft3		
Containment Cylinder Surface Area and Volume				
Area of Outer Surfac	7.92E+04	ft2	7.36E+07	cm2
Area of Inner Surface	7.54E+04	ft2	7.01E+07	cm2
Volume of Concrete	2.71E+05	ft3	7.66E+09	cm3
Containment Roof Surface Area and Volume				
Area of Outer Surfac	2.56E+03	ft2	2.37E+06	cm2
Area of Inner Surface	1.92E+03	ft2	1.79E+06	cm2
Volume of Concrete	5.96E+03	ft3	1.69E+08	cm3
Containment Total Volume (one unit)			7.83E+03	m3

Total Clean Concrete Fill Volume - Containment plus Turbine	3.21E+04 m3

Conversion Factors and Assumptions

Conversion Factor	0.0929	m2/ft2
Conversion Factor	1.0000E+06	cm3 per m3
Conversion Factor	1.000E+04	cm2 per m2
concrete density	2.35	g/cm3
Non-detect Maximu	5000	dpm/100 cm2
Conversion factor	2.2	dpm/pCi
Conversion Factor	1.00E-09	mCi/pCi
conversion Factor	7.65E-01	m3/yd3
Conversion Factor	7.65E+05	cm3/yd3

Calculation

Total Inventory Gamma in Turbine Clean Conrete Debris at MDC	1.41E+01 mCi
Total Inventory Gamma in Containment Clean Conrete Debris at MDC	6.72E+00 mCi

Inventory per m3 of fill

Turbine	8.57E-04 mCi/m3
Containment	4.29E-04 mCi/m3

Basement	**Fill Volume (m3)[1]**	**gamma inventory (mCi)**
Unit 1 Containment	1.21E+04	1.04E+01
Unit 2 Containment I	1.21E+04	1.04E+01
Auxiliary Building	3.76E+04	3.22E+01
Turbine Building	4.26E+04	3.65E+01
Crib House and Fore	3.92E+04	3.36E+01
WWTF	1.01E+03	8.66E-01
Spent Fuel Pool and	1.04E+03	8.92E-01

Note 1: Fill volumes from TSD 14-021 Revision 1, Table 23

Basement Dose Factors

	Auxiliary (mrem/y per mCi)	Containment (mrem/y per mCi)	Spent Fuel Pool/ Transfer Canals (mrem/y per mCi)	Turbine (mrem/y per mCi)	Crib House/ Forebay (mrem/y per mCi)	WWTF (mrem/y per mCi)
Co-60	1.11E-02	4.15E-02	1.63E-01	1.28E-02	2.42E-02	7.68E-01
Cs-134	1.60E-02	2.17E-01	2.17E-01	5.64E-02	6.27E-02	9.41E+00
Cs-137	3.04E-02	1.66E-01	1.66E-01	4.27E-02	4.52E-02	7.42E+00
Eu-152	5.22E-03	1.78E-02	7.66E-02	5.56E-03	1.08E-02	2.88E-01
Eu-154	5.79E-03	2.05E-02	8.47E-02	6.30E-03	1.19E-02	3.78E-01
H-3	6.37E-03	2.74E-02	2.74E-02	6.98E-03	6.93E-03	1.27E+00
Ni-63	2.94E-04	1.62E-03	1.62E-03	4.12E-04	4.11E-04	7.51E-02
Sr-90	3.38E-01	4.56E+00	4.56E+00	1.16E+00	1.15E+00	2.12E+02

Basement Inventory Limits (BIL)

	mCi	mCi	mCi	mCi	mCi	mCi
Co-60	2.25E+03	6.02E+02	1.54E+02	1.95E+03	1.03E+03	3.26E+01
Cs-134	1.56E+03	1.15E+02	1.15E+02	4.43E+02	3.99E+02	2.66E+00
Cs-137	8.22E+02	1.51E+02	1.51E+02	5.86E+02	5.53E+02	3.37E+00
Eu-152	4.79E+03	1.40E+03	3.26E+02	4.50E+03	2.31E+03	8.69E+01
Eu-154	4.32E+03	1.22E+03	2.95E+02	3.97E+03	2.10E+03	6.61E+01
H-3	3.92E+03	9.11E+02	9.11E+02	3.58E+03	3.61E+03	1.97E+01
Ni-63	8.52E+04	1.54E+04	1.54E+04	6.07E+04	6.09E+04	3.33E+02
Sr-90	7.39E+01	5.48E+00	5.48E+00	2.15E+01	2.17E+01	1.18E-01

ROC Mixture for Containment (Reference: TSD 14-019, Revision 1 Table 20)

	Perent Activity	Ratio to Cs-137
Co-60	4.675%	6.92E-02
Cs-134	0.008%	1.21E-04
Cs-137	67.582%	1.00E+00
Eu-152	0.436%	6.45E-03
Eu-154	0.058%	8.57E-04
H-3	0.074%	1.10E-03
Ni-63	26.275%	3.89E-01
Sr-90	0.027%	4.05E-04
ROC Total Percent A(	99.136%	
Insignificant Contrib	0.864%	
Total	100.000%	

ROC Mixture for Auxiliary Basement (Reference: TSD 14-019, Revision 1 Table 20)

	Perent Activity	Ratio to Cs-137
Co-60	0.908%	1.22E-02
Cs-134	0.010%	1.38E-04
Cs-137	74.597%	1.00E+00
Ni-63	23.480%	3.15E-01
Sr-90	0.051%	6.83E-04
ROC Total	99.046%	
Percent		
Insignificant	0.954%	
Total	100.00%	

Clean Concrete Hypothetical Dose Containment ROC Mixture

	Auxiliary	Containment	Spent Fuel Pool/ Transfer Canals	Turbine	Crib House/ Forebay	WWTF
	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Co-60	2.48E-02	2.98E-02	1.00E-02	3.23E-02	5.63E-02	4.60E-02
Cs-134	6.21E-05	2.71E-04	2.33E-05	2.49E-04	2.54E-04	9.83E-04
Cs-137	9.80E-01	1.72E+00	1.48E-01	1.56E+00	1.52E+00	6.42E+00
Eu-152	1.09E-03	1.19E-03	4.41E-04	1.31E-03	2.35E-03	1.61E-03
Eu-154	1.60E-04	1.82E-04	6.47E-05	1.97E-04	3.43E-04	2.81E-04
H-3	2.25E-04	3.12E-04	2.68E-05	2.79E-04	2.55E-04	1.20E-03
Ni-63	3.68E-03	6.55E-03	5.63E-04	5.85E-03	5.37E-03	2.53E-02
Sr-90	4.41E-03	1.91E-02	1.65E-03	1.72E-02	1.57E-02	7.42E-02
Total	**1.01E+00**	**1.78E+00**	**1.61E-01**	**1.62E+00**	**1.60E+00**	**6.57E+00**

Clean Concrete Hypothetical Dose Auxiliary ROC Mixture

	Auxiliary	Containment	Spent Fuel Pool/ Transfer Canals	Turbine	Crib House/ Forebay	WWTF
	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Co-60	4.36E-03	5.24E-03	1.76E-03	5.68E-03	9.90E-03	8.09E-03
Cs-134	7.12E-05	3.11E-04	2.67E-05	2.85E-04	2.91E-04	1.13E-03
Cs-137	9.80E-01	1.72E+00	1.48E-01	1.56E+00	1.52E+00	6.42E+00
Ni-63	2.98E-03	5.30E-03	4.56E-04	4.74E-03	4.35E-03	2.05E-02
Sr-90	7.45E-03	3.23E-02	2.78E-03	2.90E-02	2.65E-02	1.25E-01
Total	**9.95E-01**	**1.76E+00**	**1.53E-01**	**1.60E+00**	**1.56E+00**	**6.58E+00**