APPENDIX C

DETAILS OF DCGL DEVELOPMENT AND THE INTEGRATED DOSE ASSESSMENT

PURPOSE OF THIS APPENDIX

The purpose of this appendix is to provide supporting information related to development of deterministic derived concentration guideline levels (DCGLs) and the limited integrated dose assessment performed to ensure that cleanup criteria for surface soil, subsurface soil, and streambed sediment used in Phase 1 of the decommissioning will support any decommissioning approach that may be selected for Phase 2.

INFORMATION IN THIS APPENDIX

This appendix provides the following information:

- Table C-1 in Section 1 provides a complete list of RESRAD input parameters, except for distribution coefficients, and the bases for these parameters.
- Table C-2 in Section 1 provides a list of distribution coefficients and their bases.
- Table C-3 in Section 1 provides the exposure pathways considered in the analysis.
- Table C-4 in Section 1 provides data on measured radionuclide concentrations in the Lavery till in the area of the large excavations in Waste Management Area 1 and Waste Management Area 2.
- Section 2 describes the information that comprises Attachment 1, which supports the calculation of DCGL and cleanup goal values presented in Section 5 of the Decommissioning Plan.
- Attachment 1 provides electronic RESRAD input and output files for the three base cases (surface soil, subsurface soil, and streambed sediment), the limited integrated dose analysis, and the input parameter sensitivity analyses performed, along with the associated Microsoft Excel spreadsheets.
- Attachment 2 provides an additional electronic file (a Microsoft Excel spreadsheet) used in the preliminary dose assessments.

RELATIONSHIP TO OTHER PLAN SECTIONS

This appendix provides supporting information for Section 5. Information provided in Section 5 and in Section 1 on the project background will help place the information in this appendix into context.

1.0 Tabulated Data

Table C-1 identifies input parameters used in the RESRAD models, except for the distribution coefficients, which are included in Table C-2. Input parameters are provided for the three source exposure scenarios: surface soil (SS), subsurface soil (SB), and stream bank sediment (SD). The RESRAD input parameters presented in Table C-1 were selected as discussed in Section 5.

Distribution coefficients (K_ds) are presented in Table C-2 for chemical elements of the 18 radionuclides and their decay progeny for each of the three analyses (SS, SB and SD) for each of the modeled media (contaminated zone, unsaturated zone and saturated zone) used in RESRAD. The conceptual models assume the sand and gravel unit is representative of the three RESRAD zones, except that in the SB and SD analyses, the contaminated zone is assumed to be represented by the Lavery till. The table includes the RESRAD default value, the specific value input into the RESRAD model for $DCGL_W$ calculations, either measured site-specific or reference values (as identified in Note 1 to table C-2), and the range of values used in the sensitivity analysis. The K_d values were selected to represent the central tendency of the site-specific data or were based on specific soil strata characteristics where available. Variability/uncertainty in the K_d values was addressed through the sensitivity analysis and also in the probabilistic uncertainty analysis described in Section 5 and Appendix E.

The exposure pathways presented in Table C-3 were based on the critical groups identified for each of the source media. The resident farmer was the critical receptor for soil exposure and the recreationist was identified as the critical receptor for stream bank sediment exposure. Alternate receptors were considered as discussed in Section 5, including acute dose from subsurface material to a well driller during cistern installation, dose from subsurface material during installation of a natural gas well, and dose from surface and subsurface material to a resident gardener.

The data in Table C-4 are the basis for the maximum radionuclide concentration data in Table 5-1. These data comprise the available characterization data for radionuclides in the Lavery till within the footprints of the large excavations for the Process Building-Vitrification area and the Low-Level Waste Treatment Facility area that are described in Section 7.

Preliminary dose assessments have been performed for the remediated WMA 1 and WMA 2 excavations. These assessments made use of the maximum measured radioactivity concentration in the Lavery till for each radionuclide as summarized in Table C-4, and the maximum detection level concentration for non-detected radionuclides. (It should be noted that the minimum detection levels for non-detected radionuclides may range several orders of magnitude. Use of the maximum detection level concentration for non-detected radionuclides results in added conservatism in the reported preliminary dose assessment.) The results were as follow:

WMA 1, a maximum of 1.3 mrem a year

WMA 2, a maximum of 0.04 mrem a year

Given the limited data available, these results must be viewed as order-of-magnitude estimates. However, they do suggest that actual potential doses from the two remediated areas are likely to be substantially below 25 mrem per year. Table C-4B in Attachment 2 shows how these doses were estimated.

Note that the probabilistic uncertainty analysis described in Section 5 and Appendix E produced somewhat different results, as did other analyses such as the multi-source analysis for subsurface soil.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Area of contaminated zone (m^2)	1.00E+04	1.00E+04	SS	Assumed area of 10,000 m^2 for subsistence farmer scenario; garden is 2,000 m^2.
	1.00E+04	1.00E+02	SB	Assumed area of 100 m^2 for excavated contaminated cistern cuttings scenario. Alternative configurations were considered in the sensitivity analysis.
	1.00E+04	1.00E+03	SD	Assumed 1000 m^2 area along stream bank (3 m wide by ~330 m length).
Thickness of contaminated zone (m)	2.00E+00	1.00E+00	SS, SD	Assumed surface soil contaminated zone thickness.
	2.00E+00	3.00E-01	SB	Assumed thickness of contaminated cistern cuttings spread on surface over a 100 m^2 area. Alternative configurations were considered in the sensitivity analysis.
Length parallel to aquifer flow (m)	1.00E+02	1.65E+02	SS	Selected to achieve site specific groundwater dilution factor of 0.2, based on DEIS groundwater model correlation. Only applicable for non-dispersion model.
Time since placement of material (y)	0.00E+00	0.00E+00	All	Only non-zero if K_d values are not available. (Site-specific K_ds are available).
Cover depth (m)	0.00E+00	0.00E+00	All	No cover considered.
Density of cover material (g/cm^3)	0.00E+00	not used	All	No cover considered.
Cover depth erosion rate (m/y)	0.00E+00	not used	All	No cover considered.
Density of contaminated zone (g/cm^3)	1.50E+00	1.70E+00	All	WVNSCO 1993a and WVNSCO 1993c.
Contaminated zone erosion rate (m/y)	1.00E-03	0.00E+00	All	Assumed for no source depletion.
Contaminated zone total porosity	4.00E-01	3.60E-01	All	WVNSCO 1993c.
Contaminated zone field capacity	2.00E-01	2.00E-01	All	WVNSCO 1993c.
Contaminated zone hydraulic conductivity (m/y)	1.00E+01	1.40E+02	All	Average for Sand and Gravel Thick Bedded Unit (4.43E-03 cm/s from Table 3-19) divided by 10 to provide vertical conductivity that accounts for potential anisotropy (DEIS Appendix E, Table E-3).
Contaminated zone b parameter	5.30E+00	1.40E+00	All	Yu, et al. 2000, Att. C table 3.5-1, mean for loamy sand (ln(mean)=0.305).
Average annual wind speed (m/sec)	2.00E+00	2.60E+00	All	WVNSCO 1993d.
Humidity in air (g/m^3)	8.00E+00	not used	All	Applicable for tritium exposures only.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Evapotranspiration coefficient	5.00E-01	7.80E-01	All	Evapotranspiration and runoff coefficients selected to achieve infiltration rate of 0.26 m/y.
Precipitation (m/y)	1.00E+00	1.16E+00	All	WVNSCO 1993d.
Irrigation (m/y)	2.00E-01	4.70E-01	SS, SB	Beyeler, et al. 1999.
	2.00E-01	0.00E+00	SD	Not applicable for non-farming scenario.
Irrigation mode	overhead	overhead	All	Site-specific.
Runoff coefficient	2.00E-01	4.10E-01	All	Runoff and evapotranspiration coefficients selected to achieve infiltration rate of 0.26 m/y.
Watershed area for nearby stream or pond (m^2)	1.00E+06	1.37E+07	All	Based on drainage area of site of 13.7 km^2 or ~5.2 mi^2 for Buttermilk Creek.
Accuracy for water/soil computations	1.00E-03	1.00E-03	All	Default assumed.
Saturated zone density (g/cm^3)	1.50E+00	1.70E+00	All	WVNSCO 1993a and WVNSCO 1993c.
Saturated zone total porosity	4.00E-01	3.60E-01	All	WVNSCO 1993c.
Saturated zone effective porosity	2.00E-01	2.50E-01	All	WVNSCO 1993c.
Saturated zone field capacity	2.00E-01	2.00E-01	All	WVNSCO 1993c.
Saturated zone hydraulic conductivity (m/y)	1.00E+02	1.40E+03	All	Average for Sand and Gravel Thick Bedded Unit (4.43E-03 cm/s from Table 3-19)
Saturated zone hydraulic gradient	2.00E-02	3.00E-02	All	WVNSCO 1993b.
Saturated zone b parameter	5.30E+00	1.40E+00	All	Yu, et al. 2000, Att. C table 3.5-1, mean for loamy sand (ln(mean)=0.305).
Water table drop rate (m/y)	1.00E-03	0.00E+00	All	Site Specific.
Well pump intake depth (m below water table)	1.00E+01	5.00E+00	SS	Assumption based on site hydrogeology and site-specific groundwater dilution factor. Only applicable to non-dispersion model.
Model: Non-dispersion (ND) or Mass-Balance (MB)	ND	ND	SS	Applicable to areas >1,000 m2 (Yu, et.al. 2001, p.E-18)
	MB	MB	SB, SD	Applicable to areas <1,000 m2 (Yu, et. al. 2001, pE-18)

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Well pumping rate (m^3/y)	2.50E+02	5.72E+03	SS, SB	Based on 2.9 m^3/y drinking water (2 L/d per 4 people for 365 days), 329 m^3/y household water (225 L/d per 4 people for 365 day), 385 m^3/y livestock watering (5 beef cattle at 50 L/d, 5 milk cows 160 L/d) and 5,000 m^3/y for irrigation of 10,000 m^2 (at rate of 0.5 m/y) from Yu, et al. 2000, Attachment C, Section 3.10.
	2.50E+02	0.00E+00	SD	Not applicable for non-farming scenario.
Number of unsaturated zone strata	1.00E+00	1.00E+00	All	Assumed.
Unsaturated zone thickness (m)	4.00E+00	2.00E+00	SS, SB	Site specific.
	4.00E+00	0.00E+00	SD	Assumed saturated for stream bank.
Unsaturated zone soil density (g/cm^3)	1.50E+00	1.70E+00	SS, SB	WVNSCO 1993a and WVNSCO 1993c.
Unsaturated zone total porosity	4.00E-01	3.60E-01	SS, SB	WVNSCO 1993c.
Unsaturated zone effective porosity	2.00E-01	2.50E-01	SS, SB	WVNSCO 1993c.
Unsaturated zone field capacity	2.00E-01	2.00E-01	SS, SB	WVNSCO 1993c.
Unsaturated zone hydraulic conductivity (m/y)	1.00E+01	1.40E+02	SS, SB	Average for Sand and Gravel Thick Bedded Unit (4.43E-03 cm/s from Table 3-19) divided by 10 to provide vertical conductivity that accounts for potential anisotropy (DEIS Appendix E, Table E-3).
Unsaturated zone b parameter	5.30E+00	1.40E+00	SS, SB	Yu, et al. 2000, Att. C table 3.5-1, mean for loamy sand (ln(mean)=0.305).
Distribution coefficients – radionuclides				
Contaminated zone (mL/g)	varies	Site specific	All	See Table C-2 for distribution coefficients.
Unsaturated zone 1 (mL/g)	varies	Site specific	All	See Table C-2 for distribution coefficients.
Saturated zone (mL/g)	varies	Site specific	All	See Table C-2 for distribution coefficients.
Plant Transfer Factor	varies	Chemical-specific	All	Default values assumed.
Fish Transfer Factor	Varies	Chemical-specific	SD	Default values assumed.
Leach rate (1/y)	varies	not used	All	Using site-specific Kd values instead of assigning leach rate.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Solubility constant	varies	not used	All	Using site-specific Kd values instead of assigning solubility constant.
Inhalation rate (m^3/y)	8.40E+03	8.40E+03	All	Beyeler, et al. 1999.
Mass loading for inhalation (g/m^3)	1.00E-04	1.48E-05	All	Beyeler, et al. 1999. Based on relative time fractions and mean dust loadings. Assumes 288 hours of active farming per year.
Exposure duration (y)	3.00E+01	1.00E+00	All	Yearly dose estimates calculated.
Filtration factor, inhalation	4.00E-01	1.00E+00	SS, SB	Beyeler, et. al. 1999.
Shielding factor, external gamma	7.00E-01	2.73E-01	SS, SB	Yu, et al. 2000, Att. C Figure 7.10-1, mean of distribution approximates a frame house with slab or basement.
Fraction of time spent indoors	5.00E-01	6.60E-01	SS, SB	Yu, et al. 2000, Att. C Figure 7.6-2, value represents ~50th percentile of distribution.
	5.00E-01	0.00E+00	SD	Assumed.
Fraction of time spent outdoors	2.50E-01	2.50E-01	SS, SB	RESRAD default value used.
	2.50E-01	1.20E-02	SD	Based on 104 hours/year (2 hours/day, 2 day/week, 26 weeks/y) spent on the stream bank over 8760 residence hours per year (24 hr/day, 365 days/y)
Shape factor flag, external gamma	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Fruits, vegetables and grain consumption (kg/y)	1.60E+02	1.12E+02	SS, SB	Beyeler, et al. 1999.
Leafy vegetable consumption (kg/y)	1.40E+01	2.10E+01	SS, SB	Beyeler, et al. 1999.
Milk consumption (L/y)	9.20E+01	2.33E+02	SS, SB	Beyeler, et al. 1999.
Meat and poultry consumption (kg/y)	6.30E+01	6.50E+01	All	Beyeler, et al. 1999.
Fish consumption (kg/y)	5.40E+00	9.00E+00	SD	Exposure Factors Handbook (EPA, 1999). The value represents the 95th percentile of fish consumption by recreational anglers
Other seafood consumption (kg/y)	9.00E-01	0.00E+00	SD	Assumes only fish consumed from the stream
Soil ingestion rate (g/y)	3.65E+01	1.83E+01	All	Yu, et al. 2000, Att C. Figure 5.6-1, value represents mean of distribution for resident farmer (50 mg/d).
Drinking water intake (L/y)	5.10E+02	7.30E+02	SS, SB	Beyeler, et al. 1999.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
	5.10E+02	1.00E+00	SD	Based on 104 hour/year exposure and 10 mL/hr for wading scenario (http://www.epa.gov/Region4/waste/ots/healtbul.htm)
Contamination fraction of drinking water	1.0	1.0	All	Assumed. For streambed sediment, this is 100% of incidental ingestion.
Contamination fraction of household water	1.0	1.0	SS, SB	Assumed.
Contamination fraction of livestock water	1.0	1.0	SS, SB	Assumed.
Contamination fraction of groundwater	1.0	0	SD	All water ingested is from surface water.
Contamination fraction of irrigation water	1.0	1.0	SS, SB	Assumed.
Contamination fraction of aquatic food	1.0	1.0	SD	Assumed.
Contamination fraction of plant food	-1	1.0	SS, SB	Assumes all ingestion is from the contaminated source.
Contamination fraction of meat	-1	1.0	All	Assumes all ingestion is from the contaminated source.
Contamination fraction of milk	-1	1.0	SS, SB	Assumes all ingestion is from the contaminated source.
Livestock fodder intake for meat (kg/day)	6.80E+01	2.73E+01	SS, SB	Beyeler, et al. 1999.
	6.80E+01	2.25E+00	SD	Assumption for deer.
Livestock fodder intake for milk (kg/day)	5.50E+01	6.42E+01	SS, SB	Beyeler, et al. 1999.
Livestock water intake for meat (L/day)	5.00E+01	5.00E+01	All	Beyeler, et al. 1999, assumed for venison exposure to sediment source.
Livestock water intake for milk (L/day)	1.60E+02	1.60E+02	SS, SB	RESRAD default value used.
Livestock soil intake (kg/day)	5.00E-01	5.00E-01	All	RESRAD default, assumed for venison exposure to sediment source.
Mass loading for foliar deposition (g/m^3)	1.00E-04	4.00E-04	SS, SB	Beyeler, et al. 1999.
Depth of soil mixing layer (m)	1.50E-01	1.50E-01	SS, SB	Beyeler, et al. 1999.
Depth of roots (m)	9.00E-01	9.00E-01	All	RESRAD default, represents crops with short growing seasons.
Drinking water fraction from ground water	1.0	1.0	All	Assumed.
Household water fraction from ground water	1.0	1.0	SS, SB	Assumed.
Livestock water fraction from ground water	1.0	1.0	SS, SB	Assumed.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Irrigation fraction from ground water	1.0	1.0	SS, SB	Assumed.
Wet weight crop yield for non-leafy (kg/m^2)	7.00E-01	1.75E+00	SS, SB	Yu, et al. 2000, Att. C Figure 6.5-1 value is mean of distribution.
Wet weight crop yield for leafy (kg/m^2)	1.50E+00	1.50E+00	SS, SB	RESRAD default.
Wet weight crop yield for fodder (kg/m^2)	1.10E+00	1.10E+00	SS, SB	RESRAD default.
Growing season for non-leafy (years)	1.70E-01	1.70E-01	SS, SB	RESRAD default.
Growing season for leafy (years)	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Growing season for fodder (years)	8.00E-02	8.00E-02	SS, SB	RESRAD default.
Translocation factor for non-leafy	1.00E-01	1.00E-01	SS, SB	RESRAD default.
Translocation factor for leafy	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Translocation factor for fodder	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Dry foliar interception fraction for non-leafy	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Dry foliar interception fraction for leafy	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Dry foliar interception fraction for fodder	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Wet foliar interception fraction for non-leafy	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Wet foliar interception fraction for leafy	2.50E-01	6.70E-01	SS, SB	Yu, et al. 2000, Att. C Figure 6.7-1 represent the most likely value.
Wet foliar interception fraction for fodder	2.50E-01	2.50E-01	SS, SB	RESRAD default.
Weathering removal constant (1/y)	2.00E+01	1.80E+01	SS, SB	Yu, et al. 2000, Att. C Figure 6.6-1 represent the most likely value
Carbon-14-related exposure parameters				
C-12 concentration in water (g/cc)	2.00E-05	2.00E-05	All	RESRAD default.
C-12 concentration in soil (g/g)	3.00E-02	3.00E-02	All	RESRAD default.
Fraction of vegetable carbon from soil	2.00E-02	2.00E-02	All	RESRAD default.
Fraction of vegetable carbon from air	9.80E-01	9.80E-01	All	RESRAD default.

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
Diffusion coefficient for radon gas (m^2/sec)				
in cover material	2.00E-06	not used	All	Applicable for Radon exposures only.
in foundation material	3.00E-07	not used	All	Applicable for Radon exposures only.
in contaminated zone soil	2.00E-06	not used	All	Applicable for Radon exposures only.
Radon vertical dimension of mixing (m)	2.00E+00	not used	All	Applicable for Radon exposures only.
Average building air exchange rate (1/hr)	5.00E-01	not used	All	Applicable for Radon exposures only.
Height of building or room (m)	2.50E+00	not used	All	Applicable for Radon exposures only.
Building indoor area factor	0.00E+00	not used	All	Applicable for Radon exposures only.
Building depth below ground surface (m)	-1	not used	All	Applicable for Radon exposures only.
Emanating power of Rn-222 gas	2.50E-01	not used	All	Applicable for Radon exposures only.
Emanating power of Rn-220 gas	1.50E-01	not used	All	Applicable for Radon exposures only.

LEGEND: SS = surface soil, SB = subsurface soil, SD = streambed sediment.

Table C-2. Soil/Water Distribution Coefficients[1]

Radionuclide	RESRAD Default (mL/g)	Surface Soil DCGL Contaminated Zone (mL/g)	Subsurface Soil DCGL Contaminated Zone (mL/g)	Sediment DCGL Contaminated Zone (mL/g)	Unsaturated[2] Zone (mL/g)	Saturated[3] Zone (mL/g)
Principal Elements						
Americium	20	1900[4] (420 - 111,000)	4000[5] (420 - 111,000)	4000[5] (420 - 111,000)	1900[4] (420 - 111,000)	1900[4] (420 - 111,000)
Carbon	0	5[4] (0.7 - 12)	7[5] (0.7 - 12)	7[5] (0.7 - 12)	5[4] (0.7 - 12)	5[4] (0.7 - 12)
Curium[6]	calculated	6760 (780 – 22,970)	6760 (780 – 22,970)	6760 (780 – 22,970)	6760 (780 – 22,970)	6760 (780 – 22,970)
Cesium	4600	280[4] (48 - 4800)	480[5] (48 - 4800)	480[5] (48 - 4800)	280[4] (48 - 4800)	280[4] (48 - 4800)
Iodine	calculated	1[4] (0.4 - 3.4)	2[7] (0.4 - 3.4)	2[7] (0.4 - 3.4)	1[4] (0.4 - 3.4)	1[4] (0.4 - 3.4)
Neptunium	calculated	2.3[8] (0.5 - 5.2)	3[5] (0.5 - 5.2)	3[5] (0.5 - 5.2)	2.3[8] (0.5 - 5.2)	2.3[8] (0.5 - 5.2)
Plutonium	2000	2600[8] (5 - 27,900)	3000[5] (5 - 27,900)	3000[5] (5 - 27,900)	2600[8] (5 - 27,900)	2600[8] (5 - 27,900)
Strontium	30	5[9] (1 - 32)	15[5] (1 - 32)	15[5] (1 - 32)	5[9] (1 - 32)	5[9] (1 - 32)
Technetium	0	0.1[4] (0.01 - 4.1)	4.1[7] (1 - 10)	4.1[7] (1 - 10)	0.1[4] (0.01 - 4.1)	0.1[4] (0.01 - 4.1)
Uranium	50	35[4] (10 - 350)	10[9] (1 - 100)	10[9] (1 - 100)	35[4] (10 - 350)	35[4] (10 - 350)
Progeny Elements[10]						
Actinium	20	1740	1740	1740	1740	1740
Lead	100	2400	2400	2400	2400	2400

Table C-2. Soil/Water Distribution Coefficients[1]

Radionuclide	RESRAD Default (mL/g)	Surface Soil DCGL Contaminated Zone (mL/g)	Subsurface Soil DCGL Contaminated Zone (mL/g)	Sediment DCGL Contaminated Zone (mL/g)	Unsaturated[2] Zone (mL/g)	Saturated[3] Zone (mL/g)
Protactinium	50	2040	2040	2040`	2040	2040
Radium	70	3550	3550	3550	3550	3550
Thorium	60,000	5890	5890	5890	5890	5890

NOTES: (1) Sources of K_d values considered included Table 3-20; NUREG-5512 (Beyeler, et al. 1999), Table 6.7; RESRAD User's Guide (Yu, et al. 2001), Tables E-3, E-4; Sheppard, et. al. 2006, and Sheppard and Thibault 1990. Values in parentheses are the bounds used in the sensitivity evaluation, selected considering site-specific and literature values to reflect a reasonable range.

(2) Sediment model assumes no unsaturated zone. Values used for surface and subsurface soil evaluation only.

(3) Values presented here are those used for surface soil DCGLs based on the non-dispersion model.

(4) From Sheppard and Thibault 1990, for sand.

(5) Site specific value for the unweathered Lavery till (see Section 3.7.8, Table 3-20).

(6) Beyeler, et. al. 1999

(7) Site specific value for the Lavery till (see Section 3.7.8, Table 3-20).

(8) Site specific value for the sand and gravel unit (see Section 3.7.8, Table 3-20).

(9) Site specific data (Dames and Moore 1995a, 1995b). The Sr-90 value of 5 mL/g is consistent with the value used in the Decommissioning EIS.

(10) Progeny K_ds were not included in the sensitivity analysis; DEIS values were used in all cases.

Table C-3 Scenario exposure pathways for WVDP DCGL development

Exposure Pathways	Resident Farmer (surface soil and Lavery Till source)	Recreationist (sediment source)
Incidental ingestion of source	●	●
External exposure to source	●	●
Inhalation of airborne source	●	●
Ingestion of groundwater impacted by source	●	x
Ingestion of milk impacted by soil and water sources	●	x
Ingestion of beef impacted by soil and water sources	●	x
Ingestion of produce impacted by soil and water sources	●	x
Incidental ingestion of surface water impacted by source	○	●
Ingestion of fish impacted by source	○	●
Ingestion of venison impacted by sediment and water sources	○	●

LEGEND:

● - Pathway is considered complete and is included in DCGL development.

○ - Pathway is considered potentially complete but unlikely, and is not included in DCGL development.

x - Pathway is considered incomplete and is not included in DCGL development.

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
BH-17 (WMA 6, 1993)	Sr-90	1.1E-01	26-28
Depth to Lavery till - 27 ft	Cs-137	2.6E-02	26-28
	U-232	< 3.2E-03	26-28
	U-233/234	1.6E-01	26-28
	U-235	< 5.8E-03	26-28
	U-235/236	< 6.9E-03	26-28
	U-238	1.1E-01	26-28
	Pu-238	< 4.3E-03	26-28
	Pu-239/240	< 4.3E-03	26-28
	Pu-241	1.3E+00	26-28
	Am-241	< 9.6E-03	26-28
BH-21A (WMA 1, 1993)	Sr-90	4.5E+02	36-38
Depth to Lavery till - 37.5 ft	Cs-137	< 3.0E-02	36-38
	U-232	< 7.4E-03	36-38
	U-233/234	8.6E-02	36-38
	U-235	< 5.1E-03	36-38
	U-235/236	< 7.2E-03	36-38
	U-238	7.1E-02	36-38
	Pu-238	< 4.8E-03	36-38
	Pu-239/240	< 4.8E-03	36-38
	Pu-241	< 1.1E+00	36-38
	Am-241	< 7.2E-03	36-38
GP3098 (WMA 1, 1998)	Sr-90	6.6E+00	36.5-37
Depth to Lavery till - 37 ft	Sr-90	4.2E+00	37-37.5
	Sr-90	6.3E+00	37.5-38
	Sr-90	5.5E+01	38-38.5
	Sr-90	5.9E+01	38.5-39
	Sr-90	3.4E+01	39-39.5
	Sr-90	2.9E+01	39.5-40
GP3008 (WMA 1, 2008)	C-14	< 3.0E-01	37-39
Depth to Lavery till - 37 ft	Sr-90	1.7E+00	37-39
	Tc-99	< 5.5E-01	37-39
	I-129	< 1.1E-01	37-39
	Cs-137	< 2.0E-02	37-39

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
	U-232	< 2.2E-02	37-39
	U-233/234	9.7E-01	37-39
	U-235/236	1.3E-01	37-39
	U-238	1.1E+00	37-39
	Np-237	< 9.8E-03	37-39
	Pu-238	< 1.1E-02	37-39
	Pu-239/240	< 1.2E-02	37-39
	Pu-241	< 4.8E-01	37-39
	Am-241	< 1.2E-02	37-39
	Cm-243/244	< 1.2E-02	37-39
GP7398 (WMA 1, 1998) Depth to Lavery till - 39 ft	Sr-90	1.9E+00	40-40.5
	Sr-90	1.8E+00	40.5-41
	Sr-90	5.2E+00	41-41.5
	Sr-90	8.4E+00	41.5-42
GP7608 (WMA 1, 2008) Depth to Lavery till - 38 ft	C-14	1.1E-01	38-40
	Sr-90	1.5E+01	38-40
	Tc-99	< 2.7E-01	38-40
	I-129	< 2.9E-01	38-40
	Cs-137	3.9E+00	38-40
	U-232	< 2.7E-02	38-40
	U-233/234	2.3E+00	38-40
	U-235/236	1.0E-01	38-40
	U-238	8.1E-01	38-40
	Np-237	< 1.6E-02	38-40
	Pu-238	< 2.3E-02	38-40
	Pu-239/240	6.4E-02	38-40
	Pu-241	< 5.7E-01	38-40
	Am-241	1.3E-01	38-40
	Cm-243/244	< 2.3E-02	38-40
GP7808 (WMA 1, 2008) Depth to Lavery till - 37 ft	C-14	< 2.9E-01	37-39
	Sr-90	8.6E+00	37-39
	Tc-99	< 4.4E-01	37-39
	I-129	< 2.3E-01	37-39
	Cs-137	< 2.2E-02	37-39
	U-232	< 1.3E-02	37-39
	U-233/234	8.2E-01	37-39
	U-235/236	9.2E-02	37-39
	U-238	1.1E+00	37-39
	Np-237	< 2.1E-02	37-39
	Pu-238	< 1.1E-02	37-39

Table C-1. RESRAD Input Parameters

RESRAD Parameter (Units)	Default	Value	Medium	Comment/Reference
C-14 evasion layer thickness in soil (m)	3.00E-01	3.00E-01	All	RESRAD default.
C-14 evasion flux rate from soil (1/sec)	7.00E-07	7.00E-07	All	RESRAD default.
C-12 evasion flux rate from soil (1/sec)	1.00E-10	1.00E-10	All	RESRAD default.
Fraction of grain in beef cattle feed	0.8	0.8	All	RESRAD default.
Fraction of grain in milk cow feed	0.2	0.2	All	RESRAD default.
Storage times of contaminated foodstuff (days)				
Fruits, non-leafy vegetables, and grain	1.40E+01	1.40E+01	SS, SB	RESRAD default.
Leafy vegetables	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Milk	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Meat	2.00E+01	2.00E+01	SS, SB	RESRAD default.
Fish	7.00E+00	7.00E+00	SD	RESRAD default.
Crustacea and mollusks	7.00E+00	7.00E+00	Not used	RESRAD default.
Well water	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Surface water	1.00E+00	1.00E+00	SS, SB	RESRAD default.
Livestock fodder	4.50E+01	4.50E+01	SS, SB	RESRAD default
Radon-related exposure parameters				
Thickness of building foundation (m)	1.50E-01	not used	All	Applicable for Radon exposures only
Bulk density of building foundation (g/cc)	2.40E+00	not used	All	Applicable for Radon exposures only.
Total porosity of cover material	4.00E-01	not used	All	Applicable for Radon exposures only.
Total porosity of building foundation	1.00E-01	not used	All	Applicable for Radon exposures only.
Volumetric water constant of the cover material	5.00E-02	not used	All	Applicable for Radon exposures only.
Volumetric water constant of the foundation	3.00E-02	not used	All	Applicable for Radon exposures only.

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
	Pu-239/240	< 1.5E-02	37-39
	Pu-241	< 4.9E-01	37-39
	Am-241	< 1.7E-02	37-39
	Cm-243/244	< 1.6E-02	37-39
GP8098 (WMA 1, 1998) Depth to Lavery till - 41 ft	C-14	< 8.6E-02	40-42
	Sr-90	1.3E+01	40-42
	Tc-99	< 2.6E-01	40-42
	I-129	< 2.3E-01	40-42
	Cs-137	< 2.2E-02	40-42
	Pu-241	< 2.1E+00	40-42
GP8008 (WMA 1, 2008) Depth to Lavery till - 40 ft	C-14	< 2.8E-01	39-41
	C-14	< 2.8E-01	41-43
	Sr-90	5.3E+00	39-41
	Sr-90	1.4E+00	41-43
	Tc-99	< 3.4E-01	39-41
	Tc-99	< 3.7E-01	41-43
	I-129	< 1.2E-01	39-41
	I-129	< 1.2E-01	41-43
	Cs-137	< 2.3E-02	39-41
	Cs-137	< 2.8E-02	41-43
	U-232	< 1.0E-02	39-41
	U-232	< 1.3E-02	41-43
	U-233/234	5.2E-01	39-41
	U-233/234	1.1E+00	41-43
	U-235/236	3.9E-02	39-41
	U-235/236	1.1E-01	41-43
	U-238	8.2E-01	39-41
	U-238	1.4E+00	41-43
	Np-237	< 1.1E-02	39-41
	Np-237	< 1.2E-02	41-43
	Pu-238	< 1.5E-02	39-41
	Pu-238	< 1.5E-02	41-43
	Pu-239/240	< 1.6E-02	39-41
	Pu-239/240	< 1.5E-02	41-43
	Pu-241	< 4.4E-01	39-41
	Pu-241	< 5.2E-01	41-43
	Am-241	< 1.2E-02	39-41
	Am-241	< 1.5E-02	41-43
	Cm-243/244	< 1.3E-02	39-41
	Cm-243/244	< 1.6E-02	41-43
GP8308 (WMA 1, 2008)	C-14	< 3.5E-01	40-42

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
Depth to Lavery till - 41.5 ft	Sr-90	1.5E+00	40-42
	Tc-99	< 3.6E-01	40-42
	I-129	2.4E-01	40-42
	Cs-137	< 2.7E-02	40-42
	U-232	< 2.4E-02	40-42
	U-233/234	9.8E-01	40-42
	U-235/236	2.2E-01	40-42
	U-238	1.1E+00	40-42
	Np-237	< 1.3E-02	40-42
	Pu-238	< 1.1E-02	40-42
	Pu-239/240	< 1.1E-02	40-42
	Pu-241	< 2.7E-01	40-42
	Am-241	< 1.2E-02	40-42
	Cm-243/244	< 1.8E-02	40-42
GP8698 (WMA 1, 1998) Depth to Lavery till - 39 ft	Sr-90	2.2E+00	39-39.5
	Sr-90	1.0E+00	39.5-40
	Sr-90	3.0E+00	40-40.5
	Sr-90	1.0E+01	40.5-41
	Sr-90	4.1E+01	41-41.5
	Sr-90	3.0E+01	41.5-42
GP10008 (WMA 1, 2008) Depth to Lavery till - 37 ft	C-14	< 3.0E-01	37-39
	Sr-90	6.7E+00	37-39
	Tc-99	< 4.0E-01	37-39
	I-129	< 1.4E-01	37-39
	Cs-137	< 2.7E-02	37-39
	U-232	< 1.3E-02	37-39
	U-233/234	7.6E-01	37-39
	U-235/236	7.5E-02	37-39
	U-238	9.5E-01	37-39
	Np-237	< 1.2E-02	37-39
	Pu-238	< 2.2E-02	37-39
	Pu-239/240	< 1.1E-02	37-39
	Pu-241	< 4.3E-01	37-39
	Am-241	< 1.4E-02	37-39
	Cm-243/244	< 2.3E-02	37-39
GP10108 (WMA 1, 2008) Depth to Lavery till - 33 ft	C-14	< 3.1E-01	32-34
	Sr-90	6.3E-01	32-34
	Tc-99	< 5.4E-01	32-34
	I-129	< 9.1E-02	32-34

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
	Cs-137	< 2.6E-02	32-34
	U-232	< 1.6E-01	32-34
	U-233/234	6.0E-01	32-34
	U-235/236	5.0E-02	32-34
	U-238	7.3E-01	32-34
	Np-237	< 1.0E-02	32-34
	Pu-238	< 9.5E-03	32-34
	Pu-239/240	< 8.8E-03	32-34
	Pu-241	< 4.7E-01	32-34
	Am-241	< 1.1E-02	32-34
	Cm-243/244	< 1.1E-02	32-34
GP10408 (WMA 1, on border of WMA 2) Depth to Lavery till - 24 ft	C-14	< 3.6E-01	24-26
	Sr-90	7.4E+00	24-26
	Tc-99	< 5.1E-01	24-26
	I-129	< 1.1E-01	24-26
	Cs-137	< 5.5E-02	24-26
	U-232	4.1E-02	24-26
	U-233/234	8.8E-01	24-26
	U-235/236	1.4E-01	24-26
	U-238	7.9E-01	24-26
	Np-237	< 6.9E-03	24-26
	Pu-238	< 1.2E-02	24-26
	Pu-239/240	< 1.2E-02	24-26
	Pu-241	< 3.1E-01	24-26
	Am-241	< 1.3E-02	24-26
	Cm-243/244	< 1.4E-02	24-26
BH-05 (WMA 2, 1993), located downgradient of Lagoon 1 Depth to Lavery till - 12 ft	Sr-90	8.5E-01	12-14
	Cs-137	4.5E-01	12-14
	U-232	1.2E-02	12-14
	U-233/234	1.8E-01	12-14
	U-235	< 5.9E-03	12-14
	U-235/236	< 8.3E-03	12-14
	U-238	1.1E-01	12-14
	Pu-238	1.0E-02	12-14
	Pu-239/240	< 5.9E-03	12-14
	Pu-241	< 1.3E+00	12-14
	Am-241	3.0E-02	12-14
BH-07 (WMA 2, 1993) Depth to Lavery till - 13 ft	Sr-90	1.3E-01	12-14
	Cs-137	7.5E-02	12-14

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas[1]

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
	U-232	< 8.7E-03	12-14
	U-233/234	2.2E-01	12-14
	U-235	< 6.6E-03	12-14
	U-235/236	< 7.6E-03	12-14
	U-238	1.5E-01	12-14
	Pu-238	< 4.7E-03	12-14
	Pu-239/240	< 6.2E-03	12-14
	Pu-241	9.5E-01	12-14
	Am-241	< 5.1E-03	12-14
BH-08 (WMA 2, 1993), located downgradient of Lagoon 1 Depth to Lavery till - 11.5 ft	Sr-90	1.8E+02	10-12
	Cs-137	2.5E+02	10-12
	U-232	1.9E+01	10-12
	U-233/234	9.7E+00	10-12
	U-235	3.2E-01	10-12
	U-235/236	5.0E-01	10-12
	U-238	1.3E+01	10-12
	Pu-238	3.9E+00	10-12
	Pu-239/240	7.6E+00	10-12
	Pu-241	2.7E+01	10-12
	Am-241	1.1E+01	10-12
BH-12 (WMA 2, 1993) Depth to Lavery till - 15.5 ft	Sr-90	1.8E-01	14-16
	Cs-137	< 2.2E-02	14-16
	U-232	< 6.0E-03	14-16
	U-233/234	1.1E-01	14-16
	U-235	< 7.0E-03	14-16
	U-235/236	1.3E-02	14-16
	U-238	9.7E-02	14-16
	Pu-238	< 4.9E-03	14-16
	Pu-239/240	< 4.9E-03	14-16
	Pu-241	< 1.0E+00	14-16
	Am-241	< 4.6E-03	14-16
BH-13 (WMA 2, 1993) Depth to Lavery till - 19 ft	Sr-90	1.8E-01	18-20
	Cs-137	2.7E+00	18-20
	U-232	1.6E-02	18-20
	U-233/234	8.5E-02	18-20

Table C-4. Radiological Concentrations from Soil Samples Containing Lavery Till in the WMA 1 and WMA 2 Excavation Areas(1)

Location	Nuclide	Result (pCi/g)	Sample Depth Interval (ft)
	U-235	< 5.1E-03	18-20
	U-235/236	< 8.2E-03	18-20
	U-238	5.3E-02	18-20
	Pu-238	2.4E-02	18-20
	Pu-239/240	2.6E-02	18-20
	Pu-241	< 8.1E-01	18-20
	Am-241	9.5E-02	18-20
BH-14 (WMA 2, 1993) Depth to Lavery till - 15 ft	Sr-90	1.8E+01	14-16
	Cs-137	1.9E+00	14-16
	U-232	2.0E-02	14-16
	U-233/234	1.9E-01	14-16
	U-235	< 7.9E-03	14-16
	U-235/236	< 1.1E-02	14-16
	U-238	2.8E-01	14-16
	Pu-238	1.7E-01	14-16
	Pu-239/240	1.6E-01	14-16
	Pu-241	< 1.1E+00	14-16
	Am-241	1.1E-01	14-16

NOTE: (1) Data are from the 1993 RCRA facility investigation and the other Geoprobe® studies described in Section 4.

2.0 Information Provided in Attachment 1

Other information associated with the dose modeling is provided in Attachment 1. As explained in Section 5, the dose calculations were performed using RESRAD 6.4 and the results were exported to Microsoft Excel for post-processing. Attachment 1 provides:

- RESRAD input files to verify input parameters and model setup,
- RESRAD output files to verify input parameters and results,
- Excel result files containing (1) RESRAD output results (exported from the RESRAD summary report), (2) summaries of data [maximum dose-source ratios (DSRs) and times of maxima], (3) calculation of $DCGL_W$ values from the maximum DSRs, (4) calculation of area factors and $DCGL_{EMC}$ values, and (5) summary of sensitivity results

DCGL development was based on entering unit source concentrations (1pCi/g) for 18 radionuclides into RESRAD to generate DSRs in units of mrem/y per pCi/g (RESRAD output results based on unit concentrations can be interpreted as either the dose or DSR, and the terms are used interchangeably in this document). The individual, peak DSRs are then used to generate DCGLs for each radionuclide based on the following equation:

DCGL (pCi/g) = Dose Limit (mrem/y) / Maximum DSR (mrem/y per pCi/g) (Eq.1)

The dose limit of 25 mrem/y and maximum DSRs were used as the basis for developing the DCGLs. Further details regarding the Attachment 1 files are presented below. Because of the uncertainty in the actual distributions and mixtures of radionuclides in the environmental media, the DCGL for each radionuclide is calculated individually. Following characterization, the working cleanup levels for mixtures can be developed using the sum of fractions method discussed in Chapter 5 of the MARSSIM.

2.1 Input Parameters Tables

The parameters input to the RESRAD model include:

- Base case values for the $DCGL_W$ calculations,
- Modification of source area only for $DCGL_{EMC}$ calculations, and
- Variation of key parameters to evaluate model sensitivity

The Excel file "WV Sensitivity Parameters Table – Rev1.xls" (Table C.5) provides a summary of the following parameters which were varied to evaluate model sensitivity.

- Surface Soil Sources
  - Indoor/outdoor time fraction
  - Source thickness
  - Unsaturated zone thickness
  - Irrigation/well pumping rate
  - Soil/water distribution coefficients
  - Hydraulic conductivity (Vertical/Horizontal)
  - Runoff/Evapotranspiration coefficients/ Infiltration rate
  - Depth of well intake
  - Length of contaminated area parallel to aquifer flow
  - Hydraulic gradient
  - Gamma shielding factor
  - Indoor air filtration factor
  - Mass loading for dust inhalation
  - Depth of roots
  - Food transfer factors
  - Use of mass balance instead of non-dispersion groundwater model
- Subsurface Soil Sources (subsurface soil distributed on the surface):
  - Indoor/outdoor time fraction

- Source thickness
- Unsaturated zone thickness
- Irrigation/well pumping rate
- Soil/water distribution coefficients
- Hydraulic conductivity (Vertical/Horizontal)
- Runoff/Evapotranspiration coefficients/ Infiltration rate
- Gamma shielding factor
- Indoor air filtration factor
- Mass loading for dust inhalation
- Depth of roots
- Food transfer factors

- Stream Bank Sediment sources:
  - Outdoor time fraction
  - Source thickness
  - Unsaturated zone thickness
  - Soil/water distribution coefficients
  - Runoff/Evapotranspiration coefficients/ Infiltration rate
  - Mass loading for dust inhalation
  - Root depth
  - Food transfer factors

These sensitivity parameters were selected based on preliminary model simulations and consideration of parameter priorities presented in Table 4.2 of NUREG-6697, Attachment B (Yu, et al. 2000). The parameters selected for analysis are discussed further below.

Sensitivity parameter values were selected to represent a reasonable range in order to provide bounds on the uncertainty in the DCGL calculations. The basis for particular parameter values are discussed below.

Indoor/Outdoor fraction – varied from 0.45/0.45 to 0.8/0.1 from the base case values of 0.66/0.25. The lower indoor fraction represents equal time indoors and outdoors, while the higher fraction was selected to represent a farmer spending inordinate amounts of time indoors.

Source thickness – for surface soil and sediment, varied from 0.5 to 3m to bound the base case value of 1m with potential thicknesses resulting from remedial activities and to account for potential source erosion uncertainty. For subsurface soil, the source volume was evaluated for three thickness/area configurations to conserve the total amount of excavated material. The source thickness/area was varied from 0.1m/300m^2 to 0.6 m/50 m^2, to bound the base case of 0.3 m/100 m^2. The subsurface source thickness is dependent on the amount of material excavated during well/cistern installation, and depths less than the base case would correspond with a smaller source area for a given excavated volume (assumed to be ~30 m^3).

Unsaturated zone thickness – varied from 1 to 5 m to bound the 2 m base case value with the range possible for the site. The range of results also provides an assessment of potential source erosion uncertainty. The sediment model assumes that there is no unsaturated zone for the stream bank.

Irrigation/well pumping rate - varied from 0.2/2720 to 0.8/8720 (m/y)/(m^3/y) to bound the base case of 0.5/5720 (m/y)/(m^3/y). The irrigation rate and well pump rate are directly related and the range reflects changes in crop irrigation only. For all cases, the assumed household and livestock water ingestion rates were held constant. This parameter is applicable to soil exposure only, not to sediment exposure

Soil/Water distribution coefficients – varied for each radionuclide based on site-specific data where available. If a range of site-specific distribution coefficients was not available (as was the case for the majority of radionuclides), values were selected from the literature to provide a bound on the base case uncertainty. The conceptual models assume the sand and gravel unit is representative of the three RESRAD zones (contaminated, unsaturated and saturated), except that in the SB and SD analyses, the contaminated zone is assumed to be represented by the Lavery till.

Hydraulic conductivity – for the contaminated and unsaturated zone, varied the vertical conductivity from 63 m/y (2.0E-04 cm/s) to 220 m/y (7.0E-03 cm/s) to bound the base case value of 140 m/y (4.4E-04 cm/s) which is the average for the sand and gravel unit divided by 10 to account for anisotropy (DEIS Appendix E, Table E-3). Similarly for the saturated zone, the horizontal conductivity was varied from 630 to 2200 m/y from the base case of 1400 m/y. The conceptual model assumes the sand and gravel unit is representative of the unsaturated and saturated zone. Values were selected to ensure that the site-specific groundwater conceptual model assumptions (that the well captures the entire width of the plume, but that there is some vertical dilution within the water table) were maintained.

Runoff/evapotranspiration coefficient – varied from 0.41/0.6 to 0.41/0.9 to bound the base case of 0.41/0.78. The base case was selected to achieve infiltration rate of 0.26m/y which corresponds to the calibrated three dimensional groundwater model used in the Decommissioning EIS (DEIS Appendix E). The upper and lower bounds are assumed values for these parameters that maintain the site-specific groundwater dilution assumptions.

Depth of well intake – applicable to non-dispersion model only (surface soil base case). Varied from 3 to 10 m to bound the base case value of 5m. The lower bound represents the minimum for a 1 m contaminated thickness and 2 m unsaturated zone. The upper bound represents the upper end of observed thickness of the saturated zone on site. The upper and lower bound values for these parameters also maintain the site-specific groundwater dilution assumptions.

Length of contaminated area parallel to aquifer flow - applicable to non-dispersion model only (surface soil base case). Varied from 50 m to 200 m to bound the base case of 165 m. Base value was selected to achieve site-specific groundwater dilution factor of 0.2. Values were selected to ensure that the site-specific groundwater conceptual model assumptions (that the well captures the entire width of the plume, but that there is some vertical dilution within the water table) were maintained.

Hydraulic gradient – applicable to non-dispersion model only (surface soil base case). Varied from 0.02 to 0.04 to bound the base case of 0.03.

Gamma shielding factor – applicable to the surface and subsurface soil models. Varied from 0.17 to 0.51 to bound base case of 0.273, representing a range of possible home construction methods.

Indoor air filtration factor – applicable to the surface and subsurface soil models. Varied from 0.4 to 0.75 to evaluate less conservative assumptions than the base case value of 1.0.

Mass loading for inhalation – applicable to all models. For the soil models, the range of 4.5E-06 to 2.5E-05 bound the base case of 1.5E-05 g/m^3. For sediment, the base case of 3.2E-06 is bounded by the range of 1E-06 to 1E-05.

Root depth – applicable to all models. Varied from 0.3 to 3.0 from the base case of 0.9 m to reflect a range of potential crops.

Food transfer factors – varied from the constituent specific base cases by increasing and decreasing each parameter an order of magnitude.

Groundwater model – the surface soil base case non-dispersion model is varied to provide results for the mass balance model for comparison. The RESRAD User's Manual suggests the non-dispersion model for areas >1,000 m^2 (Yu et al. 2001, p.E-18).

2.2 RESRAD Input Files

The following RESRAD input files are provided to allow verification of input parameters and reproduction of the output files and summary graphics:

- $DCGL_W$ input files:
  - WV Surface – 10k Base.RAD (Surface soil source of 10,000 m^2)
  - WV Subsurface – 100 Base.RAD (Subsurface material as a surface source of 100 m^2)
  - WV Sediment - 1k Base.RAD (Sediment source of 1,000 m^2)
- $DCGL_{EMC}$ input files (varying only source area from $DCGL_W$ files):
  - Surface Soil Source

- WV Surface - 5k EMC.RAD (5,000 m^2 source)
- WV Surface - 1k EMC.RAD (1,000 m^2 source)
- WV Surface - 500 EMC.RAD (500 m^2 source)
- WV Surface - 100 EMC.RAD (100 m^2 source)
- WV Surface - 50 EMC.RAD (50 m^2 source)
- WV Surface - 10 EMC.RAD (10 m^2 source)
- WV Surface - 5 EMC.RAD (5 m^2 source)
- WV Surface - 1 EMC.RAD (1 m^2 source)

– Subsurface Source

- WV Subsurface - 50 EMC.RAD (50 m^2 source)
- WV Subsurface - 10 EMC.RAD (10 m^2 source)
- WV Subsurface - 5 EMC.RAD (5 m^2 source)
- WV Subsurface - 1 EMC.RAD (1 m^2 source)

– Stream Bank Sediment Source

- WV Sediment - 500 EMC.RAD (500 m^2 source)
- WV Sediment - 100 EMC.RAD (100 m^2 source)
- WV Sediment - 50 EMC.RAD (50 m^2 source)
- WV Sediment - 10 EMC.RAD (10 m^2 source)
- WV Sediment - 5 EMC.RAD (5 m^2 source)
- WV Sediment - 1 EMC.RAD (1 m^2 source)

Note: sediment source area width was maintained at 3 m when varying areas to represent assumed stream bank configuration.

- Sensitivity analysis input files:

– Surface soil Source

- WV Surface - SENS1.RAD (decreased indoor fraction)
- WV Surface - SENS2.RAD (increased indoor fraction)
- WV Surface - SENS3.RAD (decreased source layer thickness)
- WV Surface - SENS4.RAD (increased source layer thickness)
- WV Surface - SENS5.RAD (decreased unsaturated zone thickness)
- WV Surface - SENS6.RAD (increased unsaturated zone thickness)
- WV Surface - SENS7.RAD (decreased well pumping rate)

- WV Surface - SENS8.RAD (increased well pumping rate)
- WV Surface - SENS9.RAD (decreased K_d values)
- WV Surface - SENS10.RAD (increased K_d values)
- WV Surface - SENS11.RAD (decreased K_d value)
- WV Surface - SENS12.RAD (increased K_d value)
- WV Surface - SENS13.RAD (decreased runoff/evapotranspiration)
- WV Surface - SENS14.RAD (increased runoff/evapotranspiration)
- WV Surface - SENS15.RAD (decreased well intake depth)
- WV Surface - SENS16.RAD (increased well intake depth)
- WV Surface - SENS17.RAD (decreased length parallel to flow)
- WV Surface - SENS18.RAD (increased length parallel to flow)
- WV Surface – SENS19.RAD (decreased hydraulic gradient)
- WV Surface – SENS20.RAD (increased hydraulic gradient)
- WV Surface – SENS21.RAD (decreased gamma shielding factor)
- WV Surface – SENS22.RAD (increased gamma shielding factor)
- WV Surface – SENS23.RAD (decreased indoor air filtration factor)
- WV Surface – SENS24.RAD (increased indoor air filtration factor)
- WV Surface – SENS25.RAD (decreased mass loading factor for inhalation)
- WV Surface – SENS26.RAD (increased mass loading factor for inhalation)
- WV Surface – SENS27.RAD (decreased root depth)
- WV Surface – SENS28.RAD (increased root depth)
- WV Surface - SENS29.RAD (decreased food transfer factors)
- WV Surface – SENS30.RAD (increased food transfer factors)
- WV Surface - SENS31.RAD (mass balance groundwater model)

– Subsurface Soil Source

- WV Subsurface - SENS1.RAD (decreased indoor fraction)
- WV Subsurface - SENS2.RAD (increased indoor fraction)
- WV Subsurface - SENS3.RAD (decreased source layer thickness)
- WV Subsurface - SENS4.RAD (increased source layer thickness)
- WV Subsurface - SENS5.RAD (decreased unsaturated zone thickness)
- WV Subsurface - SENS6.RAD (increased unsaturated zone thickness)

- WV Subsurface - SENS7.RAD (decreased well pumping rate)
- WV Subsurface - SENS8.RAD (increased well pumping rate)
- WV Subsurface - SENS9.RAD (decreased K_d values)
- WV Subsurface - SENS10.RAD (increased K_d values)
- WV Subsurface - SENS11.RAD (decreased K_h value)
- WV Subsurface - SENS12.RAD (increased K_h value)
- WV Subsurface - SENS13.RAD (decreased runoff/evapotranspiration)
- WV Subsurface - SENS14.RAD (increased runoff/evapotranspiration)
- WV Subsurface – SENS15.RAD (decreased gamma shielding factor)
- WV Subsurface – SENS16.RAD (increased gamma shielding factor)
- WV Subsurface – SENS17.RAD (decreased indoor air filtration factor)
- WV Subsurface – SENS18.RAD (increased indoor air filtration factor)
- WV Subsurface – SENS19.RAD (decreased mass loading factor for inhalation)
- WV Subsurface – SENS20.RAD (increased mass loading factor for inhalation)
- WV Subsurface – SENS21.RAD (decreased root depth)
- WV Subsurface – SENS22.RAD (increased root depth)
- WV Subsurface - SENS23.RAD (decreased food transfer factors)
- WV Subsurface – SENS24.RAD (increased food transfer factors)

– Sediment Source

- WV Sediment - SENS1.RAD (decreased outdoor fraction)
- WV Sediment - SENS2.RAD (increased outdoor fraction)
- WV Sediment - SENS3.RAD (decreased source layer thickness)
- WV Sediment - SENS4.RAD (increased source layer thickness)
- WV Sediment - SENS5.RAD (increased unsaturated zone thickness)
- WV Sediment - SENS6.RAD (largest unsaturated zone thickness)
- WV Sediment - SENS7.RAD (decreased K_d values)
- WV Sediment - SENS8.RAD (increased K_d values)
- WV Sediment – SENS9.RAD (decreased runoff/evapotranspiration)
- WV Sediment – SENS10.RAD (increased runoff/evapotranspiration)
- WV Sediment - SENS11.RAD (decreased root depth)

- WV Sediment – SENS12.RAD (increased root depth)
- WV Sediment - SENS13.RAD (decreased food transfer factors)
- WV Sediment – SENS14.RAD (increased food transfer factors)

The dose results from the above input files were the basis for calculation of $DCGL_W$ and $DCGL_{EMC}$ values. The DCGLs were calculated in Excel spreadsheets, based on exported data from the RESRAD summary output report. The following section describes the RESRAD output files, which are provided for informational purposes.

2.3 RESRAD Output Files

The RESRAD output files are provided to allow review of results without running the simulations. For the $DCGL_W$ simulations, summary, detailed, daughter, and concentration reports are included in the QA files. The summary report is also available for the $DCGL_{EMC}$ simulations. As indicated in the previous section, DCGL calculations are based on data exported from the RESRAD summary output report. RESRAD output files generated are as follows;

- $DCGL_W$ output files:
  - Surface Soil Source
    - WV Surface – 10k Base_sum.TXT (summary report)
    - WV Surface – 10k Base_ det.TXT (detailed report)
    - WV Surface – 10k Base _dtr.TXT (daughter report)
    - WV Surface – 10k Base _conc.TXT (concentration report)
  - Subsurface Soil Source
    - WV Subsurface – 100 Base_sum.TXT (summary report)
    - WV Subsurface – 100 Base_det.TXT (detailed report)
    - WV Subsurface – 100 Base_dtr.TXT (daughter report)
    - WV Subsurface – 100 Base_conc.TXT (concentration report)
  - Sediment Source
    - WV Sediment – 1k Base_sum.TXT (summary report)
    - WV Sediment – 1k Base_det.TXT (detailed report)
    - WV Sediment – 1k Base_dtr.TXT (daughter report)
    - WV Sediment – 1k Base_conc.TXT (concentration report)
- $DCGL_{EMC}$ output files (varying only source area from $DCGL_w$ files):
  - Surface Soil Source
    - WV Surface - 5k EMC_sum.TXT (5,000 m^2 source)
    - WV Surface - 1k EMC_ sum.TXT (1,000 m^2 source)

    - WV Surface - 500 EMC_sum.TXT (500 m^2 source)
    - WV Surface - 100 EMC_sum.TXT (100 m^2 source)
    - WV Surface - 50 EMC_sum.TXT (50 m^2 source)
    - WV Surface - 10 EMC_sum.TXT (10 m^2 source)
    - WV Surface - 5 EMC_sum.TXT (5 m^2 source)
    - WV Surface - 1 EMC_sum.TXT (1 m^2 source)
  - Subsurface Soil Source
    - WV Subsurface - 50 EMC_sum.TXT (50 m^2 source)
    - WV Subsurface - 10 EMC_sum.TXT (10 m^2 source)
    - WV Subsurface - 5 EMC_sum.TXT (5 m^2 source)
    - WV Subsurface - 1 EMC_sum.TXT (1 m^2 source)
  - Sediment Source
    - WV Sediment - 500 EMC_sum.TXT (500 m^2 source)
    - WV Sediment - 100 EMC_sum.TXT (100 m^2 source)
    - WV Sediment - 50 EMC_sum.TXT (50 m^2 source)
    - WV Sediment - 10 EMC_sum.TXT (10 m^2 source)
    - WV Sediment - 5 EMC_sum.TXT (5 m^2 source)
    - WV Sediment - 1 EMC_sum.TXT (1 m^2 source)
- Sensitivity analysis output files:
  - Surface Soil Source
    - WV Surface - SENS1_sum.TXT (decreased indoor fraction)
    - WV Surface - SENS2_sum.TXT (increased indoor fraction)
    - WV Surface - SENS3_sum.TXT (decreased source layer thickness)
    - WV Surface - SENS4_sum.TXT (increased source layer thickness)
    - WV Surface - SENS5_sum.TXT (decreased unsaturated zone thickness)
    - WV Surface - SENS6_sum.TXT (increased unsaturated zone thickness)
    - WV Surface - SENS7_sum.TXT (decreased well pumping rate)
    - WV Surface - SENS8_sum.TXT (increased well pumping rate)
    - WV Surface - SENS9_sum.TXT (decreased K_d values)
    - WV Surface - SENS10_sum.TXT (increased K_d values)
    - WV Surface - SENS11_sum.TXT (decreased K value)

- WV Surface - SENS12_sum.TXT (increased K value)
- WV Surface - SENS13_sum.TXT (decreased runoff/evapotranspiration)
- WV Surface - SENS14_sum.TXT (increased runoff/evapotranspiration)
- WV Surface - SENS15_sum.TXT (decreased well intake depth)
- WV Surface - SENS16_sum.TXT (increased well intake depth)
- WV Surface - SENS17_sum.TXT (decreased length parallel to flow)
- WV Surface - SENS18_sum.TXT (increased length parallel to flow)
- WV Surface - SENS19_sum.TXT (decreased hydraulic gradient)
- WV Surface - SENS20_sum.TXT (increased hydraulic gradient)
- WV Surface - SENS21_sum.TXT (decreased gamma shielding factor)
- WV Surface - SENS22_sum.TXT (increased gamma shielding factor)
- WV Surface - SENS23_sum.TXT (decreased indoor air filtration factor)
- WV Surface - SENS24_sum.TXT (increased indoor air filtration factor)
- WV Surface - SENS25_sum.TXT (decreased mass loading factor for inhalation)
- WV Surface - SENS26_sum.TXT (increased mass loading factor for inhalation)
- WV Surface - SENS27_sum.TXT (decreased root depth)
- WV Surface - SENS28_sum.TXT (increased root depth)
- WV Surface - SENS29_sum.TXT (decreased food transfer factors)
- WV Surface - SENS30_sum.TXT (increased food transfer factors)
- WV Surface - SENS31_sum.TXT (mass balance groundwater model)

– Subsurface Soil Source
  - WV Subsurface - SENS1_sum.TXT (decreased indoor fraction)
  - WV Subsurface - SENS2_sum.TXT (increased indoor fraction)
  - WV Subsurface - SENS3_sum.TXT (decreased source layer thickness)
  - WV Subsurface - SENS4_sum.TXT (increased source layer thickness)
  - WV Subsurface - SENS5_sum.TXT (decreased unsaturated zone thickness)
  - WV Subsurface - SENS6_sum.TXT (increased unsaturated zone thickness)
  - WV Subsurface - SENS7_sum.TXT (decreased well pumping rate)

- WV Subsurface - SENS8_sum.TXT (increased well pumping rate)
- WV Subsurface - SENS9_sum.TXT (decreased K_d values)
- WV Subsurface - SENS10_sum.TXT (increased K_d values)
- WV Subsurface - SENS11_sum.TXT (decreased K value)
- WV Subsurface - SENS12_sum.TXT (increased K value)
- WV Subsurface - SENS13_sum.TXT (decreased runoff/evapotranspiration)
- WV Subsurface - SENS14_sum.TXT (increased runoff/evapotranspiration)
- WV Subsurface – SENS15.RAD (decreased gamma shielding factor)
- WV Subsurface – SENS16.RAD (increased gamma shielding factor)
- WV Subsurface – SENS17.RAD (decreased indoor air filtration factor)
- WV Subsurface – SENS18.RAD (increased indoor air filtration factor)
- WV Subsurface – SENS19.RAD (decreased mass loading factor for inhalation)
- WV Subsurface – SENS20.RAD (increased mass loading factor for inhalation)
- WV Subsurface – SENS21.RAD (decreased root depth)
- WV Subsurface – SENS22.RAD (increased root depth)
- WV Subsurface - SENS23_sum.TXT (decreased food transfer factors)
- WV Subsurface – SENS24_sum.TXT (increased food transfer factors)

– Stream Bank Sediment Source

- WV Sediment - SENS1_sum.TXT (decreased outdoor fraction)
- WV Sediment - SENS2_sum.TXT (increased outdoor fraction)
- WV Sediment - SENS3_sum.TXT (decreased source layer thickness)
- WV Sediment - SENS4_sum.TXT (increased source layer thickness)
- WV Sediment - SENS5_sum.TXT (increased unsaturated zone thickness)
- WV Sediment - SENS6_sum.TXT (largest unsaturated zone thickness)
- WV Sediment - SENS7_sum.TXT (decreased K_d values)
- WV Sediment - SENS8_sum.TXT (increased K_d values)
- WV Sediment – SENS9_sum.TXT (decreased runoff/evapotranspiration)
- WV Sediment – SENS10_sum.TXT (increased runoff/evapotranspiration)
- WV Sediment - SENS11_sum.TXT (decreased root depth)
- WV Sediment – SENS12_sum.TXT (increased root depth)

- WV Sediment - SENS13_sum.TXT (decreased food transfer factors)
- WV Sediment – SENS14_sum.TXT (increased food transfer factors)

The following section presents the methods used to generate DCGLs from the RESRAD model output previously described.

2.4 Excel Result Files

The outputs of the RESRAD simulations (the DSR for each of the radionuclides at various future times) were exported to Excel from the RESRAD summary output report (specifically, the DSR values in the table presented at the bottom of page 45 of each RESRAD summary report). For each simulation, dose results were exported for each of the 18 radionuclides, which includes the simulation year and dose (for that year) for each radionuclide. These have been generated for $DCGL_W$, $DCGL_{EMC}$, and sensitivity simulations for each source media and isotope. The peak dose for each radionuclide is identified and used as the basis for the DCGL calculation as follows;

$DCGL_w$ = Dose Limit / Peak radionuclide DSR (Eq.2)

Specific Excel result files are described below.

2.4.1 Surface Soil DCGLs

Surface soil DCGLs were calculated to conform with the annual dose limit for large areas ($DCGL_W$), smaller areas of elevated concentrations ($DCGL_{EMC}$), and to evaluate the sensitivity of the model to variations in specific parameters. The files associated with these calculations are described below.

Surface Soil $DCGL_W$ Values

The soil $DCGL_W$ values were calculated based on resident farmer exposure for a 10,000 m^2 source area and results from the RESRAD summary output report are presented in the Excel file "WVDP Surface DCGLs_Rev1.XLS" in the sheet "Base" (Table C-6). The input files for the surface soil evaluation are presented in Section 2.2. These surface soil $DCGL_W$ values are the basis for calculation of surface soil area factors and $DCGL_{EMC}$ values.

Surface Soil $DCGL_{EMC}$ Values

The $DCGL_W$ values calculated on the Excel summary sheet previously discussed serve as the base case for subsequent $DCGL_{EMC}$ development; $DCGL_{EMC}$ values are based on varying the source area from the 10,000 m^2 value used for the $DCGL_W$ as discussed in Chapter 5 of the MARSSIM. The Excel file "WV Surface DCGLs_Rev1.XLS" has sheets for each of the source areas used to generate the $DCGL_{EMC}$ (Tables C-7 to C-14). The sheet "Summary" in the Excel file "WV Surface DCGLs_Rev1.XLS" summarizes the $DCGL_{EMC}$ (Table C-15) and Soil Area Factors (TableC-16) for each of the 18 radionuclides and selected source areas (ranging from 1 to 10,000 m^2).

Surface Soil $DCGL_W$ Sensitivity Analysis

The surface soil $DCGL_W$ sensitivity to key parameters was assessed by varying the input values for specific parameters and tabulating the results. The Excel file "WV Surface DCGL Sensitivity_Rev1.XLS" contains the DSRs and DCGLs for each of 18 radionuclides from the RESRAD summary report output for each of the sensitivity simulations. Results of each run are in sheets SENS1 through SENS31 (Tables C-17 to C-47). Also included in the file are a summarization of the calculated DCGLs (Table C-48) and a summary of the percent change from the base case (Table C-49) for each of the sensitivity runs (also presented in Table 5-9). Table C-50 below presents a summary of the surface soil sensitivity results.

Table C-50 Summary of Surface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Indoor/Outdoor Fraction	1	-32%	-22%	U-232	0%	Cm-244
	2	21%	0%	C-14 I-129 Np-237 Tc-99 U-234	28%	U-232
Source Thickness	3	-50%	9%	U-232	231%	C-14
	4	200%	-57%	C-14	0%	Am-241 Cm-243 Cm-244 Cs-137 Pu-239 Pu-240
Unsaturated Zone Thickness	5	-50%	-10%	Tc-99	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232
	6	150%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232	12%	U-235
Irrigation/Pump Rate	7	-57%	-1%	U-232	65%	I-129
	8	70%	-36%	I-129	1%	U-232
Soil/Water Distribution Coefficients (K_d)	9	lower	-99%	Pu-239	2%	C-14
	10	higher	-3%	U-232	867%	U-234

Table C-50 Summary of Surface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Hydraulic Conductivity (K_h)	**11**	-55%	-36%	I-129	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232
	12	57%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232	40%	I-129
Runoff/Evaporation Coefficient	**13**	-23%	-29%	U-234	2%	U-232
	14	15%	-2%	U-232	81%	Np-237
Depth of Well Intake	**15**	-40%	-40%	I-129	0.0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232
	16	100%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232	99%	I-129
Length Parallel to Aquifer Flow	**17**	-30%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232	30%	I-129
	18	21%	-12%	I-129	0.0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Pu-241 Sr-90 U-232
Hydraulic Gradient	**19**	-33%	-23%	I-129	0.0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232

Table C-50 Summary of Surface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
	20	33%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232	23.3%	I-129
Gamma Shielding Factor	**21**	-38%	0%	no change	0.0%	no change
	22	87%	-24%	U-232	0.0%	Np-237
Indoor Dust Filtration Factor	**23**	-60%	0%	C-14 Cs-137 I-129 Np-237 Sr-90 Tc-99 U-234	0.6%	Cm-244
	24	-25%	0%	C-14 Cs-137 I-129 Np-237 Sr-90 Tc-99 U-233 U-234	0.3%	Pu-241
Dust Loading Factor	**25**	-70%	0%	C-14 Cs-137 I-129 Np-237 Sr-90 Tc-99 U-234	1.0%	Cm-244
	26	67%	-1%	Cm-244	0.0%	C-14 Cs-137 I-129 Sr-90 Tc-99 U-235 U-238
Root Depth	**27**	-67%	0%	no change	0.0%	no change
	28	233%	0%	I-129	199.7%	C-14
Food Transfer Factors	**29**	lower	-38%	U-235	875%	Sr-90
	30	higher	-97%	Sr-90	-14%	Np-237
Mass Balance Model	**31**	NA	-67%	U-234	0.0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Sr-90 U-232

2.4.2 Subsurface Soil (Lavery till) DCGLs

To evaluate an excavation that would expose the resident farmer to subsurface material, DCGLs were developed to address this potential future source. It is possible that a farmer may install a cistern or well to access groundwater, and in the excavation process, contaminated Lavery till material from the subsurface may be spread on the ground surface and be a source of exposure. The following subsections discuss the files associated with this calculation.

Subsurface Soil $DCGL_W$ Values

The subsurface $DCGL_w$ values are presented in the Excel file "WV Subsurface DCGLs_Rev1.XLS" in the sheet "Base" (TableC-51), and are based on the RESRAD input file "WV Subsurface – 100 Base.RAD" and results from page 45 of the RESRAD summary output report "WV Subsurface – 100 Base.TXT".

For calculation of the distributed soil, $DCGL_W$ values for a 100 m^2 source area of Lavery till on the surface were increased by a factor of 10 to account for an assumed blending of residually contaminated till with clean overlying soil in the excavation process (assuming 0.5 m of till for each 5 m of total excavation). This factor is applied to the final RESRAD generated DCGLw as presented in the overall summary table (See "DCGL Summary" section).

The input files for the subsurface soil evaluation are discussed in Section 2.2. These Lavery Till $DCGL_W$ values are used as the basis for calculation of the subsurface soil $DCGL_{EMC}$ values and for sensitivity analysis as described below.

Subsurface Soil $DCGL_{EMC}$ Values

Calculation of $DCGL_{EMC}$ values for the subsurface Lavery till was based on the base case area of 100 m^2 used for development of the $DCGL_W$ values (after accounting for blending). The $DCGL_{EMC}$ values were generated by varying the source area. The RESRAD output for these simulations are presented and summarized in the Excel file "WV Subsurface DCGLs_Rev1.XLS". The results for each source area are presented in individual sheets (Tables C-52 to C-55). The sheet "Summary" presents the $DCGL_{EMC}$ values (Table C-56) and subsurface soil area factors (Table C-57) for each of the 18 radionuclides and selected source areas (ranging from 1 to 100 m^2).

Subsurface Soil Sensitivity Analysis

The subsurface soil $DCGL_W$ sensitivity to key parameters was assessed by varying the input values for specific parameters and tabulating the results. The Excel file "WV Subsurface DCGL Sensitivity_Rev1.XLS" contains the DSRs and DCGLs for each of 18 radionuclides from the RESRAD summary report output for each of the sensitivity simulations. Results of each run are in sheets SENS1 through SENS24 (Tables C-58 to C-81). Also included in the file is a summarization of the calculated DCGLs (Table C-82) and a summary of the percent change from the base case (Table C-83) for each of the sensitivity runs (also presented in Table 5-10). Table C-84 below presents a summary of the subsurface soil sensitivity results.

Table C-84 Summary of Subsurface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Indoor/Outdoor Fraction	1	-32%	-25%	Cs-137	0.5%	Pu-238
	2	21%	0%	C-14	35%	U-232

Table C-84 Summary of Subsurface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Source Thickness	3	-67%	-65%	U-238	204%	Tc-99
	4	233%	-33%	C-14	98%	U-234
Unsaturated Zone Thickness	5	-50%	-2%	Np-237	58%	U-238
	6	150%	0%	Am-241 C-14 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240 Pu-241 Sr-90 Tc-99 U-232 U-235	2218%	U-234
Irrigation/Pump Rate	7	-57%	-39%	I-129	57%	U-238
	8	70%	0%	Am-241 Cm-243 Cm-244 Pu-238 Pu-239 Pu-240	20%	I-129
Soil/Water Distribution Coefficients (Kd)	9	lower	-99%	Pu-239	116%	U-232
	10	higher	-20%	U-232	2168%	U-234
Hydraulic Conductivity (K_h)	11	-55%	0%	No change	0%	No change
	12	57%	0%	No change	0%	No change
Runoff/Evaporation Coefficient	13	-23%	-44%	U-234	61%	U-238
	14	15%	-11%	U-232	117%	U-234
Indoor Gamma Shielding Factor	15	-38%	0%	U-238	19%	U-232
	16	87%	-27%	Cs-137	1%	U-238
Indoor Dust Filtration Factor	17	-60%	0%	U-238	13%	Cm-244
	18	-25%	0%	C-14 Cs-137 I-129 Np-237 Sr-90 Tc-99 U-233 U-234 U-238	5%	Cm-244
Inhalation Dust Loading	19	-70%	0%	U-238	22%	Cm-244
	20	67%	-15%	Cm-244	0%	C-14 Cs-137 I-129 Np-237 Sr-90 Tc-99
Root Depth	21	-67%	-67%	Tc-99	1%	U-233
	22	233%	0%	U-238	227%	Tc-99

Table C-84 Summary of Subsurface Soil DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Food Transfer Factors	23	lower	-0.1%	U-238	582%	Tc-99
	24	higher	-93%	Sr-90	0%	U-234

2.4.3 Streambed Sediment DCGLs

DCGLs were also developed to account for potential exposure associated with stream bank sediment (including direct pathways, fish ingestion, and venison ingestion). The stream bank rather than the streambed was the focus of the analysis because the recreationist is assumed to be in direct contact with the stream bank, and not the stream bed.

Files associated with the calculations are discussed below and presented in the files attachment.

Streambed Sediment $DCGL_W$ Values

The sediment $DCGL_W$ values were calculated based on a recreationist exposure for a 1,000 m^2 source area and results from the RESRAD summary output report are presented in the Excel file "WVDP Surface DCGLs_Rev1.XLS" in the sheet "Base" (Table C-85). The input files for the sediment evaluation are discussed in Section 2.2. These sediment $DCGL_W$ values are the basis for calculation of Sediment Area Factors and $DCGL_{EMC}$ values.

Streambed Sediment $DCGL_{EMC}$ Values

The $DCGL_W$ values calculated on the Excel summary sheet previously discussed serve as the base case for subsequent $DCGL_{EMC}$ development, which are based on varying the source area from the 1,000 m^2 value used for the $DCGL_W$ values. The RESRAD output for these simulations are presented and summarized in the Excel file "WV Sediment DCGLs_Rev1.XLS". The results for each source area are presented in individual sheets (Tables C-86 to C-91). The sheet "Summary" presents the $DCGL_{EMC}$ values (Table C-92) and sediment area factors (Table C-93) the 18 radionuclides and selected source areas (ranging from 1 to 1,000 m^2).

Streambed Sediment Sensitivity Analysis

The sediment $DCGL_W$ sensitivity to key parameters was assessed by varying the input values and tabulating the results. The Excel file "WV Sediment DCGL Sensitivity_Rev1.XLS" contains the RESRAD summary report output for each of the sensitivity simulations. Results of each run are in sheets SENS1 through SENS14 (Tables C-94 to C-107). Also included in the file is a summarization of the calculated DCGLs (Table C-108) and percent change from the base case (Table C-109) for each of the sensitivity runs (also presented in Table 5-11). Table C-110 below presents a summary of the sediment sensitivity analysis.

Table C-110 Summary of Sediment DCGL Sensitivity Analysis

Parameter	Run	Change in Sensitivity Parameter	Minimum		Maximum	
			Change	Nuclide(s)	Change	Nuclide(s)
Outdoor Fraction	1	-50%	0%	C-14	98%	Cm-243
	2	100%	-50%	Cm-243	0%	C-14
Source Thickness	3	-50%	0%	Am-241 Cm-243	157%	C-14
	4	200%	-52%	C-14	0%	Am-241 Cm-243 Cm-244 Pu-238 Pu-239 Pu-240
Soil/Water Distribution Coefficients (Kd)	5	lower	-91%	Pu-239	26%	U-232
	6	higher	-65%	U-233	52%	U-234
Runoff/Evaporation Coefficient	7	-23%	0%	Am-241 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240	4%	U-232
	8	15%	-3%	I-129	0%	Am-241 Cm-243 Cm-244 Cs-137 Pu-238 Pu-239 Pu-240
Mass Loading for Inhalation	9	-70%	0%	Np-237	1%	Cm-244
	10	67%	-4%	Cm-244	0%	C-14 Cs-137 I-129 Sr-90
Root Depth	11	-67%	0%	no change	0%	no change
	12	233%	0%	Cm-243 U-232 U-235	50%	Sr-90
Food Transfer Factors	13	lower	1%	Cm-243	852%	Sr-90
	14	higher	-98%	Sr-90	-11%	Cm-243

Consideration of Subsurface Lavery till as a Continuing Source to Groundwater

An evaluation of the potential for the Lavery till to act as a continuing source to groundwater was conducted and concluded the following (See section 3.7 and Table 3-19 of the body of the plan):

- A well screened entirely in the Lavery Till could not produce enough groundwater for the resident farmer scenario.

- A well screened in both the sand and gravel unit and Lavery till would likely pump mostly groundwater from the sand and gravel unit due to the much higher relative hydraulic conductivity and subsequent development of preferential flowpaths, and contain highly diluted contributions of contaminated groundwater from the Lavery Till.
- Advective movement from the Lavery Till to the overlying Sand and Gravel Unit is unlikely considering the vertical downward groundwater gradient.
- Diffusive movement from the Lavery Till to the Sand and Gravel Unit is unlikely considering the very low diffusion coefficients for radionuclides.
- Migration vertically upward from the till through the aquifer and into a well that is screened several meters above the till is unlikely.

DCGL Summary

The Excel File "WV DCGL Summary Tables_Rev1.xls" (Table C-111) summarizes the DCGLs for the surface soil, subsurface soil and sediment, and presents $DCGL_W$ and $DCGL_{EMC}$ for a 1 m^2 area (also presented in Table 5-8).

Integrated Dose Assessment

In order to account for potential exposure to multiple sources, a combined dose assessment was conducted. The assessment considered which combination of exposures was likely, and concluded that the resident farmer may also spend time in recreation along the stream bank.

The Excel File "WV DCGL Summary Tables_Rev1.xls" presents the calculated $DCGL_W$ and $DCGL_{EMC}$ values when considering the combined doses from surface soil (90% x 25 mrem/y = 22.5 mrem/y) and sediment sources (10% x 25 mrem/y = 2.5 mrem/y), which are summarized in Tables C-112, C-113, and C-114 (also presented in Table 5-13). In the same Excel file, Table C-115 presents the cleanup goals to be used as the criteria for the remediation activities. Values in Table C-115 represent the $DCGL_W$ and $DCGL_{EMC}$ values for surface soil and sediment (considering the combined dose), as well as cleanup goals for subsurface soil (which are 50 percent of the $DCGL_W$ and $DCGL_{EMC}$ values adjusted to provide a margin of confidence/safety factor for excavation success for each radionuclide (also presented in Table 5-12).

Evaluation of Institutional Control Period

After Phase 1 remediation there is assumed to be a 30 year period of institutional controls (associated with storage of the HLW canisters until 2041), prior to site access by the critical receptors. During this period, radionuclide inventories will be subject to decay and leaching, which will result in site concentrations at the time of exposure that are reduced from the initial concentrations left at the time of remediation. With the exception of Sr-90 and Cs-137, DCGLs were developed neglecting the effects of decay and leaching from the source during the 30 year institutional control period. The ratio of the initial concentrations in soil to the RESRAD generated soil concentration after a 30 year simulation was used to provide an evaluation of uncertainty associated with the assumption of neglecting decay/leaching. A RESRAD simulation was run using the surface soil base case without irrigation, well pumping, or plant/animal/human uptake from soil (see RESRAD input file "WV SURFACE – 10k – LCH_DCAY.RAD" and output file "WV SURFACE – 10k – LCH_DCAY_sum.txt". The RESRAD concentration output summary file (see page 8 of the file "WV SURFACE – 10k – LCH_DCAY_conc.txt") provides the soil concentration at year 30, which is then related to the initial soil concentration to quantify the effects of leaching/decay (see Excel file "WV Institutional Control.xls" Table C-116).

Evaluation of Potential Dose Drivers and Sensitivity Parameters

The impact of specific sensitivity parameters is dependent on the radionuclides that contribute the majority of the dose to the receptor. Due to limited site data, a full evaluation cannot be performed until additional site characterization data is available. In the interim, Table C-117 presented below identifies the primary dose pathways for each radionuclide and indicates which of the sensitivity parameters have significant impact on the dose. This evaluation will be refined as additional site data are collected.

Table C-117 Summary of Primary Dose Pathways

Nuclide	Primary Pathway for Dose	Key Parameters(1)	Year of Peak Dose
Surface Soil			
Am-241	Water independent (plant uptake)	plant transfer factors, source thickness	0.00E+00
C-14	Water independent (plant uptake)	source thickness	0.00E+00
Cm-243	External Exposure, Water independent (plant uptake)	plant transfer factors, source thickness	0.00E+00
Cm-244	Water independent (plant uptake)	plant transfer factors, source thickness	0.00E+00
Cs-137	External Exposure	outdoor fraction, plant transfer factors	0.00E+00
I-129	Water dependent (water ingestion, plant and milk uptake)	K, Kd, runoff/evap coefficients, well intake depth, groundwater model	9.21E+00
Np-237	Water dependent (water ingestion, plant uptake)	hydraulic conductivity, Kd, runoff/evap coefficients, well intake depth, groundwater model	2.01E+01
Pu-238	Water independent (plant uptake)	Kd, plant transfer factors	0.00E+00
Pu-239	Water independent (plant uptake)	Kd, plant transfer factors	0.00E+00
Pu-240	Water independent (plant uptake)	Kd, plant transfer factors	0.00E+00
Pu-241	Water independent (plant uptake)	Kd, plant transfer factors	5.52E+01
Sr-90	Water independent (plant uptake)	source thickness, plant transfer factors, Kd, groundwater model	0.00E+00
Tc-99	Water dependent (water ingestion, plant uptake), independent (plant uptake)	source thickness, well intake depth, plant transfer factors, length parallel to flow, Kd, K, groundwater model	1.54E+00
U-232	External Exposure	outdoor fraction, plant transfer factors	8.17E+00

Table C-117 Summary of Primary Dose Pathways

Nuclide	Primary Pathway for Dose	Key Parameters(1)	Year of Peak Dose
U-233	Water dependent (water ingestion, plant uptake)	irrigation/pump rate, Kd, runoff/evap coefficients, groundwater model	2.96E+02
U-234	Water dependent (water ingestion, plant uptake)	irrigation/pump rate, Kd, runoff/evap coefficients, groundwater model	2.96E+02
U-235	Water dependent (water ingestion, plant uptake)	irrigation/pump rate, Kd, runoff/evap coefficients, groundwater model	2.96E+02
U-238	Water dependent (water ingestion, plant uptake)	irrigation/pump rate, Kd, runoff/evap coefficients, groundwater model	2.96E+02
Subsurface Soil			
Am-241	External Exposure, Water independent (plant uptake)	source thickness, plant transfer factors	0.00E+00
C-14	Water independent (plant uptake)	source thickness	0.00E+00
Cm-243	External Exposure	outdoor fraction, source thickness	0.00E+00
Cm-244	Water independent (plant uptake)	source thickness, plant transfer factors	0.00E+00
Cs-137	External Exposure	outdoor fraction, source thickness	0.00E+00
I-129	Water dependent (water ingestion)	source thickness, irrigation/pump rate, Kd, runoff/evap coefficients	6.32E+00
Np-237	Water independent (soil ingestion, plant uptake)	source thickness, Kd, runoff/evap coefficients	1.37E+01
Pu-238	Water independent (plant uptake, soil ingestion and inhalation)	source thickness, Kd, plant transfer factors	0.00E+00
Pu-239	Water independent (plant uptake, soil ingestion and inhalation)	source thickness, Kd, plant transfer factors	0.00E+00
Pu-240	Water independent (plant uptake, soil ingestion and inhalation)	source thickness, Kd, plant transfer factors	0.00E+00
Pu-241	Water independent (plant uptake)	source thickness, Kd, plant transfer factors	6.14E+01
Sr-90	Water independent (plant uptake)	source thickness, Kd, plant transfer factors	0.00E+00
Tc-99	Water dependent (plant uptake)	source thickness, plant transfer factors	0.00E+00
U-232	External Exposure	outdoor fraction, source thickness	4.60E+00
U-233	Water dependent (water ingestion)	Kd, runoff/evap coefficients	1.97E+02
U-234	Water dependent (water ingestion)	Kd, runoff/evap coefficients	1.97E+02
U-235	External Exposure	outdoor fraction, source thickness, Kd	0.00E+00
U-238	Water dependent (water ingestion)	source thickness, irrigation/pump rate, Kd, runoff/evap coefficients, groundwater model	1.98E+02
Sediment			
Am-241	External Exposure, Soil ingestion, Water	outdoor fraction	0.00E+00

Table C-117 Summary of Primary Dose Pathways

Nuclide	Primary Pathway for Dose	Key Parameters(1)	Year of Peak Dose
	independent (meat uptake)		
C-14	Water independent (meat uptake), Water dependent (fish uptake)	source thickness, unsaturated thickness, Kd	0.00E+00
Cm-243	External Exposure	outdoor fraction	0.00E+00
Cm-244	Soil ingestion	outdoor fraction	0.00E+00
Cs-137	External Exposure	outdoor fraction	0.00E+00
I-129	Water independent (meat uptake), Water dependent (fish uptake)	unsaturated thickness, Kd, fish transfer factors	0.00E+00
Np-237	External Exposure, Water independent (meat uptake), Water dependent (fish uptake)	unsaturated thickness, Kd, fish transfer factors	0.00E+00
Pu-238	Water independent (meat uptake), Soil ingestion	outdoor fraction, Kd	0.00E+00
Pu-239	Water independent (meat uptake), Soil ingestion	outdoor fraction, Kd	2.82E-01
Pu-240	Water independent (meat uptake), Soil ingestion	outdoor fraction, Kd	1.18E-01
Pu-241	External Exposure, Water independent (meat uptake), Soil ingestion	outdoor fraction, Kd	5.78E+01
Sr-90	Water independent (meat uptake)	plant and fish transfer factors	0.00E+00
Tc-99	Water independent (meat uptake)	Kd, plant and fish transfer factors	0.00E+00
U-232	External Exposure	outdoor fraction, Kd	7.72E+00
U-233	External Exposure, Water independent (meat uptake), Water dependent (fish uptake)	outdoor fraction, unsaturated thickness, Kd, plant and fish transfer factors	1.56E-01
U-234	Water independent (meat uptake), Water dependent (fish uptake)	outdoor fraction, unsaturated thickness, Kd, fish transfer factors	1.81E-01
U-235	External Exposure	outdoor fraction	0.00E+00
U-238	External Exposure	outdoor fraction, fish transfer factors	0.00E+00

NOTE: (1) Key parameters identified in sensitivity runs. As additional site characterization data becomes available, the radionuclides driving dose and parameters most critical to calculating dose can be used to refine the sensitivity analysis.

3.0 References

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Attachments

1. Electronic Files Described in Section 2 (provided separately)
2. Electronic File Described in Section 1 (provided separately)