Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&D Project

Prepared for:

Westinghouse Electric Company
Hematite Facility
Festus, Missouri 63028

September 15, 2003

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Site-Specific Soil Parameters
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RESRAD Parameter Table for ^{99}Tc

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	179	W(i)	pCi/L	24.9	1590	7	Lognormal	1
Area of Contaminated Zone	6432	AREA	m^2	5146	7718	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.00005	VCZ	m/yr	0.00004	0.00006	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	562	UW	m^3/yr	450	674	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{99}Tc

1 ^{99}Tc ground-water concentration data were taken from piezometer GWE-6, which was sampled by Gateway Environmental and analyzed by ABB in September 1996. This information was referenced in Table 3-3, "*Investigation to Determine the Source of ^{99}TC in Groundwater Monitoring Wells 17 and 17B.*" Figure 1 shows the former location of GWE-6 and Appendix A contains a copy of Table 3-3. The low and high values of the uncertainty range correspond to concentrations from WS-14 and GWE-4, respectively.

2 ^{99}Tc data does not exist for soil. Therefore, LBG assumes the contaminated zone is based on operations where ^{99}Tc may have been stored or disposed. This includes the former ring storage area and the evaporation ponds, located immediately south of the existing structures. This assumption is based on information provided on page 15 of the "*Remedial Investigation/Feasibility Study (RI/FS) Work Plan, Revision 0,*" dated May 9, 2003. Figure 2 shows the Area of Contamination boundary for ^{99}Tc and Appendix B contains a copy of page 15. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a lack of soil data for ^{99}Tc, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 95 percent of the area of contamination is covered with impervious material, the default value was multiplied by .05 to

give a value of 0.00005 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the

values for NSSSC and DSCC as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSCC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (1.59 acres) were used for pastureland, approximately 4 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended

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RESRAD Parameter Table for ^{235}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	13.4	W(i)	pCi/L	0	60.6	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{235}U

1 ^{235}U ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in August 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (November 1998).

2 Only sparse ^{235}U data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{235}U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{235}U. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data

set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{228}Ac

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
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Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Ac

1 ^{228}Ac ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Ac data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Ac. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{228}Ac, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information

from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{212}Bi

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	1.49	W(i)	pCi/L	0	1.49	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{212}Bi

1 ^{212}Bi ground-water concentration data was taken from piezometer MW-23, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-23 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to the recommended value (1.49; May 1999).

2 Only sparse ^{212}Bi data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{212}Bi. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{212}Bi, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information

from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{212}Pb

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	31.8	W(i)	pCi/L	0	78.4	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{212}Pb

1 ^{212}Pb ground-water concentration data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in February 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-23 (February 1999).

2 Only sparse ^{212}Pb data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{212}Pb. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{212}Pb, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information

from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{208}Tl

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	8.3	W(i)	pCi/L	0	12.3	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{208}Tl

1 ^{208}Tl ground-water concentration data was taken from piezometer MW-17B, which was sampled by Leggette, Brashears & Graham, Inc. in February 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-17B and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-22 (August 1999).

2 Only sparse ^{208}Tl data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving radioactive materials occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{208}Tl. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{208}Tl, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

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13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information

from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{234}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	213	W(i)	pCi/L	0	238	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{234}U

1 ^{234}U ground-water concentration data does not exist. However ^{234}Th (a Parent isotope of ^{234}U) ground-water data does exist. If we assume that ^{234}U is in 100% equilibrium with ^{234}Th we can use the same data. ^{234}Th data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in August 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (February 1999).

2 Only sparse ^{234}U data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{234}U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{234}U. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{234}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{238}U

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	213	W(i)	pCi/L	0	238	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
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Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
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Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
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range are associated with the lowest and highest values in Table 13.1.

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entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{237}Np

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
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Groundwater Concentration	0	W(i)	pCi/L	0	1.00E+20	NA	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
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Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
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Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{237}Np

1 ^{237}Np ground-water data does not exist, and it is not in a decay series where known concentrations can be used in equilibrium. Therefore, the RESRAD default value (0 pci/L) will be used. Low and high values will also correspond to default values.

2 No ^{237}Np data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{237}Np. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Since no soil data exists for ^{237}Np, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April

1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*,"

November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{239}Pu

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	0	W(i)	pCi/L	0	1.00E+20	NA	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{239}Pu

1 ^{239}Pu ground-water data does not exist, and it is not in a decay series where known concentrations can be used in equilibrium. Therefore, the RESRAD default value (0 pci/L) will be used. Low and high values will also correspond to default values.

2 No ^{239}Pu data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving U occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{239}Pu. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Since no soil data exists for ^{239}Pu, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data*

Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty

range values are not expected to be more than 20 percent above or below the recommended value.

RESRAD Parameter Table for ^{232}Th

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{232}Th

1 ^{232}Th ground-water concentration data does not exist. However ^{228}Ac (a daughter of ^{232}Th) ground-water data does exist. If we assume that ^{232}Th is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{232}Th data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{232}Th occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{232}Th. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference

data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing,*" prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The example scenario assumes each head of cattle

will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of*

Controlled Grazing" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{228}Ra

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
Saturated Zone Effective Porosity	0.29	EPSZ	0.xx	0.281	0.425	NA	Normal	12
Saturated Zone Field Capacity	0.17	FCSZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Ra

1 ^{228}Ra ground-water concentration data does not exist. However ^{228}Ac (a daughter of ^{228}Ra) ground-water data does exist. If we assume that ^{228}Ra is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Ra data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{228}Ra occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Ra. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

4 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. The source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high uncertainty range values for the Length Parallel to Aquifer are not expected to be more than 20 percent above or below the recommended value.

5 Taken from an average of dry density calculations from work performed by Fitch, University of Missouri – Rolla, 1998, presented in "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999, and Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference

data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

6 Jefferson County does not have a published soil survey which typically provide values for erosion rates. Therefore, the default value (0.001 m/yr) provided in Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993, was used as a starting point. Since approximately 70 percent of the area of contamination is covered with impervious material, the default value was multiplied by .30 to give a value of 0.0003 m/yr. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

7 From Shannon and Wilson, (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

9 Shannon and Wilson (Appendix B of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" prepared by LBG in March 1999) performed permeability tests on numerous soil samples. The average vertical permeability (hydraulic conductivity; K) for each sample was determined by averaging the last three permeability readings (telephone communication with Mr. Chris Groves, Vice-President, Shannon and Wilson on August 13, 2003). Once averages were calculated for each sample, an average of the entire data set was determined. The vertical hydraulic conductivity test data and a table developed to show the average K per sample, and the average K for the data set are provided in Appendix D. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

10 Based on the default value for silty clay provided in Table 13.1, in "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. A copy of Table 13.1 is provided in Appendix F. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 13.1.

11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in 1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the

entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{228}Th

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
Length Parallel to Aquifer	291	LCZPAQ	m	233	349	NA	Bounded Normal	4
Density of Contaminated Zone	1.69	DENSCZ	g/cm^3	1.39	2.11	28	Normal	5
Contaminated Zone Erosion Rate	0.0003	VCZ	m/yr	0.00024	0.00036	NA	Bounded Normal	6
Contaminated Zone Total Porosity	0.45	TPCZ	0.xx	0.41	0.483	13	Normal	7
Contaminated Zone Field Capacity	0.17	FCCZ	0.xx	0.01	0.2	NA	Bounded Normal	8
Contaminated Zone Hydraulic Conductivity	14.56	HCCZ	m/yr	1.38E-03	1.45E+02	13	Lognormal	9
Contaminated Zone b Parameter	10.40	BCZ	unitless	4.05	11.4	NA	Lognormal	10
Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
Saturated Zone Total Porosity	0.45	TPSZ	0.xx	0.41	0.483	13	Normal	7
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Saturated Zone Hydraulic Conductivity	169.58	HCSZ	m/yr	1.56E+01	8.51E+01	12	Lognormal	13
Saturated Zone Hydraulic Gradient	0.015	HGWT	unitless	0.013	0.018	NA	Bounded Lognormal	14
Saturated Zone b Parameter	10.40	BSZ	unitless	4.05	11.4	NA	Lognormal	10
Water Table Drop Rate	0.00	VWT	m/yr	NA	NA	NA	None Recommended	15
Well Pump Intake Depth	9.41	DWIBWT	m	5.4	11.7	10	Bounded Normal	16
Well Pumping Rate	913	UW	m^3/yr	730	1096	NA	Bounded Normal	17

REFERENCE FOOTNOTES for ^{228}Th

1 ^{228}Th ground-water concentration data does not exist. However ^{228}Ac (a parent of ^{228}Th) ground-water data does exist. If we assume that ^{228}Th is in 100% equilibrium with ^{228}Ac, we can use the same data. ^{228}Ac data was taken from piezometer MW-32, which was sampled by Leggette, Brashears & Graham, Inc. in May 1999. This information was referenced in Table 7, "*Fourth Sampling Event Report in Conjunction with the Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*", prepared by LBG in November 1999. Figure 1 shows the location of MW-32 and Appendix A contains a copy of Table 7. The low value of the uncertainty range corresponds to the numerous non-detections during the four quarterly sampling events, and the high value corresponds to concentrations from WS-27 (August 1999).

2 Only sparse ^{228}Th data exists for soil. LBG assumes the Area of Contaminated Zone is where operations involving ^{228}Th occurred. Therefore, the Area of Contamination is defined by the following: Missouri State Highway P to the northwest, the Northeast Site Creek to the northeast, the fenceline to the southeast, and the Site Pond/Creek to the southwest. The northern limits include the Health Physics building and Red Room Roof Burial area, which are in close proximity to the highway. The eastern limits include the burial area, which is located between the plant and the Northeast Site Creek. The south fence line is just northwest of the railway easement. The western limits of extend to the Site Pond/Creek to encompass the location of the cistern/burn pit and red room roof burial area. Figure 4 shows the Area of Contamination for ^{228}Th. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

3 Due to a sparse amount of soil data for ^{235}U, the RESRAD default value was chosen, based on Table 1.3 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. Appendix C contains a copy of Table 1.3. The low value of the uncertainty range is based on the lower bounds value in Table 1.3. The high value of the uncertainty range is the maximum depth of the overburden.

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8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil*," April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

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15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

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entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

Site-Specific Soil Parameters
Westinghouse Former Fuel Cycle Facility D&&D Project

RESRAD Parameter Table for ^{224}Ra

Parameter	Recommended Value	RESRAD Code Designation	Units	Uncertainty Range			Probabilistic Function	Reference
				Low Value	High Value	Number of Samples		
Groundwater Concentration	29.3	W(i)	pCi/L	0	41.8	12	Lognormal	1
Area of Contaminated Zone	77458	AREA	m^2	61966	92950	NA	Normal	2
Thickness of Contaminated Zone	2	THICKO	m	1.00E-10	11.74	NA	Bounded Lognormal	3
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Watershed Area	998939	WAREA	m^2	988950	1008928	NA	Bounded Normal	11
Density of Saturated Zone	1.69	DENSAQ	g/cm^3	1.39	2.11	28	Normal	5
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REFERENCE FOOTNOTES for ^{224}Ra

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8 Derived using Formula 4.4 on page 28 of "*Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil,*" April 1993. The value for total porosity was taken from the average of Shannon and Wilson data (0.446; see footnote 7 above) and the value for effective porosity was based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes,*" November 2000. A copy of page 28, the completed formula, and Table 3.3-1 are provided in Appendix E. The low value of the uncertainty range cannot be zero (thus 0.01 was chosen), and the high value is derived by using the highest total porosity and effective porosity values in the calculation.

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11 The areal extent of the Watershed Area is defined on Figure 3. The low and high uncertainty range values are not expected to be more than 1 percent above or below the recommended value.

12 The effective porosity value is based on a default value for silty clay in Table 3.3-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000. A copy of Table 3.3-1 is provided in Appendix E. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 3.3-1.

13 The average horizontal hydraulic conductivity value was calculated using an average of the values for near-surface silt, silty-clay (NSSSC) and deep silty-clay, clay (DSCC) as determined in Table 2 of "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999). Appendix D includes a table with these values showing how the value was derived. It also includes a copy of the reference data. The low and high values for the uncertainty range are associated with the lowest and highest values from the data set.

14 Figure 1 shows the ground-water flow direction and gradient, and length of contaminated zone. Source of Figure 1 is from "*Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization*" performed by LBG in March 1999. The low and high values of the uncertainty range correspond to the lowest and highest gradient values from the LBG quarterly sampling reports.

15 Because the overburden aquifer is not used as a source of drinking water or for irrigation purposes, no net loss of ground water is expected to occur. Therefore, the value for the Water Table Drop Rate is zero. Low and high values of the uncertainty range are not applicable.

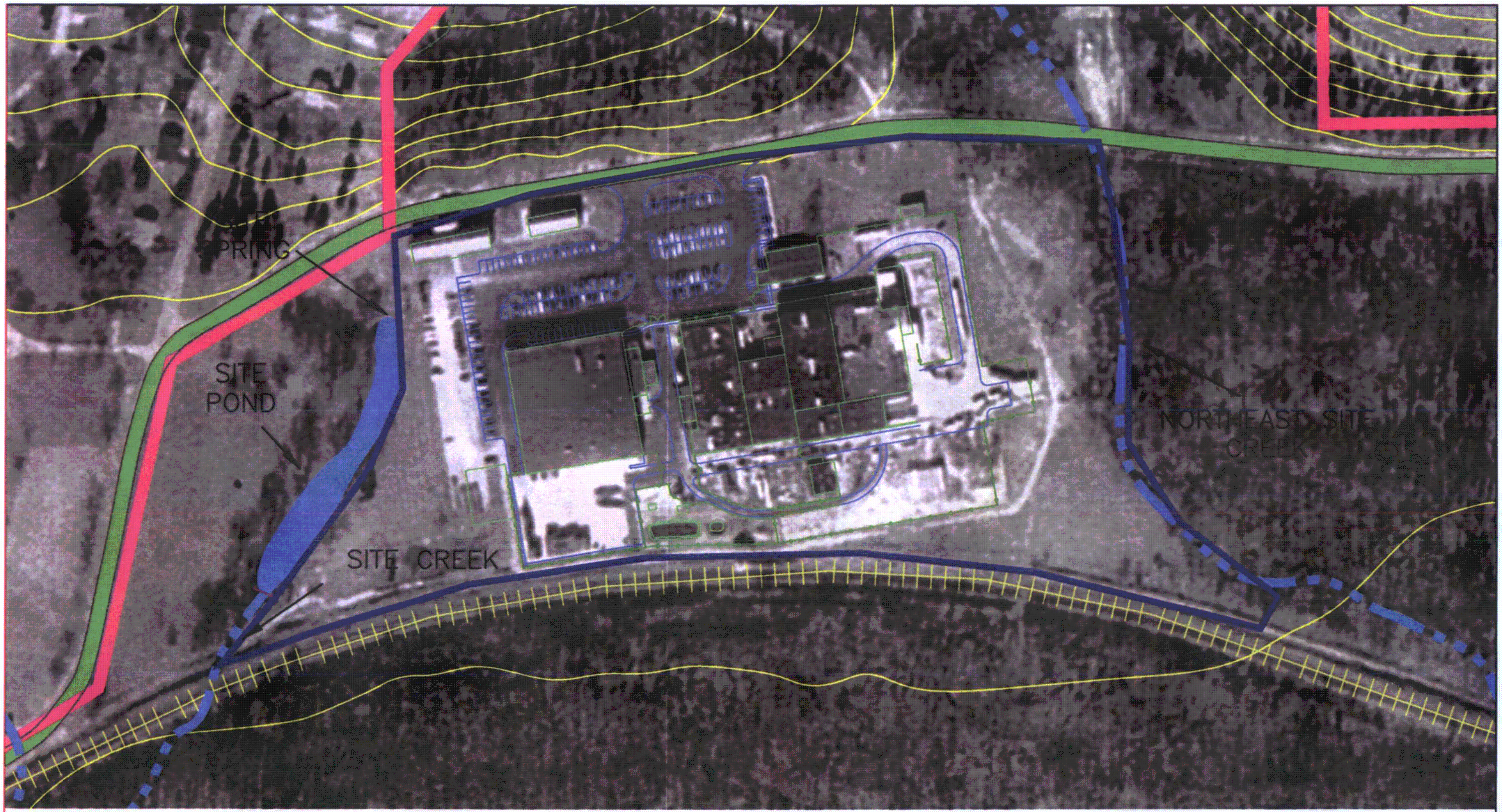
16 The Pump Intake Depth would be near the bottom of the DSCC, which would be approximately two feet above bedrock at the Site. The bottom of the screen depth of all DSSC wells was averaged and two feet was subtracted from that value. Table 5 from the RI/FS work plan was used to estimated the bottom of the wells, a copy of which is included in Appendix G. A table showing how the average was derived is also provided. The low and high values for the uncertainty range are associated with the lowest and highest values in Table 5.

17 Table 3.10-1 of "*Development of Probabilistic RESRAD 6.0 and RESRAD-Build 3.0 Computer Codes*," November 2000 provides a basis for determining the well pumping rate. The example scenario assumes a household of 4 adults, each requiring 225 liters of water per day. Agricultural parcels in this part of Missouri are typically not irrigated, so pumping rates for irrigation have not been provided. Water consumption for livestock is included in this parameter. Based on "*Principles of Controlled Grazing*," prepared by David W. Pratt in

1993, 2 head of cattle per acre on remote ranges or non-irrigated pasture is common. If the entire contaminated zone (19.14 acres) were used for pastureland, approximately 10 head of cattle would require drinking water needs. The

example scenario assumes each head of cattle will require 160 liters of Water per day. A calculation provided in Appendix H shows annual well pumping rate required for this scenario. A copy of Table 3.10-1 and pertinent information from "*Principles of Controlled Grazing*" are also provided. The low and high uncertainty range values are not expected to be more than 20 percent above or below the recommended value.

FIGURES



APPROXIMATE PROPERTY BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
10-FOOT CONTOUR LINE
FENCE LINE
AREA OF CONTAMINATED ZONE

N

0 150
FEET

SOURCES:
DIGITAL ORTHOPHOTO: USGS, MARCH 1996
DIGITAL ELEVATION MODEL: USGS, JANUARY, 1964
BORING LOCATIONS: BURDINE, 1998-1999
PROPERTY BOUNDARY: ZAHNER & ASSOC., MAY, 2000

DATE	REVISED

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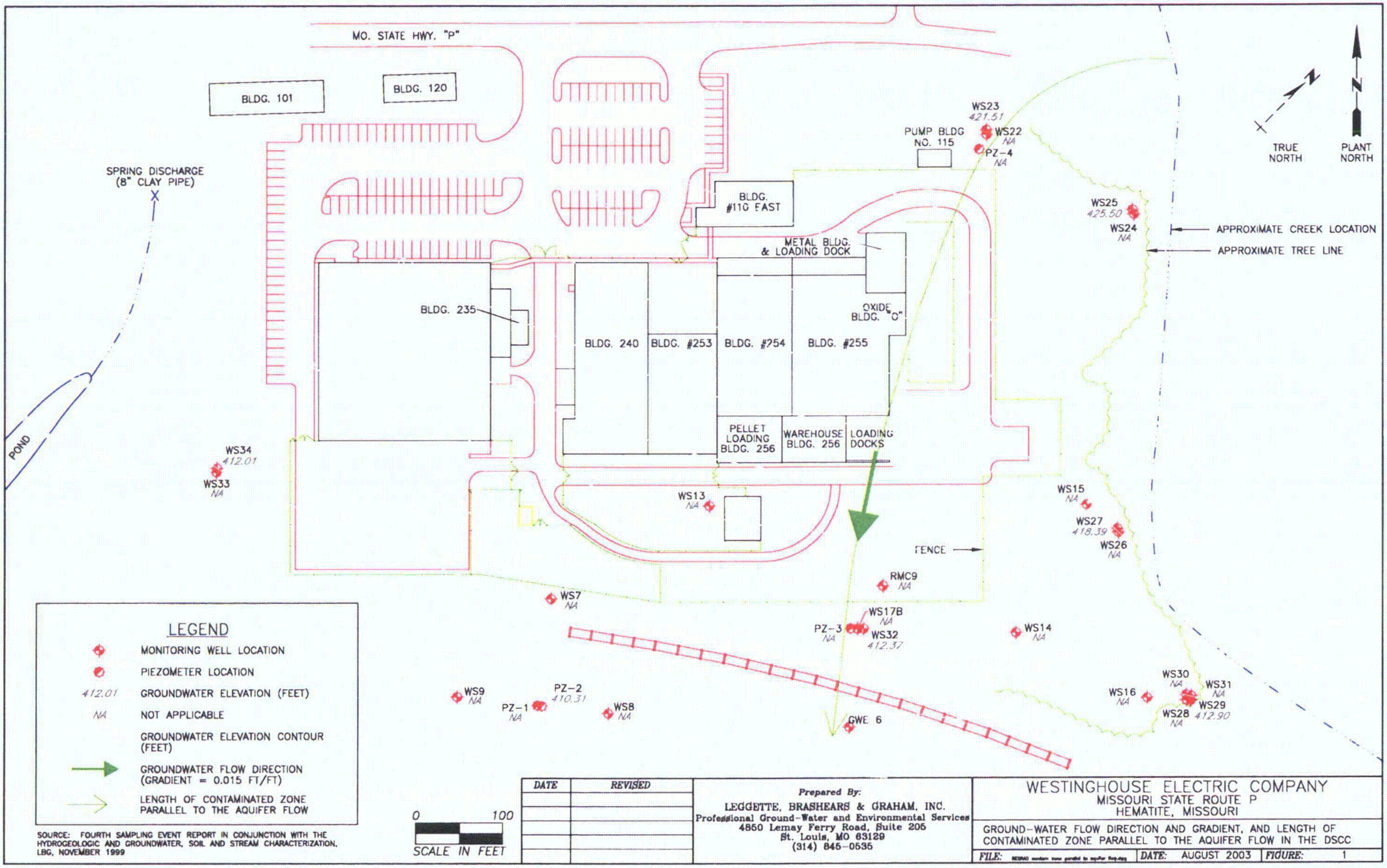
HEMATITE, MISSOURI

AREA OF CONTAMINATED ZONE -- U-235, Ac-228, Bi-212, Pb-212, Tl-208

FILE: | DATE: AUGUST 2003 | FIGURE: 4


MO. STATE HWY. "P"
BLDG. 101
BLDG. 120
SPRING DISCHARGE
(8" CLAY PIPE)
POND
PUMP BLDG
NO. 115
WS23
421.51
WS22
NA
PZ-4
NA
TRUE
NORTH
PLANT
NORTH
WS25
425.50
WS24
NA
APPROXIMATE CREEK LOCATION
APPROXIMATE TREE LINE
BLDG.
#110 EAST
METAL BLDG.
& LOADING DOCK
BLDG. 235
OXIDE
BLDG. "C"
BLDG. 240
BLDG. #253
BLDG. #254
BLDG. #255
PELLET
LOADING
BLDG. 256
WAREHOUSE
BLDG. 256
LOADING
DOCKS
WS34
412.01
WS33
NA
WS13
NA
WS15
NA
WS27
418.39
WS26
NA
FENCE
RMC9
NA
WS7
NA
WS17B
NA
PZ-3
NA
WS32
412.37
WS14
NA
WS30
NA
WS31
NA
WS16
NA
WS29
412.90
WS28
NA
WS9
NA
PZ-2
410.31
PZ-1
NA
WS8
NA
GWE 6
LEGEND
MONITORING WELL LOCATION
PIEZOMETER LOCATION
412.01 GROUNDWATER ELEVATION (FEET)
NA NOT APPLICABLE
GROUNDWATER ELEVATION CONTOUR (FEET)
GROUNDWATER FLOW DIRECTION (GRADIENT = 0.015 FT/FT)
LENGTH OF CONTAMINATED ZONE PARALLEL TO THE AQUIFER FLOW
SOURCE: FOURTH SAMPLING EVENT REPORT IN CONJUNCTION WITH THE HYDROGEOLOGIC AND GROUNDWATER, SOIL AND STREAM CHARACTERIZATION, LBG, NOVEMBER 1999
0 100
SCALE IN FEET
DATE
REVISED
Prepared By:
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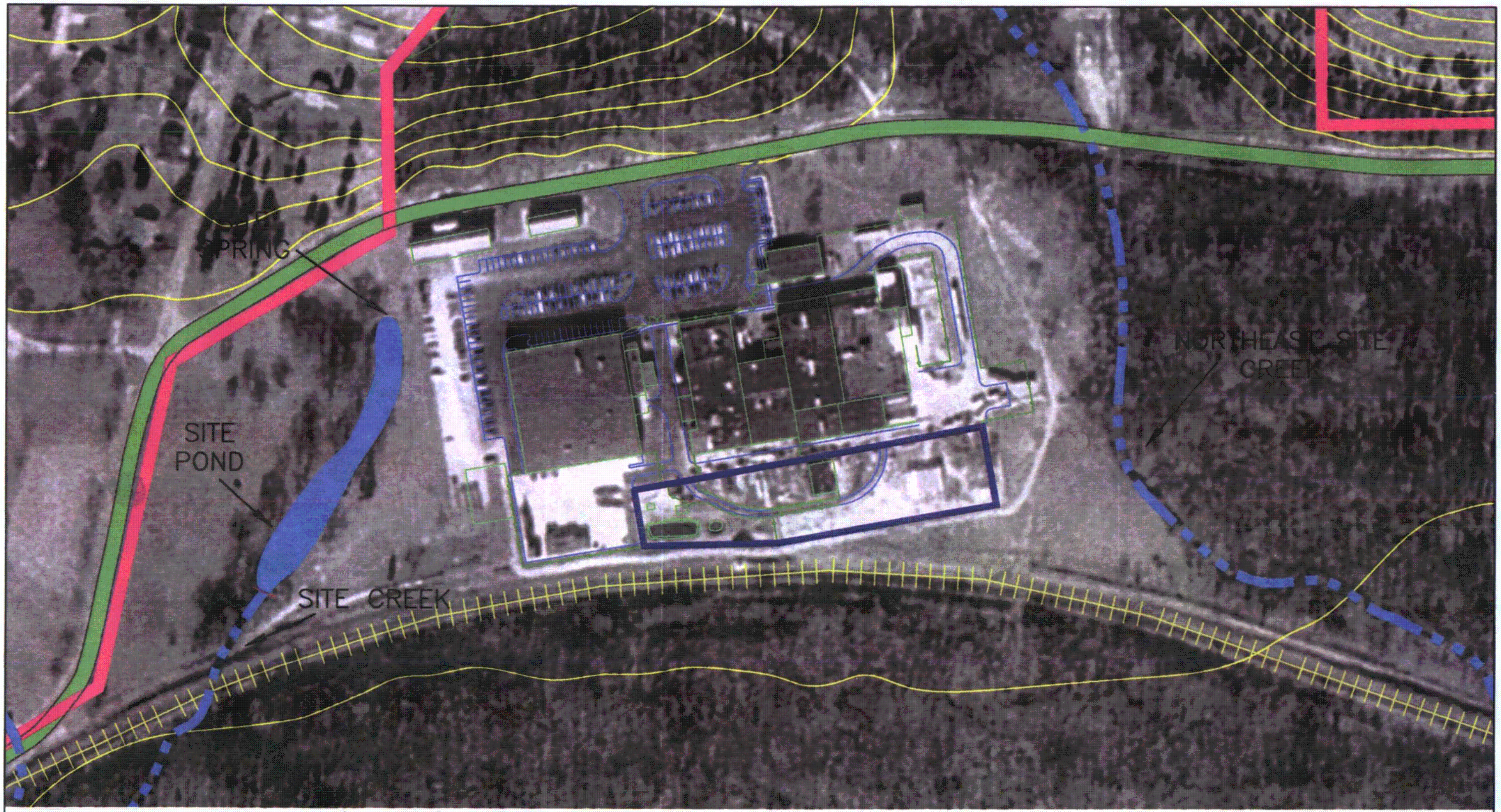
WESTINGHOUSE ELECTRIC COMPANY
MISSOURI STATE ROUTE P
HEMATITE, MISSOURI
GROUND-WATER FLOW DIRECTION AND GRADIENT, AND LENGTH OF CONTAMINATED ZONE PARALLEL TO THE AQUIFER FLOW IN THE DSCC
FILE:
DATE: AUGUST 2003
FIGURE: 1



APPROXIMATE PROPERTY BOUNDARY
PERENNIAL STREAM
INTERMITTENT STREAM
10-FOOT CONTOUR LINE
FENCE LINE
AREA OF CONTAMINATED ZONE

N

0 150
FEET

SOURCES:

DIGITAL ORTHOPHOTO: USGS, MARCH 1996
DIGITAL ELEVATION MODEL: USGS, JANUARY, 1964
BORING LOCATIONS: BURDINE, 1998-1999
PROPERTY BOUNDARY: ZAHNER & ASSOC., MAY, 2000

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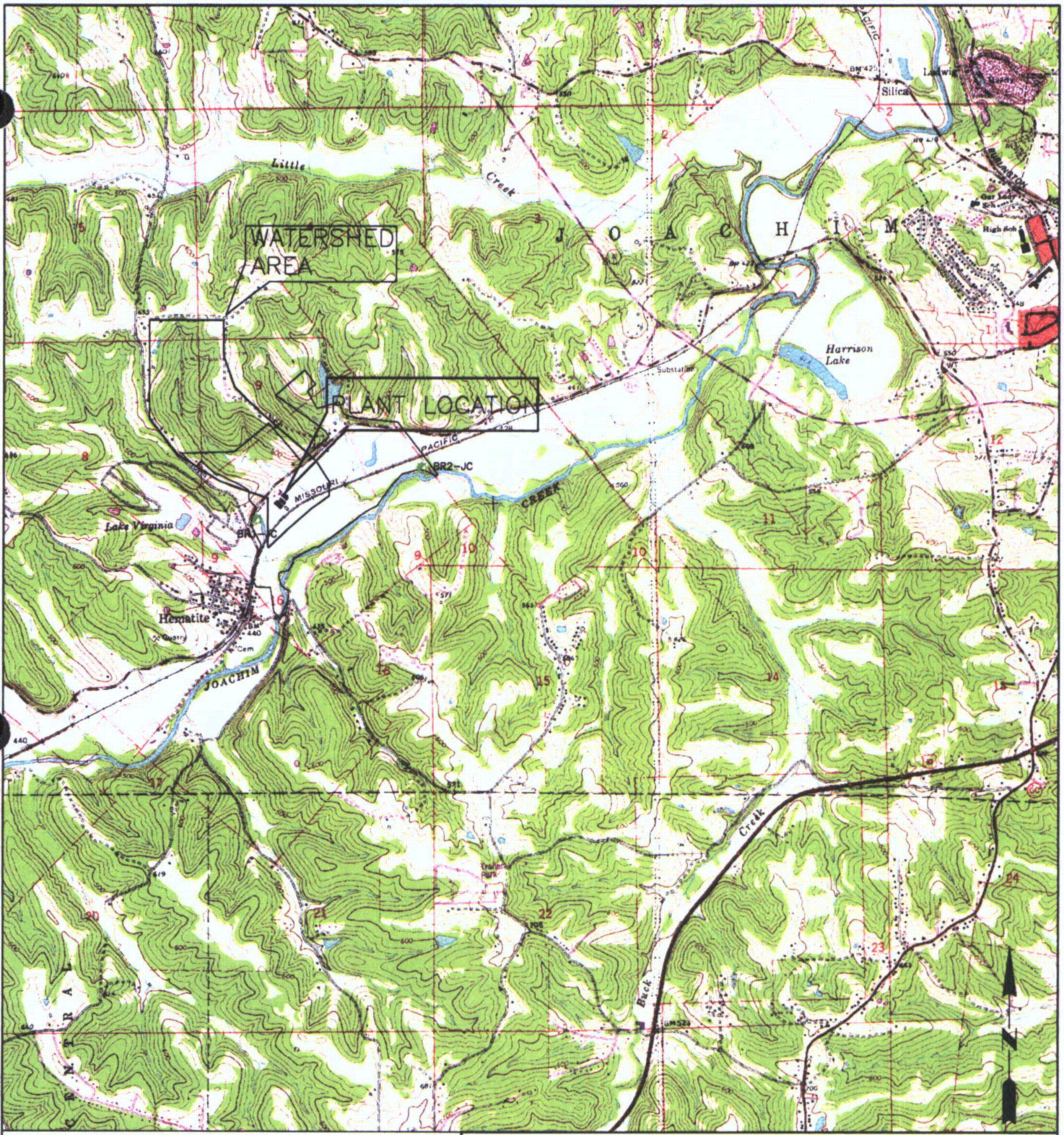
AREA OF CONTAMINATED ZONE -- TC-99

FILE: Area of Contaminated Zone — TC-99.dwg	DATE: AUGUST 2003	FIGURE: 2



0 3281
SCALE IN FEET

SOURCE:
U.S.G.S. TOPOGRAPHIC MAP
FESTUS, MISSOURI
7.5 MINUTE QUADRANGLE

WESTINGHOUSE ELECTRIC COMPANY

HEMATITE, MISSOURI FACILITY
HEMATITE, MISSOURI

WATERSHED AREA

DATE	REVISED

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FILE: WATERSHED AREA.dwg *DATE:* AUGUST 2003 *FIGURE:* 3